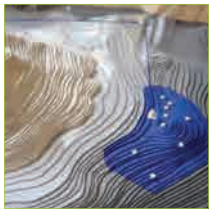
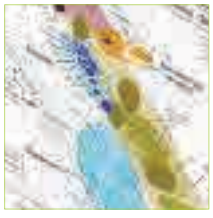
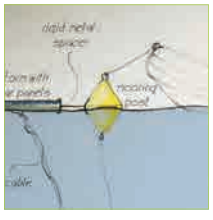


Multidisciplinarity and innovation

ASP projects 6

ALTA SCUOLA POLITECNICA





POLITECNICO DI MILANO
POLITECNICO DI TORINO

polipress

Multidisciplinarity and innovation
ASP projects 6

Preface

This book marks the sixth cycle of students that have completed their course of studies in the Alta Scuola Politecnica.
Created in 2004, the Alta Scuola Politecnica programme draws on the experience of the Politecnico di Milano and the Politecnico di Torino, two universities with different histories, conditions and methods, but that share the desire to offer to selected and talented students with an interest on multi-disciplinarity a highly-innovative course of studies.
From the outset, this ambitious project aimed to create an axis of learning between Turin and Milan. Today, as we witness the growing economic and social bonds between these two cities – both of which are key to the Italian economy – we are increasingly confident that we made the right decision eight years ago, a decision that during this time has come to fruition and has evolved and improved.
The world is witnessing a very fast technological and social development that is leading to the emergence of new paradigms; therefore, technical professionals of the future should not only be specialists in a given discipline, but also capable of building innovative solutions that are most suitable to be transferred to the products and services of the future. At the same time, when dealing with particularly talented students, we believe that universities should do more than simply issue degrees - they should also prepare these students to become future leaders and meet the specific demands that prospective employers cast on this particular segment of graduates. In this sense, the Alta Scuola Politecnica provides an added value with respect to the traditional academic approach. ASP students are given the opportunity to continuously gain insight from one another, from courses offered by both universities, and from projects at the leading edge of technology proposed by companies. Due to this unique learning experience, they develop the managerial skills and the comprehensive training that employers are increasingly seeking from top graduates in technical disciplines. Students have the opportunity to work in teams, managing complex projects which require multi-disciplinary contribution (as illustrated in this book), and follow residential courses, thereby enjoying a stimulating earning experience. The significant presence of industrial sponsors in the last ASP cycles gives evidence to the fact that industry appreciates the mix of specialized skills, coming from the Master programs, and interdisciplinary skills, coming from ASP.
This important achievement confirms that the path we chose to follow in 2004 is still very promising, and we are encouraged in continuing and improving this endeavour with the same enthusiasm shown by our ASP students.

Prof. Giovanni Azzone, Rector, Politecnico di Milano
Prof. Marco Gilli, Rector, Politecnico di Torino

ASP Sponsors

ASP is partially financially supported by external institutions which share our vision of educating talented students and promoting interdisciplinary innovation. Following a three-year initial financial support from the Italian Ministry of University Education and Research, the main supporters of ASP are currently Compagnia di San Paolo and Fondazione Cariplo. Other institutions, both private and public, have joined in by providing financial support as well as a relation aimed at developing projects and opportunities for the career development of our students. The logo of each of our sponsors is presented below and their valuable support is hereby gratefully acknowledged.

The Compagnia di San Paolo, founded in 1563 as a charitable brotherhood, is today one of the largest private-law foundations in Europe.
It pursues aims of public interest and social use, in order to foster the civil, cultural and economic development of the community in which it operates. The Compagnia is active in the sectors of scientific, economic and juridical research; education; art; preservation and valorization of cultural heritage and activities and of environmental assets; health; assistance to the socially deprived categories.
In 2010 the Compagnia awarded 689 grants in its areas of activity, amounting to 122.8 million euros. Notably, 121 grants were awarded in the Research and Higher Education sector, amounting to 44 million euros.
The Compagnia pays particular attention to advanced research and to the development of scientific and technological centres of excellence, seen both as catalysts and multipliers of research and higher education initiatives. It supports the reinforcement of Torino's university system, especially through the promotion of excellence at Politecnico di Torino and the University.
The commitment of the Compagnia in the field of Education is focused on university and postgraduate education, starting from the growth of human capital, internationalisation and the provision of infrastructures, with special attention to the conditions that assure equal access.
In this context, the ASP's focus on excellence and innovation – besides characterising it as a valuable initiative *per se* – gives this programme the capacity to enhance the global attractiveness of the Universities involved and foster, within the leaders of the future, a specific attention to the interdisciplinary and international dimension of nowadays society. The programme also represents an interesting synergy among educational institutions located in the north-western region of Italy.
The Compagnia has supported ASP since 2007: the grants are aimed at funding scholarships for the ASP course beginning in the year, requiring a special attention to students not based in Piedmont, or with an immigrant origin.

www.compagniadisanpaolo.it

Fondazione Cariplo, established in 1991 as a nonprofit organization with the purpose of furthering the common interest and the public good in various fields, is today – thanks to the sheer size of its assets (over 5.97 billions euro) - one of the world's leading philanthropic entities annually funding grants to organizations for the fulfillment of selected projects and initiatives.
The Foundation's assets, which are the fruit of the labour of generations of men and women, though considerable, are not sufficient to solve the many problems afflicting the civil society in Lombardy, Italy and the entire world. Therefore, Fondazione Cariplo efforts focus on the improvement of the living conditions in the local community. To Fondazione Cariplo this means improving the living standards of individuals as well as their social, cultural and economic environment. Fondazione Cariplo nurtures those conditions which enable individuals to achieve their potential, express their personality, freely pursue their inclination and fulfill themselves. Fondazione Cariplo gives priority to financing specific projects rather than providing general aid to organizations. This is, in fact, the only way to precisely assess whether a program is innovative and responds to the needs of the community.
The Foundation nurtures a breeding ground for scientific research, technology transfer and the development of applied research findings, by backing synergic actions geared to the creation of networks and partnerships, the participation in international projects, the development of human capital, the production of better knowledge and improved scientific communication, as well as the dissemination and enhancement of applied research findings.
In 2011 Fondazione Cariplo awarded 2.342 grants in its various areas of activity, amounting to 156.8 millions euro (+6.8% annual rate). 119 grants were awarded in the scientific research and technology transfer area, totaling 30 millions euro. Between 2009 and 2011 the scientific research sector of Fondazione Cariplo received about 1.600 applications, processed 1.400 funding requests, and funded 341 projects.
Fondazione Cariplo pays particular attention to the support and promotion of human capital development, particularly by focusing on a limited number of projects whose purpose is to start activities capable of achieving excellence in university and post-university studies. Furthermore the Foundation is also firmly convinced that actions supporting "excellence human capital" must entail a close connection between training and teaching activities, on one hand, and research and exposure to an advanced international scene, on the other.
These are the reasons underlying Fondazione Cariplo decision to support the ASP, an advanced international Faculty able to attract the best young foreign students and capable of Italian high profile graduates education.

www.fondazionecariplo.it

CAMERA DI COMMERCIO
INDUSTRIA ARTIGIANATO E AGRICOLTURA
DI TORINO

Along with an ever diversely assorted graduate education offer with 15,000 new degrees or diplomas granted every year, an excellent post graduate training system makes Piedmont and the province of Torino a centre of attraction for young talents. Moreover, thanks to the presence of more than 200 research centers, today Piemonte ranks 11,6% of Italy's investments in R&D and it is the second Italian region for private R&D investment. The region invests 1.8% of its GDP in innovation, and the private sector investment in R&D constitutes almost 80% of the total R&D expenditure.
Partnership with public and private institutions, network between territories, support to innovation and research are main objectives for the Torino Chamber of Commerce which promotes the economic development and the local businesses growth.
The Chamber offers a wide range of services to nearly 237,000 companies working in the province and listed in the public Register of Enterprises: training, technological innovation, collection and distribution of information, fostering of business relations at home and abroad, creation of services and financing of projects designed to assist new businesses, promotion and organization of events, access to financing, information and consultancy for companies involved in foreign trade.
A particular attention is dedicated to the different levels of education, from professional courses to post-university Masters, with a special focus on high education systems and international training, which represent a significant tool for the attractiveness and worldwide relations, together with the solidity of the industrial fabric, the pro-business mood of the public administration, the quality of life in a creative, cultural and artistic context.
This is the reason why the Torino Chamber of Commerce, three years ago, decided to cooperate with the ASP, the advanced international Faculty, founded by Politecnico di Torino and Politecnico di Milano, to enhance links between the two cities.
Italian Chambers of Commerce work to build local area networks between research centers and enterprises, individual enterprises, institutions, territories and cities, as well as technological networks.
Torino, Milan and Genoa Chambers of Commerce support the development of North-western macroeconomic region by means of projects.
Figures are significant: north-western Italy (Piemonte, Lombardia, Val d'Aosta and Liguria) is one of the European biggest areas, with a population that overcomes 16 million people and more than 1.600.000 enterprises. It is an integrated territory that can proudly compete with the other European polycentric regions.
The North-western region needs economical and infrastructural actions, as the new railway connection between Torino and Milan, but also stronger cultural relations, focusing in particular on art, with a special attention to the contemporary art, education and organization of international events, as Milano Expo 2015.

Torino Chamber of Commerce: working with businesses to build the future

www.to.camcom.it

accenture
High performance. Delivered.

Accenture is a global management consulting, technology services and outsourcing company, with more than 246,000 people serving clients in over 120 countries. Combining unparalleled experience, comprehensive capabilities across all industries and business functions, and extensive research on the world's most successful companies, Accenture collaborates with clients to help them become high-performance businesses and governments. The company generated net revenues of US$25.5 billion for the fiscal year ended Aug. 31, 2011. In Italy, all Accenture's group companies employ more than 10.500 people (Milan, Rome, Turin, and Verona) and generated net revenues of 1.029 million Euros in the fiscal year ended Aug. 31, 2011.

We are able to deliver leading-edge solutions to our clients by bringing together highly talented people in a creative, multicultural and collaborative environment, where everyone is strongly encouraged to make the difference through innovative, non conventional ideas.

As the global demand for highly skilled people grows, education excellence is increasing in importance. Accenture supports Alta Scuola Politecnica as we are committed in helping young talented people, with a passion for innovation and a deep interest in multidisciplinarity, to develop their potential and capabilities through qualified academic initiatives, contributing to their continuous improvement.

To learn more about Accenture visit

www.accenture.com

BCG
The Boston Consulting Group

The Boston Consulting Group is a global management consulting firm and the world's leading advisor on business strategy. Founded in 1963, BCG has 75 offices in 42 countries.
We partner with clients in all sectors and regions to identify their highest-value opportunities, address their most critical challenges, and transform their businesses. Our customized approach combines deep insight into the dynamics of companies and markets with close collaboration at all levels of the client organization. This ensures that our clients achieve sustainable competitive advantage, build more capable organizations, and secure lasting results. In our client work, we aspire to make a difference, and we succeed because we are different. We help our clients change the rules of the game, not just play better.

The BCG difference lies in the power of individuals: challenged by mentors, supported in teams, motivated by results. We look for outstanding talents and people who have the curiosity and drive to find innovative solutions. Our consultants work with clients to define the problem and determine the best approach. BCG offers to all its employees to grow further challenging their mind, partnering with leaders, making a difference and ultimately charting a career that fits them.

Our goal is therefore to help ASP students better understand the challenges and opportunities of a consulting career. We are highly committed to develop initiatives to meet, interact and support ASP students in their growth.
BCG. Grow Further! Shaping Your Future. Together.

www.bcg.com

McKinsey&Company

McKinsey & Company, global leader in management consulting, is proud to be sponsor of Alta Scuola Politecnica (ASP), a prestigious source of excellence within the Italian academic landscape.
We firmly believe that students at Alta Scuola Politecnica have the opportunity to develop a unique mix of skills and experiences that makes them mature and open-minded; furthermore, this distinctive combination strengthens their talent and directs them towards a focused management approach grounded on a "project-based" methodology that entails the development of highly valuable finished products and a real bent for meeting deadlines and experiencing team work.

These attitudes, together with their analytical and problem solving capabilities, fit particularly well with McKinsey's culture and values. These are, moreover, the qualities that McKinsey looks for in its consultants and prospect candidates.

Thanks to these features, all ASP Alumni who had joined McKinsey have proved very successful and have embarked on a career path of excellence and exponential growth.

www.mckinsey.it

Communication design
Bottega dei Segni

Graphic editing
Simone Castiglioni

Proof reading
Trans Edit Group

Photos
We would like to thank all students for their photos.

Project Coordinator
Gianna Campaioli

ISBN 978 88 7398 0766

Summary

Alta Scuola Politecnica celebrates its eighth Birthday

The **Alta Scuola Politecnica** (ASP) is a school of excellence rooted within the Politecnico di Milano (PoliMi) and Politecnico di Torino (PoliTo). This volume presents the final results of the multidisciplinary projects of the VI Cycle of ASP, while the VII and VIII Cycles are still ongoing. Since its foundation, ASP has progressively grown to include a community of more than one thousand students and Alumni. The first eight years of activity have been characterized by evolution through continuous change – coherently with the strongly innovative, pioneering and exploratory nature of the ASP programme. Such evolution has led to a growing awareness of the ASP approach and its values within the Board, the Faculty and the students. This article offers readers a brief description of how ASP has been growing, and provides recent data on its current status. During the last year, several events have taken place, including the appointment of the first cohort of **ASP Fellows,** recognizing the professors that have mostly contributed to establishing ASP, and the opening of a dedicated **YouTube Channel**; a more detailed description of ASP fellowships and of ASP on YouTube are presented in the appendix.

Mission and Programme

Every year, since its foundation in 2004, ASP selects 150 young and exceptionally talented students among the applicants to the Master of Science programmes in Engineering, Architecture and Design of the two Universities. The **mission** of ASP is to provide society with high-profile graduates combining in-depth (vertical) disciplinary knowledge from their Master of Science programmes with interdisciplinary (horizontal) competencies that are needed to work in a truly multidisciplinary environment.

The ASP programme runs in parallel with the Master of Science programmes offered by the two Universities; at the end of their ASP studies, students who complete the programme receive a double degree from PoliMi and PoliTo, as well as the ASP diploma. The same programme is offered to all ASP students, regardless of their school of origin. In order to achieve this target, the two-year ASP programme is built around two major elements:

- full-immersion, week-long **ASP Interdisciplinary Courses**, dedicated to the development of interdisciplinary expertise between the very different technical backgrounds of ASP students;
- continuous, two-year **ASP Multidisciplinary Projects**, developed by small multidisciplinary teams of students, academic tutors and companies or public institutions.

Thanks to this curriculum, ASP graduates are expected to significantly contribute to a future class of talented professionals, capable of leading innovation processes in a variety of fields, in Italy and abroad. In the words of the ASP advisory board and of the sponsoring corporations, ASP is effectively developing "a new kind of technical graduate".

In the eight years of ASP history, Management of the School has moved from Milano to Torino and then back to Milano. ASP is managed by a Board of eight professors (four from each University) with different backgrounds, representing architecture, design and engineering; the main tasks of the Board concern the management of courses, projects and students' careers. ASP educational activities in these eight years have been carried out by a large body of about 600 professors, from both the two founding Universities and other academic institutions, who have tutored projects and courses; moreover, about 250 private and public institutions have contributed to projects as sponsors and/or active stakeholders.

Admission

The admission process is very demanding, since the quality and success of ASP depends on forming a community of students who are not only talented from an academic point of view but also passionate about the themes that underlie the ASP programme. Figure 1 shows the total of eligible applications (i.e. with respect to academic requirements) and admitted students at PoliMi and PoliTo in the last five cycles. Since 2007, ASP has 3 admission channels.

	APPLICATIONS		ADMITTED STUDENTS		FOREIGN STUDENTS		
CYCLE	MILANO	TORINO	MILANO	TORINO	MILANO	TORINO	TOTAL FOREIGN STUDENTS
IV (2007)	174	110	83	57	18	8	26
V (2008)	251	230	90	60	28	11	39
VI (2009)	293	200	90	59	22	13	35
VII (2010)	240	255	90	59	26	8	34
VIII (2011)	219	146	90	57	19	8	27

1 *Admissions in the last five cycles*

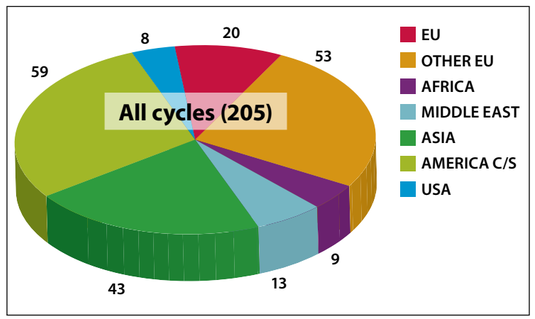
As far as **regular students** from PoliMi and PoliTo are concerned, applications are invited from the top 5-10% students from every course of studies in the fifteen Schools of the two Universities. The figure of merit used for such pre-selection is a weighted product of credits and marks for all exams passed at the end of their fifth semester in the Bachelor of Science programme; this figure evaluates students in terms of quality and speed in their studies. By construction, this group of potential applicants is evenly distributed among all study courses, thereby avoiding uneven distributions of students which occurred in the first ASP cycles, when applicants were selected by using an absolute figure of merit. Normally, about 50% of pre-selected students apply to ASP and, subsequently, about 50% of these are selected through an interview, before summer vacations; admission is subject to completing the Bachelor of Science programme and enrolling in the Master of Science programme.

Foreign students are admitted in Spring, during admission to the Master of Science programmes of the two Universities, in cooperation with the Internationalization offices. The most promising applicants are preselected based on their rankings, as produced by the offices in cooperation with the admissions commissions of each programme.

Finally, a "call for applications" from **all students** is open until about mid October; applicants must have obtained their Bachelor of Science with average marks exceeding 27. The main purpose of this call is to admit **students from other universities,** who decide to move to PoliMi or PoliTo; in any case, this call is also open to regular students from PoliMi and PoliTo and to foreign students.

In the selection of ASP applicants, a central aspect is the assessment of their understanding of the ASP programme and of the desire to invest in interdisciplinary education. Selection is carried out through a motivation letter and a face-to-face or a Skype interview. In general, about twice as many students as are admitted are interviewed.

During the last three years, foreign students have ranged from between 39 (in the V cycle) and 27 (in the VIII cycle), representing a very diverse population from all over the world. Figure 2 shows the distribution of the 205 foreign students admitted to ASP during the eight cycles, subdivided by region.



2 *International students in ASP, all cycles*

Women are well represented in ASP, with a percentage which has grown from 30-35% in the first 4 cycles to about 40% in the last 4 cycles; in the VIII cycle, 42% of students are female.

Courses

Since its inception in 2004, ASP offers six courses in each cycle, equally divided among the two years of Master of Science studies. Courses are residential; students are taken offsite from Milano and Torino, typically for one week; if possible, courses of two cycles in the same week and in the same location are offered so that two generations of students have an opportunity to meet. Professors teaching at ASP are from the two Universities, as well as from leading national and international institutes, including Cornell, MIT, Harvard and Amsterdam University among others.

During 2012, two weeks in March and May were spent in Belgirate on Lago Maggiore, and one week will be spent in July in Sestriere, in the facilities that hosted the Olympic Villages in the 2006 Winter Olympic Games. Courses are offered during the spring semester so that ASP students are free from ASP obligations during the first semester of the second year when many of them participate in exchange programmes – such as Erasmus.

Thanks to continuous monitoring and to student feedback, it has become clear that ASP courses have special traits which distinguish them. Firstly, ASP Courses have a participative structure; students are involved in study groups and discussions, leading to short presentations by students, given either in front of the entire class or within smaller groups. Secondly, ASP courses are closely linked to ASP projects, either because the subjects taught in the former can be directly applied to the latter (e.g. understanding the project stakeholders and potential conflicts, defining a business model, and so on), or because projects can provide material for case studies which are discussed within student groups.

During the last seven years, many changes have occurred in ASP courses. Normally, one or two new courses are opened at every new cycle. Meanwhile, the overall course programme has evolved and consolidated and new teaching methods have been experimented. The first four courses are dedicated to the foundations of interdisciplinarity and innovation; they provide educational principles that are immediately applicable in the ASP multidisciplinary projects.

- The course on **Innovation & Society (Prof. Costanzo Ranci)** has the goal of interpreting the socio-technical context in which innovation takes place and develops a broad understanding of how values and normative cultures shape and guide innovation and technical design.
- The course on **Design Methods (Prof. Gaetano Cascini)** teaches a common lexicon on design methods and gives students awareness on the existing approaches to design, on the main stages of product/service design and their fundamentals. Students then learn and apply exemplary design tools and take part in a collaborative design contest.
- The course on **Management of Innovation (Prof. Mario Calderini)** aims at developing students' capability to perform strategic analysis on the business implications of innovation, as well as developing skills and experience in group work and external communication capacities.
- The course on **Complex Decision Making in the Public and the Private Sphere (Profs. Giovanni Azzone and Bruno Dente)** teaches the theoretical framework and the analytical instruments to design and manage decision making processes in the context of complex projects involving government and private sector firms.

The last two courses are dedicated to important problems of today's world: sustainability and de-growth.

- The course on **Global Change and Sustainability (Profs. Barbara Betti, Stefano Consonni and Marino Gatto)** introduces the problems of global change, outlines the policies and technical advancements that could shape sustainability paths, so that students can commit to bringing the ideas of social, economic and environmental sustainability into their professional life.
- The course on **Dynamics of Creativity Against De-growth (Prof. Agata Spaziante)** discusses how creativity and innovation can help tackle the on-going economic situation and promote development, in the face of a deep economic crisis, by reasoning about how de-growth can "positively" affect areas such as urban organization, lifestyle, city life and activity financing, in order to help strategic change.

The "design methods" and "dynamics of creativity against de-growth" courses were designed during the last two years and the "decision making" course was recently broadened to incorporate the public sphere; the first edition of "design methods" took place in 2012.

Projects

Projects are the second backbone of ASP education. Coherently with the ASP cultural approach, projects must be at the leading edge of innovation, complex and systemic; they deal with ill-defined problems, involving a number of stakeholders and a significant degree of ambiguity and uncertainty. Students must correctly assess existing solutions, analyze the needs of the various players and stakeholders involved, define technical solutions and plan an innovation process within the project domain, evaluating feasibility and impact with respect to different aspects (technical performance, response to the needs of the parties involved, socio-economic impact and sustainability). This "problem setting" approach implies that students involved in ASP multidisciplinary projects must start from the identification of "innovative concepts", perform the analysis of their feasibility and implications and conclude with a well-defined solution in terms of technological, social and economic implications. Projects are not usually expected to delve deeply into specific disciplinary details; this marks a clear difference with respect to the work performed during the development of a Master of Science thesis, which is generally oriented to "problem solving" with a narrower and more focused approach.

While all ASP projects must be oriented to innovation and multidisciplinarity, from the VI cycle on, certain structural differences have led them to be grouped into two categories: design-driven projects and technology & research-driven projects.

Design driven projects are characterized by a broad level of multidisciplinarity and focus on innovation scenarios that are mostly unexplored from a technical, structural and functional point of view. Students must first understand the problem at hand and then find a technical solution.

Technology & research driven projects address a technological innovation scenario where multidisciplinarity is the main focus; the field has already been covered at the level of research activities and students must explore opportunities for technology transfer and industrial applications.

The two different kinds of projects are usually expected to generate different final outcomes:

- Design driven projects deliver a final result that explores the problem situation, compares possible solutions and evaluates the feasibility of the most promising and innovative options more thoroughly;
- Technology & research driven projects start from a more restricted project brief and aim to deliver a feasibility study of a solution which is compared to others and selected based upon its properties, with a number of demonstrators which

assess the feasibility in well-defined, specific dimensions of the solution space.

Projects are either proposed by ASP sponsors or by Professors of the two Universities. The ASP Board mentors company-sponsored programmes during their preparation, by facilitating the association with tutors belonging to the Universities, and selects among proposed projects the best suited to ASP, in either of the above two categories. Each project has a principal academic tutor, an interdisciplinary team of tutors representing both Universities and one or more external institutions as stakeholders.

Projects are then presented to students at the beginning of the ASP programme and accompany them throughout their education in ASP. The final exam consists of the presentation of project results. Grouping students into teams of about six students each, this is performed by the ASP Board on the basis of the students' preferences, which are collected immediately after the project presentations. Projects not having enough preferences are typically dropped at this stage. Each project has normally one or two teams working in parallel, although in some special cases projects may have three teams.

During the schools, students have some allotted time to deal with projects and receive feedback from the ASP Board, especially during a "project midterm" presentation. However, each team is free to organize work independently; students also have a budget (approximately one thousand euro each) to be spent on the project goals, e.g. covering the costs for site visits, buying materials or services, etc. Similarly, tutors have a small budget which is provided in the form of a research grant transferred to the principal tutor's department.

Companies involved in projects have pointed out that a period of about twenty months (from admission to graduation) is too long for the typical corporate project. Project scheduling has therefore been changed by recommending that the first year be spent in preparatory work (state of the art, requirement collection, identification of stakeholders and of their needs) while the core of the project activity should take place during the last seven months of the project and in close connection with external companies and institutions; in practice, this is also the time when students devote most of their efforts to project work.

News from the VI Cycle and beyond

This book is dedicated to the projects of the VI Cycle. Below is a brief summary as well as some of the most recent ASP news.

During the VI Cycle, 75 Professors from both Universities were involved as project tutors and 62 Professors were involved as course professors and tutors. This book describes 14 projects with 23 teams; out of these, three teams were evaluated with "excellent" at the final exam by the ASP Board. They were: Team A (ENJOYING THE PRESENT - Fruition of an underwater archaeological site) and Team B (SAVING THE PAST - Conservation of an underwater archaeological site) of the project TETI - Integrated Technologies for the Sustainable Management of Underwater Cultural Heritage, and Team A (A Sustainable Innovation for Dishwashing Detergents) of the project REPACK - Sustainable packaging for fast moving consumer goods.

During March 2011, ASP convened its **Sponsors Committee** for the first time, constituted by the Cariplo and San-Paolo Foundations, the Turin Chamber of Commerce, the European Patent Agency and nine companies: Accenture, Barilla, BCG – The Boston Consulting Group, ENI, Luxottica, McKinsey&Company, Procter&Gamble, Reply and Unicredit. In the presence of the two Rectors, Giovanni Azzone and Francesco Profumo, and of six Alumni, headed by their former president Alessandro Pradelli, members of the committee have substantially endorsed the ASP programme, at the same time providing important suggestions for improvement; a number of sponsor testimonials are provided above.

During January 2012, ASP organized its annual **Professor's Council**, dedicated to presenting the course programme and a number of testimonials from excellent projects of the V and VI cycles to tutors of the projects selected for the VIII cycle. Professors Costanzo Ranci, Gaetano Cascini, Mario Calderini and Bruno Dente presented their courses; Corinna Morandi and Sabrina Grassini presented the projects EXP-HOST and TETI, respectively. Then, 18 ASP Fellows were appointed – see Appendix A.

In February, ASP organized its **Eighth Cycle Opening Event,** dedicating the morning session to explaining the various aspects of ASP to new students of the VIII Cycle and the afternoon session to a keynote speaker. This year, we hosted prof. Banny Banerjee from the Design School of Stanford, who gave a brilliant talk on "Design Thinking: A Tool for Strategic Transformations"; a video of the talk is now available on the ASP YouTube channel, described Appendix B.

ASP is currently forging links with other European and International educational activities with a similar approach. Students from the Technical University Delft attended the Spring ASP School in 2011 for a first student exchange, while discussions are ongoing with Purdue University (Prof. Michael Dyrenfurth) and with the iFoundry Programme at the University of Illinois at Urbana-Champaign (Prof. David Goldberg) for students and academic exchanges. Along these lines, ASP is organizing a **Global Forum on "Creating Innovation Leaders"**, with the objectives of creating an important event for discussion around advancement, best practices, enabling systems, scaling, diffusion and optimal directions for innovation and of creating an "Invisible College" – as a networked community of global thought leaders on the subjects which share the same principles as ASP. The forum, organized with the participation of prof. Banny Banerjee from the Stanford Design School, will take place in Como, villa del Grumello, in September 2012, hosting worldwide experts on innovation and leadership.

Alumni

Graduates from ASP have founded the ASP Alumni Association, a lively and well-connected cluster of former students who maintain strong connections with ASP and who periodically meet for sharing cultural and social activites. The Alumni recently renewed their executive board and elected Giusy Cannone as their president. Alumni have an intense activity which includes both educational and recreative events. Among the former, the Alumni organized in April 2012, together with Confindustria, an event for **Promoting excellence and innovation**, primarily centered on selection of the best ASP multidisciplinary projects, chosen from the projects which had an excellent grade; the event was attended by many members of Confindustria (including Luigi Serra and the new President elect, Giorgio Squinzi) and by the Rectors Giovanni Azzone and Marco Gilli, while the Minister of Education, Francesco Profumo, former Rector of PoliTo, addressed students with a message. During the event, six projects were briefly presented (one from each of the six completed ASP cycles) and then evaluated by a jury. The program also hosted a panel on "excellence and merit for the young generations", presented by journalist Sergio Nava.

3 *ASP "Sliding sessions" in Bardonecchia*

Among the recreational events, Alumni and the students of the VII Cycle recently organized "sliding sessions" in Bardonecchia that were attended by over 65 skiers and supporters.

In summary, with six completed cycles, ASP has collected a wealth of useful experience; the main ASP asset is a growing community of more than one thousand young, enthusiastic and talented students and alumni.

The ASP Board

Stefano Ceri (Director) and Marco Cantamessa (Deputy Director)
Franco Bernelli and Romano Borchiellini (Student Careers)
Guya Bertelli and Marco Trisciuoglio (Courses)
Elena Baralis and Paola Bertola (Projects)

Appendix A: ASP Fellowship 2012

By establishing ASP Fellows, the ASP Executive Board has decided to give a tribute to the lecturers and professors who have most contributed to the success of ASP activities and to the development of its cultural message. ASP Fellows were appointed by the ASP Board taking into account the quality and the continuity of the effort spent. Fellows are listed in categories, depending on the main role they have had as project tutors, lecturers in courses, or members of the Board. Given their outstanding contributions and the cultural affinity to ASP values, the Fellows will be an increasingly important asset for the future development of ASP.

ASP Multidisciplinary Projects

- **Emma Angelini,** *Politecnico di Torino*
  Principal Tutor of the projects:

  NANOTRA - Integrating nanotechnologies with the design of materials and components of the future transport systems: towards the formation of a nano-engineer (2nd cycle)

  TETI - Integrated Technologies for the Sustainable Management of Underwater Cultural Heritage (6th cycle)

- **Andrea Bonarini,** *Politecnico di Milano*
  Principal Tutor of the projects:

  WoMan - Windows on MAN (2nd cycle)

  SenSoBot - Sensors and control for societal robots (3rd cycle)

- **Giuseppina Gini,** *Politecnico di Milano*
  Principal Tutor of the projects:

  ViChem - New mathematical molecular descriptors in drug design and risk assessment (3rd cycle)

  REMEDIA - REinvent MEDical Ambient (6th cycle)

- **Corinna Morandi,** *Politecnico di Milano*
  Principal Tutor of the projects:

  COMPITO - Monitoring Territorial Effects due to Commercial Polarities along the Milan-Turin Connection (1st cycle)

  Expo 2015 - Towards a polycentric Milano (3rd cycle)

  EXP-HOST - Great events and hospitality. Milan Expo 2015 and Turin Italia 150: new concepts and formats for new populations (5th cycle)

- **Emilio Paolucci,** *Politecnico di Torino*
  Principal Tutor of the projects:

  B2M - The broadcasting revolution: social impacts and opportunities (3rd cycle)

  DigiLife - Network Enabled Business Fabric (5th cycle)

  SME 2.0. - "Software as a service" as a breakthrough change for Small and Medium Enterprises (7th cycle)

ASP Courses

- **Alessandro Balducci,** *Politecnico di Milano*
  Coordinator of the course The Dynamics of Creativity
  3rd, 4th and 5th cycle

- **Massimiano Bucchi,** *Università degli Studi di Trento*
  Coordinator of the courses Innovation: Why, and for Whom? and Innovation & Society
  5th, 6th and 7th cycle

- **Mario Calderini,** *Politecnico di Torino*
  Coordinator of the course Management of Innovation
  1st, 2nd, 3rd, 4th, 5th, 6th and 7th cycle

- **Bruno Dente**, *Politecnico di Milano*
  Coordinator of the course Decision Making
  1st, 2nd, 3rd, 4th, 5th and 6th cycle

- **Sergio Rinaldi**, *Politecnico di Milano*
  Coordinator of the course The Art of Modelling
  1st, 2nd, 3rd, 4th, 5th and 6th cycle

International Lecturers

- **Keith Goffin**, *Cranfield University, School of Management*
  Lecturer in the course Management of innovation
  3rd, 4th and 5th cycle
- **Trevor J. Pinch**, *Cornell University, Dept. of Science and Technology Studies*
  Lecturer in the courses Innovation: Why, and for Whom? and Innovation & Society
  5th, 6th and 7th cycle
- **Alexander J. Wurzer**, *Director, Institute for Intellectual Property Management, Steinbeis University*
  Lecturer in the course Management of innovation
  1st, 2nd, 3rd and 5th cycle

ASP Executive Board

- **Sergio Benedetto**, *Politecnico di Torino*
  ASP Exceutive Board (student careers), 2007-2010 term
- **Costanzo Ranci Ortigosa**, *Politecnico di Milano*
  ASP Exceutive Board (courses), 2004-2007 and 2007-2010 terms
- **Agata Spaziante**, *Politecnico di Torino*
  ASP Vice-Director, 2004-2007 term
  ASP Exceutive Board (students careers), 2007-2010 term
- **Roberto Verganti**, *Politecnico di Milano*
  ASP Director, 2004-2007 term
- **Roberto Zanino**, *Politecnico di Torino*
  ASP Director, 2007-2010 term

Appendix B: ASP YouTube Channel

In February 2012, ASP opened its official YouTube Channel, at www.youtube.com/asppoli. Within just a few weeks of its launch, the Channel achieved interesting results, with more than 6000 viewings from 81 different countries.

4 *The ASP YouTube Channel*

The channel's main purpose is – for the time being – to provide anyone interested in ASP with an in-depth understanding of the programme and of its main elements. The intended audience therefore includes prospective students, firms and public bodies, as well as academics involved in interdisciplinary education.

The initial contents of the YouTube Channel are:

- The opening event of the VIII cycle, with presentations pertaining to the different aspects of the ASP experience.
- A selection of lectures from past ASP opening events (Banny Banerjee, Professor at Stanford University Design School, and Frank DeWinne, recent Commander of the Space Station, from the European Space Agency),
- The main lectures from the course "Innovation – Why and for Whom?"
- The final presentations from a selection of projects of the VI ASP Cycle,
- A lecture given by prof. Carlo Ratti, MIT, at one of the ASP Alumni events.

5 *The Playlists of the ASP YouTube Channel*

The contents will be progressively updated and might eventually lead to an innovative way of disseminating the ASP culture of multidisciplinary education beyond the community of students who are directly following the programme.

PROJECT 1

HASEW

HOUSEHOLD APPLIANCE SYSTEM WITH EQUIPPED WALL

HOUSEHOLD APPLIANCE SYSTEM WITH EQUIPPED WALLS

HASEW
Household Appliance System with Equipped Walls

project 1

The HASEW (Household Appliance System with Equipped Walls) project, developed in cooperation with INDESIT SpA, aims to investigate innovative integrated solutions for home appliances

PRINCIPAL ACADEMIC TUTOR

Pietro Asinari
Energetics, Politecnico di Torino

ACADEMIC TUTORS

Luigi Bistagnino
Architectural and Industrial Design, Politecnico di Torino

Andrea Bonarini
Electronics and Information, Politecnico di Milano

Ingrid Paoletti
Building Environment Sciences and Technology, Politecnico di Milano

EXTERNAL INSTITUTION

Indesit Company

EXTERNAL TUTOR

Dino Bongini
IDD – Innovation and Digital Design, Indesit Company

TEAM A

Aurora Cugno [Team controller]
Energy and Nuclear Engineering

Matteo Fasano
Mechanical Engineering

Fulvio Garbella Tavernin
Energy and Nuclear Engineering

Eugenia Gasparri
Building Engineering

Alexandru Popescu
Architecture (Construction)

Lucia Righetto
Architecture

TEAM B

Mattia Vincenzo Edoardo Massone
[Team controller]
Energy and Nuclear Engineering

Elisa Cucchetto
[Project Communication Coordinator]
Industrial Design

Francesco Laviola
Electronic Engineering

Sebastiano Maltese
Building Engineering

Lorenzo Piacentino
Architecture (Construction)

Giovanni Battista Porcellana
Energy and Nuclear Engineering

PROJECT DESCRIPTION

The Challenge

Three quarters of the global population are predicted to live in urban areas by 2050. Shortcomings of natural resources and increasing demand of user-friendly domotics make the design of innovative home environments imperative. The goal goes far beyond collecting different appliances, each independently designed. The real challenge is to design a synergic home environment in order for appliances to work harmoniously together, taking advantage of the optimization opportunities in each process and exploiting the (otherwise) wasted resources. A second, more subtle, challenge is the need to integrate the solutions developed in existing buildings (in Europe, low quality buildings represent more than half of the existing stock). Finally, this challenge has to be met at a European level, where different needs/habits have to be taken into account.

This project aims to explore innovative solutions for external/internal units equipping the building wall, which can collect and store primary energy resources (e.g. solar energy, rain water, etc.) to feed household appliances. The system should be able to feed certain household appliances with limited use during the day (washing machines, dishwashers, tumble dryers, ovens, etc.). The appliances must also ensure technical flexibility, easy accessibility, high mobility and user-friendly interfaces.

The teams developed their concepts focusing on new buildings (Team A) and existing buildings (Team B) respectively. Both teams fruitfully interacted with the TU Delft faculty of Industrial Design Engineering (Prof. dr. Angèle H.M.E. Reinders).

The teams

Team A focused on innovative solutions, designed from scratch for new buildings, with particular emphasis on energy savings,

better quality of life and environmental sustainability. The ambition is to provide to the new building construction field an innovative technology for domestic systems. The result is a modular system flexible towards consumer needs, sustainable due to a reduction in energy consumption and prefabrication, which facilitates a significant reduction in construction times and costs. Without loss of generality, the chosen case study building is a social-housing prototype (for comparison with the work done by the TEAM B).

Team B focused on the refurbishment of a broad stock of existing , high resource consuming buildings with low quality of life standards from both the environmental and social point of view. “Mirafiori Sud”, a council house estate in Turin (Italy) built for FIAT workers in the sixties, has been chosen as a case study. The refurbished district includes a network of pedestrian and cycling paths and public green areas, all lit by the new urban furnishing itself. All household appliances of each apartment are connected to the equipped wall which constitutes the terminal node of the district network.
To sum up, the goal of the project was achieved by both teams. Students have shown a considerable multidisciplinary integration and degree of autonomy in the achievement of project objectives.

project 1A

IN_DESIGN your home
From choice to change

TASKS & SKILLS

Cugno Aurora worked on photovoltaic/solar thermal panels sizing and on the thermal energy recovery system of the Equipped Wall, focusing on the energy and economic analysis.

Fasano Matteo carried out the heating/cooling system sizing, the water recovery system design and the CAD model of the entire Domestic systems.

Garbella Tavernin Fulvio performed the thermal simulation of the hot water storage tank and made the economic analysis of the other domestic systems.

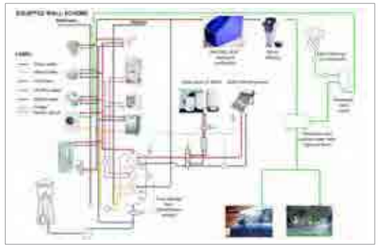
Eugenia Gasparri brought her experience in building technologies for designing the building structures of the modules and their prefabrication.

Alexandru Popescu dealt with the architectural composition of the housing modules and made the CAD model of the case study building.

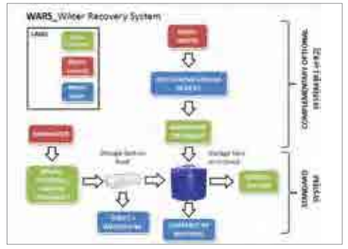
Lucia Righetto explored the state of the art of interior design in order to study the disposal of household appliances in kitchens and bathrooms.

ABSTRACT

Nowadays the issue of energy saving is strictly connected to the building construction sector, in order to achieve a better quality of life and the goal of environmental sustainability.
Hence, since users pay increasing attention to architectural integration as well as to energetic sustainability, this project aims to develop the innovative technology for domestic systems, called "Equipped Wall", in the new building construction field.
Development of the Equipped Wall is driven by a number of fundamental topics: flexibility, sustainability and prefabrication. Therefore, the result is a modular system which is flexible towards customerneeds and sustainable due toa decrease in energy consumption and prefabrication, which facilitates a significant reduction in construction times and costs.
Moreover, an improvement of quality of life is achieved. The user becomes more aware about technologies and the importance of "green" behavior, thanks to a user-friendly interface, as well as the optional strategy we are proposing for the architectural envelope and system choices.
The case study building we propose is a social-housing prototype. However, we believe that our strategy could be applied to different building types, as well as different geographical and social contexts. In order to broaden the target beyond the Italian market, we have compared our project with European lines of research, such as the Dutch context (we were hosted for a workshop at the TU Delft faculty of Industrial Design Engineering).
Summarizing, the global approach to this project and its results have shown an innovative technology for the development of new buildings, focussing on energy consumption and the new dynamics of social life.



1 *Overall scheme of the Equipped Wall and the integrated domestic systems*



2 *Outline of the WARS (Water Recovery System)*

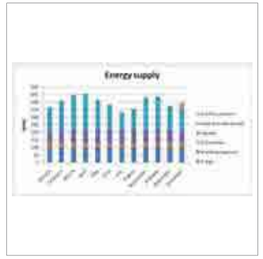
3 *Outline of the TERS (Thermal Energy Recovery System)*

UNDERSTANDING THE PROBLEM

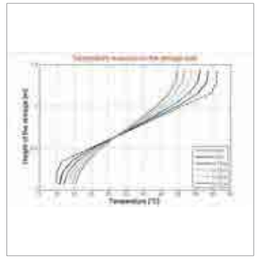
The HASEW project had the objective of elaborating an innovative system of interrelation of all household appliances, through an Equipped Wall integrated in an organic scheme with the living space. Specifically, our Team was focused on the problem from the point of view of ex-novo design, not as part of the prevailing building approach on the market but rather that of the prefabricated housing modules industry.
This possibility was considered not only for its intrinsic innovative character, which has been experimented many times in recent decades, but also because it was perfectly fitted our project purpose: a way of building cheap, "green" buildings with ample possibility of customization, particularly suitable to house our Equipped Wall.
Since the beginning it was clear that, taken for granted environmental sustainability, significant importance had to be given to the other two spheres of the sustainability concept: sociality and economics.
To provide answers to both these essential issues, we imagined a new player able to manage this innovation as a new product on the market: "IN_DESIGN your home". This enterprise would be the fulcrum of a relatively new and small market of housing modules, able to put in contact the various stakeholders active in the field.
The hypothetical applications are many and varied: from single modules with their innumerable end uses to large aggregations for private, social or student housing. Concretely, we analysed the social housing issue in depth, assuming a relation between the enterprise and all public players involved (regional government, City council, Social housing department of the city management).
The product sold by "IN_DESIGN your home" is innovative above all in its structure, which starts with the Equipped Wall and goes as far as the urban design of large developments.

EXPLORING THE OPPORTUNITIES

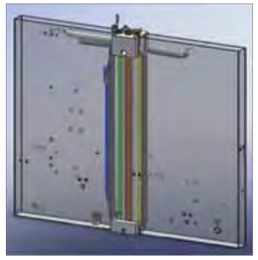
In order to meet user demand, we are proposing an alternative to the traditional strategy , intended as the opportunity to choose the size and arrangement of the living units.
The idea of flexibility, due to the necessity to pursue the above stated objectives, has a crucial role in the field of architectural design and could soon lead to the use of innovative building systems, such as prefabrication and dry technologies. These engineering choices will ensure the respect of building costs and times, transforming the traditional construction site through a complete industrialization of the process.
In domestic system design, the challenge has been focused on the satisfaction of user needs (water, electricity and heat supplies) not only following a sustainable approach but also maintaining module flexibility and the possibility to choose the desired solution, according to user preferences.



4 *Analysis of the user energy supply with recovery system and solar thermal panels*



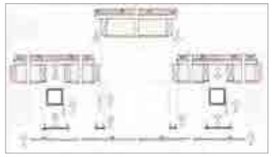
5 *Thermal simulation of the temperature behavior inside the storage tank in case of no energy recovery*



6 *3D model of the main domestic systems inside the Equipped Wall*

7 *Bathroom side of the Equipped Wall*
8 *Kitchen side of the Equipped Wall*

9 *IN_DESIGN Your Home logo*



10 *Assembly scheme of the building envelope*

11 *Flexibility of building modules, according to user needs*

12 *Detail of a vertical building joint*

13 *Plan of the proposed social housing building*

For this reason the first step has been to evaluate solutions for reducing electrical and thermal consumption (e.g. PV and solar thermal panels) and to choose an adequate heating/cooling system within the most innovative yet existing solutions.
Secondly, we have also investigated user requirements in order to focus the analysis on the most keenly perceived issues: particular interest was noticed concerning water waste and heat loss of household appliance drains. This feedback encouraged us to develop a customizable water management system, able to use less water and to recover rainwater, as well as a thermal energy recovery system. In particular, this latter system has been designed considering that water drained from many household appliances still has a significant heat energy content which could still be exploited instead of being wasted.

GENERATING A SOLUTION

The focal point of our project is the design of the Equipped Wall, that is a technology allowing the integration of domestic systems and services in the bathroom and kitchen.
This solution has the following advantages:

- Minimization of water and energy waste and optimization of piping.
- Opportunity to customize the product through various domestic system configurations, according to user needs and different building types.
- Easy-to-install due to the prefabricated features of the Equipped Wall and its plug-in interconnections.

After identifying the main features of the Equipped Wall, domestic systems were sized and their commercial components chosen, in order to estimate the costs and evaluate the payback period.
Two criteria drove the design process: the easy plug-in of household appliances and fixtures to the Equipped Wall systems and the modularity of the Equipped Wall itself, that is its potent to connect to other Wall types. In particular, the most innovative systems designed are the *Thermal Energy Recovery System* (TERS) and the *Water Recovery System* (WARS).
TERS harmonizes the contribution of solar thermal panels and of drain water from household appliances and fixtures for heating the water of a thermal stratified storage tank. We envisaged heat recovery from washing machines, dishwashers, shower drains and fridge/freezers in which the traditional air condensers have been substituted with water versions.
WARS, on the other hand, optimizes the consumption of freshwater, according to three milestones: use of less water, use of different water and rainwater storage. Hence, low water requirement household appliances have been chosen, a low energy rainwater recovery and storage system has been designed and a biological purifier for the treatment and reuse of grey and black water has been introduced.
Subsequently, we tried to imagine the most suitable architectural scheme to better exploit the Equipped Wall potential. The three concepts of flexibility, sustainability and prefabrication drove us towards the final solution.
The first goal is achieved through the study of different intended uses of an "ideal module", which can be composed in a varity of ways to obtain, time after time, different configurations. Moreover, the choice of multilayered panels facilitates easy customization of facades, thanks to the use of four different exterior finishes: wood, fiber cement, metal and solar panels.
The second is pursued by taking care of all those aspects which are linked to energy saving, both in the plant system and in the technological design: according to Italian regulations, the building we propose is certified in energy class A.
As regards the aspects related to prefabrication, on the other hand, the system is conceived via the "ad hoc" design of technological structural and non-structural details which facilitate a significant reduction in execution costs and times and also bring many advantages during the construction site phase, such as minimization of accidents and reduction of work at height.
Finally, we have designed a pilot-building, in which all the main features of our project are present.
In this case study great attention has also been paid to the new forms of living related to social changes: it is a social-housing building whose aim is to draw attention to the issues of sustainability and contemporary life styles.

project 1B

HASEW, AS U

ABSTRACT

"HASEW, AS U" project focuses on the refurbishment of a broad stock of existing, high resource consuming buildings with low quality of life standards from both the environmental and social point of view. Mirafiori Sud, a council house estate in Turin built for FIAT workers in the sixties, has been chosen as a case study. The aim is significant infrastructure development for resource saving and improvement of the quality of life of users.

In Italy, as in Europe, low quality building represents more than half of the existing stock; therefore, an intervention in this field would be strategic for a significant reduction in resource consumption. Moreover, districts such as these often present social problems, population aging and limited integration with the rest of the city, with consequent depreciation of properties.

The refurbished district would include a network of pedestrian and cycling paths and public green areas, al lit by the new urban furnishing itself.

All household appliances of each apartment are connected to the equipped wall which constitutes the terminal node of the district network. The walls collect data from appliances and distribute the resources required. A large amount of resource (water, heat, electricity) requirements are supplied by solar panels and rain water collection. Dedicated equipment takes care of flattening the electricity demand curve, which further reduces the environmental impact of the stock.

The targets of resource consumption reduction and quality of life improvement are achieved by smart use of existing technologies. In this case, technology provides benefits which are invested in social and environmental upgrades, thus creating a virtuous upgrading cycle.

The collected data are processed and used to provide users with feedback on resource consumptions and to suggest actions to be adopted in order to reduce their environmental impact.

The proposed intervention was proven to be economically feasible and can be considered an investment with an acceptable payback period. In addition, it represents a bright opportunity for district renovation in terms of quality of life and the economic value of houses, the energy performance of which would pass from class G to A (33,7 kWh/m^2).

TASKS & SKILLS

Elisa Cucchetto focused on the design of the Equipped Wall and its integration both in the kitchen and in the bathroom, also creating an user-friendly interface.

Francesco Laviola mainly developed the electronic components for controlling and managing the plant and the grid of the buildings in the district.

Sebastiano Maltese worked on the construction issues - refurbishment and energetic upgrade - and the integration of the new plant in existing building.

Mattia Massone sized the plant components, studied the resource flows and assessed the interactions between household appliances and the whole system.

Lorenzo Piacentino focused mainly on the integration of the HASEW grid in the entire district, also providing a social improvement to the district itself.

Giovanni Porcellana in particular developed the energetic consumptions and savings calculations and the economic analysis and feasibility of the project.

1 *Prototype of Mirafiori Area 01*

2 *Prototype of Mirafiori Area 02*

3 *Prototype of building 01*

5 *Render of Mirafiori Area 01*

4 *Prototype of building 02*

UNDERSTANDING THE PROBLEM

At the beginning of the project the main idea was to focus on household appliances and their integration with the entire house, but with specific attention to the former. Since our team had to deal with existing buildings, we decided to concentrate efforts on the house in its entirety, going beyond its classical concept.

For this reason we have chosen as a case study the Mirafiori district in Turin: a council house estate built in the late sixties for FIAT workers. This makes the developed system applicable to many other buildings since this type of houses are built almost identically and with the same – poor – characteristics. We decided, therefore, to aim for significant refurbishment without demolishing the houses, so as to provide clear evidence for the entire district. The main goals identified were sustainability and resource (energy, water) saving.

EXPLORING THE OPPORTUNITIES

Starting from this point, many alternatives arose. First of all the concrete possibility of bulldozing and rebuilding the entire house; however, this radical solution is antithetic to project objective of building preservation. For the same reason, even keeping just the external structure and reorganizing the interior was not feasible as we chose to minimize disruption to inhabitants by keeping the intervention as focused and localized as possible. Thus the opposite alternative arose: a very low profile solution with no explicit evidence of our intervention; but this idea too was rejected since we believe that people – even outside the house – should be aware of the refurbishment within the stock requalification framework.

We then studied the needs and preferences of different user classes, with particular focus on the kitchen and bathroom, the main rooms of our intervention. Hence, we started developing ideas on household appliance integration able to maximize resource saving by processing information from the appliances themselves.

Our objective was the development of a building that could produce, collect, store and reuse heat, water and electricity; in brief, the main resources needed in a house. We also considered a larger scale of intervention with resource sharing among the buildings of the entire district. Nevertheless, as physical resource sharing would be unfeasible, from this point of view we had to focus on single buildings. In this single building framework, bearing in mind our objective of less disturbing but evident intervention, we developed the concept of the equipped wall which is described in detail in the next section.

Finally, it is important to underline the fact that, since we had

6 *Render of Mirafiori Area 02*

7 *Render of HASEW kitchen*

8 *User interface within of HASEW kitchen*

9 *Render of HASEW bathroom*

to deal with an existing building (a situation characterized by many constraints), we chose to implement in our project only simple technology elements, without looking for very advanced components. In fact, the innovation of our project consists of the framework, the way this technology has been used for our purposes. Therefore, most of the elements of the wall itself, similarl to those of common household components, consist of simple pipes, valves and pumps, put together in an innovative way to achieve truly high performances.

GENERATING A SOLUTION

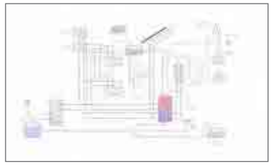
As already explained, since one of the main aims of the project is to keep the intervention simple, the technology involved has to be as simple as possible.

Firstly, we aim to reduce energy consumption as much as possible by optimizing energy use. The reduction of heating energy dispersion is the backbone of the intervention: by external coating and substitution of the windows we are able to pass from 240.3 kWh/m^2 energy consumption, corresponding to class G, to class *A* with 33.7 kWh/m^2.

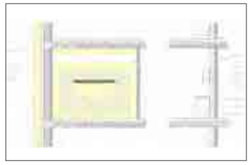
The other key feature of our project is represented by the equipped wall. The great innovation, in this sense, is the fact that all the systems of the house are centralized and situated in the basement, connected to individual apartments through pipes contained in the wall. The latter is placed outside the building and is the main signature of the intervention: it has to be seen from outside and the owners have to be proud of it. The pipes bringing water, electricity, heat and gas are placed inside the wall. The main heat source is district heating (since our case study is in the south of Turin) which feeds the heating/cooling system – based on absorber and Air Handling Units – and the domestic hot water system.

The system has been designed to recover and reuse heat from drain water and to optimize the use of energy, favouring thermal energy to electric energy in the framework of enhancement of the energetic and exergetic efficiency. Moreover, rain water is collected and purified for usage in flushing the WC and in washing machines.

A system of hybrid photovoltaic/thermal panels is installed on the roof providing both heat and electricity. Finally, the system implements a smart grid based on a simple energy storage (a series of battery packs), designed to deal with self-produced energy and to flatten the profile of energy demand. This action could help power suppliers in optimizing the usage of the power plant pool, thus reducing resort to less efficient systems, usually switched on during peak demand.



10 *General scheme of the HASEW plant system*



11 *Equipped wall construction detail – internal and external*

12 *Screenshot of the HASEW Unified User Interface*

The equipped wall is conceived as an eco- and user-friendly network of household appliances in both kitchen and bathroom.

The equipped wall structure is composed of modular elements and is designed as a new volume added to existing walls, in order to minimize the number of destructive interventions due to refurbishment.

The wall has the function of transporting systems inside the apartment in order to feed household appliances and represents the structure on which household appliances as well as kitchen/bathroom elements are hung. Thanks to the flexibility of the system, this solution can be easily adapted to a wide range of houses and customized by users according their specific needs.

The core of the equipped wall is an unified user interface allowing the user to manage all the devices from the same place, also providing information on availability times of resources. This solution aims to make users aware of energy consumption, encouraging them to use appliances when it is most convenient (such as when certain energy is produced as an output of another activity) through a "green point" system.

13 *Team B logo*

Since the whole project is quite expensive, we considered dividing the intervention in two different packages: a basic version, including just external and internal refurbishment and insulation, with payback period of eleven years; the true HASEW choice, complete with the heat and water recovery system, with payback period of fourteen years. The greater economical outlay, however, is compensated by fairly obvious advantages from the sustainability point of view.

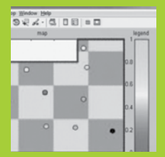
Finally, the project is not only focused on a single house but we proceeded to plan the refurbishment of the entire district: by sharing certain resources (information and electricity in the smart grid) among all buildings already treated with HASEW it is possible to imagine a completely new area of greater quality both in terms of lifestyle and sustainable development: a feasible urban dream!

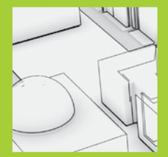
MAIN BIBLIOGRAPHICAL REFERENCES

[1] Kibert C. J., *Sustainable Construction: Green Building Design and Delivery*, John Wiley & Sons, Hoboken, 2005

[2] Tamborrini P., *Design Sostenibile: Oggetti, sistemi e comportamenti*, Electa, Milano, 2009

PROJECT 2





REMEDIA

REinvent MEDIcal Ambient

REINVENT MEDICAL AMBIENT

REMEDIA
REinvent MEDical Ambient

project 2

REMEDIA (REinvent MEDIcal Ambient), developed in cooperation with Scientific Institute S. Raffaele, proposes a new integration of medical practice and technological structural components.

PRINCIPAL ACADEMIC TUTOR

Giuseppina Gini
Electronics and Information, Politecnico di Milano

ACADEMIC TUTORS

Alessandro Carlini
Electronics and Information, Politecnico di Milano

Claudio Germak
Architecture and Design, Politecnico di Torino

Bartolomeo Montrucchio
Control and Computer Engineering, Politecnico di Torino

Lucia Rampino
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

EXTERNAL INSTITUTION

Fondazione San Raffaele del Monte Tabor

EXTERNAL TUTOR

Alberto Sanna
IRIS - Innovation & Research in life and health Services Unit, Fondazione San Raffaele del Monte Tabor

TEAM A

Giovanni Luongo [Team controller]
Management, Economics and Industrial Engineering

Ivan Cenci
Biomedical Engineering

Francesca Maria Claudio
[Project Communication Coordinator]
Management, Economics and Industrial Engineering

Pierluigi Dalla Rosa
Engineering for Cinema and Methods of Communications

Jacopo Spigaroli
Architecture

TEAM B

Giacomo Saibene [Team controller]
Management, Economics and Industrial Engineering

Alessandro Barardi
Mathematical modelling in Engineering

Michael Boris Mandirola
Computer Engineering

Alessandra Lo Moro
Biomedical Engineering

Valerio Turri
Automation Engineering

PROJECT DESCRIPTION

The Challenge

The concept of the hospital has evolved, over time, to become that of an institution central in advancing clinical techniques. Today hospitals are facing new challenges. New technical solutions can support patient care and provide new services for the staff. On the other side those technologies require more space devoted to machinery, and impose new constraints.

Hospitals have to give the best patient care. This focus will drive significant changes in managing physical spaces, staffing strategies, and patient care models. Technology will be the thread that ties those innovations together. Improved clinical documentation and automated admissions will minimize errors and improve efficiency. Patient-monitoring devices will allow doctors to manage patients from afar. Smart beds that automatically transmit patients' biological signals can alert nurses. Robots that glide through halls can assist visitors and transport equipment. Technology should allow hospitals to reach three goals: improve clinical care, reduce error rates, and reduce patient stress.

REMEDIA Project accepted this challenge. Students of both teams have worked to understand the problems with the external tutor from San Raffaele Hospital (HSR). Finally they identified a list of improvable conditions, and worked on solutions:

- to improve the mobility of patients and visitors,
- to improve the daily staff's activity with new tools to manage the ambient conditions.

The teams

Team A addressed the mobility issue and focused on servicing users to navigate and to reach given places and desired services. Their challenge was to improve mobility through better communication, personalized information, and integrated services. A questionnaire helped to understand users' behaviours and necessities. The hospital expressly asks to improve the patient support to optimize the usability of the hospital services. The mobility improvement includes infrastructural solutions to provide easier indications and direction as well as info-screens and mobile systems. In proposing such a solution they focused on the sustainability of the proposal beside acceptance and usability.

Team B decided to apply the latest findings of the automation and robotics technology to a hospital environment. HSR presented its interest in sanitization and cleaning as crucial services both for patients and workers. According to their indications, team B found a way to apply new technological solutions and protocols without main structural modifications in the building. Their research addresses a long-term cleaning task that will exploit robots to ensure almost full, certified coverage, and a short-term robotised task to verify the sanitization condition, and to support the periodic control of the cleanliness. They worked to assess the sustainability of the long-term vision, and developed the main functions of the short-term one.

Two main results have been achieved

Generally speaking, the value of autonomous robots is not clear to the business world. While surgical robotics has gained acceptance, the same is not true with other applications that require whole solutions that go beyond the robot itself. Team B developed such robotised innovative cleaning system.
Team A clearly identified the mobility problems. They also heavily invested in the various hospital applications that their technology is targeted to improve. They successfully developed a hospital solution providing innovative services and applications that address core functions of the hospital.

project 2A

REMOBILA
REInvent
MOBilityAmbient

ABSTRACT

The REMEDIA Project, carried out in collaboration with "IRIS" Scientific Institute San Raffaele, has the objective of designing the "hospital of the future", in which medical care goes hand in hand with livability and socialization. In particular, Team A's Project – REMOBILA, Reinvent MOBILity Ambient – has the objective of improving mobility services within the San Raffaele Hospital (hSR) structure. Indeed, the actual support given to orientation and mobility of patients and visitors presents vast room for improvement in terms of user-orientation and support to disabled people, with particular reference to visually impaired and wheelchair users. In order to define an innovative and integrated mobility support service, capable of providing real and incisive support to users, the Team first analyzed stakeholders' needs and requirements, paying particular attention to users. It then conducted a flow analysis within hSR external paths and looked at best practices, both in the medical environment and in other contexts. In this manner it was possible to design alternative concepts from which, downstream of the evaluation phase, the final solution emerged. As modern smartphones provide a countless variety of communication channels, the engaging challenge and final target of the Project was the definition of an effective solution for people mobility exploiting these technological devices. Firstly, a location-aware WLAN with the task of tracking Wi-Fi devices was depicted and dimensioned. The Team then defined the characteristics of the smartphone application and built a prototype to simulate navigation along a demonstrative route. Many indices, such as smartphone adoption growing at an astonishing rate, promising profitability studies on the solution and massive portability of the mobile device point to the Smartphone Application as a concrete and valuable support for hSR user mobility.

TASKS & SKILLS

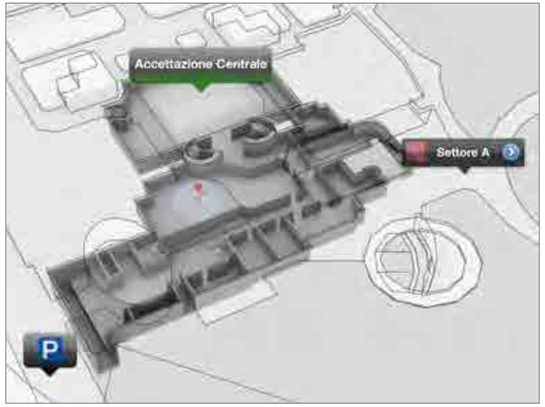
Ivan Cenci worked on the hardware design of the final solution. In order to acquire the needed knowhow he undertook a preliminary research on best practices in hospital mobility support.

Francesca Maria Claudio focused on the valuation of the alternative concepts that led to the choice of the final solution. In addition, she addressed its economic feasibility and developed a profitability valuation tool.

Pierluigi Dalla Rosa designed and developed the software aspects of the final solution. In addition, he defined and structured the services it should offer to users.

Giovanni Luongo developed the requirements analysis in order to identify hospital user needs and defined the functions of the solutions proposed.

Jacopo Spigaroli concentrated on the patients and visitors' flow analysis within hSR and built the maps necessary to allow a real-time navigation through smartphone.



1 *3D map for user navigation; REMOBILA interface*

2 *Different navigation methods provided by the REMOBILA Smartphone application*

UNDERSTANDING THE PROBLEM

The healthcare system is currently facing the challenge of integrating medical care with services capable of improving patient livability. One of the targets of San Raffaele Hospital (hSR) is to address this challenge: many services to improve the effectiveness in care and liveability have been set up, such as a zoo to entertain younger patients, and shops and bars to render the hospital environment more enjoyable. On the contrary, a service that still requires radical improvement is mobility support, since the complexity of the hSR structure (11 departments and 48 special clinics distributed over a surface area of more than 300.000m2), together with the old-fashioned philosophy on which signs are based, turns the simple activity of reaching a specific ward into a real challenge for patients and visitors. The problem is further amplified for visually impaired patients who experience difficulties in reading signs, and for wheelchair users, whose mobility is restricted to particular routes.

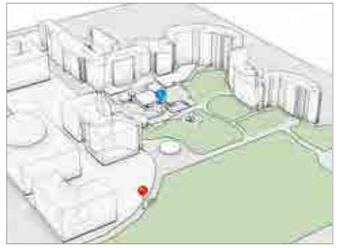
The REMOBILA–REinvent MOBILity Ambient Project aims to improve the mobility support service through the definition of an innovative and integrated system capable of meeting user needs.

Following this user-oriented perspective, great importance was given to the analysis of user needs and requirements. The analysis was conducted through direct interviews with hSR patients and visitors and led to indentification of the following main user requirements:

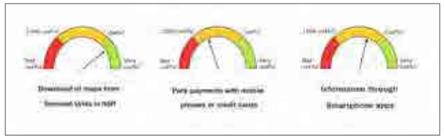
- Improvement of the orientation support system within hSR;
- Enhancement of the parking system, with particular attention to price reduction;
- Reduction of queues, in particular at the Central Desk;
- Improvement of information delivery, with particular attention to the Central Desk.

The interviews were also useful to gather user suggestions for the improvement of the mobility support system. Following a co-creative approach, suggestions were taken into consideration in the design phase. In addition, a flow analysis facilitated prioritization of areas in need of mobility support and to point out issues related to specific routes.

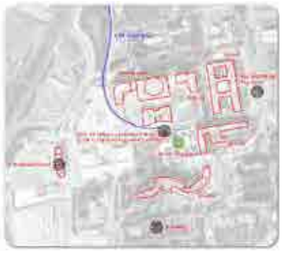
User requirements, user suggestions and flow analysis, together with the requirements of the other main stakeholders – "IRIS" Scientific Institute San Raffaele, San Raffaele Monte Tabor foun-



3 *3D stylized map for user navigation; REMOBILA interface*



4 *User appeal towards possible mobility improvements*



5 *Main access and destination points within hSR*

6 *Flow analysis within hSR. The darker the colour of the stylized path, the higher the flow density. Main issues are listed next to the path they refer to*

7 *Example of multiple choice menu; REMOBILA interface*

8 *REMOBILA: the Smartphone application to support mobility within hSR*

dation , hSR personnel and hSR Customer Care Dept. – constitute the main building blocks that guided the activities carried out within the REMOBILA Project.

EXPLORING THE OPPORTUNITIES

In order to improve the mobility service, the REMOBILA Team conducted research on best practices in the medical environment. Since hSR owns large outdoor areas and most of the techniques and the approaches used in hospitals are related to internal mobility, an additional research activity was performed in order to analyze best practices in mobility support outside the medical environment.

A significant contribution to the analysis was provided by the exhibition "Hospital Build Asia 2011" (Singapore) and the visit to Singapore General Hospital. The exhibition showed the most technologically advanced solutions regarding mobility tracking and tracing for hospitals, whereas the visit was useful to understand how these innovative solutions could be operationally applied to improve user liveability.

After careful analysis of the state of the art of mobility issues, two possible mobility support solutions were developed. The first consists of the introduction of Terminal Units, based on an icon interface, inside the hSR village. A specific software application can support people mobility through functions such as route calculation or map printing. The second solution comprises the use of the Smartphone as a support to people mobility inside the hSR village. A dedicated application, similar to that on the Terminal Units, acts as a real-time navigator guiding the user from the starting point to the final destination.

GENERATING A SOLUTION

Choice of the priority solution. The aptitude of hSR towards disruptive innovation in the hospital experience prompted the Team to follow the most engaging and out-of-the-box solution. Although the interviews revealed that Terminal Units are more appealing to users, especially for the elderly, the Smartphone Application presents greater advantages in terms of resolution of user mobility issues, impact on hSR requirements and sustainability. Therefore, the latter proposal was chosen by the Team as the priority solution.

Detailing the final concept. Designing a system able to transform a smartphone into a sort of "hSR pathfinder" is certainly a challenging task. The standard solutions exploiting GPS signals are not sustainable due to the lack of GPS coverage in indoor spaces, therefore wireless triangulation was taken into account as the gold standard. Besides solving the issue of smartphone location, the installation of a location-aware WLAN might satisfy many other hospital needs currently emerging, such as asset tracking and patient management. After an extended research on location-aware WLAN providers, the Team decided to take into consideration the solution proposed by Cisco Systems® since it is the market leader in this kind of platform and its products are specifically addressed to professional environments such as enterprises and hospitals. Moreover, the infrastructure was dimensioned in terms of deployment of access points for the most misleading areas of hSR, namely the outdoor space and the underground corridors linking the various wards.

Economic feasibility analysis. Profitability represents a fundamental requirement for "IRIS" Scientific Institute San Raffaele, the external partner of the Project. For this reason the financial impact of the solution was studied associating strategic impacts (e.g. increased mobility service level) and main actions (e.g. purchase and installation of the WLAN infrastructure) with the financial dimensions (i.e. revenues or costs) they have an impact on. Furthermore, the Team designed an evaluation tool addressed to any hospital or company intending to adopt the solution proposed. The program receives the most significant economic parameters as inputs and calculates Net Present Value and Payback Period of the solution.

Demonstration building. The point of arrival of the Project is represented by the development of a software application to be installed on a smartphone simulating navigation along a demonstration route. In this context, the user interface must guarantee clear and rapid access to application functions. As the cognitive perception of the interface depends on the familiarity of users with technology, the Team decided to elaborate a variety of navigation methods tailored to different segments. Nevertheless, each method provides information on directions and time to destination, name of the final destination, ads and extra content such as public transport timetables and symbols referring to places of interest (e.g. toilets). In addition, those concerned can benefit from the online payment service.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Raskin, Jef, *The Humane Interface: New Directions for Designing Interactive Systems*, Addison-Wesley Professional, 2000.

[2] Cisco Systems Inc., *Enterprise Mobility 4.1 Design Guide*, San Josè (CA, USA), 2009.

[3] *Hospital Build Asia 2011 Exibition & Congress*, Marina Bay Sands, Singapore, 9 – 11 May 2011.

project 2B

RECLEA
(REinvent CLEaning Activities)

ABSTRACT

Activities performed by humans have always been affected by innovation, such as the introduction of automated processes. The introduction of a large number of technological innovations in the 19th and 20thcenturies led to the greatest advancements in human welfare in history. Healthcare and hospitals benefited greatly from all these innovations, leading to a far greater awareness of the medical possibilities in treating diseases. The quality of health services, however, is definitely more than just the medical aspects, and the cleaning process plays a significant role among the services that a hospital must deliver. This service, still completely manual, shows some critical areas that could be overcome by introducing a system with a certain level of automation.

Cleaning is a process which requires different tasks: inspecting its effectiveness ex-post is indeed a crucial activity, especially when considering automated systems. Therefore, we differentiated between the cleaning task itself and cleanliness verification. Given the current available technologies, introducing an automated cleaning system is still an uneconomic option; the inefficiency of robots leads to costs which are higher than the benefits. On the other hand, designing and introducing an automated cleanliness verification system is a viable option. Therefore, we argue that the cleanliness verification system can be introduced in the short term, while the cleaning system itself only in the long term. Accordingly, we focused on two core issues: (i) the cleaning task in the long term, which focuses on the organisation and the sizing of a swarm group of robots; (ii) the verification task in the short term, which focuses on the issues related to navigation and measurement of cleanliness.

The cleaning task requires a system composed of simple automated units cooperating together, whose control system represents the critical issue. The cleanliness verification task may be performed by single automated units, one for every area, through the adoption of simple positioning and movement methods and of basic sampling systems.

TASKS & SKILLS

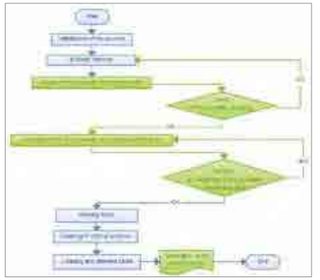
All team members gathered information on the state of the art and contributed to the definition of the proposed solutions. In addition, each of us coordinated a particular ASPect of the project.

Alessandro Barardi and **Alessandra Lo Moro** proposed a mathematical analysis of the sizing problem for the cleaning system from a long-term perspective.

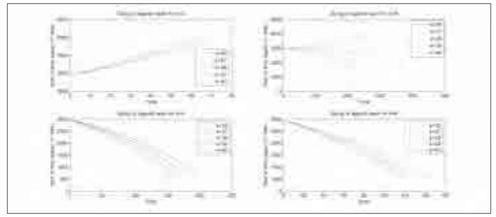
Michael Boris Mandirola and **Valerio Turri** focused on the conception of the cleanliness verification system from a short-term perspective, detailing its main characteristics addressing cleanliness measurement and navigation, respectively.

Giacomo Saibene performed an investment analysis, leading to define different approaches for the long-term and the short-term solutions.

1 *Standard MOP cleaning system: completely manual*



2 *Diagram of a cleaning process [3]*



3 *Evolution of the size of the dirty region in function of the number of cleaning agents: k=number of agents=[36, 37, 38, 40]; d=contamination spread step=[3, 4, 5, 6]*

UNDERSTANDING THE PROBLEM

The hospital is a complex institution. There are many problems and critical issues which are not exclusively related to medical aspects, such as handling of objects (e.g. medication and meals), movement of patients, transmission of data and the cleaning process. Among these, in accordance with the needs of our main stakeholders, we chose to innovate the cleaning process by studying the introduction of an automated system for floor cleaning with a multidisciplinary approach.

Every day many people (patients, relatives, doctors and other workers) enter and exit hospitals. Patients under medical treatment, and often with weakened immunity or contagious diseases, could be prone to infections. Hence, cleanliness deserves special attention in hospital environments and any discussion on the subject must address many different dimensions: economic, environmental, social, health and quality of service. Besides, because of the complexity of the problem, there are many different actions that could be taken into account in order to improve the situation from different points of view:

- economic: saving on materials, chemicals and on working time required by humans;
- environmental: optimizing the dosage of chemicals, favouring green solutions and environmental sustainability;
- social: making dangerous and poorly-qualified jobs unnecessary, such as janitor services, in order to promote the creation of highly-qualified jobs;
- health: a cleaner environment translates into a healthier environment;
- quality: improving the cleaning system contributes to quality improvement.

When considering automated systems, we must distinguish between two parts of the cleaning process; the cleaning task itself and the ex-post verification of its effectiveness. Accordingly, implementation of an automated system involves two main fields of action in which significant improvements may be achieved. We consider two phases of the cleaning process:

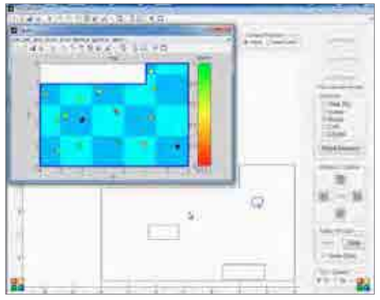
1 cleaning: the task of removing dirt (intended as loose dirt, attached dirt or microbiological dirt) from the floor surface.
2 cleanliness verification: the task of detection, measurement, and localisation of dirt.

EXPLORING THE OPPORTUNITIES

The first step of our work was research of the state of the art. This has been performed in different ways: research on the web,

4 *iRobot ® Create equipped with the positioning system*

5 *Virtual rendering of the cleanliness verification system inside a hospital ward*



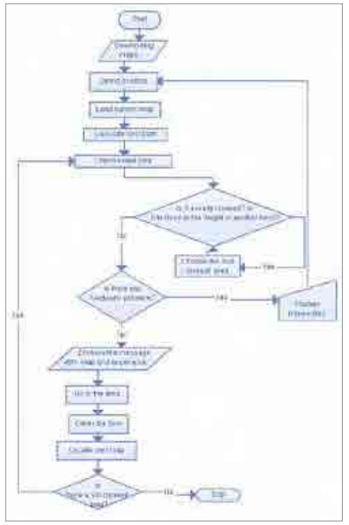
6 *Simulation of the behavior of the navigation algorithm. Mathlab Simulation Toolbox*

live meetings with the "Ufficio Decoro" of HSR and visits to a number of cleaning exhibitions. By attending the latter, we discovered that, currently, there are no automated solutions for hospitals. Our analysis led us to exclude a fully automated system. In fact, artificial intelligence is not yet capable of autonomously managing the whole output of an automated cleanliness verification system. We believe that the human contribution is too important to be completely excluded from the process: there is a large amount of promising research on persistent autonomy, but very few products, if any, which can be safely used in such complex and dynamic environments such as hospitals. Therefore, we are aiming at a semi-automated system, in which the human intervention is still required for exceptional cases.

GENERATING A SOLUTION

Given the technology available in the short-term, the introduction of a semi-automated cleaning system (composed of autonomous units that efficiently clean the floor) is still an uneconomic option; the inefficiency of current robots leads to costs which are higher than the benefits. Indeed, following a number of analyses, we concluded that such a semi-automatic cleaning system does not seem to be efficient, robust and safe enough for daily use in a hospital environment. On the other hand, the design and the introduction of a semi-automated cleanliness verification system is a viable option, since the technological platform for its implementation is, conversely, already available. Therefore, we concluded that introduction of the cleanliness verification system is viable in the short term, while the cleaning system is only viable in the long term. Accordingly, we analysed these two phases of the cleaning process from two complementary perspectives: the short-term and the long-term. Our long-term solution focuses on the organisation and sizing of a swarm group of robots, while our short-term solution focuses on the issues related to cleanliness navigation and measurement.

Long term. From a long-term perspective we examined an optimisation problem inspired by the work of Altshuler *et al.* [1], in which a multi-agent system, (*swarm),* plays a central role. The latter is defined as a decentralised group of multiple autonomous agents which are simple and have limited capabilities. Regardless of the improvement in performance, such systems are usually much more adaptive, scalable and robust than those based on a single, highly capable agent, when properly sized. This problem assumes a grid, part of which is dirty and in which this dirty part is a connected region of the grid. On this dirty grid region several agents move, each having the ability to 'clean' the area ('tile', 'pixel' or 'square') it is located in, while the goal of the agents is to clean all the dirty tiles in the shortest time possible. These agents work in a dynamic environment in which a deterministic contamination spread is simulated every d time steps. A way to decide whether k agents can successfully carry out their cleaning task is to provide a lower bound (figure) valid for each cleaning protocol [2]. Figure 3 shows that a minimal number of agents is necessary in order to carry out their task with a specific initial dirty area and a certain contamination spread step d. Due to the dynamic nature of the problem, we introduce a shape factor which takes into account that the contaminated region can change during the cleaning process. In order to make the model more realistic, it is interesting to replace the deterministic expansion with a stochastic version.



7 *Process diagram representing the cleaning behavior*

Short-term. In this perspective, we outlined a solution for the verification system. We used a more practical approach including detailed positioning and navigation strategies as well as the methods for sampling, measuring and stocking the dirt on the floor. The input of the navigation system is a complete map of the room and the fixed obstacles. The navigation algorithm guarantees that the robot collects dust samples in points randomly and homogeneously spread over the area. At the same time, the positioning system (based on a camera and markers on the ceiling) ensures correctness of sample coordinates. The navigation system is also able to manage certain critical situations such as fixed and mobile obstacles. The system measures the dust level as an indicator of the cleanliness of the floor. The dust is collected on an adhesive tape. A light is directed to a light sensor through the tape. In this way it is possible to measure the level of cleanliness. The tape is then re-wound, avoiding cross-contamination and keeping the measurement geolocalisable and available for further analyses.

In the last part of the project we tested the positioning and navigation systems in the real world for the verification phase: we implemented the positioning system on an iRobot Create (Figure 4) and simulated the behaviour of the navigation algorithm (Figure 6).

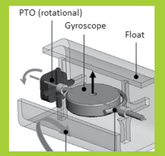
MAIN BIBLIOGRAPHICAL REFERENCES

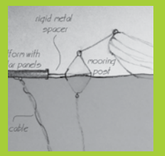
[1] Y. Altshuler, V. Yanovsky, I. A. Wagner and A. M. Bruckstein. *Swarm Intelligence. Searchers, Cleaners and Hunters* (2006)

[2] Y. Altshuler, V. Yanovski, I. A. Wagner, A. M. Bruckstein. *Multi-agent cooperative Cleaning of Expanding Domains. The International Journal of Robotics Research* (2010)

[3] ISPESL. *I profili di rischio nei comparti produttivi dell'artigianato, delle piccole e medie industrie e pubblici esercizi - Comparto: imprese di pulizia*. Ricerca: B28.7 (2004)

PROJECT 3





TETI

INTEGRATED TECHNOLOGIES FOR SUSTAINABLE MANAGEMENT OF UNDERWATER CULTURAL HERITAGE

TETI
Integrated technologies for sustainable management of underwater cultural heritage

project 3

TETI is an attempt
to save the memory of our past,
bring it to the present
and take it into the future

PRINCIPAL ACADEMIC TUTOR

Emma Angelini
Materials Science and Chemical Engineering, Politecnico di Torino

ACADEMIC TUTORS

Simone Corbellini
Electronics, Politecnico di Torino

Loredana Cristaldi
Electrical Engineering, Politecnico di Milano

Marco Faifer
Electrical Engineering, Politecnico di Milano

Alessandro Ferrero
Electrical Engineering, Politecnico di Milano

Sabrina Grassini
Materials Science and Chemical Engineering, Politecnico di Torino

Marco Parvis
Electronics, Politecnico di Torino

EXTERNAL INSTITUTIONS

Soprintendenza del Mare per la Regione Sicilia

UNESCO

EXTERNAL TUTOR

Sebastiano Tusa
Soprintendenza del Mare per la Regione Sicilia

TEAM A

Davide Agostoni [Team controller]
Materials Engineering

Roberta Finotti
Architecture for restoration and preservation of architectural and environmental heritage

Matteo Ravasi
Telecommunications Engineering

Elena Redaelli
Architecture

Syeda Fatima Rizvi
Electronic Engineering

TEAM B

Cléry Bionaz [Team controller]
Architecture for restoration and preservation of architectural and environmental heritage

Alessandro Sala
[Project Communication Coordinator]
Environmental and Land Planning Engineering

Nosherwan Shoaib
Electronic Engineering

Mattia Speziali
Telecommunications Engineering

PROJECT DESCRIPTION

The challenge
Four out of five parts of the world are underwater and sea also acts as a jealous custodian of the traces of human evolution.
Today, technology can have unfortunate consequences on this well-established equilibrium, allowing people to destroy in few years what has been sleeping in the deep for centuries.
We must save our past, we must preserve the underwater traces of our history; we must also allow people to get to know, enjoy and look at them.
TETI is our small contribution to this challenge through a sustainable management of underwater cultural heritage.
Underwater archaeological sites are very difficult to be preserved and are very sensitive to intrusion and maritime activities, the effects of which are always underestimated.
Recognizing the urgent need to preserve and protect such heritage, UNESCO elaborated in 2001 the *Convention on the Protection of the Underwater Cultural Heritage*, which sets out basic principles and practice for fruition and conservation of underwater cultural heritage. The *in situ* preservation of underwater cultural heritage should be considered "the first option before allowing or engaging in any activities directed at this heritage".

The teams
Fruition and conservation of underwater archaeological sites require a multidisciplinary approach devoted both to the development of specific protection procedures for the artefacts and to the design of integrated systems for monitoring, safeguard and musealisation of these areas.
TETI addresses all these aspects bringing together different kinds of expertise in electronics and telecommunications, material science, environmental engineering, architecture and restoration.
Underwater sites contain wood, ceramic and metallic artefacts of various dimensions and usually dispersed in large areas. Managing these sites requires artefact conservation issues to be addressed, allowing conscious direct fruition through the development of scuba

diving tracking strategies, artefact lighting and underwater visiting routes, protecting the site from illegal access through a surveillance system to detect intrusion and encouraging the indirect fruition through proper musealisation.
Two teams addressed the wide range of problems: team A focused on both direct and indirect site fruition, working on the tracking system, lighting, conservation of tools and musealisation; team B focused on the protection of artefacts and on site surveillance, finding sustainable solutions for the supply of power to all the technologies to be employed.

The results
A still unmanaged site off the coast of Filicudi Island was chosen as a case study for application of the developed solutions.
An integrated system has been studied, which allows both location of authorised scuba divers as well as detection of unauthorised access to specific sensitive areas. An innovative lighting system has been designed: it marks the fruition routes and indicates the most important remains. Tailored conservation procedures have been developed to preserve both the artefacts and the technical instrumentation from natural degradation. A low-impact solar and wave energy system has been studied to power all the electrical devices, thus not requiring any power supply from the mainland. Two plastic models of the site have been designed and created, both for indirect fruition and to show the relation between the developed system and the actual environment.

project 3A

Enjoying the present
Fruition of an underwater archaeological site

TASKS & SKILLS

Davide Agostoni took care of the conservation of tools, trying to find lasting solutions to fight corrosion of metallic components and to avoid the bio-fouling phenomenon.

Roberta Finotti worked on the musealisation of the archaeological site, studying the position of the artefacts in order to define routes for scuba divers and focusing on the lighting system.

Matteo Ravasi developed a system consisting of hydrophones and transducers to track the scuba divers' movements and to guarantee their safety during the underwater tour.

Elena Redaelli worked on the musealisation of the archaeological site, defining the underwater routes for scuba divers and creating the plastic models of the site.

Syeda Fatima Rizvi designed the underwater lighting system based on LED sources and optical fibres in order to provide a visible route for scuba divers.

ABSTRACT

In 2001 UNESCO drew up the *Convention on the Protection of the Underwater Cultural Heritage*, focusing on the issue of the fruition of sites, stating that "public access to in situ underwater cultural heritage shall be promoted, except where such access is incompatible with protection and management". The public fruition of underwater archaeological sites represents an integral part of the education and training process targeted by UNESCO: therefore, the goal of the project is the design of a fruition system in which the underwater site is available to all, not only as a mere tourist destination but also as a "learning site".

In the context of Filicudi (Aeolian Islands), direct fruition is achieved through an integrated system: two underwater routes are defined and various devices allow scuba divers to follow them. Two arrays of hydrophones track the visitors' movements and guarantee their safety, while optical fibres mark the routes creating a fascinating effect. All the tools employed are protected against degradation due to the marine environment. To encourage indirect fruition, besides the standard info-pack available in the local museum, two plastic models have been prepared showing the archaeological site.

This system definitely needs further testing and has growth and improvement potential; nevertheless, even if designed on Filicudi, it could represent a model to be applied in many other underwater archaeological sites.

1 *Fields of intervention*

2 *Plastic model showing the archaeological site and its context*

3 *Scheme of the underwater fruition system*

4 *Two arrays of hydrophones along the perimeter of the route*

UNDERSTANDING THE PROBLEM

Today, access to underwater sites is made possible in the majority of cases thanks to tourist initiatives promoted by local scuba diving centres. However, the UNESCO Convention mentions "public awareness" and "public access": this means that everyone should be able to approach ancient cultures, even without a specific license. Combining the idea of creating an underwater museum for scuba divers and the necessity of achieving universal fruition of archaeological sites represents an exciting and interesting challenge which is, in this case, the drive behind innovation.

How should the difficulties this "double fruition" implies be addressed? How should artefacts and the route be signposted in an effective manner? How should the scuba divers be guided during their visit using an innovative solution? How should other people be allowed to enjoy the beauties of the site? How should the technical tools employed to gather all these requirements be employed in the marine environment?

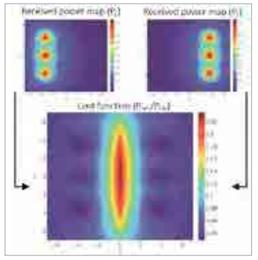
Analysing the case study of *Filicudi* (Aeolian Islands), the project attempts to provide a solution to all these issues, adopting a multidisciplinary approach based on collaboration and interaction among the various skills.

EXPLORING THE OPPORTUNITIES

The approach traditionally used to encourage fruition consists of removing the artefacts from their original environment and collecting them into a traditional museum: everyone is thus allowed to enjoy the ancient cultural heritage without any restriction. But in this manner, only the principle of *public fruition* is pursued, while the other principle stated by the Convention – *in situ conservation* – is neglected. This is the case, for example, of the Aeolian Museum in Lipari. A further step towards compliance with the UNESCO guidelines is represented by the imaginative project of Alexandria of Egypt, where adherence to the two principles clashes with respect for the marine environment: here, artefacts are conserved in their original location, but they can only be viewed from an underwater building which is obviously invasive.

Among all the solutions that attempt to combine the UNESCO requirements with respect for the site is the pioneering project developed by the Soprintendenza del Mare della Regione Siciliana in Pantelleria: the proposed system can be defined as "dual" since, on the one hand , it provides direct access to the site, thanks to the installation of a number of information tags, and to a floating rope showing the route and, on the other, guarantees

5 *Test of efficiency of the detection system in a swimming pool*



6 *Computation of the power received from the hydrophone arrays and of the cost function employed to identify where and where not scuba divers are allowed to be*

7 *Bio-fouling and corrosion effect on a camera employed in an underwater archaeological site (image by courtesy of Westend s.r.l., http://www.westendpro.com)*

8 *Cleaning of the external surface of a dome camera with a common sponge (image by courtesy of Westend s.r.l., http://www.westendpro.com)*

indirect fruition by the use of cameras. This solution presents a number of reservations concerning effectiveness of the musealisation system and maintenance of the tools underwater. Therefore, different systems can be considered in order to track the scuba divers' movements and guarantee their safety during the underwater tour. Firstly, a well-known technique implies the use of a sonar system; but this solution must be discarded, especially due to the high costs and intensive use of ultrasonic waves that could be dangerous for the marine environment. Therefore, the definitive step is the development of an innovative system using a limited number of low amplitude ultrasonic pulses.

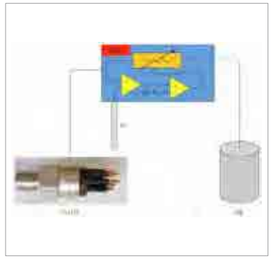
Moreover, also the durability of the entire system in seawater should be taken into account: bio-chemical agents can affect the tools and hide the text on information tags. UV-lamps and protective films on the surface can be used to cope with the problem of bio-fouling which, however, cannot be totally avoided but at least controlled. At the same time, various solutions have been discussed concerning the problem of corrosion of metallic components caused by the saline environment: more resistant materials, different geometries or a cathodic protection system.

A further step towards direct fruition concerns the lighting system: as regards the illumination of artefacts, the hypothesis of using LED sources is taken into account; but the results of specific analyses demonstrate that a system consisting of floating tags of reflective material is better than the idea of using LED sources. In fact, a LED-based lighting system would be more expensive and have a high environmental impact, also due to the necessity of laying a large number of electrical cables in the area.

GENERATING A SOLUTION

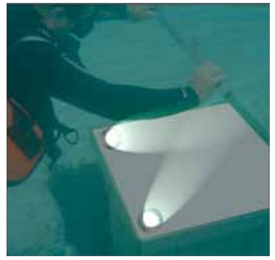
Collaboration among the various skills in the team is crucial in the development of the entire fruition system: all these interact to create musealisation in the various aspects involved, generating a true multidisciplinary solution.

The use of two arrays of hydrophones is at the core of the solution proposed to track the scuba divers' movements and to guarantee their safety: along the perimeter of the archaeological site, an unambiguous signal is periodically recorded at a given frequency from a transmitter provided to scuba divers. The received information is processed to understand if the scuba diver is inside or outside the route. This technique is called *antenna diversity*: comparing the two different signals and discriminating the most powerful, the position of scuba divers can be identified. When a scuba diver deviates from the route, an audio alarm message is sent. An integrated lighting system, created using dispersive polymeric optical fibres, is also employed to



9 *Cathodic protection system scheme with active resistance control*

10 *Visual effect ofoptical fibres positioned along the route*



11 *The "info box", with the descriptive panel equipped with a lighting system*

12 *Creation of the plastic models*

mark the route: this solution represents a further guarantee of security and confers an added aesthetic value, thanks to its fascinating soft neon-like effect.

The installation of a number of "info point" boxes, illuminated by a LED source, allows visitors to obtain the most important information concerning the site in summary form. Moreover, a number of reflective tags have the function of indicating the most significant artefacts.

All technologies used to satisfy the above-mentioned aims require a specific protection and maintenance system. Cathodic protection seems to be the most suitable solution against corrosion: an "active resistance" system decreases consumption of the sacrificial anode, maintaining metallic components in a safe state and preserving them from degradation. As far as the bio-fouling problem is concerned, the solution of depositing an anti bio-fouling film on boxes has the very important advantage of not requiring electricity.

Indirect fruition of the site is supported by the current Filicudi museum where visitors have the opportunity to find info-packs concerning the entire site – including images and videos – and a number of recovered artefacts displayed in cases. Here, two plastic models show the preserved marine area in front of Capo Graziano and the underwater museum; these tools have two different objectives: to show the site to scuba divers before immersion and to place the archaeological remains in the specific section of the museum in context.

Cooperation between the two teams is fundamental to the development of this solution which paves the way for non-underwater fruition of the site: implementation of a prototype for both plastic models represents the final step of the entire work.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Liu L., Zhou S., Cui H., *Prospects and problems of wireless communication for underwater sensor networks*, Wiley WCMC Special Issue on Underwater sensor networks, 2008.

[2] Pedeferri P., Bolzoni F., Ormellese M., Lazzari L., Pedeferri M.P., *Corrosione e protezione dei materiali metallici*, Polipress, Milano 2007.

[3] Spigo U., Martinelli M.C., *Dieci anni al Museo Eoliano (1987-1996). Ricerche e studi*, "Quaderni del Museo Archeologico Regionale Eoliano", vol. 1, Messina 1996.

[4] UNESCO, *Convention on the protection of the underwater cultural heritage*, Paris 2001.

project 3B

Saving the past
Conservation of an underwater archaeological site

TASKS & SKILLS

Cléry Bionaz worked on conservation of ancient artefacts, focusing on preservation of iron and bronze objects, through specific treatment and corrosion protection methods.

Alessandro Sala identified and studied the renewable energy sources available on site and, using a GIS-based software, performed site characterizations for the creation of virtual and plastic models.

Mattia Speziali developed a surveillance system for intrusion detection based on signal processing of the bubble noise generated by scuba divers.

Nosherwan Shoaib designed and dimensioned solar panels and wave energy converters for power supply, respecting the estimated requirements and minimizing maintenance costs and environmental impact.

ABSTRACT

The *Convention for the Protection of the Underwater Cultural Heritage* developed by UNESCO in 2001 states that artefacts are fully linked with the place of discovery since, through the same, it is possible to reconstruct ancient trades, locate harbours, understand the main objects exchanged and the places where they were produced. For these reasons, the Convention states that "the preservation *in situ* of underwater cultural heritage shall be considered as the first option", therefore finds and wrecks must be protected in their environment, avoiding shocks caused by climate change, transport and breakdown into multiple parts to facilitate transport but with the risk of wrong re-composition.

The *in situ* conservation, applied here in Filicudi (Aeolian Islands), entails a multitude of problems. Techniques for conservation of iron and bronze are based on active cathodic protection and corrosion inhibitors. Hydrophones and ultrasonic transmitters ensure surveillance by processing the bubble noise signal emitted by scuba divers.

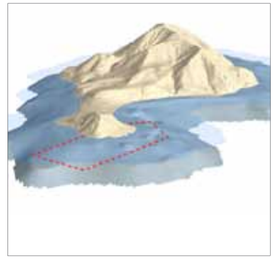
Systems to produce energy in an environmentally friendly manner are developed to ensure the power supply required by the above-mentioned devices: solar panels and wave energy converters are able to exploit the energy sources available on site.

The aim is to address these aspects from different points of view, in order to develop innovative, multitasking and feasible solutions that could also be applied in other contexts.

1 *Fields of intervention*

2 *Underwater positioning of technological instruments for artefact conservation (image by courtesy of Westend s.r.l., http://www.westendpro.com)*

3 *Testing the scuba detection algorithm (hydrophones are placed at the bottom)*



4 *Virtual model used for site characterisation*

UNDERSTANDING THE PROBLEM

The preservation of underwater archaeological sites is defined by the UNESCO Convention of 2001, which considers *in situ* conservation the best way of preserving memory and enhancing the cultural value of the site.

But what does *conservation* mean exactly? Which are the main aspects involved? And how should they be dealt with? A multidisciplinary approach appears to be the key to achieve an integrated solution able to address all these tasks.

The double meaning of the term *conservation* implies protection of the underwater cultural heritage not only from environmental agents but also from despicable anthropic actions. According to the UNESCO Convention, innovative techniques to be employed *in situ* have been developed.

As ceramics and wooden wrecks are commonly considered as durable in saline environments, a very interesting challenge concerns the conservation of metallic objects which are seriously damaged by seawater.

Since in the past many archaeological artefacts have been stolen from several underwater sites, a further challenge is the design of a detection system, in order to control access to the archaeological site. This system should be sustainable in terms of impact, costs and power requirements and must be completely automated in order to reduce the need for constant maintenance.

Analysis and design of an efficient, environmentally friendly, feasible and sustainable power supply technology is thus necessary to support the above-mentioned system. The Filicudi site (Aeolian Islands) will serve as a case study to develop technologies based on eco-friendly criteria.

EXPLORING THE OPPORTUNITIES

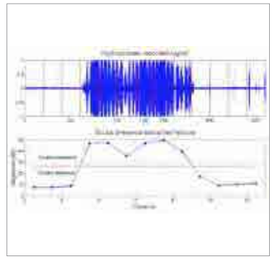
Before the UNESCO Convention, the most common practice for solving conservation problems was to recover and transport the artefacts on land to restore and exhibit them in a protected environment.

This approach has the advantage of preserving the finds from thefts and damages that intruders or even scuba divers may cause.

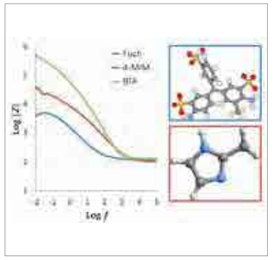
Today, this choice is no longer acceptable: the safeguard of archaeological sites requires suitable and innovative solutions in order to preserve the heritage of ancient cultures in the original context. This is a significant change of perspective, even if it entails technological limits, which requires significant research efforts.

To develop innovative methods for the *in situ* conservation of metallic finds, the focus was placed on iron and bronze, as these

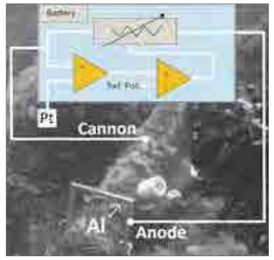
5 *Experimental setup for test of the intrusion detection algorithm*



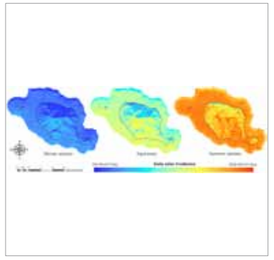
6 *Bubble noise signal processing algorithm*



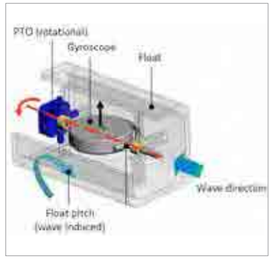
7 *Protective effectiveness of green inhibitors: EIS Bode plots of bronze in inhibition solution*



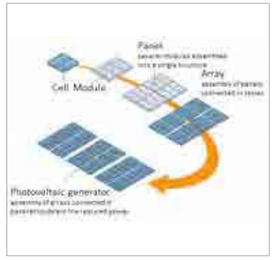
8 *Enhanced sacrificial anode protection on an iron cannon*



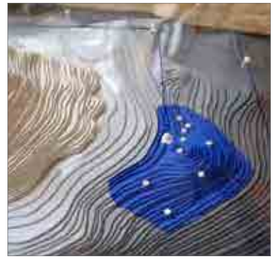
9 *Daily solar irradiance received by the Filicudi area*



10 *Inertial sea wave energy converter (ISWEC)*



11 *Solar panel design hierarchy*



12 *Plastic model showing the archaeological site and the buoy on which solar panels and ISWECs are installed*

were the most common materials employed during ancient times. Regarding this topic, certain tailored procedures for *in situ* conservation have been investigated, such as green inhibitors and cathodic protection methods.
At the same time, two alternatives have also been taken into consideration for the detection and surveillance system. The first is based on RFID (Radio Frequency Identification), consisting of the installation of small RFID tags in the artefacts and a nearby transponder, able to detect theft of the artefacts themselves. The second solution, rather than focusing on the removal of artefacts, aims at detection of intruders using a technology based on the bubble noise emitted by scuba divers.
Both the analysed solutions must be supported by an adequate power supply system able to ensure the correct functioning of the installed devices. The first step is the identification of the renewable energy sources directly available in Filicudi. Among these, all those requiring invasive storage and/or generation plants have been rejected. Considering the location of the site and the climatic and environmental features of the area, the main focus has been placed on solar and marine motion (waves, tides and currents) energy.

GENERATING A SOLUTION

The proposed solution attempts to respond to all UNESCO Convention requirements concerning the issue of conservation and surveillance of underwater archaeological sites. Another prerogative is to plan environmental compatible and non-invasive interventions for the preservation of the whole area.
TETI integrated technologies have been conceived for Filicudi, even if they aspire to be a model which can be applied in other contexts.
For *in situ* conservation of iron artefacts, the most feasible solution is passive cathodic protection using aluminium or magnesium sacrificial anodes. In fact, even if corrosion inhibitors can provide good protective effectiveness on bronze alloys, as confirmed by electrochemical impedance measurements (EIS), their application underwater is very difficult. On the contrary, cathodic protection employing different sacrificial anodes can be successfully proposed for long-term preservation of iron artefacts.
As far as the security and surveillance system is concerned, the hypothesis of an RFID-based system was discarded due to its is extremely small range of utilization and unsuitability for this application. Therefore, the solution developed comprises an ultrasonic transmitter worn by authorized scuba divers and an array of hydrophones delimiting the site. Hydrophones are sensitive to the peculiar frequency emitted by the transmitter and to the bubble noise generated by scuba divers. Through digital signal processing applied to the bubble noise, it is possible to detect the visitor's presence; should the hydrophones pick up only the bubble and not the ultrasonic tone, this means that the visitor is not authorized and the alarm can be transmitted.
In order to present a complete setup, the system has been dimensioned according to the features of the area involved. This analysis also includes a power requirement estimate for the entire system: the proposed solution includes use of renewable energy sources such as solar energy during daylight and wave energy during the night. The designed solar power system is composed of a photovoltaic module, an inverter and a battery able to store sufficient energy, while the wave energy converter transforms the wave-induced motion of a buoy into electrical power by means of gyroscopic effects. One of the main advantages of this system is that externally it is composed only of a floating body without moving parts working in sea water, thus achieving improved reliability and lower maintenance costs.
Moreover, all the work was carried out in close collaboration with Team A: the intrusion detection system is completely integrated with the solution developed by the other team for fruition and scuba diver localization. Cooperation between the two teams speeded up the development of a complex system, which is demonstrated by a plastic model of the entire site including all the tools employed.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Bracco G., *A gyroscopic wave energy converter*, Doctorate degree thesis, Politecnico Di Torino, 2010.
[2] Marabelli M., *Conservazione e restauro dei metalli d'arte*, Accademia Nazionale dei Lincei, Roma 1995.
[3] Petriaggi R., Davidde B., *Archeologia sott'acqua: teoria e pratica*, Fabrizio Serra Editore, Pisa 2007.
[4] Stolkin R., Radhakrishnan S., Sutin A., Rountree R., *Passive acoustic detection of modulated underwater sounds from biological and anthropogenic sources*, IEEE OCEANS 2007.
[5] UNESCO, *Convention on the protection of the underwater cultural heritage*, Paris 2001.

PROJECT 4

CitySpaces

A VIRTUAL/REAL PLATFORM FOR EXPLORING, LEARNING ABOUT AND INTERACTING WITH THE LAYERED HISTORIES OF CITY SPACES

project 4

CitySpaces

A virtual/real platform for exploring, learning about and interacting with the layered histories of city spaces

CitySpaces, developed in cooperation with Stanford Humanities Lab, explores the navigation of cities in 4D (3D + time) for cultural heritage applications and exhibition scenarios.

PRINCIPAL ACADEMIC TUTOR

Piero Fraternali
Electronics and Information,
Politecnico di Milano

ACADEMIC TUTOR

Maria Brovelli
Environmental, Hydraulic, Infrastructures and Surveying Engineering, Politecnico di Milano

EXTERNAL INSTITUTIONS

Radio Televisione Italiana

CEFRIEL

Stanford University

University of California Los Angeles

Carlo Gavazzi Space

EXTERNAL TUTOR

Silvia Negri
Radio Televisione Italiana

TEAM A

Can Umut Ileri [Team controller]
Computer Engineering

Veronica Arianna
Architecture

Francesca Corà
Architecture

Lucia Marengo
Engineering for Cinema
and Methods of Communications

Xiaofei Yan
Telecommunication Engineering

Anita Maria Cinthia Sala
Architecture

TEAM B

Alberto Quattrini Li [Team controller and Project Communication Coordinator]
Computer Engineering

Clara Arango
Architecture

Adriana Cavagna
Architecture

Alessandra Grassi
Engineering for Cinema
and Methods of Communications

Diana Pagliari
Environmental
and Land Planning Engineering

Martha Karina Santos Olano
Urban Planning and Policy Design

PROJECT DESCRIPTION

The Challenge

The CitySpaces project has the objective of conceiving a multi-channel digital media approach for exploring, learning about and interacting with the layered histories of city spaces. A CitySpaces is a virtual-real system for exploring cities overlaid with their rich geo-history, including the diverse histories of people, architecture and the urban environment, as well as the social and cultural history.

Technically, the CitySpaces challenge is that of designing a sophisticated mash-up built on interaction devices, Web Geographical Information Systems, integrated with augmented reality worlds, sitting on top of distributed content repositories and user-generated media streams, organized in space and time. The design takes into account four principal axes: the locations, their geography and history, the available content, either user-generated or pre-existing, the user experience and the technology mix supporting the envisaged experience. The CitySpaces design takes the city of Milan as a showcase, focusing on its rich economic, environmental, architectural, demographic, agricultural and gastronomical history, thus building a concept that can be made available for further exploitation in the context of Expo 2015.

The design teams encompass a range of complementary skills: urban planners and architects provided their capacity of "reading" the city space and history; ICT engineers contributed knowledge of tools and software platforms supporting the design concepts; environmental engineers focused on the problem of managing geo-referenced data, user position and tracking; industrial designers participated in the definition of the user experience; media engineers looked after the story-boarding and video prototyping of the interaction concept.

The teams

Team A focused on designing an augmented reality map. Through the original use of foldable screens equipped with video cameras and positioning sensors, a poly-functional foldable surface is defined which accompanies the visitor in an augmented reality tour of the town, with a special focus on the local and global gastronomic traditions and histories disseminated in the area, thus providing an ICT-mediated channel for living the Expo 2015 global food values. Visitors use the map to design their own path through the social history of food in Milan, as a time lens to see the past of the city, or just lay it on a restaurant table to obtain an information rich, interactive menu telling stories of what they are eating and seeing.

Team B chose instead the serious game paradigm as the main interaction metaphor. Visitors can enroll in missions that lead them to a progressive discovery of the town water districts, in accordance with the "water spirit" of Expo 2015, of the people that live and lived there and of their rich historical background. The user experience is designed to happen mostly outdoors and addresses not only the goal of involving visitors in an engaging cultural experience but also that of promoting physical activity, as part of a sustainable and healthy life style, that well matches the green flavor of Expo 2015. An original mix of wearable 3d vision devices and body sensors provides a practical way to run or walk through the city, while discovering hidden clues and accomplishing objectives which determine the progression of the mission. The human factor is not neglected since the game also incorporates social activities to be performed in the real world and with real "city ambassadors", contributing to making the experience engaging and unforgettable.

project 4A

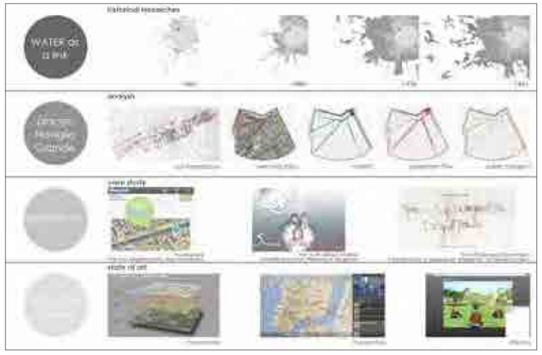
TASTEaway
Designing an interactive digital service to enjoy the city

ABSTRACT

Can a project reinterpret a city via unusual itineraries which reveal its lesser-known parts?
The TASTEaway project aims to respond to this need. It originates from the Expo 2015 event which will be hosted by the city of Milan and according to the theme of the exposition, *"Feeding the planet, Energy for life"*, provides a new map providing the user a new urban experience with an unusual level of interaction with the city.
The users will be visitors to the Expo but also normal tourists in Milan wishing to experience a new tour of the city, a food itinerary. The visitor will receive a digital and interactive map that will guide him through a selected part of Milan, discovering all the aspects of a particular dish, from the ingredients to the history of the meal, from the tools to prepare it to the recipe itself.
Thanks to a FOLED technology (Flexible Organic Light Emitting Diodes) we plan to create a modern map integrating images, videos and 3D models in the urban environment and guide the tourist in an immersive city tour linking places and culture. TASTEaway is an innovative way to discover the history of the city: it uses food culture as a universal context to commit users to the project and to make them discover Milan's hidden histories.
The portable device takes on three different meanings and uses: starting from being a map subdividing Milan into different areas according to the culinary culture, it becomes a window showing all hidden content at each stage of the itinerary. At the end of the itinerary, the device can even turn into a small electronic placemat which recognizes the dish the user is eating. This last function gives the user the possibility to record a short, live audio review of the tasting and share it with other people via the Internet.
In order to show how the guide works, we analysed two particular examples: a Milanese and a Chinese recipe, providing a sample of what the map could become in the real Milanese context.
The TASTEaway project consists of a number of selected itineraries relating to food culture, organized to provide an atypical way of visiting the city. The sequential and well-structured stories add a multicultural value to interpreting Milan, discovering other ethnic cultures within the city.

TASKS & SKILLS

Veronica Arianna analysed the urban environment of Milan. She studied several solutions and developed the project concept, organizing interviews to provide more input to project research.
Francesca Corà developed the concept, selecting the areas of Milan and working on the organization of the various steps. She contributed to the overall graphic presentation of the project.
Can Umut Ileri dealt with exploration of the current state of the art and possible enhancements of technologies related with the project. He was also involved in determining user requirements by analysing survey results.
Lucia Marengo developed the concept and acted as a link between the technology and content sub groups. She developed the user experience and user interaction structure.
Anita Maria Cinthia Sala carried out preliminary research on the different areas of Milan. She developed the itinerary through selection of information.
Xiaofei Yan developed the technical implementations in a heuristic manner by introducing the current state of art and describing the possible technical solutions for the project.



1 *First studies on Milan, the selected area, and some correlated technology*

2 *First ideas and possible solutions*

UNDERSTANDING THE PROBLEM

The CitySpaces project takes Milan as a showcase, focusing on its rich cultural, demographic, agricultural and gastronomic history, thus developing a concept linked to the context of Expo 2015. The exposition theme will show the frontiers of science and technology and will be an opportunity for promotion and communication in the food business.
The importance of the theme on such a global stage became the starting point of our project, an opportunity to create a new network in Milan based on the culture of food. "Food" has been regarded not just as a primary need but also as a way to socialize and improve cultural awareness.
Because of the international nature of the event, another issue we considered and included in our project was the multicultural aspect of food and its repercussions on the Milanese area. The concept should concern not just Italian food culture (in particular that of Lombardy and Milan) but also the main foreign immigrant communities living in the city today.
Expo 2015 represents a great communication and promotion venue for primary producing communities: farmers, food firms, the logistics and distribution chain, the restaurant and catering industry, research centers and any company seeking visibility. The perspective we were most interested in was that attempting to involve visitors and tourists not just in the Expo itself (an area close to Rho Fiera Milano) but also in the city centre. Our project adds value to the Expo, taking it from the exhibition area and bringing it into the city itself. In this way, the entire Milanese context can be involved in the exposition during its entire period (6 months).
Moreover, the visitor could socialize with the locals and take away a recollection of the experience, improving his personal knowledge of Milan and the global food culture.
Another important aspect that modern trends and the EXPO itself highlight is the need for awareness of consumers concerning the environmental impact of products; something which is still missing in everyday life and which we could provide with our project.
Since the beginning we considered the technological dimension as support to convey our concepts, but also as an ingredient that would have change the results. Technical issues have deep influence on users and their experience.

3 *A possible visitor using the TASTEaway tool as a map along the Naviglio Grande*

4 *Visualization of the first function of the tool: the map*

5 *Possible visitors using the TASTEaway tool as a window on the Naviglio Grande*

6 *Visualization of the second function of the tool: the window*

7 *A possible visitor using the TASTEaway tool as a table cloth in a restaurant*

8 *Visualization of the third function of the tool: the table cloth*

9 *Possible design of the bag for the TASTEaway tool*

EXPLORING THE OPPORTUNITIES

The existing city books are static and unstructured; it's hard to find a guide that can convey the tourist the food theme with a multi-dimensional concept. We wanted to create a new kind of digital framework able to collect food information and connect it with the geographical areas of Milan, reflecting its cultural differences.
The peculiarities of Italian cuisine, which has been handed down orally in the family and is deeply connected with Italian culture, was another reason that drove us toward the concept of 'personal cookbook'; a written record, easy to disseminate. What was interesting for us was not just the final product itself but also the process behind the dish; the history of the ingredients, the preparation of the dish, the differences between the various recipes, the tools needed for its preparation, interesting curiosities concerning the dish and its relationship with the city and its history. This provides the food theme a cultural value that goes beyond dishes and recipes.
Once again, this opportunity had to involve all the different communities living in Milan: diverse stories for diverse dishes for diverse cultures. And the different stories might overlap each other, touching several historic periods and coming together in a contemporary context.

From a technological perspective, we searched for a way to convey content in an immediate and participative manner, we focused on creating something with a real connection to the physical space of the city, integrated in, but not disturbing, the urban landscape.

GENERATING A SOLUTION

All the previous assumptions brought us to the design of a particular map concept: a thin screen that can guide the user in the city showing windows on the hidden history and the culinary traditions. Thanks to this application, an itinerary is proposed to the tourist who walks around in a defined area of Milan, learning from the stories he sees on the tablet. In this way, the visit to Milan becomes a treasure hunt: passing from the history of the ingredients, the user can see the preparation of a recipe while tasting it in a restaurant.
The map of Milan is divided into thematic areas, each of which is associated with a host country of the Expo proposing a particular recipe. The selection of itineraries and also of recipes varies periodically, involving various areas of the city.
The different routes are all structured in steps. The first is the history of the ingredients, how they are cultivated, where they come from. This is followed by the curiosity chapter with historic or even amusing tales concerning the traditional meal. The third step collects all the extra information ranging from table accessories to the choice of wine. Here, the user also has the opportunity to acquire information on events, meetings or occasions related to the topic. The fourth step is dedicated to the preparation of the dish; the traditional and reinterpreted recipe can be consulted, if the user is interested and he can also provide a review of the dish after tasting it.
Thanks to FOLED (Flexible Organic Light Emitting Diodes) technology, it is possible to create portable devices which are thin and flexible. This tool, during the itinerary, can take on diverse appearances and functions. First of all the user will have a map, a tangible, portable, interactive and multifunctional plan of the city. The map shows the city in two dimensions, providing the itinerary and its various stages, guiding the user in the selected area. During the visit, the map becomes a window showing hidden content. This is possible thanks to augmented reality technology which integrates 3D models in the real environment as if they were physically present. Finally, while tasting the meal in a restaurant and putting the dish on the device, the application scans the code on the bottom of the dish and provides additional content (nutritional values, carbon footprint). After the experience, the user can download and collect memories of his city tour on his smartphone, integrating system data and information with multimedia content recorded during the day. At each stop, the tourist comes into contact with virtual information and, at the same time, with local buildings, such as institutions and commercial or cultural centres, defining his personal idea of the itinerary. The collection improves by repeating the experience with other itineraries. The device could be seen as a sample technology for other towns, also out the scope of expositions.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Multiplicity lab., *Milano: cronache dell'abitare*, Mondadori, Milano, 2007
[2] Schnapp J. with Burdick A., Drucker J., Lunenfeld P. and Presner T., *Digital_Humanities*, Cambridge, MIT Press, 2012
[3] www.oled-display.net

project 4B

MEN.SA.NA
Revealing Martesana

ABSTRACT

Nowadays, tourism is facing changes in its traditional form to become more sustainable; indeed, alternative tourism has seen an evolution during the last decade, thanks to the availability of innovative technologies.

MEN.SA.NA: REVEALING MARTESANA aims to provide a new way of rediscovering and increasing the value of areas, both remotely and physically. It implies improving quality of life and attractiveness of a place, also fostering social interaction, by exploiting innovative technologies.

The case study identified was Naviglio della Martesana, a niche tourism location, but rich in history and architecture, focusing on the Milan Expo 2015 theme of water. The target will be active people with particular interests in culture, sports and environment.

The analysis on the state of the art of user experience of similar projects, performed in a first phase, led to the *gamification* of the experience of visiting the location. The game is accessible from different devices and is composed of several missions to be accomplished on different sub-paths. The player can move both in space and time dimensions. This design hides a more serious purpose, namely discovering and learning about different aspects, or what we call layers, of Martesana, such as the historical, architectonic, cultural and social aspects, among others.

This approach makes tourism more appealing, since a game makes the visit of Naviglio della Martesana more enjoyable and the points mechanism provides real rewards and prizes to successful players. In addition, it promotes social interaction among inhabitants, since certain missions require communication between visitors and local people.

The project is innovative from the experience point of view since the game embeds the time dimension and translates the sport in the game to a real environment. Last but not least, it combines, in an innovative manner, new cutting edge technologies such as stereoscopic and augmented reality and geo-referenced data.

The tangible outcome of this project is a number of scenarios that could be applied in Naviglio della Martesana, thanks to a hypothetical collaboration with certain stakeholders.

TASKS & SKILLS

Clara Arango On-site survey, bibliographic and photographic database, evaluation of natural, architectonical, anthropological and urban elements to guarantee the quality of the content of the project. Research and development on the graphical communication of the project according to the concept intents.

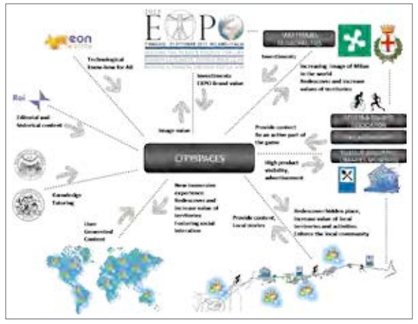
Adriana Cavagna On-site survey to understand the area, identifying significant buildings and places and collecting project content. Research and design of the different types of devices for the game.

Alessandra Grassi Experience case-study analysis. On-site survey and bibliographic research for collecting content and verifying experience feasibility. Development of game contents and experience design. Definition of game devices.

Diana Pagliari Digital maps and geographic content bibliographic research. Technology feasibility study, especially GPS device integration.

Alberto Quattrini Li Coordination of group work and communication with stakeholders. Experience analysis and design. On-site survey for collecting content and verifying experience feasibility. Analysis of technological feasibility.

Martha Karina Santos Olano Bibliographic research of possible locations for the case study with territorial, architectonic and historical significance. Identification of meaningful spots for development of the experience, support in on-site surveys and experience design.



1 *The stakeholder role and benefits*

2 *Naviglio La Martesana: The game location*

3 *Website functions, mission registration, location and information*

UNDERSTANDING THE PROBLEM

The valorization of contemporary areas requires a deep analysis of tourism in order to elaborate innovative methods to combine visitor expectations with the cultural heritage of a location (Levi Sacerdotti, Mauro, Gasca, 2011).

First of all, we focused on the Milan Expo 2015 theme, namely the motto "Feed the planet, energy for life". Specifically, we were requested to focus on the water theme and to develop the project in Naviglio della Martesana. Secondly, another requirement set is that the project should allow a spatio-temporal navigation of the layered histories.

Finally, the project should have a high level of innovation, in terms of technology used, by adopting GIS systems for collecting geo-referenced data to be placed in Navigli maps.

Therefore, the problem consisted of revealing the value of Martesana, which we discovered to be full of interesting architectural and folklore-cultural heritages, as well as an ideal environment for sports activities, since it has a bicycle lane and a number of green areas along the canal where people can walk, run or bike.

Due to the particular nature of Martesana and the concomitant event of Expo 2015, the target on which we focused was the most open-to-technology part of the population, which spans from an age of 20 to 60 years, interested in culture (GFK Eurisko, 2011), but also leading an active and *green* lifestyle.

Combining the location with the target, we obtained as fundamental values sport and culture, which will constitute the foundation of the project content and experience.

There are several stakeholders that are and could be interested in MEN.SA.NA. All their resources and needs have been considered during the solution design. One interesting point to remark is that all stakeholders interviewed along the Martesana canal (e.g. shopkeepers, inhabitants, municipalities) were available to provide us information and hypothetical participation in the project.

EXPLORING THE OPPORTUNITIES

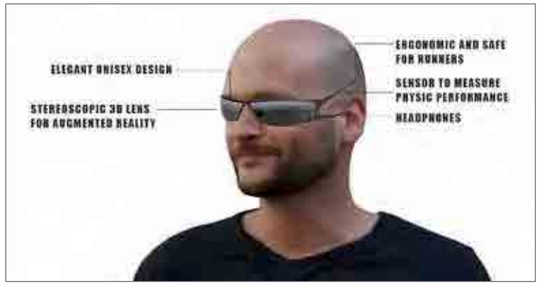
We conducted research on the state of the art concerning experience by studying similar projects. We identified three models, with different levels of immersivity in terms of user experience:

- **3DRewind**: immersive, one-off stereoscopic experience with a limited level of interaction, where content and timing are defined *a priori*.
- **One in 8 Million**: projects of limited duration based on con-

4 *An example of Augmented Reality*

5 *Function of the glasses when practicing sports activities: physical performance monitoring and display of information via the glasses*

6 *Function of the watch when practicing sports activities: physical performance monitoring and voice recognition*



7 *Stereoscopic glasses for Augmented Reality*

8 *Function of the glasses: different information with different head orientation*

tent archives created by administrators and explored or commented by users.
- **GoogleEarth**: projects based on maps. Users can navigate and interactively view and add geo-referenced content.

In addition, we extracted from case-studies several experience paradigms, by which is meant the door through which the user enters our Martesana story: we identified The Game, The Memory Bank, The Urban Exploration and finally we discovered many projects which used The Water as a stage of exhibitions and daily life.

GENERATING A SOLUTION

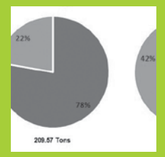
Gamification is truly a trend which will be exploited by 50 percent of organizations by 2015 (Gartner, 2011). Thus, we designed a new form of tourism by combining all models identified and exploiting the game paradigm, together with a points mechanism which stimulates people to play the game. In this way, learning becomes more natural and enjoyable, incentivating people to spend time together.
This is very innovative because, usually, games are designed only for entertainment purposes with no ulterior motive. We believe that the richness of Italian history must be exploited to create a great opportunity to export new ideas in the gaming field.

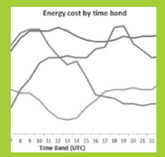
We started considering the remote experience and designed a website from which, for example, the player can join the game community, check the status of his missions and view the map of Naviglio della Martesana with active players displayed.
To design the missions we used a user-centric methodology, considering the physical context and exploiting the content directly and bibliographically collected in the various locations of the Martesana area.
The Game starts with enrolment of the player as a secret agent of the MEN.SA.NA secret agency:
"You are a secret agent of the *MEN.SA.NA* agency. The *Energy for Life* research group has discovered the chemical formula of a powerful source of energy and life which, if properly used, can save the world and the human race. Unfortunately, it has fallen into the wrong hands of *Insane Mind* and this can have serious consequences. Your mission involves recovering the formula, hidden in Milan along the Naviglio della Martesana. You can join other teams or work alone".
The player can then choose from the website which mission he/she wants to solve along the Martesana canal.
Finally, if the mission goal is completed, certain bonus contents are displayed and other missions are unlocked which lead to the end of the game. Above all, the player receives points which can be stored in his/her profile or can be spent immediately for discount in traditional shops.
The innovation in the project is mostly in the user experience part. First of all, we provide navigation in time, necessary for solving enigmas of the game, with augmented reality. Secondly, we added a sport component to the game, shifting the Nintendo Wii paradigm to the real world: in order to accomplish missions, players must go to the Naviglio and physically perform activities in a designed fitness trail. A point to highlight is that we incorporated a number of social activities in the game by designing certain interactions with locals during certain missions and by allowing players to team up in order to rediscover the community and the human factor.
All these features are in accordance with the cultural and ecological spirit of Expo 2015.
To provide the smoothest user experience, we considered different devices with different levels of immersivity in order to enter the game. In particular, we introduced a smart watch, which works as a GPS navigator, an augmented-reality smartphone application and stereoscopic glasses for augmented reality. The most interesting and innovative feature is that we considered augmented reality glasses that are able to correctly reconstruct the visual angle, namely depending on the current position and where the user looks towards. Another relevant characteristic is that the devices are equipped with sensors that are able to measure physiological data. The devices are enriched with headphones, which increase the immersive experience since sound is the main vehicle of emotions. Moreover, they facilitate fruition of game content while the user is involved in sports activities and therefore unable to check a screen. We designed all devices to fit with our target: they are smart and ideal for sports activities. Each player can choose to play using one, two or three devices: they can be used alone, but used together enhance each other and, finally, the game experience.

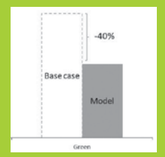
MAIN BIBLIOGRAPHICAL REFERENCES

[1] Gartner, (2011). *"Gartner Says By 2015, More Than 50 Percent of Organizations That Manage Innovation Processes Will Gamify Those Processes"*.
[2] GfK Eurisko (2011). *"Sinottica: dalla comprensione del contesto socio-culturale alla progettazione di target e azioni"*.
[3] Levi Sacerdotti S., Mauro S., Gasca E., (2011). *"Visitor Management Turismo, Territorio, Innovazione"*, Torino, CELID.

PROJECT 5







Green Cloud

GREEN CLOUD

ADVANCED ENERGY MANAGEMENT IN CLOUD SYSTEMS

Green Cloud
Advanced Energy Management in Cloud systems

project 5

Green Cloud studies energy-saving methods in cloud computing considering both data centers and networks, developed in cooperation with Alcatel Lucent, IBM and Lutech

PRINCIPAL ACADEMIC TUTOR

Antonio Capone
Electronics and Information, Politecnico di Milano

ACADEMIC TUTORS

Danilo Ardagna
Electronics and Information, Politecnico di Milano

Giuliana Carello
Electronics and Information, Politecnico di Milano

Federico Della Croce
Control and Computer Engineering, Politecnico di Milano

Marco Mellia
Electronics, Politecnico di Torino

Michela Meo
Electronics, Politecnico di Torino

EXTERNAL INSTITUTIONS

Alcatel Lucent

IBM Italia

Lutech Spa

EXTERNAL TUTORS

Fabrizio Leone
Lutech Spa

Massimo Leoni
IBM Italia

Carlo Spinelli
Alcatel Lucent

TEAM A

Stefano Viganò [Team controller and Project Communication Coordinator]
Management, Economics and Industrial Engineering

Ahmed Allam
Computer Engineering

Riccardo Chiodaroli
Computer Engineering

Francesco Lunetta
Computer Engineering

Stefano Ziller
Mathematical Engineering

PROJECT DESCRIPTION

The Challenge

Climate debate and carbon dioxide emission reduction are fostering the development of — green policies — with the aim of improving environmental performance and putting global warming and the enhancement of resource usage at the top of the list of the world's global challenges.
Information and Communication Technology (ICT) plays a key role in this greening process. Since environmental policies started to become of strategic importance worldwide, ICT applications have been considered as part of the solution as they can significantly improve the environmental performance of all the other sectors of the world economy by reducing their energy consumption and facilitating more environmentally sustainable energy generation using renewable sources. More recently, awareness of the potential impact of carbon emissions of the ICT sector itself has rapidly increased. Overall, ICT accounts for between 2% and 4% of global CO_2 emissions and is projected to reach 10% in 5-10 years. The challenge for ICT is to be able to reduce its footprint, while maintaining a high growth rate of communication infrastructures. These two issues are not disjointed. In fact, as more and more systems make use of ICT to reduce their own energy consumption, it would be of paramount importance for ICT to be as green as possible in order to reduce the global carbon footprint of the planet.
The general goal of the Green Cloud project is to develop a systematic set of methods for the design of novel resource allocation policies for energy-aware Clouds. Energy and cost savings are pursued by dynamically allocating computing resources of geographically distributed data centers.

Even if system computing and networking components have been designed and managed quite independently so far, the current trend is for significant integration based on the concept of Cloud. We argue that this new computing approach can be used not only to provide service flexibility to end users but also to

manage resources available in geographically distributed computing centers and in the network interconnecting the same in a flexible manner.
Indeed, the geographical distribution of computing facilities presents many opportunities for optimizing energy consumption and costs by intelligently distributing the computational workload, exploiting the different time zones in which the service centers are located and the hourly pricing of energy. In this scenario, energy and cost savings can be pursued by dynamically allocating service centre computing resources to applications at a global level, trading off service centre performance and energy consumption as well as that of the network used for redirecting requests among distributed sites.

Within the Green Cloud project, students developed a novel interdisciplinary approach based on expertise from several research areas: Cloud technologies, networking, optimization, performance evaluation and energy production and distribution.

project 5A

Green Cloud
Advanced Energy Management in Cloud systems

ABSTRACT

Nowadays, the Information Technology field is witnessing rapid development, leveraged by a multiplicity of innovative ideas. Such ideas represent the core contribution of diverse fields to pursue the evolution process in this domain. As a corollary, our team, whose members come from various engineering backgrounds, tackled the challenge of finding an innovative solution for energy management in Cloud Systems. The problem is characterized by aspects spanning different areas such as energy policies, systems architecture, communication networks and alternative energy production methods. Our team, with the support of our tutors, set up a series of possible scenarios, considering a set of Data Centers located throughout the world to serve incoming user requests. Our proposed solution is an optimization-based model, chosen for its flexibility and consolidated theoretical framework. In particular, the optimization model aims to reduce energy consumption in the Cloud system, taking into account the communication network and the energy generation methods, emphasizing the use of green and renewable energies. The added value of our approach is the allocation policy which intelligently determines the path of the user requests to be served. The main decision driver was minimization of energy costs in both Data Centers and in the network. Secondarily, we considered the energy generation method powering Data Centers, favoring green and renewable energy policies. Finally, our optimization model considered the availability of servers and network channels for each Data Center to execute application requests. Such considerations characterize the uniqueness of our approach, which leads to energy cost savings of up to 40% with respect to solutions which serve requests only locally, without redirecting traffic over the network. Furthermore, with the possibility of green energy generation, we experienced an important reduction in greenhouse gas emissions, very promising for future improvement.

TASKS & SKILLS

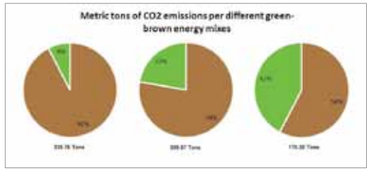
Ahmad Allam focused on gathering information on Data Center energy consumption and was involved in the definition and development of the optimization model.

Riccardo Chiodaroli worked on analysis of results and comparison of the different performance which can be achieved by the various model formulations.

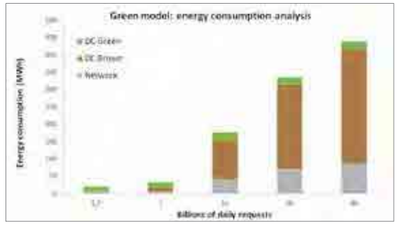
Francesco Lunetta following a research phase on network technologies, worked on numerical analyses supported by mathematical programming tools.

Stefano Viganò coordinated the group's work and provided and analyzed data on the energy market and green energy production and consumption for Data Centers.

Stefano Ziller focused his effort on the development of the mathematical models, following examination of the state of the art and the main solutions which can be implemented using current technology.



1 *Emissions*



2 *Energy consumption Graph*

UNDERSTANDING THE PROBLEM

"Green Cloud Computing": the problem we were introduced to was both challenging and incredibly broad. The first step of our work was the definition of a theoretical framework able to adequately represent the problem and current technology. In detail, this was broken down into three different steps. Firstly, we carried out a broad analysis of what Green could mean in a Cloud Computing context. Indeed, as the composition of our team clearly states, there was little difficulty in defining what Cloud Computing was, but none of us had ever considered energy consumption and pollution applied to such an infrastructure-based technology.

Cloud Computing can be defined as a Web-based processing system, whereby shared resources and software information are provided to computers and other devices on demand over the Internet. The main idea is that the system is composed of one or more Data Centers (DCs), the places where computation occurs whenever a user request is made over the Internet. The "Cloud" in the name arises from the idea of movement of information (i.e. computation and processing of information) to a different location, since DCs are connected through a network.

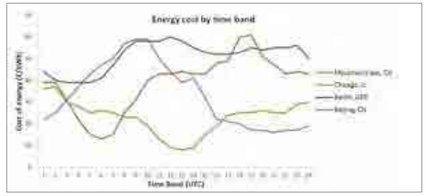
When one thinks about making something "greener", one usually thinks about a technological evolution able to change the way an object or process uses resources. But in this case, we were faced with a network based computing approach based on a huge amount of different technologies and solutions, from physical DCs and Network Routers to Virtualization and Routing. In any case, we agreed that focusing on a single hardware or software part of the Cloud would not help us in finding a truly innovative solution.

EXPLORING THE OPPORTUNITIES

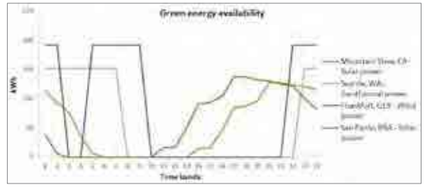
For these reasons, and thanks to the support of our tutors, we focused our attention on a more "system based" solution that could integrate the concepts of Cloud and Green into Computing. In order to do so, we went through the second step of the analysis: research on the state of the art in order to help us investigate which paths could be followed and which had already been sufficiently exploited. This research was broad and focused on all the various skills our team was able to provide:

- A detailed study on energy consumption and energy cost issues in the industry related to Cloud Computing and Computing in general. How can the average firm, whose business is not strictly linked to IT, take advantage of a greener approach to Cloud Computing? How can the more IT-intensive firm exploit a greener Cloud for its business?
- A comprehensive analysis of Cloud Computing evolution in recent years, with a detailed focus on all the involved technologies, such as: Virtual Machines, Servers, Data Storage, Data Center Cooling Systems, Networks.
- A broad analysis of the mathematical approaches to Cloud Computing, in order to discover how Cloud Systems can be modeled and to better understand the way they work in an analytical framework.

At the end of this phase, we moved to the third and final stage of the problem definition: finding an original solution to be devel-



3 *Energy cost Graph*



4 *Green Energy availability Graph*

5 *Green*

6 *IBM-Watson*

oped in the following months of work. After scouting different approaches, together with the academic tutor we chose to model the Cloud System as a single entity composed both of the DCs and the Network connecting them. In this sense, the Network serves as a resource for our system, since it allows application request forwarding, based on specific efficiency policies aimed at reducing costs or maximizing green energy usage.

With this in mind, we would be able to produce an optimization model capable of considering both the Computing as well as the Data Transfer part of the Cloud. This is also what makes our proposed solution innovative: there is no model in literature able to tackle energy consumption considering both parts of a Cloud Computing System.

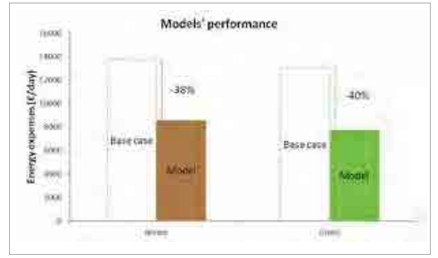
GENERATING A SOLUTION

The solution our group decided to develop was therefore an optimization model aimed at solving the request assignment issue in Data Centers located throughout the world and the network connecting them, keeping in mind our goal, i.e. minimization of energy consumption and maximization of green energy which would benefit IT operating firms, reduce energy costs related to their core business and obviously the environment, which would benefit from the reduction of greenhouse gas emissions.

Simulating requests arriving at the various DCs, with peaks related to the local time zones, the main task was the decision whether to serve a request directly at the entry Data Center or send it to another DC in the network. This problem was solved for an entire, knowing in advance the quantity and type of requests.

Our optimization-based model was developed using the CPLEX software. A first useful feature of this method is the reliability of the solution algorithms, providing optimum and significant flexibility in terms of choice of scenario (more or less complex) and of model parameters, in order for the model to be adapted and customized to meet the needs of the Cloud provider. In fact, we first took into account the most generic scenario, with a large number of request types and different types of servers to process the same; we then moved towards a more realistic scenario, considering appropriate and realistic parameters and variables, following in-depth research.

7 *Mappa zone*



8 *Performance Graph*

Moreover, the main advantage of the solution obtained is the possibility to include in such a model all the variables and constraints playing a role in a Cloud system. As a matter of fact, the constraints ensure that neither the DCs nor the network connections are overloaded in order to ensure fast response times to users.

As expected, the proposed solution is able to redirect requests in certain time zones to the location where the energy cost is lowest (mostly night-time locations, due to energy cost fluctuations). As a direct implication, the results show advantages with respect to an approach in which DC and network consumption are considered separately, which is the usual approach. We considered different scenarios, in terms of number of user requests and server characteristics, and we experienced savings of up to 40% in terms of energy costs with respect to the base case in which request forwarding is not available.

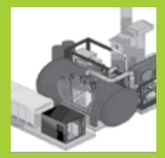
In addition, we proposed a green model in which we took into account the possibility of green energy generation, coming from various renewable sources and varying according to the geographical location and the time zone. With this second model, we not only experienced significant cost reduction but also environmental advantages, deriving from flexibility in the choice of active DCs, in terms of greenhouse gas emission that go beyond financial savings.

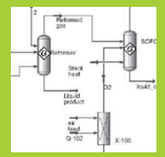
In conclusion, the optimization model developed could be exploited by any Cloud provider with a private (or even pay-as-you-go) network aiming to reduce its carbon footprint as well as its energy costs.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Armbrust, M. et al. (2009) *"Above the Clouds: A Berkeley View of Cloud Computing"*, Technical Report No. UCB/EECS-2009-28, University of California at Berkley, USA.
[2] Gupta, M. and Singh, S. (2003) *"Greening of the Internet"*, in Proceedings of ACM SIGCOMM '03, Karlsruhe, Germany.
[3] Qureshi, A. et al. (2009) *"Cutting the Electric Bill for Internet-Scale Systems"*, in Proceedings of ACM SIGCOMM '09, Barcelona, Spain.

PROJECT 6





FCE

FUEL CELLS FOR ENERGY

FUEL CELLS FOR ENERGY

FCE
Fuel Cells for Energy

project 6

Fuel cells fed by renewable primary sources as a strategic energy route for a Nation: analysis in cooperation with a large Italian energy producer (Edison)

PRINCIPAL ACADEMIC TUTORS

Michele Calì
Energy, Politecnico di Torino

Massimo Santarelli
Energy, Politecnico di Torino

ACADEMIC TUTORS

Andrea Casalegno
Energy, Politecnico di Milano

Gianpiero Groppi
Department of Chemistry Materials and Chemical Engineering
Politecnico di Milano

Renzo Marchesi
Energy, Politecnico di Milano

Emilio Paolucci
Production Systems and Business Economics,
Politecnico di Torino

Milena Salvo
Material Science and Chemical Engineering,
Politecnico di Torino

Alberto Tenconi
Industrial Electrical Engineering,
Politecnico di Torino

EXTERNAL INSTITUTION

Edison Spa

EXTERNAL TUTORS

Davide Beretta
Edison Spa

Stefano Ginocchio
Edison Spa

TEAM A

Lucia Colombo [Team controller]
Energy Engineering

Gianfrancesco Melina
[Project Communication Coordinator]
Aerospace Engineering

Piergiorgio Luigi Montrucchio
Industrial Engineering and Management

PROJECT DESCRIPTION

The Challenge

The project has been based on the evidence that the use of a fuel cell system can generate heat and power with high efficiency. The necessity of investigating a new path to energy conversion compared to thermal engines for power generation is related to the global energy problem which is becoming increasingly relevant. In fact, reduction of greenhouse gas emissions as well as a significant decrease in fossil fuel consumption are two outstanding topics to be addressed. For these reasons, governments are proposing green policies whose goals are to foster the use of renewable sources, reduce energy demand and increase energy production efficiency, thus reducing fuel supply. In this general scenario, the project was built to develop an analysis of the technical, economical and environmental benefits of producing distributed heat and electricity through integrated systems based on fuel cell technology. The final purpose was to identify an innovative solution able to respond to the project requirements: the design of a medium size (1 MW) SOFC plant fed by fuel derived from renewable resources, a possible alternative to the current use of natural gas, actually still the best solution.
Thus the project has been divided in two parts.
The first has been devoted to the choice of a suitable fuel to be used in the cell, selecting among different renewable fuels pointing towards the concept of sustainability. According to the results of a multi-criteria analysis on different types of biomass (animal excrement, agricultural and industrial scrap), biogas produced by anaerobic digestion of civil sewage has emerged to be a good solution in order to guarantee high performance, consistency with existing infrastructures, local availability and constant rate of supply for the plant. Moreover, the solution generates value from waste.
The second part of the project dealt with a deeper analysis of the solution concept, both from a technical and economical perspective. The starting points of this phase were identification of the stakeholders and investigation of their needs. A map of existing

Italian collection centres has been built. Furthermore, a detailed analysis of the biogas treatment process has been performed, focusing on the desulphurization issue that has emerged to be the most significant issue to be addressed in order to guarantee fuel cell integrity and thus technical feasibility.
Subsequently, a possible layout of the plant, with sizing of all components, has been proposed. An economic analysis has also been performed, considering all the benefits of using a renewable source.
According to the solution concept defined, several institutions have been involved. In particular, Edison has allowed us to understand the state of the art of the Italian power market and its future scenarios, while SMAT has provided us essential information to define and detail the proposed concept.

project 6A

FCE
Fuel Cells for Energy

ABSTRACT

The Fuel Cell for Energy (FCE) project addresses the global energy problem by proposing innovative and sustainable solutions, in particular focusing on an Italian perspective. The reduction in greenhouse gas emissions of 20% at least, as well as the reduction in the dependency on hydrocarbons are primary issues to be solved in order to lower the environmental impact of non-sustainable power generation.

The analysis proposed in the FCE project started with the search for a suitable renewable fuel and the best biogas treatment in order to obtain a pollutant-free biogas. It then continued with the technical and economical sizing of a plant fed by the selected fuel.

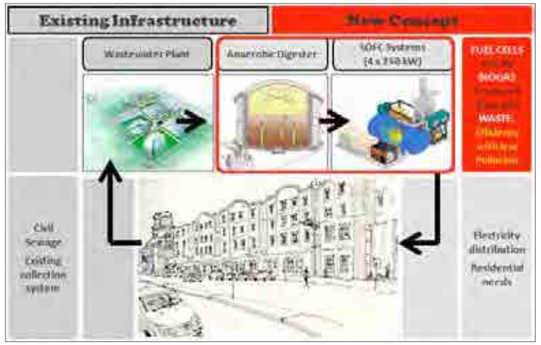
More in detail, the FCE team has investigated the feasibility of a system able to generate heat and power by operating a Solid Oxide Fuel Cell (SOFC) co-generative plant with clean hydrogen, derived from reforming a stream of biogas produced from the anaerobic digestion of civil sewage. FCE is designed to be installed in existing Italian wastewater collecting centres with a minimum catchment area of 100.000 equivalent inhabitants which is the size below which the installation of an anaerobic digester has emerged to be no longer economical. The choice of SOFC is an assumption which is however justified by its significant resistance to pollutants and its future perspectives. The defined nominal power for the plant is 1 MWel. Through the described solution, energy production is delocalized throughout the country with smaller but highly-efficienct plants, reducing the transmission losses on the electrical grid. Moreover, electricity can be produced from renewable treated biomass with positive effects on the surrounding area. Finally, the solution achieves the purpose of producing clean energy whilst limiting the impact on the electricity bill.

TASKS & SKILLS

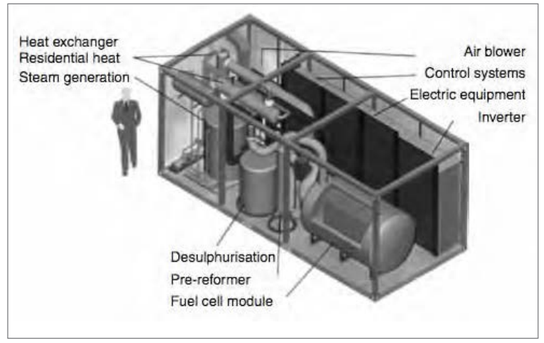
Lucia Colombo worked mainly on process design, focusing on the desulphurization issue and on the detailed plant design.

Gianfrancesco Melina was focused on the analysis of the state of the art of the fuel cells and biomasses.

Piergiorgio Montrucchio worked mainly on the mapping of wastewater plants and on the economic analysis.



1 *Concept solution*



2 *Fuel Cell Module*

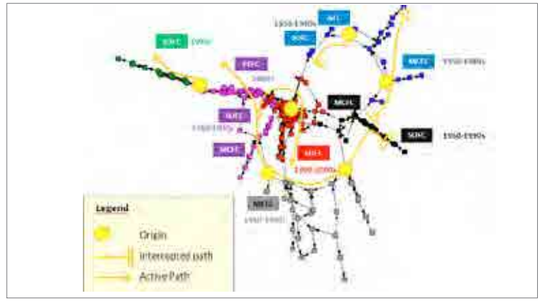
UNDERSTANDING THE PROBLEM

The general brief assigned to the FCE project was to explore the feasibility of distributed medium size co-generative plants throughout Italy, generating energy by the use of fuel cell technology and exploiting biomass available in the area. The starting point was detection of stakeholder requirements : we firstly identified governments and citizens as the main stakeholders. The former are interested in reducing the use of fossil fuels and in limiting the environmental impact of energy generation while the latter are interested in a cleaner environment. Moreover, an FCE plant would also involve the biomass providers as stakeholder, concerned with selling their product, especially if this means a reduction in the cost of treatment. Energy companies would be possible investors since they are required to produce at least 5% of green energy.

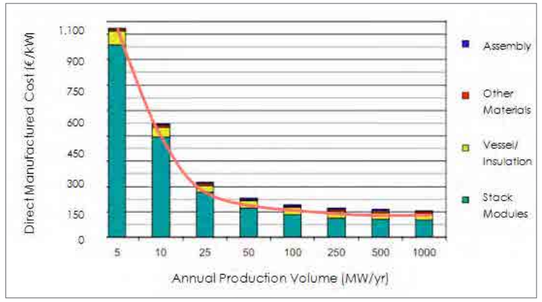
Dealing with system requirements, identification of the needs of the FCE plant started with analysis of the technology. Unlike traditional devices used to generate heat and power (such as internal combustion engines, gas or steam turbines) fuel cells are a new technology working under strictly controlled conditions. For this reason, it is necessary to have biomass at a constant rate and biogas with a fixed composition. These features allow the plant to constantly work at nominal conditions and to guarantee homogeneous feed at the anode, without rapidly degrading the cell. The use of existing infrastructures to collect fuel and distribute power would then faciliate containment of system costs, highlighting the benefits of the fuel cells.

EXPLORING THE OPPORTUNITIES

Several challenges have been faced during the project. In particular, in the first phase we focused on investigation of the best match between cell and fuel. This started from an in-depth analysis of the state-of-art of the fuel cell, in order to better understand its potential and critical issues. Thus, an innovative reticular analysis of the technological trajectories was conducted, based on the information provided by the 196.000 worldwide fuel cell patents. Fuel cell technology turned out to be radically different from devices available on the market for producing heat and power since it works without any combustion. For this reason, the efficiency of the cell is not subject to the Carnot limit and thus can reach a 60% level also in small-size plants. The use



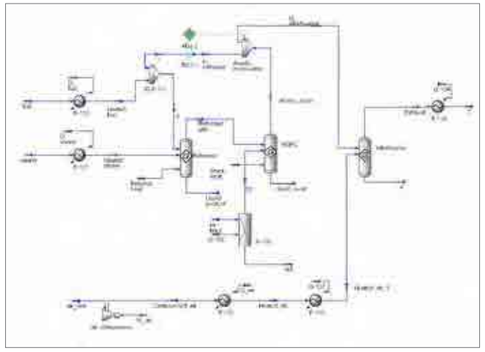
3 *Analysis of the Technological Trajectories in the Fuel Cells' field (based on a patent research)*



4 *Analysis of a Fuel Cell Cost depending on the annual production volume*

Biogas Composition	Biogas from Wastewater treatment plants sludge
CH_4 % vol.	50-60
CO_2 % vol.	38-34
N_2 % vol.	5-0
O_2 % vol.	1-0
H_2O % vol.	6 (at 40 °C)
H_2S mg/m^3	1000-900
NH_3 mg/m^3	-
Aromatic mg/m^3	0-200

5 *Average Composition of Biogas from civil sewage*



6 *Plant design*

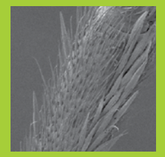
of biogenous fuels could pursue the goal of sustainability.
Nevertheless, fuel cells are also characterized by significant critical issues due to the fact that they are highly vulnerable to pollutants, such as sulphur compounds and particulate. For this reason, not all types of biomass are suitable for fuelling the cell. Thus we performed a multi-criteria analysis to compare different fuels derived from biomasses. Liquid fuels were soon excluded since they need to be vaporized inside the anode before use in the cell. Moreover, as opposed to gaseous fuels, liquid fuels cannot be delivered using the existing transport infrastructure. Therefore, only gaseous fuels have been compared according to criteria regarding the cost of fuels, their suitability to be easily transported, their availability throughout the country, the problems that can occur by using them in the cell and government incentives. The result of this analysis leads to the choice of biogas derived from anaerobic digestion of civil sewage.
The next step has been to identify the places that could supply such gas. Thus we mapped the existing Italian collection centres in which biomass represented a troublesome burden. FCE installation would fit perfectly in these centres, allowing recovery of the biomass and the production of a green energy. It would also lead to an income for the plant owners who are interested in selling the biomass and reducing the treatment load.
In order to complete the scenario, we also identified the most competitive alternatives to the use of fuel cells for producing heat and power from sewage, focusing our attention on internal combustion gas engines.

GENERATING A SOLUTION

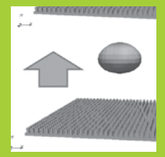
As a result of the collaboration with SMAT and the multi-criteria analysis, biogas produced from civil wastewater was chosen as a fuel to be used in a fuel cell plant. A technical and economic feasibility analysis has been performed in the second phase of the project.
The aim was to develop the design of a medium size plant which could be customized for each wastewater collecting centre with a catchment area large enough to justify the investment.
The generated power would be used for internal needs and the surplus released into the electric grid. Furthermore, supposing the installation of FCE in all the suitable collection centres and taking as a reference the Italian energy supply of 320 TWh/year, the percentage of producible green energy has emerged to be about 1%. This would be not a negligible share within the Italian mix; moreover, according to a more realistic vision, even if deployed on fewer sites, the solution would help to diversify energy production which is considered a winning strategy to solve the complex energy problem. Finally, the recovery of waste could respond to the specific problem of one of the stakeholders involved, the wastewater plant owner.
Thus, the innovation in the described solution consists of the combination of different technologies in order to respond to specific stakeholder requirements, limiting investments in complementary assets.
Plant design was divided in two sequential phases. The first was devoted to the biogas desulphurization process: all the existing techniques were considered in this phase. In particular, we focused on finding the most suitable adsorption materials to meet SOFC requirements, comparing different commercial (and not) products. Having identified the biogas treatment process, the next step was the fuel cell system design and sizing of the necessary components. Plant design has also been useful for the economical feasibility study. In this phase, both the capital costs and the economic benefits arising from incentives granted for renewable sources have been considered. From the analysis it turns out that there is still much to be done (first of all, on the cell life time) in order to make the system truly competitive on the market, but all the involved technologies are very promising.
Finally, a hybrid scenario has been considered as a possible future development: efficiency can also be increased by installation of a gas turbine which expands the exhaust gases from the system post-combustor.

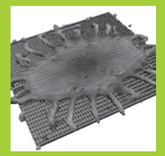
MAIN BIBLIOGRAPHICAL REFERENCES

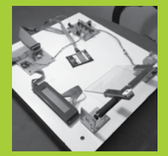
[1] Garret D. E, 1989, *Chemical Engineering Economics*, Van Nostrand Reinold, New York
[2] Verspagen B., 2005, *Mapping Technological Trajectories as Patent Citation Networks. A Study on the History of Fuel Cell Research*, Eindhoven Centre for Innovation Studies, The Netherlands
[3] Larminie J., Dicks A.,2003, *Fuel Cell System Explained*, Wiley



PROJECT 7







Gecko vs Lotus

SUPER-ADHESIVE OR ANTI-ADHESIVE BIO-INSPIRED NANOMATERIALS

project 7

Gecko vs Lotus
Super-Adhesive or Anti-adhesive Bio-inspired Nanomaterials

The aim of the "gecko vs lotus" project is the design and fabrication of bio-inspired super-adhesive (with Vibram) or anti-adhesive (with Indesit) nano-surfaces

PRINCIPAL ACADEMIC TUTOR

Nicola Pugno
Structural and Geotechnical Engineering, Politecnico di Torino

ACADEMIC TUTORS

Alberto Corigliano
Structural Engineering, Politecnico di Milano

Barbara Del Curto
Chemistry Materials and Chemical Engineering "Giulio Natta", Politecnico di Milano

EXTERNAL INSTITUTIONS

Indesit Company

Vibram SpA

EXTERNAL TUTORS

Paolo Faraldi
Indesit Company

Antonello Ghignone
Vibram SpA

TEAM A

Francesca Letizia [Team controller and Project Communication Coordinator]
Aerospace Engineering

Pietro Brambilla
Aeronautical Engineering

Jacopo De Amicis
Nuclear Engineering

Chiara Saggese
Chemical Engineering

TEAM B

Isabella Bertoli [Team controller]
Nuclear Engineering

Anna Botto
Civil Engineering

Davide Guzzetti
Space Engineering

Stefano Larentis
Electronic Engineering

Giancarlo Soavi
Physics Engineering

PROJECT DESCRIPTION

Introduction
The "Giuseppe Maria Pugno" Laboratory of Bio-inspired Nanomechanics (http://areeweb.polito.it/ricerca/bionanomech) has significant experience in designing new bio-inspired nanomaterials and has thus proposed this project, in line with its current research activity (e.g. the first self-cleaning polystyrene@Polito, POLOTO, was previously obtained thanks to a collaboration between Indesit Company and our Lab), to the Alta Scuola Politecnica.

The Challenge
Several animals, such as insects, spiders and geckos have developed fascinating nano-architectures in order to maximize and control adhesion. Adhesion-prevention solutions are also suggested by nature: peculiar plant leaves, such as the famous lotus, are able to prevent insect adhesion, again thanks to nano-architectures, even if insects evolved in order to maximize adhesion. The replication of such super-adhesion or anti-adhesion mechanisms, thanks to bio-inspired nanomaterials, is a challenge of the current material science and is key for developing advanced applications, such as new super-adhesive or anti-adhesive nanomaterials.

The teams
The Teams have worked on the design and fabrication of bio-inspired adhesive (Team A, "Gecko") or anti-adhesive (Team B, "Lotus") nanomaterials.

The results
Two case studies have been considered: adhesive materials for new soles with high grip on wet surfaces (Team Gecko in collaboration with Vibram Company) and self-cleaning polystyrene for refrigerators (Team Lotus in collaboration with Indesit Company). In particular, prototypes of new soles based on macroscopic and microscopic suction cups and porous materials have been designed, developed and characterized. Complementarily, Indesit polystyrene materials have been experimentally tested and the best solution has thus been identified; moreover, a new design has been proposed thanks to numerical simulations to further increase the self-cleaning ability of the refrigerator.

GECKO

TASKS & SKILLS

Pietro Brambilla studied adhesion in nature, carrying out experiments on cockroaches; he then contributed to the production and testing of soles with varying porosity.
Jacopo De Amicis studied the mechanism of adhesion of the suction cups; he produced and tested the suction cup soles, comparing them with traditional types.
Francesca Letizia studied the adhesion mechanism and behaviour of visco-elastic materials, through laboratory tests and analysis of the soles produced.
Chiara Saggese studied adhesion in nature, observing the organization of hierarchical surfaces; she then contributed to the production and the testing of soles with varying porosity.

ABSTRACT

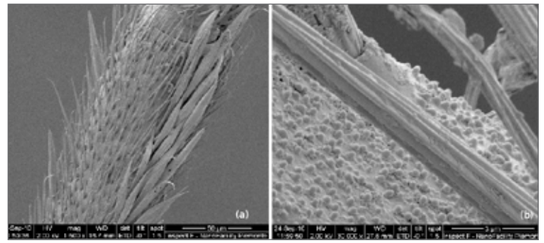
Slips and falls are ones of the most common causes of occupational accidents, a problem that has a significant impact both at the social and at the economic level. For this reason in the last years there is an increasing interest in studying mechanisms of interaction between the shoe sole and the floor.

The activity of our group was focused on the study of innovative concepts to improve the adhesion of the sole, evaluating some changes in its design and in its material. Our research was inspired by the observation of various phenomena of adhesion in Nature, such as in geckos' feet, insects' claws, spiders' webs, or even octopuses' tentacles. Different approaches were developed and examined through laboratory experiments.

The fruitful collaboration with Vibram, a leader company in the field of safety soles, helped us to highlight the basic requirements for the product, both in terms of safety and industrial feasibility. The analysis of the requirements suggested us to evaluate the effect of the porosity of the compound on the behaviour of the sole. The idea underlying this research is that varying the porosity it could be possible to achieve the optimal dimension and density of the pores in the surface in order to obtain suction-cup effect, that can avoid slip even if the floor is contaminated by dirt or liquids. The tests show that increasing the porosity of the sole modifies its performance; moreover the reduction of the weight of the sole is beneficial to the wearer's feedback during the slipping. In fact, the human factor is fundamental in slip and fall events and we had the chance to take advantage of the experience of Vibram Tester Team to evaluate the performance of our soles.

1 *Laboratory apparatus to reproduce the condition of detachment of an adhesive tape*

2 *Two subsequent frames showing the detatchment of a Blatta Orientalis*



3 *SEM image of a water strider's leg*

UNDERSTANDING THE PROBLEM

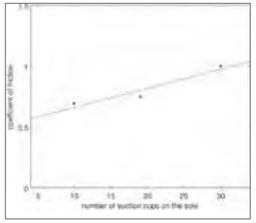
Our project is based on the exploration of the potential of bio-inspired materials and, in particular, our team studied their adhesive proprieties. The aim of this research is to improve the grip of a shoe sole in different conditions.
This aspect is relevant for sports applications and even essential for the professional footwear of workers in dangerous environments.
In order to reduce slippage it is useful to increase friction at the interface between the shoe sole and the ground. It is possible to obtain this result acting on several parameters, such as the sole material or the tread pattern.
However the improvement in the behaviour of the sole cannot be quantified only by the coefficient of friction between the surfaces. For example, it is also very important that the sole does not lose grip rapidly in the transition from static to dynamic conditions: in this way the wearer has better control of his/her position and better feedback from his/her movements. This observation highlights the fact that also the dynamic behaviour of the sole is fundamental to obtain a reliable product; considering this aspect, however, introduces a higher level of complexity since it can only be evaluated by reproducing the actual conditions of use.
Moreover, the sole performance should be as time independent as possible: this requires the sole to be self-cleaning, since dirt might cause a progressive loss of grip, and that the effect of the wear on the sole surface does not reduce its functions.
We tried to conceive an innovation able to fulfil all these requirements and which could be implemented within two years, which is the average time that Vibram spends from the R&D phase to the commercialisation of a new product.

EXPLORING THE OPPORTUNITIES

Several footwear characteristics influence the interaction between the sole of the shoe and the ground, such as the sole material, the tread pattern and the shape of the cleats.
The sole material is usually a rubber whose hardness is chosen carefully, considering that a hard material is better in supporting weight, while a softer one provides better slip resistance. The hardness of a sole has significant influence on its life, since softer soles have a lower resistance to abrasion. The behaviour of the material is studied firstly theoretically through a model that

4 *Different concepts of the suction-cups sole*

5 *Standardized test to measure the resistance to slip of the sole*



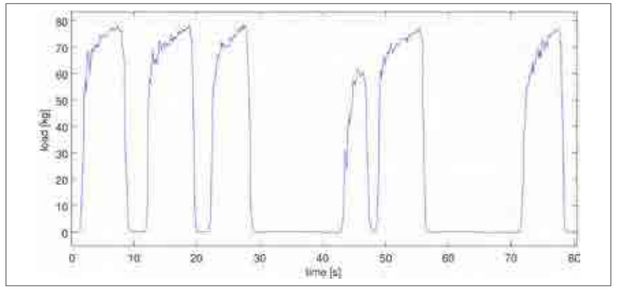
6 *Behaviour of the coefficient of friction with the number of suction cups present on the sole*

7 *Three different sole compounds with varying porosity*

considers its non-linear elasticity and subsequently experiments are conducted in order to understand under which conditions the detachment occurs.
The modifications in the tread pattern should follow the SATRA (Shoe and Allied Trade Research Association) guidelines to design a slip-resistant sole. In particular, these guidelines contain indications on how to make a sole behave evenly, regardless of the slip direction, to limit its tendency in getting dirty and its sensitivity to contamination.
In nature it is possible to find systems that present all these features. In fact several insects and other animals, such as geckos, have highly remarkable adhesive capacity coupled with the fundamental possibility of obtaining easy detachment when needed, keeping clean both their feet and the surface on which they are moving. These mechanisms represent possible techniques to improve the grip of a sole and therefore we decided to study them in depth in order to understand how the different phenomena work and how it could be possible to apply them to soles. The research period consisted of an initial bibliographic research and then a number of laboratory experiments. In particular, we performed in vivo experiments on cockroaches to quantify their adhesive capacity and the examination of the water striders' claws under the microscope showed us the surface arrangement.
The legs of the insects present a very complex architecture, organized in different dimensional scales. This structure assures a high level of adhesion but presents two main drawbacks:
- the wear of the sole can quickly erode the architecture of the surface, radically changing its performance,
- the production of this kind of sole is extremely complex and it would require significant changes in the industrial processes, thus leading to a very long time before its commercialization.
We therefore concluded that we needed to find inspiration in a different field and thus we considered the adoption of suction cups as a more feasible option offering interesting performance, even with contaminated surfaces.

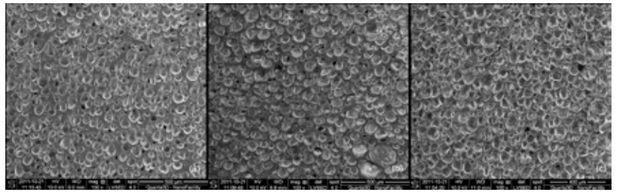
GENERATING A SOLUTION

In the second phase we worked in collaboration with Vibram: in their facilities we created the soles and then tested them under different conditions.
First, we made a number of prototypes of soles applying suction cups of different material, size and quantity to a flat sole. The soles were tested together with the Vibram Tester Team and we obtained numerical data of the coefficient of static adhesion and qualitative data concerning the feeling the sole provides. The soles were tested on surfaces with different roughness and, as expected, we obtained highest adhesion on the smoothest surface. We tested the soles with a SATRA standard machine which provides a measure of the dynamic coefficient of friction.
The tests on the suction cup sole show that it presents a very high coefficient of friction in the static condition but its behaviour during transition to the dynamic condition is not acceptable since the wearer does not obtain adequate feedback of slippage and there is too much difference between the static and dynamic behaviour.
We know that safety is the main target in sole design and, since dynamic behaviour is the most important parameter, the suction cup concept had to be discarded. In order to maintain the beneficial effect of the suction cups, we considred creating a porous sole. Therefore, a spongy sole was made of expanded rubber containing many micro pores which, at the interface, might behave like a micro suction cup.
Having a sole made of a (macroscopically) continuous material, instead of one with a number of large suction cups applied to it, is a huge advantage in terms of sole life: even if the sole is worn, the new layer can maintain the characteristics of the previous since the sole is homogeneous throughout its thickness. In this way, we expect the behaviour of the sole not to change radically over time.
In order to obtain soles with varying porosity, we created them (at the Vibram R&D Department) by modifying the quantity of the blowing agent in the rubber compound. We thus produced three soles with different density and porosity and later tested them on several surfaces. From the static tests we did not obtain as positive results as with the macro suction cups but we discovered that, if the porosity changes, the sole performs in a different way during slippage since the micro-pores increase roughness at the interface. Moreover, a lighter and more flexible sole contributes to improving the wearer's feedback.



8 *Final result of the process of production of the soles*

9 *Behaviour of the coefficient of friction with the number of suction cups present on the sole*



10 *Nicola Faccinetto (Vibram tester team) testing a new concept sole*

11 *SEM image*

project 7B

LOTUS

TASKS & SKILLS

Davide Guzzetti, investigated the dynamics underlying the drop impact on super-hydrophobic surfaces and performed numerical simulations using OpenFoam. He also developed an open innovation model for the project.

Giancarlo Soavi, investigated the physics behind the drop transport and electrowetting phenomena and evaluated the introduction of the self cleaning refrigerator on the market as a possible investment for a household appliance company.

Isabella Bertoli, investigated drop rolling/sliding behavior through numerical simulations with OpenFoam and designed the layout of the "self-cleaning" refrigerator.

Anna Botto, experimentally investigated drop rolling/sliding on inclined surfaces.

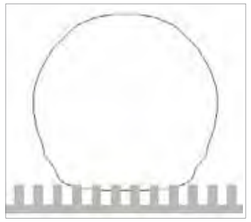
Stefano Larentis, investigated the dynamics underlying the drop impact on hydrophobic surfaces and designed the conceptual scheme for the "Follow-The-Drop" approach.

ABSTRACT

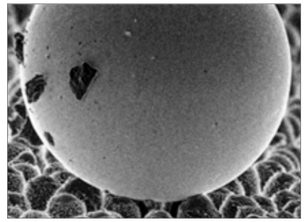
Lotus effect is a fascinating and inspiring phenomenon that can be observed in nature: after rainfalls, water droplets tend to reside in spherical form on the lotus leaf and do not wet the surface. Moreover, when the leaf is inclined, the droplets gently roll off, efficiently removing the dirt, obtaining a wet and clean surface. Inspired by this effect, much research is currently conducted in order to investigate the phenomenon and grasp its secrets. Superficial texture and a high degree of roughness seem to be the key aspects of this amazing effect. By disclosing the physics of this phenomenon and the most important underlying parameters, the lotus effect could be reproduced for commercial exploitation with almost an infinite number of possible applications.

Our project aim is to study the super-hydrophobic, self-cleaning and anti-adhesive features of lotus-like surfaces in order to be able to produce artificial surfaces. All the aspects related to drop interaction with the surfaces have been studied. By adopting a "Follow-The-Drop" approach, all drop-surface interactions are studied, starting from the drop falling on the surface and ending with the drop removal. Experimental work and numerical simulations are employed to capture the phenomenon and its key parameters. Finally, a possible application is considered. All the results obtained from the different phases of the "drop cycle" are summarized in a possible "self-cleaning" fridge design and also prototypical layouts are proposed.

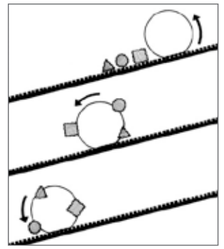
1 *Lotus effect*



2 *Fakir*



3 *Superficial Texture*



4 *Lotus dust*

UNDERSTANDING THE PROBLEM

The Lotus Team project is a bio-inspired nano-materials project. Our aim is to use a bio mimesis approach taking inspiration from nature for developing new innovative technologies. This process, called biomimicry, has been increasingly developed in recent years, borrowing ideas and inspiration from nature in order to replicate extremely interesting effects. One of the most attractive is the Lotus effect, exhibited by the Lotus leaf, which is characterized by amazing super-hydrophobic, anti-adhesive and self-cleaning properties.

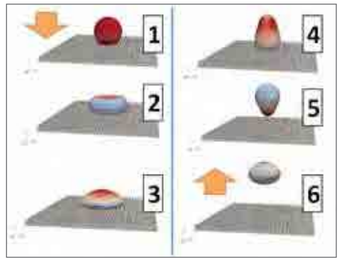
The main objective of the project was to provide a comprehensive knowledge of the Lotus effect and understand how this effect and its properties could be replicated in order to create innovative, bio-inspired, anti-adhesive, super-hydrophobic and self-cleaning surfaces. The key aspect of the problem lies precisely in the identification of those parameters that could make possible the creation of a surface with all of these features at once. Indeed, super-hydrophobic, self-cleaning coatings and materials are believed to be a major breakthrough, both in academia and industry, leading to new understanding in physics and, at the same time, new industrial applications. The team extensively developed both sides of this challenge, also paying attention to the social, environmental and economic feasibility of the entire project.

In particular, as a case-study, the team focused on the development of an innovative super-hydrophobic, self-cleaning fridge. This is one of the possible applications of this technology. Therefore, the team partnered with INDESIT, a leading company in the manufacture of "white goods", with more than 16 million household appliances produced. INDESIT is very sensitive to green, eco-compatible technology and is also pursuing an R&D oriented company policy.

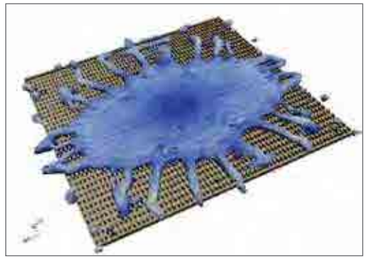
EXPLORING THE OPPORTUNITIES

The investigation of the relationship between the material and the liquid is fundamental. Liquid-surface interaction is a complex process, made up of different steps: first, drop impacts on the surface, second, drop rolls or slides on the surface and third, drop can be removed from the surface. Consequently, different kinds of properties and parameters, i.e. static and dynamic properties, are part of the entire phenomenon and influence the resulting properties of the surface in terms of i) hydrophobic, ii) self-cleaning and ii) anti-adhesive features.

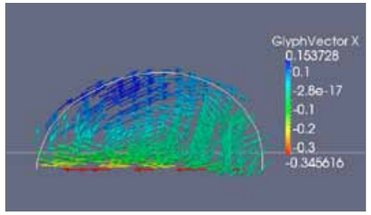
Therefore, these three main steps have been thoroughly investigated by our team in order to identify the key parameters able to calibrate the hydrophobic properties of a surface. The ultimate aim is a concrete application of these surfaces. Although many researchers have studied this topic for several years, a detailed understanding of the lotus effect is still lacking. Therefore, an



5 *Drop rebound*



6 *Splash*



7 *Internal motus*

in-depth research oriented assessment is necessary to understand how this technology could be successfully implemented in actual products (e.g. refrigerator). For these reasons, our group performed a wide range of research activities. Extensive numerical simulations (e.g. OpenFOAM) and experiments of drop dynamics were performed with Pugno Lab to study the drop impact, rolling/sliding and the movement on flat surfaces (e.g. electro-wetting). Using the knowledge directly acquired during the research part, we can assess that it is possible to calibrate the hydrophobic properties of theoretically any surface by thoroughly patterning the surface material (e.g. complex surfaces) in order to obtain the desired responses such as:

1. Rejection of impacting droplets;
2. Rolling of drops with enhanced capability to collect dirt particles from the surface;
3. Steering the position and the shape of a particular drop.

Each of these responses offers a broad spectrum of opportunities. Rejection of impacting droplets can be used for ever-dry surfaces which can be implemented on benches that remain dry even after a rainstorm, for graffiti-resistant walls capable of repelling the writer's spray or in general for obtaining non-splash surfaces. Rolling drops collect a significantly higher number of dirt particles compared to sliding drops and this leads to the most appealing and impactful potential application, i.e. self-cleaning surfaces for INDESIT refrigerators. Finally, steering the position and the shape of drops can be implemented by following the example of certain desert beetles which direct droplets on prescribed itineraries to their mouth, thus being able to feed themselves with morning dew. The most significant challenge is combining all these features in just one application, leading to possible exploitation of all the benefits deriving from each of these features at the same time, in complete analogy with the Lotus Leaf. Therefore, instead of focusing on one property at a time, independently from the others, in order to optimize and fully exploit its potential, the key idea of the project is to explore each challenge in order to capture the most important parameters influencing the physical phenomena involved and consequently understand how each property could be related to the other in order to have not just one result but a complete perspective of all the aspects.

GENERATING A SOLUTION

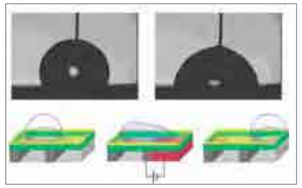
A first important output of the study is the conceptual approach defined by the three steps mentioned above, which has been named "Follow-the-Drop-Approach", which investigates each peculiar phase of the water-surface interaction. Firstly, we characterized the drop impact with respect to the surface features through numerical simulation. We studied drop retraction dynamics and the drop fragmentation problem. The transition between the Fakir and Wenzel state as a function of the impact velocity and pillar geometry were studied; we also addressed the challenge of optimization of pillar geometry in order to achieve the Wenzel state. Secondly, experiments were performed on polystyrene surfaces provided by INDESIT to address the motion of droplets on inclined solid surfaces, testing different inclinations and surface types different motion regimes were described. Also, the existence of a stationary velocity of a drop moving on such surfaces was characterized as a function of the drop dimension. Finally, the feasibility of transporting a drop by adopting the electro-wetting technique was evaluated. As a matter of fact, in order to effectively implement the technology, the research steps we covered are fundamental since it allows us to understand the parameters governing the overall physical process, facilitating successful technology transfer to actual products able to respond to consumer needs.

Finally, a possible application in the field of household appliances was developed. A preliminary design of an innovative self-cleaning fridge was studied, taking into account both the fundamental insights on super-hydrophobic surfaces provided by the research and the company and user requirements. Different layouts were considered in order to address the needs of different customers: from a basic and immediately applicable solution to a more ingenious one, which is meant to mark a turning point for the entire concept. Consequently, three different trade-offs were proposed:

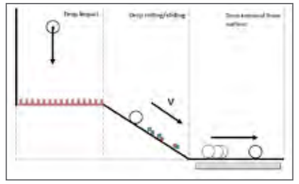
1. Self-cleaning shelves to replace obsolete versions and get the consumer used to self-cleaning technology;
2. Built-in super-hydrophobic technology in new products, while maintaining the current, well-known fridge layout;
3. Gradual revision of the fridge layout to completely automate the cleaning procedure by implementing an auxiliary washing line and circular rotating shelves which leverage on centrifugal force for self-drying.

These proposed concepts are intended to fully exploit the revolutionary potential of the new technology we addressed. The refrigerator we designed can be considered just the first example of the potential revolution this technology could bring about.

8 *Experimental setup*



9 *Drop transport*



10 *FTDA*

11 *Sf FRIDGE*

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Barthlott W., Neinhuis C. (1997) *Purity of the sacred lotus, or escape from contamination in biological surfaces*. Planta, 202, 1-8.

[2] Yoon J.Y., Robin L.G. (2003) *Preventing Biomolecular Adsorption in Electrowetting-Based Biofluidic Chips*, Anal. Chem., 75, 5097-5102.

[3] Patankar N.A., (2004) *Mimicking the Lotus Effect: Influence of Double Roughness Structures and Slender Pillars*, Langmuir, 20(19), 8209-8213.

PROJECT 8

Rethinking Industrial Cities

ianus

IVREA AS UNESCO SITE

Rethinking Industrial Cities
Ivrea as Unesco Site

project 8

Strategies and policies to revive industrial cities. Ivrea and its heritage, resources, players and actions in the long-term process of candidacy as a Unesco Site

PRINCIPAL ACADEMIC TUTORS

Patrizia Bonifazio
Architecture and Planning,
Politecnico di Milano

Alessandro De Magistris
Architecture and Planning,
Politecnico di Milano

ACADEMIC TUTORS

Carlo Alberto Barbieri
Inter-university Territorial Studies
and Planning, Politecnico di Torino

Filippo De Pieri
Architectural and Industrial Design,
Politecnico di Torino

Paolo Galuzzi
Architecture and Planning,
Politecnico di Milano

Federico Oliva
Architecture and Planning,
Politecnico di Milano

Gabriele Pasqui
Architecture and Planning,
Politecnico di Milano

Rossella Salerno
Architecture and Planning,
Politecnico di Milano

Giorgio Vitillo
Architecture and Planning,
Politecnico di Milano

EXTERNAL INSTITUTIONS

Comune di Ivrea

Fondazione Adriano Olivetti

MuseoTorino

Studioata

EXTERNAL TUTORS

Giovanna Codato
Comune di Ivrea

Melina De Caro
Fondazione Adriano Olivetti

Francesca Filippi
MuseoTorino

Gracialiano Berrocal
Studioata

TEAM A

Alessia Mapelli [Team controller]
Architecture

Annalisa Andaloro
Building Engineering

Lara Di Chio
Engineering for Cinema
and Methods of Communications

Francesca Giliberto
Architecture for restoration and preservation
of architectural and environmental heritage

Andrea Migliarese
Architecture

Matteo Novati
[Project Communication Coordinator]
Building Engineering and Architecture

PROJECT DESCRIPTION

The Challenge
During the 20th century industrial cities underwent experimentation with new models of production systems, often linking industrial projects with the modernity of architectural and housing development models and new conceptions of planning. After the decline and dismantling of industrial sectors, the communities affected had to find new ways to relaunch and maintain the physical structures of the industrial city, which were often of excellent architectural quality. Today these cities find themselves rethinking their territory in order to host new activities and processes of innovation and development. Triggering this change means organizing a long-term project that requires the exploitation of the local heritage, recognition of the potential of local players and resources, the involvement of communities and the communities' capacity to create a new future scenario in which to recognize themselves. Various strategies have been used: the policies of major events, the recognition of "cities of culture", the organization of important modern buildings by well famous architects.
Among these, there is also that of Unesco recognition, which places two different actions together: that associated with the utilization of the cultural experience that characterizes locations and that associated with the capacity to "maintain" the asset that is the object of recognition over time and to place it within the contemporary, through a so-called management plan (which is obligatory for presentation of the candidacy dossier). The management plan therefore could become a full-blown strategic plan, a plan that makes the cultural heritage an important element in policies of innovation and development. The project proposed to consider the experiences under way in North America and Europe (in western countries and in ex Soviet countries) in a comparative key and to organize experimentation in the field starting with the case study of Ivrea, the city of (Adriano) Olivetti and Olivetti itself, which is about to inaugurate its process of candidacy as a Unesco site.

The Team
During the first phase, the team has analyzed two specific themes: the Unesco candidacy as starting point for the development of a strategy toward the city transformation and relaunch; the typical structure of management plans required by Unesco, in order to understand the fundamental actions for the maintenance and valorization of the heritage. This analysis has involved, together with the students, the academic tutors who explored, within their studies, a specific attention to the themes of strategic planning.
In the second phase, the team pointed out the realization of an urban museum (IANUS) as promoter of a new attention toward the city of the Nineteenth century: this cultural institution could become a new place for public decisions and debate among citizens. In this design phase, the team was followed by a museum curator, who helped the definition of the project concept and the classification of real and virtual collections in the urban museum; meanwhile, a set of urban transformations has been planned with the aid of an architect, rethinking some of the public areas and interpreting the collective needs.

The result
IANUS is the concept of a urban museum, and its subparts propose several hypotheses for future transformations in the city of Ivrea: the new meaning and significance of virtual museums; the idea and perception of public spaces; the importance of participation in the municipality.

project 8A

IANUS
Ivrea: Architecture 'n Urban Stories

ABSTRACT

Ivrea has been influenced by the physical and ideological presence of Olivetti, determining a unique model within modern post-industrial cities. Its heritage is not only composed of high quality architectural buildings but also of a huge set of values, an immaterial richness which needs to be brought to light in order to make every single citizen more aware of the alternative industrial society project proposed by Adriano Olivetti. The suggested strategy aims to give new relevance to the town through the Great Event of Unesco candidacy. The task is therefore to render the effects of candidacy permanent, providing a solid base for future development with a long-term perspective.

Considering the specific characteristics of the architectural heritage, the main challenge for the team has been to find a creative preservation policy, in contrast with the traditional idea of a monument proposed by Unesco, coherent with the particular nature of Ivrea: currently, the heritage is spread throughout the town, covering more than 70% of its municipal area; moreover, ownership is fragmented among 1200 different people. For this reason, preservation of the architectural heritage has to shift from a single element to cover entire quarters.

The team focused on strategies e useful in managing the heritage in an innovative and active way, working both on a local as well as an international level: locally by increasing interaction between public and private sphere; globally by involving international users.

The framework for city development is a grid for the mandatory Unesco management plan intended to become a strategic plan for the entire city of Ivrea.

Within various strategies, the main solution proposed is the creation of a new museum, working as a tool for future urban transformation. It will not be or look like a traditional museum, both in terms of structure and contents: the innovation lies in the re-interpretation of an ordinary tool, the museum, in an unconventional way. Its functions will be halfway between architectural heritage management and urban planning.

TASKS & SKILLS

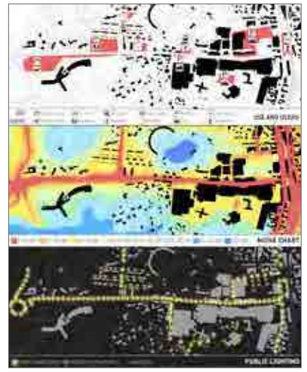
Annalisa Andaloro and **Alessia Mapelli** analysed the strategic planning dynamics and developed the grid for the Ivrea management planfollowing and innovating Unesco guidelines.

Lara Di Chio designed the overall structure of the virtual museum, defining the idea concerning the layout, animation, graphics and main navigation tree.

Francesca Giliberto analysed existing typologies of museum and proposed a new urban museum as a medium to deliver local cultural policies, defining its structure and functions.

Andrea Migliarese and **Matteo Novati** analysed the urban fabric of Ivrea, developed the museum's concept and designed two public spaces in the town as a demonstrative application of the principles.

In addition, the entire group worked together in the preliminary phase, studying the context of intervention, the Unesco procedures and exploring the potential of strategic planning through case studies.



1 *Scheme of the strategic-management plan*

2 *IANUS concept: museum references and suggestions.*

3 *Analysis of via Jervis urban fabric: users, noise levels and public lightening*

4 *Urban requalification of the public space between Via Jervis and Via Di Vittorio and new interpretation centre*

5 *Aerial rendering of the new public space from via Di Vittorio: green roof above the car park and watchtower*

6 *Rendering of the exhibition space between via Jervis and via Di Vittorio*

UNDERSTANDING THE PROBLEM

A central issue arose when the team started dealing with the complex matter of the heritage left by Adriano Olivetti in the city of Ivrea: a general lack of awareness with respect to the material and immaterial legacy and a common disregard for the contribution to the collective identity.

More than 70% of the building heritage is of private domain, fragmented among hundreds of owners: shared strategies for preservation are difficult and dialogue among institutions is poor.

Communication and promotion of the heritage are missing: internally, since citizens do not consider it as worthy of preservation and protection; externally, given that the renown of the city is limited to a sectorial audience.

EXPLORING THE OPPORTUNITIES

The team performed an analysis of the behaviours of other post-industrial cities in Europe: many of these towns are successfully rethinking their future and their set of values through strategic planning. Unlike traditional urban management tools, a strategic plan combines dynamic participation among public and private actors and development of a shared vision for the future.

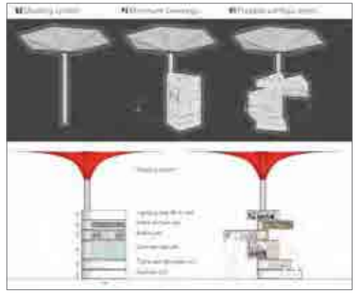
Among the effective policies adopted by the case studies, the team focused its attention on the organization of Great Events as a catalyst of development, able to attract general attention, ideas, people and investments.

GENERATING A SOLUTION

The Unesco recognition is thus identified as the Great Event that can start and contribute to guiding the transformation of Ivrea. Given the characteristics of the heritage of the city, the management plan, mandatory for Unesco candidacy, can become the strategic plan for the city.

The team decided to work on exploring different lines of action, under the common frame of the plan: the existing open-air Museum of Architecture (MaAM) is destined to undergo a radical change, increasing its role in the community dynamics and in the institutional debate, renovating public spaces located along the museum itinerary, and enhancing the virtual section with new contents.

All these strategies go under the concept of IANUS (Ivrea: Architecture 'n Urban Stories). The comparison with the Roman divinity Ianus, with its double face, underlines unity and continuity be-



7 *Example of urban learniture: kiosk with exhibition facilities*

8 *Requalification of the courtyard behind the former Olivetti factory*

9 *Scheme of the virtual museum*

tween city and museum, two sides of the same entity: the city *is* the museum, the museum *is* the city.

The strategic-management plan

The general management plan model provided by Unesco is subdivided into four different parts, called "projects": knowledge, conservation, strategic valorisation, control and monitoring.
To satisfy Unesco requirements, the team developed a specific grid of actions, characterized by innovation of previously existing techniques, for the Ivrea case. In particular, the themes of conservation, promotion and communication of the architectural heritage, which are the main aims of the project, have been dealt with using a traditional tool, i.e. the creation of a *museum*, but giving it a *contemporary* and *unconventional* interpretation. In fact, it is the result of a *strategy* for the city's renewal and, as such, should provide guidelines for its future development. The crucial innovation is the way the museum works since it is intended to *actively preserve* the heritage and create values, in contrast with traditional conservation principles which tend to put objects in a steady state where nothing can change.

IANUS - Ivrea: Architecture 'n Urban Stories

IANUS adopts a number of features from existing typologies of urban museum, but also additional characteristics make it a pioneering structure. Firstly, it is a medium to deliver local policies, promoting strategic actions:

- Actively preserving and managing the architectural heritage and consequently the cultural legacy;
- Building and interpreting the collective memory and the sense of community with direct involvement of citizens;
- Promoting studies and connecting cities around the world, linked by on-going urban transformation processes, allowing participants and visitors to discuss, exchange ideas and contribute to the creation of a shared knowledge on urban change.

Ivrea: Architecture 'n Urban Stories is composed of an interpretation centre (the core of the museum), a set of itineraries and public spaces spread throughout the city, a virtual platform available on the web.

IANUS interpretation centre

It has a cultural, institutional and research role: it is the access portal to the architectures and the city, seat of permanent and temporary exhibitions, where the visitor is initiated to the museum visit. It provides a debating arena for institutions and citizens where decisions are taken in cooperation. In addition, it produces knowledge on the theme of urban and architectural transformation, both at a local as well as international level.

IANUS around the city

Following the principle of unity between city and museum, the architectural itineraries are designed in correspondence with the most popular daily routes of citizens: if public spaces and urban furniture are to perform a dual function (museum space and city space), their use and liveliness must be continuous. An analysis methodology has been developed using the case study of via Jervis which could then be applied to the rest of the urban fabric: it involves studies on mobility flows, noise, lightening systems and private and public property.
Interstitial and marginal areas are seen as potential strengths of the urban system: they are renovated by adding parking lots, green areas and pedestrian paths, kiosks, fountains and bus stops. In the meantime, they are redesigned enhancing their role of "museum spaces": scenic and preferable viewpoints are favoured, exhibition areas are provided.
Creating flexible objects and areas makes the renovation investments worthwhile: a line on the road can serve as a separation for bike lanes while marking a museum itinerary; an elevator can bring people down to an underground car park or up to a panoramic viewpoint; a kiosk can serve as an information point. Urban furniture becomes urban *learn*-iture, an educational environment.

IANUS on the web

The virtual museum consists of a multilevel web portal featuring several interactive facilities.
It is a catalogue of knowledge on the heritage and the city of Ivrea, a collective database of memory and facts. Technical information on the Olivetti experience will be available with links to existing websites, creating a network. The complex theme of social, architectural and urban change is introduced in a visual and attractive way by means of virtual itineraries.

An interactive section for news and events stimulates involvement of visitors and citizens. In addition, users have the possibility to become *prosumers* thus creating, developing and sharing the contents of the web portal and being an active part of the information process of the virtual museum: photos, personal memories and experience contribute to writing "urban stories", available for future visitors. People walking in the physical museum can connect to the virtual museum through mobile applications.
Finally, the virtual museum acts as a showcase for news and events, an interactive noticeboard advertising the cultural liveliness of IANUS.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Carmona M., *Public places, urban spaces: the dimensions of urban design,* Architectural Press, Oxford, 2010.
[2] Ministero per i Beni e le Attività Culturali - Commissione Nazionale Siti UNESCO e Sistemi Turistici Locali (edited by), *Il modello del piano di gestione dei Beni Culturali iscritti alla lista del Patrimonio dell'Umanità - Linee Guida*, Paestum, 2004.
[3] Serrazanetti F., *Architectures on stage. Exhibit in absence/ exhibit in presence*, PhD. thesis in Urban and Architectural Planning, Rel. Prof. Raffaele Pugliese, Politecnico di Milano, 2010.

PROJECT 9

PCV

PERSONAL COMMUTING VEHICLES

PCV
Personal Commuting Vehicles

project 9

Personal Mobility: safe, clean and performing vehicles for commuting and recreational usage based on TTW active tilt & steer and electric hybrid technology

PRINCIPAL ACADEMIC TUTOR

Stefano Carabelli
Control and Computer Engineering,
Politecnico di Torino

ACADEMIC TUTORS

Gianpiero Mastinu
Mechanics, Politecnico di Milano

Gianmario Pellegrino
Electrical Engineering,
Politecnico di Torino

EXTERNAL INSTITUTIONS

TTW S.r.l.

Amet S.r.l

EXTERNAL TUTOR

Paolo Cavallo
TTW S.r.l - Amet S.r.l.

TEAM A

Vittoriano Renò [Team controller]
Environmentally friendly product Design

Corinna Conway
Materials Engineering

Pasquale D'Avino
Automotive Engineering

Piergiorgio Di Miscio
Automotive Engineering

Claudio Fichera
Mechanical Engineering

Ulrico Peckelsen
[Project Communication Coordinator]
Mechanical Engineering

PROJECT DESCRIPTION

The Challenge

With a seating capacity of two and a small footprint, a Personal Commuting Vehicle perfectly fully reflects the requirements in personal mobility of most commuters – because most trips are taken alone (In European cities, the average commute occupancy rate is 1.1-1.2 persons per vehicle). Moreover PCV should be as safe, stable, and energy efficient as possible. PCVs represent a design opportunity that extends from technology and style to topics that deal with social navigation, distributed data sensing for real-time representation of environmental conditions, traffic and parking optimization, peer-to-peer freight, and civic engagement. As a starting baseline for the project a Three Tilting Wheel vehicle with two seats in line, crashproof frame, and hybrid traction is proposed as a feasible solution of PCV in between maxiscooters and citycars. The main project objective is the analysis of consumer "real" demand for innovative vehicles in terms of functionality, style, and driving feelings, in particular for Personal Commuting Vehicles and the related technology needs (and costs) to achieve the goal.

Vela Concept Car
Recreate your Recreation

ABSTRACT

A new class of vehicles has emerged to serve the personal mobility market: the Personal Commuting Vehicle (PCV). PCVs are defined as three wheeled vehicles with a seating capacity of two persons and are characterized by combining the safety and comfort of a car with the driving excitement, convenience and economic savings of a motorcycle. They are designed to be as close to energy neutral as possible with low emissions and fuel consumption, as well as to have a small vehicle footprint, helping to reduce traffic and parking issues. PCVs represent an opportunity to significantly change commuting as we know it. Our original aim was to focus on personal mobility, commuting and car sharing; however, society is not ready to accept a three wheeled tilting vehicle.

The reason for this rejection is based on the image that society has attached to everyday commuting vehicles. Vehicles are *either* four wheeled cars or two wheeled motorcycles. Not only this, but also a car or a motorcycle makes a strong image statement about the driver. The New York Times described cars as "rolling advertisements for ourselves and the chief difficulty (of choosing a car) is in choosing the right billboard." Therefore it is easy to see why the general public would hesitate in purchasing a distinctly different vehicle as a representation of their personal image. This conclusion was also based on the research and interviews conducted with industry experts.

Change is possible; however, it must be achieved in small, well-planned steps. Society has a certain capacity for change and all steps must fall within this capacity in order to be acceptable. Therefore, if a strategy is well-planned it is possible to introduce the PCV into society over time. It was at this point that we decided to change the project direction and begin the initial steps for the introduction of a three wheeled tilting vehicle into society in an acceptable way, in the hope that in the future further penetratation will be possible and that the vehicle can serve the purpose it was created for. Thus we stripped down the vehicle, salvaging only the base technology, the three wheeled tilting system, and turned our attention to the recreational vehicle industry.

Thus the *Vela* was created.

TASKS & SKILLS

Corinna Conway is responsible for the market research and the branding: she made suggestions for the design and invented the clothing line.

Pasquale D'Avino and **Piergiorgio Di Miscio** did the scenario analysis (SWOT responsible) and the technical and technological development of exteriors.

Claudio Fichera collected and analysed the survey data in order to understand which features should be developed and how we may improve them.

Ulrico Peckelsen collaborated to market research, analysing how the vehicle meets customer needs compared to already existing vehicles. Moreover, he managed communication within the team.

Vittoriano Renò realized the design and the three-dimensional project of the vehicle. Further he created images and the videos for the project development.

1 *Drop*
2, 3, 4 *Some renders of Vela*

UNDERSTANDING THE PROBLEM

The main challenge of this project, as stated above, was initially the production of a marketable commuting vehicle. However, it later evolved into the challenge of introducing a new technology into society in an acceptable way. The evolution of the project and the understanding of the true problem occurred as follows. We started by performing a market analysis on our defined target market. We determined the best cities in which to first release our PCV, as well as the upper and lower bounds of customer costs. We carried out extensive research in determining what our target market saw as important aspects to have in a commuting vehicle, as well as commuting times in order to turn the product into a truly personalized vehicle. Having all the necessary comforts to make commuting as enjoyable as possible, a sanctuary from the disorder and chaos of commuting in a city. During research of this initial step of the project we became increasingly aware of a very important problem. A red flag, most of our competitors were failing. Further analysis, and interviews conducted with market experts, revealed that the market was not ready for such an innovation. Although the idea was solid, with many clear benefits, society did not seem to be ready to accept the PCV. The response we received was "maybe in ten years, it's an investment for the future". Therefore, our approach to the project did not make sense. In ten years everything we had researched and all the innovative technologies we were planning on introducing in the vehicle would be obsolete. As it was, many of our ideas for new integration of existing technologies we saw being implemented at the Geneva motor show. This was encouraging as it confirmed that our ideas and thoughts were pointed in the right direction.

It was at this point that a new problem surfaced. How could this technology for a three-wheeled tilting vehicle be introduced into society in a way that would help facilitate its widespread adoption? This is a very important question, as well as a very important phase for the technology. If the technology is intro-

5 *Vehicle*
6 *Open doors*

7 *Tilting*
8 *Tilting*

9 *Vela in piazza Vittorio*

10, 11, 12, 13 *Different views of Vela*

duced in the wrong way it could damage its future acceptance into society. We therefore needed to introduce the technology in a positive light and thus our final project was developed. Instead of technological innovation our innovation was in the business model, in taking a technology, stripping it down and redressing it in a way to make it attractive.

GENERATING A SOLUTION

Now that we understood our problem we needed to develop our solution. The first step was determining where a technology like ours would be seen as something new and innovative in a positive light. After much research and searching we finally decided on the recreation industry. An industry in which new looks and different are often seen as positives and selling points. Once we determined our sector, it became an issue of deciding how to package the technology and position the vehicle in order to be successful in this industry. The answer to this came in the form of creating an image through branding. We were now focusing on the image the consumer had of the product. Our goal was to make the product marketable to our target market as well as to show other companies that it was possible to sell the vehicle. In essence, we had two target markets: selling our brand and concept to individuals as well as to other companies who might want to take over the brand.

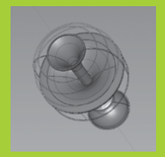
Our brand became the *Vela*, both the name of the vehicle and the brand. Just to clarify, a brand seeks to make a product seem unique or special by delivering a clear message and motivating the buyer. Brands are created by a combination of: name, sign, symbol, color combination and/or slogan. Through these, a product personality is created. We proceeded to define our brand, creating a name, logo, slogan, clothing line, vehicle design, sport and promotion schemes.

Our brand aimed to create an adventurous, cool and extreme personality. The name, Vela; the logo, a stylized signature; the slogan, *Recreate your Recreation;* the clothing, a type of jacket reinforcing the vehicle image; the vehicle, a long process of drafting, consulting target customers and then redrafting until the image satisfied the brand image as well as consumer preferences; the sport, to help pull the image together and reinforce the vehicle personality in the mind of the public; the promotion, to spread the word and let the public to experience the Vela.

Much attention was dedicated to the logo and vehicle design, since these are the visual aspects of the project and play a significant role in creating the image. We conducted surveys, consulted individuals within our target market as well as other market research to help create the vehicle image. In the end we decided on the following: The logo is a black and white abstract line drawing of a sail, derived from the meaning of the name. The vehicle, seen from above, resembles a “drop of water”, which never falls on the asphalt but simply grazes it. A “drop” which acts almost like a sailboat, “does not get lost or die in the water but constantly bounces and splashes away in any direction with great freedom of movement.” The passenger seating position was also experimented with, from a racing motorbike to the final position of a racing car in order to optimize the driving experience, satisfy customer desires and provide pleasing aesthetics.

The clothing line and logo were created to help strengthen the link between customer and brand, as well as promote the chic/cool image of the brand. In this way, even those who cannot afford to purchase the vehicle can still benefit from the brand image as well as help disseminate it.

Solutions for manufacturing possibilities, materials and promotion were also carried out and included in order to focus part of the project on the technical aspect and offer solutions and innovation to other aspects of the vehicle.



PROJECT 10

REPACK

Re-pack
Team A-B

SUSTAINABLE PACKAGING
FOR FAST MOVING CONSUMERS GOODS

REPACK
Sustainable packaging for fast moving consumers goods

project 10

The project uses plastics from renewable resources to reduce the environmental impact of packaging and has been developed in cooperation with Procter & Gamble

PRINCIPAL ACADEMIC TUTOR

Roberto Frassine
Chemistry Materials and Chemical Engineering, Politecnico di Milano

ACADEMIC TUTORS

Sergio Bocchini
Material Science and Chemical Engineering, Politecnico di Torino

Giovanni Camino
Material Science and Chemical Engineering, Politecnico di Torino

Giulio Ceppi
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Marina Foschia
Material Science and Chemical Engineering, Politecnico di Torino

Alberto Franche
Material Science and Chemical Engineering, Politecnico di Torino

Francesco Geobaldo
Material Science and Chemical Engineering, Politecnico di Torino

EXTERNAL INSTITUTION

Procter & Gamble

EXTERNAL TUTORS

Emily Boswell
Procter & Gamble

Christian Gerlach
Procter & Gamble

Bob Rohrbaugh
Procter & Gamble

TEAM A

Carlo Maria Campelli [Team controller]
Chemical Engineering

Raffaele Almici
Management, Economics and Industrial Engineering

Ahmet Aysan
Industrial Engineering and Management

Marco Bonaiti
Materials Engineering

Giuliano Butti
[Project Communication Coordinator]
Biomedical Engineering

TEAM B

Luca Macedoni [Team controller]
Management, Economics and Industrial Engineering

Serena Camere
Industrial Design

Veronica Ceruleo
Chemical Engineering

Alessandro Stagni
Chemical Engineering

PROJECT DESCRIPTION

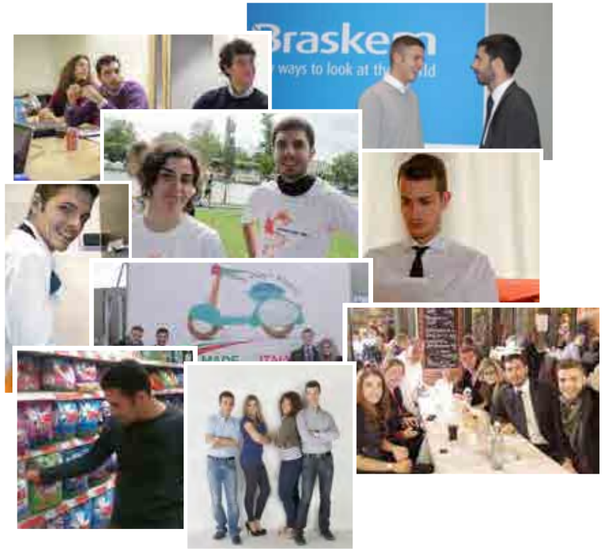
The aim of *REPACK – Sustainable Packaging for Fast Moving Consumer Good* is to achieve a more sustainable packaging for Household Care Products. Procter & Gamble, a leading company in consumer goods, is the principal partner involved in this project. According to the company footprint concerning life cycle, packaging plays a crucial role in terms of environmental impact. Addressing packaging solutions represents a key point; packaging is highly visible and therefore potentially vulnerable: it is in fact the type of waste the consumers interact with more directly. The students were required to consider not only the technical aspects but also the consumer reaction and to take into account retailer needs.

Studying possible solutions, the students stressed the 5 R's concept (Reduce, Recycle, Replace, Remove and Reuse) to evaluate how they could make more sustainable packaging for this project. Certain successful criteria boosted challenging solutions: costs must remain the same or to be lower than for current in-market products and packaging needs to be at least 10% more sustainable according Life Cycle Analysis (LCA) criteria. Furthermore, no significant trade-offs must emerge compared to current technologies. Finally, an equal or better consumer experience than in current execution was required. The students were also asked to design a product with a 3 year shelf life; in this category such a request can be tricky, mostly because detergents contain some very aggressive products, e.g. bleach, that can affect packaging properties.

This project required a combination of chemical knowledge concerning the solution for the material and innovative ideas regarding the effective strategy to promote this product, evaluating its market impact. The two groups focused on sustainable packaging for rigid bottles and flexible laminates, respectively.

REPACK TEAM A – RIGID BOTTLES SOLUTION

The objective of team A was to develop a sustainable packaging solution for rigid bottles. This kind of product is typical of developed countries. The students developed a solution involving all the life cycle phases of the product, starting with bio-derived plastic material in the production phase and redesigning the usage phase thanks to a device able to create foam, mixing water and soap. Finally they focused on the end of life scenario, introducing an effective refill solution. In order to assess the feasibility of this approach they implemented a questionnaire based on Italian consumer needs.



REPACK TEAM B – FLEXIBLE LAMINATES SOLUTION

Team B was assigned to flexible laminates, a type of solution mostly in use in developing countries. The team studied an innovative approach, replacing the traditional oil-based laminated packaging with PLA. Tests carried out in the lab proved the feasibility of this approach. India and China were selected as principal targets for this study and the group also considered an educational strategy toward sustainability.

project 10A

REPACK
Sustainable packaging for rigid bottles for household care products

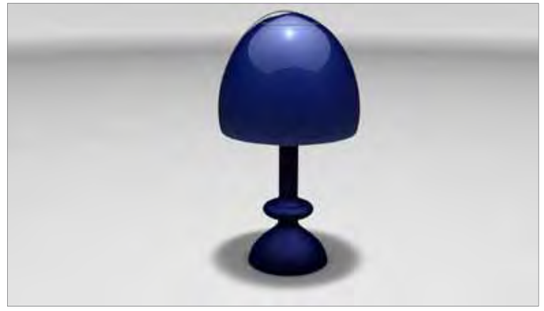
ABSTRACT

The REPACK Project arises from the growing interest that corporations such as P&G have in considering environmental and social concerns an important part of their development and innovation strategy. As a consequence, a product is not only the output of a profit-driven strategy but also has to take into consideration the impact related to its production, use and end of life scenario.
As Team A, our main aim was to develop a new sustainable rigid packaging for Fast Moving Consumer Goods (FMCG) in a home-care business unit, i.e. a hand dishwashing detergent. Success criteria in this research are the ability to reduce the overall impact of packaging with no trade-off in terms of user experience. The focus of the research, therefore,should not be only on technical aspects but rather embrace the overall product: from raw materials chosen and their supply chain to marketing positioning, finding a way to satisfy consumers and enhance their user experience.
Our methodology relied on quantitative benchmarking thanks to the approach oriented towards Life Cycle Assessment (LCA) analysis which constituted the backbone of the overall project. LCA analysis, even if not implemented in its complete format, allowed us to compare the sustainability of different solutions, make choices between materials and stress the most critical points. Moreover, it provided a means of benchmarking the improvements achieved. This led us to consider the introduction of Polyethilene from sugar cane as an alternative material. Moreover, the design of the product itself increases overall sustainability since the new cap designed for the bottle is conceived to be applied to the sink during washing, to act as both a detergent doser, to help the consumer use only the amount needed, and a foam producer to wash with less water.
Thanks to a multidisciplinary approach, the fields covered ranged from material technology to design and supply chain management. Finally, social considerations were a paramount part of the REPACK Project, due to our strong belief that an innovation-driven process must today address the main protagonist: people.

TASKS & SKILLS

Ahmet Aysan participated in the marketing part of the project and carried out research on the FMCG market and also P&G. He also has worked on the questionnaire via which the group was seeking a solution.
Carlo Maria Campelli, in his role as Team Controller, participated in the project development both with regard to the technical details as well as an overall perspective, ensuring consistency of content and continuity of communication among tutors and students.
Giuliano Butti acted as Communication Coordinator for both project teams, organizing work among students and supervisors for preparation of the posters. He also studied ways to certify product sustainability.
Marco Bonaiti handled the more technical issues of the project, including selection of material and comparative LCA analysis. Together with Carlo, he also developed the foam maximizer design.
Raffaele Almici was assigned the role of coordinating team activities, supporting Carlo in the division of work and in time management. He also organized and followed the focus group with designers, collaborating with Prof. Ceppi.

1 *Dusseldorf, K Show, 29 October 2010 _ Packaging machinery for rigid bottle*



2 *Virtual prototype of the Foam Maximizer*

UNDERSTANDING THE PROBLEM

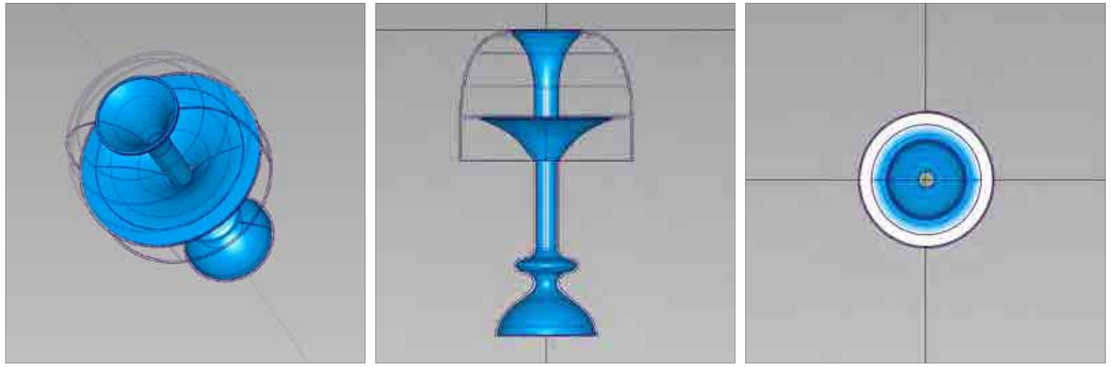
In order to meet the client's requirements we began concentrating on consumer needs. P&G assigned us the challenge of developing a new washing solution which would reduce its entire environmental impact without significantly increasing the cost. We were required to focus on the developed countries market, which provided the right parameters to set up the problem, addressing our attention to the sector of rigid bottles. ASP values have been a constant driver during the process, encouraging us to explore innovative opportunities and address the problem with a multidisciplinary approach.

By working in a team, we started brainstorming opportunities to improve the environmental sustainability of our product or to develop a concept which could truly add value for the consumer. We decided to converge all our efforts on the hand dishwashing sector, since we recognized that it was the segment in which our ideas seemed to introduce the most innovation. This particular objective allowed us to reach a complete solution with significant improvements in many areas.

To be sure to meet the target's needs and to guarantee that consumers would appreciate and exploit all the features of our innovation we also decided to set up a questionnaire. We devised a list of ten questions to investigate the preferences of product purchasers, in general and in relation to their demographic status, since our solution introduces new washing concepts, explained later. We understood that about a half of consumers would be keen to spend a little more on a more sustainable detergent, thus we identified a possible market for our solution.

EXPLORING THE OPPORTUNITIES

The methodology we chose was to approach the problem from many different angles. To develop a truly innovative solution exploring all the opportunities was only the beginning. We firstly decided what could add real value to our result and chose to focus on three main areas: technology, creativity and awareness. It was necessary to exploit new technologies to propose something which could satisfy market requirements but creativity was what we thought could really add a different and new value to our solution. Within this vision, we included in the analysis not only the product itself but everything connecting it with the consumer, primarily its choice and use. To do this we focused on consumer awareness, meaning that we tried in the end to quantify the reduction in pollution and to make this clear to the purchaser.



3, 4, 5, 6, 7, 8 *Different views of the virtual prototype of the Foam Maximizer*

With this approach in mind, we improved the environmental sustainability of our product through several ways, exploiting concepts such as recycling, reducing, refilling, reusing, reinventing and replacing. Some of these concepts eventually led to part of the solution while others did not. We firstly explored the possibility of using recycled materials but we finally ended up combining the recycling concept with that of replacement: the material adopted is both obtainable from renewable resources and recyclable at its end of life.

We tried to imagine how to exploit refilling and ended up with a new home refilling concept which is also directly connected with a reinvention of all dishwashing operations. However, not all the opportunities we focused on gave implementable results: we identified reduction of the polymer used as a possible improvement, but a complete analysis of its structure would have been beyond our capabilities in terms of time and expertise.

The same was true for the other approach we chose to improve, sustainability: analysing every single step of the product, from its cradle to a new cradle. We succeeded in reducing the polluting impact in many of these steps, from production to use and recollection for recycling. Not all presented the same degree of difficulties but in most we were able to study feasible solutions using latest technology combined with our creativity. To do this we were taught and inspired by the many activities we attended around Italy and Europe, including participation in an important trade fair (K- Show in Dusseldorf), visits to technical centers (P&G's "Brussels Innovation Center") and seminars (e.g. "Biopolymer and LCA" conference in Alessandria).

GENERATING A SOLUTION

The solution we developed comprises three different components. The first is what we called the foam maximizer. It takes water directly from the tap to which it is attached; a mechanism inside combines and mixes the water with the soap the device already contains. Foam is produced and then released from the bottom of the device in order to fill the sink. This foam replaces the combination of water and soap still used in the traditional approach, allowing the user to wash plates and cutlery. This device is recharged using a 750 ml plastic bottle in which it is inserted in order to obtain the soap required to create foam once attached to the tap. These bottles are refilled using 1.5 liter bags that can last for two applications. All these devices are created using **Polyethylene from sugar cane**; the high density version of this polymer is required for bottles and the *foam maximizer*; the low density version will be used for the bags.

The innovation in our concept lies in the approach. We tried to redesign the usage phase in which we noticed that energy consumption is higher than in the production and end of life phases. This purpose led us to design something that can reduce the amount of water required in the simplest way possible. Our approach involves all the product life cycle phases. What we obtain from this solution is a reduction in the use of packaging due to the refill, replacement of oil-based polyethylene with a bio-derived version and also an increase in sustainability in use, reducing the consumption of water thanks to the *foam maximizer* we conceived. In place of simply changing the packaging material or promoting refill behavior, leaving consumption as it is, our approach turned out to be challenging and to strongly boost the sustainability of the hand dishwashing sector.

Our product is quite different compared to traditional products in the sector; furthermore it requires a change in user behavior. Therefore, the importance of communicating the concept of sustainability and ease-of-use of our device requires intelligent communication with users in order to be able to succeed. The way this new product is accepted by users is fundamental to its success, allowing an astonishing improvement in sustainability of household care products

MAIN BIBLIOGRAPHICAL REFERENCES

[1] C. Liptow and A. Tillman, *Comparative life cycle assessment of polyethylene based on sugarcane and crude oil*, Chalmers University of Technology, Report No. 2009:14 Göteborg, Sweden, 2009
[2] G. Sparovek, A. Barretto, G. Berndes, S. Martins, R. Maule, (2009), *Environmental, land-use and economic implications of Brazilian sugarcane expansion 1996-2006*, Mitigation and Adaptation Strategies for Global Change, 285-298
[3] S. Boylston, *Designing Sustainable Packaging*, (2009), Laurence King Publishers

project 10B

REPACK
Sustainable packaging for flexible laminates for household care products

ABSTRACT

The REPACK project dealt, as the name may suggest, with the design of a new sustainable packaging for household goods; in particular, our team had to focus on developing countries as a target and therefore on flexible laminates.

Our objective consisted of developing a concept for brand new sustainable products, with the same or lower costs and a three year shelf life; several choices were made throughout the project process, such as replacing the material with a new type, focusing on the markets of China and India, selecting sachets as the most interesting typology, designing consumer-appealing packaging and, last but not least, building a scenario for education towards sustainability.

From the very outset, an optimal balance between experimentation and research had to be maintained: after a preliminary study of materials, we chose to replace the traditional oil-based laminated packaging with PLA, a bioplastic derived from sugarcane. A number of tests were carried out in the University labs in order to verify the compatibility of PLA with samples of shampoo and laundry detergent.

Understanding that sustainability is no longer only an ethical value but more reasonably an added value of the product is the first step to ensure good packaging design; therefore usability, distribution and, of course, appeal of the product itself must all be taken into consideration. Yet, reaching a good level of awareness of the targets we were going to work on has not been an easy task: reliable information sources are mostly missing, but comparing results from marketing and the socio-anthropological analysis we managed to obtain a good picture of India and China. Other sources of inspiration came from widespread research in the packaging design field which was particularly interesting in order to develop a specific brief and to understand the main features our product should respect. Cultures, traditions and people, first and foremost, have been our target, aiming to improve the daily routine with a new, sustainable and innovative concept.

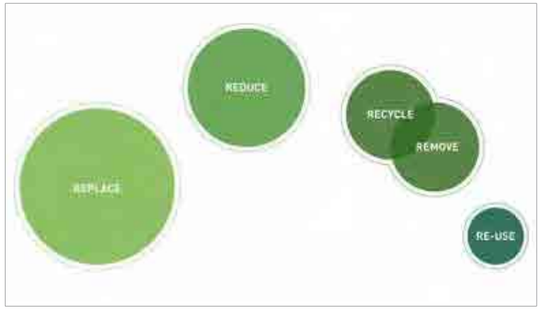
TASKS & SKILLS

Serena Camere carried out a benchmarking case-study in the packaging design field and managed the design of the final output.

Veronica Ceruleo helped in defining the technical solution, dealing with the selection of material and the experiments required to validate the choice.

Luca Macedoni provided a market analysis of developing countries and the economical feasibility of the final solution.

Alessandro Stagni dealt with evaluating the environmental impact of materials and also assured proper communication between the team and the stakeholders.



1 *5R-01 - 5Rs Strategies for Sustainability*

2 *P&G products in high frequency stores - P&G products in high frequency stores*

UNDERSTANDING THE PROBLEM

Designing sustainable packaging in developing countries is not an easy task. Firstly, improvement efforts should be focused on a limited set of products; secondly, to cover all aspects of sustainability, the project should be based on a consolidated approach.

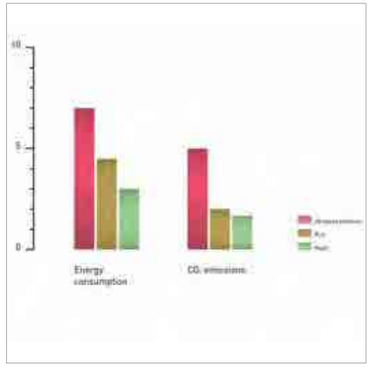
Selection of products requires a market analysis of developing countries. In fact, despite high growth rates, poor people are still the majority in emerging economies. The gap in pro capita income between Western countries and developing economies brings about several differences in the market for consumer goods. The first difference involves affordability: as the average Chinese consumer spends 3$ a year on P&G products, they must have affordable prices. This aim is achieved by reducing the features or the dimensions of goods, such as mono-use packages of shampoos and detergents; therefore, price will be a crucial constraint of the final solution. The second difference between developed and emerging markets involves the distribution system. In developing markets, virtually 70% of P&G products are sold in high frequency stores, which are small kiosks filled with products. In these kiosks, the visibility of products is crucial. Meanwhile, such different cultures affect the product perception by customers who are greener and much more innovation-driven than one might expect.

Our approach followed a well-known approach called the 5R's strategy: *reducing* and *removing* material from the package is the most rife solution among FMCG firms. *Recycling* and *reusing* are less used because of the lack of control on the end of life of the product. *Replacing* the incumbent material with renewable material is constrained by a series of challenges, from the required shelf life to the pressure on costs. Each strategy was analyzed, considering its effectiveness with the Life Cycle Assessment, which provides a measure of product sustainability.

EXPLORING THE OPPORTUNITIES

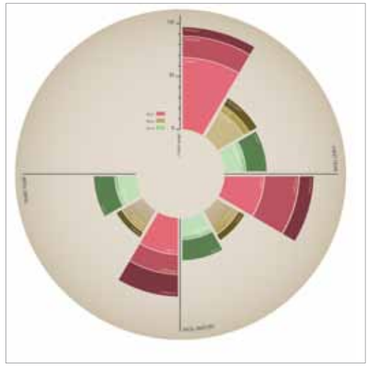
Starting from the 5R's approach, we decided to first concentrate on the *replace* keyword, changing the packaging material. Currently, the development of alternative polymers is moving in two different directions: bioderived polymers, obtained from renewable resources, and biodegradable polymers which completely solve the issue of the end of life of packaging.

One of the most promising materials in this field, both bioderived and biodegradable, is polylactic acid (PLA). When compared to traditional polymers, a similarity of several mechanical



3 *energy consumption and CO2 emissions-02 – Comparison between environmental impact of traditional raw materials and PLA*

4 *Snapshot of PLA samples tested in Alessandria lab*



5 *Trend of tests on PLA samples held in Alessandria lab*

properties can be observed. Yet, PLA behaves very differently from conventional plastics in terms of barrier properties: its higher permeability coefficients strongly influence product shelf life since it is necessary to avoid dehydration. Therefore, we decided to make experimental tests in severe conditions (high temperature and physical stress) to simulate material decay, thus accelerating the time required and verifying whether the new material was compatible with the three year shelf life required by our external institution. We tested three different materials: first of all, pure PLA has been taken into consideration; then, its performance has been compared to two different types of coated PLA.

The test results were then compared with similar experiments on single-dose products already bought on the market. It was found that thebest performance was achieved by one of the two kinds of coated PLA, which anyway decays, in terms of percentage loss of weight of the content, nine times faster than traditional polymers. This issue could be faced studying the storage system in a proper manner.

At the same time, an in-depth research on packaging design was carried out, analyzing some interesting case-studies and understanding the various features we had to focus on: we drew up a list of the characteristics our product should consider, such as a user-friendly dispensing system, a well-designed opening and closure method (possibly without including other materials), a good distribution service and, of course, high appeal and clear communication. Also, a range of esthetical values was defined: transparency, cardboard integration (also to protect the product) and a recall to tradition.

GENERATING A SOLUTION

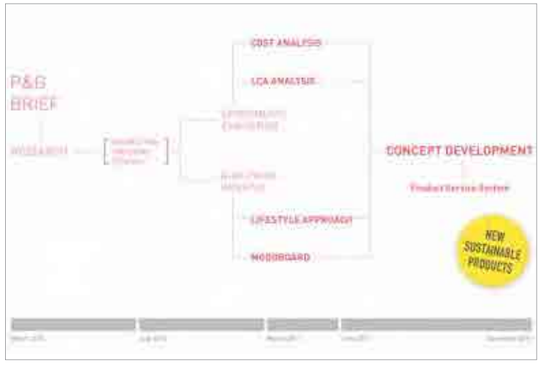
The experimental results achieved by performing tests on the old and new material served as a solid basis for developing the final concept. Indeed, the final product had to meet two main requirements: having at least the same techno-economical features as current solutions on the market but, in particular, with the added value of sustainability. Sustainability in packaging can be defined from three different points of view: economical, social and environmental. Thus, all of these three aspects were considered in assessing the validity of the proposed solution.

The team analyzed the available background literature in depth in terms of technical and environmental data concerning raw materials, as well as finished products. First of all, the eco-profiles of the old and new materials were compared: analyzing the trends shown in the figures, it is clear that the production of polylactic acid has a much lower environmental impact than other traditional polymers currently used for packaging.

On the other hand, a full understanding of the environmental impact can be achieved through a complete, cradle-to-cradle, Life Cycle Assessment on finished products. Also in this case, the results are very promising: thanks to technological enhancements in the PLA production process, eco-indicators show a significant reduction in its environmental impact, compared both to traditional polymers and to PLA itself, as produced in 2005.

Of course, LCA alone cannot provide a universal answer to the issue of sustainability, since results strongly depend on the hypotheses made; nevertheless, it has been an essential tool in providing a quantitative answer to the comparison between the traditional and the new background.

As soon as the experimental part ended, we started the design of our new products, concentrating on two kinds of packaging: a single-dose for a shampoo and a multi-dose for laundry detergents. Focusing on the markets of China and India, we studied their traditions and attitudes towards these daily and intimate activities and came to the following conclusion. For the shampoo, inspired by an innovative dispensing system, we decided to turn one of the possible weak points of the material, i.e. its rigidity, into a product feature: breaking the pack in the center, it opens up forming a comb, through which the shampoo is distributed. Concerning the laundry scenario, we focused on the quantity of detergent to be sold: we assumed that a laundry single-dose could contain up to six washing doses and so we developed a very functional packaging that can be



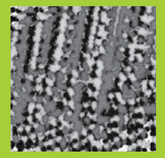
6 *Repack Team B project timeline*

produced and sold as three to six doses. Thanks to its shape, it can be easily separated in order to use just one dose at a time.

Finally, we worked on an educational campaign towards compostability, building a scenario involving different players and timings, taking inspiration from the sense of collectivity which is much stronger in Indian and Chinese cultures than in Western society.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Auras R., Harte B., Selke S., "*An Overview of Polylactides as Packaging Materials*", Macromolecular Bioscience 4:835-864, (2004)
[2] Vercalsteren A., Spirinckx C., Geerken T., Claeys P., "*Comparative LCA of 4 types of drinking cups used at events*", OVAM, Belgium, (2006)
[3] Bucchetti V., Ciravegna E., "*Innovation in Packaging Design. Keywords and Tools*" Ed. Dativo, (2010)



PROJECT 11

Build Smart

Build Smart

ENERGY EFFICIENCY AND RENEWABLE ENERGY FOR INTELLIGENT AND SUSTAINABLE BUILDINGS

Build Smart
Energy Efficiency and Renewable Energy for Intelligent and Sustainable Buildings

project 11

Expert tool providing guidelines for the design and integration of technical solutions for minimizing primary energy consumption of buildings. Supported by ENI.

PRINCIPAL ACADEMIC TUTOR

Giovanni Vincenzo Fracastoro
Energetics, Politecnico di Torino

ACADEMIC TUTORS

Cristiana Bolchini
Electronics and Information, Politecnico di Milano

Federico Butera
Building Environment Science Technology, Politecnico di Milano

Pier Luca Lanzi
Electronics and Information, Politecnico di Milano

Bartolomeo Montrucchio
Control and Computer Engineering, Politecnico di Torino

Roberto Pagani
Human Settlements Science and Technology, Politecnico di Torino

Maurizio Rebaudengo
Control and Computer Engineering, Politecnico di Torino

EXTERNAL INSTITUTION

ENI S.p.a.

EXTERNAL TUTOR

Lorenzo De Vita
ENI S.p.a.

TEAM A

Alessandro Aimar [Team controller]
Energy and Nuclear Engineering

Carlotta Berta
Building Engineering

Daniele Ferrigni
Aeronautical Engineering

Yangfan Gao
Computer Engineering

Ilaria Ricci Curbastro
Architecture

Beatrice Spolidoro
Architecture

TEAM B

Matteo Ronchi [Team controller]
Mechanical Engineering

Simone Barra
Environmental and Landscape Architecture

Matteo Carminati
Computer Engineering

Chiara Gammaraccio
Building Engineering

Andrea Lambertenghi
Aeronautical Engineering

Luca Malvicino
Architecture (Urban and Territorial Design)

Xintao Ye
Architecture

PROJECT DESCRIPTION

The Challenge

The two teams addressed an important and topical challenge: how to design a new residential or office building achieving the best energy performance at a certain extra cost, or minimizing the extra cost required to achieve a certain energy performance.
To that aim, a number of specific data bases of the most important technologies for building envelopes, thermal and air conditioning systems and renewable energy systems were prepared and specially tailored for the two building typologies analyzed. The databases include costs and energy performance of these components, along with meteorological data of different Italian cities.
An original software was written for the evaluation of heating and cooling energy requirements and primary energy demand for the two building typologies. The software also performs an optimization analysis and, as an example, has been used to analyze a typical residential and office building.
Both teams were composed of students with a heterogeneous background: architects, building engineers, energy and mechanical engineers and information technology engineers. They had to frequently interact and an interesting integration of their cultural background had to take place in order to achieve reasonable and consistent results. To this aim, they participated in a number of events, such as the Bologna SAIE Congress and ENI the Donegani Research Centre in Novara.
Team A has devoted its analysis to *office buildings* while Team B worked on *dwellings*. The two building typologies have different energy requirements and make use of different building envelopes and installation technologies. Team A considered the heating, ventilating and cooling demand of offices while Team B focused on ambient heating and domestic hot water demand of residential buildings. On the other hand, while Team A considered only Photovoltaic Team B also considered Solar Thermal systems. All together, the efforts were well balanced between the two teams, as well as within each team.

The final result is a software tool which can be used to evaluate the energy performance of the two building typologies and identify the best set of technologies to achieve a certain target in terms of primary energy demand. The multicultural technical approach, along with the economic evaluation which is always carried out together with the technological choices, has produced an interesting and original result which may be used at the first design stage of new buildings.
Further developments may easily extend the analysis to other geographical and climatic areas, and other building typologies, while a somewhat larger effort would be required to include other energy demands such as lighting and other electrical usages. On the installation side, a more thorough analysis would be required to describe all relevant innovative technologies, especially those based on renewable energy (ground-coupled heat pumps, solar cooling, greenhouses, PV windows, etc.). Finally, the data bases would need to be periodically updated in order to take into account varying energy and component costs. Regular updating of this software will ensure its reliability, so as to make it a valuable tool for the designer.

project office 13A

Build Smart Office
Energy Efficiency and Renewable Energy for Intelligent and Sustainable Buildings

TASKS & SKILLS

Alessandro Aimar worked on the establishment of the database providing data on heating systems and solar panels and helped computer programmers, paying attention to formulas implemented and result exactness.

Daniele Ferrigni worked on the main script of the software, implementing the calculation of energy requirements and costs of all the technological solutions.

Carlotta Berta contributed to the establishment of the database for the building envelope, to the development of the program for the part concerning the energy requirements for heating and to the analysis of the geometrical inputs of the software.

Yangfan Gao contributed to the creation of the database and the design of the software interface, taking care the technical and computer aspects.

Ilaria Ricci Curbastro took part in the database construction and case studies analysis. She took care of the qualitative shape of the software with focus on aspects useful to designers and worked on the graphic development of the project.

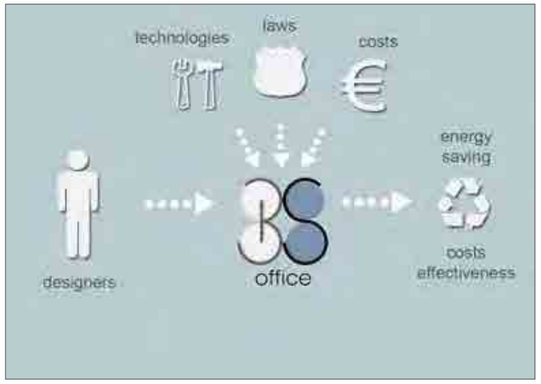
Beatrice Spolidoro participated in the database construction process (frames), analyzed the architectural aspects of the software, designed the logo and helped in developing the guidelines.

ABSTRACT

Architecture and energy science can now converge in a smart way. The issue of sustainability in the construction field, approached from an energetic point of view, is the core of the Build Smart project. This software can help architects, engineers and designers in giving shape to an energetically efficient building project, helping them in the preliminary design process. The main overall feature of the software is that of providing a variety of possibilities in choosing materials, technologies, design strategies and systems in order to obtain the best ratio between energy consumption and the global cost of technologies.

The final aim is not to reach the complete zero-energy building, since that would be the best solution from the energetic point of view but is not the smartest in terms of cost-effectiveness in real life. Values are assumed as references and these are: the worst possible from an energetic point of view and those suggested by legal constraints. The "greenest" solution cannot be the smartest from an economic point of view.

Developed in parallel from an architectural and energetic point of view, according to each team member's ability, our software was written specifically for offices and commercial buildings. The issue of a sustainable office, even temporarily putting aside legal issues and the moral onus, is topical and data confirm that it is highly recommendable to start to consider the development of suitable tools to respond to the increasing energy demand; BS_office not only provides useful guidelines to initial planning but also explores a variety of different solutions in order to reduce such demand, leaving the user complete freedom in the decision process.



1 *Exploring the opportunities*

UNDERSTANDING THE PROBLEM

One of the most characteristic worries of the nineties' was related to the energetic crisis. If in the past almost nobody cared about the problem and trusted in a steady infinite development, both industrial and economic, at least since the seventies' it is clear that we can no longer imagine to consume energy in the same way we were used to in the past.

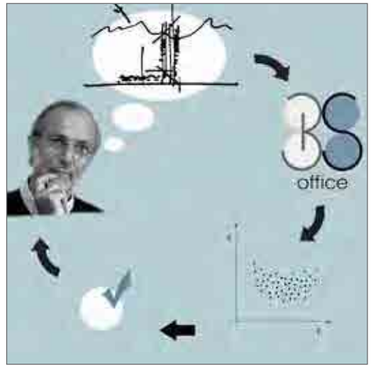
The present situation of caring for the environment is a real concern of almost all countries, with specific laws to be respected. Italy is no exception and, according to the EU trend, we must consider that every aspect of our life is destined to become increasingly sustainable. The Build Smart project has been designed to help designers in an effective way in solving certain internal contradictions typical of the design process in a building. Team A developed the software dedicated to offices and, considering the data provided by the research "RAPPORTO ENERGIA AMBIENTE 2007-2008" by Enea (the Italian National Agency for new technologies), it is evident that the tertiary field has particular needs in terms of energy demand. Looking at the final consumption of electric energy for the 2007, for example, one can see that comparing industry with the residential and tertiary sectors, the former consumed 11.999 thousand TOE of electricity compared to 13.221 thousand TOE of the latter; tertiary alone, in the specific analysis, consumed 7.440 thousand TOE. It goes without saying that all these consumptions are constantly increasing to date.

Reducing both electricity and gas demand (other Enea research clearly shows that the main consumption in the tertiary sector is related to these sources) depends on a number of factors strictly correlated with a correct design process, but is not immediately apparent to the designer without software such as this. Based on sector studies, on a selection of suitable technologies and on energy demands and legal requirements, BS_office can truly play a fundamental role, making the difference in the consumption panorama.

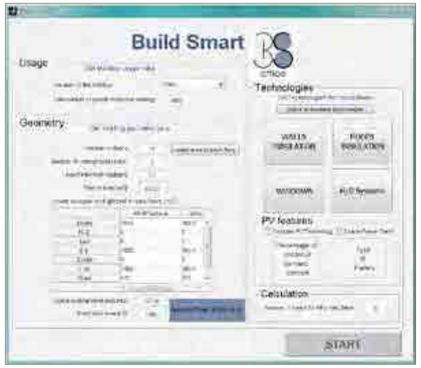
EXPLORING THE OPPORTUNITIES

The analysis of computer programs now available for energy simulation of buildings opens up a wide scenario of alternatives. These programs are all based on Italian legal constraints and are widely used for the Energy Certification of buildings. "EdilClima", "TERMOLOG EpiX 2", and "DoCEt" are just some of the most important and successful ones. All of these products allow users to calculate and verify energy use in buildings, thanks to a vast database of climate data and building materials, and therefore they are basically used in an a posteriori phase to verify designers decisions.

What makes our "Build Smart" different from other products available on the market is the opportunity to use it in a pro-active way during the preliminary design of the building since it is not just aimed at passive calculation of energy requirements of the building once designed. Thus, the software provides architects and designers with real feedback, helping them generate an optimal solution, aiming to maximize energy saving whilst minimizing investment. BS_office can provide a user-friendly approach to this task, guiding him through all phases of the job and providing prompt support in three main ways: calculation of energy requirements of the

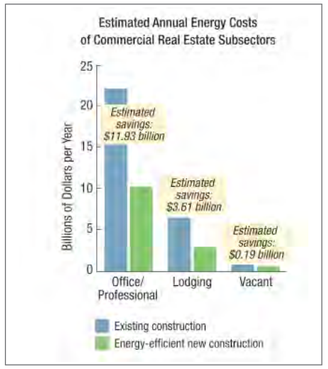


2 *Generating a solution*

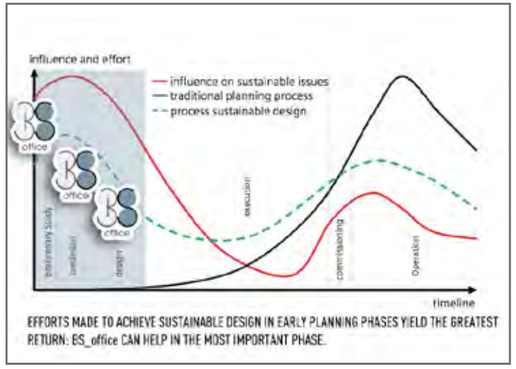


3 *Sample picture of the software realized by Team A*

4 *Image of external studies conducted to analyze the types of consumption by source (by U.S. Department of Energy)*



5 *Estimating Annual energy costs of commercial real estate subsectors (by U.S. Department of Energy)*



6 *Influence of BS-office in the early planning phases*

7 *"Build Smart Office" logo*

building, direct comparison of several technologies and creation of a "cloud of possibilities" from which to choose.
The first, probably similar to other programmes already on the market, is the calculation of the energy requirements of a building as it is designed with all the technical features the designer has chosen.
The second useful possibility is the comparison of new consumption and costs related to different technologies; this means that the user can directly evaluate the result of his choices beyond the strictly aesthetic point of view, clearly seeing the direct consequences of the selection of a certain kind of window, wall, roof or system.
The third and most innovative opportunity provided by Build Smart is that concerning the possibility to examine a large range of technologies, before choosing the final solution, by analyzing the "energy consumption-costs" cloud-graph to find out the most suitable solution in terms of cost/benefit; this allows the designer to directly and easily compare the percentage of energy saved and the related technologies that make this possible, together with the corresponding costs.

GENERATING A SOLUTION

Following an insight of the energy-calculation software market, the Build-Smart group decided to develop its own software using MATLAB®, a computer science platform used for mathematical applications with an high-level library of existing functions. This choice was made in view of team members' programming skills and also due to the capability of the software to process mathematical objects such as arrays or matrices.
The Graphic User Interface (GUI) of the program is the starting point for calculation: the user inserts in the specified windows geometrical properties of the commercial building, such as the value of each surface exposed to North, South, West or East, its location in different Italian cities, the number of workers on each floor and the value of each glazed surface.
In addition, the user can choose from a set of possible technological solutions to be taken into account to provide insulation, heating, cooling and generation of electricity for a standard commercial building.
The GUI allows the user to choose from a list of several types of walls, with different insulation features, as well as windows or types of roofs which can be installed on commercial buildings. Regarding the systems, the GUI offers a list of four possible solutions to provide heating; for each of these,the program selects another to provide cooling during the summer. Since the need for electricity is significant in commercial buildings, the latter is provided by a photovoltaic system, installed on the roof, and the user may choose among three different types of panels. Moreover, there is the possibility to set the percentage of the overall electricicity requirement to be satisfied by PV panels.
The software then starts the calculation and finally provides the results in both graphic and numeric form. For each combination of technological solutions, the program calculates the percentage of annual energy saving compared to the worst case, along with carbon-fossil emissions and the Net Present Value after fifteen years, recording all data in a report. The user can finally see in this document which is the most convenient solution in terms of energy saving, as well as the global financial expenditure, including investments and energy consumption costs.
At the end of the software process, BS_office will not guide designers towards a unique solution but will provide graphs and a text file showing the range of reasonable possibilities to be immediately compared and easily evaluated. The guidelines, therefore, will help users in finding a variety of case studies to compare the obtained results with, understanding the possible choices and implementing an aware and smart project.

Build Smart @ home
Energy Efficiency and Renewable Energy for Intelligent and Sustainable Buildings

ABSTRACT

Sustainable building is nowadays becoming not only a possibility but also a necessity. BS@home can be very useful in tackling this problem, especially conceived for architects and designers of residential buildings. This tool has the capability of merging different crucial aspects related to sustainable building, taking into account the whole. These aspects, that is the energetic and economic aspect, were traditionally treated by architects based on their experience and sensitivity: This approach, with the exponential growth of new technological solutions, is becoming increasingly less accurate and the need for an expert-tool is felt. The main opportunity that BS@home provides to an architect is to explore a virtually infinite number of cases, obtained by combining all the different choices imaginable in a building: walls, windows, roof, heating systems, solar panels, photovoltaic panels and many more can now be taken into account in a unified vision. The expert-tool is thus able to calculate the energetic and economic requirements of each of the thousands of combinations that can be obtained. The designer could never do all this in his mind! At the end of the calculation, which are also carried out according to local laws, he will be able to choose, among all the solutions available, those which are most economically advantageous in an appropriate future time horizon and have visibility on the percentage energy saving they provide when compared to a traditional base case. It should be highlighted that the software is also designed so as not to limit the architect more than expected, leaving him the freedom of expressing his creativity, but also guiding him every step of the way in making the most important decisions throughout the development of the project. BS@home, as the name suggests, is especially designed for residential buildings and offers an expandable database of suitable technologies suitable for the home, covering a wide range of house dimensions, ranging for a small detached house to a big skyscraper. These very different types of buildings, as well as the building location and exposure, can be easily described to the software by using its very intuitive graphical interface.

TASKS & SKILLS

Matteo Ronchi coordinated the team for subroutine integration and implemented the calculations for building energy requirements, total economic evaluation, photovoltaic performance and solar window applications.

Simone Barra participated in the creation of the database, taking care of the aspects related to the roof component in its technical and economic aspects. He participated in developing the final of case study data on which the software was tested.

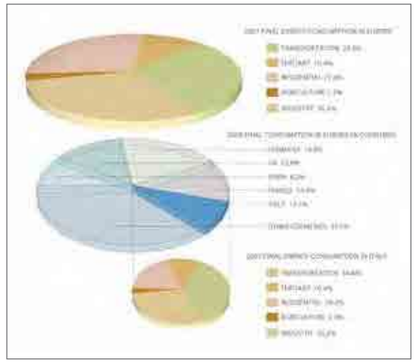
Matteo Carminati focused his attention on selecting the programming tools and in designing/implementing the GUI expert tool (first in Java, then in Matlab). He collaborated in software design, implementation and debugging.

Chiara Gammaraccio developed the technology database, focusing especially on the wall. She collaborated on the simulation of case studies to verify the accuracy of the software.

Andrea Lambertenghi worked on preliminary software analysis and architecture, implemented the solar-thermal routine. He collaborated in software validation and debugging and studied initial GUI solutions.

Luca Malvicino analyzed different technologies for the database. He collaborated in implementation of the solar-thermal calculation and in the choice of the software input data. He simulated a number of case studies to test the software.

Xintao Ye analyzed building envelopes and organized materials for the computer assisted design method. He participated in logo design and researched the PV part of the project.



1 *Energy consumption statistics in Europe and in Italy – Enea*

2 *Software applications that the designer uses in the different part of the project and BS@home software*

3 *From building energy needs to green solutions: the idea behind BS@home.*

UNDERSTANDING THE PROBLEM

A sustainable building can minimize or eliminate negative environmental impact, thanks to a conscious choice. This can be made possible through the improvement of design, construction and usage measures compared to common techniques. A project conceived with sustainable criteria can reduce operating and maintenance costs and increases the market value of the building. The payback regards users of the building, the owners, the occupants and the general public. Therefore, adoption of sustainable practices in building design generates environmental, economic and social benefits, locally as well as globally.

The environmental impact of building usage is significant: 2006 European statistics showed that residential buildings are responsible, directly or indirectly, for approx. 28% of energy consumption, the same as transportation or industry. In Italy, the final energy consumption in 2007 by sector is very different, according to ENEA "Rapporto energia ambiente 2007–2008": transportation consumed 45,432 ktep (thousand tonnes of oil equivalent), industry 39,681 ktep, residential 26,437 ktep and tertiary 16,398 ktep. [1] The need to reduce the energy load and to increase global residential building efficiency is thus a challenging issue.

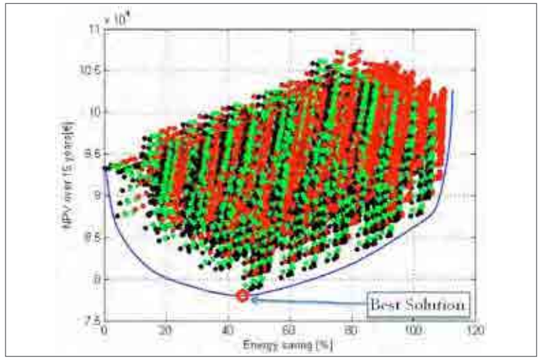
The stakeholders of the project, which need to discuss overall green building strategy, are: architects, building engineers, energy engineers, designers, final users and Eni. The legal requirements, constantly updated, should not be omitted from this analysis in order to ensure an integrated design approach.

EXPLORING THE OPPORTUNITIES

State of art

The BS@home software, being an expert tool, fits into a specific genre of programs that help designers in the creation of sustainable buildings. There are many software products related to this subject but they can be divided into two groups: software for energy certification of buildings, such as DOCET, EDILCLIMA, KLIMA HAUS, THERMOLOG EPIX..., which aim to calculate the energy requirements of an existing building and software which helps the designer in various parts of the design process, such as ECOTECT ANALYSIS, POLYSUN, and so on.

4 *"Build Smart @ Home" Graphical User Interface*



5 *Graphical display of results showing the best economical solutions*

In creating BS@home, we tried to combine these two types of software. In fact, it is an expert tool that can help the designer in selecting the best technologies, those that provide better energy saving in relation to their cost and the location of the building and can be used in the preliminary phase of the project or simply to check the building's energy requirements.

Technology database

In particular, to develop the software, we created a database with the most common technologies used in the design of residential buildings: vertical opaque envelope, roof, basement, heating system and, in addition to traditional windows, we included the innovative solar windows of ENI, our principal sponsor. This was necessary to allow the program to choose the best combination and obtain a unique solution that optimizes the positive qualities of all the elements of a building and provides the best balance between energetic quality and price for all elements considered.

A specific study was carried out for solar panel technology. The Italian law (D. lgs 311/06) states that, in all new buildings, at least 50% of domestic hot water needs should be met by solar thermal and/or renewable sources. In our database, therefore, different types of solar collectors were included and a function taking account of the Italian law in relation to DHW was implemented in the software. [2]

Programming environment

The choice of the programming environment for the expert tool proved to be one of the most critical steps in project implementation. Two were the fundamental requirements we were looking for. On the one hand, a large mathematical library containing all the functions needed to perform our computations. On the other, an easy way to implement an appealing graphical user interface. At the beginning we focused our attention on the Java programming language, offering simple yet powerful graphical libraries. However, the available mathematical functions were not sufficient for the computations of our expert tool. Finally, we decided to use Matlab as programming environment, preferring the broad mathematical support to more complex graphical libraries.

GENERATING A SOLUTION

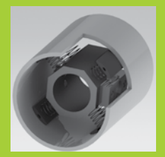
The solution was developed in a Matlab® environment in order to best meet our programming abilities, having at the same time the possibility to write code with a certain flexibility and ease. The software is composed of different sub-routines which interact in order to perform all the required calculations and display the results to the user. These calculations are transparent to the user who is only asked to run the software by using a Graphical User Interface, designed ad-hoc. For BS@home, the main input data is related to building usage and location, as well as geometric data such as the number of people, the number of floors, the Gross Volume and all the wall and window exposures and corresponding surfaces (and many more). The program can then be run is two different modes: a 'free' and a 'constrained' mode. In the free mode, which is obtained by clicking on the 'Select all available technologies', the software will automatically run considering all the possible technologies which have been chosen as suitable for residential buildings according to our analysis. These technologies can be gathered in different groups, which are walls, roof, windows, thermal solar panels, photovoltaic panels and heating technologies. It has to be pointed out that under each of the groups there are different technologies, not only in terms of performance, but also in terms of physical principles on which they are based. To leave the user more freedom, certain technologies under each group can be excluded in order to put additional constraints on the solutions. For example, the designer could choose to heat the house with condensation boilers or not to install any PV panels: all these decisions can easily be made by the user via the GUI. When the user presses the 'Start' button, the software, using the entire data set provided, starts calculations on the thousands of possible combinations originating from the selected technologies. For each solution, depending on the location and geometrical features, the energy requirement of the building is calculated, both in terms of thermal energy (for heating and domestic water) and in terms of electricity (based on the average consumption of the family units living in the building): these are all then translated into primary energy. The calculation can take from some seconds up to approx. one hour, depending on the number of technologies chosen; the results are then displayed both in graphical and text form, showing the designer which solution is the best in economic and energetic terms.

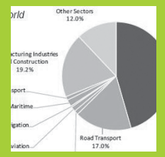
6 *"Build Smart @ Home" logo*

To test the validity of the program and verify its usefulness in the definition of the architectural concept, we chose nine case studies of residential buildings, recently built and available in major architecture magazines. The choice was made purely according to dimensions (large, medium and small) and type (tall or low, single or multi-family...). From this point we extrapolated the data of all building components for each building (opaque and transparent surfaces according to the different exposures, cover size...) in order to enter them in the program and perform the simulation according to the previously developed technologies. In this way it was possible obtain feedback on which part of the building requires most attention in its design in order to find the best balance between energy savings and costs incurred.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] *Rapporto energia ambiente 2007-2008*; Enea, 2009
[2] Battistini R., Corrado A., Micangeli A.; *Impianti solari termici, acqua calda con l'energia solare*; Franco Munzio Editore, Roma, 2005





PROJECT 12

Smart Environments

INDOOR AND OUTDOOR MONITORING APPLICATION USING WIRELESS SENSOR NETWORKS

Smart Environments
Indoor and Outdoor Monitoring application using Wireless Sensor Networks

project 12

The project, developed in cooperation with Concept Reply, aims at designing and implementing a self powering wireless CO_2 sensor to be installed at the outlet of a car exhaust pipe.

PRINCIPAL ACADEMIC TUTOR

Giovanni Malnati
Control and Computer Engineering,
Politecnico di Torino

ACADEMIC TUTORS

Aldo Canova
Electrical Engineering,
Politecnico di Torino

Cosimo Greco
Control and Computer Engineering,
Politecnico di Torino

EXTERNAL INSTITUTION

Santer Reply S. p. A.

EXTERNAL TUTOR

Daniele Marietta Bersana
Santer Reply S.p.A.

TEAM A

Shangwen Qiu [Team controller]
Automotive Engineering

Luca Gaetano Amaru
Electronic Engineering

Federico Capiaghi
Biomedical Engineering

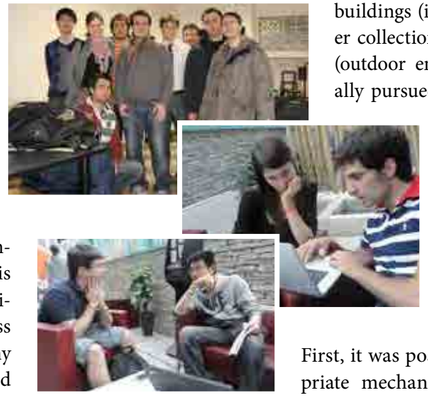
Michele Miccio
Automotive Engineering

Viktoriya Sendyureva
Environmental Engineering

Camillo Stefanucci
[Project Communication Coordinator]
ICT Nanotechnologies Engineering

PROJECT DESCRIPTION

The Challenge



The reduction of environmental CO_2 emissions is one of the major challenges for growth sustainability of the present century. Road transportation and building heating, ventilation and air conditioning (HVAC) systems constitute the two most relevant sources of carbon dioxide in consumer related activities. In order to reduce these emissions, it is possible to leverage on several factors: using more efficient technologies, adopting less polluting energy sources and reducing end-user needs. This last option can be stimulated through appropriate incentivizing policies, and creating awareness of the consequences of certain behaviour. In any case, analytical details concerning quantities and localization of CO_2 emissions and energy consumption processes are necessary. Although appreciable results can be obtained as a consequence of careful design in new buildings or vehicles, to measure the approximate amount of emissions and consumption in the existing installed base, retrofit systems must be planned, designed and installed. This information, together with its space-time context, provides an indication of individual and collective behaviour, in the light of which, efficient system decisions can be taken to encourage virtuous behaviour and discourage other less virtuous types. The goal of this research was the design of affordable systems for pervasively measuring, collecting and distributing analytical data on energy consumption and CO_2 emissions. These measurements must be carried out in the context of highly distributed systems which have not been explicitly designed to provide such information.

The teams

Although the initial research proposal was conceived along two complementary directions, one concerning energy monitoring in buildings (indoor environment) and the other collection of CO_2 emissions from vehicles (outdoor environment), only one was actually pursued due to the availability of a single group of students. Given the actual interests and expertise of the group, the outdoor project was chosen. The heterogeneous skills of students involved contributed in effectively addressing the multiple scientific and engineering problems associated with this issue.

First, it was possible to identify the most appropriate mechanical, automotive, hardware and software technologies and to produce a laboratory prototype of the envisaged system. Other studies were conducted concerning the economic viability of the project through identification of the stakeholders involved and development of an appropriate business model.

The results

The activity led to the creation of a prototype, its validation in the laboratory and the definition of a set of specifications for its conversion into an industrial product.

Particular emphasis was given to adoption of technologies facilitating low-power operation of the wireless sensor nodes using energy harvesting techniques to collect all the energy required from renewable sources in the surrounding environment (vibrations and heat).

The business model showed that, through the appropriate use of incentives, it is possible to create conditions making the adoption of the designed system sustainable and affordable, at least in urban areas with high-density traffic.

project 12A

Smart Environments
Indoor and Outdoor Monitoring application using Wireless Sensor Networks

ABSTRACT

In the 19th century, the connection between the increase in greenhouse gas levels in the atmosphere and that of the average temperature of the Earth was first investigated. Later it was discovered that up to 26% of the global warming effect is due to carbon dioxide (CO_2) emissions. The United Nations Intergovernmental Panel on Climate Change (IPCC) states that further measures to reduce CO_2 emissions need to be taken since the effects of global warming can be already seen. According to OECD-ITF Joint Transport Research Committee Working Group, globally 23% of CO_2 emissions from fossil fuel combustion is generated by road transport: as the number of vehicles on the roads increases yearly, so does the level of carbon dioxide in the atmosphere.

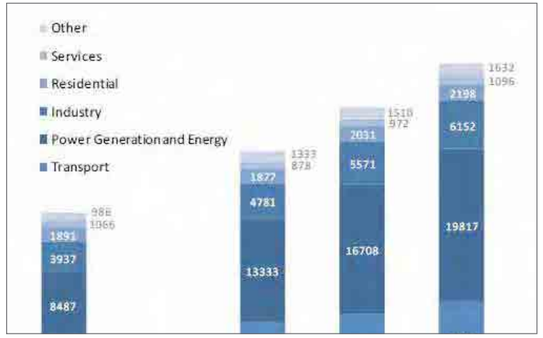
In order to control CO_2 emissions and to mitigate global warming, policies aimed at tightening emission limits for each country have been introduced and modified. As a result, it is important to consider novel ways to monitor vehicle exhaust gases as well as industrial and environmental levels of greenhouse gases. In this project we explored the possibility of monitoring the CO_2 emissions of combustion engine vehicles online using Wireless Sensor Networks (WSNs). WSNs consist of small-size wireless sensor nodes equipped with radio transceivers and one or more sensors. In our case, the sensor-node is mounted in the exhaust pipe and should be non-invasive and energy-independent. Road-side collector nodes receive CO_2 measurements and communicate them to the municipality or other organizations involved. This kind of approach could lead to a fair pricing policy for vehicle CO_2 emissions and, in the future, could replace the Milan ECOPASS. In addition to CO_2 control, additional services such as traffic and parking monitoring could also be provided.

Finally, in this project we analyzed the feasibility, both economic and technical, of CO_2-WSNs inside a city center for various scenarios.

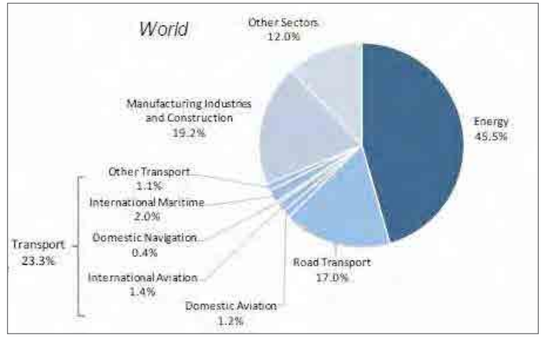
TASKS & SKILLS

Luca Gaetano Amaru developed the electronic circuitry needed to test the final sensor prototype.
Federico Capiaghi developed the business feasibility plan of the device, analyzing possible market scenarios.
Michele Miccio was responsible for energy harvesting solutions and worked on the mechanical design of the prototype.
Shangwen Qiu coordinated group work, providing his contribution in the sensor mechanical housing design.
Viktoriya Sendyureva gathered information on CO_2 emission legislation, analyzing different government policies, and contributing to development of the business plan.
Camillo Stefanucci studied the required sensing technologies, providing support for energy harvesting solutions.

We would like to acknowledge the contribution of **Francesco Santoro** who helped in implementing the electronic circuitry and prototype testing. We would also like to acknowledge the contribution of **Meccanica Panni S.r.l** in the precise machining of the mechanical housing for this project.



1 *World energy-related CO_2 emissions*



2 *CO_2 emission from fossil fuel*

UNDERSTANDING THE PROBLEM

The project purpose is the design of a new device able to measure CO_2 emitted by vehicles and transmit the data to a network infrastructure. Such a target involves many areas of expertise: the need to use ultra low power electronics, mechanical adaptability inside the vehicle exhaust pipe, the attempt to implement an energy harvesting system and potential strategies to sell the final product to the market. CO_2 emissions significantly influence air quality and this is not a local or regional problem but rather a global issue requirung international cooperation on data collection and implementation strategies. In 2002, the International Energy Agency predicted a 50% increase of transport emissions by 2020. In order to control CO_2 emissions, the reduction of the car CO_2 emissions from 163 g/km to 120 g/km by 2012 was indicated as one of the EU sustainable development objectives. To regulate pollution reduction measures, the system of allowances providing the right to emit one tonne of CO_2 within a specified period was developed. Currently, there is no technology able to define the individual contribution of single vehicles to total pollution, collect information on emissions and regulate the quantity of carbon dioxide in order to remain within the limits established by international allowances. Moreover, only coupling the technical solution with the specific policy can provide the opportunity to reach this environmental target.

Due to the complex project scenario, a fundamental question addressed by the team was; who are the stakeholders and how can they be involved? Air quality is a key issue for the well-being of citizens and therefore the first stakeholders are public authorities, from central government to the single municipality which has the direct responsibility of local air pollution; but not only government is impacted by the project, also other institutions, such as research centers and environmental monitoring agencies are interested in the data collected to build and validate their models. Furthermore, the project implements an embedded sensor and distributed management of data, which are business fields in which private firms are increasingly investing. Finally, users, identified as common citizens who own and drive a vehicle, are the real market driver and, therefore, the main and additional services related to device usage need to be addressed to them.

3 *Sestriere, 20 July 2011. Team planning prototype characterization measurements.*

4 *Laboratory tests of a Peltier cell for energy harvesting*

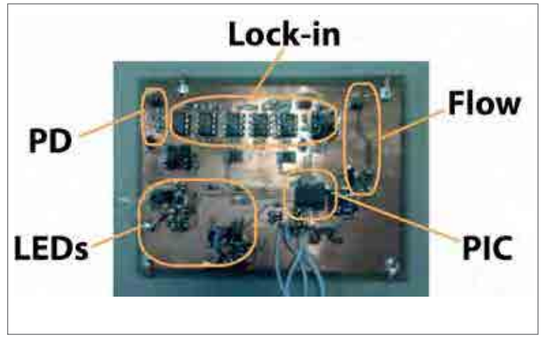
EXPLORING THE OPPORTUNITIES

In order to monitor CO_2 emissions, a number of technological solutions are available using WSNs placed in the area of interest or mounting sensors on public transport, using the bus routes to evaluate pollution of city centers.
The acquired data are used to quantify air quality of in a very economical and easy way, even though these are always average values. Our goal is to move CO_2 sensing to individual vehicles and have direct and continuous metering of emissions. In this context, while data can be managed by on-road receiver networks with possible additional services such as intelligent parking systems or traffic monitoring, sensors must be installed on private cars. As a consequence, we face a technological problem since this means placing the sensor inside the exhaust pipe which represents a harsh environment for any type of electronics, due to temperature gradients, chemicals and vibrations. For data transmission, whilst well-known transceivers are available in the market, the problem is to find appropriate technologies to obtain accurate gas sensors at a reasonable price. Moreover, to evaluate emissions, we need not only CO_2 concentration but also flow measurement which can be achieved using ultrasound technologies or thermal mass flowmeters. The result is a complex system in which electronics is required to manage the various sensor inputs and transmit data at an appropriate rate.
Regarding the mechanical housing, this must be able not only to house the various electric components and wiring, but also to be attached to the exhaust pipe of a vehicle.
Since exhaust pipes come in various shapes and sizes, the two alternative solutions are external housing with different sets of geometries and dimensions or internal housing with flexible fitting, such as springs. Finally, the system requires energy to work and a possible approach is energy harvesting. Energy harvesting is the process by which energy is derived from external sources, captured, and stored. With current technologies, harvesting devices are able to produce a relatively small density of power that can vary significantly, depending on the harvesting conditions. A low-power CO_2 sensor can be implemented by harvesting the energy from thermal gradients or car vibrations. The main advantages are production of energy with no additional costs and the possibility to feed a device with the requested power, avoiding wires and batteries.

GENERATING A SOLUTION

Analyzing sensor alternatives, the most promising technology available for CO_2 concentration measurement for a plug-in,low-cost device is the Non Dispersive InfraRed (NDIR) sensor. Since the signal level at the NDIR receiver could be extremely small, a lock-in technique is employed for extracting and amplifying faint signals from noise. For the gas flow sensor, an Ultrasonic Transit Time flowmeter (UFM) is a good candidate due to its non-invasive, low power characteristics.

5 *3D rendering of mechanical housing of car exhaust pipe sensor*



6 *PCB implemented with electronics necessary for the NDIR CO_2 gas sensor*

Given the complexity of UFM sensing technology development, we studied this possibility in detail but selected a thermal mass flow sensor in the prototype for proof of concept. The prototype we created consists of two LEDs, a photodetector (PD), a PD signal lock-in amplifier, a thermal flowmeter and a temperature sensor. The whole system is managed by a micro-controller. Calibration results of the various components demonstrated the technological feasibility of the chosen solution.
Subsequently, via preliminary research, the shapes of exhaust pipes were observed to be round or elliptic which, together with the factor of different dimensions, makes it difficult for an externally fixed housing to adapt to an arbitrary exhaust pipe. Therefore, an internal housing unit was preferred, connected with rigid springs to the internal wall of an exhaust pipe. In this case, the problem of varying shapes and dimensions is solved by the flexibility of springs, adjusting the length according to the distance needed.
Finally, the main challenges faced while developing an energy harvesting device were to be able to reach the power production target and develop a device able to resist for a lengthy period in a hostile environement. In the case of an exhaust pipe, vibrations and thermal gradient between the pipe and the environment are the 2 main sources.
With further analyses it emerged that the variation of the resonance frequency of the pipe is too large and depends on a wide range of factors, such as engine speed, external conditions, age of the car, road surface, maintenance timing and so on. The thermal solution seems to be more suitable for the specific application. According to the pipe temperature (approx. 70°C) and the temperature extremes in the 2 main cities in Italy (Milan: 1-24°C, Rome: 4-29°C) the thermal generator can benefit from a temperature gradient of between 10°C to 30°C, depending on the season.
Apart from the technological aspects, another important step was evaluation of inputs and outputs concerning costs and benefits for each stakeholder involved, in order to identify financial support opportunities along with technical solutions for, project implementation. For example, government coverage of infrastructure costs, part of the product costs and international penalties due to exceeded emissions has an income from the penalty system we developed.

PROJECT 13

B-TRANS

SHANGHAI URBAN-RURAL PUBLIC BICYCLE TRANSPORTATION SYSTEM DESIGN

B-TRANS
Shanghai Urban-Rural Public Bicycle Transportation System Design

project 13

A multidisciplinary project with Tongji University to design product service system for sustainable tourism/transport connecting agricultural and urban contex

ACADEMIC TUTOR

Luisa Collina
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

ACADEMIC TUTORS

Davide Fassi
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Ezio Manzini
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Anna Meroni
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Francesca Rizzo
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Giulia Simeone
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

EXTERNAL INSTITUTION

IDEO

Provincia di Milano*

Slowfood*

Tongji University

EXTERNAL TUTORS

Susan Evans
IDEO

Lou Yongqi
College of Design and Innovation, Tongji University

TEAM A

Maria Franco [Team controller]
Biomedical Engineering

Andrea Cairati
Civil Engineering

Corina Macnovit
Product-Service-Systems Design

Aurelie Soizic Sabatier
Architecture

TEAM B

Francesco Cavagnis [Team controller]
Civil Engineering

Laura Varvello
[Project Communication Coordinator]
Architecture

Marta Alice Fattorossi
Design & Engineering

Stefano Tedesco
Civil Engineering

PROJECT DESCRIPTION

The Challenge

Peri-urban bike-sharing is the focus of this project, intended as a means of strengthening proximity tourism, both in terms of application in a non-urban context of a sharing system and as of use of the bicycle as a means of sustainable transport.
The project was initiated by a request from the Shanghai context (How to promote the use of bicycles in China, in a context where this means of transport is now out of fashion? How to promote an agricultural area close to Shanghai, the island of Chong Ming, trying to protect it from speculative pressures?). Starting from an initial research and design exploration conducted in situ (Shanghai Expo 2010 and Chong Ming island), the project was then developed in the context of Milan, by connecting the output with an existing scenario (the "Parco Agricolo Sud Milano") and one in the making (Expo 2015).
Application of a bike-sharing system, limited mainly to town centers, to a context with very different environmental characteristics, users, activities and conditions, led to focus on other possibilities: increasing value from an environmental, social and economic point of view of an agricultural/rural context and stimulation a "green oriented" culture in the contemporary citizen.

The teams

Skills from engineering, design and architectural areas led to the division of work in two teams, with clear and detailed tasks, within the same project: the first focused on identification of cycling routes in the area and design of sets of experiences to be proposed to the user (Team A), the second was more involved in the development of a strategic plan linked to the product system by understanding its feasibility, operation and implementation (Team B). The two teams worked with significant interaction within the project, interfacing with a variety of local players for implementation of the various stages of research and development of the concept and taking advantage of specific skills involved across the board. At the same time, they generated two distinct insights that strengthened the unitary project characterized by a systemic approach.

The results

After having developed the service concept and logistics system, the two teams organized a prototype with a selected group of users who experimented a test-path (from Abbiategrasso MM2 underground station to "Cascina Zipo" in Zibido San Giacomo (MI) and back, passing through several cultural and environmental points of interest), generating valuable feedback for the development of the service system.
Once established, the service will provide bicycle sharing in "Parco Agricolo Sud Milano" with a strategic plan prepared by Team B which identified tangible and intangible system elements, defined how bikes could be stocked in farms (selected because they are close to public transport connecting them with the city of Milan) and created guidelines for application of the system to other contexts.
With the cooperation of the Province of Milan, the institutional representative for the Park, team A then identified a number of possible bicycle routes, points of interest and transport infrastructures to be integrated in the system, which will be communicated on an 'open source' online platform, linked to the "Nutrire Milano" web-portal, promoted by Slow Food in collaboration with Politecnico di Milano – INDACO department - with the help of the Cariplo Foundation, the Municipality and the Province of Milan. According to the Province, this project could become an additional Park service with effects on the economic (local tourism, direct sales of local products, availability of bikes for startup of the system), cultural (dissemination of "local skills" as a means of disseminating the culture of an area, promotion of local artistic, architectural and environmental points of interest) and social (integration of the inhabitants of a highly urbanized environment with public, agricultural and rural areas) system. This set of services may assume particular significance within the scope of Expo 2015.

project 13A

B-TRANS
The user experience: a multi-value offer for sustainable tourism in peri-urban areas

TASKS & SKILLS

Andrea Cairati investigated the demand for slow-mobility in the Parco Agricolo Sud Milano and examined the legal framework in which the designed system is expected to work. He also managed interaction with potential players in the project in order to understand its actual feasibility and the possible critical issues.

Maria Franco developed the general framework comprising project implementation in the analyzed case studies of both Parco Agricolo Sud Milano and Chong Ming, Shanghai. She coordinated the division of workload among members of the two teams and managed the organizational aspects of the on-field group experiences.

Corina Macnovit developed the project product service system as well as monitoring progress of the design process steps. Her activity included the design of independent system components as well as interaction among the same - connection between the virtual and tangible parts of the system and the players involved.

Aurélie Sabatier contributed to developing the service by studying the potential of Parco Agricolo Sud Milano and its infrastructures and gates connecting it to the city. Moreover, she studied the future platforms, both real and virtual, in order to establish a strong bond between the two contexts, the city and the countryside. Finally, she proposed a set of thematic trails for users to customize and experience.

ABSTRACT

The B-Trans project has the objective of designing an innovative, low cost and sustainable bike sharing system which connects a city to its surrounding countryside. The intervention target is therefore any peri-urban area where the desire shortening of distances between the city and its natural surroundings is felt by citizens, both residents as well as visitors.

The connection the project attempts to establish is both physical and meta-physical: if bikes, trails and stations are the tangible and concrete components of the designed service, on the other hand, values, agricultural traditions and knowledge are the immaterial elements to convey through this bridge between areas, people, lifestyles and cultures.

At the same time, the proposed solution will encourage implementation of alternative models of development, specifically intended for rural areas and based on the revitalization of local communities, the diffusion of responsible agro-tourism and the defence of food quality and security: all central themes of the coming Universal Exposition to be held in Milan in 2015.

Starting from both desk and field research, we became acquainted with two possible contexts of application of the project: Parco Agricolo Sud Milano and Chong Ming island, Shanghai. During specific workshops we identified several personas who could represent reference users of the system and whose needs and expectations have been deeply analysed. Hence, different experiences have been designed to constitute a probable future offer of the service. Such possible inputs have been presented to a number of potential users and their feedback gave us suggestions to create a guideline for implementation of the system in similar contexts.








1 *Chong Ming, Mapping State of Art*
2 *Observation*
3 *Observation*
4 *Evaluating State of Art*
5 *Parco Agricolo Sud, Mapping State of Art*
6 *Observation*
7 *Observation*
8 *Evaluating State of Art*

UNDERSTANDING THE PROBLEM

Both Parco Sud and Chong Ming island represent fragile rural areas surrounding metropolises involved in never-ending expansion. The contrast between these two worlds is significant. On the one hand, pollution, congestion, noise and frenetic life-style compromise citizens' quality of life; on the other, nature, quietness and slow life-style are often forgotten.

Hence the claim for a "return to nature" by means of temporary escape from everyday life, in search of relax, silence and healthy practices. The B-Trans project uses the bicycle as a means to shorten the distances between the city and the countryside in order to reconcile these two opposite, yet complementary, aspects of the same region.

Thanks to its inherent environmental sustainability, the bicycle appears to be the best choice for entering a natural environment in an appropriate and respectful way. Implementation of a public bike sharing system, integrated with the existing local transport network, could make this possible by providing better accessibility to the countryside.

However, to implement a bike sharing system in such a wide area, a different and innovative approach to the design of the service and its related experiences is required. Our project intends to develop a low-cost, simple and sustainable solution, suited to the areas in which it is located.

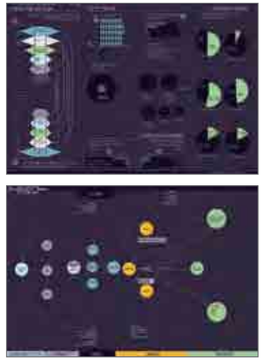
EXPLORING THE OPPORTUNITIES

The designed bike sharing system is conceived so as to exploit all the inherent potential characterizing the area of application in a sustainable manner, both from the environmental as well as economic point of view. In particular, the service attempts to fulfil the main desires shared by a number of potential users interviewed during the research phase and grouped into six different personas: the sports enthusiast, the citizen, the young family, the businessman, the silence seeker and children. Hence it has been possible to model a custom-made offer centred on three main probable experiences, common to any peri-urban area: the possibility of practicing sport, contact with nature - through a protected milieu and genuine food - and knowledge of the local cultural assets, both material and immaterial.

9,10,11,12 *Protobiking in Chong Ming*

13,14,15,16 *Protobiking in PAS*

17 *Person APROFILES*



18 *User feedback*

19 *System map*

20 *Journey Map*

In this vision, the bicycle constitutes, from the user point of view, the means of access to the set of opportunities provided; however, the designed network, constituted by bikes, trails, stations and rest areas, does not represent the ultimate goal of the project which is, on the contrary, interested in triggering off a sort of virtuous circle with farm houses as epicentres. In fact, farm houses (known as "cascinas" in the Parco Sud), together with the inherent agricultural traditional background, are the real active protagonists in the process of shortening the distance between the urban and rural worlds. Thus, tasting succulent specialities, purchase of local groceries or handicraft, discovery of ancient crafts should guarantee certain added value to the bike experience itself. In a word, creation of an integrated, multi-value and multi-sensorial "formula" for sustainable agro-tourism is the issue at stake.

Finally, the expected solution takes the form of a "positive sum game" from which all those involved can profit, thanks to a multi-level pattern of interaction based on principles such as collaborative partnership, knowledge sharing, alternative marketing strategies, self-financing and management. As a consequence, the final system should be a viable and exportable solution, especially intended for those peri-urban areas in stand-by, in search of alternative models ensuring prosperity without unsustainable and traditional economic growth.

GENERATING A SOLUTION

The proposed system requires the user to create the tour best suited to his desires using a web-based service platform. Logging in on the website, the tourist can book the bike(s) for the selected day(s), choose the type of trail and play an active role in shaping the best combination of features offered by the system; in this way it is possible to create a true, custom-made experience.
The first step is the choice of the start and finish points where bikes are picked up and returned. Such points are the farm houses/cascinas located in the vicinity of a public transport stop: here the bicycles, in a number depending on actual demand, are kept by the farmers. The user is asked to select the length of the trail he would like to ride. Theere are four intuitive options: S is the shortest (from 5 to 10 km) and destined to young families and schools, M is instead created for families or individuals who enjoy a longer ride in nature (from 10 to 20 km); the L (from 20 to 35 km) is thought for groups of friends, while XL, the longest (over 35km) is specifically designed for sports enthusiasts.
As a next step, the user chooses the theme of the trail and the points of interest he would like to visit, according to his personal preferences. For instance, a "gastronomic tour" can include a series of local cuisine and wine tastings served in selected farm houses or restaurants; on the contrary, a "nature trail" is likely to explore wildlife reserves or parks, wetlands and lakes where autochthonous flora and fauna can be admired; finally, choosing the "heritage tour", the visitor interested in rural architecture can discover a water mill, a medieval abbey or an ancient castle.

In order to complete the offer, a number of pre-defined package tours are proposed. These options include specific sets of activities and services at a fixed price. Since the system is flexible and scalable, as the tourist starts experimenting such services, he will also be able to interactively shape new trails and comment on those already experienced. An online community is therefore imagined to upload personal feedback, storyboards and pictures that can act as suggestions for future users.
The concept of the user actively planning his experience is at the heart of our system, making it extremely suitable for diverse needs and putting interaction between visitor and context at the forefront.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] AA.V.V. (2009). *"Cascine di Milano verso e oltre Expo 2015: un sistema di luoghi dedicati all'agricoltura, all'alimentazione, all'abitare e alla cura del territorio"*.
[2] Molina, G. (2010) *"Guida alle aziende agricole – Parco Agricolo Sud Milano"*, Provincia di Milano (Milano).
[3] "*The European Greenways Good Practice Guide: Examples of Actions Undertaken in Cities and the Periphery*", European Commission.

project 13B

BIKEPASS
The core-hardware of the system: devices and organization

ABSTRACT

Though bike-sharing is a recent evolution in public transport, it is already very popular in the urban areas of many of the largest cities in the world. The purpose of this service is to achieve a sustainable and zero-impact means of public transport and thus reduce the effect of human traffic on the environment. This means of transport, however, is limited to the city, or city center, and, consequently, a citizen has to use motor vehicles to reach distant areas outside the city, including natural or agricultural areas.

The aim of our thesis is to design a bike-sharing system suited to these contexts, often forgotten because of their inaccessibility but still very important from the natural and historical viewpoint, and include them in the areas covered by a sustainable means of transport.

The analysis initially retraces both our desk and field research. The desk research studies existing bike sharing systems in order to understand the structure of this type of public transport, while field research consists of surveys and interviews with potential users.

In order to obtain the widest point of view possible, our project studies two very different situations, such as Chong Ming Island in China and Parco Agricolo Sud, near Milan, Italy, and draws up guidelines applicable to many different contexts.

The thesis then presents all the designed aspects, starting from the system characteristics in general i.e. bicycles, stations and equipment and how these are all related.

Moreover, planning also addresses the successful relation between the bike-sharing system and the context. Therefore we studied all environmental aspects affected by implementation of the system with the purpose planning a positive sum game for the citizen, the farmers and the municipality.

TASKS & SKILLS

Francesco Cavagnis worked on feasibility studies, both on the Chong Ming, Shanghai and Parco Agricolo Sud Milano sites. He participated in designing a tool-kit to outline the main implementation steps of a bike sharing system in a peri-urban area. His knowledge was fundamental in preparing the business plan.

Marta Alice Fattorossi built relationships with players and users in terms of communication and promotion, both in field and by alternative channels. She contributed to the development of the service in terms of partnerships. Her direct responsibility was the organization of promotional events, communication and data processing and development of the web-platform.

Stefano Tedesco analyzed the problem of future users of the service. He contributed to the identification of general rules and instructions to be followed in order to create a bike sharing system in peri-urban areas, assembling them in the tool-kit. He also worked on the business plan of the service to provide a more technical presentation of the project for possible future implementation.

Laura Varvello studied the logistic issues. She focused her skills on the distribution and density of the single elements of the system and their organization in the areas of application. Furthermore, she studied integration of our project with existing infrastructures, services and resources in order to accomplish an integrated planning policy in the form of an Urban Revitalization Plan.








1 *Chong Ming, Mapping State of Art*
2 *Observation*
3 *Observation*
4 *Evaluating State of Art*
5 *Parco Agricolo Sud, Mapping State of Art*
6 *Observation*
7 *Observation*
8 *Evaluating State of Art*

UNDERSTANDING THE PROBLEM

The aim of our project is to create a sustainable and community-based micro economy thanks to cooperation of the various players and sharing of the diverse resources present in situ. The bike itself is a means, not an end. Thanks to its inherent environmental sustainability, the bicycle appears to be the best choice for entering a natural environment in an appropriate and respectful way.

The project attempts to connect the densely urbanized areas of the city with the nearby suburban areas characterized by a strong presence of agriculture and nature. From our interviews it emerged that the biggest obstacle to fruition of natural areas is accessibility from the city and clear information concerning the points of interest in the park. Therefore, increasing accessibility of these areas means increasing the number of visitors to peri-urban areas and therefore to farms. The project aims, therefore, not only to create an easily reachable green belt but also represents an important opportunity to revitalize the local micro economy.

However, the biggest challenge is creating a well organized, sustainable system for a small number of customers (when compared to the urban context) in the rural framework, which comprises extended distances, using the bike sharing service designed for the characteristics of the city which comprises a host of points of interest.

EXPLORING THE OPPORTUNITIES

Our research involved both analysis of the literature, field experience and a survey of local residents conducted via internet and in field (at markets and in other public places), in order to better comprehend existing bike sharing systems, user needs, the alternatives and opportunities bike-sharing programs offer, as well as the general interest, support and willingness to pay for this type of service.

Each aspect of the physics of the system, the hardware base, was analyzed in detail taking into consideration the criteria of usability, ease of maintenance and costs over the lifespan of the scheme. First of all, we considered various methods of access to bikes in a rural area: person in charge, credit cards or scheme cards. Secondly, we estimated possible alternatives for the design and technology of stations: low-tech and high-tech. Low-tech stations are mainly offered in small schemes: bikes are locked to the docking point mechanically and transactions related to tak-



9,10,11 *Protobiking in Chong Ming*

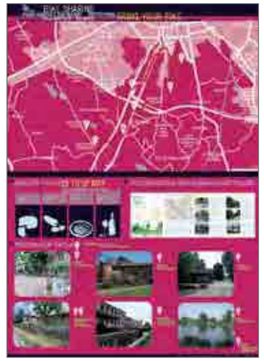



12, 13,14,15 *Protobiking in PAS*

16 *Person APROFILES*


17 *User feedback*

18 *System map*



19 *Event communication*

20 *Filed signs*

21 *Layout Piataforma*

ing out and return are supervised by a person in charge. High-tech stations are mainly incorporated in large schemes: bikes are locked to an electronically controlled docking point and the rental process takes place at the docking station itself.
We then considered the alternatives in service design, as far as station location, station density and service availability (yearly or seasonal) were concerned.
Subsequently, since registration is required to identify the user in order to avoid loss of bikes taken out by anonymous users, we identified that the different ways in which this could be provided are via a website, by telephone or at the station itself and that possible pricing structures are hourly, daily, monthly or yearly. Redistribution was then addressed as a challenge regarding both capacity and environmental impact; we analyzed redistribution methods which usually involve trucks to move bikes from one station to another.
Finally, we examined financing solutions. The majority of public systems are operated by advertising companies which, in exchange for advertising space, provide equipment and manage system operations . In contrast, a local non profit organization develops the business using a combination of usage fees, sponsorships and subsidies and procures the bicycles.

The design of a public bike sharing system in a peri-urban area, integrated with the existing local transport network, followed a process of exploring possible alternatives aimed at developing an innovative system to the benefitof the image of the area. Its implementation demonstrates a progressive attitude towards sustainable transportation and sustainable development. The expected solution takes the form of an exportable solution for those peri-urban areas planning to shorten the distances between the city and the surrounding areas via the use of bicycles.

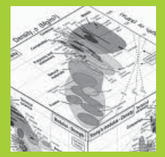
GENERATING A SOLUTION

As a result of the analysis, the system we designed is sustainable, user-friendly and economically feasible. It is structured using farm-houses which act as stations, located in the vicinity of a public transport stop. To create an effective and usable network, stations are also located close to trip generators, transit nodes, and along bicycle routes. The system is characterized by the presence of other fixed points, “bay points”, with different features and location. These are points of interest for cultural, naturalistic and culinary reasons which are conceived as stopovers during a tour.

The system provides both adult, with adjustable seats, and children’s bikes which are strong, secure and easy to manoeuvre. Both stations and bay points are designed with low-tech docking points and provide information on the area and the surrounding points thanks to an information column. In this way, without any groundwork or technological access, we reduce installation costs.
Stations are networked to a centralized computer system that requires users to register for free and book the bike(s) for the selected day(s) on a website. The online booking method guides users’ choices to facilitate bike redistribution of without using trucks. In fact, the system is structured bearing in mind the consideration that cycling from A to B is the same as cycling from B to A, as both stations are connected to public transport stops. The system memorizes the imbalances and guides users to choose trail A-B or B-A indifferently, taking into consideration only the quantity of bicycles available at both stations at the moment of reservation. The system is thus self-balancing.
On taking possession of the bike, the system blocks a deposit from the customer’s credit card. This inhibits potential customers without a credit card but prevents thefts and vandalism.
The system requires an initial investment for planning, equipment procurement and station and bay point construction. In order to better respond to user interests, the system is supervised by a local non-profit organization. The main sources of revenue are user fees and sponsors which place ads on stations and on the bicycles themselves, and possibly a start up fund allocated by the municipality. The organization cooperates with locals who keep the bikes, provide the service and manage the process of bike maintenance. Transactions related to taking out and returning a bicycle are supervised by local farmers provided with a maintenance kit, standardized parts and trained staff. Therefore, the role of local farmers is crucial to create a sustainable system which is not forced by external organizations but able to grow through the bottom-up dissemination of a common vision, aimed at expressing the hidden potential of an area with a view to sustainable development.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Bike Sharing Guide, Transport Canada, March 2009
[2] *The European Greenways Good Practice Guide: Examples of Actions Undertaken in Cities and the Periphery,* European Commission. *How to prepare a business plan,* United Nations Conference on trade and development, 2002



PROJECT 14

SportFood.PD

SportFood

PACKAGING DESIGN OF A NEW FOOD PLATFORM DEDICATED TO SPORT THROUGH A MULTIDISCIPLINARY APPROACH

project 14

SportFood.PD
Packaging Design of a new food platform dedicated to Sport through a multidisciplinary approach

Packaging design project, using a multidisciplinary approach, for a new line of functional, natural carb-based foods (bar, gel, liquid) dedicated to sport

PRINCIPAL ACADEMIC TUTOR

Valeria Bucchetti
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

ACADEMIC TUTORS

Erik Ciravegna
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Barbara Del Curto
Chemistry Materials and Chemical Engineering, Politecnico di Milano

Sara Sanvito
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Umberto Tolino
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Giulio Zotteri
Production Systems and Business Economics, Politecnico di Torino

EXTERNAL INSTITUTION

Barilla Group

EXTERNAL TUTOR

Michele Amigoni
Barilla Group

TEAM A

Jose Gabriel Islas Montero [Team controller]
Management, Economics and Industrial Engineering

Alessandro Bombelli
Aeronautical Engineering

Alessandra Erra
Management, Economics and Industrial Engineering

Ambra Farris
Communication Design

Marta Gallo [Project Team Coordinator]
Biomedical Engineering

TEAM B

Andrea Rongone [Team controller]
Management, Economics and Industrial Engineering

Ekaterina Kim
Management, Economics and Industrial Engineering

Ece Özdil
Product-Service-Systems Design

Paolo Rossi
Chemical Engineering

PROJECT DESCRIPTION

The Challenge

The ambition was to launch a series of food products to improve the physical conditions of those who practice sport activities, both in terms of performance and in terms of post-activity recovery.
The objective was to outline a new offer for the market, characterized by the use of functional natural ingredients, due to the particular recipe and selection.
There are three main product categories: solid bars (before sport activity); drink with a high density, gel type structure (during sport activity); liquid beverage (after sport activity).
The features required, from the product and packaging design point of view, were: maximum portability, ability to use during activity, minimization of packaging waste (as sportsmen often do not know where to dispose of waste during activity, it is important to avoid throwing waste on the ground), mono-portion and ability to use the product (opening, use, closure) with one hand.
In particular, for project development, what was asked by the company partner was to analyze many topics in depth: from product implications (rheology and surface, target shelf life, passive and active barrier, etc.) and impact on people (consumption habits, level of service, etc.) to choice of materials (sourcing, manufacturing, product performance and waste disposal after consumption); from environmental sustainability (LCA evaluation and end of life cycle management) and distribution and logistics implications (efficiency and optimization flows) to impact on variable product costs and effects on profitability.
The project also includes an experimental component related to methods and tools useful in conducting research and development of complex product platforms.

Teams

The two groups facing the challenge chose to jointly define the workplan and develop the research phase with the aim of monitoring more closely the different areas of investigation. Each group then analyzed specific parts of their different design solutions in depth.

Each group then focused on development of its own project and, during the concept generation and development phase, worked independently, creating two different product lines: the first called “play-fuel”, the second “organi-active”.
Given the specificity of the challenge, a central role – the real core of the work - was played by design, in its various declinations: product design, packaging design, communication design but also ergonomics and sustainability. Other disciplines, due to how the work plan had been established, did not have the same centrality.

Results

The design solutions proposed by the two teams represent an innovative response to the reference market sector. They have in fact: a strong identity, personality, ability to generate new forms of gesture and new consumption “rituals”, as well as having quality performance.
This result makes it possible to foresee subsequent stages of product development, verification and prototype testing and represents the precondition for the emergence of a new generation of products for the sport.

project 14A

Playfuel

ABSTRACT

The **SportFood PD** project arose from the intention of Barilla to experiment and gather external ideas regarding innovative packaging for sport food. The premise of the solution was to match the three consumption phases of sport activity with three distinct but complementary products: before activity (solid bars), during activity (gel type products) and after activity (liquid beverages). Barilla's intention of delivering sport food products using packaging design as a competitive advantage acted as the main driver during the project.

Following customer and market research composed of in-store interviews, face to face conversations with packaging and food experts and other related activities, a detailed picture of customer needs and the target market was obtained. This outcome was the cornerstone on which the team based its assumptions and the potential solution in the concept generation phase.

Several rough ideas were developed for each sport activity consumption phase, in which mono portion, design and one-hand portability were compared each time with solutions available on the market. A design mood concerning customer and brand implications was improved over time in numerous external and internal meetings. In addition, for each rough concept, potential materials were assessed by means of computer software analysis, as well as logistics implications and launch price scenarios.

STIK and **BRING**, covering a **Playfuel** mood, were delivered and approved at the end of the concept generation phase. The former, a dynamic push-pop-like concept, entails a solution whose shape and method of consumption completely breaks the modus operandi in which a normal sport food bar is consumed. The latter, a playful ring-like concept, includes an easy-to-carry solution both as a ring and as a small attachment to sport clothes. BRING embraces a method of carrying high performance sport food different from that encountered in normal gel type doses. Both concepts are intended to reflect a strong, dynamic, high performance but playful identity; they reshuffle the current state of the art in terms of sport food packaging design available on the mass markets and on some niche market shelves.

TASKS & SKILLS

Alessandra Erra evaluated the logistic implications of the proposed solutions related to the design process, assisted in the design of physical prototypes and gave suggestions on the feasibility of design proposals.

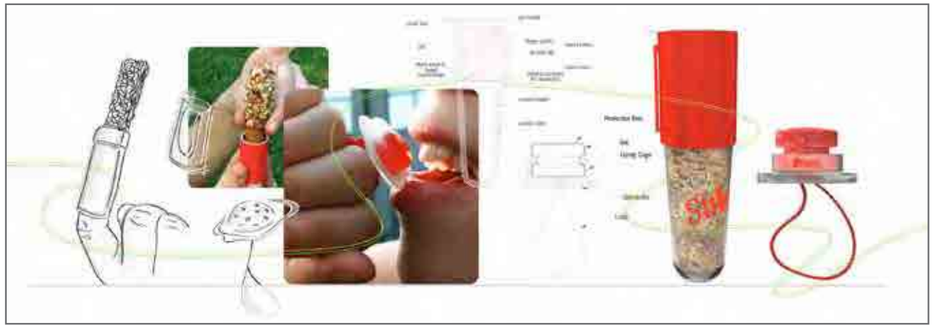
Alessandro Bombelli contributed in the design of physical prototypes, participated in the evaluation phase of potential materials for packaging solutions and the feasibility of design proposals.

Ambra Farris performed an in-depth customer and packaging research analysis, dealt with visual concept aspects (3D rendering models, moodboard and logo), made physical prototypes and prepared high quality presentations.

Jose Gabriel Islas Montero contributed to the research and marketing phase and analyzed and set pricing scenarios for the proposed solutions.

Marta Gallo analyzed and evaluated potential materials for the packaging solutions, performed high quality technical and meeting reports and gave suggestions on the feasibility of design proposals.

All team members contributed in the concept generation phase.



1 *DESIGN PROCESS: from initial sketches to the feasable products*

The idea behind both concepts is to provide the customer with products which distinguish themselves from the average sport food available on the market, especially in terms of portability, appeal and innovation. This has been the main driver, as well as the target of pursuing sustainability in the development of the entire project.

UNDERSTANDING THE PROBLEM

A new generation of sport food is expected to hit the market in a 5 to 10 years timeframe. The ability to dose and prepare natural elements without alteration is seen as the added value of products which do not contain chemical or synthetic elements but exploit the properties of genuine and simple ingredients. In their concept, these products are expected to be increasingly linked to wellbeing and less to competition; they are designed to let consumers choose their own pace, in delightful harmony between inside and outside in a natural context. On the basis of such a premise, Barilla, the external institution, requested the packaging design of a new food platform dedicated to sport, using a multidisciplinary approach in which one-hand portability, minimizing packaging waste and mono-portion were some of the main requirements expected to be encompassed in the final solution.

To better understand the main issues concerning customer needs and current sport foods available on the market, a customer discovery and market research analysis were performed. Several in-store analyses of existing products, interviews with consumers and food packaging experts, as well as various secondary information sources (questionnaires, internet, software on materials and books) were conducted and consulted. On the basis of the information obtained concerning consumer needs and the target market, a user profile was created for each of the potential customer segments which allowed the team to comprehend the main behavioral and demographic characteristics of those classes. At the same time, different material properties were assessed with the aim of finding a potential solution that could lead to more sustainable packaging.

Extensive research of the state of the art of packaging solutions involving sport food and other related spheres was carried out. Every time, the idea of covering the different sport activity consumption phases - before activity (solid bars), during activity (gel type products) and after activity (liquid beverages) - was considered.

The main outcome of the research phase was identification of the principal problems to be solved, understanding the needs of the different stakeholders involved and, finally, orchestration of the way the team would address the problem.

2 *HOW DO THE PRODUCTS WORK? Two mini-storyboards which explain gestures of positioning and consumption*

EXPLORING THE OPPORTUNITIES

After the research phase which had allowed the team to understand the problem and its dimensions, the concept phase was set up by plotting a list of four potential scenarios which were developed and refined during several internal meetings. Some of these proposals were focused more on the moods emerging from the research analysis rather than the functionality of the product. After a meeting with Barilla, however, those ideas less in line with the initial brief were abandoned and new solutions, more related to functionality (one-hand portability and mono-portion above all) and focused on runners and bikers, were conceived.
During an intense concept generation phase, the team developed new ideas; these proposals were then presented, together with the those of team B, to Barilla, clustered in three macro categories:

- The **Ready, Push, Go!** concept category was conceived on the basis of the candybar PushPop. The underlying idea was to re-invent the mechanism of the traditional candybar in a concept embodying a childish style.
- The **Monodose Ready to Wear** concept category was conceived as the intersection of the mono-portion dose and wearability. Both characteristics encompass Barilla's portability concern, as well as user needs regarding easy-to-carry sport food, as discovered in the research phase. Moreover, this constraint allowed the team to focus on solutions able to dislodge the average sport food product found on the shelves.
- The **Sporty Shaker** concept category emerged to cover the beverages segment, which turns out to be the largest in the sport food market. A strong emphasis on user gestures when mixing water and powder was used as the basis to develop the concepts in this segment.

Different moods regarding each of the ideas developed within the three categories, as well as the different potential materials covering sustainability issues, were designed and evaluated during several external and internal meetings.

GENERATING A SOLUTION

During a meeting with Barilla, two of the proposals of team A were chosen: these ideas were then elaborated and developed in detail in order to obtain, starting from a general concept, a realistic product defined in all its characteristics. Shapes, materials, functional details and corresponding technical drawings, product contents and logistics were carefully designed. Production and hygiene constraints led to a revision of a number of initial requirements, with the aim of reaching a compromise between efficacy and pertinence to the initial brief. By means of computer software to calculate a preliminary LCA (Life Cycle Assessment), a potential set of materials was assessed for each concept in order to ensure an improvement in sustainability with respect to sport food packaging available on the market. The use of mono-material polypropylene, thanks to its total recyclability, turned out to be the best solution. Moreover, different logistics and price scenarios were evaluated with the aim of defining an overall picture of how packaging design influences the number of units on a pallet and the potential launch price among current sport food products.
The iterative process of meetings with both internal and external tutors led to two final concepts: **STIK** and **BRING**.
The former, a dynamic pen-like concept, entails a solution whose shape and consumption is completely different from that of present bars. STIK, in fact, allows the consumer to push, with a simple piston-like gesture, a soft energetic marmalade inside a crispy cover, thus providing a tasteful sport food based on two different consistencies (soft and crispy). The user can thus "create" his own snack on the spot and take it with him thanks to its wearable packaging. Separation of the two ingredients is necessary for three main reasons: hygiene, preservation of the crunchiness of the cover and desire to provide the sport food with a dynamic movement.

3 *PLAYFUEL CONCEPT: dynamic, performance, playful, strong colours*

The latter, a playful ring-like concept, comprises an easy-to-carry solution both as a ring and as a small attachment to sport clothes. An energetic jelly is set on the ring like a gem and can be easily eaten by simply bringing the ring to the mouth and biting the jelly. The ring, moreover, can be re-filled with new jelly and re-used. BRING, therefore, clearly embraces a method of carrying high performance sport food different from the that encountered in normal gel type doses.
Both concepts were designed around a Playfuel mood, which is governed by a strong, dynamic, high performance, playful and technological identity. They are targeted to those people practicing sports activities daily, pursuing a natural life style, practicing sport not only as a passion but also as a healthy activity.
STIK and BRING, which are intended to be composed of natural ingredients with no artificial flavoring, are designed to respond to the needs of this target and, at the same time, respect the initial requirements of sustainability, ease of consumption and portability, thanks to the mono-material packaging, the simple gestures required to eat them and wearability. For all these reasons, BRING and STIK seem to have the potential necessary to revitalize the sport food market which is currently dormant.

project 14B

Organi-active

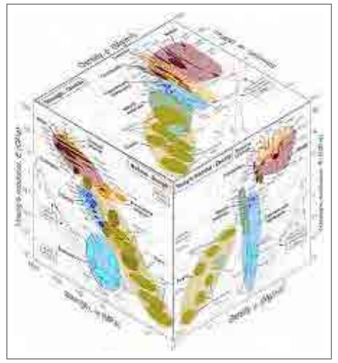
ABSTRACT

"People use products to make meaning in their lives and make statements about who they are. Customers often can't articulate those connections, because meaning isn't always a matter of conscious belief. You can't just listen to what people say. You have to understand how they interact with their environment and with other people. That's why you have to watch."
Rick Robinson, E-Lab cofounder

Naturalness is the key, as emerging from research on customer consumption habits. Amateur sport enthusiasts seek relaxing, open-air, balanced activities to keep more in contact with nature, thus we adopted this mood to create a new vision and meaning for sport food, designed to be integrated into people's life style. Given the organic nature of our products, we aimed at providing incremental values to our potential client, potentially laying the foundation for disruptive innovation in this standardized market.
Our result - two products, GELLA and SPRINK, unified by the common mood of being ORGANIACTIVE - transmits a clean and easy message to the user by communicating a pure and open image and creating a smooth interaction with the customer. Designed to deliver increased functionality, they provide freedom and flexibility to the user by allowing him to choose the consumption pace and freeing them during their sport activity. Innovative products in the form of a ring or the pouch that easily fits in the palm of the hand are a radical interpretation of existing products.
At the same time, while building the new identity we also bore in mind environmental issues. We stressed our attention to creating packaging requiring low energy consumption and and with as few emissions as possible over its entire life cycle. Our logistic policy provides maximum flexibility and distribution channels are organized in the most efficient way in order to decrease the impact on the environment.

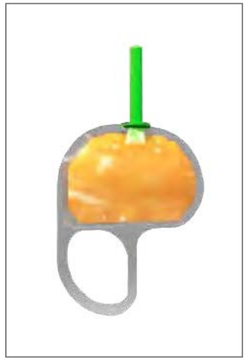
TASKS & SKILLS

Ekaterina Kim gathered information on marketing trends for sport products, was responsible for product positioning, brand identity and pricing strategy and contributed to the logistic analysis.
Ece Özdil analyzed and evaluated consumption habits, helped define the customer target, studied the design reference brands and implemented the visual characteristics of our products.
Andrea Rongone (team controller) coordinated the team work, providing feedback to the design phase through logistic analysis, was responsible for logistic research and contributed to the definition of a common marketing strategy.
Paolo Rossi performed an analysis of possible materials, with emphasis on their physical properties and their entire life cycle, highlighting the state of the art and proposing the final solution for materials.



1 *3D Visual of the main material reference, CES Edupack Software*

2 *3D visual of the Gella product, proposed to the external institution on October 24th, Milan*

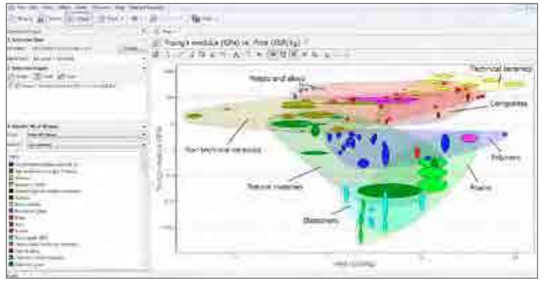


3 *3D visual of the Sprink product, proposed to the external institution on October 24th, Milan*

4 *Logo of the main material reference, CES Edupack Software*

UNDERSTANDING THE PROBLEM

Practicing sport in our lives is more than just a "hobby". An increasing trend towards a healthy lifestyle is stimulating an increasing number of enthusiasts to become more active, in contrast with the shortage of time of stressful, hectic lifestyles, and this is the main emerging driver of consumer pattern changes. It is therefore the family, nature and community, together with balanced nutrition and organic consumption that are becoming the new pillars of consumer choices. But so far there is no specific market to tackle such a customer target. Previously introduced sport food was traditionally aimed at professionals and performance-oriented sportsmen, mainly focusing on the chemical content of the product with standardized offers. Others were guided to obtain energy from bio-organic nutrition that might well be not balanced enough to sustain the needs of the sportsman's body.
The challenge Barilla proposed was to fill the gap between these markets, which are so different in nature yet so common in their target aidience, in order to provide people with healthy, well-balanced, biological sport food and, at the same time, with active ingredients, specific for sport activities, to support the body's needs and keep their customers in harmony.
The task was to create a new product line articulating a new meaning for customers and to build an interaction between the client and the product, namely to deliver a new message to our clients, expressing a fresh idea of sport food being functional, portable, flexible and easy-to-use. Such an innovative approach revolves around intangible product attributes creating completely new textual and functional layers in an increasingly bio-demanding socio-cultural context. Potentially disruptive design innovation coexists with marketable technological innovation. That is why the final request was to address the issue of sustainability via our main bio-organic concept through the use of materials with low energy consumption and carbon dioxide emissions related to the entire life cycle of the packaging, possibly re-using the product and organizing the distribution channel in a more optimized fashion.



5 *Working module of CES Edupack Software*

6 *Proposal for the OrganiActive texture, proposed to the external institution on October 24th, Milan*

7 *Focus on competitors (Aptonia), shown in the research presented on September 13th, Parma*

8 *Focus on the naturalness of existing products, shown in the research presented on September 13th, Parma*

EXPLORING THE OPPORTUNITIES

The research phase, carried out on a multidisciplinary basis, showed us that existing sport food has artificial flavoring associated with powerful and strong images. Regarding the consumption habits of of amateur sportsmen, it also made clear that their need is for hydration and energy provision. Studying existing products we identified what could be the marketing strategy, possible distribution policies as well as material usage.
Focusing on the general brief, our idea was to change the existing perception of sport food towards a cleaner and more relaxed image. As a reference point we took the Barilla Mulino Bianco brand, which delivers the message of home, sharing and cozy feelings but we still had to merge these with the dynamic line of our concept, choosing as a reference brand Aptonia, with its transparency and brand identity completeness.
To satisfy the sustainability requirement we considered using different recyclable materials for food packaging. Also new renewable materials have become available in recent years, such as PLA or thermo plasticized starch, but they cannot provide the desired shelf life of six months or withstand a temperature of 100°C necessary for the sterilization process for reasons of hygiene. The choice, therefore, had to be thoroughly revised.
The mass production strategy imposed by Barilla implied working with the large-scale retail distribution market, with constraints such as standardized pallet dimensions and distribution channel flexibility. On the one hand, the Syncro project, owned by one of Barilla's third party partners, represents the state of the art in logistic efficiency: in fact, it operates with a multi-distributor logic on a commonly shared information platform, minimizing logistic costs. On the other, different logistic channels such as bio-shops, natural or green chains were considered due to the nature of the product.

GENERATING A SOLUTION

Through questionnaires, interviews with consumers, direct purchase and tasting, the final identity was generated. The mood we chose transmits the idea of reaching performance in a healthy manner and was named ORGANIACTIVE, a tasty organic concept for products made of pure and natural ingredients to provide the energy and stimulus needed during sports activity. The two innovative products, GELLA and SPRINK, are highly portable, ergonomic and designed to be used with only one hand. A transparent packaging was imagined in order to communicate the message "what you see is what you eat" and to stress the idea of naturalness, transparency and cleanness.
GELLA can be easily worn as a ring and used as a "one shot" energy booster whenever the consumer wants. Given its particular shape, it is suitable for runners and bikers. SPRINK is the beverage which imitates the shape of the palm of your hand and can be carried during sports activity. Totally flexible, it has a special valve to prevent leaks and spills. Thank to these features, the products are designed to give the consumer complete control over time of consumption of the sport food and provide a feeling of hydration and satisfaction.
The packaging materials used are the most sustainable among those able to fulfill the given constraints. This sustainability is certified by an LCA study which compared all the possible solutions and led to the decision of using PP (Polypropilene, a recyclable plastic) as the main material for primary and secondary packaging.
A full market strategy was created, starting from the premium quality of the product, in a very design-driven approach; applying a premium price is coherent with the products themselves and with mass distribution based on maximum flexibility. Dimensioning our products in such a way as to minimize wasted space in transportation, we aimed to reduce total cost of distribution and increase timeliness of product delivery.
This approach of organizing each step of product development adds value through the entire supply chain, minimizing idle processes and losses. Finally, starting from a design-driven approach triggered by socio-cultural events, we managed to shape the new identity and create sustainabity in the SportFood system.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] CES EduPack 2011.2 Version 7.0.0
[2] *Marketing Management*, P.Kotler, Prentice-Hall, Upper addle River, 1967
[3] *Designing Sustainable Packaging*, S. Boylston, Laurence King Publishing, Boston, 2009

Preface

This book marks the sixth cycle of students that have completed their course of studies in the Alta Scuola Politecnica.
Created in 2004, the Alta Scuola Politecnica programme draws on the experience of the Politecnico di Milano and the Politecnico di Torino, two universities with different histories, conditions and methods, but that share the desire to offer to selected and talented students with an interest on multi-disciplinarity a highly-innovative course of studies.
From the outset, this ambitious project aimed to create an axis of learning between Turin and Milan. Today, as we witness the growing economic and social bonds between these two cities – both of which are key to the Italian economy – we are increasingly confident that we made the right decision eight years ago, a decision that during this time has come to fruition and has evolved and improved.
The world is witnessing a very fast technological and social development that is leading to the emergence of new paradigms; therefore, technical professionals of the future should not only be specialists in a given discipline, but also capable of building innovative solutions that are most suitable to be transferred to the products and services of the future. At the same time, when dealing with particularly talented students, we believe that universities should do more than simply issue degrees - they should also prepare these students to become future leaders and meet the specific demands that prospective employers cast on this particular segment of graduates. In this sense, the Alta Scuola Politecnica provides an added value with respect to the traditional academic approach. ASP students are given the opportunity to continuously gain insight from one another, from courses offered by both universities, and from projects at the leading edge of technology proposed by companies. Due to this unique learning experience, they develop the managerial skills and the comprehensive training that employers are increasingly seeking from top graduates in technical disciplines. Students have the opportunity to work in teams, managing complex projects which require multi-disciplinary contribution (as illustrated in this book), and follow residential courses, thereby enjoying a stimulating earning experience. The significant presence of industrial sponsors in the last ASP cycles gives evidence to the fact that industry appreciates the mix of specialized skills, coming from the Master programs, and interdisciplinary skills, coming from ASP.
This important achievement confirms that the path we chose to follow in 2004 is still very promising, and we are encouraged in continuing and improving this endeavour with the same enthusiasm shown by our ASP students.

Prof. Giovanni Azzone, Rector, Politecnico di Milano
Prof. Marco Gilli, Rector, Politecnico di Torino

ASP Sponsors

ASP is partially financially supported by external institutions which share our vision of educating talented students and promoting interdisciplinary innovation. Following a three-year initial financial support from the Italian Ministry of University Education and Research, the main supporters of ASP are currently Compagnia di San Paolo and Fondazione Cariplo. Other institutions, both private and public, have joined in by providing financial support as well as a relation aimed at developing projects and opportunities for the career development of our students. The logo of each of our sponsors is presented below and their valuable support is hereby gratefully acknowledged.

The Compagnia di San Paolo, founded in 1563 as a charitable brotherhood, is today one of the largest private-law foundations in Europe.
It pursues aims of public interest and social use, in order to foster the civil, cultural and economic development of the community in which it operates. The Compagnia is active in the sectors of scientific, economic and juridical research; education; art; preservation and valorization of cultural heritage and activities and of environmental assets; health; assistance to the socially deprived categories.
In 2010 the Compagnia awarded 689 grants in its areas of activity, amounting to 122.8 million euros. Notably, 121 grants were awarded in the Research and Higher Education sector, amounting to 44 million euros.
The Compagnia pays particular attention to advanced research and to the development of scientific and technological centres of excellence, seen both as catalysts and multipliers of research and higher education initiatives. It supports the reinforcement of Torino's university system, especially through the promotion of excellence at Politecnico di Torino and the University.
The commitment of the Compagnia in the field of Education is focused on university and postgraduate education, starting from the growth of human capital, internationalisation and the provision of infrastructures, with special attention to the conditions that assure equal access.
In this context, the ASP's focus on excellence and innovation – besides characterising it as a valuable initiative *per se* – gives this programme the capacity to enhance the global attractiveness of the Universities involved and foster, within the leaders of the future, a specific attention to the interdisciplinary and international dimension of nowadays society. The programme also represents an interesting synergy among educational institutions located in the north-western region of Italy.
The Compagnia has supported ASP since 2007: the grants are aimed at funding scholarships for the ASP course beginning in the year, requiring a special attention to students not based in Piedmont, or with an immigrant origin.

www.compagniadisanpaolo.it

Fondazione Cariplo, established in 1991 as a nonprofit organization with the purpose of furthering the common interest and the public good in various fields, is today – thanks to the sheer size of its assets (over 5.97 billions euro) - one of the world's leading philanthropic entities annually funding grants to organizations for the fulfillment of selected projects and initiatives.
The Foundation's assets, which are the fruit of the labour of generations of men and women, though considerable, are not sufficient to solve the many problems afflicting the civil society in Lombardy, Italy and the entire world. Therefore, Fondazione Cariplo efforts focus on the improvement of the living conditions in the local community. To Fondazione Cariplo this means improving the living standards of individuals as well as their social, cultural and economic environment. Fondazione Cariplo nurtures those conditions which enable individuals to achieve their potential, express their personality, freely pursue their inclination and fulfill themselves. Fondazione Cariplo gives priority to financing specific projects rather than providing general aid to organizations. This is, in fact, the only way to precisely assess whether a program is innovative and responds to the needs of the community.
The Foundation nurtures a breeding ground for scientific research, technology transfer and the development of applied research findings, by backing synergic actions geared to the creation of networks and partnerships, the participation in international projects, the development of human capital, the production of better knowledge and improved scientific communication, as well as the dissemination and enhancement of applied research findings.
In 2011 Fondazione Cariplo awarded 2.342 grants in its various areas of activity, amounting to 156.8 millions euro (+6.8% annual rate). 119 grants were awarded in the scientific research and technology transfer area, totaling 30 millions euro. Between 2009 and 2011 the scientific research sector of Fondazione Cariplo received about 1.600 applications, processed 1.400 funding requests, and funded 341 projects.
Fondazione Cariplo pays particular attention to the support and promotion of human capital development, particularly by focusing on a limited number of projects whose purpose is to start activities capable of achieving excellence in university and post-university studies. Furthermore the Foundation is also firmly convinced that actions supporting "excellence human capital" must entail a close connection between training and teaching activities, on one hand, and research and exposure to an advanced international scene, on the other.
These are the reasons underlying Fondazione Cariplo decision to support the ASP, an advanced international Faculty able to attract the best young foreign students and capable of Italian high profile graduates education.

www.fondazionecariplo.it

CAMERA DI COMMERCIO
INDUSTRIA ARTIGIANATO E AGRICOLTURA
DI TORINO

Along with an ever diversely assorted graduate education offer with 15,000 new degrees or diplomas granted every year, an excellent post graduate training system makes Piedmont and the province of Torino a centre of attraction for young talents. Moreover, thanks to the presence of more than 200 research centers, today Piemonte ranks 11,6% of Italy's investments in R&D and it is the second Italian region for private R&D investment. The region invests 1.8% of its GDP in innovation, and the private sector investment in R&D constitutes almost 80% of the total R&D expenditure.
Partnership with public and private institutions, network between territories, support to innovation and research are main objectives for the Torino Chamber of Commerce which promotes the economic development and the local businesses growth.
The Chamber offers a wide range of services to nearly 237,000 companies working in the province and listed in the public Register of Enterprises: training, technological innovation, collection and distribution of information, fostering of business relations at home and abroad, creation of services and financing of projects designed to assist new businesses, promotion and organization of events, access to financing, information and consultancy for companies involved in foreign trade.
A particular attention is dedicated to the different levels of education, from professional courses to post-university Masters, with a special focus on high education systems and international training, which represent a significant tool for the attractiveness and worldwide relations, together with the solidity of the industrial fabric, the pro-business mood of the public administration, the quality of life in a creative, cultural and artistic context.
This is the reason why the Torino Chamber of Commerce, three years ago, decided to cooperate with the ASP, the advanced international Faculty, founded by Politecnico di Torino and Politecnico di Milano, to enhance links between the two cities.
Italian Chambers of Commerce work to build local area networks between research centers and enterprises, individual enterprises, institutions, territories and cities, as well as technological networks.
Torino, Milan and Genoa Chambers of Commerce support the development of North-western macroeconomic region by means of projects.
Figures are significant: north-western Italy (Piemonte, Lombardia, Val d'Aosta and Liguria) is one of the European biggest areas, with a population that overcomes 16 million people and more than 1.600.000 enterprises. It is an integrated territory that can proudly compete with the other European polycentric regions.
The North-western region needs economical and infrastructural actions, as the new railway connection between Torino and Milan, but also stronger cultural relations, focusing in particular on art, with a special attention to the contemporary art, education and organization of international events, as Milano Expo 2015.

Torino Chamber of Commerce: working with businesses to build the future

www.to.camcom.it

accenture
High performance. Delivered.

Accenture is a global management consulting, technology services and outsourcing company, with more than 246,000 people serving clients in over 120 countries. Combining unparalleled experience, comprehensive capabilities across all industries and business functions, and extensive research on the world's most successful companies, Accenture collaborates with clients to help them become high-performance businesses and governments. The company generated net revenues of US$25.5 billion for the fiscal year ended Aug. 31, 2011. In Italy, all Accenture's group companies employ more than 10.500 people (Milan, Rome, Turin, and Verona) and generated net revenues of 1.029 million Euros in the fiscal year ended Aug. 31, 2011.

We are able to deliver leading-edge solutions to our clients by bringing together highly talented people in a creative, multicultural and collaborative environment, where everyone is strongly encouraged to make the difference through innovative, non conventional ideas.

As the global demand for highly skilled people grows, education excellence is increasing in importance. Accenture supports Alta Scuola Politecnica as we are committed in helping young talented people, with a passion for innovation and a deep interest in multidisciplinarity, to develop their potential and capabilities through qualified academic initiatives, contributing to their continuous improvement.

To learn more about Accenture visit

www.accenture.com

BCG
The Boston Consulting Group

The Boston Consulting Group is a global management consulting firm and the world's leading advisor on business strategy. Founded in 1963, BCG has 75 offices in 42 countries.
We partner with clients in all sectors and regions to identify their highest-value opportunities, address their most critical challenges, and transform their businesses. Our customized approach combines deep insight into the dynamics of companies and markets with close collaboration at all levels of the client organization. This ensures that our clients achieve sustainable competitive advantage, build more capable organizations, and secure lasting results. In our client work, we aspire to make a difference, and we succeed because we are different. We help our clients change the rules of the game, not just play better.

The BCG difference lies in the power of individuals: challenged by mentors, supported in teams, motivated by results. We look for outstanding talents and people who have the curiosity and drive to find innovative solutions. Our consultants work with clients to define the problem and determine the best approach. BCG offers to all its employees to grow further challenging their mind, partnering with leaders, making a difference and ultimately charting a career that fits them.

Our goal is therefore to help ASP students better understand the challenges and opportunities of a consulting career. We are highly committed to develop initiatives to meet, interact and support ASP students in their growth.
BCG. Grow Further! Shaping Your Future. Together.

www.bcg.com

McKinsey&Company

McKinsey & Company, global leader in management consulting, is proud to be sponsor of Alta Scuola Politecnica (ASP), a prestigious source of excellence within the Italian academic landscape.
We firmly believe that students at Alta Scuola Politecnica have the opportunity to develop a unique mix of skills and experiences that makes them mature and open-minded; furthermore, this distinctive combination strengthens their talent and directs them towards a focused management approach grounded on a "project-based" methodology that entails the development of highly valuable finished products and a real bent for meeting deadlines and experiencing team work.

These attitudes, together with their analytical and problem solving capabilities, fit particularly well with McKinsey's culture and values. These are, moreover, the qualities that McKinsey looks for in its consultants and prospect candidates.

Thanks to these features, all ASP Alumni who had joined McKinsey have proved very successful and have embarked on a career path of excellence and exponential growth.

www.mckinsey.it

Communication design
Bottega dei Segni

Graphic editing
Simone Castiglioni

Proof reading
Trans Edit Group

Photos
We would like to thank all students for their photos.

Project Coordinator
Gianna Campaioli

ISBN 978 88 7398 0766

Summary

Alta Scuola Politecnica celebrates its eighth Birthday

The **Alta Scuola Politecnica** (ASP) is a school of excellence rooted within the Politecnico di Milano (PoliMi) and Politecnico di Torino (PoliTo). This volume presents the final results of the multidisciplinary projects of the VI Cycle of ASP, while the VII and VIII Cycles are still ongoing. Since its foundation, ASP has progressively grown to include a community of more than one thousand students and Alumni. The first eight years of activity have been characterized by evolution through continuous change – coherently with the strongly innovative, pioneering and exploratory nature of the ASP programme. Such evolution has led to a growing awareness of the ASP approach and its values within the Board, the Faculty and the students. This article offers readers a brief description of how ASP has been growing, and provides recent data on its current status. During the last year, several events have taken place, including the appointment of the first cohort of **ASP Fellows,** recognizing the professors that have mostly contributed to establishing ASP, and the opening of a dedicated **YouTube Channel**; a more detailed description of ASP fellowships and of ASP on YouTube are presented in the appendix.

Mission and Programme

Every year, since its foundation in 2004, ASP selects 150 young and exceptionally talented students among the applicants to the Master of Science programmes in Engineering, Architecture and Design of the two Universities. The **mission** of ASP is to provide society with high-profile graduates combining in-depth (vertical) disciplinary knowledge from their Master of Science programmes with interdisciplinary (horizontal) competencies that are needed to work in a truly multidisciplinary environment.

The ASP programme runs in parallel with the Master of Science programmes offered by the two Universities; at the end of their ASP studies, students who complete the programme receive a double degree from PoliMi and PoliTo, as well as the ASP diploma. The same programme is offered to all ASP students, regardless of their school of origin. In order to achieve this target, the two-year ASP programme is built around two major elements:

- full-immersion, week-long **ASP Interdisciplinary Courses**, dedicated to the development of interdisciplinary expertise between the very different technical backgrounds of ASP students;
- continuous, two-year **ASP Multidisciplinary Projects**, developed by small multidisciplinary teams of students, academic tutors and companies or public institutions.

Thanks to this curriculum, ASP graduates are expected to significantly contribute to a future class of talented professionals, capable of leading innovation processes in a variety of fields, in Italy and abroad. In the words of the ASP advisory board and of the sponsoring corporations, ASP is effectively developing "a new kind of technical graduate".

In the eight years of ASP history, Management of the School has moved from Milano to Torino and then back to Milano. ASP is managed by a Board of eight professors (four from each University) with different backgrounds, representing architecture, design and engineering; the main tasks of the Board concern the management of courses, projects and students' careers. ASP educational activities in these eight years have been carried out by a large body of about 600 professors, from both the two founding Universities and other academic institutions, who have tutored projects and courses; moreover, about 250 private and public institutions have contributed to projects as sponsors and/or active stakeholders.

Admission

The admission process is very demanding, since the quality and success of ASP depends on forming a community of students who are not only talented from an academic point of view but also passionate about the themes that underlie the ASP programme. Figure 1 shows the total of eligible applications (i.e. with respect to academic requirements) and admitted students at PoliMi and PoliTo in the last five cycles. Since 2007, ASP has 3 admission channels.

	APPLICATIONS		ADMITTED STUDENTS		FOREIGN STUDENTS		
CYCLE	MILANO	TORINO	MILANO	TORINO	MILANO	TORINO	TOTAL FOREIGN STUDENTS
IV (2007)	174	110	83	57	18	8	26
V (2008)	251	230	90	60	28	11	39
VI (2009)	293	200	90	59	22	13	35
VII (2010)	240	255	90	59	26	8	34
VIII (2011)	219	146	90	57	19	8	27

1 *Admissions in the last five cycles*

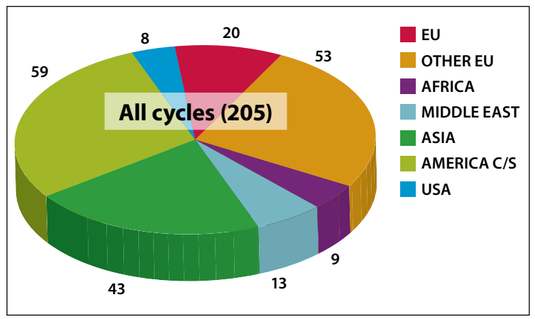
As far as **regular students** from PoliMi and PoliTo are concerned, applications are invited from the top 5-10% students from every course of studies in the fifteen Schools of the two Universities. The figure of merit used for such pre-selection is a weighted product of credits and marks for all exams passed at the end of their fifth semester in the Bachelor of Science programme; this figure evaluates students in terms of quality and speed in their studies. By construction, this group of potential applicants is evenly distributed among all study courses, thereby avoiding uneven distributions of students which occurred in the first ASP cycles, when applicants were selected by using an absolute figure of merit. Normally, about 50% of pre-selected students apply to ASP and, subsequently, about 50% of these are selected through an interview, before summer vacations; admission is subject to completing the Bachelor of Science programme and enrolling in the Master of Science programme.

Foreign students are admitted in Spring, during admission to the Master of Science programmes of the two Universities, in cooperation with the Internationalization offices. The most promising applicants are preselected based on their rankings, as produced by the offices in cooperation with the admissions commissions of each programme.

Finally, a "call for applications" from **all students** is open until about mid October; applicants must have obtained their Bachelor of Science with average marks exceeding 27. The main purpose of this call is to admit **students from other universities,** who decide to move to PoliMi or PoliTo; in any case, this call is also open to regular students from PoliMi and PoliTo and to foreign students.

In the selection of ASP applicants, a central aspect is the assessment of their understanding of the ASP programme and of the desire to invest in interdisciplinary education. Selection is carried out through a motivation letter and a face-to-face or a Skype interview. In general, about twice as many students as are admitted are interviewed.

During the last three years, foreign students have ranged from between 39 (in the V cycle) and 27 (in the VIII cycle), representing a very diverse population from all over the world. Figure 2 shows the distribution of the 205 foreign students admitted to ASP during the eight cycles, subdivided by region.



2 *International students in ASP, all cycles*

Women are well represented in ASP, with a percentage which has grown from 30-35% in the first 4 cycles to about 40% in the last 4 cycles; in the VIII cycle, 42% of students are female.

Courses

Since its inception in 2004, ASP offers six courses in each cycle, equally divided among the two years of Master of Science studies. Courses are residential; students are taken offsite from Milano and Torino, typically for one week; if possible, courses of two cycles in the same week and in the same location are offered so that two generations of students have an opportunity to meet. Professors teaching at ASP are from the two Universities, as well as from leading national and international institutes, including Cornell, MIT, Harvard and Amsterdam University among others.

During 2012, two weeks in March and May were spent in Belgirate on Lago Maggiore, and one week will be spent in July in Sestriere, in the facilities that hosted the Olympic Villages in the 2006 Winter Olympic Games. Courses are offered during the spring semester so that ASP students are free from ASP obligations during the first semester of the second year when many of them participate in exchange programmes – such as Erasmus.

Thanks to continuous monitoring and to student feedback, it has become clear that ASP courses have special traits which distinguish them. Firstly, ASP Courses have a participative structure; students are involved in study groups and discussions, leading to short presentations by students, given either in front of the entire class or within smaller groups. Secondly, ASP courses are closely linked to ASP projects, either because the subjects taught in the former can be directly applied to the latter (e.g. understanding the project stakeholders and potential conflicts, defining a business model, and so on), or because projects can provide material for case studies which are discussed within student groups.

During the last seven years, many changes have occurred in ASP courses. Normally, one or two new courses are opened at every new cycle. Meanwhile, the overall course programme has evolved and consolidated and new teaching methods have been experimented. The first four courses are dedicated to the foundations of interdisciplinarity and innovation; they provide educational principles that are immediately applicable in the ASP multidisciplinary projects.

- The course on **Innovation & Society (Prof. Costanzo Ranci)** has the goal of interpreting the socio-technical context in which innovation takes place and develops a broad understanding of how values and normative cultures shape and guide innovation and technical design.
- The course on **Design Methods (Prof. Gaetano Cascini)** teaches a common lexicon on design methods and gives students awareness on the existing approaches to design, on the main stages of product/service design and their fundamentals. Students then learn and apply exemplary design tools and take part in a collaborative design contest.
- The course on **Management of Innovation (Prof. Mario Calderini)** aims at developing students' capability to perform strategic analysis on the business implications of innovation, as well as developing skills and experience in group work and external communication capacities.
- The course on **Complex Decision Making in the Public and the Private Sphere (Profs. Giovanni Azzone and Bruno Dente)** teaches the theoretical framework and the analytical instruments to design and manage decision making processes in the context of complex projects involving government and private sector firms.

The last two courses are dedicated to important problems of today's world: sustainability and de-growth.

- The course on **Global Change and Sustainability (Profs. Barbara Betti, Stefano Consonni and Marino Gatto)** introduces the problems of global change, outlines the policies and technical advancements that could shape sustainability paths, so that students can commit to bringing the ideas of social, economic and environmental sustainability into their professional life.
- The course on **Dynamics of Creativity Against De-growth (Prof. Agata Spaziante)** discusses how creativity and innovation can help tackle the on-going economic situation and promote development, in the face of a deep economic crisis, by reasoning about how de-growth can "positively" affect areas such as urban organization, lifestyle, city life and activity financing, in order to help strategic change.

The "design methods" and "dynamics of creativity against de-growth" courses were designed during the last two years and the "decision making" course was recently broadened to incorporate the public sphere; the first edition of "design methods" took place in 2012.

Projects

Projects are the second backbone of ASP education. Coherently with the ASP cultural approach, projects must be at the leading edge of innovation, complex and systemic; they deal with ill-defined problems, involving a number of stakeholders and a significant degree of ambiguity and uncertainty. Students must correctly assess existing solutions, analyze the needs of the various players and stakeholders involved, define technical solutions and plan an innovation process within the project domain, evaluating feasibility and impact with respect to different aspects (technical performance, response to the needs of the parties involved, socio-economic impact and sustainability). This "problem setting" approach implies that students involved in ASP multidisciplinary projects must start from the identification of "innovative concepts", perform the analysis of their feasibility and implications and conclude with a well-defined solution in terms of technological, social and economic implications. Projects are not usually expected to delve deeply into specific disciplinary details; this marks a clear difference with respect to the work performed during the development of a Master of Science thesis, which is generally oriented to "problem solving" with a narrower and more focused approach.

While all ASP projects must be oriented to innovation and multidisciplinarity, from the VI cycle on, certain structural differences have led them to be grouped into two categories: design-driven projects and technology & research-driven projects.

Design driven projects are characterized by a broad level of multidisciplinarity and focus on innovation scenarios that are mostly unexplored from a technical, structural and functional point of view. Students must first understand the problem at hand and then find a technical solution.

Technology & research driven projects address a technological innovation scenario where multidisciplinarity is the main focus; the field has already been covered at the level of research activities and students must explore opportunities for technology transfer and industrial applications.

The two different kinds of projects are usually expected to generate different final outcomes:

- Design driven projects deliver a final result that explores the problem situation, compares possible solutions and evaluates the feasibility of the most promising and innovative options more thoroughly;
- Technology & research driven projects start from a more restricted project brief and aim to deliver a feasibility study of a solution which is compared to others and selected based upon its properties, with a number of demonstrators which

assess the feasibility in well-defined, specific dimensions of the solution space.

Projects are either proposed by ASP sponsors or by Professors of the two Universities. The ASP Board mentors company-sponsored programmes during their preparation, by facilitating the association with tutors belonging to the Universities, and selects among proposed projects the best suited to ASP, in either of the above two categories. Each project has a principal academic tutor, an interdisciplinary team of tutors representing both Universities and one or more external institutions as stakeholders.

Projects are then presented to students at the beginning of the ASP programme and accompany them throughout their education in ASP. The final exam consists of the presentation of project results. Grouping students into teams of about six students each, this is performed by the ASP Board on the basis of the students' preferences, which are collected immediately after the project presentations. Projects not having enough preferences are typically dropped at this stage. Each project has normally one or two teams working in parallel, although in some special cases projects may have three teams.

During the schools, students have some allotted time to deal with projects and receive feedback from the ASP Board, especially during a "project midterm" presentation. However, each team is free to organize work independently; students also have a budget (approximately one thousand euro each) to be spent on the project goals, e.g. covering the costs for site visits, buying materials or services, etc. Similarly, tutors have a small budget which is provided in the form of a research grant transferred to the principal tutor's department.

Companies involved in projects have pointed out that a period of about twenty months (from admission to graduation) is too long for the typical corporate project. Project scheduling has therefore been changed by recommending that the first year be spent in preparatory work (state of the art, requirement collection, identification of stakeholders and of their needs) while the core of the project activity should take place during the last seven months of the project and in close connection with external companies and institutions; in practice, this is also the time when students devote most of their efforts to project work.

News from the VI Cycle and beyond

This book is dedicated to the projects of the VI Cycle. Below is a brief summary as well as some of the most recent ASP news.

During the VI Cycle, 75 Professors from both Universities were involved as project tutors and 62 Professors were involved as course professors and tutors. This book describes 14 projects with 23 teams; out of these, three teams were evaluated with "excellent" at the final exam by the ASP Board. They were: Team A (ENJOYING THE PRESENT - Fruition of an underwater archaeological site) and Team B (SAVING THE PAST - Conservation of an underwater archaeological site) of the project TETI - Integrated Technologies for the Sustainable Management of Underwater Cultural Heritage, and Team A (A Sustainable Innovation for Dishwashing Detergents) of the project REPACK - Sustainable packaging for fast moving consumer goods.

During March 2011, ASP convened its **Sponsors Committee** for the first time, constituted by the Cariplo and San-Paolo Foundations, the Turin Chamber of Commerce, the European Patent Agency and nine companies: Accenture, Barilla, BCG – The Boston Consulting Group, ENI, Luxottica, McKinsey&Company, Procter&Gamble, Reply and Unicredit. In the presence of the two Rectors, Giovanni Azzone and Francesco Profumo, and of six Alumni, headed by their former president Alessandro Pradelli, members of the committee have substantially endorsed the ASP programme, at the same time providing important suggestions for improvement; a number of sponsor testimonials are provided above.

During January 2012, ASP organized its annual **Professor's Council**, dedicated to presenting the course programme and a number of testimonials from excellent projects of the V and VI cycles to tutors of the projects selected for the VIII cycle. Professors Costanzo Ranci, Gaetano Cascini, Mario Calderini and Bruno Dente presented their courses; Corinna Morandi and Sabrina Grassini presented the projects EXP-HOST and TETI, respectively. Then, 18 ASP Fellows were appointed – see Appendix A.

In February, ASP organized its **Eighth Cycle Opening Event,** dedicating the morning session to explaining the various aspects of ASP to new students of the VIII Cycle and the afternoon session to a keynote speaker. This year, we hosted prof. Banny Banerjee from the Design School of Stanford, who gave a brilliant talk on "Design Thinking: A Tool for Strategic Transformations"; a video of the talk is now available on the ASP YouTube channel, described Appendix B.

ASP is currently forging links with other European and International educational activities with a similar approach. Students from the Technical University Delft attended the Spring ASP School in 2011 for a first student exchange, while discussions are ongoing with Purdue University (Prof. Michael Dyrenfurth) and with the iFoundry Programme at the University of Illinois at Urbana-Champaign (Prof. David Goldberg) for students and academic exchanges. Along these lines, ASP is organizing a **Global Forum on "Creating Innovation Leaders"**, with the objectives of creating an important event for discussion around advancement, best practices, enabling systems, scaling, diffusion and optimal directions for innovation and of creating an "Invisible College" – as a networked community of global thought leaders on the subjects which share the same principles as ASP. The forum, organized with the participation of prof. Banny Banerjee from the Stanford Design School, will take place in Como, villa del Grumello, in September 2012, hosting worldwide experts on innovation and leadership.

Alumni

Graduates from ASP have founded the ASP Alumni Association, a lively and well-connected cluster of former students who maintain strong connections with ASP and who periodically meet for sharing cultural and social activites. The Alumni recently renewed their executive board and elected Giusy Cannone as their president. Alumni have an intense activity which includes both educational and recreative events. Among the former, the Alumni organized in April 2012, together with Confindustria, an event for **Promoting excellence and innovation**, primarily centered on selection of the best ASP multidisciplinary projects, chosen from the projects which had an excellent grade; the event was attended by many members of Confindustria (including Luigi Serra and the new President elect, Giorgio Squinzi) and by the Rectors Giovanni Azzone and Marco Gilli, while the Minister of Education, Francesco Profumo, former Rector of PoliTo, addressed students with a message. During the event, six projects were briefly presented (one from each of the six completed ASP cycles) and then evaluated by a jury. The program also hosted a panel on "excellence and merit for the young generations", presented by journalist Sergio Nava.

3 *ASP "Sliding sessions" in Bardonecchia*

Among the recreational events, Alumni and the students of the VII Cycle recently organized "sliding sessions" in Bardonecchia that were attended by over 65 skiers and supporters.

In summary, with six completed cycles, ASP has collected a wealth of useful experience; the main ASP asset is a growing community of more than one thousand young, enthusiastic and talented students and alumni.

The ASP Board

Stefano Ceri (Director) and Marco Cantamessa (Deputy Director)
Franco Bernelli and Romano Borchiellini (Student Careers)
Guya Bertelli and Marco Trisciuoglio (Courses)
Elena Baralis and Paola Bertola (Projects)

Appendix A: ASP Fellowship 2012

By establishing ASP Fellows, the ASP Executive Board has decided to give a tribute to the lecturers and professors who have most contributed to the success of ASP activities and to the development of its cultural message. ASP Fellows were appointed by the ASP Board taking into account the quality and the continuity of the effort spent. Fellows are listed in categories, depending on the main role they have had as project tutors, lecturers in courses, or members of the Board. Given their outstanding contributions and the cultural affinity to ASP values, the Fellows will be an increasingly important asset for the future development of ASP.

ASP Multidisciplinary Projects

- **Emma Angelini,** *Politecnico di Torino*
  Principal Tutor of the projects:

  NANOTRA - Integrating nanotechnologies with the design of materials and components of the future transport systems: towards the formation of a nano-engineer (2nd cycle)

  TETI - Integrated Technologies for the Sustainable Management of Underwater Cultural Heritage (6th cycle)

- **Andrea Bonarini,** *Politecnico di Milano*
  Principal Tutor of the projects:

  WoMan - Windows on MAN (2nd cycle)

  SenSoBot - Sensors and control for societal robots (3rd cycle)

- **Giuseppina Gini,** *Politecnico di Milano*
  Principal Tutor of the projects:

  ViChem - New mathematical molecular descriptors in drug design and risk assessment (3rd cycle)

  REMEDIA - REinvent MEDical Ambient (6th cycle)

- **Corinna Morandi,** *Politecnico di Milano*
  Principal Tutor of the projects:

  COMPITO - Monitoring Territorial Effects due to Commercial Polarities along the Milan-Turin Connection (1st cycle)

  Expo 2015 - Towards a polycentric Milano (3rd cycle)

  EXP-HOST - Great events and hospitality. Milan Expo 2015 and Turin Italia 150: new concepts and formats for new populations (5th cycle)

- **Emilio Paolucci,** *Politecnico di Torino*
  Principal Tutor of the projects:

  B2M - The broadcasting revolution: social impacts and opportunities (3rd cycle)

  DigiLife - Network Enabled Business Fabric (5th cycle)

  SME 2.0. - "Software as a service" as a breakthrough change for Small and Medium Enterprises (7th cycle)

ASP Courses

- **Alessandro Balducci,** *Politecnico di Milano*
  Coordinator of the course The Dynamics of Creativity
  3rd, 4th and 5th cycle

- **Massimiano Bucchi,** *Università degli Studi di Trento*
  Coordinator of the courses Innovation: Why, and for Whom? and Innovation & Society
  5th, 6th and 7th cycle

- **Mario Calderini,** *Politecnico di Torino*
  Coordinator of the course Management of Innovation
  1st, 2nd, 3rd, 4th, 5th, 6th and 7th cycle

- **Bruno Dente**, *Politecnico di Milano*
  Coordinator of the course Decision Making
  1st, 2nd, 3rd, 4th, 5th and 6th cycle

- **Sergio Rinaldi**, *Politecnico di Milano*
  Coordinator of the course The Art of Modelling
  1st, 2nd, 3rd, 4th, 5th and 6th cycle

International Lecturers

- **Keith Goffin**, *Cranfield University, School of Management*
  Lecturer in the course Management of innovation
  3rd, 4th and 5th cycle
- **Trevor J. Pinch**, *Cornell University, Dept. of Science and Technology Studies*
  Lecturer in the courses Innovation: Why, and for Whom? and Innovation & Society
  5th, 6th and 7th cycle
- **Alexander J. Wurzer**, *Director, Institute for Intellectual Property Management, Steinbeis University*
  Lecturer in the course Management of innovation
  1st, 2nd, 3rd and 5th cycle

ASP Executive Board

- **Sergio Benedetto**, *Politecnico di Torino*
  ASP Exceutive Board (student careers), 2007-2010 term
- **Costanzo Ranci Ortigosa**, *Politecnico di Milano*
  ASP Exceutive Board (courses), 2004-2007 and 2007-2010 terms
- **Agata Spaziante**, *Politecnico di Torino*
  ASP Vice-Director, 2004-2007 term
  ASP Exceutive Board (students careers), 2007-2010 term
- **Roberto Verganti**, *Politecnico di Milano*
  ASP Director, 2004-2007 term
- **Roberto Zanino**, *Politecnico di Torino*
  ASP Director, 2007-2010 term

Appendix B: ASP YouTube Channel

In February 2012, ASP opened its official YouTube Channel, at www.youtube.com/asppoli. Within just a few weeks of its launch, the Channel achieved interesting results, with more than 6000 viewings from 81 different countries.

4 *The ASP YouTube Channel*

The channel's main purpose is – for the time being – to provide anyone interested in ASP with an in-depth understanding of the programme and of its main elements. The intended audience therefore includes prospective students, firms and public bodies, as well as academics involved in interdisciplinary education.

The initial contents of the YouTube Channel are:

- The opening event of the VIII cycle, with presentations pertaining to the different aspects of the ASP experience.
- A selection of lectures from past ASP opening events (Banny Banerjee, Professor at Stanford University Design School, and Frank DeWinne, recent Commander of the Space Station, from the European Space Agency),
- The main lectures from the course "Innovation – Why and for Whom?"
- The final presentations from a selection of projects of the VI ASP Cycle,
- A lecture given by prof. Carlo Ratti, MIT, at one of the ASP Alumni events.

5 *The Playlists of the ASP YouTube Channel*

The contents will be progressively updated and might eventually lead to an innovative way of disseminating the ASP culture of multidisciplinary education beyond the community of students who are directly following the programme.

PROJECT 1

HASEW

HOUSEHOLD APPLIANCE SYSTEM WITH EQUIPPED WALL

HOUSEHOLD APPLIANCE SYSTEM WITH EQUIPPED WALLS

HASEW
Household Appliance System with Equipped Walls

project 1

The HASEW (Household Appliance System with Equipped Walls) project, developed in cooperation with INDESIT SpA, aims to investigate innovative integrated solutions for home appliances

PRINCIPAL ACADEMIC TUTOR

Pietro Asinari
Energetics, Politecnico di Torino

ACADEMIC TUTORS

Luigi Bistagnino
Architectural and Industrial Design, Politecnico di Torino

Andrea Bonarini
Electronics and Information, Politecnico di Milano

Ingrid Paoletti
Building Environment Sciences and Technology, Politecnico di Milano

EXTERNAL INSTITUTION

Indesit Company

EXTERNAL TUTOR

Dino Bongini
IDD – Innovation and Digital Design, Indesit Company

TEAM A

Aurora Cugno [Team controller]
Energy and Nuclear Engineering

Matteo Fasano
Mechanical Engineering

Fulvio Garbella Tavernin
Energy and Nuclear Engineering

Eugenia Gasparri
Building Engineering

Alexandru Popescu
Architecture (Construction)

Lucia Righetto
Architecture

TEAM B

Mattia Vincenzo Edoardo Massone
[Team controller]
Energy and Nuclear Engineering

Elisa Cucchetto
[Project Communication Coordinator]
Industrial Design

Francesco Laviola
Electronic Engineering

Sebastiano Maltese
Building Engineering

Lorenzo Piacentino
Architecture (Construction)

Giovanni Battista Porcellana
Energy and Nuclear Engineering

PROJECT DESCRIPTION

The Challenge

Three quarters of the global population are predicted to live in urban areas by 2050. Shortcomings of natural resources and increasing demand of user-friendly domotics make the design of innovative home environments imperative. The goal goes far beyond collecting different appliances, each independently designed. The real challenge is to design a synergic home environment in order for appliances to work harmoniously together, taking advantage of the optimization opportunities in each process and exploiting the (otherwise) wasted resources. A second, more subtle, challenge is the need to integrate the solutions developed in existing buildings (in Europe, low quality buildings represent more than half of the existing stock). Finally, this challenge has to be met at a European level, where different needs/habits have to be taken into account.

This project aims to explore innovative solutions for external/internal units equipping the building wall, which can collect and store primary energy resources (e.g. solar energy, rain water, etc.) to feed household appliances. The system should be able to feed certain household appliances with limited use during the day (washing machines, dishwashers, tumble dryers, ovens, etc.). The appliances must also ensure technical flexibility, easy accessibility, high mobility and user-friendly interfaces.

The teams developed their concepts focusing on new buildings (Team A) and existing buildings (Team B) respectively. Both teams fruitfully interacted with the TU Delft faculty of Industrial Design Engineering (Prof. dr. Angèle H.M.E. Reinders).

The teams

Team A focused on innovative solutions, designed from scratch for new buildings, with particular emphasis on energy savings,

better quality of life and environmental sustainability. The ambition is to provide to the new building construction field an innovative technology for domestic systems. The result is a modular system flexible towards consumer needs, sustainable due to a reduction in energy consumption and prefabrication, which facilitates a significant reduction in construction times and costs. Without loss of generality, the chosen case study building is a social-housing prototype (for comparison with the work done by the TEAM B).

Team B focused on the refurbishment of a broad stock of existing , high resource consuming buildings with low quality of life standards from both the environmental and social point of view. “Mirafiori Sud”, a council house estate in Turin (Italy) built for FIAT workers in the sixties, has been chosen as a case study. The refurbished district includes a network of pedestrian and cycling paths and public green areas, all lit by the new urban furnishing itself. All household appliances of each apartment are connected to the equipped wall which constitutes the terminal node of the district network.
To sum up, the goal of the project was achieved by both teams. Students have shown a considerable multidisciplinary integration and degree of autonomy in the achievement of project objectives.

project 1A

IN_DESIGN your home
From choice to change

TASKS & SKILLS

Cugno Aurora worked on photovoltaic/solar thermal panels sizing and on the thermal energy recovery system of the Equipped Wall, focusing on the energy and economic analysis.

Fasano Matteo carried out the heating/cooling system sizing, the water recovery system design and the CAD model of the entire Domestic systems.

Garbella Tavernin Fulvio performed the thermal simulation of the hot water storage tank and made the economic analysis of the other domestic systems.

Eugenia Gasparri brought her experience in building technologies for designing the building structures of the modules and their prefabrication.

Alexandru Popescu dealt with the architectural composition of the housing modules and made the CAD model of the case study building.

Lucia Righetto explored the state of the art of interior design in order to study the disposal of household appliances in kitchens and bathrooms.

ABSTRACT

Nowadays the issue of energy saving is strictly connected to the building construction sector, in order to achieve a better quality of life and the goal of environmental sustainability.

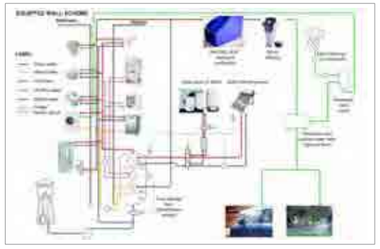
Hence, since users pay increasing attention to architectural integration as well as to energetic sustainability, this project aims to develop the innovative technology for domestic systems, called "Equipped Wall", in the new building construction field.

Development of the Equipped Wall is driven by a number of fundamental topics: flexibility, sustainability and prefabrication. Therefore, the result is a modular system which is flexible towards customerneeds and sustainable due toa decrease in energy consumption and prefabrication, which facilitates a significant reduction in construction times and costs.

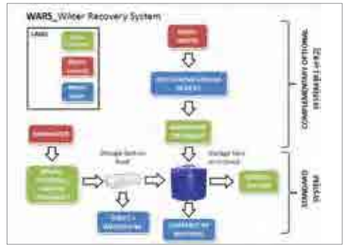
Moreover, an improvement of quality of life is achieved. The user becomes more aware about technologies and the importance of "green" behavior, thanks to a user-friendly interface, as well as the optional strategy we are proposing for the architectural envelope and system choices.

The case study building we propose is a social-housing prototype. However, we believe that our strategy could be applied to different building types, as well as different geographical and social contexts. In order to broaden the target beyond the Italian market, we have compared our project with European lines of research, such as the Dutch context (we were hosted for a workshop at the TU Delft faculty of Industrial Design Engineering).

Summarizing, the global approach to this project and its results have shown an innovative technology for the development of new buildings, focussing on energy consumption and the new dynamics of social life.



1 *Overall scheme of the Equipped Wall and the integrated domestic systems*



2 *Outline of the WARS (Water Recovery System)*

3 *Outline of the TERS (Thermal Energy Recovery System)*

UNDERSTANDING THE PROBLEM

The HASEW project had the objective of elaborating an innovative system of interrelation of all household appliances, through an Equipped Wall integrated in an organic scheme with the living space. Specifically, our Team was focused on the problem from the point of view of ex-novo design, not as part of the prevailing building approach on the market but rather that of the prefabricated housing modules industry.

This possibility was considered not only for its intrinsic innovative character, which has been experimented many times in recent decades, but also because it was perfectly fitted our project purpose: a way of building cheap, "green" buildings with ample possibility of customization, particularly suitable to house our Equipped Wall.

Since the beginning it was clear that, taken for granted environmental sustainability, significant importance had to be given to the other two spheres of the sustainability concept: sociality and economics.

To provide answers to both these essential issues, we imagined a new player able to manage this innovation as a new product on the market: "IN_DESIGN your home". This enterprise would be the fulcrum of a relatively new and small market of housing modules, able to put in contact the various stakeholders active in the field.

The hypothetical applications are many and varied: from single modules with their innumerable end uses to large aggregations for private, social or student housing. Concretely, we analysed the social housing issue in depth, assuming a relation between the enterprise and all public players involved (regional government, City council, Social housing department of the city management).

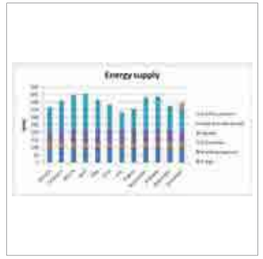
The product sold by "IN_DESIGN your home" is innovative above all in its structure, which starts with the Equipped Wall and goes as far as the urban design of large developments.

EXPLORING THE OPPORTUNITIES

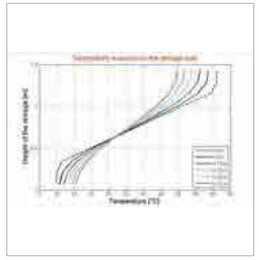
In order to meet user demand, we are proposing an alternative to the traditional strategy , intended as the opportunity to choose the size and arrangement of the living units.

The idea of flexibility, due to the necessity to pursue the above stated objectives, has a crucial role in the field of architectural design and could soon lead to the use of innovative building systems, such as prefabrication and dry technologies. These engineering choices will ensure the respect of building costs and times, transforming the traditional construction site through a complete industrialization of the process.

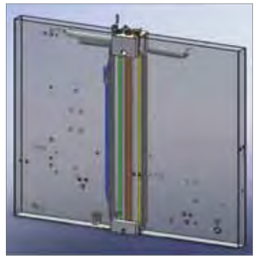
In domestic system design, the challenge has been focused on the satisfaction of user needs (water, electricity and heat supplies) not only following a sustainable approach but also maintaining module flexibility and the possibility to choose the desired solution, according to user preferences.



4 *Analysis of the user energy supply with recovery system and solar thermal panels*



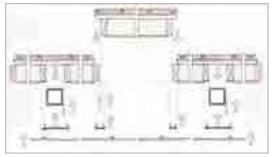
5 *Thermal simulation of the temperature behavior inside the storage tank in case of no energy recovery*



6 *3D model of the main domestic systems inside the Equipped Wall*

7 *Bathroom side of the Equipped Wall*
8 *Kitchen side of the Equipped Wall*

9 *IN_DESIGN Your Home logo*



10 *Assembly scheme of the building envelope*

11 *Flexibility of building modules, according to user needs*

12 *Detail of a vertical building joint*

13 *Plan of the proposed social housing building*

For this reason the first step has been to evaluate solutions for reducing electrical and thermal consumption (e.g. PV and solar thermal panels) and to choose an adequate heating/cooling system within the most innovative yet existing solutions.
Secondly, we have also investigated user requirements in order to focus the analysis on the most keenly perceived issues: particular interest was noticed concerning water waste and heat loss of household appliance drains. This feedback encouraged us to develop a customizable water management system, able to use less water and to recover rainwater, as well as a thermal energy recovery system. In particular, this latter system has been designed considering that water drained from many household appliances still has a significant heat energy content which could still be exploited instead of being wasted.

GENERATING A SOLUTION

The focal point of our project is the design of the Equipped Wall, that is a technology allowing the integration of domestic systems and services in the bathroom and kitchen.
This solution has the following advantages:

- Minimization of water and energy waste and optimization of piping.
- Opportunity to customize the product through various domestic system configurations, according to user needs and different building types.
- Easy-to-install due to the prefabricated features of the Equipped Wall and its plug-in interconnections.

After identifying the main features of the Equipped Wall, domestic systems were sized and their commercial components chosen, in order to estimate the costs and evaluate the payback period.
Two criteria drove the design process: the easy plug-in of household appliances and fixtures to the Equipped Wall systems and the modularity of the Equipped Wall itself, that is its potent to connect to other Wall types. In particular, the most innovative systems designed are the *Thermal Energy Recovery System* (TERS) and the *Water Recovery System* (WARS).
TERS harmonizes the contribution of solar thermal panels and of drain water from household appliances and fixtures for heating the water of a thermal stratified storage tank. We envisaged heat recovery from washing machines, dishwashers, shower drains and fridge/freezers in which the traditional air condensers have been substituted with water versions.
WARS, on the other hand, optimizes the consumption of freshwater, according to three milestones: use of less water, use of different water and rainwater storage. Hence, low water requirement household appliances have been chosen, a low energy rainwater recovery and storage system has been designed and a biological purifier for the treatment and reuse of grey and black water has been introduced.
Subsequently, we tried to imagine the most suitable architectural scheme to better exploit the Equipped Wall potential. The three concepts of flexibility, sustainability and prefabrication drove us towards the final solution.
The first goal is achieved through the study of different intended uses of an "ideal module", which can be composed in a varity of ways to obtain, time after time, different configurations. Moreover, the choice of multilayered panels facilitates easy customization of facades, thanks to the use of four different exterior finishes: wood, fiber cement, metal and solar panels.
The second is pursued by taking care of all those aspects which are linked to energy saving, both in the plant system and in the technological design: according to Italian regulations, the building we propose is certified in energy class A.
As regards the aspects related to prefabrication, on the other hand, the system is conceived via the "ad hoc" design of technological structural and non-structural details which facilitate a significant reduction in execution costs and times and also bring many advantages during the construction site phase, such as minimization of accidents and reduction of work at height.
Finally, we have designed a pilot-building, in which all the main features of our project are present.
In this case study great attention has also been paid to the new forms of living related to social changes: it is a social-housing building whose aim is to draw attention to the issues of sustainability and contemporary life styles.

project 1B

HASEW, AS U

ABSTRACT

"HASEW, AS U" project focuses on the refurbishment of a broad stock of existing, high resource consuming buildings with low quality of life standards from both the environmental and social point of view. Mirafiori Sud, a council house estate in Turin built for FIAT workers in the sixties, has been chosen as a case study. The aim is significant infrastructure development for resource saving and improvement of the quality of life of users.

In Italy, as in Europe, low quality building represents more than half of the existing stock; therefore, an intervention in this field would be strategic for a significant reduction in resource consumption. Moreover, districts such as these often present social problems, population aging and limited integration with the rest of the city, with consequent depreciation of properties.

The refurbished district would include a network of pedestrian and cycling paths and public green areas, al lit by the new urban furnishing itself.

All household appliances of each apartment are connected to the equipped wall which constitutes the terminal node of the district network. The walls collect data from appliances and distribute the resources required. A large amount of resource (water, heat, electricity) requirements are supplied by solar panels and rain water collection. Dedicated equipment takes care of flattening the electricity demand curve, which further reduces the environmental impact of the stock.

The targets of resource consumption reduction and quality of life improvement are achieved by smart use of existing technologies. In this case, technology provides benefits which are invested in social and environmental upgrades, thus creating a virtuous upgrading cycle.

The collected data are processed and used to provide users with feedback on resource consumptions and to suggest actions to be adopted in order to reduce their environmental impact.

The proposed intervention was proven to be economically feasible and can be considered an investment with an acceptable payback period. In addition, it represents a bright opportunity for district renovation in terms of quality of life and the economic value of houses, the energy performance of which would pass from class G to A (33,7 kWh/m^2).

TASKS & SKILLS

Elisa Cucchetto focused on the design of the Equipped Wall and its integration both in the kitchen and in the bathroom, also creating an user-friendly interface.

Francesco Laviola mainly developed the electronic components for controlling and managing the plant and the grid of the buildings in the district.

Sebastiano Maltese worked on the construction issues - refurbishment and energetic upgrade - and the integration of the new plant in existing building.

Mattia Massone sized the plant components, studied the resource flows and assessed the interactions between household appliances and the whole system.

Lorenzo Piacentino focused mainly on the integration of the HASEW grid in the entire district, also providing a social improvement to the district itself.

Giovanni Porcellana in particular developed the energetic consumptions and savings calculations and the economic analysis and feasibility of the project.

1 *Prototype of Mirafiori Area 01*

2 *Prototype of Mirafiori Area 02*

3 *Prototype of building 01*

5 *Render of Mirafiori Area 01*

4 *Prototype of building 02*

UNDERSTANDING THE PROBLEM

At the beginning of the project the main idea was to focus on household appliances and their integration with the entire house, but with specific attention to the former. Since our team had to deal with existing buildings, we decided to concentrate efforts on the house in its entirety, going beyond its classical concept.

For this reason we have chosen as a case study the Mirafiori district in Turin: a council house estate built in the late sixties for FIAT workers. This makes the developed system applicable to many other buildings since this type of houses are built almost identically and with the same – poor – characteristics. We decided, therefore, to aim for significant refurbishment without demolishing the houses, so as to provide clear evidence for the entire district. The main goals identified were sustainability and resource (energy, water) saving.

EXPLORING THE OPPORTUNITIES

Starting from this point, many alternatives arose. First of all the concrete possibility of bulldozing and rebuilding the entire house; however, this radical solution is antithetic to project objective of building preservation. For the same reason, even keeping just the external structure and reorganizing the interior was not feasible as we chose to minimize disruption to inhabitants by keeping the intervention as focused and localized as possible. Thus the opposite alternative arose: a very low profile solution with no explicit evidence of our intervention; but this idea too was rejected since we believe that people – even outside the house – should be aware of the refurbishment within the stock requalification framework.

We then studied the needs and preferences of different user classes, with particular focus on the kitchen and bathroom, the main rooms of our intervention. Hence, we started developing ideas on household appliance integration able to maximize resource saving by processing information from the appliances themselves.

Our objective was the development of a building that could produce, collect, store and reuse heat, water and electricity; in brief, the main resources needed in a house. We also considered a larger scale of intervention with resource sharing among the buildings of the entire district. Nevertheless, as physical resource sharing would be unfeasible, from this point of view we had to focus on single buildings. In this single building framework, bearing in mind our objective of less disturbing but evident intervention, we developed the concept of the equipped wall which is described in detail in the next section.

Finally, it is important to underline the fact that, since we had

6 *Render of Mirafiori Area 02*

7 *Render of HASEW kitchen*

8 *User interface within of HASEW kitchen*

9 *Render of HASEW bathroom*

to deal with an existing building (a situation characterized by many constraints), we chose to implement in our project only simple technology elements, without looking for very advanced components. In fact, the innovation of our project consists of the framework, the way this technology has been used for our purposes. Therefore, most of the elements of the wall itself, similarl to those of common household components, consist of simple pipes, valves and pumps, put together in an innovative way to achieve truly high performances.

GENERATING A SOLUTION

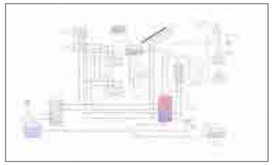
As already explained, since one of the main aims of the project is to keep the intervention simple, the technology involved has to be as simple as possible.

Firstly, we aim to reduce energy consumption as much as possible by optimizing energy use. The reduction of heating energy dispersion is the backbone of the intervention: by external coating and substitution of the windows we are able to pass from 240.3 kWh/m^2 energy consumption, corresponding to class G, to class *A* with 33.7 kWh/m^2.

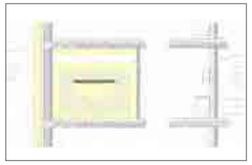
The other key feature of our project is represented by the equipped wall. The great innovation, in this sense, is the fact that all the systems of the house are centralized and situated in the basement, connected to individual apartments through pipes contained in the wall. The latter is placed outside the building and is the main signature of the intervention: it has to be seen from outside and the owners have to be proud of it. The pipes bringing water, electricity, heat and gas are placed inside the wall. The main heat source is district heating (since our case study is in the south of Turin) which feeds the heating/cooling system – based on absorber and Air Handling Units – and the domestic hot water system.

The system has been designed to recover and reuse heat from drain water and to optimize the use of energy, favouring thermal energy to electric energy in the framework of enhancement of the energetic and exergetic efficiency. Moreover, rain water is collected and purified for usage in flushing the WC and in washing machines.

A system of hybrid photovoltaic/thermal panels is installed on the roof providing both heat and electricity. Finally, the system implements a smart grid based on a simple energy storage (a series of battery packs), designed to deal with self-produced energy and to flatten the profile of energy demand. This action could help power suppliers in optimizing the usage of the power plant pool, thus reducing resort to less efficient systems, usually switched on during peak demand.



10 *General scheme of the HASEW plant system*



11 *Equipped wall construction detail – internal and external*

12 *Screenshot of the HASEW Unified User Interface*

The equipped wall is conceived as an eco- and user-friendly network of household appliances in both kitchen and bathroom.

The equipped wall structure is composed of modular elements and is designed as a new volume added to existing walls, in order to minimize the number of destructive interventions due to refurbishment.

The wall has the function of transporting systems inside the apartment in order to feed household appliances and represents the structure on which household appliances as well as kitchen/bathroom elements are hung. Thanks to the flexibility of the system, this solution can be easily adapted to a wide range of houses and customized by users according their specific needs.

The core of the equipped wall is an unified user interface allowing the user to manage all the devices from the same place, also providing information on availability times of resources. This solution aims to make users aware of energy consumption, encouraging them to use appliances when it is most convenient (such as when certain energy is produced as an output of another activity) through a "green point" system.

13 *Team B logo*

Since the whole project is quite expensive, we considered dividing the intervention in two different packages: a basic version, including just external and internal refurbishment and insulation, with payback period of eleven years; the true HASEW choice, complete with the heat and water recovery system, with payback period of fourteen years. The greater economical outlay, however, is compensated by fairly obvious advantages from the sustainability point of view.

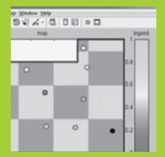
Finally, the project is not only focused on a single house but we proceeded to plan the refurbishment of the entire district: by sharing certain resources (information and electricity in the smart grid) among all buildings already treated with HASEW it is possible to imagine a completely new area of greater quality both in terms of lifestyle and sustainable development: a feasible urban dream!

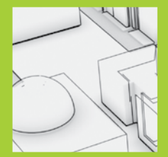
MAIN BIBLIOGRAPHICAL REFERENCES

[1] Kibert C. J., *Sustainable Construction: Green Building Design and Delivery*, John Wiley & Sons, Hoboken, 2005

[2] Tamborrini P., *Design Sostenibile: Oggetti, sistemi e comportamenti*, Electa, Milano, 2009

PROJECT 2





REMEDIA

REinvent MEDIcal Ambient

REINVENT MEDICAL AMBIENT

REMEDIA
REinvent MEDical Ambient

project 2

REMEDIA (REinvent MEDIcal Ambient), developed in cooperation with Scientific Institute S. Raffaele, proposes a new integration of medical practice and technological structural components.

PRINCIPAL ACADEMIC TUTOR

Giuseppina Gini
Electronics and Information, Politecnico di Milano

ACADEMIC TUTORS

Alessandro Carlini
Electronics and Information, Politecnico di Milano

Claudio Germak
Architecture and Design, Politecnico di Torino

Bartolomeo Montrucchio
Control and Computer Engineering, Politecnico di Torino

Lucia Rampino
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

EXTERNAL INSTITUTION

Fondazione San Raffaele del Monte Tabor

EXTERNAL TUTOR

Alberto Sanna
IRIS - Innovation & Research in life and health Services Unit, Fondazione San Raffaele del Monte Tabor

TEAM A

Giovanni Luongo [Team controller]
Management, Economics and Industrial Engineering

Ivan Cenci
Biomedical Engineering

Francesca Maria Claudio
[Project Communication Coordinator]
Management, Economics and Industrial Engineering

Pierluigi Dalla Rosa
Engineering for Cinema and Methods of Communications

Jacopo Spigaroli
Architecture

TEAM B

Giacomo Saibene [Team controller]
Management, Economics and Industrial Engineering

Alessandro Barardi
Mathematical modelling in Engineering

Michael Boris Mandirola
Computer Engineering

Alessandra Lo Moro
Biomedical Engineering

Valerio Turri
Automation Engineering

PROJECT DESCRIPTION

The Challenge

The concept of the hospital has evolved, over time, to become that of an institution central in advancing clinical techniques. Today hospitals are facing new challenges. New technical solutions can support patient care and provide new services for the staff. On the other side those technologies require more space devoted to machinery, and impose new constraints.

Hospitals have to give the best patient care. This focus will drive significant changes in managing physical spaces, staffing strategies, and patient care models. Technology will be the thread that ties those innovations together. Improved clinical documentation and automated admissions will minimize errors and improve efficiency. Patient-monitoring devices will allow doctors to manage patients from afar. Smart beds that automatically transmit patients' biological signals can alert nurses. Robots that glide through halls can assist visitors and transport equipment. Technology should allow hospitals to reach three goals: improve clinical care, reduce error rates, and reduce patient stress.

REMEDIA Project accepted this challenge. Students of both teams have worked to understand the problems with the external tutor from San Raffaele Hospital (HSR). Finally they identified a list of improvable conditions, and worked on solutions:

- to improve the mobility of patients and visitors,
- to improve the daily staff's activity with new tools to manage the ambient conditions.

The teams

Team A addressed the mobility issue and focused on servicing users to navigate and to reach given places and desired services. Their challenge was to improve mobility through better communication, personalized information, and integrated services. A questionnaire helped to understand users' behaviours and necessities. The hospital expressly asks to improve the patient support to optimize the usability of the hospital services. The mobility improvement includes infrastructural solutions to provide easier indications and direction as well as info-screens and mobile systems. In proposing such a solution they focused on the sustainability of the proposal beside acceptance and usability.

Team B decided to apply the latest findings of the automation and robotics technology to a hospital environment. HSR presented its interest in sanitization and cleaning as crucial services both for patients and workers. According to their indications, team B found a way to apply new technological solutions and protocols without main structural modifications in the building. Their research addresses a long-term cleaning task that will exploit robots to ensure almost full, certified coverage, and a short-term robotised task to verify the sanitization condition, and to support the periodic control of the cleanliness. They worked to assess the sustainability of the long-term vision, and developed the main functions of the short-term one.

Two main results have been achieved

Generally speaking, the value of autonomous robots is not clear to the business world. While surgical robotics has gained acceptance, the same is not true with other applications that require whole solutions that go beyond the robot itself. Team B developed such robotised innovative cleaning system.
Team A clearly identified the mobility problems. They also heavily invested in the various hospital applications that their technology is targeted to improve. They successfully developed a hospital solution providing innovative services and applications that address core functions of the hospital.

project 2A

REMOBILA
REInvent
MOBilityAmbient

ABSTRACT

The REMEDIA Project, carried out in collaboration with "IRIS" Scientific Institute San Raffaele, has the objective of designing the "hospital of the future", in which medical care goes hand in hand with livability and socialization. In particular, Team A's Project – REMOBILA, Reinvent MOBILity Ambient – has the objective of improving mobility services within the San Raffaele Hospital (hSR) structure. Indeed, the actual support given to orientation and mobility of patients and visitors presents vast room for improvement in terms of user-orientation and support to disabled people, with particular reference to visually impaired and wheelchair users. In order to define an innovative and integrated mobility support service, capable of providing real and incisive support to users, the Team first analyzed stakeholders' needs and requirements, paying particular attention to users. It then conducted a flow analysis within hSR external paths and looked at best practices, both in the medical environment and in other contexts. In this manner it was possible to design alternative concepts from which, downstream of the evaluation phase, the final solution emerged. As modern smartphones provide a countless variety of communication channels, the engaging challenge and final target of the Project was the definition of an effective solution for people mobility exploiting these technological devices. Firstly, a location-aware WLAN with the task of tracking Wi-Fi devices was depicted and dimensioned. The Team then defined the characteristics of the smartphone application and built a prototype to simulate navigation along a demonstrative route. Many indices, such as smartphone adoption growing at an astonishing rate, promising profitability studies on the solution and massive portability of the mobile device point to the Smartphone Application as a concrete and valuable support for hSR user mobility.

TASKS & SKILLS

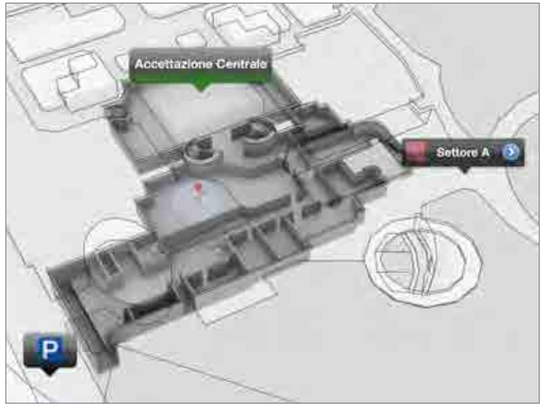
Ivan Cenci worked on the hardware design of the final solution. In order to acquire the needed knowhow he undertook a preliminary research on best practices in hospital mobility support.

Francesca Maria Claudio focused on the valuation of the alternative concepts that led to the choice of the final solution. In addition, she addressed its economic feasibility and developed a profitability valuation tool.

Pierluigi Dalla Rosa designed and developed the software aspects of the final solution. In addition, he defined and structured the services it should offer to users.

Giovanni Luongo developed the requirements analysis in order to identify hospital user needs and defined the functions of the solutions proposed.

Jacopo Spigaroli concentrated on the patients and visitors' flow analysis within hSR and built the maps necessary to allow a real-time navigation through smartphone.



1 *3D map for user navigation; REMOBILA interface*

2 *Different navigation methods provided by the REMOBILA Smartphone application*

UNDERSTANDING THE PROBLEM

The healthcare system is currently facing the challenge of integrating medical care with services capable of improving patient livability. One of the targets of San Raffaele Hospital (hSR) is to address this challenge: many services to improve the effectiveness in care and liveability have been set up, such as a zoo to entertain younger patients, and shops and bars to render the hospital environment more enjoyable. On the contrary, a service that still requires radical improvement is mobility support, since the complexity of the hSR structure (11 departments and 48 special clinics distributed over a surface area of more than 300.000m2), together with the old-fashioned philosophy on which signs are based, turns the simple activity of reaching a specific ward into a real challenge for patients and visitors. The problem is further amplified for visually impaired patients who experience difficulties in reading signs, and for wheelchair users, whose mobility is restricted to particular routes.

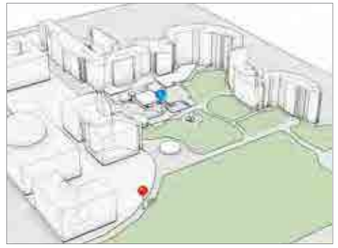
The REMOBILA–REinvent MOBILity Ambient Project aims to improve the mobility support service through the definition of an innovative and integrated system capable of meeting user needs.

Following this user-oriented perspective, great importance was given to the analysis of user needs and requirements. The analysis was conducted through direct interviews with hSR patients and visitors and led to indentification of the following main user requirements:

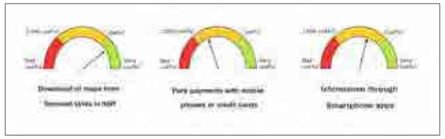
- Improvement of the orientation support system within hSR;
- Enhancement of the parking system, with particular attention to price reduction;
- Reduction of queues, in particular at the Central Desk;
- Improvement of information delivery, with particular attention to the Central Desk.

The interviews were also useful to gather user suggestions for the improvement of the mobility support system. Following a co-creative approach, suggestions were taken into consideration in the design phase. In addition, a flow analysis facilitated prioritization of areas in need of mobility support and to point out issues related to specific routes.

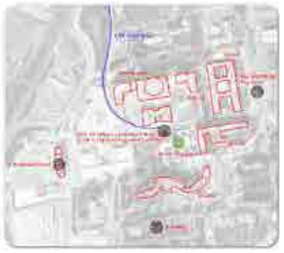
User requirements, user suggestions and flow analysis, together with the requirements of the other main stakeholders – "IRIS" Scientific Institute San Raffaele, San Raffaele Monte Tabor foun-



3 *3D stylized map for user navigation; REMOBILA interface*



4 *User appeal towards possible mobility improvements*



5 *Main access and destination points within hSR*

6 *Flow analysis within hSR. The darker the colour of the stylized path, the higher the flow density. Main issues are listed next to the path they refer to*

7 *Example of multiple choice menu; REMOBILA interface*

8 *REMOBILA: the Smartphone application to support mobility within hSR*

dation , hSR personnel and hSR Customer Care Dept. – constitute the main building blocks that guided the activities carried out within the REMOBILA Project.

EXPLORING THE OPPORTUNITIES

In order to improve the mobility service, the REMOBILA Team conducted research on best practices in the medical environment. Since hSR owns large outdoor areas and most of the techniques and the approaches used in hospitals are related to internal mobility, an additional research activity was performed in order to analyze best practices in mobility support outside the medical environment.

A significant contribution to the analysis was provided by the exhibition "Hospital Build Asia 2011" (Singapore) and the visit to Singapore General Hospital. The exhibition showed the most technologically advanced solutions regarding mobility tracking and tracing for hospitals, whereas the visit was useful to understand how these innovative solutions could be operationally applied to improve user liveability.

After careful analysis of the state of the art of mobility issues, two possible mobility support solutions were developed. The first consists of the introduction of Terminal Units, based on an icon interface, inside the hSR village. A specific software application can support people mobility through functions such as route calculation or map printing. The second solution comprises the use of the Smartphone as a support to people mobility inside the hSR village. A dedicated application, similar to that on the Terminal Units, acts as a real-time navigator guiding the user from the starting point to the final destination.

GENERATING A SOLUTION

Choice of the priority solution. The aptitude of hSR towards disruptive innovation in the hospital experience prompted the Team to follow the most engaging and out-of-the-box solution. Although the interviews revealed that Terminal Units are more appealing to users, especially for the elderly, the Smartphone Application presents greater advantages in terms of resolution of user mobility issues, impact on hSR requirements and sustainability. Therefore, the latter proposal was chosen by the Team as the priority solution.

Detailing the final concept. Designing a system able to transform a smartphone into a sort of "hSR pathfinder" is certainly a challenging task. The standard solutions exploiting GPS signals are not sustainable due to the lack of GPS coverage in indoor spaces, therefore wireless triangulation was taken into account as the gold standard. Besides solving the issue of smartphone location, the installation of a location-aware WLAN might satisfy many other hospital needs currently emerging, such as asset tracking and patient management. After an extended research on location-aware WLAN providers, the Team decided to take into consideration the solution proposed by Cisco Systems® since it is the market leader in this kind of platform and its products are specifically addressed to professional environments such as enterprises and hospitals. Moreover, the infrastructure was dimensioned in terms of deployment of access points for the most misleading areas of hSR, namely the outdoor space and the underground corridors linking the various wards.

Economic feasibility analysis. Profitability represents a fundamental requirement for "IRIS" Scientific Institute San Raffaele, the external partner of the Project. For this reason the financial impact of the solution was studied associating strategic impacts (e.g. increased mobility service level) and main actions (e.g. purchase and installation of the WLAN infrastructure) with the financial dimensions (i.e. revenues or costs) they have an impact on. Furthermore, the Team designed an evaluation tool addressed to any hospital or company intending to adopt the solution proposed. The program receives the most significant economic parameters as inputs and calculates Net Present Value and Payback Period of the solution.

Demonstration building. The point of arrival of the Project is represented by the development of a software application to be installed on a smartphone simulating navigation along a demonstration route. In this context, the user interface must guarantee clear and rapid access to application functions. As the cognitive perception of the interface depends on the familiarity of users with technology, the Team decided to elaborate a variety of navigation methods tailored to different segments. Nevertheless, each method provides information on directions and time to destination, name of the final destination, ads and extra content such as public transport timetables and symbols referring to places of interest (e.g. toilets). In addition, those concerned can benefit from the online payment service.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Raskin, Jef, *The Humane Interface: New Directions for Designing Interactive Systems*, Addison-Wesley Professional, 2000.

[2] Cisco Systems Inc., *Enterprise Mobility 4.1 Design Guide*, San Josè (CA, USA), 2009.

[3] *Hospital Build Asia 2011 Exibition & Congress*, Marina Bay Sands, Singapore, 9 – 11 May 2011.

project 2B

RECLEA
(REinvent CLEaning Activities)

ABSTRACT

Activities performed by humans have always been affected by innovation, such as the introduction of automated processes. The introduction of a large number of technological innovations in the 19th and 20thcenturies led to the greatest advancements in human welfare in history. Healthcare and hospitals benefited greatly from all these innovations, leading to a far greater awareness of the medical possibilities in treating diseases. The quality of health services, however, is definitely more than just the medical aspects, and the cleaning process plays a significant role among the services that a hospital must deliver. This service, still completely manual, shows some critical areas that could be overcome by introducing a system with a certain level of automation.

Cleaning is a process which requires different tasks: inspecting its effectiveness ex-post is indeed a crucial activity, especially when considering automated systems. Therefore, we differentiated between the cleaning task itself and cleanliness verification. Given the current available technologies, introducing an automated cleaning system is still an uneconomic option; the inefficiency of robots leads to costs which are higher than the benefits. On the other hand, designing and introducing an automated cleanliness verification system is a viable option. Therefore, we argue that the cleanliness verification system can be introduced in the short term, while the cleaning system itself only in the long term. Accordingly, we focused on two core issues: (i) the cleaning task in the long term, which focuses on the organisation and the sizing of a swarm group of robots; (ii) the verification task in the short term, which focuses on the issues related to navigation and measurement of cleanliness.

The cleaning task requires a system composed of simple automated units cooperating together, whose control system represents the critical issue. The cleanliness verification task may be performed by single automated units, one for every area, through the adoption of simple positioning and movement methods and of basic sampling systems.

TASKS & SKILLS

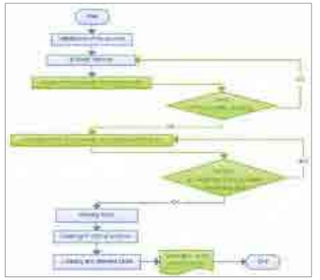
All team members gathered information on the state of the art and contributed to the definition of the proposed solutions. In addition, each of us coordinated a particular ASPect of the project.

Alessandro Barardi and **Alessandra Lo Moro** proposed a mathematical analysis of the sizing problem for the cleaning system from a long-term perspective.

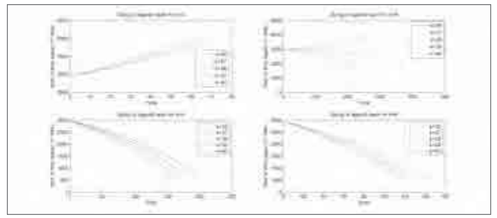
Michael Boris Mandirola and **Valerio Turri** focused on the conception of the cleanliness verification system from a short-term perspective, detailing its main characteristics addressing cleanliness measurement and navigation, respectively.

Giacomo Saibene performed an investment analysis, leading to define different approaches for the long-term and the short-term solutions.

1 *Standard MOP cleaning system: completely manual*



2 *Diagram of a cleaning process [3]*



3 *Evolution of the size of the dirty region in function of the number of cleaning agents: k=number of agents=[36, 37, 38, 40]; d=contamination spread step=[3, 4, 5, 6]*

UNDERSTANDING THE PROBLEM

The hospital is a complex institution. There are many problems and critical issues which are not exclusively related to medical aspects, such as handling of objects (e.g. medication and meals), movement of patients, transmission of data and the cleaning process. Among these, in accordance with the needs of our main stakeholders, we chose to innovate the cleaning process by studying the introduction of an automated system for floor cleaning with a multidisciplinary approach.

Every day many people (patients, relatives, doctors and other workers) enter and exit hospitals. Patients under medical treatment, and often with weakened immunity or contagious diseases, could be prone to infections. Hence, cleanliness deserves special attention in hospital environments and any discussion on the subject must address many different dimensions: economic, environmental, social, health and quality of service. Besides, because of the complexity of the problem, there are many different actions that could be taken into account in order to improve the situation from different points of view:

- economic: saving on materials, chemicals and on working time required by humans;
- environmental: optimizing the dosage of chemicals, favouring green solutions and environmental sustainability;
- social: making dangerous and poorly-qualified jobs unnecessary, such as janitor services, in order to promote the creation of highly-qualified jobs;
- health: a cleaner environment translates into a healthier environment;
- quality: improving the cleaning system contributes to quality improvement.

When considering automated systems, we must distinguish between two parts of the cleaning process; the cleaning task itself and the ex-post verification of its effectiveness. Accordingly, implementation of an automated system involves two main fields of action in which significant improvements may be achieved. We consider two phases of the cleaning process:

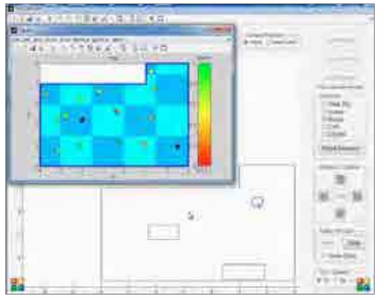
1 cleaning: the task of removing dirt (intended as loose dirt, attached dirt or microbiological dirt) from the floor surface.
2 cleanliness verification: the task of detection, measurement, and localisation of dirt.

EXPLORING THE OPPORTUNITIES

The first step of our work was research of the state of the art. This has been performed in different ways: research on the web,

4 *iRobot ® Create equipped with the positioning system*

5 *Virtual rendering of the cleanliness verification system inside a hospital ward*



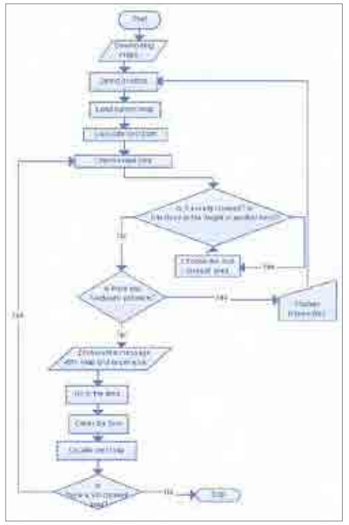
6 *Simulation of the behavior of the navigation algorithm. Mathlab Simulation Toolbox*

live meetings with the "Ufficio Decoro" of HSR and visits to a number of cleaning exhibitions. By attending the latter, we discovered that, currently, there are no automated solutions for hospitals. Our analysis led us to exclude a fully automated system. In fact, artificial intelligence is not yet capable of autonomously managing the whole output of an automated cleanliness verification system. We believe that the human contribution is too important to be completely excluded from the process: there is a large amount of promising research on persistent autonomy, but very few products, if any, which can be safely used in such complex and dynamic environments such as hospitals. Therefore, we are aiming at a semi-automated system, in which the human intervention is still required for exceptional cases.

GENERATING A SOLUTION

Given the technology available in the short-term, the introduction of a semi-automated cleaning system (composed of autonomous units that efficiently clean the floor) is still an uneconomic option; the inefficiency of current robots leads to costs which are higher than the benefits. Indeed, following a number of analyses, we concluded that such a semi-automatic cleaning system does not seem to be efficient, robust and safe enough for daily use in a hospital environment. On the other hand, the design and the introduction of a semi-automated cleanliness verification system is a viable option, since the technological platform for its implementation is, conversely, already available. Therefore, we concluded that introduction of the cleanliness verification system is viable in the short term, while the cleaning system is only viable in the long term. Accordingly, we analysed these two phases of the cleaning process from two complementary perspectives: the short-term and the long-term. Our long-term solution focuses on the organisation and sizing of a swarm group of robots, while our short-term solution focuses on the issues related to cleanliness navigation and measurement.

Long term. From a long-term perspective we examined an optimisation problem inspired by the work of Altshuler *et al.* [1], in which a multi-agent system, (*swarm),* plays a central role. The latter is defined as a decentralised group of multiple autonomous agents which are simple and have limited capabilities. Regardless of the improvement in performance, such systems are usually much more adaptive, scalable and robust than those based on a single, highly capable agent, when properly sized. This problem assumes a grid, part of which is dirty and in which this dirty part is a connected region of the grid. On this dirty grid region several agents move, each having the ability to 'clean' the area ('tile', 'pixel' or 'square') it is located in, while the goal of the agents is to clean all the dirty tiles in the shortest time possible. These agents work in a dynamic environment in which a deterministic contamination spread is simulated every d time steps. A way to decide whether k agents can successfully carry out their cleaning task is to provide a lower bound (figure) valid for each cleaning protocol [2]. Figure 3 shows that a minimal number of agents is necessary in order to carry out their task with a specific initial dirty area and a certain contamination spread step d. Due to the dynamic nature of the problem, we introduce a shape factor which takes into account that the contaminated region can change during the cleaning process. In order to make the model more realistic, it is interesting to replace the deterministic expansion with a stochastic version.



7 *Process diagram representing the cleaning behavior*

Short-term. In this perspective, we outlined a solution for the verification system. We used a more practical approach including detailed positioning and navigation strategies as well as the methods for sampling, measuring and stocking the dirt on the floor. The input of the navigation system is a complete map of the room and the fixed obstacles. The navigation algorithm guarantees that the robot collects dust samples in points randomly and homogeneously spread over the area. At the same time, the positioning system (based on a camera and markers on the ceiling) ensures correctness of sample coordinates. The navigation system is also able to manage certain critical situations such as fixed and mobile obstacles. The system measures the dust level as an indicator of the cleanliness of the floor. The dust is collected on an adhesive tape. A light is directed to a light sensor through the tape. In this way it is possible to measure the level of cleanliness. The tape is then re-wound, avoiding cross-contamination and keeping the measurement geolocalisable and available for further analyses.

In the last part of the project we tested the positioning and navigation systems in the real world for the verification phase: we implemented the positioning system on an iRobot Create (Figure 4) and simulated the behaviour of the navigation algorithm (Figure 6).

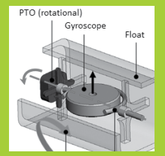
MAIN BIBLIOGRAPHICAL REFERENCES

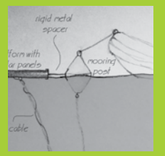
[1] Y. Altshuler, V. Yanovsky, I. A. Wagner and A. M. Bruckstein. *Swarm Intelligence. Searchers, Cleaners and Hunters* (2006)

[2] Y. Altshuler, V. Yanovski, I. A. Wagner, A. M. Bruckstein. *Multi-agent cooperative Cleaning of Expanding Domains. The International Journal of Robotics Research* (2010)

[3] ISPESL. *I profili di rischio nei comparti produttivi dell'artigianato, delle piccole e medie industrie e pubblici esercizi - Comparto: imprese di pulizia*. Ricerca: B28.7 (2004)

PROJECT 3





TETI

INTEGRATED TECHNOLOGIES FOR SUSTAINABLE MANAGEMENT OF UNDERWATER CULTURAL HERITAGE

TETI
Integrated technologies for sustainable management of underwater cultural heritage

project 3

TETI is an attempt
to save the memory of our past,
bring it to the present
and take it into the future

PRINCIPAL ACADEMIC TUTOR

Emma Angelini
Materials Science and Chemical Engineering, Politecnico di Torino

ACADEMIC TUTORS

Simone Corbellini
Electronics, Politecnico di Torino

Loredana Cristaldi
Electrical Engineering, Politecnico di Milano

Marco Faifer
Electrical Engineering, Politecnico di Milano

Alessandro Ferrero
Electrical Engineering, Politecnico di Milano

Sabrina Grassini
Materials Science and Chemical Engineering, Politecnico di Torino

Marco Parvis
Electronics, Politecnico di Torino

EXTERNAL INSTITUTIONS

Soprintendenza del Mare per la Regione Sicilia

UNESCO

EXTERNAL TUTOR

Sebastiano Tusa
Soprintendenza del Mare per la Regione Sicilia

TEAM A

Davide Agostoni [Team controller]
Materials Engineering

Roberta Finotti
Architecture for restoration and preservation of architectural and environmental heritage

Matteo Ravasi
Telecommunications Engineering

Elena Redaelli
Architecture

Syeda Fatima Rizvi
Electronic Engineering

TEAM B

Cléry Bionaz [Team controller]
Architecture for restoration and preservation of architectural and environmental heritage

Alessandro Sala
[Project Communication Coordinator]
Environmental and Land Planning Engineering

Nosherwan Shoaib
Electronic Engineering

Mattia Speziali
Telecommunications Engineering

PROJECT DESCRIPTION

The challenge
Four out of five parts of the world are underwater and sea also acts as a jealous custodian of the traces of human evolution.
Today, technology can have unfortunate consequences on this well-established equilibrium, allowing people to destroy in few years what has been sleeping in the deep for centuries.
We must save our past, we must preserve the underwater traces of our history; we must also allow people to get to know, enjoy and look at them.
TETI is our small contribution to this challenge through a sustainable management of underwater cultural heritage.
Underwater archaeological sites are very difficult to be preserved and are very sensitive to intrusion and maritime activities, the effects of which are always underestimated.
Recognizing the urgent need to preserve and protect such heritage, UNESCO elaborated in 2001 the *Convention on the Protection of the Underwater Cultural Heritage*, which sets out basic principles and practice for fruition and conservation of underwater cultural heritage. The *in situ* preservation of underwater cultural heritage should be considered "the first option before allowing or engaging in any activities directed at this heritage".

The teams
Fruition and conservation of underwater archaeological sites require a multidisciplinary approach devoted both to the development of specific protection procedures for the artefacts and to the design of integrated systems for monitoring, safeguard and musealisation of these areas.
TETI addresses all these aspects bringing together different kinds of expertise in electronics and telecommunications, material science, environmental engineering, architecture and restoration.
Underwater sites contain wood, ceramic and metallic artefacts of various dimensions and usually dispersed in large areas. Managing these sites requires artefact conservation issues to be addressed, allowing conscious direct fruition through the development of scuba

diving tracking strategies, artefact lighting and underwater visiting routes, protecting the site from illegal access through a surveillance system to detect intrusion and encouraging the indirect fruition through proper musealisation.
Two teams addressed the wide range of problems: team A focused on both direct and indirect site fruition, working on the tracking system, lighting, conservation of tools and musealisation; team B focused on the protection of artefacts and on site surveillance, finding sustainable solutions for the supply of power to all the technologies to be employed.

The results
A still unmanaged site off the coast of Filicudi Island was chosen as a case study for application of the developed solutions.
An integrated system has been studied, which allows both location of authorised scuba divers as well as detection of unauthorised access to specific sensitive areas. An innovative lighting system has been designed: it marks the fruition routes and indicates the most important remains. Tailored conservation procedures have been developed to preserve both the artefacts and the technical instrumentation from natural degradation. A low-impact solar and wave energy system has been studied to power all the electrical devices, thus not requiring any power supply from the mainland. Two plastic models of the site have been designed and created, both for indirect fruition and to show the relation between the developed system and the actual environment.

project 3A

Enjoying the present
Fruition of an underwater archaeological site

TASKS & SKILLS

Davide Agostoni took care of the conservation of tools, trying to find lasting solutions to fight corrosion of metallic components and to avoid the bio-fouling phenomenon.

Roberta Finotti worked on the musealisation of the archaeological site, studying the position of the artefacts in order to define routes for scuba divers and focusing on the lighting system.

Matteo Ravasi developed a system consisting of hydrophones and transducers to track the scuba divers' movements and to guarantee their safety during the underwater tour.

Elena Redaelli worked on the musealisation of the archaeological site, defining the underwater routes for scuba divers and creating the plastic models of the site.

Syeda Fatima Rizvi designed the underwater lighting system based on LED sources and optical fibres in order to provide a visible route for scuba divers.

ABSTRACT

In 2001 UNESCO drew up the *Convention on the Protection of the Underwater Cultural Heritage*, focusing on the issue of the fruition of sites, stating that "public access to in situ underwater cultural heritage shall be promoted, except where such access is incompatible with protection and management". The public fruition of underwater archaeological sites represents an integral part of the education and training process targeted by UNESCO: therefore, the goal of the project is the design of a fruition system in which the underwater site is available to all, not only as a mere tourist destination but also as a "learning site".

In the context of Filicudi (Aeolian Islands), direct fruition is achieved through an integrated system: two underwater routes are defined and various devices allow scuba divers to follow them. Two arrays of hydrophones track the visitors' movements and guarantee their safety, while optical fibres mark the routes creating a fascinating effect. All the tools employed are protected against degradation due to the marine environment. To encourage indirect fruition, besides the standard info-pack available in the local museum, two plastic models have been prepared showing the archaeological site.

This system definitely needs further testing and has growth and improvement potential; nevertheless, even if designed on Filicudi, it could represent a model to be applied in many other underwater archaeological sites.

1 *Fields of intervention*

2 *Plastic model showing the archaeological site and its context*

3 *Scheme of the underwater fruition system*

4 *Two arrays of hydrophones along the perimeter of the route*

UNDERSTANDING THE PROBLEM

Today, access to underwater sites is made possible in the majority of cases thanks to tourist initiatives promoted by local scuba diving centres. However, the UNESCO Convention mentions "public awareness" and "public access": this means that everyone should be able to approach ancient cultures, even without a specific license. Combining the idea of creating an underwater museum for scuba divers and the necessity of achieving universal fruition of archaeological sites represents an exciting and interesting challenge which is, in this case, the drive behind innovation.

How should the difficulties this "double fruition" implies be addressed? How should artefacts and the route be signposted in an effective manner? How should the scuba divers be guided during their visit using an innovative solution? How should other people be allowed to enjoy the beauties of the site? How should the technical tools employed to gather all these requirements be employed in the marine environment?

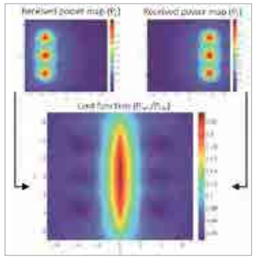
Analysing the case study of *Filicudi* (Aeolian Islands), the project attempts to provide a solution to all these issues, adopting a multidisciplinary approach based on collaboration and interaction among the various skills.

EXPLORING THE OPPORTUNITIES

The approach traditionally used to encourage fruition consists of removing the artefacts from their original environment and collecting them into a traditional museum: everyone is thus allowed to enjoy the ancient cultural heritage without any restriction. But in this manner, only the principle of *public fruition* is pursued, while the other principle stated by the Convention – *in situ conservation* – is neglected. This is the case, for example, of the Aeolian Museum in Lipari. A further step towards compliance with the UNESCO guidelines is represented by the imaginative project of Alexandria of Egypt, where adherence to the two principles clashes with respect for the marine environment: here, artefacts are conserved in their original location, but they can only be viewed from an underwater building which is obviously invasive.

Among all the solutions that attempt to combine the UNESCO requirements with respect for the site is the pioneering project developed by the Soprintendenza del Mare della Regione Siciliana in Pantelleria: the proposed system can be defined as "dual" since, on the one hand , it provides direct access to the site, thanks to the installation of a number of information tags, and to a floating rope showing the route and, on the other, guarantees

5 *Test of efficiency of the detection system in a swimming pool*



6 *Computation of the power received from the hydrophone arrays and of the cost function employed to identify where and where not scuba divers are allowed to be*

7 *Bio-fouling and corrosion effect on a camera employed in an underwater archaeological site (image by courtesy of Westend s.r.l., http://www.westendpro.com)*

8 *Cleaning of the external surface of a dome camera with a common sponge (image by courtesy of Westend s.r.l., http://www.westendpro.com)*

indirect fruition by the use of cameras. This solution presents a number of reservations concerning effectiveness of the musealisation system and maintenance of the tools underwater. Therefore, different systems can be considered in order to track the scuba divers' movements and guarantee their safety during the underwater tour. Firstly, a well-known technique implies the use of a sonar system; but this solution must be discarded, especially due to the high costs and intensive use of ultrasonic waves that could be dangerous for the marine environment. Therefore, the definitive step is the development of an innovative system using a limited number of low amplitude ultrasonic pulses.

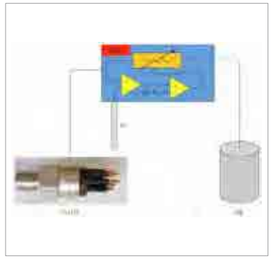
Moreover, also the durability of the entire system in seawater should be taken into account: bio-chemical agents can affect the tools and hide the text on information tags. UV-lamps and protective films on the surface can be used to cope with the problem of bio-fouling which, however, cannot be totally avoided but at least controlled. At the same time, various solutions have been discussed concerning the problem of corrosion of metallic components caused by the saline environment: more resistant materials, different geometries or a cathodic protection system.

A further step towards direct fruition concerns the lighting system: as regards the illumination of artefacts, the hypothesis of using LED sources is taken into account; but the results of specific analyses demonstrate that a system consisting of floating tags of reflective material is better than the idea of using LED sources. In fact, a LED-based lighting system would be more expensive and have a high environmental impact, also due to the necessity of laying a large number of electrical cables in the area.

GENERATING A SOLUTION

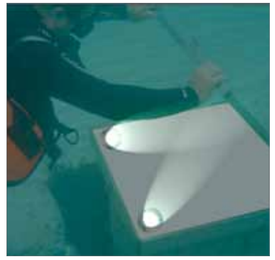
Collaboration among the various skills in the team is crucial in the development of the entire fruition system: all these interact to create musealisation in the various aspects involved, generating a true multidisciplinary solution.

The use of two arrays of hydrophones is at the core of the solution proposed to track the scuba divers' movements and to guarantee their safety: along the perimeter of the archaeological site, an unambiguous signal is periodically recorded at a given frequency from a transmitter provided to scuba divers. The received information is processed to understand if the scuba diver is inside or outside the route. This technique is called *antenna diversity*: comparing the two different signals and discriminating the most powerful, the position of scuba divers can be identified. When a scuba diver deviates from the route, an audio alarm message is sent. An integrated lighting system, created using dispersive polymeric optical fibres, is also employed to



9 *Cathodic protection system scheme with active resistance control*

10 *Visual effect ofoptical fibres positioned along the route*



11 *The "info box", with the descriptive panel equipped with a lighting system*

12 *Creation of the plastic models*

mark the route: this solution represents a further guarantee of security and confers an added aesthetic value, thanks to its fascinating soft neon-like effect.

The installation of a number of "info point" boxes, illuminated by a LED source, allows visitors to obtain the most important information concerning the site in summary form. Moreover, a number of reflective tags have the function of indicating the most significant artefacts.

All technologies used to satisfy the above-mentioned aims require a specific protection and maintenance system. Cathodic protection seems to be the most suitable solution against corrosion: an "active resistance" system decreases consumption of the sacrificial anode, maintaining metallic components in a safe state and preserving them from degradation. As far as the bio-fouling problem is concerned, the solution of depositing an anti bio-fouling film on boxes has the very important advantage of not requiring electricity.

Indirect fruition of the site is supported by the current Filicudi museum where visitors have the opportunity to find info-packs concerning the entire site – including images and videos – and a number of recovered artefacts displayed in cases. Here, two plastic models show the preserved marine area in front of Capo Graziano and the underwater museum; these tools have two different objectives: to show the site to scuba divers before immersion and to place the archaeological remains in the specific section of the museum in context.

Cooperation between the two teams is fundamental to the development of this solution which paves the way for non-underwater fruition of the site: implementation of a prototype for both plastic models represents the final step of the entire work.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Liu L., Zhou S., Cui H., *Prospects and problems of wireless communication for underwater sensor networks*, Wiley WCMC Special Issue on Underwater sensor networks, 2008.

[2] Pedeferri P., Bolzoni F., Ormellese M., Lazzari L., Pedeferri M.P., *Corrosione e protezione dei materiali metallici*, Polipress, Milano 2007.

[3] Spigo U., Martinelli M.C., *Dieci anni al Museo Eoliano (1987-1996). Ricerche e studi*, "Quaderni del Museo Archeologico Regionale Eoliano", vol. 1, Messina 1996.

[4] UNESCO, *Convention on the protection of the underwater cultural heritage*, Paris 2001.

project 3B

Saving the past
Conservation of an underwater archaeological site

TASKS & SKILLS

Cléry Bionaz worked on conservation of ancient artefacts, focusing on preservation of iron and bronze objects, through specific treatment and corrosion protection methods.

Alessandro Sala identified and studied the renewable energy sources available on site and, using a GIS-based software, performed site characterizations for the creation of virtual and plastic models.

Mattia Speziali developed a surveillance system for intrusion detection based on signal processing of the bubble noise generated by scuba divers.

Nosherwan Shoaib designed and dimensioned solar panels and wave energy converters for power supply, respecting the estimated requirements and minimizing maintenance costs and environmental impact.

ABSTRACT

The *Convention for the Protection of the Underwater Cultural Heritage* developed by UNESCO in 2001 states that artefacts are fully linked with the place of discovery since, through the same, it is possible to reconstruct ancient trades, locate harbours, understand the main objects exchanged and the places where they were produced. For these reasons, the Convention states that "the preservation *in situ* of underwater cultural heritage shall be considered as the first option", therefore finds and wrecks must be protected in their environment, avoiding shocks caused by climate change, transport and breakdown into multiple parts to facilitate transport but with the risk of wrong re-composition.

The *in situ* conservation, applied here in Filicudi (Aeolian Islands), entails a multitude of problems. Techniques for conservation of iron and bronze are based on active cathodic protection and corrosion inhibitors. Hydrophones and ultrasonic transmitters ensure surveillance by processing the bubble noise signal emitted by scuba divers.

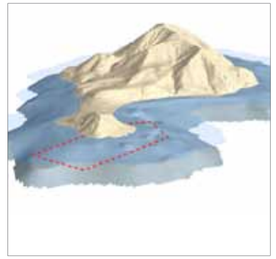
Systems to produce energy in an environmentally friendly manner are developed to ensure the power supply required by the above-mentioned devices: solar panels and wave energy converters are able to exploit the energy sources available on site.

The aim is to address these aspects from different points of view, in order to develop innovative, multitasking and feasible solutions that could also be applied in other contexts.

1 *Fields of intervention*

2 *Underwater positioning of technological instruments for artefact conservation (image by courtesy of Westend s.r.l., http://www.westendpro.com)*

3 *Testing the scuba detection algorithm (hydrophones are placed at the bottom)*



4 *Virtual model used for site characterisation*

UNDERSTANDING THE PROBLEM

The preservation of underwater archaeological sites is defined by the UNESCO Convention of 2001, which considers *in situ* conservation the best way of preserving memory and enhancing the cultural value of the site.

But what does *conservation* mean exactly? Which are the main aspects involved? And how should they be dealt with? A multidisciplinary approach appears to be the key to achieve an integrated solution able to address all these tasks.

The double meaning of the term *conservation* implies protection of the underwater cultural heritage not only from environmental agents but also from despicable anthropic actions. According to the UNESCO Convention, innovative techniques to be employed *in situ* have been developed.

As ceramics and wooden wrecks are commonly considered as durable in saline environments, a very interesting challenge concerns the conservation of metallic objects which are seriously damaged by seawater.

Since in the past many archaeological artefacts have been stolen from several underwater sites, a further challenge is the design of a detection system, in order to control access to the archaeological site. This system should be sustainable in terms of impact, costs and power requirements and must be completely automated in order to reduce the need for constant maintenance.

Analysis and design of an efficient, environmentally friendly, feasible and sustainable power supply technology is thus necessary to support the above-mentioned system. The Filicudi site (Aeolian Islands) will serve as a case study to develop technologies based on eco-friendly criteria.

EXPLORING THE OPPORTUNITIES

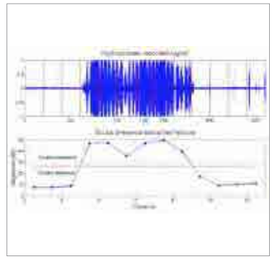
Before the UNESCO Convention, the most common practice for solving conservation problems was to recover and transport the artefacts on land to restore and exhibit them in a protected environment.

This approach has the advantage of preserving the finds from thefts and damages that intruders or even scuba divers may cause.

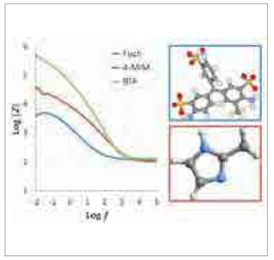
Today, this choice is no longer acceptable: the safeguard of archaeological sites requires suitable and innovative solutions in order to preserve the heritage of ancient cultures in the original context. This is a significant change of perspective, even if it entails technological limits, which requires significant research efforts.

To develop innovative methods for the *in situ* conservation of metallic finds, the focus was placed on iron and bronze, as these

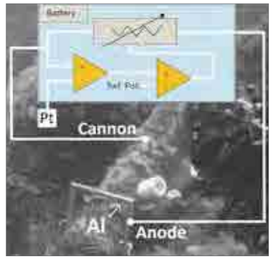
5 *Experimental setup for test of the intrusion detection algorithm*



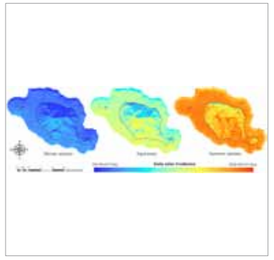
6 *Bubble noise signal processing algorithm*



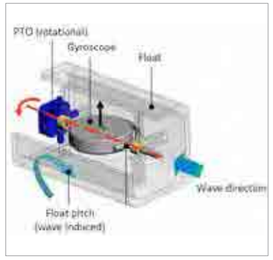
7 *Protective effectiveness of green inhibitors: EIS Bode plots of bronze in inhibition solution*



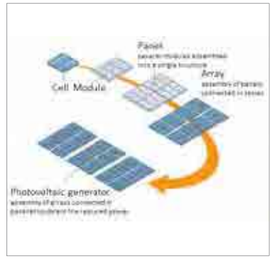
8 *Enhanced sacrificial anode protection on an iron cannon*



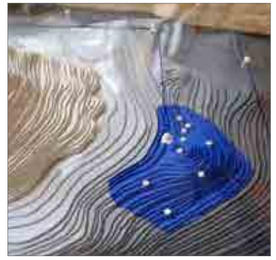
9 *Daily solar irradiance received by the Filicudi area*



10 *Inertial sea wave energy converter (ISWEC)*



11 *Solar panel design hierarchy*



12 *Plastic model showing the archaeological site and the buoy on which solar panels and ISWECs are installed*

were the most common materials employed during ancient times. Regarding this topic, certain tailored procedures for *in situ* conservation have been investigated, such as green inhibitors and cathodic protection methods.
At the same time, two alternatives have also been taken into consideration for the detection and surveillance system. The first is based on RFID (Radio Frequency Identification), consisting of the installation of small RFID tags in the artefacts and a nearby transponder, able to detect theft of the artefacts themselves. The second solution, rather than focusing on the removal of artefacts, aims at detection of intruders using a technology based on the bubble noise emitted by scuba divers.
Both the analysed solutions must be supported by an adequate power supply system able to ensure the correct functioning of the installed devices. The first step is the identification of the renewable energy sources directly available in Filicudi. Among these, all those requiring invasive storage and/or generation plants have been rejected. Considering the location of the site and the climatic and environmental features of the area, the main focus has been placed on solar and marine motion (waves, tides and currents) energy.

GENERATING A SOLUTION

The proposed solution attempts to respond to all UNESCO Convention requirements concerning the issue of conservation and surveillance of underwater archaeological sites. Another prerogative is to plan environmental compatible and non-invasive interventions for the preservation of the whole area.
TETI integrated technologies have been conceived for Filicudi, even if they aspire to be a model which can be applied in other contexts.
For *in situ* conservation of iron artefacts, the most feasible solution is passive cathodic protection using aluminium or magnesium sacrificial anodes. In fact, even if corrosion inhibitors can provide good protective effectiveness on bronze alloys, as confirmed by electrochemical impedance measurements (EIS), their application underwater is very difficult. On the contrary, cathodic protection employing different sacrificial anodes can be successfully proposed for long-term preservation of iron artefacts.
As far as the security and surveillance system is concerned, the hypothesis of an RFID-based system was discarded due to its is extremely small range of utilization and unsuitability for this application. Therefore, the solution developed comprises an ultrasonic transmitter worn by authorized scuba divers and an array of hydrophones delimiting the site. Hydrophones are sensitive to the peculiar frequency emitted by the transmitter and to the bubble noise generated by scuba divers. Through digital signal processing applied to the bubble noise, it is possible to detect the visitor's presence; should the hydrophones pick up only the bubble and not the ultrasonic tone, this means that the visitor is not authorized and the alarm can be transmitted.
In order to present a complete setup, the system has been dimensioned according to the features of the area involved. This analysis also includes a power requirement estimate for the entire system: the proposed solution includes use of renewable energy sources such as solar energy during daylight and wave energy during the night. The designed solar power system is composed of a photovoltaic module, an inverter and a battery able to store sufficient energy, while the wave energy converter transforms the wave-induced motion of a buoy into electrical power by means of gyroscopic effects. One of the main advantages of this system is that externally it is composed only of a floating body without moving parts working in sea water, thus achieving improved reliability and lower maintenance costs.
Moreover, all the work was carried out in close collaboration with Team A: the intrusion detection system is completely integrated with the solution developed by the other team for fruition and scuba diver localization. Cooperation between the two teams speeded up the development of a complex system, which is demonstrated by a plastic model of the entire site including all the tools employed.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Bracco G., *A gyroscopic wave energy converter*, Doctorate degree thesis, Politecnico Di Torino, 2010.
[2] Marabelli M., *Conservazione e restauro dei metalli d'arte*, Accademia Nazionale dei Lincei, Roma 1995.
[3] Petriaggi R., Davidde B., *Archeologia sott'acqua: teoria e pratica*, Fabrizio Serra Editore, Pisa 2007.
[4] Stolkin R., Radhakrishnan S., Sutin A., Rountree R., *Passive acoustic detection of modulated underwater sounds from biological and anthropogenic sources*, IEEE OCEANS 2007.
[5] UNESCO, *Convention on the protection of the underwater cultural heritage*, Paris 2001.

PROJECT 4

CitySpaces

A VIRTUAL/REAL PLATFORM FOR EXPLORING, LEARNING ABOUT AND INTERACTING WITH THE LAYERED HISTORIES OF CITY SPACES

project 4

CitySpaces

A virtual/real platform for exploring, learning about and interacting with the layered histories of city spaces

CitySpaces, developed in cooperation with Stanford Humanities Lab, explores the navigation of cities in 4D (3D + time) for cultural heritage applications and exhibition scenarios.

PRINCIPAL ACADEMIC TUTOR

Piero Fraternali
Electronics and Information,
Politecnico di Milano

ACADEMIC TUTOR

Maria Brovelli
Environmental, Hydraulic, Infrastructures and Surveying Engineering, Politecnico di Milano

EXTERNAL INSTITUTIONS

Radio Televisione Italiana

CEFRIEL

Stanford University

University of California Los Angeles

Carlo Gavazzi Space

EXTERNAL TUTOR

Silvia Negri
Radio Televisione Italiana

TEAM A

Can Umut Ileri [Team controller]
Computer Engineering

Veronica Arianna
Architecture

Francesca Corà
Architecture

Lucia Marengo
Engineering for Cinema
and Methods of Communications

Xiaofei Yan
Telecommunication Engineering

Anita Maria Cinthia Sala
Architecture

TEAM B

Alberto Quattrini Li [Team controller and Project Communication Coordinator]
Computer Engineering

Clara Arango
Architecture

Adriana Cavagna
Architecture

Alessandra Grassi
Engineering for Cinema
and Methods of Communications

Diana Pagliari
Environmental
and Land Planning Engineering

Martha Karina Santos Olano
Urban Planning and Policy Design

PROJECT DESCRIPTION

The Challenge

The CitySpaces project has the objective of conceiving a multi-channel digital media approach for exploring, learning about and interacting with the layered histories of city spaces. A CitySpaces is a virtual-real system for exploring cities overlaid with their rich geo-history, including the diverse histories of people, architecture and the urban environment, as well as the social and cultural history.

Technically, the CitySpaces challenge is that of designing a sophisticated mash-up built on interaction devices, Web Geographical Information Systems, integrated with augmented reality worlds, sitting on top of distributed content repositories and user-generated media streams, organized in space and time. The design takes into account four principal axes: the locations, their geography and history, the available content, either user-generated or pre-existing, the user experience and the technology mix supporting the envisaged experience. The CitySpaces design takes the city of Milan as a showcase, focusing on its rich economic, environmental, architectural, demographic, agricultural and gastronomical history, thus building a concept that can be made available for further exploitation in the context of Expo 2015.

The design teams encompass a range of complementary skills: urban planners and architects provided their capacity of "reading" the city space and history; ICT engineers contributed knowledge of tools and software platforms supporting the design concepts; environmental engineers focused on the problem of managing geo-referenced data, user position and tracking; industrial designers participated in the definition of the user experience; media engineers looked after the story-boarding and video prototyping of the interaction concept.

The teams

Team A focused on designing an augmented reality map. Through the original use of foldable screens equipped with video cameras and positioning sensors, a poly-functional foldable surface is defined which accompanies the visitor in an augmented reality tour of the town, with a special focus on the local and global gastronomic traditions and histories disseminated in the area, thus providing an ICT-mediated channel for living the Expo 2015 global food values. Visitors use the map to design their own path through the social history of food in Milan, as a time lens to see the past of the city, or just lay it on a restaurant table to obtain an information rich, interactive menu telling stories of what they are eating and seeing.

Team B chose instead the serious game paradigm as the main interaction metaphor. Visitors can enroll in missions that lead them to a progressive discovery of the town water districts, in accordance with the "water spirit" of Expo 2015, of the people that live and lived there and of their rich historical background. The user experience is designed to happen mostly outdoors and addresses not only the goal of involving visitors in an engaging cultural experience but also that of promoting physical activity, as part of a sustainable and healthy life style, that well matches the green flavor of Expo 2015. An original mix of wearable 3d vision devices and body sensors provides a practical way to run or walk through the city, while discovering hidden clues and accomplishing objectives which determine the progression of the mission. The human factor is not neglected since the game also incorporates social activities to be performed in the real world and with real "city ambassadors", contributing to making the experience engaging and unforgettable.

project 4A

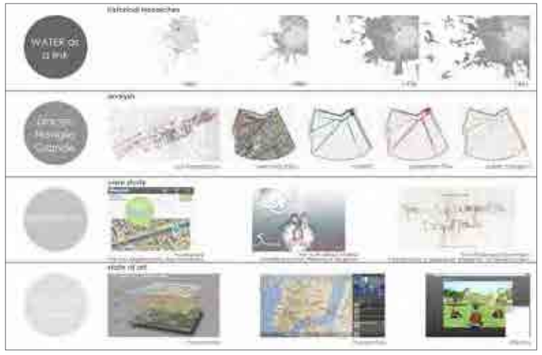
TASTEaway
Designing an interactive digital service to enjoy the city

ABSTRACT

Can a project reinterpret a city via unusual itineraries which reveal its lesser-known parts?
The TASTEaway project aims to respond to this need. It originates from the Expo 2015 event which will be hosted by the city of Milan and according to the theme of the exposition, *"Feeding the planet, Energy for life"*, provides a new map providing the user a new urban experience with an unusual level of interaction with the city.
The users will be visitors to the Expo but also normal tourists in Milan wishing to experience a new tour of the city, a food itinerary. The visitor will receive a digital and interactive map that will guide him through a selected part of Milan, discovering all the aspects of a particular dish, from the ingredients to the history of the meal, from the tools to prepare it to the recipe itself.
Thanks to a FOLED technology (Flexible Organic Light Emitting Diodes) we plan to create a modern map integrating images, videos and 3D models in the urban environment and guide the tourist in an immersive city tour linking places and culture. TASTEaway is an innovative way to discover the history of the city: it uses food culture as a universal context to commit users to the project and to make them discover Milan's hidden histories.
The portable device takes on three different meanings and uses: starting from being a map subdividing Milan into different areas according to the culinary culture, it becomes a window showing all hidden content at each stage of the itinerary. At the end of the itinerary, the device can even turn into a small electronic placemat which recognizes the dish the user is eating. This last function gives the user the possibility to record a short, live audio review of the tasting and share it with other people via the Internet.
In order to show how the guide works, we analysed two particular examples: a Milanese and a Chinese recipe, providing a sample of what the map could become in the real Milanese context.
The TASTEaway project consists of a number of selected itineraries relating to food culture, organized to provide an atypical way of visiting the city. The sequential and well-structured stories add a multicultural value to interpreting Milan, discovering other ethnic cultures within the city.

TASKS & SKILLS

Veronica Arianna analysed the urban environment of Milan. She studied several solutions and developed the project concept, organizing interviews to provide more input to project research.
Francesca Corà developed the concept, selecting the areas of Milan and working on the organization of the various steps. She contributed to the overall graphic presentation of the project.
Can Umut Ileri dealt with exploration of the current state of the art and possible enhancements of technologies related with the project. He was also involved in determining user requirements by analysing survey results.
Lucia Marengo developed the concept and acted as a link between the technology and content sub groups. She developed the user experience and user interaction structure.
Anita Maria Cinthia Sala carried out preliminary research on the different areas of Milan. She developed the itinerary through selection of information.
Xiaofei Yan developed the technical implementations in a heuristic manner by introducing the current state of art and describing the possible technical solutions for the project.



1 *First studies on Milan, the selected area, and some correlated technology*

2 *First ideas and possible solutions*

UNDERSTANDING THE PROBLEM

The CitySpaces project takes Milan as a showcase, focusing on its rich cultural, demographic, agricultural and gastronomic history, thus developing a concept linked to the context of Expo 2015. The exposition theme will show the frontiers of science and technology and will be an opportunity for promotion and communication in the food business.
The importance of the theme on such a global stage became the starting point of our project, an opportunity to create a new network in Milan based on the culture of food. "Food" has been regarded not just as a primary need but also as a way to socialize and improve cultural awareness.
Because of the international nature of the event, another issue we considered and included in our project was the multicultural aspect of food and its repercussions on the Milanese area. The concept should concern not just Italian food culture (in particular that of Lombardy and Milan) but also the main foreign immigrant communities living in the city today.
Expo 2015 represents a great communication and promotion venue for primary producing communities: farmers, food firms, the logistics and distribution chain, the restaurant and catering industry, research centers and any company seeking visibility. The perspective we were most interested in was that attempting to involve visitors and tourists not just in the Expo itself (an area close to Rho Fiera Milano) but also in the city centre. Our project adds value to the Expo, taking it from the exhibition area and bringing it into the city itself. In this way, the entire Milanese context can be involved in the exposition during its entire period (6 months).
Moreover, the visitor could socialize with the locals and take away a recollection of the experience, improving his personal knowledge of Milan and the global food culture.
Another important aspect that modern trends and the EXPO itself highlight is the need for awareness of consumers concerning the environmental impact of products; something which is still missing in everyday life and which we could provide with our project.
Since the beginning we considered the technological dimension as support to convey our concepts, but also as an ingredient that would have change the results. Technical issues have deep influence on users and their experience.

3 *A possible visitor using the TASTEaway tool as a map along the Naviglio Grande*

4 *Visualization of the first function of the tool: the map*

5 *Possible visitors using the TASTEaway tool as a window on the Naviglio Grande*

6 *Visualization of the second function of the tool: the window*

7 *A possible visitor using the TASTEaway tool as a table cloth in a restaurant*

8 *Visualization of the third function of the tool: the table cloth*

9 *Possible design of the bag for the TASTEaway tool*

EXPLORING THE OPPORTUNITIES

The existing city books are static and unstructured; it's hard to find a guide that can convey the tourist the food theme with a multi-dimensional concept. We wanted to create a new kind of digital framework able to collect food information and connect it with the geographical areas of Milan, reflecting its cultural differences.
The peculiarities of Italian cuisine, which has been handed down orally in the family and is deeply connected with Italian culture, was another reason that drove us toward the concept of 'personal cookbook'; a written record, easy to disseminate. What was interesting for us was not just the final product itself but also the process behind the dish; the history of the ingredients, the preparation of the dish, the differences between the various recipes, the tools needed for its preparation, interesting curiosities concerning the dish and its relationship with the city and its history. This provides the food theme a cultural value that goes beyond dishes and recipes.
Once again, this opportunity had to involve all the different communities living in Milan: diverse stories for diverse dishes for diverse cultures. And the different stories might overlap each other, touching several historic periods and coming together in a contemporary context.

From a technological perspective, we searched for a way to convey content in an immediate and participative manner, we focused on creating something with a real connection to the physical space of the city, integrated in, but not disturbing, the urban landscape.

GENERATING A SOLUTION

All the previous assumptions brought us to the design of a particular map concept: a thin screen that can guide the user in the city showing windows on the hidden history and the culinary traditions. Thanks to this application, an itinerary is proposed to the tourist who walks around in a defined area of Milan, learning from the stories he sees on the tablet. In this way, the visit to Milan becomes a treasure hunt: passing from the history of the ingredients, the user can see the preparation of a recipe while tasting it in a restaurant.
The map of Milan is divided into thematic areas, each of which is associated with a host country of the Expo proposing a particular recipe. The selection of itineraries and also of recipes varies periodically, involving various areas of the city.
The different routes are all structured in steps. The first is the history of the ingredients, how they are cultivated, where they come from. This is followed by the curiosity chapter with historic or even amusing tales concerning the traditional meal. The third step collects all the extra information ranging from table accessories to the choice of wine. Here, the user also has the opportunity to acquire information on events, meetings or occasions related to the topic. The fourth step is dedicated to the preparation of the dish; the traditional and reinterpreted recipe can be consulted, if the user is interested and he can also provide a review of the dish after tasting it.
Thanks to FOLED (Flexible Organic Light Emitting Diodes) technology, it is possible to create portable devices which are thin and flexible. This tool, during the itinerary, can take on diverse appearances and functions. First of all the user will have a map, a tangible, portable, interactive and multifunctional plan of the city. The map shows the city in two dimensions, providing the itinerary and its various stages, guiding the user in the selected area. During the visit, the map becomes a window showing hidden content. This is possible thanks to augmented reality technology which integrates 3D models in the real environment as if they were physically present. Finally, while tasting the meal in a restaurant and putting the dish on the device, the application scans the code on the bottom of the dish and provides additional content (nutritional values, carbon footprint). After the experience, the user can download and collect memories of his city tour on his smartphone, integrating system data and information with multimedia content recorded during the day. At each stop, the tourist comes into contact with virtual information and, at the same time, with local buildings, such as institutions and commercial or cultural centres, defining his personal idea of the itinerary. The collection improves by repeating the experience with other itineraries. The device could be seen as a sample technology for other towns, also out the scope of expositions.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Multiplicity lab., *Milano: cronache dell'abitare*, Mondadori, Milano, 2007
[2] Schnapp J. with Burdick A., Drucker J., Lunenfeld P. and Presner T., *Digital_Humanities*, Cambridge, MIT Press, 2012
[3] www.oled-display.net

project 4B

MEN.SA.NA
Revealing Martesana

ABSTRACT

Nowadays, tourism is facing changes in its traditional form to become more sustainable; indeed, alternative tourism has seen an evolution during the last decade, thanks to the availability of innovative technologies.

MEN.SA.NA: REVEALING MARTESANA aims to provide a new way of rediscovering and increasing the value of areas, both remotely and physically. It implies improving quality of life and attractiveness of a place, also fostering social interaction, by exploiting innovative technologies.

The case study identified was Naviglio della Martesana, a niche tourism location, but rich in history and architecture, focusing on the Milan Expo 2015 theme of water. The target will be active people with particular interests in culture, sports and environment.

The analysis on the state of the art of user experience of similar projects, performed in a first phase, led to the *gamification* of the experience of visiting the location. The game is accessible from different devices and is composed of several missions to be accomplished on different sub-paths. The player can move both in space and time dimensions. This design hides a more serious purpose, namely discovering and learning about different aspects, or what we call layers, of Martesana, such as the historical, architectonic, cultural and social aspects, among others.

This approach makes tourism more appealing, since a game makes the visit of Naviglio della Martesana more enjoyable and the points mechanism provides real rewards and prizes to successful players. In addition, it promotes social interaction among inhabitants, since certain missions require communication between visitors and local people.

The project is innovative from the experience point of view since the game embeds the time dimension and translates the sport in the game to a real environment. Last but not least, it combines, in an innovative manner, new cutting edge technologies such as stereoscopic and augmented reality and geo-referenced data.

The tangible outcome of this project is a number of scenarios that could be applied in Naviglio della Martesana, thanks to a hypothetical collaboration with certain stakeholders.

TASKS & SKILLS

Clara Arango On-site survey, bibliographic and photographic database, evaluation of natural, architectonical, anthropological and urban elements to guarantee the quality of the content of the project. Research and development on the graphical communication of the project according to the concept intents.

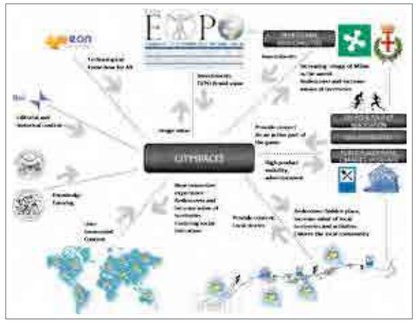
Adriana Cavagna On-site survey to understand the area, identifying significant buildings and places and collecting project content. Research and design of the different types of devices for the game.

Alessandra Grassi Experience case-study analysis. On-site survey and bibliographic research for collecting content and verifying experience feasibility. Development of game contents and experience design. Definition of game devices.

Diana Pagliari Digital maps and geographic content bibliographic research. Technology feasibility study, especially GPS device integration.

Alberto Quattrini Li Coordination of group work and communication with stakeholders. Experience analysis and design. On-site survey for collecting content and verifying experience feasibility. Analysis of technological feasibility.

Martha Karina Santos Olano Bibliographic research of possible locations for the case study with territorial, architectonic and historical significance. Identification of meaningful spots for development of the experience, support in on-site surveys and experience design.



1 *The stakeholder role and benefits*

2 *Naviglio La Martesana: The game location*

3 *Website functions, mission registration, location and information*

UNDERSTANDING THE PROBLEM

The valorization of contemporary areas requires a deep analysis of tourism in order to elaborate innovative methods to combine visitor expectations with the cultural heritage of a location (Levi Sacerdotti, Mauro, Gasca, 2011).

First of all, we focused on the Milan Expo 2015 theme, namely the motto "Feed the planet, energy for life". Specifically, we were requested to focus on the water theme and to develop the project in Naviglio della Martesana. Secondly, another requirement set is that the project should allow a spatio-temporal navigation of the layered histories.

Finally, the project should have a high level of innovation, in terms of technology used, by adopting GIS systems for collecting geo-referenced data to be placed in Navigli maps.

Therefore, the problem consisted of revealing the value of Martesana, which we discovered to be full of interesting architectural and folklore-cultural heritages, as well as an ideal environment for sports activities, since it has a bicycle lane and a number of green areas along the canal where people can walk, run or bike.

Due to the particular nature of Martesana and the concomitant event of Expo 2015, the target on which we focused was the most open-to-technology part of the population, which spans from an age of 20 to 60 years, interested in culture (GFK Eurisko, 2011), but also leading an active and *green* lifestyle.

Combining the location with the target, we obtained as fundamental values sport and culture, which will constitute the foundation of the project content and experience.

There are several stakeholders that are and could be interested in MEN.SA.NA. All their resources and needs have been considered during the solution design. One interesting point to remark is that all stakeholders interviewed along the Martesana canal (e.g. shopkeepers, inhabitants, municipalities) were available to provide us information and hypothetical participation in the project.

EXPLORING THE OPPORTUNITIES

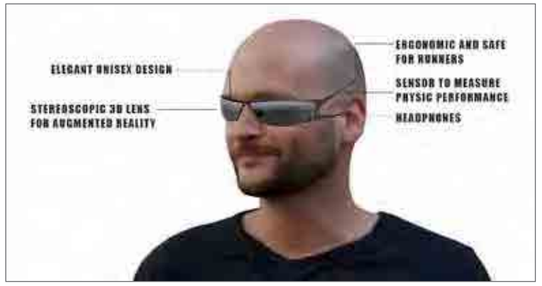
We conducted research on the state of the art concerning experience by studying similar projects. We identified three models, with different levels of immersivity in terms of user experience:

- **3DRewind**: immersive, one-off stereoscopic experience with a limited level of interaction, where content and timing are defined *a priori*.
- **One in 8 Million**: projects of limited duration based on con-

4 *An example of Augmented Reality*

5 *Function of the glasses when practicing sports activities: physical performance monitoring and display of information via the glasses*

6 *Function of the watch when practicing sports activities: physical performance monitoring and voice recognition*



7 *Stereoscopic glasses for Augmented Reality*

8 *Function of the glasses: different information with different head orientation*

tent archives created by administrators and explored or commented by users.
- **GoogleEarth**: projects based on maps. Users can navigate and interactively view and add geo-referenced content.

In addition, we extracted from case-studies several experience paradigms, by which is meant the door through which the user enters our Martesana story: we identified The Game, The Memory Bank, The Urban Exploration and finally we discovered many projects which used The Water as a stage of exhibitions and daily life.

GENERATING A SOLUTION

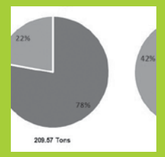
Gamification is truly a trend which will be exploited by 50 percent of organizations by 2015 (Gartner, 2011). Thus, we designed a new form of tourism by combining all models identified and exploiting the game paradigm, together with a points mechanism which stimulates people to play the game. In this way, learning becomes more natural and enjoyable, incentivating people to spend time together.
This is very innovative because, usually, games are designed only for entertainment purposes with no ulterior motive. We believe that the richness of Italian history must be exploited to create a great opportunity to export new ideas in the gaming field.

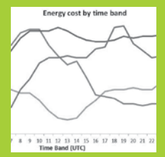
We started considering the remote experience and designed a website from which, for example, the player can join the game community, check the status of his missions and view the map of Naviglio della Martesana with active players displayed.
To design the missions we used a user-centric methodology, considering the physical context and exploiting the content directly and bibliographically collected in the various locations of the Martesana area.
The Game starts with enrolment of the player as a secret agent of the MEN.SA.NA secret agency:
"You are a secret agent of the *MEN.SA.NA* agency. The *Energy for Life* research group has discovered the chemical formula of a powerful source of energy and life which, if properly used, can save the world and the human race. Unfortunately, it has fallen into the wrong hands of *Insane Mind* and this can have serious consequences. Your mission involves recovering the formula, hidden in Milan along the Naviglio della Martesana. You can join other teams or work alone".
The player can then choose from the website which mission he/she wants to solve along the Martesana canal.
Finally, if the mission goal is completed, certain bonus contents are displayed and other missions are unlocked which lead to the end of the game. Above all, the player receives points which can be stored in his/her profile or can be spent immediately for discount in traditional shops.
The innovation in the project is mostly in the user experience part. First of all, we provide navigation in time, necessary for solving enigmas of the game, with augmented reality. Secondly, we added a sport component to the game, shifting the Nintendo Wii paradigm to the real world: in order to accomplish missions, players must go to the Naviglio and physically perform activities in a designed fitness trail. A point to highlight is that we incorporated a number of social activities in the game by designing certain interactions with locals during certain missions and by allowing players to team up in order to rediscover the community and the human factor.
All these features are in accordance with the cultural and ecological spirit of Expo 2015.
To provide the smoothest user experience, we considered different devices with different levels of immersivity in order to enter the game. In particular, we introduced a smart watch, which works as a GPS navigator, an augmented-reality smartphone application and stereoscopic glasses for augmented reality. The most interesting and innovative feature is that we considered augmented reality glasses that are able to correctly reconstruct the visual angle, namely depending on the current position and where the user looks towards. Another relevant characteristic is that the devices are equipped with sensors that are able to measure physiological data. The devices are enriched with headphones, which increase the immersive experience since sound is the main vehicle of emotions. Moreover, they facilitate fruition of game content while the user is involved in sports activities and therefore unable to check a screen. We designed all devices to fit with our target: they are smart and ideal for sports activities. Each player can choose to play using one, two or three devices: they can be used alone, but used together enhance each other and, finally, the game experience.

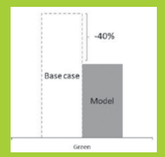
MAIN BIBLIOGRAPHICAL REFERENCES

[1] Gartner, (2011). *"Gartner Says By 2015, More Than 50 Percent of Organizations That Manage Innovation Processes Will Gamify Those Processes"*.
[2] GfK Eurisko (2011). *"Sinottica: dalla comprensione del contesto socio-culturale alla progettazione di target e azioni"*.
[3] Levi Sacerdotti S., Mauro S., Gasca E., (2011). *"Visitor Management Turismo, Territorio, Innovazione"*, Torino, CELID.

PROJECT 5







Green Cloud

GREEN CLOUD

ADVANCED ENERGY MANAGEMENT IN CLOUD SYSTEMS

Green Cloud
Advanced Energy Management in Cloud systems

project 5

Green Cloud studies energy-saving methods in cloud computing considering both data centers and networks, developed in cooperation with Alcatel Lucent, IBM and Lutech

PRINCIPAL ACADEMIC TUTOR

Antonio Capone
Electronics and Information, Politecnico di Milano

ACADEMIC TUTORS

Danilo Ardagna
Electronics and Information, Politecnico di Milano

Giuliana Carello
Electronics and Information, Politecnico di Milano

Federico Della Croce
Control and Computer Engineering, Politecnico di Milano

Marco Mellia
Electronics, Politecnico di Torino

Michela Meo
Electronics, Politecnico di Torino

EXTERNAL INSTITUTIONS

Alcatel Lucent

IBM Italia

Lutech Spa

EXTERNAL TUTORS

Fabrizio Leone
Lutech Spa

Massimo Leoni
IBM Italia

Carlo Spinelli
Alcatel Lucent

TEAM A

Stefano Viganò [Team controller and Project Communication Coordinator]
Management, Economics and Industrial Engineering

Ahmed Allam
Computer Engineering

Riccardo Chiodaroli
Computer Engineering

Francesco Lunetta
Computer Engineering

Stefano Ziller
Mathematical Engineering

PROJECT DESCRIPTION

The Challenge

Climate debate and carbon dioxide emission reduction are fostering the development of — green policies — with the aim of improving environmental performance and putting global warming and the enhancement of resource usage at the top of the list of the world's global challenges.
Information and Communication Technology (ICT) plays a key role in this greening process. Since environmental policies started to become of strategic importance worldwide, ICT applications have been considered as part of the solution as they can significantly improve the environmental performance of all the other sectors of the world economy by reducing their energy consumption and facilitating more environmentally sustainable energy generation using renewable sources. More recently, awareness of the potential impact of carbon emissions of the ICT sector itself has rapidly increased. Overall, ICT accounts for between 2% and 4% of global CO_2 emissions and is projected to reach 10% in 5-10 years. The challenge for ICT is to be able to reduce its footprint, while maintaining a high growth rate of communication infrastructures. These two issues are not disjointed. In fact, as more and more systems make use of ICT to reduce their own energy consumption, it would be of paramount importance for ICT to be as green as possible in order to reduce the global carbon footprint of the planet.
The general goal of the Green Cloud project is to develop a systematic set of methods for the design of novel resource allocation policies for energy-aware Clouds. Energy and cost savings are pursued by dynamically allocating computing resources of geographically distributed data centers.

Even if system computing and networking components have been designed and managed quite independently so far, the current trend is for significant integration based on the concept of Cloud. We argue that this new computing approach can be used not only to provide service flexibility to end users but also to

manage resources available in geographically distributed computing centers and in the network interconnecting the same in a flexible manner.
Indeed, the geographical distribution of computing facilities presents many opportunities for optimizing energy consumption and costs by intelligently distributing the computational workload, exploiting the different time zones in which the service centers are located and the hourly pricing of energy. In this scenario, energy and cost savings can be pursued by dynamically allocating service centre computing resources to applications at a global level, trading off service centre performance and energy consumption as well as that of the network used for redirecting requests among distributed sites.

Within the Green Cloud project, students developed a novel interdisciplinary approach based on expertise from several research areas: Cloud technologies, networking, optimization, performance evaluation and energy production and distribution.

project 5A

Green Cloud
Advanced Energy Management in Cloud systems

ABSTRACT

Nowadays, the Information Technology field is witnessing rapid development, leveraged by a multiplicity of innovative ideas. Such ideas represent the core contribution of diverse fields to pursue the evolution process in this domain. As a corollary, our team, whose members come from various engineering backgrounds, tackled the challenge of finding an innovative solution for energy management in Cloud Systems. The problem is characterized by aspects spanning different areas such as energy policies, systems architecture, communication networks and alternative energy production methods. Our team, with the support of our tutors, set up a series of possible scenarios, considering a set of Data Centers located throughout the world to serve incoming user requests. Our proposed solution is an optimization-based model, chosen for its flexibility and consolidated theoretical framework. In particular, the optimization model aims to reduce energy consumption in the Cloud system, taking into account the communication network and the energy generation methods, emphasizing the use of green and renewable energies. The added value of our approach is the allocation policy which intelligently determines the path of the user requests to be served. The main decision driver was minimization of energy costs in both Data Centers and in the network. Secondarily, we considered the energy generation method powering Data Centers, favoring green and renewable energy policies. Finally, our optimization model considered the availability of servers and network channels for each Data Center to execute application requests. Such considerations characterize the uniqueness of our approach, which leads to energy cost savings of up to 40% with respect to solutions which serve requests only locally, without redirecting traffic over the network. Furthermore, with the possibility of green energy generation, we experienced an important reduction in greenhouse gas emissions, very promising for future improvement.

TASKS & SKILLS

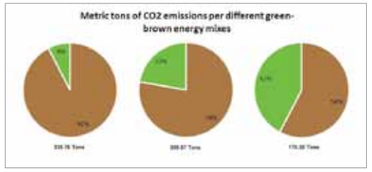
Ahmad Allam focused on gathering information on Data Center energy consumption and was involved in the definition and development of the optimization model.

Riccardo Chiodaroli worked on analysis of results and comparison of the different performance which can be achieved by the various model formulations.

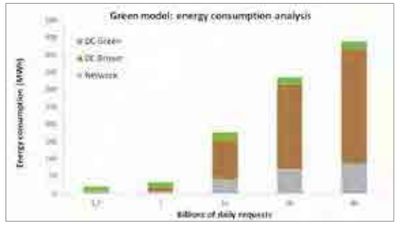
Francesco Lunetta following a research phase on network technologies, worked on numerical analyses supported by mathematical programming tools.

Stefano Viganò coordinated the group's work and provided and analyzed data on the energy market and green energy production and consumption for Data Centers.

Stefano Ziller focused his effort on the development of the mathematical models, following examination of the state of the art and the main solutions which can be implemented using current technology.



1 *Emissions*



2 *Energy consumption Graph*

UNDERSTANDING THE PROBLEM

"Green Cloud Computing": the problem we were introduced to was both challenging and incredibly broad. The first step of our work was the definition of a theoretical framework able to adequately represent the problem and current technology. In detail, this was broken down into three different steps. Firstly, we carried out a broad analysis of what Green could mean in a Cloud Computing context. Indeed, as the composition of our team clearly states, there was little difficulty in defining what Cloud Computing was, but none of us had ever considered energy consumption and pollution applied to such an infrastructure-based technology.

Cloud Computing can be defined as a Web-based processing system, whereby shared resources and software information are provided to computers and other devices on demand over the Internet. The main idea is that the system is composed of one or more Data Centers (DCs), the places where computation occurs whenever a user request is made over the Internet. The "Cloud" in the name arises from the idea of movement of information (i.e. computation and processing of information) to a different location, since DCs are connected through a network.

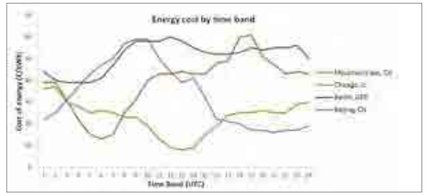
When one thinks about making something "greener", one usually thinks about a technological evolution able to change the way an object or process uses resources. But in this case, we were faced with a network based computing approach based on a huge amount of different technologies and solutions, from physical DCs and Network Routers to Virtualization and Routing. In any case, we agreed that focusing on a single hardware or software part of the Cloud would not help us in finding a truly innovative solution.

EXPLORING THE OPPORTUNITIES

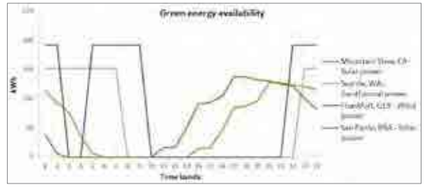
For these reasons, and thanks to the support of our tutors, we focused our attention on a more "system based" solution that could integrate the concepts of Cloud and Green into Computing. In order to do so, we went through the second step of the analysis: research on the state of the art in order to help us investigate which paths could be followed and which had already been sufficiently exploited. This research was broad and focused on all the various skills our team was able to provide:

- A detailed study on energy consumption and energy cost issues in the industry related to Cloud Computing and Computing in general. How can the average firm, whose business is not strictly linked to IT, take advantage of a greener approach to Cloud Computing? How can the more IT-intensive firm exploit a greener Cloud for its business?
- A comprehensive analysis of Cloud Computing evolution in recent years, with a detailed focus on all the involved technologies, such as: Virtual Machines, Servers, Data Storage, Data Center Cooling Systems, Networks.
- A broad analysis of the mathematical approaches to Cloud Computing, in order to discover how Cloud Systems can be modeled and to better understand the way they work in an analytical framework.

At the end of this phase, we moved to the third and final stage of the problem definition: finding an original solution to be devel-



3 *Energy cost Graph*



4 *Green Energy availability Graph*

5 *Green*

6 *IBM-Watson*

oped in the following months of work. After scouting different approaches, together with the academic tutor we chose to model the Cloud System as a single entity composed both of the DCs and the Network connecting them. In this sense, the Network serves as a resource for our system, since it allows application request forwarding, based on specific efficiency policies aimed at reducing costs or maximizing green energy usage.

With this in mind, we would be able to produce an optimization model capable of considering both the Computing as well as the Data Transfer part of the Cloud. This is also what makes our proposed solution innovative: there is no model in literature able to tackle energy consumption considering both parts of a Cloud Computing System.

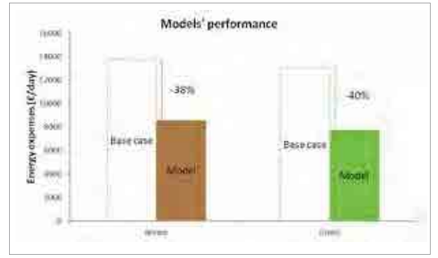
GENERATING A SOLUTION

The solution our group decided to develop was therefore an optimization model aimed at solving the request assignment issue in Data Centers located throughout the world and the network connecting them, keeping in mind our goal, i.e. minimization of energy consumption and maximization of green energy which would benefit IT operating firms, reduce energy costs related to their core business and obviously the environment, which would benefit from the reduction of greenhouse gas emissions.

Simulating requests arriving at the various DCs, with peaks related to the local time zones, the main task was the decision whether to serve a request directly at the entry Data Center or send it to another DC in the network. This problem was solved for an entire, knowing in advance the quantity and type of requests.

Our optimization-based model was developed using the CPLEX software. A first useful feature of this method is the reliability of the solution algorithms, providing optimum and significant flexibility in terms of choice of scenario (more or less complex) and of model parameters, in order for the model to be adapted and customized to meet the needs of the Cloud provider. In fact, we first took into account the most generic scenario, with a large number of request types and different types of servers to process the same; we then moved towards a more realistic scenario, considering appropriate and realistic parameters and variables, following in-depth research.

7 *Mappa zone*



8 *Performance Graph*

Moreover, the main advantage of the solution obtained is the possibility to include in such a model all the variables and constraints playing a role in a Cloud system. As a matter of fact, the constraints ensure that neither the DCs nor the network connections are overloaded in order to ensure fast response times to users.

As expected, the proposed solution is able to redirect requests in certain time zones to the location where the energy cost is lowest (mostly night-time locations, due to energy cost fluctuations). As a direct implication, the results show advantages with respect to an approach in which DC and network consumption are considered separately, which is the usual approach. We considered different scenarios, in terms of number of user requests and server characteristics, and we experienced savings of up to 40% in terms of energy costs with respect to the base case in which request forwarding is not available.

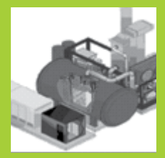
In addition, we proposed a green model in which we took into account the possibility of green energy generation, coming from various renewable sources and varying according to the geographical location and the time zone. With this second model, we not only experienced significant cost reduction but also environmental advantages, deriving from flexibility in the choice of active DCs, in terms of greenhouse gas emission that go beyond financial savings.

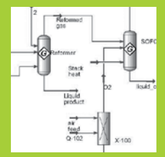
In conclusion, the optimization model developed could be exploited by any Cloud provider with a private (or even pay-as-you-go) network aiming to reduce its carbon footprint as well as its energy costs.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Armbrust, M. et al. (2009) *"Above the Clouds: A Berkeley View of Cloud Computing"*, Technical Report No. UCB/EECS-2009-28, University of California at Berkley, USA.
[2] Gupta, M. and Singh, S. (2003) *"Greening of the Internet"*, in Proceedings of ACM SIGCOMM '03, Karlsruhe, Germany.
[3] Qureshi, A. et al. (2009) *"Cutting the Electric Bill for Internet-Scale Systems"*, in Proceedings of ACM SIGCOMM '09, Barcelona, Spain.

PROJECT 6





FCE

FUEL CELLS FOR ENERGY

FUEL CELLS FOR ENERGY

FCE
Fuel Cells for Energy

project 6

Fuel cells fed by renewable primary sources as a strategic energy route for a Nation: analysis in cooperation with a large Italian energy producer (Edison)

PRINCIPAL ACADEMIC TUTORS

Michele Calì
Energy, Politecnico di Torino

Massimo Santarelli
Energy, Politecnico di Torino

ACADEMIC TUTORS

Andrea Casalegno
Energy, Politecnico di Milano

Gianpiero Groppi
Department of Chemistry Materials and Chemical Engineering
Politecnico di Milano

Renzo Marchesi
Energy, Politecnico di Milano

Emilio Paolucci
Production Systems and Business Economics,
Politecnico di Torino

Milena Salvo
Material Science and Chemical Engineering,
Politecnico di Torino

Alberto Tenconi
Industrial Electrical Engineering,
Politecnico di Torino

EXTERNAL INSTITUTION

Edison Spa

EXTERNAL TUTORS

Davide Beretta
Edison Spa

Stefano Ginocchio
Edison Spa

TEAM A

Lucia Colombo [Team controller]
Energy Engineering

Gianfrancesco Melina
[Project Communication Coordinator]
Aerospace Engineering

Piergiorgio Luigi Montrucchio
Industrial Engineering and Management

PROJECT DESCRIPTION

The Challenge

The project has been based on the evidence that the use of a fuel cell system can generate heat and power with high efficiency. The necessity of investigating a new path to energy conversion compared to thermal engines for power generation is related to the global energy problem which is becoming increasingly relevant. In fact, reduction of greenhouse gas emissions as well as a significant decrease in fossil fuel consumption are two outstanding topics to be addressed. For these reasons, governments are proposing green policies whose goals are to foster the use of renewable sources, reduce energy demand and increase energy production efficiency, thus reducing fuel supply. In this general scenario, the project was built to develop an analysis of the technical, economical and environmental benefits of producing distributed heat and electricity through integrated systems based on fuel cell technology. The final purpose was to identify an innovative solution able to respond to the project requirements: the design of a medium size (1 MW) SOFC plant fed by fuel derived from renewable resources, a possible alternative to the current use of natural gas, actually still the best solution.
Thus the project has been divided in two parts.
The first has been devoted to the choice of a suitable fuel to be used in the cell, selecting among different renewable fuels pointing towards the concept of sustainability. According to the results of a multi-criteria analysis on different types of biomass (animal excrement, agricultural and industrial scrap), biogas produced by anaerobic digestion of civil sewage has emerged to be a good solution in order to guarantee high performance, consistency with existing infrastructures, local availability and constant rate of supply for the plant. Moreover, the solution generates value from waste.
The second part of the project dealt with a deeper analysis of the solution concept, both from a technical and economical perspective. The starting points of this phase were identification of the stakeholders and investigation of their needs. A map of existing

Italian collection centres has been built. Furthermore, a detailed analysis of the biogas treatment process has been performed, focusing on the desulphurization issue that has emerged to be the most significant issue to be addressed in order to guarantee fuel cell integrity and thus technical feasibility.
Subsequently, a possible layout of the plant, with sizing of all components, has been proposed. An economic analysis has also been performed, considering all the benefits of using a renewable source.
According to the solution concept defined, several institutions have been involved. In particular, Edison has allowed us to understand the state of the art of the Italian power market and its future scenarios, while SMAT has provided us essential information to define and detail the proposed concept.

project 6A

FCE
Fuel Cells for Energy

ABSTRACT

The Fuel Cell for Energy (FCE) project addresses the global energy problem by proposing innovative and sustainable solutions, in particular focusing on an Italian perspective. The reduction in greenhouse gas emissions of 20% at least, as well as the reduction in the dependency on hydrocarbons are primary issues to be solved in order to lower the environmental impact of non-sustainable power generation.

The analysis proposed in the FCE project started with the search for a suitable renewable fuel and the best biogas treatment in order to obtain a pollutant-free biogas. It then continued with the technical and economical sizing of a plant fed by the selected fuel.

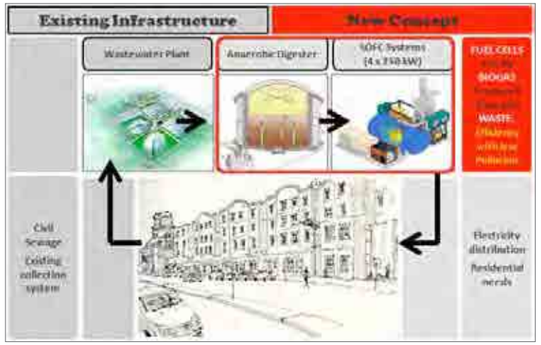
More in detail, the FCE team has investigated the feasibility of a system able to generate heat and power by operating a Solid Oxide Fuel Cell (SOFC) co-generative plant with clean hydrogen, derived from reforming a stream of biogas produced from the anaerobic digestion of civil sewage. FCE is designed to be installed in existing Italian wastewater collecting centres with a minimum catchment area of 100.000 equivalent inhabitants which is the size below which the installation of an anaerobic digester has emerged to be no longer economical. The choice of SOFC is an assumption which is however justified by its significant resistance to pollutants and its future perspectives. The defined nominal power for the plant is 1 MWel. Through the described solution, energy production is delocalized throughout the country with smaller but highly-efficienct plants, reducing the transmission losses on the electrical grid. Moreover, electricity can be produced from renewable treated biomass with positive effects on the surrounding area. Finally, the solution achieves the purpose of producing clean energy whilst limiting the impact on the electricity bill.

TASKS & SKILLS

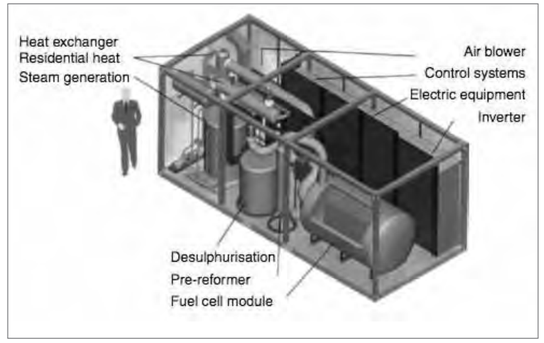
Lucia Colombo worked mainly on process design, focusing on the desulphurization issue and on the detailed plant design.

Gianfrancesco Melina was focused on the analysis of the state of the art of the fuel cells and biomasses.

Piergiorgio Montrucchio worked mainly on the mapping of wastewater plants and on the economic analysis.



1 *Concept solution*



2 *Fuel Cell Module*

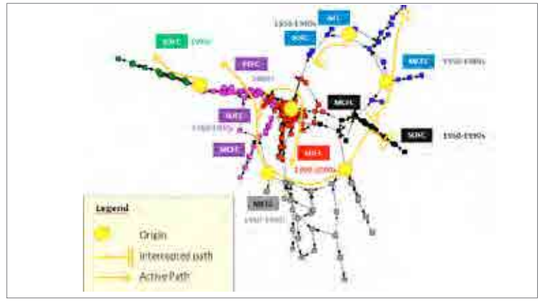
UNDERSTANDING THE PROBLEM

The general brief assigned to the FCE project was to explore the feasibility of distributed medium size co-generative plants throughout Italy, generating energy by the use of fuel cell technology and exploiting biomass available in the area. The starting point was detection of stakeholder requirements : we firstly identified governments and citizens as the main stakeholders. The former are interested in reducing the use of fossil fuels and in limiting the environmental impact of energy generation while the latter are interested in a cleaner environment. Moreover, an FCE plant would also involve the biomass providers as stakeholder, concerned with selling their product, especially if this means a reduction in the cost of treatment. Energy companies would be possible investors since they are required to produce at least 5% of green energy.

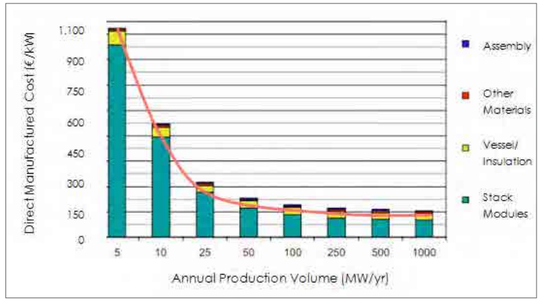
Dealing with system requirements, identification of the needs of the FCE plant started with analysis of the technology. Unlike traditional devices used to generate heat and power (such as internal combustion engines, gas or steam turbines) fuel cells are a new technology working under strictly controlled conditions. For this reason, it is necessary to have biomass at a constant rate and biogas with a fixed composition. These features allow the plant to constantly work at nominal conditions and to guarantee homogeneous feed at the anode, without rapidly degrading the cell. The use of existing infrastructures to collect fuel and distribute power would then faciliate containment of system costs, highlighting the benefits of the fuel cells.

EXPLORING THE OPPORTUNITIES

Several challenges have been faced during the project. In particular, in the first phase we focused on investigation of the best match between cell and fuel. This started from an in-depth analysis of the state-of-art of the fuel cell, in order to better understand its potential and critical issues. Thus, an innovative reticular analysis of the technological trajectories was conducted, based on the information provided by the 196.000 worldwide fuel cell patents. Fuel cell technology turned out to be radically different from devices available on the market for producing heat and power since it works without any combustion. For this reason, the efficiency of the cell is not subject to the Carnot limit and thus can reach a 60% level also in small-size plants. The use



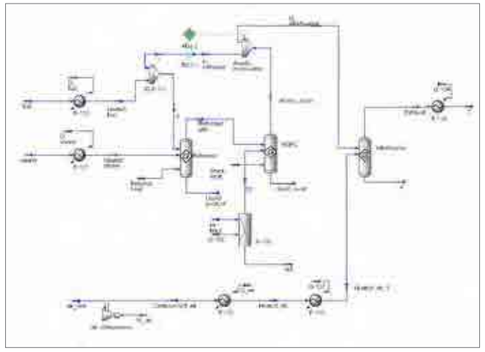
3 *Analysis of the Technological Trajectories in the Fuel Cells' field (based on a patent research)*



4 *Analysis of a Fuel Cell Cost depending on the annual production volume*

Biogas Composition	Biogas from Wastewater treatment plants sludge
CH_4 % vol.	50-60
CO_2 % vol.	38-34
N_2 % vol.	5-0
O_2 % vol.	1-0
H_2O % vol.	6 (at 40 °C)
H_2S mg/m^3	1000-900
NH_3 mg/m^3	-
Aromatic mg/m^3	0-200

5 *Average Composition of Biogas from civil sewage*



6 *Plant design*

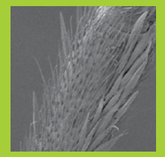
of biogenous fuels could pursue the goal of sustainability.
Nevertheless, fuel cells are also characterized by significant critical issues due to the fact that they are highly vulnerable to pollutants, such as sulphur compounds and particulate. For this reason, not all types of biomass are suitable for fuelling the cell. Thus we performed a multi-criteria analysis to compare different fuels derived from biomasses. Liquid fuels were soon excluded since they need to be vaporized inside the anode before use in the cell. Moreover, as opposed to gaseous fuels, liquid fuels cannot be delivered using the existing transport infrastructure. Therefore, only gaseous fuels have been compared according to criteria regarding the cost of fuels, their suitability to be easily transported, their availability throughout the country, the problems that can occur by using them in the cell and government incentives. The result of this analysis leads to the choice of biogas derived from anaerobic digestion of civil sewage.
The next step has been to identify the places that could supply such gas. Thus we mapped the existing Italian collection centres in which biomass represented a troublesome burden. FCE installation would fit perfectly in these centres, allowing recovery of the biomass and the production of a green energy. It would also lead to an income for the plant owners who are interested in selling the biomass and reducing the treatment load.
In order to complete the scenario, we also identified the most competitive alternatives to the use of fuel cells for producing heat and power from sewage, focusing our attention on internal combustion gas engines.

GENERATING A SOLUTION

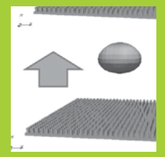
As a result of the collaboration with SMAT and the multi-criteria analysis, biogas produced from civil wastewater was chosen as a fuel to be used in a fuel cell plant. A technical and economic feasibility analysis has been performed in the second phase of the project.
The aim was to develop the design of a medium size plant which could be customized for each wastewater collecting centre with a catchment area large enough to justify the investment.
The generated power would be used for internal needs and the surplus released into the electric grid. Furthermore, supposing the installation of FCE in all the suitable collection centres and taking as a reference the Italian energy supply of 320 TWh/year, the percentage of producible green energy has emerged to be about 1%. This would be not a negligible share within the Italian mix; moreover, according to a more realistic vision, even if deployed on fewer sites, the solution would help to diversify energy production which is considered a winning strategy to solve the complex energy problem. Finally, the recovery of waste could respond to the specific problem of one of the stakeholders involved, the wastewater plant owner.
Thus, the innovation in the described solution consists of the combination of different technologies in order to respond to specific stakeholder requirements, limiting investments in complementary assets.
Plant design was divided in two sequential phases. The first was devoted to the biogas desulphurization process: all the existing techniques were considered in this phase. In particular, we focused on finding the most suitable adsorption materials to meet SOFC requirements, comparing different commercial (and not) products. Having identified the biogas treatment process, the next step was the fuel cell system design and sizing of the necessary components. Plant design has also been useful for the economical feasibility study. In this phase, both the capital costs and the economic benefits arising from incentives granted for renewable sources have been considered. From the analysis it turns out that there is still much to be done (first of all, on the cell life time) in order to make the system truly competitive on the market, but all the involved technologies are very promising.
Finally, a hybrid scenario has been considered as a possible future development: efficiency can also be increased by installation of a gas turbine which expands the exhaust gases from the system post-combustor.

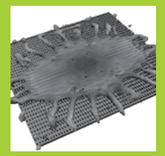
MAIN BIBLIOGRAPHICAL REFERENCES

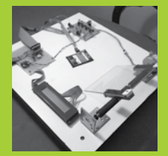
[1] Garret D. E, 1989, *Chemical Engineering Economics*, Van Nostrand Reinold, New York
[2] Verspagen B., 2005, *Mapping Technological Trajectories as Patent Citation Networks. A Study on the History of Fuel Cell Research*, Eindhoven Centre for Innovation Studies, The Netherlands
[3] Larminie J., Dicks A.,2003, *Fuel Cell System Explained*, Wiley



PROJECT 7







Gecko vs Lotus

SUPER-ADHESIVE OR ANTI-ADHESIVE BIO-INSPIRED NANOMATERIALS

project 7

Gecko vs Lotus
Super-Adhesive or Anti-adhesive Bio-inspired Nanomaterials

The aim of the "gecko vs lotus" project is the design and fabrication of bio-inspired super-adhesive (with Vibram) or anti-adhesive (with Indesit) nano-surfaces

PRINCIPAL ACADEMIC TUTOR

Nicola Pugno
Structural and Geotechnical Engineering, Politecnico di Torino

ACADEMIC TUTORS

Alberto Corigliano
Structural Engineering, Politecnico di Milano

Barbara Del Curto
Chemistry Materials and Chemical Engineering "Giulio Natta", Politecnico di Milano

EXTERNAL INSTITUTIONS

Indesit Company

Vibram SpA

EXTERNAL TUTORS

Paolo Faraldi
Indesit Company

Antonello Ghignone
Vibram SpA

TEAM A

Francesca Letizia [Team controller and Project Communication Coordinator]
Aerospace Engineering

Pietro Brambilla
Aeronautical Engineering

Jacopo De Amicis
Nuclear Engineering

Chiara Saggese
Chemical Engineering

TEAM B

Isabella Bertoli [Team controller]
Nuclear Engineering

Anna Botto
Civil Engineering

Davide Guzzetti
Space Engineering

Stefano Larentis
Electronic Engineering

Giancarlo Soavi
Physics Engineering

PROJECT DESCRIPTION

Introduction
The "Giuseppe Maria Pugno" Laboratory of Bio-inspired Nanomechanics (http://areeweb.polito.it/ricerca/bionanomech) has significant experience in designing new bio-inspired nanomaterials and has thus proposed this project, in line with its current research activity (e.g. the first self-cleaning polystyrene@Polito, POLOTO, was previously obtained thanks to a collaboration between Indesit Company and our Lab), to the Alta Scuola Politecnica.

The Challenge
Several animals, such as insects, spiders and geckos have developed fascinating nano-architectures in order to maximize and control adhesion. Adhesion-prevention solutions are also suggested by nature: peculiar plant leaves, such as the famous lotus, are able to prevent insect adhesion, again thanks to nano-architectures, even if insects evolved in order to maximize adhesion. The replication of such super-adhesion or anti-adhesion mechanisms, thanks to bio-inspired nanomaterials, is a challenge of the current material science and is key for developing advanced applications, such as new super-adhesive or anti-adhesive nanomaterials.

The teams
The Teams have worked on the design and fabrication of bio-inspired adhesive (Team A, "Gecko") or anti-adhesive (Team B, "Lotus") nanomaterials.

The results
Two case studies have been considered: adhesive materials for new soles with high grip on wet surfaces (Team Gecko in collaboration with Vibram Company) and self-cleaning polystyrene for refrigerators (Team Lotus in collaboration with Indesit Company). In particular, prototypes of new soles based on macroscopic and microscopic suction cups and porous materials have been designed, developed and characterized. Complementarily, Indesit polystyrene materials have been experimentally tested and the best solution has thus been identified; moreover, a new design has been proposed thanks to numerical simulations to further increase the self-cleaning ability of the refrigerator.

GECKO

ABSTRACT

Slips and falls are ones of the most common causes of occupational accidents, a problem that has a significant impact both at the social and at the economic level. For this reason in the last years there is an increasing interest in studying mechanisms of interaction between the shoe sole and the floor.

The activity of our group was focused on the study of innovative concepts to improve the adhesion of the sole, evaluating some changes in its design and in its material. Our research was inspired by the observation of various phenomena of adhesion in Nature, such as in geckos' feet, insects' claws, spiders' webs, or even octopuses' tentacles. Different approaches were developed and examined through laboratory experiments.

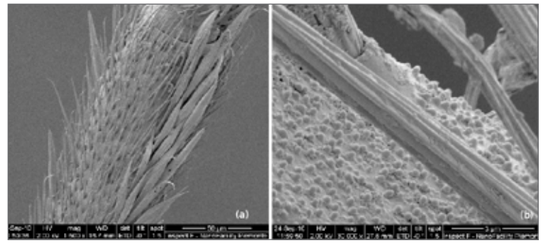
The fruitful collaboration with Vibram, a leader company in the field of safety soles, helped us to highlight the basic requirements for the product, both in terms of safety and industrial feasibility. The analysis of the requirements suggested us to evaluate the effect of the porosity of the compound on the behaviour of the sole. The idea underlying this research is that varying the porosity it could be possible to achieve the optimal dimension and density of the pores in the surface in order to obtain suction-cup effect, that can avoid slip even if the floor is contaminated by dirt or liquids. The tests show that increasing the porosity of the sole modifies its performance; moreover the reduction of the weight of the sole is beneficial to the wearer's feedback during the slipping. In fact, the human factor is fundamental in slip and fall events and we had the chance to take advantage of the experience of Vibram Tester Team to evaluate the performance of our soles.

TASKS & SKILLS

Pietro Brambilla studied adhesion in nature, carrying out experiments on cockroaches; he then contributed to the production and testing of soles with varying porosity.
Jacopo De Amicis studied the mechanism of adhesion of the suction cups; he produced and tested the suction cup soles, comparing them with traditional types.
Francesca Letizia studied the adhesion mechanism and behaviour of visco-elastic materials, through laboratory tests and analysis of the soles produced.
Chiara Saggese studied adhesion in nature, observing the organization of hierarchical surfaces; she then contributed to the production and the testing of soles with varying porosity.

1 *Laboratory apparatus to reproduce the condition of detachment of an adhesive tape*

2 *Two subsequent frames showing the detatchment of a Blatta Orientalis*



3 *SEM image of a water strider's leg*

UNDERSTANDING THE PROBLEM

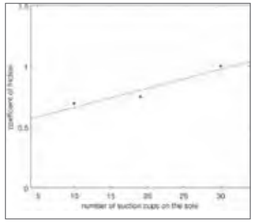
Our project is based on the exploration of the potential of bio-inspired materials and, in particular, our team studied their adhesive proprieties. The aim of this research is to improve the grip of a shoe sole in different conditions.
This aspect is relevant for sports applications and even essential for the professional footwear of workers in dangerous environments.
In order to reduce slippage it is useful to increase friction at the interface between the shoe sole and the ground. It is possible to obtain this result acting on several parameters, such as the sole material or the tread pattern.
However the improvement in the behaviour of the sole cannot be quantified only by the coefficient of friction between the surfaces. For example, it is also very important that the sole does not lose grip rapidly in the transition from static to dynamic conditions: in this way the wearer has better control of his/her position and better feedback from his/her movements. This observation highlights the fact that also the dynamic behaviour of the sole is fundamental to obtain a reliable product; considering this aspect, however, introduces a higher level of complexity since it can only be evaluated by reproducing the actual conditions of use.
Moreover, the sole performance should be as time independent as possible: this requires the sole to be self-cleaning, since dirt might cause a progressive loss of grip, and that the effect of the wear on the sole surface does not reduce its functions.
We tried to conceive an innovation able to fulfil all these requirements and which could be implemented within two years, which is the average time that Vibram spends from the R&D phase to the commercialisation of a new product.

EXPLORING THE OPPORTUNITIES

Several footwear characteristics influence the interaction between the sole of the shoe and the ground, such as the sole material, the tread pattern and the shape of the cleats.
The sole material is usually a rubber whose hardness is chosen carefully, considering that a hard material is better in supporting weight, while a softer one provides better slip resistance. The hardness of a sole has significant influence on its life, since softer soles have a lower resistance to abrasion. The behaviour of the material is studied firstly theoretically through a model that

4 *Different concepts of the suction-cups sole*

5 *Standardized test to measure the resistance to slip of the sole*



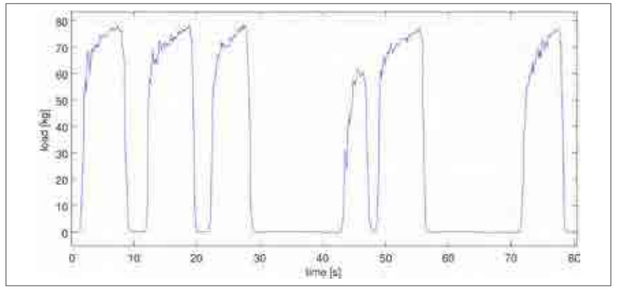
6 *Behaviour of the coefficient of friction with the number of suction cups present on the sole*

7 *Three different sole compounds with varying porosity*

considers its non-linear elasticity and subsequently experiments are conducted in order to understand under which conditions the detachment occurs.
The modifications in the tread pattern should follow the SATRA (Shoe and Allied Trade Research Association) guidelines to design a slip-resistant sole. In particular, these guidelines contain indications on how to make a sole behave evenly, regardless of the slip direction, to limit its tendency in getting dirty and its sensitivity to contamination.
In nature it is possible to find systems that present all these features. In fact several insects and other animals, such as geckos, have highly remarkable adhesive capacity coupled with the fundamental possibility of obtaining easy detachment when needed, keeping clean both their feet and the surface on which they are moving. These mechanisms represent possible techniques to improve the grip of a sole and therefore we decided to study them in depth in order to understand how the different phenomena work and how it could be possible to apply them to soles. The research period consisted of an initial bibliographic research and then a number of laboratory experiments. In particular, we performed in vivo experiments on cockroaches to quantify their adhesive capacity and the examination of the water striders' claws under the microscope showed us the surface arrangement.
The legs of the insects present a very complex architecture, organized in different dimensional scales. This structure assures a high level of adhesion but presents two main drawbacks:
- the wear of the sole can quickly erode the architecture of the surface, radically changing its performance,
- the production of this kind of sole is extremely complex and it would require significant changes in the industrial processes, thus leading to a very long time before its commercialization.
We therefore concluded that we needed to find inspiration in a different field and thus we considered the adoption of suction cups as a more feasible option offering interesting performance, even with contaminated surfaces.

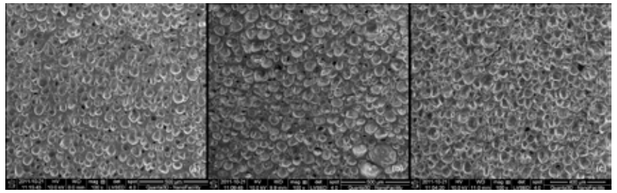
GENERATING A SOLUTION

In the second phase we worked in collaboration with Vibram: in their facilities we created the soles and then tested them under different conditions.
First, we made a number of prototypes of soles applying suction cups of different material, size and quantity to a flat sole. The soles were tested together with the Vibram Tester Team and we obtained numerical data of the coefficient of static adhesion and qualitative data concerning the feeling the sole provides. The soles were tested on surfaces with different roughness and, as expected, we obtained highest adhesion on the smoothest surface. We tested the soles with a SATRA standard machine which provides a measure of the dynamic coefficient of friction.
The tests on the suction cup sole show that it presents a very high coefficient of friction in the static condition but its behaviour during transition to the dynamic condition is not acceptable since the wearer does not obtain adequate feedback of slippage and there is too much difference between the static and dynamic behaviour.
We know that safety is the main target in sole design and, since dynamic behaviour is the most important parameter, the suction cup concept had to be discarded. In order to maintain the beneficial effect of the suction cups, we considred creating a porous sole. Therefore, a spongy sole was made of expanded rubber containing many micro pores which, at the interface, might behave like a micro suction cup.
Having a sole made of a (macroscopically) continuous material, instead of one with a number of large suction cups applied to it, is a huge advantage in terms of sole life: even if the sole is worn, the new layer can maintain the characteristics of the previous since the sole is homogeneous throughout its thickness. In this way, we expect the behaviour of the sole not to change radically over time.
In order to obtain soles with varying porosity, we created them (at the Vibram R&D Department) by modifying the quantity of the blowing agent in the rubber compound. We thus produced three soles with different density and porosity and later tested them on several surfaces. From the static tests we did not obtain as positive results as with the macro suction cups but we discovered that, if the porosity changes, the sole performs in a different way during slippage since the micro-pores increase roughness at the interface. Moreover, a lighter and more flexible sole contributes to improving the wearer's feedback.



8 *Final result of the process of production of the soles*

9 *Behaviour of the coefficient of friction with the number of suction cups present on the sole*



10 *Nicola Faccinetto (Vibram tester team) testing a new concept sole*

11 *SEM image*

project 7B

LOTUS

TASKS & SKILLS

Davide Guzzetti, investigated the dynamics underlying the drop impact on super-hydrophobic surfaces and performed numerical simulations using OpenFoam. He also developed an open innovation model for the project.

Giancarlo Soavi, investigated the physics behind the drop transport and electrowetting phenomena and evaluated the introduction of the self cleaning refrigerator on the market as a possible investment for a household appliance company.

Isabella Bertoli, investigated drop rolling/sliding behavior through numerical simulations with OpenFoam and designed the layout of the "self-cleaning" refrigerator.

Anna Botto, experimentally investigated drop rolling/sliding on inclined surfaces.

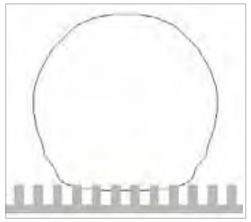
Stefano Larentis, investigated the dynamics underlying the drop impact on hydrophobic surfaces and designed the conceptual scheme for the "Follow-The-Drop" approach.

ABSTRACT

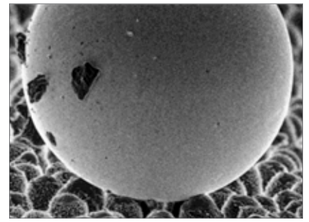
Lotus effect is a fascinating and inspiring phenomenon that can be observed in nature: after rainfalls, water droplets tend to reside in spherical form on the lotus leaf and do not wet the surface. Moreover, when the leaf is inclined, the droplets gently roll off, efficiently removing the dirt, obtaining a wet and clean surface. Inspired by this effect, much research is currently conducted in order to investigate the phenomenon and grasp its secrets. Superficial texture and a high degree of roughness seem to be the key aspects of this amazing effect. By disclosing the physics of this phenomenon and the most important underlying parameters, the lotus effect could be reproduced for commercial exploitation with almost an infinite number of possible applications.

Our project aim is to study the super-hydrophobic, self-cleaning and anti-adhesive features of lotus-like surfaces in order to be able to produce artificial surfaces. All the aspects related to drop interaction with the surfaces have been studied. By adopting a "Follow-The-Drop" approach, all drop-surface interactions are studied, starting from the drop falling on the surface and ending with the drop removal. Experimental work and numerical simulations are employed to capture the phenomenon and its key parameters. Finally, a possible application is considered. All the results obtained from the different phases of the "drop cycle" are summarized in a possible "self-cleaning" fridge design and also prototypical layouts are proposed.

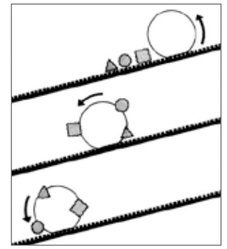
1 *Lotus effect*



2 *Fakir*



3 *Superficial Texture*



4 *Lotus dust*

UNDERSTANDING THE PROBLEM

The Lotus Team project is a bio-inspired nano-materials project. Our aim is to use a bio mimesis approach taking inspiration from nature for developing new innovative technologies. This process, called biomimicry, has been increasingly developed in recent years, borrowing ideas and inspiration from nature in order to replicate extremely interesting effects. One of the most attractive is the Lotus effect, exhibited by the Lotus leaf, which is characterized by amazing super-hydrophobic, anti-adhesive and self-cleaning properties.

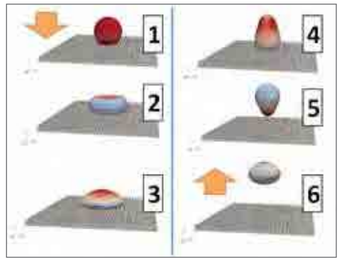
The main objective of the project was to provide a comprehensive knowledge of the Lotus effect and understand how this effect and its properties could be replicated in order to create innovative, bio-inspired, anti-adhesive, super-hydrophobic and self-cleaning surfaces. The key aspect of the problem lies precisely in the identification of those parameters that could make possible the creation of a surface with all of these features at once. Indeed, super-hydrophobic, self-cleaning coatings and materials are believed to be a major breakthrough, both in academia and industry, leading to new understanding in physics and, at the same time, new industrial applications. The team extensively developed both sides of this challenge, also paying attention to the social, environmental and economic feasibility of the entire project.

In particular, as a case-study, the team focused on the development of an innovative super-hydrophobic, self-cleaning fridge. This is one of the possible applications of this technology. Therefore, the team partnered with INDESIT, a leading company in the manufacture of "white goods", with more than 16 million household appliances produced. INDESIT is very sensitive to green, eco-compatible technology and is also pursuing an R&D oriented company policy.

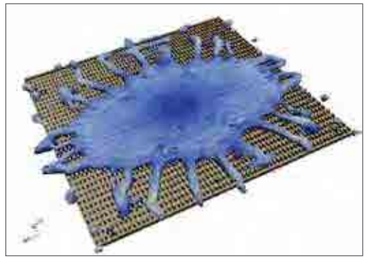
EXPLORING THE OPPORTUNITIES

The investigation of the relationship between the material and the liquid is fundamental. Liquid-surface interaction is a complex process, made up of different steps: first, drop impacts on the surface, second, drop rolls or slides on the surface and third, drop can be removed from the surface. Consequently, different kinds of properties and parameters, i.e. static and dynamic properties, are part of the entire phenomenon and influence the resulting properties of the surface in terms of i) hydrophobic, ii) self-cleaning and ii) anti-adhesive features.

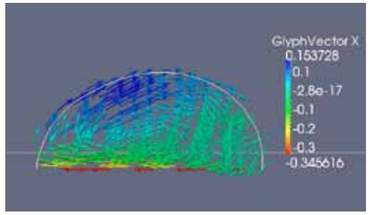
Therefore, these three main steps have been thoroughly investigated by our team in order to identify the key parameters able to calibrate the hydrophobic properties of a surface. The ultimate aim is a concrete application of these surfaces. Although many researchers have studied this topic for several years, a detailed understanding of the lotus effect is still lacking. Therefore, an



5 *Drop rebound*



6 *Splash*



7 *Internal motus*

in-depth research oriented assessment is necessary to understand how this technology could be successfully implemented in actual products (e.g. refrigerator). For these reasons, our group performed a wide range of research activities. Extensive numerical simulations (e.g. OpenFOAM) and experiments of drop dynamics were performed with Pugno Lab to study the drop impact, rolling/sliding and the movement on flat surfaces (e.g. electro-wetting). Using the knowledge directly acquired during the research part, we can assess that it is possible to calibrate the hydrophobic properties of theoretically any surface by thoroughly patterning the surface material (e.g. complex surfaces) in order to obtain the desired responses such as:

1. Rejection of impacting droplets;
2. Rolling of drops with enhanced capability to collect dirt particles from the surface;
3. Steering the position and the shape of a particular drop.

Each of these responses offers a broad spectrum of opportunities. Rejection of impacting droplets can be used for ever-dry surfaces which can be implemented on benches that remain dry even after a rainstorm, for graffiti-resistant walls capable of repelling the writer's spray or in general for obtaining non-splash surfaces. Rolling drops collect a significantly higher number of dirt particles compared to sliding drops and this leads to the most appealing and impactful potential application, i.e. self-cleaning surfaces for INDESIT refrigerators. Finally, steering the position and the shape of drops can be implemented by following the example of certain desert beetles which direct droplets on prescribed itineraries to their mouth, thus being able to feed themselves with morning dew. The most significant challenge is combining all these features in just one application, leading to possible exploitation of all the benefits deriving from each of these features at the same time, in complete analogy with the Lotus Leaf. Therefore, instead of focusing on one property at a time, independently from the others, in order to optimize and fully exploit its potential, the key idea of the project is to explore each challenge in order to capture the most important parameters influencing the physical phenomena involved and consequently understand how each property could be related to the other in order to have not just one result but a complete perspective of all the aspects.

GENERATING A SOLUTION

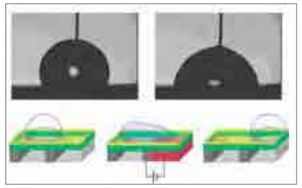
A first important output of the study is the conceptual approach defined by the three steps mentioned above, which has been named "Follow-the-Drop-Approach", which investigates each peculiar phase of the water-surface interaction. Firstly, we characterized the drop impact with respect to the surface features through numerical simulation. We studied drop retraction dynamics and the drop fragmentation problem. The transition between the Fakir and Wenzel state as a function of the impact velocity and pillar geometry were studied; we also addressed the challenge of optimization of pillar geometry in order to achieve the Wenzel state. Secondly, experiments were performed on polystyrene surfaces provided by INDESIT to address the motion of droplets on inclined solid surfaces, testing different inclinations and surface types different motion regimes were described. Also, the existence of a stationary velocity of a drop moving on such surfaces was characterized as a function of the drop dimension. Finally, the feasibility of transporting a drop by adopting the electro-wetting technique was evaluated. As a matter of fact, in order to effectively implement the technology, the research steps we covered are fundamental since it allows us to understand the parameters governing the overall physical process, facilitating successful technology transfer to actual products able to respond to consumer needs.

Finally, a possible application in the field of household appliances was developed. A preliminary design of an innovative self-cleaning fridge was studied, taking into account both the fundamental insights on super-hydrophobic surfaces provided by the research and the company and user requirements. Different layouts were considered in order to address the needs of different customers: from a basic and immediately applicable solution to a more ingenious one, which is meant to mark a turning point for the entire concept. Consequently, three different trade-offs were proposed:

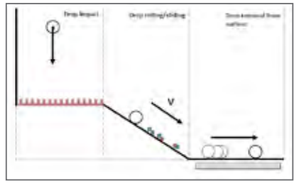
1. Self-cleaning shelves to replace obsolete versions and get the consumer used to self-cleaning technology;
2. Built-in super-hydrophobic technology in new products, while maintaining the current, well-known fridge layout;
3. Gradual revision of the fridge layout to completely automate the cleaning procedure by implementing an auxiliary washing line and circular rotating shelves which leverage on centrifugal force for self-drying.

These proposed concepts are intended to fully exploit the revolutionary potential of the new technology we addressed. The refrigerator we designed can be considered just the first example of the potential revolution this technology could bring about.

8 *Experimental setup*



9 *Drop transport*



10 *FTDA*

11 *Sf FRIDGE*

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Barthlott W., Neinhuis C. (1997) *Purity of the sacred lotus, or escape from contamination in biological surfaces*. Planta, 202, 1-8.

[2] Yoon J.Y., Robin L.G. (2003) *Preventing Biomolecular Adsorption in Electrowetting-Based Biofluidic Chips*, Anal. Chem., 75, 5097-5102.

[3] Patankar N.A., (2004) *Mimicking the Lotus Effect: Influence of Double Roughness Structures and Slender Pillars*, Langmuir, 20(19), 8209-8213.

PROJECT 8

Rethinking Industrial Cities

ianus

IVREA AS UNESCO SITE

Rethinking Industrial Cities
Ivrea as Unesco Site

project 8

Strategies and policies to revive industrial cities. Ivrea and its heritage, resources, players and actions in the long-term process of candidacy as a Unesco Site

PRINCIPAL ACADEMIC TUTORS

Patrizia Bonifazio
Architecture and Planning,
Politecnico di Milano

Alessandro De Magistris
Architecture and Planning,
Politecnico di Milano

ACADEMIC TUTORS

Carlo Alberto Barbieri
Inter-university Territorial Studies
and Planning, Politecnico di Torino

Filippo De Pieri
Architectural and Industrial Design,
Politecnico di Torino

Paolo Galuzzi
Architecture and Planning,
Politecnico di Milano

Federico Oliva
Architecture and Planning,
Politecnico di Milano

Gabriele Pasqui
Architecture and Planning,
Politecnico di Milano

Rossella Salerno
Architecture and Planning,
Politecnico di Milano

Giorgio Vitillo
Architecture and Planning,
Politecnico di Milano

EXTERNAL INSTITUTIONS

Comune di Ivrea

Fondazione Adriano Olivetti

MuseoTorino

Studioata

EXTERNAL TUTORS

Giovanna Codato
Comune di Ivrea

Melina De Caro
Fondazione Adriano Olivetti

Francesca Filippi
MuseoTorino

Gracialiano Berrocal
Studioata

TEAM A

Alessia Mapelli [Team controller]
Architecture

Annalisa Andaloro
Building Engineering

Lara Di Chio
Engineering for Cinema
and Methods of Communications

Francesca Giliberto
Architecture for restoration and preservation
of architectural and environmental heritage

Andrea Migliarese
Architecture

Matteo Novati
[Project Communication Coordinator]
Building Engineering and Architecture

PROJECT DESCRIPTION

The Challenge
During the 20th century industrial cities underwent experimentation with new models of production systems, often linking industrial projects with the modernity of architectural and housing development models and new conceptions of planning. After the decline and dismantling of industrial sectors, the communities affected had to find new ways to relaunch and maintain the physical structures of the industrial city, which were often of excellent architectural quality. Today these cities find themselves rethinking their territory in order to host new activities and processes of innovation and development. Triggering this change means organizing a long-term project that requires the exploitation of the local heritage, recognition of the potential of local players and resources, the involvement of communities and the communities' capacity to create a new future scenario in which to recognize themselves. Various strategies have been used: the policies of major events, the recognition of "cities of culture", the organization of important modern buildings by well famous architects.
Among these, there is also that of Unesco recognition, which places two different actions together: that associated with the utilization of the cultural experience that characterizes locations and that associated with the capacity to "maintain" the asset that is the object of recognition over time and to place it within the contemporary, through a so-called management plan (which is obligatory for presentation of the candidacy dossier). The management plan therefore could become a full-blown strategic plan, a plan that makes the cultural heritage an important element in policies of innovation and development. The project proposed to consider the experiences under way in North America and Europe (in western countries and in ex Soviet countries) in a comparative key and to organize experimentation in the field starting with the case study of Ivrea, the city of (Adriano) Olivetti and Olivetti itself, which is about to inaugurate its process of candidacy as a Unesco site.

The Team
During the first phase, the team has analyzed two specific themes: the Unesco candidacy as starting point for the development of a strategy toward the city transformation and relaunch; the typical structure of management plans required by Unesco, in order to understand the fundamental actions for the maintenance and valorization of the heritage. This analysis has involved, together with the students, the academic tutors who explored, within their studies, a specific attention to the themes of strategic planning.
In the second phase, the team pointed out the realization of an urban museum (IANUS) as promoter of a new attention toward the city of the Nineteenth century: this cultural institution could become a new place for public decisions and debate among citizens. In this design phase, the team was followed by a museum curator, who helped the definition of the project concept and the classification of real and virtual collections in the urban museum; meanwhile, a set of urban transformations has been planned with the aid of an architect, rethinking some of the public areas and interpreting the collective needs.

The result
IANUS is the concept of a urban museum, and its subparts propose several hypotheses for future transformations in the city of Ivrea: the new meaning and significance of virtual museums; the idea and perception of public spaces; the importance of participation in the municipality.

project 8A

IANUS
Ivrea: Architecture 'n Urban Stories

ABSTRACT

Ivrea has been influenced by the physical and ideological presence of Olivetti, determining a unique model within modern post-industrial cities. Its heritage is not only composed of high quality architectural buildings but also of a huge set of values, an immaterial richness which needs to be brought to light in order to make every single citizen more aware of the alternative industrial society project proposed by Adriano Olivetti. The suggested strategy aims to give new relevance to the town through the Great Event of Unesco candidacy. The task is therefore to render the effects of candidacy permanent, providing a solid base for future development with a long-term perspective.

Considering the specific characteristics of the architectural heritage, the main challenge for the team has been to find a creative preservation policy, in contrast with the traditional idea of a monument proposed by Unesco, coherent with the particular nature of Ivrea: currently, the heritage is spread throughout the town, covering more than 70% of its municipal area; moreover, ownership is fragmented among 1200 different people. For this reason, preservation of the architectural heritage has to shift from a single element to cover entire quarters.

The team focused on strategies e useful in managing the heritage in an innovative and active way, working both on a local as well as an international level: locally by increasing interaction between public and private sphere; globally by involving international users.

The framework for city development is a grid for the mandatory Unesco management plan intended to become a strategic plan for the entire city of Ivrea.

Within various strategies, the main solution proposed is the creation of a new museum, working as a tool for future urban transformation. It will not be or look like a traditional museum, both in terms of structure and contents: the innovation lies in the re-interpretation of an ordinary tool, the museum, in an unconventional way. Its functions will be halfway between architectural heritage management and urban planning.

TASKS & SKILLS

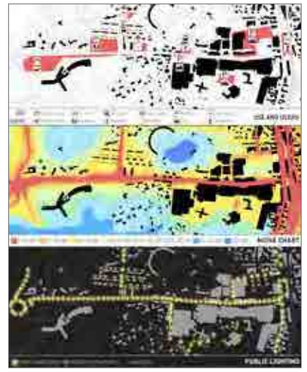
Annalisa Andaloro and **Alessia Mapelli** analysed the strategic planning dynamics and developed the grid for the Ivrea management planfollowing and innovating Unesco guidelines.

Lara Di Chio designed the overall structure of the virtual museum, defining the idea concerning the layout, animation, graphics and main navigation tree.

Francesca Giliberto analysed existing typologies of museum and proposed a new urban museum as a medium to deliver local cultural policies, defining its structure and functions.

Andrea Migliarese and **Matteo Novati** analysed the urban fabric of Ivrea, developed the museum's concept and designed two public spaces in the town as a demonstrative application of the principles.

In addition, the entire group worked together in the preliminary phase, studying the context of intervention, the Unesco procedures and exploring the potential of strategic planning through case studies.



1 *Scheme of the strategic-management plan*

2 *IANUS concept: museum references and suggestions.*

3 *Analysis of via Jervis urban fabric: users, noise levels and public lightening*

4 *Urban requalification of the public space between Via Jervis and Via Di Vittorio and new interpretation centre*

5 *Aerial rendering of the new public space from via Di Vittorio: green roof above the car park and watchtower*

6 *Rendering of the exhibition space between via Jervis and via Di Vittorio*

UNDERSTANDING THE PROBLEM

A central issue arose when the team started dealing with the complex matter of the heritage left by Adriano Olivetti in the city of Ivrea: a general lack of awareness with respect to the material and immaterial legacy and a common disregard for the contribution to the collective identity.

More than 70% of the building heritage is of private domain, fragmented among hundreds of owners: shared strategies for preservation are difficult and dialogue among institutions is poor.

Communication and promotion of the heritage are missing: internally, since citizens do not consider it as worthy of preservation and protection; externally, given that the renown of the city is limited to a sectorial audience.

EXPLORING THE OPPORTUNITIES

The team performed an analysis of the behaviours of other post-industrial cities in Europe: many of these towns are successfully rethinking their future and their set of values through strategic planning. Unlike traditional urban management tools, a strategic plan combines dynamic participation among public and private actors and development of a shared vision for the future.

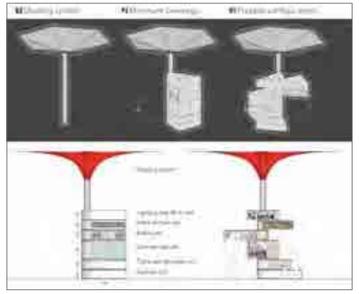
Among the effective policies adopted by the case studies, the team focused its attention on the organization of Great Events as a catalyst of development, able to attract general attention, ideas, people and investments.

GENERATING A SOLUTION

The Unesco recognition is thus identified as the Great Event that can start and contribute to guiding the transformation of Ivrea. Given the characteristics of the heritage of the city, the management plan, mandatory for Unesco candidacy, can become the strategic plan for the city.

The team decided to work on exploring different lines of action, under the common frame of the plan: the existing open-air Museum of Architecture (MaAM) is destined to undergo a radical change, increasing its role in the community dynamics and in the institutional debate, renovating public spaces located along the museum itinerary, and enhancing the virtual section with new contents.

All these strategies go under the concept of IANUS (Ivrea: Architecture 'n Urban Stories). The comparison with the Roman divinity Ianus, with its double face, underlines unity and continuity be-



7 *Example of urban learniture: kiosk with exhibition facilities*

8 *Requalification of the courtyard behind the former Olivetti factory*

9 *Scheme of the virtual museum*

tween city and museum, two sides of the same entity: the city *is* the museum, the museum *is* the city.

The strategic-management plan

The general management plan model provided by Unesco is subdivided into four different parts, called "projects": knowledge, conservation, strategic valorisation, control and monitoring.
To satisfy Unesco requirements, the team developed a specific grid of actions, characterized by innovation of previously existing techniques, for the Ivrea case. In particular, the themes of conservation, promotion and communication of the architectural heritage, which are the main aims of the project, have been dealt with using a traditional tool, i.e. the creation of a *museum*, but giving it a *contemporary* and *unconventional* interpretation. In fact, it is the result of a *strategy* for the city's renewal and, as such, should provide guidelines for its future development. The crucial innovation is the way the museum works since it is intended to *actively preserve* the heritage and create values, in contrast with traditional conservation principles which tend to put objects in a steady state where nothing can change.

IANUS - Ivrea: Architecture 'n Urban Stories

IANUS adopts a number of features from existing typologies of urban museum, but also additional characteristics make it a pioneering structure. Firstly, it is a medium to deliver local policies, promoting strategic actions:

- Actively preserving and managing the architectural heritage and consequently the cultural legacy;
- Building and interpreting the collective memory and the sense of community with direct involvement of citizens;
- Promoting studies and connecting cities around the world, linked by on-going urban transformation processes, allowing participants and visitors to discuss, exchange ideas and contribute to the creation of a shared knowledge on urban change.

Ivrea: Architecture 'n Urban Stories is composed of an interpretation centre (the core of the museum), a set of itineraries and public spaces spread throughout the city, a virtual platform available on the web.

IANUS interpretation centre

It has a cultural, institutional and research role: it is the access portal to the architectures and the city, seat of permanent and temporary exhibitions, where the visitor is initiated to the museum visit. It provides a debating arena for institutions and citizens where decisions are taken in cooperation. In addition, it produces knowledge on the theme of urban and architectural transformation, both at a local as well as international level.

IANUS around the city

Following the principle of unity between city and museum, the architectural itineraries are designed in correspondence with the most popular daily routes of citizens: if public spaces and urban furniture are to perform a dual function (museum space and city space), their use and liveliness must be continuous. An analysis methodology has been developed using the case study of via Jervis which could then be applied to the rest of the urban fabric: it involves studies on mobility flows, noise, lightening systems and private and public property.
Interstitial and marginal areas are seen as potential strengths of the urban system: they are renovated by adding parking lots, green areas and pedestrian paths, kiosks, fountains and bus stops. In the meantime, they are redesigned enhancing their role of "museum spaces": scenic and preferable viewpoints are favoured, exhibition areas are provided.
Creating flexible objects and areas makes the renovation investments worthwhile: a line on the road can serve as a separation for bike lanes while marking a museum itinerary; an elevator can bring people down to an underground car park or up to a panoramic viewpoint; a kiosk can serve as an information point. Urban furniture becomes urban *learn*-iture, an educational environment.

IANUS on the web

The virtual museum consists of a multilevel web portal featuring several interactive facilities.
It is a catalogue of knowledge on the heritage and the city of Ivrea, a collective database of memory and facts. Technical information on the Olivetti experience will be available with links to existing websites, creating a network. The complex theme of social, architectural and urban change is introduced in a visual and attractive way by means of virtual itineraries.

An interactive section for news and events stimulates involvement of visitors and citizens. In addition, users have the possibility to become *prosumers* thus creating, developing and sharing the contents of the web portal and being an active part of the information process of the virtual museum: photos, personal memories and experience contribute to writing "urban stories", available for future visitors. People walking in the physical museum can connect to the virtual museum through mobile applications.
Finally, the virtual museum acts as a showcase for news and events, an interactive noticeboard advertising the cultural liveliness of IANUS.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Carmona M., *Public places, urban spaces: the dimensions of urban design,* Architectural Press, Oxford, 2010.
[2] Ministero per i Beni e le Attività Culturali - Commissione Nazionale Siti UNESCO e Sistemi Turistici Locali (edited by), *Il modello del piano di gestione dei Beni Culturali iscritti alla lista del Patrimonio dell'Umanità - Linee Guida*, Paestum, 2004.
[3] Serrazanetti F., *Architectures on stage. Exhibit in absence/ exhibit in presence*, PhD. thesis in Urban and Architectural Planning, Rel. Prof. Raffaele Pugliese, Politecnico di Milano, 2010.

PROJECT 9

PCV

PERSONAL COMMUTING VEHICLES

project 9

PCV
Personal Commuting Vehicles

Personal Mobility: safe, clean and performing vehicles for commuting and recreational usage based on TTW active tilt & steer and electric hybrid technology

PRINCIPAL ACADEMIC TUTOR

Stefano Carabelli
Control and Computer Engineering, Politecnico di Torino

ACADEMIC TUTORS

Gianpiero Mastinu
Mechanics, Politecnico di Milano

Gianmario Pellegrino
Electrical Engineering, Politecnico di Torino

EXTERNAL INSTITUTIONS

TTW S.r.l.

Amet S.r.l

EXTERNAL TUTOR

Paolo Cavallo
TTW S.r.l - Amet S.r.l.

TEAM A

Vittoriano Renò [Team controller]
Environmentally friendly product Design

Corinna Conway
Materials Engineering

Pasquale D'Avino
Automotive Engineering

Piergiorgio Di Miscio
Automotive Engineering

Claudio Fichera
Mechanical Engineering

Ulrico Peckelsen
[Project Communication Coordinator]
Mechanical Engineering

PROJECT DESCRIPTION

The Challenge

With a seating capacity of two and a small footprint, a Personal Commuting Vehicle perfectly fully reflects the requirements in personal mobility of most commuters – because most trips are taken alone (In European cities, the average commute occupancy rate is 1.1-1.2 persons per vehicle). Moreover PCV should be as safe, stable, and energy efficient as possible. PCVs represent a design opportunity that extends from technology and style to topics that deal with social navigation, distributed data sensing for real-time representation of environmental conditions, traffic and parking optimization, peer-to-peer freight, and civic engagement. As a starting baseline for the project a Three Tilting Wheel vehicle with two seats in line, crashproof frame, and hybrid traction is proposed as a feasible solution of PCV in between maxiscooters and citycars. The main project objective is the analysis of consumer "real" demand for innovative vehicles in terms of functionality, style, and driving feelings, in particular for Personal Commuting Vehicles and the related technology needs (and costs) to achieve the goal.

project 9A

Vela Concept Car
Recreate your Recreation

ABSTRACT

A new class of vehicles has emerged to serve the personal mobility market: the Personal Commuting Vehicle (PCV). PCVs are defined as three wheeled vehicles with a seating capacity of two persons and are characterized by combining the safety and comfort of a car with the driving excitement, convenience and economic savings of a motorcycle. They are designed to be as close to energy neutral as possible with low emissions and fuel consumption, as well as to have a small vehicle footprint, helping to reduce traffic and parking issues. PCVs represent an opportunity to significantly change commuting as we know it. Our original aim was to focus on personal mobility, commuting and car sharing; however, society is not ready to accept a three wheeled tilting vehicle.

The reason for this rejection is based on the image that society has attached to everyday commuting vehicles. Vehicles are *either* four wheeled cars or two wheeled motorcycles. Not only this, but also a car or a motorcycle makes a strong image statement about the driver. The New York Times described cars as "rolling advertisements for ourselves and the chief difficulty (of choosing a car) is in choosing the right billboard." Therefore it is easy to see why the general public would hesitate in purchasing a distinctly different vehicle as a representation of their personal image. This conclusion was also based on the research and interviews conducted with industry experts.

Change is possible; however, it must be achieved in small, well-planned steps. Society has a certain capacity for change and all steps must fall within this capacity in order to be acceptable. Therefore, if a strategy is well-planned it is possible to introduce the PCV into society over time. It was at this point that we decided to change the project direction and begin the initial steps for the introduction of a three wheeled tilting vehicle into society in an acceptable way, in the hope that in the future further penetratation will be possible and that the vehicle can serve the purpose it was created for. Thus we stripped down the vehicle, salvaging only the base technology, the three wheeled tilting system, and turned our attention to the recreational vehicle industry.

Thus the *Vela* was created.

TASKS & SKILLS

Corinna Conway is responsible for the market research and the branding: she made suggestions for the design and invented the clothing line.

Pasquale D'Avino and **Piergiorgio Di Miscio** did the scenario analysis (SWOT responsible) and the technical and technological development of exteriors.

Claudio Fichera collected and analysed the survey data in order to understand which features should be developed and how we may improve them.

Ulrico Peckelsen collaborated to market research, analysing how the vehicle meets customer needs compared to already existing vehicles. Moreover, he managed communication within the team.

Vittoriano Renò realized the design and the three-dimensional project of the vehicle. Further he created images and the videos for the project development.

1 *Drop*
2, 3, 4 *Some renders of Vela*

UNDERSTANDING THE PROBLEM

The main challenge of this project, as stated above, was initially the production of a marketable commuting vehicle. However, it later evolved into the challenge of introducing a new technology into society in an acceptable way. The evolution of the project and the understanding of the true problem occurred as follows. We started by performing a market analysis on our defined target market. We determined the best cities in which to first release our PCV, as well as the upper and lower bounds of customer costs. We carried out extensive research in determining what our target market saw as important aspects to have in a commuting vehicle, as well as commuting times in order to turn the product into a truly personalized vehicle. Having all the necessary comforts to make commuting as enjoyable as possible, a sanctuary from the disorder and chaos of commuting in a city. During research of this initial step of the project we became increasingly aware of a very important problem. A red flag, most of our competitors were failing. Further analysis, and interviews conducted with market experts, revealed that the market was not ready for such an innovation. Although the idea was solid, with many clear benefits, society did not seem to be ready to accept the PCV. The response we received was "maybe in ten years, it's an investment for the future". Therefore, our approach to the project did not make sense. In ten years everything we had researched and all the innovative technologies we were planning on introducing in the vehicle would be obsolete. As it was, many of our ideas for new integration of existing technologies we saw being implemented at the Geneva motor show. This was encouraging as it confirmed that our ideas and thoughts were pointed in the right direction.

It was at this point that a new problem surfaced. How could this technology for a three-wheeled tilting vehicle be introduced into society in a way that would help facilitate its widespread adoption? This is a very important question, as well as a very important phase for the technology. If the technology is intro-

5 *Vehicle*
6 *Open doors*

7 *Tilting*
8 *Tilting*

9 *Vela in piazza Vittorio*

10, 11, 12, 13 *Different views of Vela*

duced in the wrong way it could damage its future acceptance into society. We therefore needed to introduce the technology in a positive light and thus our final project was developed. Instead of technological innovation our innovation was in the business model, in taking a technology, stripping it down and redressing it in a way to make it attractive.

GENERATING A SOLUTION

Now that we understood our problem we needed to develop our solution. The first step was determining where a technology like ours would be seen as something new and innovative in a positive light. After much research and searching we finally decided on the recreation industry. An industry in which new looks and different are often seen as positives and selling points. Once we determined our sector, it became an issue of deciding how to package the technology and position the vehicle in order to be successful in this industry. The answer to this came in the form of creating an image through branding. We were now focusing on the image the consumer had of the product. Our goal was to make the product marketable to our target market as well as to show other companies that it was possible to sell the vehicle. In essence, we had two target markets: selling our brand and concept to individuals as well as to other companies who might want to take over the brand.

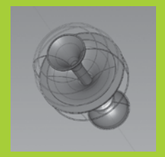
Our brand became the *Vela*, both the name of the vehicle and the brand. Just to clarify, a brand seeks to make a product seem unique or special by delivering a clear message and motivating the buyer. Brands are created by a combination of: name, sign, symbol, color combination and/or slogan. Through these, a product personality is created. We proceeded to define our brand, creating a name, logo, slogan, clothing line, vehicle design, sport and promotion schemes.

Our brand aimed to create an adventurous, cool and extreme personality. The name, Vela; the logo, a stylized signature; the slogan, *Recreate your Recreation;* the clothing, a type of jacket reinforcing the vehicle image; the vehicle, a long process of drafting, consulting target customers and then redrafting until the image satisfied the brand image as well as consumer preferences; the sport, to help pull the image together and reinforce the vehicle personality in the mind of the public; the promotion, to spread the word and let the public to experience the Vela.

Much attention was dedicated to the logo and vehicle design, since these are the visual aspects of the project and play a significant role in creating the image. We conducted surveys, consulted individuals within our target market as well as other market research to help create the vehicle image. In the end we decided on the following: The logo is a black and white abstract line drawing of a sail, derived from the meaning of the name. The vehicle, seen from above, resembles a “drop of water”, which never falls on the asphalt but simply grazes it. A “drop” which acts almost like a sailboat, “does not get lost or die in the water but constantly bounces and splashes away in any direction with great freedom of movement.” The passenger seating position was also experimented with, from a racing motorbike to the final position of a racing car in order to optimize the driving experience, satisfy customer desires and provide pleasing aesthetics.

The clothing line and logo were created to help strengthen the link between customer and brand, as well as promote the chic/cool image of the brand. In this way, even those who cannot afford to purchase the vehicle can still benefit from the brand image as well as help disseminate it.

Solutions for manufacturing possibilities, materials and promotion were also carried out and included in order to focus part of the project on the technical aspect and offer solutions and innovation to other aspects of the vehicle.



REPACK

Re-pack
Team A-B

PROJECT 10

SUSTAINABLE PACKAGING
FOR FAST MOVING CONSUMERS GOODS

project 10

REPACK
Sustainable packaging for fast moving consumers goods

The project uses plastics from renewable resources to reduce the environmental impact of packaging and has been developed in cooperation with Procter & Gamble

PRINCIPAL ACADEMIC TUTOR

Roberto Frassine
Chemistry Materials and Chemical Engineering, Politecnico di Milano

ACADEMIC TUTORS

Sergio Bocchini
Material Science and Chemical Engineering, Politecnico di Torino

Giovanni Camino
Material Science and Chemical Engineering, Politecnico di Torino

Giulio Ceppi
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Marina Foschia
Material Science and Chemical Engineering, Politecnico di Torino

Alberto Franche
Material Science and Chemical Engineering, Politecnico di Torino

Francesco Geobaldo
Material Science and Chemical Engineering, Politecnico di Torino

EXTERNAL INSTITUTION

Procter & Gamble

EXTERNAL TUTORS

Emily Boswell
Procter & Gamble

Christian Gerlach
Procter & Gamble

Bob Rohrbaugh
Procter & Gamble

TEAM A

Carlo Maria Campelli [Team controller]
Chemical Engineering

Raffaele Almici
Management, Economics and Industrial Engineering

Ahmet Aysan
Industrial Engineering and Management

Marco Bonaiti
Materials Engineering

Giuliano Butti
[Project Communication Coordinator]
Biomedical Engineering

TEAM B

Luca Macedoni [Team controller]
Management, Economics and Industrial Engineering

Serena Camere
Industrial Design

Veronica Ceruleo
Chemical Engineering

Alessandro Stagni
Chemical Engineering

PROJECT DESCRIPTION

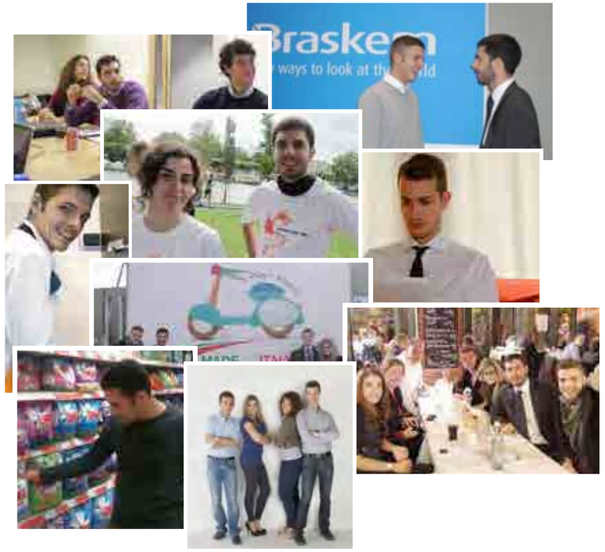
The aim of *REPACK – Sustainable Packaging for Fast Moving Consumer Good* is to achieve a more sustainable packaging for Household Care Products. Procter & Gamble, a leading company in consumer goods, is the principal partner involved in this project. According to the company footprint concerning life cycle, packaging plays a crucial role in terms of environmental impact. Addressing packaging solutions represents a key point; packaging is highly visible and therefore potentially vulnerable: it is in fact the type of waste the consumers interact with more directly. The students were required to consider not only the technical aspects but also the consumer reaction and to take into account retailer needs.

Studying possible solutions, the students stressed the 5 R's concept (Reduce, Recycle, Replace, Remove and Reuse) to evaluate how they could make more sustainable packaging for this project. Certain successful criteria boosted challenging solutions: costs must remain the same or to be lower than for current in-market products and packaging needs to be at least 10% more sustainable according Life Cycle Analysis (LCA) criteria. Furthermore, no significant trade-offs must emerge compared to current technologies. Finally, an equal or better consumer experience than in current execution was required. The students were also asked to design a product with a 3 year shelf life; in this category such a request can be tricky, mostly because detergents contain some very aggressive products, e.g. bleach, that can affect packaging properties.

This project required a combination of chemical knowledge concerning the solution for the material and innovative ideas regarding the effective strategy to promote this product, evaluating its market impact. The two groups focused on sustainable packaging for rigid bottles and flexible laminates, respectively.

REPACK TEAM A – RIGID BOTTLES SOLUTION

The objective of team A was to develop a sustainable packaging solution for rigid bottles. This kind of product is typical of developed countries. The students developed a solution involving all the life cycle phases of the product, starting with bio-derived plastic material in the production phase and redesigning the usage phase thanks to a device able to create foam, mixing water and soap. Finally they focused on the end of life scenario, introducing an effective refill solution. In order to assess the feasibility of this approach they implemented a questionnaire based on Italian consumer needs.



REPACK TEAM B – FLEXIBLE LAMINATES SOLUTION

Team B was assigned to flexible laminates, a type of solution mostly in use in developing countries. The team studied an innovative approach, replacing the traditional oil-based laminated packaging with PLA. Tests carried out in the lab proved the feasibility of this approach. India and China were selected as principal targets for this study and the group also considered an educational strategy toward sustainability.

project 10A

REPACK
Sustainable packaging for rigid bottles for household care products

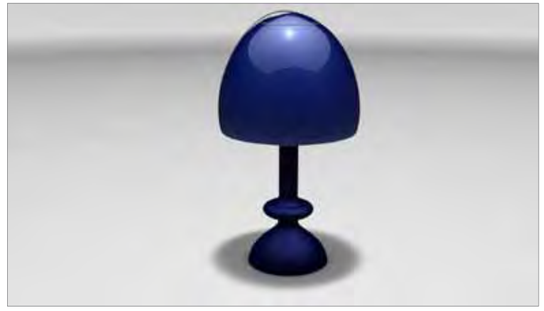
ABSTRACT

The REPACK Project arises from the growing interest that corporations such as P&G have in considering environmental and social concerns an important part of their development and innovation strategy. As a consequence, a product is not only the output of a profit-driven strategy but also has to take into consideration the impact related to its production, use and end of life scenario.
As Team A, our main aim was to develop a new sustainable rigid packaging for Fast Moving Consumer Goods (FMCG) in a home-care business unit, i.e. a hand dishwashing detergent. Success criteria in this research are the ability to reduce the overall impact of packaging with no trade-off in terms of user experience. The focus of the research, therefore,should not be only on technical aspects but rather embrace the overall product: from raw materials chosen and their supply chain to marketing positioning, finding a way to satisfy consumers and enhance their user experience.
Our methodology relied on quantitative benchmarking thanks to the approach oriented towards Life Cycle Assessment (LCA) analysis which constituted the backbone of the overall project. LCA analysis, even if not implemented in its complete format, allowed us to compare the sustainability of different solutions, make choices between materials and stress the most critical points. Moreover, it provided a means of benchmarking the improvements achieved. This led us to consider the introduction of Polyethilene from sugar cane as an alternative material. Moreover, the design of the product itself increases overall sustainability since the new cap designed for the bottle is conceived to be applied to the sink during washing, to act as both a detergent doser, to help the consumer use only the amount needed, and a foam producer to wash with less water.
Thanks to a multidisciplinary approach, the fields covered ranged from material technology to design and supply chain management. Finally, social considerations were a paramount part of the REPACK Project, due to our strong belief that an innovation-driven process must today address the main protagonist: people.

TASKS & SKILLS

Ahmet Aysan participated in the marketing part of the project and carried out research on the FMCG market and also P&G. He also has worked on the questionnaire via which the group was seeking a solution.
Carlo Maria Campelli, in his role as Team Controller, participated in the project development both with regard to the technical details as well as an overall perspective, ensuring consistency of content and continuity of communication among tutors and students.
Giuliano Butti acted as Communication Coordinator for both project teams, organizing work among students and supervisors for preparation of the posters. He also studied ways to certify product sustainability.
Marco Bonaiti handled the more technical issues of the project, including selection of material and comparative LCA analysis. Together with Carlo, he also developed the foam maximizer design.
Raffaele Almici was assigned the role of coordinating team activities, supporting Carlo in the division of work and in time management. He also organized and followed the focus group with designers, collaborating with Prof. Ceppi.

1 *Dusseldorf, K Show, 29 October 2010 _ Packaging machinery for rigid bottle*



2 *Virtual prototype of the Foam Maximizer*

UNDERSTANDING THE PROBLEM

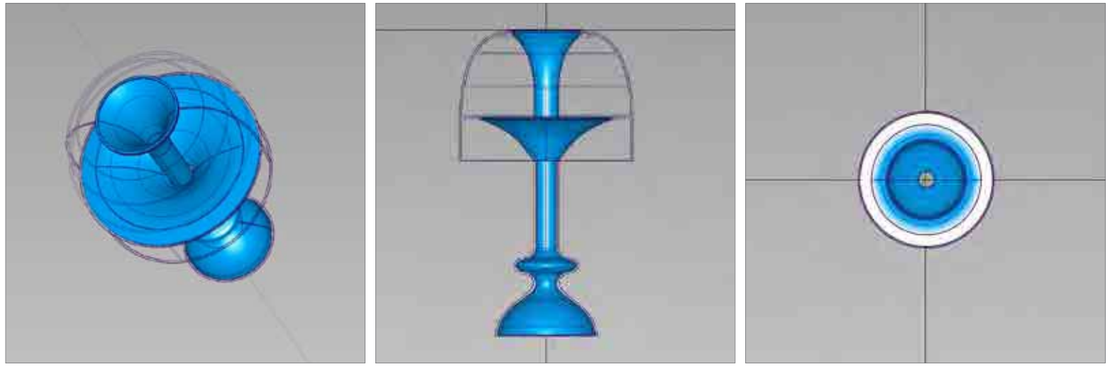
In order to meet the client's requirements we began concentrating on consumer needs. P&G assigned us the challenge of developing a new washing solution which would reduce its entire environmental impact without significantly increasing the cost. We were required to focus on the developed countries market, which provided the right parameters to set up the problem, addressing our attention to the sector of rigid bottles. ASP values have been a constant driver during the process, encouraging us to explore innovative opportunities and address the problem with a multidisciplinary approach.

By working in a team, we started brainstorming opportunities to improve the environmental sustainability of our product or to develop a concept which could truly add value for the consumer. We decided to converge all our efforts on the hand dishwashing sector, since we recognized that it was the segment in which our ideas seemed to introduce the most innovation. This particular objective allowed us to reach a complete solution with significant improvements in many areas.

To be sure to meet the target's needs and to guarantee that consumers would appreciate and exploit all the features of our innovation we also decided to set up a questionnaire. We devised a list of ten questions to investigate the preferences of product purchasers, in general and in relation to their demographic status, since our solution introduces new washing concepts, explained later. We understood that about a half of consumers would be keen to spend a little more on a more sustainable detergent, thus we identified a possible market for our solution.

EXPLORING THE OPPORTUNITIES

The methodology we chose was to approach the problem from many different angles. To develop a truly innovative solution exploring all the opportunities was only the beginning. We firstly decided what could add real value to our result and chose to focus on three main areas: technology, creativity and awareness. It was necessary to exploit new technologies to propose something which could satisfy market requirements but creativity was what we thought could really add a different and new value to our solution. Within this vision, we included in the analysis not only the product itself but everything connecting it with the consumer, primarily its choice and use. To do this we focused on consumer awareness, meaning that we tried in the end to quantify the reduction in pollution and to make this clear to the purchaser.



3, 4, 5, 6, 7, 8 *Different views of the virtual prototype of the Foam Maximizer*

With this approach in mind, we improved the environmental sustainability of our product through several ways, exploiting concepts such as recycling, reducing, refilling, reusing, reinventing and replacing. Some of these concepts eventually led to part of the solution while others did not. We firstly explored the possibility of using recycled materials but we finally ended up combining the recycling concept with that of replacement: the material adopted is both obtainable from renewable resources and recyclable at its end of life.

We tried to imagine how to exploit refilling and ended up with a new home refilling concept which is also directly connected with a reinvention of all dishwashing operations. However, not all the opportunities we focused on gave implementable results: we identified reduction of the polymer used as a possible improvement, but a complete analysis of its structure would have been beyond our capabilities in terms of time and expertise.

The same was true for the other approach we chose to improve, sustainability: analysing every single step of the product, from its cradle to a new cradle. We succeeded in reducing the polluting impact in many of these steps, from production to use and recollection for recycling. Not all presented the same degree of difficulties but in most we were able to study feasible solutions using latest technology combined with our creativity. To do this we were taught and inspired by the many activities we attended around Italy and Europe, including participation in an important trade fair (K- Show in Dusseldorf), visits to technical centers (P&G's "Brussels Innovation Center") and seminars (e.g. "Biopolymer and LCA" conference in Alessandria).

GENERATING A SOLUTION

The solution we developed comprises three different components. The first is what we called the foam maximizer. It takes water directly from the tap to which it is attached; a mechanism inside combines and mixes the water with the soap the device already contains. Foam is produced and then released from the bottom of the device in order to fill the sink. This foam replaces the combination of water and soap still used in the traditional approach, allowing the user to wash plates and cutlery. This device is recharged using a 750 ml plastic bottle in which it is inserted in order to obtain the soap required to create foam once attached to the tap. These bottles are refilled using 1.5 liter bags that can last for two applications. All these devices are created using **Polyethylene from sugar cane**; the high density version of this polymer is required for bottles and the *foam maximizer*; the low density version will be used for the bags.

The innovation in our concept lies in the approach. We tried to redesign the usage phase in which we noticed that energy consumption is higher than in the production and end of life phases. This purpose led us to design something that can reduce the amount of water required in the simplest way possible. Our approach involves all the product life cycle phases. What we obtain from this solution is a reduction in the use of packaging due to the refill, replacement of oil-based polyethylene with a bio-derived version and also an increase in sustainability in use, reducing the consumption of water thanks to the *foam maximizer* we conceived. In place of simply changing the packaging material or promoting refill behavior, leaving consumption as it is, our approach turned out to be challenging and to strongly boost the sustainability of the hand dishwashing sector.

Our product is quite different compared to traditional products in the sector; furthermore it requires a change in user behavior. Therefore, the importance of communicating the concept of sustainability and ease-of-use of our device requires intelligent communication with users in order to be able to succeed. The way this new product is accepted by users is fundamental to its success, allowing an astonishing improvement in sustainability of household care products

MAIN BIBLIOGRAPHICAL REFERENCES

[1] C. Liptow and A. Tillman, *Comparative life cycle assessment of polyethylene based on sugarcane and crude oil*, Chalmers University of Technology, Report No. 2009:14 Göteborg, Sweden, 2009
[2] G. Sparovek, A. Barretto, G. Berndes, S. Martins, R. Maule, (2009), *Environmental, land-use and economic implications of Brazilian sugarcane expansion 1996-2006*, Mitigation and Adaptation Strategies for Global Change, 285-298
[3] S. Boylston, *Designing Sustainable Packaging*, (2009), Laurence King Publishers

project 10B

REPACK
Sustainable packaging for flexible laminates for household care products

ABSTRACT

The REPACK project dealt, as the name may suggest, with the design of a new sustainable packaging for household goods; in particular, our team had to focus on developing countries as a target and therefore on flexible laminates.

Our objective consisted of developing a concept for brand new sustainable products, with the same or lower costs and a three year shelf life; several choices were made throughout the project process, such as replacing the material with a new type, focusing on the markets of China and India, selecting sachets as the most interesting typology, designing consumer-appealing packaging and, last but not least, building a scenario for education towards sustainability.

From the very outset, an optimal balance between experimentation and research had to be maintained: after a preliminary study of materials, we chose to replace the traditional oil-based laminated packaging with PLA, a bioplastic derived from sugarcane. A number of tests were carried out in the University labs in order to verify the compatibility of PLA with samples of shampoo and laundry detergent.

Understanding that sustainability is no longer only an ethical value but more reasonably an added value of the product is the first step to ensure good packaging design; therefore usability, distribution and, of course, appeal of the product itself must all be taken into consideration. Yet, reaching a good level of awareness of the targets we were going to work on has not been an easy task: reliable information sources are mostly missing, but comparing results from marketing and the socio-anthropological analysis we managed to obtain a good picture of India and China. Other sources of inspiration came from widespread research in the packaging design field which was particularly interesting in order to develop a specific brief and to understand the main features our product should respect. Cultures, traditions and people, first and foremost, have been our target, aiming to improve the daily routine with a new, sustainable and innovative concept.

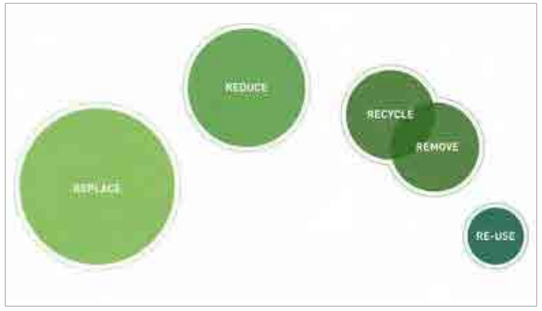
TASKS & SKILLS

Serena Camere carried out a benchmarking case-study in the packaging design field and managed the design of the final output.

Veronica Ceruleo helped in defining the technical solution, dealing with the selection of material and the experiments required to validate the choice.

Luca Macedoni provided a market analysis of developing countries and the economical feasibility of the final solution.

Alessandro Stagni dealt with evaluating the environmental impact of materials and also assured proper communication between the team and the stakeholders.



1 *5R-01 - 5Rs Strategies for Sustainability*

2 *P&G products in high frequency stores - P&G products in high frequency stores*

UNDERSTANDING THE PROBLEM

Designing sustainable packaging in developing countries is not an easy task. Firstly, improvement efforts should be focused on a limited set of products; secondly, to cover all aspects of sustainability, the project should be based on a consolidated approach.

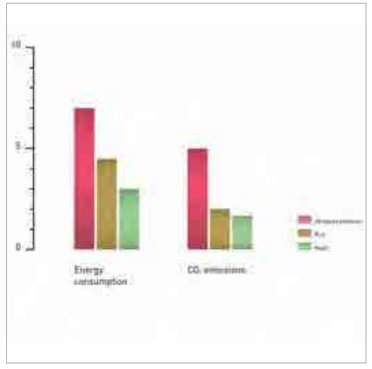
Selection of products requires a market analysis of developing countries. In fact, despite high growth rates, poor people are still the majority in emerging economies. The gap in pro capita income between Western countries and developing economies brings about several differences in the market for consumer goods. The first difference involves affordability: as the average Chinese consumer spends 3$ a year on P&G products, they must have affordable prices. This aim is achieved by reducing the features or the dimensions of goods, such as mono-use packages of shampoos and detergents; therefore, price will be a crucial constraint of the final solution. The second difference between developed and emerging markets involves the distribution system. In developing markets, virtually 70% of P&G products are sold in high frequency stores, which are small kiosks filled with products. In these kiosks, the visibility of products is crucial. Meanwhile, such different cultures affect the product perception by customers who are greener and much more innovation-driven than one might expect.

Our approach followed a well-known approach called the 5R's strategy: *reducing* and *removing* material from the package is the most rife solution among FMCG firms. *Recycling* and *reusing* are less used because of the lack of control on the end of life of the product. *Replacing* the incumbent material with renewable material is constrained by a series of challenges, from the required shelf life to the pressure on costs. Each strategy was analyzed, considering its effectiveness with the Life Cycle Assessment, which provides a measure of product sustainability.

EXPLORING THE OPPORTUNITIES

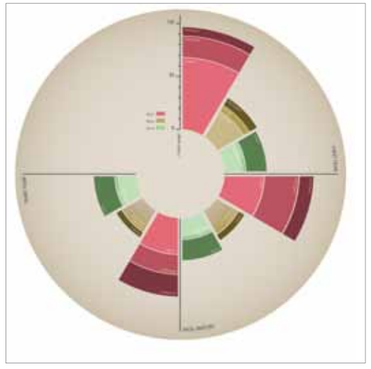
Starting from the 5R's approach, we decided to first concentrate on the *replace* keyword, changing the packaging material. Currently, the development of alternative polymers is moving in two different directions: bioderived polymers, obtained from renewable resources, and biodegradable polymers which completely solve the issue of the end of life of packaging.

One of the most promising materials in this field, both bioderived and biodegradable, is polylactic acid (PLA). When compared to traditional polymers, a similarity of several mechanical



3 *energy consumption and CO2 emissions-02 – Comparison between environmental impact of traditional raw materials and PLA*

4 *Snapshot of PLA samples tested in Alessandria lab*



5 *Trend of tests on PLA samples held in Alessandria lab*

properties can be observed. Yet, PLA behaves very differently from conventional plastics in terms of barrier properties: its higher permeability coefficients strongly influence product shelf life since it is necessary to avoid dehydration. Therefore, we decided to make experimental tests in severe conditions (high temperature and physical stress) to simulate material decay, thus accelerating the time required and verifying whether the new material was compatible with the three year shelf life required by our external institution. We tested three different materials: first of all, pure PLA has been taken into consideration; then, its performance has been compared to two different types of coated PLA.

The test results were then compared with similar experiments on single-dose products already bought on the market. It was found that thebest performance was achieved by one of the two kinds of coated PLA, which anyway decays, in terms of percentage loss of weight of the content, nine times faster than traditional polymers. This issue could be faced studying the storage system in a proper manner.

At the same time, an in-depth research on packaging design was carried out, analyzing some interesting case-studies and understanding the various features we had to focus on: we drew up a list of the characteristics our product should consider, such as a user-friendly dispensing system, a well-designed opening and closure method (possibly without including other materials), a good distribution service and, of course, high appeal and clear communication. Also, a range of esthetical values was defined: transparency, cardboard integration (also to protect the product) and a recall to tradition.

GENERATING A SOLUTION

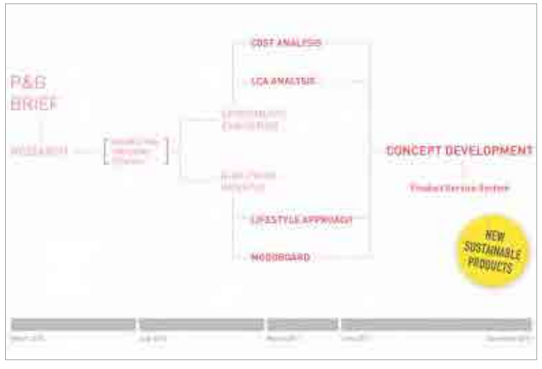
The experimental results achieved by performing tests on the old and new material served as a solid basis for developing the final concept. Indeed, the final product had to meet two main requirements: having at least the same techno-economical features as current solutions on the market but, in particular, with the added value of sustainability. Sustainability in packaging can be defined from three different points of view: economical, social and environmental. Thus, all of these three aspects were considered in assessing the validity of the proposed solution.

The team analyzed the available background literature in depth in terms of technical and environmental data concerning raw materials, as well as finished products. First of all, the eco-profiles of the old and new materials were compared: analyzing the trends shown in the figures, it is clear that the production of polylactic acid has a much lower environmental impact than other traditional polymers currently used for packaging.

On the other hand, a full understanding of the environmental impact can be achieved through a complete, cradle-to-cradle, Life Cycle Assessment on finished products. Also in this case, the results are very promising: thanks to technological enhancements in the PLA production process, eco-indicators show a significant reduction in its environmental impact, compared both to traditional polymers and to PLA itself, as produced in 2005.

Of course, LCA alone cannot provide a universal answer to the issue of sustainability, since results strongly depend on the hypotheses made; nevertheless, it has been an essential tool in providing a quantitative answer to the comparison between the traditional and the new background.

As soon as the experimental part ended, we started the design of our new products, concentrating on two kinds of packaging: a single-dose for a shampoo and a multi-dose for laundry detergents. Focusing on the markets of China and India, we studied their traditions and attitudes towards these daily and intimate activities and came to the following conclusion. For the shampoo, inspired by an innovative dispensing system, we decided to turn one of the possible weak points of the material, i.e. its rigidity, into a product feature: breaking the pack in the center, it opens up forming a comb, through which the shampoo is distributed. Concerning the laundry scenario, we focused on the quantity of detergent to be sold: we assumed that a laundry single-dose could contain up to six washing doses and so we developed a very functional packaging that can be



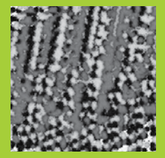
6 *Repack Team B project timeline*

produced and sold as three to six doses. Thanks to its shape, it can be easily separated in order to use just one dose at a time.

Finally, we worked on an educational campaign towards compostability, building a scenario involving different players and timings, taking inspiration from the sense of collectivity which is much stronger in Indian and Chinese cultures than in Western society.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Auras R., Harte B., Selke S., "*An Overview of Polylactides as Packaging Materials*", Macromolecular Bioscience 4:835-864, (2004)
[2] Vercalsteren A., Spirinckx C., Geerken T., Claeys P., "*Comparative LCA of 4 types of drinking cups used at events*", OVAM, Belgium, (2006)
[3] Bucchetti V., Ciravegna E., "*Innovation in Packaging Design. Keywords and Tools*" Ed. Dativo, (2010)



PROJECT 11

Build Smart

Build Smart

ENERGY EFFICIENCY AND RENEWABLE ENERGY FOR INTELLIGENT AND SUSTAINABLE BUILDINGS

Build Smart
Energy Efficiency and Renewable Energy for Intelligent and Sustainable Buildings

project 11

Expert tool providing guidelines for the design and integration of technical solutions for minimizing primary energy consumption of buildings. Supported by ENI.

PRINCIPAL ACADEMIC TUTOR

Giovanni Vincenzo Fracastoro
Energetics, Politecnico di Torino

ACADEMIC TUTORS

Cristiana Bolchini
Electronics and Information, Politecnico di Milano

Federico Butera
Building Environment Science Technology, Politecnico di Milano

Pier Luca Lanzi
Electronics and Information, Politecnico di Milano

Bartolomeo Montrucchio
Control and Computer Engineering, Politecnico di Torino

Roberto Pagani
Human Settlements Science and Technology, Politecnico di Torino

Maurizio Rebaudengo
Control and Computer Engineering, Politecnico di Torino

EXTERNAL INSTITUTION

ENI S.p.a.

EXTERNAL TUTOR

Lorenzo De Vita
ENI S.p.a.

TEAM A

Alessandro Aimar [Team controller]
Energy and Nuclear Engineering

Carlotta Berta
Building Engineering

Daniele Ferrigni
Aeronautical Engineering

Yangfan Gao
Computer Engineering

Ilaria Ricci Curbastro
Architecture

Beatrice Spolidoro
Architecture

TEAM B

Matteo Ronchi [Team controller]
Mechanical Engineering

Simone Barra
Environmental and Landscape Architecture

Matteo Carminati
Computer Engineering

Chiara Gammaraccio
Building Engineering

Andrea Lambertenghi
Aeronautical Engineering

Luca Malvicino
Architecture (Urban and Territorial Design)

Xintao Ye
Architecture

PROJECT DESCRIPTION

The Challenge

The two teams addressed an important and topical challenge: how to design a new residential or office building achieving the best energy performance at a certain extra cost, or minimizing the extra cost required to achieve a certain energy performance.
To that aim, a number of specific data bases of the most important technologies for building envelopes, thermal and air conditioning systems and renewable energy systems were prepared and specially tailored for the two building typologies analyzed. The databases include costs and energy performance of these components, along with meteorological data of different Italian cities.
An original software was written for the evaluation of heating and cooling energy requirements and primary energy demand for the two building typologies. The software also performs an optimization analysis and, as an example, has been used to analyze a typical residential and office building.
Both teams were composed of students with a heterogeneous background: architects, building engineers, energy and mechanical engineers and information technology engineers. They had to frequently interact and an interesting integration of their cultural background had to take place in order to achieve reasonable and consistent results. To this aim, they participated in a number of events, such as the Bologna SAIE Congress and ENI the Donegani Research Centre in Novara.
Team A has devoted its analysis to *office buildings* while Team B worked on *dwellings*. The two building typologies have different energy requirements and make use of different building envelopes and installation technologies. Team A considered the heating, ventilating and cooling demand of offices while Team B focused on ambient heating and domestic hot water demand of residential buildings. On the other hand, while Team A considered only Photovoltaic Team B also considered Solar Thermal systems. All together, the efforts were well balanced between the two teams, as well as within each team.

The final result is a software tool which can be used to evaluate the energy performance of the two building typologies and identify the best set of technologies to achieve a certain target in terms of primary energy demand. The multicultural technical approach, along with the economic evaluation which is always carried out together with the technological choices, has produced an interesting and original result which may be used at the first design stage of new buildings.
Further developments may easily extend the analysis to other geographical and climatic areas, and other building typologies, while a somewhat larger effort would be required to include other energy demands such as lighting and other electrical usages. On the installation side, a more thorough analysis would be required to describe all relevant innovative technologies, especially those based on renewable energy (ground-coupled heat pumps, solar cooling, greenhouses, PV windows, etc.). Finally, the data bases would need to be periodically updated in order to take into account varying energy and component costs. Regular updating of this software will ensure its reliability, so as to make it a valuable tool for the designer.

project office 13A

Build Smart Office

Energy Efficiency and Renewable Energy for Intelligent and Sustainable Buildings

TASKS & SKILLS

Alessandro Aimar worked on the establishment of the database providing data on heating systems and solar panels and helped computer programmers, paying attention to formulas implemented and result exactness.

Daniele Ferrigni worked on the main script of the software, implementing the calculation of energy requirements and costs of all the technological solutions.

Carlotta Berta contributed to the establishment of the database for the building envelope, to the development of the program for the part concerning the energy requirements for heating and to the analysis of the geometrical inputs of the software.

Yangfan Gao contributed to the creation of the database and the design of the software interface, taking care the technical and computer aspects.

Ilaria Ricci Curbastro took part in the database construction and case studies analysis. She took care of the qualitative shape of the software with focus on aspects useful to designers and worked on the graphic development of the project.

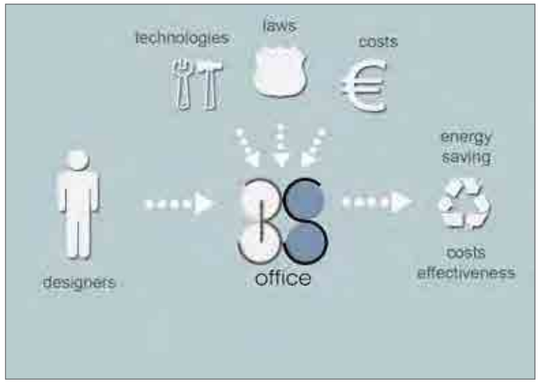
Beatrice Spolidoro participated in the database construction process (frames), analyzed the architectural aspects of the software, designed the logo and helped in developing the guidelines.

ABSTRACT

Architecture and energy science can now converge in a smart way. The issue of sustainability in the construction field, approached from an energetic point of view, is the core of the Build Smart project. This software can help architects, engineers and designers in giving shape to an energetically efficient building project, helping them in the preliminary design process. The main overall feature of the software is that of providing a variety of possibilities in choosing materials, technologies, design strategies and systems in order to obtain the best ratio between energy consumption and the global cost of technologies.

The final aim is not to reach the complete zero-energy building, since that would be the best solution from the energetic point of view but is not the smartest in terms of cost-effectiveness in real life. Values are assumed as references and these are: the worst possible from an energetic point of view and those suggested by legal constraints. The "greenest" solution cannot be the smartest from an economic point of view.

Developed in parallel from an architectural and energetic point of view, according to each team member's ability, our software was written specifically for offices and commercial buildings. The issue of a sustainable office, even temporarily putting aside legal issues and the moral onus, is topical and data confirm that it is highly recommendable to start to consider the development of suitable tools to respond to the increasing energy demand; BS_office not only provides useful guidelines to initial planning but also explores a variety of different solutions in order to reduce such demand, leaving the user complete freedom in the decision process.



1 *Exploring the opportunities*

UNDERSTANDING THE PROBLEM

One of the most characteristic worries of the nineties' was related to the energetic crisis. If in the past almost nobody cared about the problem and trusted in a steady infinite development, both industrial and economic, at least since the seventies' it is clear that we can no longer imagine to consume energy in the same way we were used to in the past.

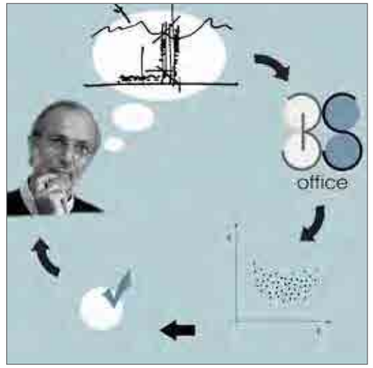
The present situation of caring for the environment is a real concern of almost all countries, with specific laws to be respected. Italy is no exception and, according to the EU trend, we must consider that every aspect of our life is destined to become increasingly sustainable. The Build Smart project has been designed to help designers in an effective way in solving certain internal contradictions typical of the design process in a building. Team A developed the software dedicated to offices and, considering the data provided by the research "RAPPORTO ENERGIA AMBIENTE 2007-2008" by Enea (the Italian National Agency for new technologies), it is evident that the tertiary field has particular needs in terms of energy demand. Looking at the final consumption of electric energy for the 2007, for example, one can see that comparing industry with the residential and tertiary sectors, the former consumed 11.999 thousand TOE of electricity compared to 13.221 thousand TOE of the latter; tertiary alone, in the specific analysis, consumed 7.440 thousand TOE. It goes without saying that all these consumptions are constantly increasing to date.

Reducing both electricity and gas demand (other Enea research clearly shows that the main consumption in the tertiary sector is related to these sources) depends on a number of factors strictly correlated with a correct design process, but is not immediately apparent to the designer without software such as this. Based on sector studies, on a selection of suitable technologies and on energy demands and legal requirements, BS_office can truly play a fundamental role, making the difference in the consumption panorama.

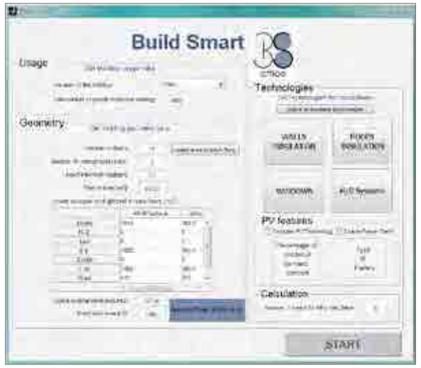
EXPLORING THE OPPORTUNITIES

The analysis of computer programs now available for energy simulation of buildings opens up a wide scenario of alternatives. These programs are all based on Italian legal constraints and are widely used for the Energy Certification of buildings. "EdilClima", "TERMOLOG EpiX 2", and "DoCEt" are just some of the most important and successful ones. All of these products allow users to calculate and verify energy use in buildings, thanks to a vast database of climate data and building materials, and therefore they are basically used in an a posteriori phase to verify designers decisions.

What makes our "Build Smart" different from other products available on the market is the opportunity to use it in a pro-active way during the preliminary design of the building since it is not just aimed at passive calculation of energy requirements of the building once designed. Thus, the software provides architects and designers with real feedback, helping them generate an optimal solution, aiming to maximize energy saving whilst minimizing investment. BS_office can provide a user-friendly approach to this task, guiding him through all phases of the job and providing prompt support in three main ways: calculation of energy requirements of the

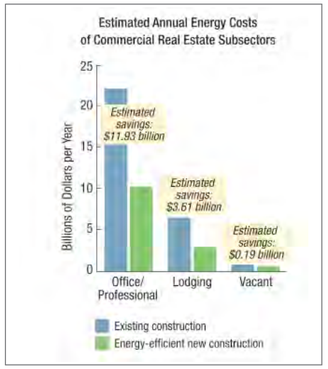


2 *Generating a solution*

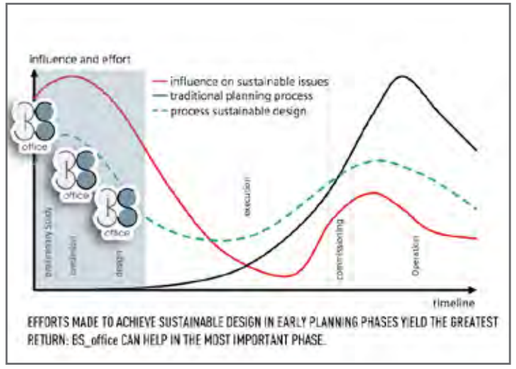


3 *Sample picture of the software realized by Team A*

4 *Image of external studies conducted to analyze the types of consumption by source (by U.S. Department of Energy)*



5 *Estimating Annual energy costs of commercial real estate subsectors (by U.S. Department of Energy)*



6 *Influence of BS-office in the early planning phases*

7 *"Build Smart Office" logo*

building, direct comparison of several technologies and creation of a "cloud of possibilities" from which to choose.
The first, probably similar to other programmes already on the market, is the calculation of the energy requirements of a building as it is designed with all the technical features the designer has chosen.
The second useful possibility is the comparison of new consumption and costs related to different technologies; this means that the user can directly evaluate the result of his choices beyond the strictly aesthetic point of view, clearly seeing the direct consequences of the selection of a certain kind of window, wall, roof or system.
The third and most innovative opportunity provided by Build Smart is that concerning the possibility to examine a large range of technologies, before choosing the final solution, by analyzing the "energy consumption-costs" cloud-graph to find out the most suitable solution in terms of cost/benefit; this allows the designer to directly and easily compare the percentage of energy saved and the related technologies that make this possible, together with the corresponding costs.

GENERATING A SOLUTION

Following an insight of the energy-calculation software market, the Build-Smart group decided to develop its own software using MATLAB®, a computer science platform used for mathematical applications with an high-level library of existing functions. This choice was made in view of team members' programming skills and also due to the capability of the software to process mathematical objects such as arrays or matrices.
The Graphic User Interface (GUI) of the program is the starting point for calculation: the user inserts in the specified windows geometrical properties of the commercial building, such as the value of each surface exposed to North, South, West or East, its location in different Italian cities, the number of workers on each floor and the value of each glazed surface.
In addition, the user can choose from a set of possible technological solutions to be taken into account to provide insulation, heating, cooling and generation of electricity for a standard commercial building.
The GUI allows the user to choose from a list of several types of walls, with different insulation features, as well as windows or types of roofs which can be installed on commercial buildings. Regarding the systems, the GUI offers a list of four possible solutions to provide heating; for each of these,the program selects another to provide cooling during the summer. Since the need for electricity is significant in commercial buildings, the latter is provided by a photovoltaic system, installed on the roof, and the user may choose among three different types of panels. Moreover, there is the possibility to set the percentage of the overall electricicity requirement to be satisfied by PV panels.
The software then starts the calculation and finally provides the results in both graphic and numeric form. For each combination of technological solutions, the program calculates the percentage of annual energy saving compared to the worst case, along with carbon-fossil emissions and the Net Present Value after fifteen years, recording all data in a report. The user can finally see in this document which is the most convenient solution in terms of energy saving, as well as the global financial expenditure, including investments and energy consumption costs.
At the end of the software process, BS_office will not guide designers towards a unique solution but will provide graphs and a text file showing the range of reasonable possibilities to be immediately compared and easily evaluated. The guidelines, therefore, will help users in finding a variety of case studies to compare the obtained results with, understanding the possible choices and implementing an aware and smart project.

project 13

Build Smart @ home

Energy Efficiency and Renewable Energy for Intelligent and Sustainable Buildings

ABSTRACT

Sustainable building is nowadays becoming not only a possibility but also a necessity. BS@home can be very useful in tackling this problem, especially conceived for architects and designers of residential buildings. This tool has the capability of merging different crucial aspects related to sustainable building, taking into account the whole. These aspects, that is the energetic and economic aspect, were traditionally treated by architects based on their experience and sensitivity: This approach, with the exponential growth of new technological solutions, is becoming increasingly less accurate and the need for an expert-tool is felt. The main opportunity that BS@home provides to an architect is to explore a virtually infinite number of cases, obtained by combining all the different choices imaginable in a building: walls, windows, roof, heating systems, solar panels, photovoltaic panels and many more can now be taken into account in a unified vision. The expert-tool is thus able to calculate the energetic and economic requirements of each of the thousands of combinations that can be obtained. The designer could never do all this in his mind! At the end of the calculation, which are also carried out according to local laws, he will be able to choose, among all the solutions available, those which are most economically advantageous in an appropriate future time horizon and have visibility on the percentage energy saving they provide when compared to a traditional base case. It should be highlighted that the software is also designed so as not to limit the architect more than expected, leaving him the freedom of expressing his creativity, but also guiding him every step of the way in making the most important decisions throughout the development of the project. BS@home, as the name suggests, is especially designed for residential buildings and offers an expandable database of suitable technologies suitable for the home, covering a wide range of house dimensions, ranging for a small detached house to a big skyscraper. These very different types of buildings, as well as the building location and exposure, can be easily described to the software by using its very intuitive graphical interface.

TASKS & SKILLS

Matteo Ronchi coordinated the team for subroutine integration and implemented the calculations for building energy requirements, total economic evaluation, photovoltaic performance and solar window applications.

Simone Barra participated in the creation of the database, taking care of the aspects related to the roof component in its technical and economic aspects. He participated in developing the final of case study data on which the software was tested.

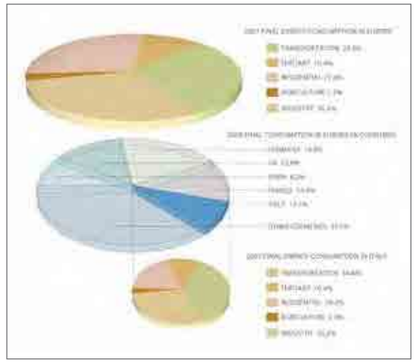
Matteo Carminati focused his attention on selecting the programming tools and in designing/implementing the GUI expert tool (first in Java, then in Matlab). He collaborated in software design, implementation and debugging.

Chiara Gammaraccio developed the technology database, focusing especially on the wall. She collaborated on the simulation of case studies to verify the accuracy of the software.

Andrea Lambertenghi worked on preliminary software analysis and architecture, implemented the solar-thermal routine. He collaborated in software validation and debugging and studied initial GUI solutions.

Luca Malvicino analyzed different technologies for the database. He collaborated in implementation of the solar-thermal calculation and in the choice of the software input data. He simulated a number of case studies to test the software.

Xintao Ye analyzed building envelopes and organized materials for the computer assisted design method. He participated in logo design and researched the PV part of the project.



1 *Energy consumption statistics in Europe and in Italy – Enea*

2 *Software applications that the designer uses in the different part of the project and BS@home software*

3 *From building energy needs to green solutions: the idea behind BS@home.*

UNDERSTANDING THE PROBLEM

A sustainable building can minimize or eliminate negative environmental impact, thanks to a conscious choice. This can be made possible through the improvement of design, construction and usage measures compared to common techniques. A project conceived with sustainable criteria can reduce operating and maintenance costs and increases the market value of the building. The payback regards users of the building, the owners, the occupants and the general public. Therefore, adoption of sustainable practices in building design generates environmental, economic and social benefits, locally as well as globally.

The environmental impact of building usage is significant: 2006 European statistics showed that residential buildings are responsible, directly or indirectly, for approx. 28% of energy consumption, the same as transportation or industry. In Italy, the final energy consumption in 2007 by sector is very different, according to ENEA "Rapporto energia ambiente 2007–2008": transportation consumed 45,432 ktep (thousand tonnes of oil equivalent), industry 39,681 ktep, residential 26,437 ktep and tertiary 16,398 ktep. [1] The need to reduce the energy load and to increase global residential building efficiency is thus a challenging issue.

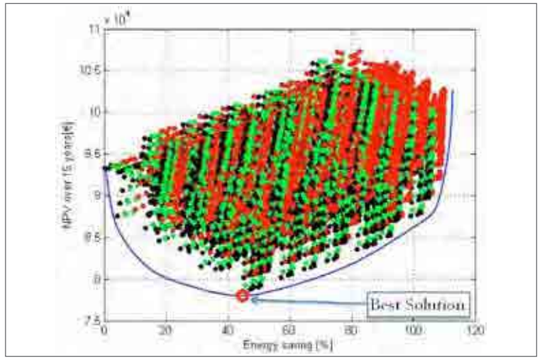
The stakeholders of the project, which need to discuss overall green building strategy, are: architects, building engineers, energy engineers, designers, final users and Eni. The legal requirements, constantly updated, should not be omitted from this analysis in order to ensure an integrated design approach.

EXPLORING THE OPPORTUNITIES

State of art

The BS@home software, being an expert tool, fits into a specific genre of programs that help designers in the creation of sustainable buildings. There are many software products related to this subject but they can be divided into two groups: software for energy certification of buildings, such as DOCET, EDILCLIMA, KLIMA HAUS, THERMOLOG EPIX..., which aim to calculate the energy requirements of an existing building and software which helps the designer in various parts of the design process, such as ECOTECT ANALYSIS, POLYSUN, and so on.

4 *"Build Smart @ Home" Graphical User Interface*



5 *Graphical display of results showing the best economical solutions*

In creating BS@home, we tried to combine these two types of software. In fact, it is an expert tool that can help the designer in selecting the best technologies, those that provide better energy saving in relation to their cost and the location of the building and can be used in the preliminary phase of the project or simply to check the building's energy requirements.

Technology database

In particular, to develop the software, we created a database with the most common technologies used in the design of residential buildings: vertical opaque envelope, roof, basement, heating system and, in addition to traditional windows, we included the innovative solar windows of ENI, our principal sponsor. This was necessary to allow the program to choose the best combination and obtain a unique solution that optimizes the positive qualities of all the elements of a building and provides the best balance between energetic quality and price for all elements considered.

A specific study was carried out for solar panel technology. The Italian law (D. lgs 311/06) states that, in all new buildings, at least 50% of domestic hot water needs should be met by solar thermal and/or renewable sources. In our database, therefore, different types of solar collectors were included and a function taking account of the Italian law in relation to DHW was implemented in the software. [2]

Programming environment

The choice of the programming environment for the expert tool proved to be one of the most critical steps in project implementation. Two were the fundamental requirements we were looking for. On the one hand, a large mathematical library containing all the functions needed to perform our computations. On the other, an easy way to implement an appealing graphical user interface. At the beginning we focused our attention on the Java programming language, offering simple yet powerful graphical libraries. However, the available mathematical functions were not sufficient for the computations of our expert tool. Finally, we decided to use Matlab as programming environment, preferring the broad mathematical support to more complex graphical libraries.

GENERATING A SOLUTION

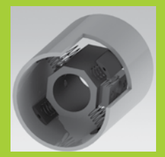
The solution was developed in a Matlab® environment in order to best meet our programming abilities, having at the same time the possibility to write code with a certain flexibility and ease. The software is composed of different sub-routines which interact in order to perform all the required calculations and display the results to the user. These calculations are transparent to the user who is only asked to run the software by using a Graphical User Interface, designed ad-hoc. For BS@home, the main input data is related to building usage and location, as well as geometric data such as the number of people, the number of floors, the Gross Volume and all the wall and window exposures and corresponding surfaces (and many more). The program can then be run is two different modes: a 'free' and a 'constrained' mode. In the free mode, which is obtained by clicking on the 'Select all available technologies', the software will automatically run considering all the possible technologies which have been chosen as suitable for residential buildings according to our analysis. These technologies can be gathered in different groups, which are walls, roof, windows, thermal solar panels, photovoltaic panels and heating technologies. It has to be pointed out that under each of the groups there are different technologies, not only in terms of performance, but also in terms of physical principles on which they are based. To leave the user more freedom, certain technologies under each group can be excluded in order to put additional constraints on the solutions. For example, the designer could choose to heat the house with condensation boilers or not to install any PV panels: all these decisions can easily be made by the user via the GUI. When the user presses the 'Start' button, the software, using the entire data set provided, starts calculations on the thousands of possible combinations originating from the selected technologies. For each solution, depending on the location and geometrical features, the energy requirement of the building is calculated, both in terms of thermal energy (for heating and domestic water) and in terms of electricity (based on the average consumption of the family units living in the building): these are all then translated into primary energy. The calculation can take from some seconds up to approx. one hour, depending on the number of technologies chosen; the results are then displayed both in graphical and text form, showing the designer which solution is the best in economic and energetic terms.

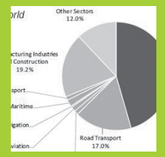
6 *"Build Smart @ Home" logo*

To test the validity of the program and verify its usefulness in the definition of the architectural concept, we chose nine case studies of residential buildings, recently built and available in major architecture magazines. The choice was made purely according to dimensions (large, medium and small) and type (tall or low, single or multi-family...). From this point we extrapolated the data of all building components for each building (opaque and transparent surfaces according to the different exposures, cover size...) in order to enter them in the program and perform the simulation according to the previously developed technologies. In this way it was possible obtain feedback on which part of the building requires most attention in its design in order to find the best balance between energy savings and costs incurred.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] *Rapporto energia ambiente 2007-2008*; Enea, 2009
[2] Battistini R., Corrado A., Micangeli A.; *Impianti solari termici, acqua calda con l'energia solare*; Franco Munzio Editore, Roma, 2005





PROJECT 12

Smart Environments

INDOOR AND OUTDOOR MONITORING APPLICATION USING WIRELESS SENSOR NETWORKS

Smart Environments
Indoor and Outdoor Monitoring application using Wireless Sensor Networks

project 12

The project, developed in cooperation with Concept Reply, aims at designing and implementing a self powering wireless CO_2 sensor to be installed at the outlet of a car exhaust pipe.

PRINCIPAL ACADEMIC TUTOR

Giovanni Malnati
Control and Computer Engineering,
Politecnico di Torino

ACADEMIC TUTORS

Aldo Canova
Electrical Engineering,
Politecnico di Torino

Cosimo Greco
Control and Computer Engineering,
Politecnico di Torino

EXTERNAL INSTITUTION

Santer Reply S. p. A.

EXTERNAL TUTOR

Daniele Marietta Bersana
Santer Reply S.p.A.

TEAM A

Shangwen Qiu [Team controller]
Automotive Engineering

Luca Gaetano Amaru
Electronic Engineering

Federico Capiaghi
Biomedical Engineering

Michele Miccio
Automotive Engineering

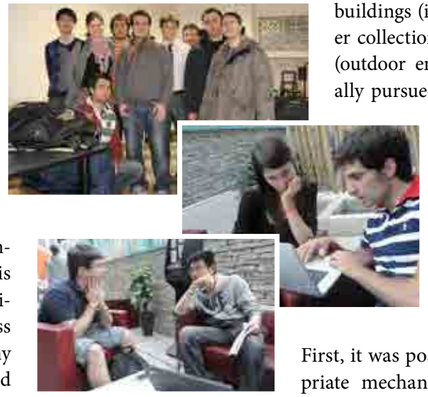
Viktoriya Sendyureva
Environmental Engineering

Camillo Stefanucci
[Project Communication Coordinator]
ICT Nanotechnologies Engineering

PROJECT DESCRIPTION

The Challenge

The reduction of environmental CO_2 emissions is one of the major challenges for growth sustainability of the present century. Road transportation and building heating, ventilation and air conditioning (HVAC) systems constitute the two most relevant sources of carbon dioxide in consumer related activities. In order to reduce these emissions, it is possible to leverage on several factors: using more efficient technologies, adopting less polluting energy sources and reducing end-user needs. This last option can be stimulated through appropriate incentivizing policies, and creating awareness of the consequences of certain behaviour. In any case, analytical details concerning quantities and localization of CO_2 emissions and energy consumption processes are necessary. Although appreciable results can be obtained as a consequence of careful design in new buildings or vehicles, to measure the approximate amount of emissions and consumption in the existing installed base, retrofit systems must be planned, designed and installed. This information, together with its space-time context, provides an indication of individual and collective behaviour, in the light of which, efficient system decisions can be taken to encourage virtuous behaviour and discourage other less virtuous types. The goal of this research was the design of affordable systems for pervasively measuring, collecting and distributing analytical data on energy consumption and CO_2 emissions. These measurements must be carried out in the context of highly distributed systems which have not been explicitly designed to provide such information.



The teams

Although the initial research proposal was conceived along two complementary directions, one concerning energy monitoring in buildings (indoor environment) and the other collection of CO_2 emissions from vehicles (outdoor environment), only one was actually pursued due to the availability of a single group of students. Given the actual interests and expertise of the group, the outdoor project was chosen. The heterogeneous skills of students involved contributed in effectively addressing the multiple scientific and engineering problems associated with this issue.

First, it was possible to identify the most appropriate mechanical, automotive, hardware and software technologies and to produce a laboratory prototype of the envisaged system. Other studies were conducted concerning the economic viability of the project through identification of the stakeholders involved and development of an appropriate business model.

The results

The activity led to the creation of a prototype, its validation in the laboratory and the definition of a set of specifications for its conversion into an industrial product.

Particular emphasis was given to adoption of technologies facilitating low-power operation of the wireless sensor nodes using energy harvesting techniques to collect all the energy required from renewable sources in the surrounding environment (vibrations and heat).

The business model showed that, through the appropriate use of incentives, it is possible to create conditions making the adoption of the designed system sustainable and affordable, at least in urban areas with high-density traffic.

project 12A

Smart Environments
Indoor and Outdoor Monitoring application using Wireless Sensor Networks

ABSTRACT

In the 19th century, the connection between the increase in greenhouse gas levels in the atmosphere and that of the average temperature of the Earth was first investigated. Later it was discovered that up to 26% of the global warming effect is due to carbon dioxide (CO_2) emissions. The United Nations Intergovernmental Panel on Climate Change (IPCC) states that further measures to reduce CO_2 emissions need to be taken since the effects of global warming can be already seen. According to OECD-ITF Joint Transport Research Committee Working Group, globally 23% of CO_2 emissions from fossil fuel combustion is generated by road transport: as the number of vehicles on the roads increases yearly, so does the level of carbon dioxide in the atmosphere.

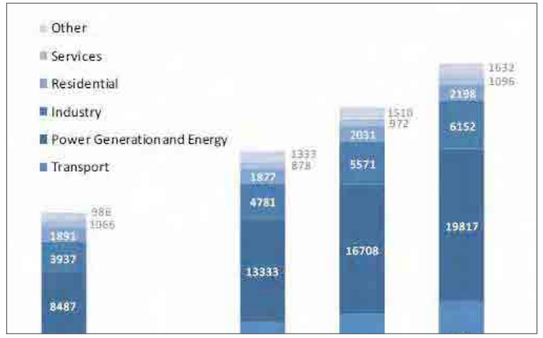
In order to control CO_2 emissions and to mitigate global warming, policies aimed at tightening emission limits for each country have been introduced and modified. As a result, it is important to consider novel ways to monitor vehicle exhaust gases as well as industrial and environmental levels of greenhouse gases. In this project we explored the possibility of monitoring the CO_2 emissions of combustion engine vehicles online using Wireless Sensor Networks (WSNs). WSNs consist of small-size wireless sensor nodes equipped with radio transceivers and one or more sensors. In our case, the sensor-node is mounted in the exhaust pipe and should be non-invasive and energy-independent. Road-side collector nodes receive CO_2 measurements and communicate them to the municipality or other organizations involved. This kind of approach could lead to a fair pricing policy for vehicle CO_2 emissions and, in the future, could replace the Milan ECOPASS. In addition to CO_2 control, additional services such as traffic and parking monitoring could also be provided.

Finally, in this project we analyzed the feasibility, both economic and technical, of CO_2-WSNs inside a city center for various scenarios.

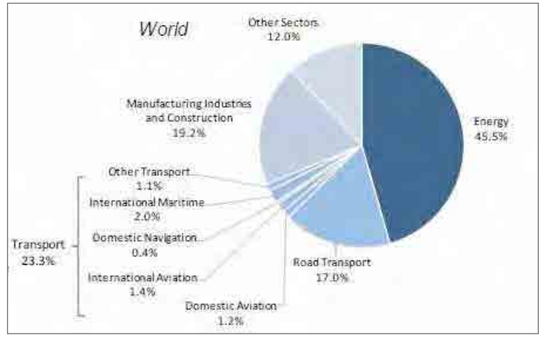
TASKS & SKILLS

Luca Gaetano Amaru developed the electronic circuitry needed to test the final sensor prototype.
Federico Capiaghi developed the business feasibility plan of the device, analyzing possible market scenarios.
Michele Miccio was responsible for energy harvesting solutions and worked on the mechanical design of the prototype.
Shangwen Qiu coordinated group work, providing his contribution in the sensor mechanical housing design.
Viktoriya Sendyureva gathered information on CO_2 emission legislation, analyzing different government policies, and contributing to development of the business plan.
Camillo Stefanucci studied the required sensing technologies, providing support for energy harvesting solutions.

We would like to acknowledge the contribution of **Francesco Santoro** who helped in implementing the electronic circuitry and prototype testing. We would also like to acknowledge the contribution of **Meccanica Panni S.r.l** in the precise machining of the mechanical housing for this project.



1 *World energy-related CO_2 emissions*



2 *CO_2 emission from fossil fuel*

UNDERSTANDING THE PROBLEM

The project purpose is the design of a new device able to measure CO_2 emitted by vehicles and transmit the data to a network infrastructure. Such a target involves many areas of expertise: the need to use ultra low power electronics, mechanical adaptability inside the vehicle exhaust pipe, the attempt to implement an energy harvesting system and potential strategies to sell the final product to the market. CO_2 emissions significantly influence air quality and this is not a local or regional problem but rather a global issue requirung international cooperation on data collection and implementation strategies. In 2002, the International Energy Agency predicted a 50% increase of transport emissions by 2020. In order to control CO_2 emissions, the reduction of the car CO_2 emissions from 163 g/km to 120 g/km by 2012 was indicated as one of the EU sustainable development objectives. To regulate pollution reduction measures, the system of allowances providing the right to emit one tonne of CO_2 within a specified period was developed. Currently, there is no technology able to define the individual contribution of single vehicles to total pollution, collect information on emissions and regulate the quantity of carbon dioxide in order to remain within the limits established by international allowances. Moreover, only coupling the technical solution with the specific policy can provide the opportunity to reach this environmental target.

Due to the complex project scenario, a fundamental question addressed by the team was; who are the stakeholders and how can they be involved? Air quality is a key issue for the well-being of citizens and therefore the first stakeholders are public authorities, from central government to the single municipality which has the direct responsibility of local air pollution; but not only government is impacted by the project, also other institutions, such as research centers and environmental monitoring agencies are interested in the data collected to build and validate their models. Furthermore, the project implements an embedded sensor and distributed management of data, which are business fields in which private firms are increasingly investing. Finally, users, identified as common citizens who own and drive a vehicle, are the real market driver and, therefore, the main and additional services related to device usage need to be addressed to them.

3 *Sestriere, 20 July 2011. Team planning prototype characterization measurements.*

4 *Laboratory tests of a Peltier cell for energy harvesting*

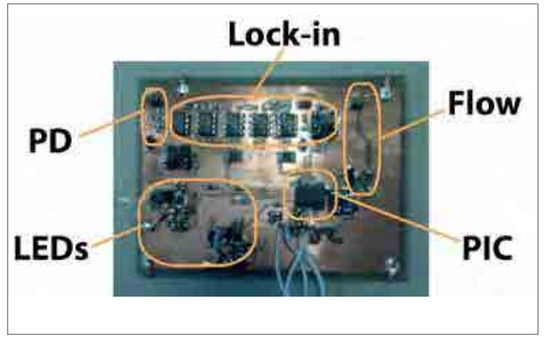
EXPLORING THE OPPORTUNITIES

In order to monitor CO_2 emissions, a number of technological solutions are available using WSNs placed in the area of interest or mounting sensors on public transport, using the bus routes to evaluate pollution of city centers.
The acquired data are used to quantify air quality of in a very economical and easy way, even though these are always average values. Our goal is to move CO_2 sensing to individual vehicles and have direct and continuous metering of emissions. In this context, while data can be managed by on-road receiver networks with possible additional services such as intelligent parking systems or traffic monitoring, sensors must be installed on private cars. As a consequence, we face a technological problem since this means placing the sensor inside the exhaust pipe which represents a harsh environment for any type of electronics, due to temperature gradients, chemicals and vibrations. For data transmission, whilst well-known transceivers are available in the market, the problem is to find appropriate technologies to obtain accurate gas sensors at a reasonable price. Moreover, to evaluate emissions, we need not only CO_2 concentration but also flow measurement which can be achieved using ultrasound technologies or thermal mass flowmeters. The result is a complex system in which electronics is required to manage the various sensor inputs and transmit data at an appropriate rate.
Regarding the mechanical housing, this must be able not only to house the various electric components and wiring, but also to be attached to the exhaust pipe of a vehicle.
Since exhaust pipes come in various shapes and sizes, the two alternative solutions are external housing with different sets of geometries and dimensions or internal housing with flexible fitting, such as springs. Finally, the system requires energy to work and a possible approach is energy harvesting. Energy harvesting is the process by which energy is derived from external sources, captured, and stored. With current technologies, harvesting devices are able to produce a relatively small density of power that can vary significantly, depending on the harvesting conditions. A low-power CO_2 sensor can be implemented by harvesting the energy from thermal gradients or car vibrations. The main advantages are production of energy with no additional costs and the possibility to feed a device with the requested power, avoiding wires and batteries.

GENERATING A SOLUTION

Analyzing sensor alternatives, the most promising technology available for CO_2 concentration measurement for a plug-in,low-cost device is the Non Dispersive InfraRed (NDIR) sensor. Since the signal level at the NDIR receiver could be extremely small, a lock-in technique is employed for extracting and amplifying faint signals from noise. For the gas flow sensor, an Ultrasonic Transit Time flowmeter (UFM) is a good candidate due to its non-invasive, low power characteristics.

5 *3D rendering of mechanical housing of car exhaust pipe sensor*



6 *PCB implemented with electronics necessary for the NDIR CO_2 gas sensor*

Given the complexity of UFM sensing technology development, we studied this possibility in detail but selected a thermal mass flow sensor in the prototype for proof of concept. The prototype we created consists of two LEDs, a photodetector (PD), a PD signal lock-in amplifier, a thermal flowmeter and a temperature sensor. The whole system is managed by a micro-controller. Calibration results of the various components demonstrated the technological feasibility of the chosen solution.
Subsequently, via preliminary research, the shapes of exhaust pipes were observed to be round or elliptic which, together with the factor of different dimensions, makes it difficult for an externally fixed housing to adapt to an arbitrary exhaust pipe. Therefore, an internal housing unit was preferred, connected with rigid springs to the internal wall of an exhaust pipe. In this case, the problem of varying shapes and dimensions is solved by the flexibility of springs, adjusting the length according to the distance needed.
Finally, the main challenges faced while developing an energy harvesting device were to be able to reach the power production target and develop a device able to resist for a lengthy period in a hostile environement. In the case of an exhaust pipe, vibrations and thermal gradient between the pipe and the environment are the 2 main sources.
With further analyses it emerged that the variation of the resonance frequency of the pipe is too large and depends on a wide range of factors, such as engine speed, external conditions, age of the car, road surface, maintenance timing and so on. The thermal solution seems to be more suitable for the specific application. According to the pipe temperature (approx. 70°C) and the temperature extremes in the 2 main cities in Italy (Milan: 1-24°C, Rome: 4-29°C) the thermal generator can benefit from a temperature gradient of between 10°C to 30°C, depending on the season.
Apart from the technological aspects, another important step was evaluation of inputs and outputs concerning costs and benefits for each stakeholder involved, in order to identify financial support opportunities along with technical solutions for, project implementation. For example, government coverage of infrastructure costs, part of the product costs and international penalties due to exceeded emissions has an income from the penalty system we developed.

PROJECT 13

B-TRANS

SHANGHAI URBAN-RURAL PUBLIC BICYCLE TRANSPORTATION SYSTEM DESIGN

B-TRANS
Shanghai Urban-Rural Public Bicycle Transportation System Design

project 13

A multidisciplinary project with Tongji University to design product service system for sustainable tourism/transport connecting agricultural and urban contex

ACADEMIC TUTOR

Luisa Collina
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

ACADEMIC TUTORS

Davide Fassi
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Ezio Manzini
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Anna Meroni
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Francesca Rizzo
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Giulia Simeone
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

EXTERNAL INSTITUTION

IDEO

Provincia di Milano*

Slowfood*

Tongji University

EXTERNAL TUTORS

Susan Evans
IDEO

Lou Yongqi
College of Design and Innovation, Tongji University

TEAM A

Maria Franco [Team controller]
Biomedical Engineering

Andrea Cairati
Civil Engineering

Corina Macnovit
Product-Service-Systems Design

Aurelie Soizic Sabatier
Architecture

TEAM B

Francesco Cavagnis [Team controller]
Civil Engineering

Laura Varvello
[Project Communication Coordinator]
Architecture

Marta Alice Fattorossi
Design & Engineering

Stefano Tedesco
Civil Engineering

PROJECT DESCRIPTION

The Challenge

Peri-urban bike-sharing is the focus of this project, intended as a means of strengthening proximity tourism, both in terms of application in a non-urban context of a sharing system and as of use of the bicycle as a means of sustainable transport.
The project was initiated by a request from the Shanghai context (How to promote the use of bicycles in China, in a context where this means of transport is now out of fashion? How to promote an agricultural area close to Shanghai, the island of Chong Ming, trying to protect it from speculative pressures?). Starting from an initial research and design exploration conducted in situ (Shanghai Expo 2010 and Chong Ming island), the project was then developed in the context of Milan, by connecting the output with an existing scenario (the "Parco Agricolo Sud Milano") and one in the making (Expo 2015).
Application of a bike-sharing system, limited mainly to town centers, to a context with very different environmental characteristics, users, activities and conditions, led to focus on other possibilities: increasing value from an environmental, social and economic point of view of an agricultural/rural context and stimulation a "green oriented" culture in the contemporary citizen.

The teams

Skills from engineering, design and architectural areas led to the division of work in two teams, with clear and detailed tasks, within the same project: the first focused on identification of cycling routes in the area and design of sets of experiences to be proposed to the user (Team A), the second was more involved in the development of a strategic plan linked to the product system by understanding its feasibility, operation and implementation (Team B). The two teams worked with significant interaction within the project, interfacing with a variety of local players for implementation of the various stages of research and development of the concept and taking advantage of specific skills involved across the board. At the same time, they generated two distinct insights that strengthened the unitary project characterized by a systemic approach.

The results

After having developed the service concept and logistics system, the two teams organized a prototype with a selected group of users who experimented a test-path (from Abbiategrasso MM2 underground station to "Cascina Zipo" in Zibido San Giacomo (MI) and back, passing through several cultural and environmental points of interest), generating valuable feedback for the development of the service system.
Once established, the service will provide bicycle sharing in "Parco Agricolo Sud Milano" with a strategic plan prepared by Team B which identified tangible and intangible system elements, defined how bikes could be stocked in farms (selected because they are close to public transport connecting them with the city of Milan) and created guidelines for application of the system to other contexts.
With the cooperation of the Province of Milan, the institutional representative for the Park, team A then identified a number of possible bicycle routes, points of interest and transport infrastructures to be integrated in the system, which will be communicated on an 'open source' online platform, linked to the "Nutrire Milano" web-portal, promoted by Slow Food in collaboration with Politecnico di Milano – INDACO department - with the help of the Cariplo Foundation, the Municipality and the Province of Milan. According to the Province, this project could become an additional Park service with effects on the economic (local tourism, direct sales of local products, availability of bikes for startup of the system), cultural (dissemination of "local skills" as a means of disseminating the culture of an area, promotion of local artistic, architectural and environmental points of interest) and social (integration of the inhabitants of a highly urbanized environment with public, agricultural and rural areas) system. This set of services may assume particular significance within the scope of Expo 2015.

project 13A

B-TRANS
The user experience: a multi-value offer for sustainable tourism in peri-urban areas

TASKS & SKILLS

Andrea Cairati investigated the demand for slow-mobility in the Parco Agricolo Sud Milano and examined the legal framework in which the designed system is expected to work. He also managed interaction with potential players in the project in order to understand its actual feasibility and the possible critical issues.

Maria Franco developed the general framework comprising project implementation in the analyzed case studies of both Parco Agricolo Sud Milano and Chong Ming, Shanghai. She coordinated the division of workload among members of the two teams and managed the organizational aspects of the on-field group experiences.

Corina Macnovit developed the project product service system as well as monitoring progress of the design process steps. Her activity included the design of independent system components as well as interaction among the same - connection between the virtual and tangible parts of the system and the players involved.

Aurélie Sabatier contributed to developing the service by studying the potential of Parco Agricolo Sud Milano and its infrastructures and gates connecting it to the city. Moreover, she studied the future platforms, both real and virtual, in order to establish a strong bond between the two contexts, the city and the countryside. Finally, she proposed a set of thematic trails for users to customize and experience.

ABSTRACT

The B-Trans project has the objective of designing an innovative, low cost and sustainable bike sharing system which connects a city to its surrounding countryside. The intervention target is therefore any peri-urban area where the desire shortening of distances between the city and its natural surroundings is felt by citizens, both residents as well as visitors.
The connection the project attempts to establish is both physical and meta-physical: if bikes, trails and stations are the tangible and concrete components of the designed service, on the other hand, values, agricultural traditions and knowledge are the immaterial elements to convey through this bridge between areas, people, lifestyles and cultures.
At the same time, the proposed solution will encourage implementation of alternative models of development, specifically intended for rural areas and based on the revitalization of local communities, the diffusion of responsible agro-tourism and the defence of food quality and security: all central themes of the coming Universal Exposition to be held in Milan in 2015.
Starting from both desk and field research, we became acquainted with two possible contexts of application of the project: Parco Agricolo Sud Milano and Chong Ming island, Shanghai. During specific workshops we identified several personas who could represent reference users of the system and whose needs and expectations have been deeply analysed. Hence, different experiences have been designed to constitute a probable future offer of the service. Such possible inputs have been presented to a number of potential users and their feedback gave us suggestions to create a guideline for implementation of the system in similar contexts.








1 *Chong Ming, Mapping State of Art*
2 *Observation*
3 *Observation*
4 *Evaluating State of Art*
5 *Parco Agricolo Sud, Mapping State of Art*
6 *Observation*
7 *Observation*
8 *Evaluating State of Art*

UNDERSTANDING THE PROBLEM

Both Parco Sud and Chong Ming island represent fragile rural areas surrounding metropolises involved in never-ending expansion. The contrast between these two worlds is significant. On the one hand, pollution, congestion, noise and frenetic life-style compromise citizens' quality of life; on the other, nature, quietness and slow life-style are often forgotten.
Hence the claim for a "return to nature" by means of temporary escape from everyday life, in search of relax, silence and healthy practices. The B-Trans project uses the bicycle as a means to shorten the distances between the city and the countryside in order to reconcile these two opposite, yet complementary, aspects of the same region.
Thanks to its inherent environmental sustainability, the bicycle appears to be the best choice for entering a natural environment in an appropriate and respectful way. Implementation of a public bike sharing system, integrated with the existing local transport network, could make this possible by providing better accessibility to the countryside.
However, to implement a bike sharing system in such a wide area, a different and innovative approach to the design of the service and its related experiences is required. Our project intends to develop a low-cost, simple and sustainable solution, suited to the areas in which it is located.

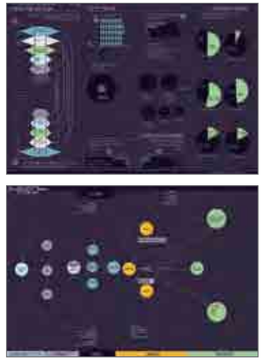
EXPLORING THE OPPORTUNITIES

The designed bike sharing system is conceived so as to exploit all the inherent potential characterizing the area of application in a sustainable manner, both from the environmental as well as economic point of view. In particular, the service attempts to fulfil the main desires shared by a number of potential users interviewed during the research phase and grouped into six different personas: the sports enthusiast, the citizen, the young family, the businessman, the silence seeker and children. Hence it has been possible to model a custom-made offer centred on three main probable experiences, common to any peri-urban area: the possibility of practicing sport, contact with nature - through a protected milieu and genuine food - and knowledge of the local cultural assets, both material and immaterial.

9,10,11,12 *Protobiking in Chong Ming*

13,14,15,16 *Protobiking in PAS*

17 *Person APROFILES*



18 *User feedback*

19 *System map*

20 *Journey Map*

In this vision, the bicycle constitutes, from the user point of view, the means of access to the set of opportunities provided; however, the designed network, constituted by bikes, trails, stations and rest areas, does not represent the ultimate goal of the project which is, on the contrary, interested in triggering off a sort of virtuous circle with farm houses as epicentres. In fact, farm houses (known as "cascinas" in the Parco Sud), together with the inherent agricultural traditional background, are the real active protagonists in the process of shortening the distance between the urban and rural worlds. Thus, tasting succulent specialities, purchase of local groceries or handicraft, discovery of ancient crafts should guarantee certain added value to the bike experience itself. In a word, creation of an integrated, multi-value and multi-sensorial "formula" for sustainable agro-tourism is the issue at stake.

Finally, the expected solution takes the form of a "positive sum game" from which all those involved can profit, thanks to a multi-level pattern of interaction based on principles such as collaborative partnership, knowledge sharing, alternative marketing strategies, self-financing and management. As a consequence, the final system should be a viable and exportable solution, especially intended for those peri-urban areas in stand-by, in search of alternative models ensuring prosperity without unsustainable and traditional economic growth.

GENERATING A SOLUTION

The proposed system requires the user to create the tour best suited to his desires using a web-based service platform. Logging in on the website, the tourist can book the bike(s) for the selected day(s), choose the type of trail and play an active role in shaping the best combination of features offered by the system; in this way it is possible to create a true, custom-made experience.
The first step is the choice of the start and finish points where bikes are picked up and returned. Such points are the farm houses/cascinas located in the vicinity of a public transport stop: here the bicycles, in a number depending on actual demand, are kept by the farmers. The user is asked to select the length of the trail he would like to ride. Theere are four intuitive options: S is the shortest (from 5 to 10 km) and destined to young families and schools, M is instead created for families or individuals who enjoy a longer ride in nature (from 10 to 20 km); the L (from 20 to 35 km) is thought for groups of friends, while XL, the longest (over 35km) is specifically designed for sports enthusiasts.
As a next step, the user chooses the theme of the trail and the points of interest he would like to visit, according to his personal preferences. For instance, a "gastronomic tour" can include a series of local cuisine and wine tastings served in selected farm houses or restaurants; on the contrary, a "nature trail" is likely to explore wildlife reserves or parks, wetlands and lakes where autochthonous flora and fauna can be admired; finally, choosing the "heritage tour", the visitor interested in rural architecture can discover a water mill, a medieval abbey or an ancient castle.

In order to complete the offer, a number of pre-defined package tours are proposed. These options include specific sets of activities and services at a fixed price. Since the system is flexible and scalable, as the tourist starts experimenting such services, he will also be able to interactively shape new trails and comment on those already experienced. An online community is therefore imagined to upload personal feedback, storyboards and pictures that can act as suggestions for future users.
The concept of the user actively planning his experience is at the heart of our system, making it extremely suitable for diverse needs and putting interaction between visitor and context at the forefront.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] AA.V.V. (2009). *"Cascine di Milano verso e oltre Expo 2015: un sistema di luoghi dedicati all'agricoltura, all'alimentazione, all'abitare e alla cura del territorio"*.
[2] Molina, G. (2010) *"Guida alle aziende agricole – Parco Agricolo Sud Milano"*, Provincia di Milano (Milano).
[3] "*The European Greenways Good Practice Guide: Examples of Actions Undertaken in Cities and the Periphery*", European Commission.

project 13B

BIKEPASS
The core-hardware of the system: devices and organization

ABSTRACT

Though bike-sharing is a recent evolution in public transport, it is already very popular in the urban areas of many of the largest cities in the world. The purpose of this service is to achieve a sustainable and zero-impact means of public transport and thus reduce the effect of human traffic on the environment. This means of transport, however, is limited to the city, or city center, and, consequently, a citizen has to use motor vehicles to reach distant areas outside the city, including natural or agricultural areas.

The aim of our thesis is to design a bike-sharing system suited to these contexts, often forgotten because of their inaccessibility but still very important from the natural and historical viewpoint, and include them in the areas covered by a sustainable means of transport.

The analysis initially retraces both our desk and field research. The desk research studies existing bike sharing systems in order to understand the structure of this type of public transport, while field research consists of surveys and interviews with potential users.

In order to obtain the widest point of view possible, our project studies two very different situations, such as Chong Ming Island in China and Parco Agricolo Sud, near Milan, Italy, and draws up guidelines applicable to many different contexts.

The thesis then presents all the designed aspects, starting from the system characteristics in general i.e. bicycles, stations and equipment and how these are all related.

Moreover, planning also addresses the successful relation between the bike-sharing system and the context. Therefore we studied all environmental aspects affected by implementation of the system with the purpose planning a positive sum game for the citizen, the farmers and the municipality.

TASKS & SKILLS

Francesco Cavagnis worked on feasibility studies, both on the Chong Ming, Shanghai and Parco Agricolo Sud Milano sites. He participated in designing a tool-kit to outline the main implementation steps of a bike sharing system in a peri-urban area. His knowledge was fundamental in preparing the business plan.

Marta Alice Fattorossi built relationships with players and users in terms of communication and promotion, both in field and by alternative channels. She contributed to the development of the service in terms of partnerships. Her direct responsibility was the organization of promotional events, communication and data processing and development of the web-platform.

Stefano Tedesco analyzed the problem of future users of the service. He contributed to the identification of general rules and instructions to be followed in order to create a bike sharing system in peri-urban areas, assembling them in the tool-kit. He also worked on the business plan of the service to provide a more technical presentation of the project for possible future implementation.

Laura Varvello studied the logistic issues. She focused her skills on the distribution and density of the single elements of the system and their organization in the areas of application. Furthermore, she studied integration of our project with existing infrastructures, services and resources in order to accomplish an integrated planning policy in the form of an Urban Revitalization Plan.








1 *Chong Ming, Mapping State of Art*
2 *Observation*
3 *Observation*
4 *Evaluating State of Art*
5 *Parco Agricolo Sud, Mapping State of Art*
6 *Observation*
7 *Observation*
8 *Evaluating State of Art*

UNDERSTANDING THE PROBLEM

The aim of our project is to create a sustainable and community-based micro economy thanks to cooperation of the various players and sharing of the diverse resources present in situ. The bike itself is a means, not an end. Thanks to its inherent environmental sustainability, the bicycle appears to be the best choice for entering a natural environment in an appropriate and respectful way.

The project attempts to connect the densely urbanized areas of the city with the nearby suburban areas characterized by a strong presence of agriculture and nature. From our interviews it emerged that the biggest obstacle to fruition of natural areas is accessibility from the city and clear information concerning the points of interest in the park. Therefore, increasing accessibility of these areas means increasing the number of visitors to peri-urban areas and therefore to farms. The project aims, therefore, not only to create an easily reachable green belt but also represents an important opportunity to revitalize the local micro economy.

However, the biggest challenge is creating a well organized, sustainable system for a small number of customers (when compared to the urban context) in the rural framework, which comprises extended distances, using the bike sharing service designed for the characteristics of the city which comprises a host of points of interest.

EXPLORING THE OPPORTUNITIES

Our research involved both analysis of the literature, field experience and a survey of local residents conducted via internet and in field (at markets and in other public places), in order to better comprehend existing bike sharing systems, user needs, the alternatives and opportunities bike-sharing programs offer, as well as the general interest, support and willingness to pay for this type of service.

Each aspect of the physics of the system, the hardware base, was analyzed in detail taking into consideration the criteria of usability, ease of maintenance and costs over the lifespan of the scheme. First of all, we considered various methods of access to bikes in a rural area: person in charge, credit cards or scheme cards. Secondly, we estimated possible alternatives for the design and technology of stations: low-tech and high-tech. Low-tech stations are mainly offered in small schemes: bikes are locked to the docking point mechanically and transactions related to tak-

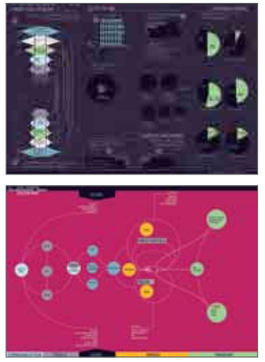


9,10,11 *Protobiking in Chong Ming*



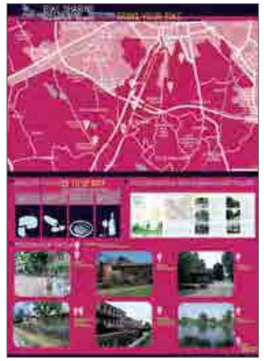

12, 13,14,15 *Protobiking in PAS*

16 *Person APROFILES*



17 *User feedback*

18 *System map*



19 *Event communication*

20 *Filed signs*

21 *Layout Piataforma*

ing out and return are supervised by a person in charge. High-tech stations are mainly incorporated in large schemes: bikes are locked to an electronically controlled docking point and the rental process takes place at the docking station itself.
We then considered the alternatives in service design, as far as station location, station density and service availability (yearly or seasonal) were concerned.
Subsequently, since registration is required to identify the user in order to avoid loss of bikes taken out by anonymous users, we identified that the different ways in which this could be provided are via a website, by telephone or at the station itself and that possible pricing structures are hourly, daily, monthly or yearly. Redistribution was then addressed as a challenge regarding both capacity and environmental impact; we analyzed redistribution methods which usually involve trucks to move bikes from one station to another.
Finally, we examined financing solutions. The majority of public systems are operated by advertising companies which, in exchange for advertising space, provide equipment and manage system operations . In contrast, a local non profit organization develops the business using a combination of usage fees, sponsorships and subsidies and procures the bicycles.

The design of a public bike sharing system in a peri-urban area, integrated with the existing local transport network, followed a process of exploring possible alternatives aimed at developing an innovative system to the benefitof the image of the area. Its implementation demonstrates a progressive attitude towards sustainable transportation and sustainable development. The expected solution takes the form of an exportable solution for those peri-urban areas planning to shorten the distances between the city and the surrounding areas via the use of bicycles.

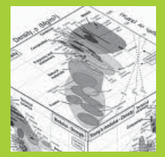
GENERATING A SOLUTION

As a result of the analysis, the system we designed is sustainable, user-friendly and economically feasible. It is structured using farm-houses which act as stations, located in the vicinity of a public transport stop. To create an effective and usable network, stations are also located close to trip generators, transit nodes, and along bicycle routes. The system is characterized by the presence of other fixed points, “bay points”, with different features and location. These are points of interest for cultural, naturalistic and culinary reasons which are conceived as stopovers during a tour.

The system provides both adult, with adjustable seats, and children’s bikes which are strong, secure and easy to manoeuvre. Both stations and bay points are designed with low-tech docking points and provide information on the area and the surrounding points thanks to an information column. In this way, without any groundwork or technological access, we reduce installation costs.
Stations are networked to a centralized computer system that requires users to register for free and book the bike(s) for the selected day(s) on a website. The online booking method guides users’ choices to facilitate bike redistribution of without using trucks. In fact, the system is structured bearing in mind the consideration that cycling from A to B is the same as cycling from B to A, as both stations are connected to public transport stops. The system memorizes the imbalances and guides users to choose trail A-B or B-A indifferently, taking into consideration only the quantity of bicycles available at both stations at the moment of reservation. The system is thus self-balancing.
On taking possession of the bike, the system blocks a deposit from the customer’s credit card. This inhibits potential customers without a credit card but prevents thefts and vandalism.
The system requires an initial investment for planning, equipment procurement and station and bay point construction. In order to better respond to user interests, the system is supervised by a local non-profit organization. The main sources of revenue are user fees and sponsors which place ads on stations and on the bicycles themselves, and possibly a start up fund allocated by the municipality. The organization cooperates with locals who keep the bikes, provide the service and manage the process of bike maintenance. Transactions related to taking out and returning a bicycle are supervised by local farmers provided with a maintenance kit, standardized parts and trained staff. Therefore, the role of local farmers is crucial to create a sustainable system which is not forced by external organizations but able to grow through the bottom-up dissemination of a common vision, aimed at expressing the hidden potential of an area with a view to sustainable development.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] Bike Sharing Guide, Transport Canada, March 2009
[2] *The European Greenways Good Practice Guide: Examples of Actions Undertaken in Cities and the Periphery,* European Commission. *How to prepare a business plan,* United Nations Conference on trade and development, 2002



PROJECT 14

SportFood.PD

SportFood

PACKAGING DESIGN OF A NEW FOOD PLATFORM DEDICATED TO SPORT THROUGH A MULTIDISCIPLINARY APPROACH

project 14

SportFood.PD
Packaging Design of a new food platform dedicated to Sport through a multidisciplinary approach

Packaging design project, using a multidisciplinary approach, for a new line of functional, natural carb-based foods (bar, gel, liquid) dedicated to sport

PRINCIPAL ACADEMIC TUTOR

Valeria Bucchetti
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

ACADEMIC TUTORS

Erik Ciravegna
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Barbara Del Curto
Chemistry Materials and Chemical Engineering, Politecnico di Milano

Sara Sanvito
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Umberto Tolino
Industrial Design, Arts, Communication and Fashion, Politecnico di Milano

Giulio Zotteri
Production Systems and Business Economics, Politecnico di Torino

EXTERNAL INSTITUTION

Barilla Group

EXTERNAL TUTOR

Michele Amigoni
Barilla Group

TEAM A

Jose Gabriel Islas Montero [Team controller]
Management, Economics and Industrial Engineering

Alessandro Bombelli
Aeronautical Engineering

Alessandra Erra
Management, Economics and Industrial Engineering

Ambra Farris
Communication Design

Marta Gallo [Project Team Coordinator]
Biomedical Engineering

TEAM B

Andrea Rongone [Team controller]
Management, Economics and Industrial Engineering

Ekaterina Kim
Management, Economics and Industrial Engineering

Ece Özdil
Product-Service-Systems Design

Paolo Rossi
Chemical Engineering

PROJECT DESCRIPTION

The Challenge

The ambition was to launch a series of food products to improve the physical conditions of those who practice sport activities, both in terms of performance and in terms of post-activity recovery.
The objective was to outline a new offer for the market, characterized by the use of functional natural ingredients, due to the particular recipe and selection.
There are three main product categories: solid bars (before sport activity); drink with a high density, gel type structure (during sport activity); liquid beverage (after sport activity).
The features required, from the product and packaging design point of view, were: maximum portability, ability to use during activity, minimization of packaging waste (as sportsmen often do not know where to dispose of waste during activity, it is important to avoid throwing waste on the ground), mono-portion and ability to use the product (opening, use, closure) with one hand.
In particular, for project development, what was asked by the company partner was to analyze many topics in depth: from product implications (rheology and surface, target shelf life, passive and active barrier, etc.) and impact on people (consumption habits, level of service, etc.) to choice of materials (sourcing, manufacturing, product performance and waste disposal after consumption); from environmental sustainability (LCA evaluation and end of life cycle management) and distribution and logistics implications (efficiency and optimization flows) to impact on variable product costs and effects on profitability.
The project also includes an experimental component related to methods and tools useful in conducting research and development of complex product platforms.

Teams

The two groups facing the challenge chose to jointly define the workplan and develop the research phase with the aim of monitoring more closely the different areas of investigation. Each group then analyzed specific parts of their different design solutions in depth.

Each group then focused on development of its own project and, during the concept generation and development phase, worked independently, creating two different product lines: the first called “play-fuel”, the second “organi-active”.
Given the specificity of the challenge, a central role – the real core of the work - was played by design, in its various declinations: product design, packaging design, communication design but also ergonomics and sustainability. Other disciplines, due to how the work plan had been established, did not have the same centrality.

Results

The design solutions proposed by the two teams represent an innovative response to the reference market sector. They have in fact: a strong identity, personality, ability to generate new forms of gesture and new consumption “rituals”, as well as having quality performance.
This result makes it possible to foresee subsequent stages of product development, verification and prototype testing and represents the precondition for the emergence of a new generation of products for the sport.

project 14A

Playfuel

ABSTRACT

The **SportFood PD** project arose from the intention of Barilla to experiment and gather external ideas regarding innovative packaging for sport food. The premise of the solution was to match the three consumption phases of sport activity with three distinct but complementary products: before activity (solid bars), during activity (gel type products) and after activity (liquid beverages). Barilla's intention of delivering sport food products using packaging design as a competitive advantage acted as the main driver during the project.

Following customer and market research composed of in-store interviews, face to face conversations with packaging and food experts and other related activities, a detailed picture of customer needs and the target market was obtained. This outcome was the cornerstone on which the team based its assumptions and the potential solution in the concept generation phase.

Several rough ideas were developed for each sport activity consumption phase, in which mono portion, design and one-hand portability were compared each time with solutions available on the market. A design mood concerning customer and brand implications was improved over time in numerous external and internal meetings. In addition, for each rough concept, potential materials were assessed by means of computer software analysis, as well as logistics implications and launch price scenarios.

STIK and **BRING**, covering a **Playfuel** mood, were delivered and approved at the end of the concept generation phase. The former, a dynamic push-pop-like concept, entails a solution whose shape and method of consumption completely breaks the modus operandi in which a normal sport food bar is consumed. The latter, a playful ring-like concept, includes an easy-to-carry solution both as a ring and as a small attachment to sport clothes. BRING embraces a method of carrying high performance sport food different from that encountered in normal gel type doses. Both concepts are intended to reflect a strong, dynamic, high performance but playful identity; they reshuffle the current state of the art in terms of sport food packaging design available on the mass markets and on some niche market shelves.

TASKS & SKILLS

Alessandra Erra evaluated the logistic implications of the proposed solutions related to the design process, assisted in the design of physical prototypes and gave suggestions on the feasibility of design proposals.

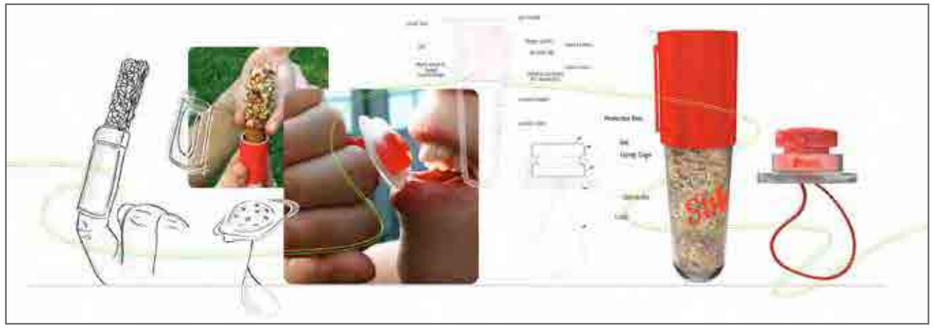
Alessandro Bombelli contributed in the design of physical prototypes, participated in the evaluation phase of potential materials for packaging solutions and the feasibility of design proposals.

Ambra Farris performed an in-depth customer and packaging research analysis, dealt with visual concept aspects (3D rendering models, moodboard and logo), made physical prototypes and prepared high quality presentations.

Jose Gabriel Islas Montero contributed to the research and marketing phase and analyzed and set pricing scenarios for the proposed solutions.

Marta Gallo analyzed and evaluated potential materials for the packaging solutions, performed high quality technical and meeting reports and gave suggestions on the feasibility of design proposals.

All team members contributed in the concept generation phase.



1 *DESIGN PROCESS: from initial sketches to the feasable products*

The idea behind both concepts is to provide the customer with products which distinguish themselves from the average sport food available on the market, especially in terms of portability, appeal and innovation. This has been the main driver, as well as the target of pursuing sustainability in the development of the entire project.

UNDERSTANDING THE PROBLEM

A new generation of sport food is expected to hit the market in a 5 to 10 years timeframe. The ability to dose and prepare natural elements without alteration is seen as the added value of products which do not contain chemical or synthetic elements but exploit the properties of genuine and simple ingredients. In their concept, these products are expected to be increasingly linked to wellbeing and less to competition; they are designed to let consumers choose their own pace, in delightful harmony between inside and outside in a natural context. On the basis of such a premise, Barilla, the external institution, requested the packaging design of a new food platform dedicated to sport, using a multidisciplinary approach in which one-hand portability, minimizing packaging waste and mono-portion were some of the main requirements expected to be encompassed in the final solution.

To better understand the main issues concerning customer needs and current sport foods available on the market, a customer discovery and market research analysis were performed. Several in-store analyses of existing products, interviews with consumers and food packaging experts, as well as various secondary information sources (questionnaires, internet, software on materials and books) were conducted and consulted. On the basis of the information obtained concerning consumer needs and the target market, a user profile was created for each of the potential customer segments which allowed the team to comprehend the main behavioral and demographic characteristics of those classes. At the same time, different material properties were assessed with the aim of finding a potential solution that could lead to more sustainable packaging.

Extensive research of the state of the art of packaging solutions involving sport food and other related spheres was carried out. Every time, the idea of covering the different sport activity consumption phases - before activity (solid bars), during activity (gel type products) and after activity (liquid beverages) - was considered.

The main outcome of the research phase was identification of the principal problems to be solved, understanding the needs of the different stakeholders involved and, finally, orchestration of the way the team would address the problem.

2 *HOW DO THE PRODUCTS WORK? Two mini-storyboards which explain gestures of positioning and consumption*

EXPLORING THE OPPORTUNITIES

After the research phase which had allowed the team to understand the problem and its dimensions, the concept phase was set up by plotting a list of four potential scenarios which were developed and refined during several internal meetings. Some of these proposals were focused more on the moods emerging from the research analysis rather than the functionality of the product. After a meeting with Barilla, however, those ideas less in line with the initial brief were abandoned and new solutions, more related to functionality (one-hand portability and mono-portion above all) and focused on runners and bikers, were conceived.
During an intense concept generation phase, the team developed new ideas; these proposals were then presented, together with the those of team B, to Barilla, clustered in three macro categories:

- The **Ready, Push, Go!** concept category was conceived on the basis of the candybar PushPop. The underlying idea was to re-invent the mechanism of the traditional candybar in a concept embodying a childish style.
- The **Monodose Ready to Wear** concept category was conceived as the intersection of the mono-portion dose and wearability. Both characteristics encompass Barilla's portability concern, as well as user needs regarding easy-to-carry sport food, as discovered in the research phase. Moreover, this constraint allowed the team to focus on solutions able to dislodge the average sport food product found on the shelves.
- The **Sporty Shaker** concept category emerged to cover the beverages segment, which turns out to be the largest in the sport food market. A strong emphasis on user gestures when mixing water and powder was used as the basis to develop the concepts in this segment.

Different moods regarding each of the ideas developed within the three categories, as well as the different potential materials covering sustainability issues, were designed and evaluated during several external and internal meetings.

GENERATING A SOLUTION

During a meeting with Barilla, two of the proposals of team A were chosen: these ideas were then elaborated and developed in detail in order to obtain, starting from a general concept, a realistic product defined in all its characteristics. Shapes, materials, functional details and corresponding technical drawings, product contents and logistics were carefully designed. Production and hygiene constraints led to a revision of a number of initial requirements, with the aim of reaching a compromise between efficacy and pertinence to the initial brief. By means of computer software to calculate a preliminary LCA (Life Cycle Assessment), a potential set of materials was assessed for each concept in order to ensure an improvement in sustainability with respect to sport food packaging available on the market. The use of mono-material polypropylene, thanks to its total recyclability, turned out to be the best solution. Moreover, different logistics and price scenarios were evaluated with the aim of defining an overall picture of how packaging design influences the number of units on a pallet and the potential launch price among current sport food products.
The iterative process of meetings with both internal and external tutors led to two final concepts: **STIK** and **BRING**.
The former, a dynamic pen-like concept, entails a solution whose shape and consumption is completely different from that of present bars. STIK, in fact, allows the consumer to push, with a simple piston-like gesture, a soft energetic marmalade inside a crispy cover, thus providing a tasteful sport food based on two different consistencies (soft and crispy). The user can thus "create" his own snack on the spot and take it with him thanks to its wearable packaging. Separation of the two ingredients is necessary for three main reasons: hygiene, preservation of the crunchiness of the cover and desire to provide the sport food with a dynamic movement.

3 *PLAYFUEL CONCEPT: dynamic, performance, playful, strong colours*

The latter, a playful ring-like concept, comprises an easy-to-carry solution both as a ring and as a small attachment to sport clothes. An energetic jelly is set on the ring like a gem and can be easily eaten by simply bringing the ring to the mouth and biting the jelly. The ring, moreover, can be re-filled with new jelly and re-used. BRING, therefore, clearly embraces a method of carrying high performance sport food different from the that encountered in normal gel type doses.
Both concepts were designed around a Playfuel mood, which is governed by a strong, dynamic, high performance, playful and technological identity. They are targeted to those people practicing sports activities daily, pursuing a natural life style, practicing sport not only as a passion but also as a healthy activity.
STIK and BRING, which are intended to be composed of natural ingredients with no artificial flavoring, are designed to respond to the needs of this target and, at the same time, respect the initial requirements of sustainability, ease of consumption and portability, thanks to the mono-material packaging, the simple gestures required to eat them and wearability. For all these reasons, BRING and STIK seem to have the potential necessary to revitalize the sport food market which is currently dormant.

project 14B

Organi-active

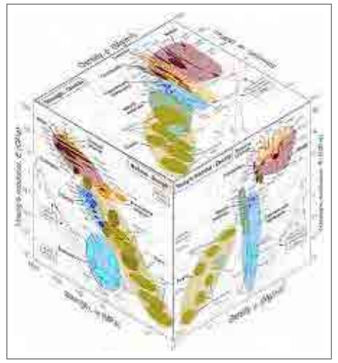
ABSTRACT

"People use products to make meaning in their lives and make statements about who they are. Customers often can't articulate those connections, because meaning isn't always a matter of conscious belief. You can't just listen to what people say. You have to understand how they interact with their environment and with other people. That's why you have to watch."
Rick Robinson, E-Lab cofounder

Naturalness is the key, as emerging from research on customer consumption habits. Amateur sport enthusiasts seek relaxing, open-air, balanced activities to keep more in contact with nature, thus we adopted this mood to create a new vision and meaning for sport food, designed to be integrated into people's life style. Given the organic nature of our products, we aimed at providing incremental values to our potential client, potentially laying the foundation for disruptive innovation in this standardized market.
Our result - two products, GELLA and SPRINK, unified by the common mood of being ORGANIACTIVE - transmits a clean and easy message to the user by communicating a pure and open image and creating a smooth interaction with the customer. Designed to deliver increased functionality, they provide freedom and flexibility to the user by allowing him to choose the consumption pace and freeing them during their sport activity. Innovative products in the form of a ring or the pouch that easily fits in the palm of the hand are a radical interpretation of existing products.
At the same time, while building the new identity we also bore in mind environmental issues. We stressed our attention to creating packaging requiring low energy consumption and and with as few emissions as possible over its entire life cycle. Our logistic policy provides maximum flexibility and distribution channels are organized in the most efficient way in order to decrease the impact on the environment.

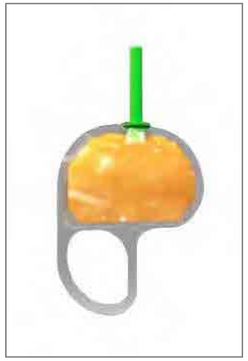
TASKS & SKILLS

Ekaterina Kim gathered information on marketing trends for sport products, was responsible for product positioning, brand identity and pricing strategy and contributed to the logistic analysis.
Ece Özdil analyzed and evaluated consumption habits, helped define the customer target, studied the design reference brands and implemented the visual characteristics of our products.
Andrea Rongone (team controller) coordinated the team work, providing feedback to the design phase through logistic analysis, was responsible for logistic research and contributed to the definition of a common marketing strategy.
Paolo Rossi performed an analysis of possible materials, with emphasis on their physical properties and their entire life cycle, highlighting the state of the art and proposing the final solution for materials.



1 *3D Visual of the main material reference, CES Edupack Software*

2 *3D visual of the Gella product, proposed to the external institution on October 24th, Milan*

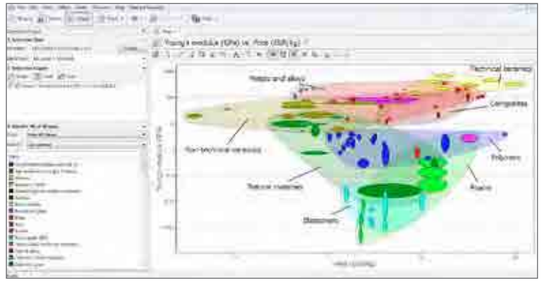


3 *3D visual of the Sprink product, proposed to the external institution on October 24th, Milan*

4 *Logo of the main material reference, CES Edupack Software*

UNDERSTANDING THE PROBLEM

Practicing sport in our lives is more than just a "hobby". An increasing trend towards a healthy lifestyle is stimulating an increasing number of enthusiasts to become more active, in contrast with the shortage of time of stressful, hectic lifestyles, and this is the main emerging driver of consumer pattern changes. It is therefore the family, nature and community, together with balanced nutrition and organic consumption that are becoming the new pillars of consumer choices. But so far there is no specific market to tackle such a customer target. Previously introduced sport food was traditionally aimed at professionals and performance-oriented sportsmen, mainly focusing on the chemical content of the product with standardized offers. Others were guided to obtain energy from bio-organic nutrition that might well be not balanced enough to sustain the needs of the sportsman's body.
The challenge Barilla proposed was to fill the gap between these markets, which are so different in nature yet so common in their target aidience, in order to provide people with healthy, well-balanced, biological sport food and, at the same time, with active ingredients, specific for sport activities, to support the body's needs and keep their customers in harmony.
The task was to create a new product line articulating a new meaning for customers and to build an interaction between the client and the product, namely to deliver a new message to our clients, expressing a fresh idea of sport food being functional, portable, flexible and easy-to-use. Such an innovative approach revolves around intangible product attributes creating completely new textual and functional layers in an increasingly biodemanding socio-cultural context. Potentially disruptive design innovation coexists with marketable technological innovation. That is why the final request was to address the issue of sustainability via our main bio-organic concept through the use of materials with low energy consumption and carbon dioxide emissions related to the entire life cycle of the packaging, possibly re-using the product and organizing the distribution channel in a more optimized fashion.



5 *Working module of CES Edupack Software*

6 *Proposal for the OrganiActive texture, proposed to the external institution on October 24th, Milan*

7 *Focus on competitors (Aptonia), shown in the research presented on September 13th, Parma*

8 *Focus on the naturalness of existing products, shown in the research presented on September 13th, Parma*

EXPLORING THE OPPORTUNITIES

The research phase, carried out on a multidisciplinary basis, showed us that existing sport food has artificial flavoring associated with powerful and strong images. Regarding the consumption habits of of amateur sportsmen, it also made clear that their need is for hydration and energy provision. Studying existing products we identified what could be the marketing strategy, possible distribution policies as well as material usage.
Focusing on the general brief, our idea was to change the existing perception of sport food towards a cleaner and more relaxed image. As a reference point we took the Barilla Mulino Bianco brand, which delivers the message of home, sharing and cozy feelings but we still had to merge these with the dynamic line of our concept, choosing as a reference brand Aptonia, with its transparency and brand identity completeness.
To satisfy the sustainability requirement we considered using different recyclable materials for food packaging. Also new renewable materials have become available in recent years, such as PLA or thermo plasticized starch, but they cannot provide the desired shelf life of six months or withstand a temperature of 100°C necessary for the sterilization process for reasons of hygiene. The choice, therefore, had to be thoroughly revised.
The mass production strategy imposed by Barilla implied working with the large-scale retail distribution market, with constraints such as standardized pallet dimensions and distribution channel flexibility. On the one hand, the Syncro project, owned by one of Barilla's third party partners, represents the state of the art in logistic efficiency: in fact, it operates with a multi-distributor logic on a commonly shared information platform, minimizing logistic costs. On the other, different logistic channels such as bio-shops, natural or green chains were considered due to the nature of the product.

GENERATING A SOLUTION

Through questionnaires, interviews with consumers, direct purchase and tasting, the final identity was generated. The mood we chose transmits the idea of reaching performance in a healthy manner and was named ORGANIACTIVE, a tasty organic concept for products made of pure and natural ingredients to provide the energy and stimulus needed during sports activity. The two innovative products, GELLA and SPRINK, are highly portable, ergonomic and designed to be used with only one hand. A transparent packaging was imagined in order to communicate the message "what you see is what you eat" and to stress the idea of naturalness, transparency and cleanness.
GELLA can be easily worn as a ring and used as a "one shot" energy booster whenever the consumer wants. Given its particular shape, it is suitable for runners and bikers. SPRINK is the beverage which imitates the shape of the palm of your hand and can be carried during sports activity. Totally flexible, it has a special valve to prevent leaks and spills. Thank to these features, the products are designed to give the consumer complete control over time of consumption of the sport food and provide a feeling of hydration and satisfaction.
The packaging materials used are the most sustainable among those able to fulfill the given constraints. This sustainability is certified by an LCA study which compared all the possible solutions and led to the decision of using PP (Polypropilene, a recyclable plastic) as the main material for primary and secondary packaging.
A full market strategy was created, starting from the premium quality of the product, in a very design-driven approach; applying a premium price is coherent with the products themselves and with mass distribution based on maximum flexibility. Dimensioning our products in such a way as to minimize wasted space in transportation, we aimed to reduce total cost of distribution and increase timeliness of product delivery.
This approach of organizing each step of product development adds value through the entire supply chain, minimizing idle processes and losses. Finally, starting from a design-driven approach triggered by socio-cultural events, we managed to shape the new identity and create sustainabity in the SportFood system.

MAIN BIBLIOGRAPHICAL REFERENCES

[1] CES EduPack 2011.2 Version 7.0.0
[2] *Marketing Management*, P.Kotler, Prentice-Hall, Upper addle River, 1967
[3] *Designing Sustainable Packaging*, S. Boylston, Laurence King Publishing, Boston, 2009