Whenergy
HOME ENERGY ADVISOR

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Executive Summary

The Whenergy project focuses on producing a proof of concept to demonstrate the possibility to reduce non-renewable energy consumption by working on the interaction between humans and smart appliances. The main stakeholders are the NecstLab from Politecnico di Milano and the eNovia company.

The project is driven by the increasing interest of consumers to know more about their energy consumption and follow a more eco-friendly life. The other key drivers of innovation are the development of energetic communities and the increasing diffusion of smart devices in consumer's homes.

The work conducted led to Whenergy, a domestic recommendation system to coach and support the residents of a house to improve their energy consumption habits. The system is composed of a central hub to install in one's house and a mobile app, through which the user can monitor consumption and receive suggestions. Whenergy observes the users behaviour when using appliances and consuming energy, recording the energy usage during the day. Then, it suggests small time changes in their routine of use of home-devices, matching moments in which the user is at home and available to do the task, to the objective of consuming energy when it is "greener", namely largely produced by renewable energy. And the more Whenergy is used, the better it knows its owner's needs and ways. The user experience is based on personal or community goals that can be achieved over time by rescheduling their activities according to Whenergy prompts.

Eco-conscious trends, evolution in the energy market and actions from "early bird" entities in the field indicate evolution of the experience of energy consumption following this path. Whenergy tries to respond to new potential market needs emerging from these weak signals, in a positioning that still has very little competition but a growing interest from the public.

Keywords

Smart home
Sustainability
Recommendation system
Energy communities

Image 1: The Whenergy system includes a physical device and a mobile app.

Image 2: Overview of Whenergy mobile app sections and features.

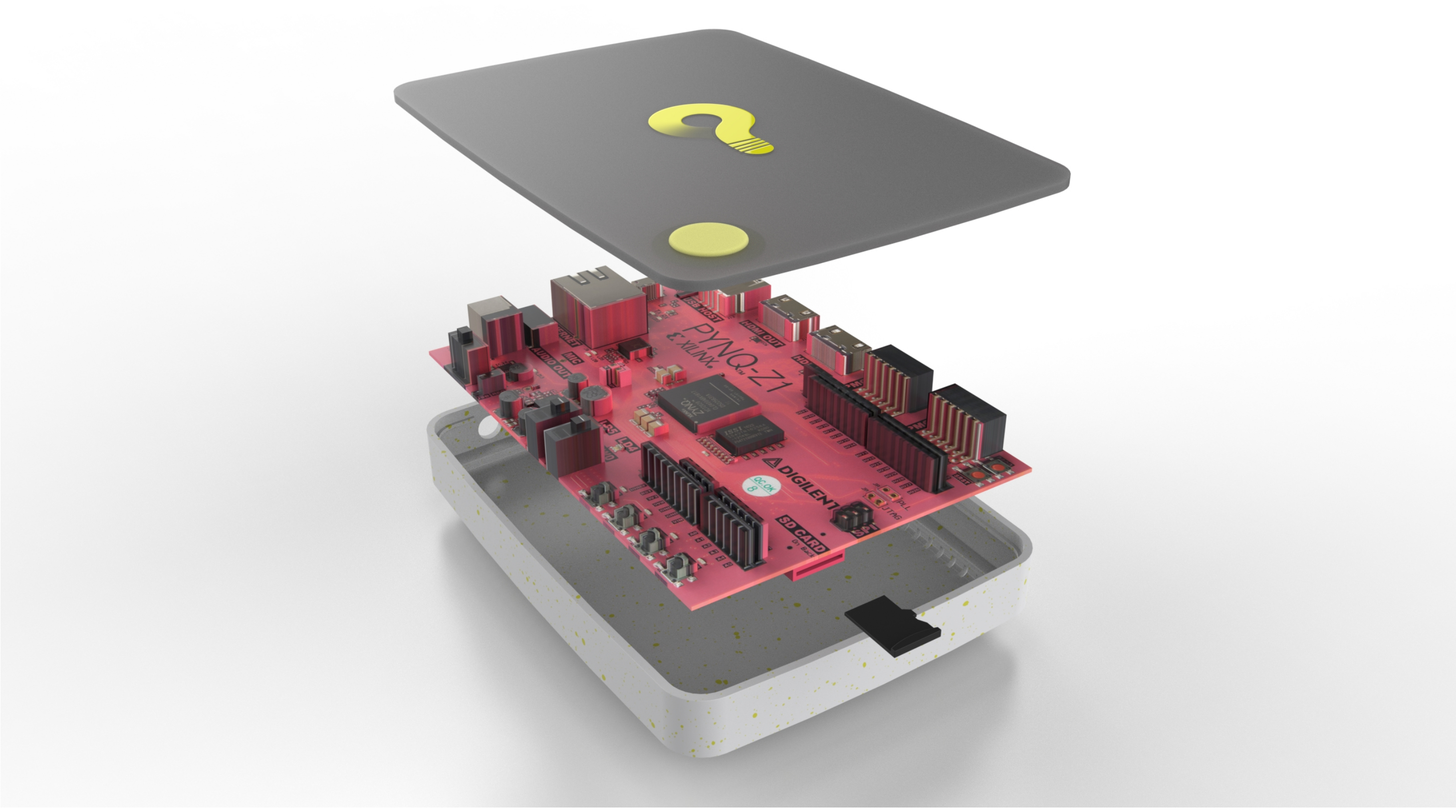

Image 3: Exploded view of the Whenergy physical device.

Project description written by the Principal Academic Tutor

The project has the goal of devising and prototyping a human-centric recommendation engine for smart home experience sharing.

Focused on smart residential and home-office environments, the project aims to understand, profile, and compare tenants' patterns of interaction with smart appliances. The final goal is to build a recommendation system that can identify similar behaviors among clusters of participants and support the spread of innovative usages of smart devices. Thanks to the human-centric approach, the project aims to bridge the gap between the individuals' needs of functional, pleasant, and simple environments with an always wider range of so-called "smart" devices invading the market and our living spaces chaotically.

Lifting the problem from the already-targeted construction of "virtual home assistants," the project's mission is to support the creation of a network of tenants organized in communities. Each of these communities will share a common goal, be it the reduction of the overall energy consumption, the increase of the percentage of green energy budget from renewable sources, or other collaborative endeavors. Once the community goal is set, the recommendation engine will exploit its profile of the tenants it supervises and negotiate with the other engines in the same community which participants are the best candidates to slightly change their appliances' usage to meet the goal better. Then, such targeted engines will formulate a suggestion and reward the tenants when they follow it.

While a single, overall recommendation engine could achieve the goal by accessing the whole community consumption patterns, a fundamental constraint of the project is to preserve privacy by creating a network of recommendation engines, sharing the tiniest information possible on each household or small-office consumption profile.

Team description by skill

The Whenergy team is composed of 6 students, who all brought their skills and experience to the project. The team is highly heterogeneous, including 2 people with a design background and 4 with an engineering one. In the initial phase of the project the team worked closely together on discovering the state of the art and context surrounding the project and setting the drivers to follow for the second phase.

The team then split into 3 groups, each working on part of the final solution. The design team, composed by a student of Product Service System Design and one of Digital and Interaction Design, conducted the user research and established the user requirements; they also defined the main touchpoints of the solution and the user experience of the mobile application. The model team, which includes a student of Data Science and Engineering and one of Mathematical Engineering and Quantitative Finance, worked on the definition and validation of the models and algorithms to process the data about the behavior of the user, to forecast the energy production and to generate the best suggestions to let the user adjust their consumption habits. The hardware team, composed of a student of Automation and Control Engineering and one of Computer Engineering, worked on the implementation and validation of the algorithm on embedded hardware using an FPGA to keep all the data processing local and to maintain highly reliable performances.

Goals

The project has 3 main goals.

The first goal of Whenergy is to deliver simple and non-invasive recommendations that help tenants reduce the energy impact of their house. Awareness and active involvement of the consumer is fundamental to reduce the energy consumption of buildings. In recent years, the smart home market developed notably, resulting in increased sales of smart appliances and home automation hubs. Among them, smart home devices that analyze the energy consumption of buildings to promote the awareness of the consumer are already on the market, but in these systems no recommendations are given to the users to improve their behavior. For this reason, Whenergy supports actively users with suggestions on how to improve their consumption habits.

The second goal of Whenergy is to take advantage of the data available from second-generation smart meters to develop a profitable business model. Second-generation smart meters are being installed by energy providers in Italy and in the EU. These devices provide real-time data on electricity usage to the user and to third-party services, enabling the spread of innovative solutions in the field of smart electricity consumption. Then they create an opportunity to enter the market.

The third goal of Whenergy is to support the birth and the spread of energy communities. Indeed, the constitution of energy communities is emerging in the EU as a promising way to support citizen participation in the reduction of CO2 emissions, where sharing local renewable energy and storage units allows to lower their electricity bills while providing flexibility to the power grid. However, such a collective organization requires an organized cooperation between the participants to manage in the best way the available resources. Then, Whenergy meets this need bringing people together, and giving the possibility to develop virtual energy communities, too.

Understanding the problem

The team conducted a state of the art analysis focusing on the aspects surrounding energy production and consumption.

We analyzed the current state of the energy market in Italy and its likely future evolution, focusing on metering technology, discovering that more than 95% of users in Italy own a first generation smart meter. Such a device cannot send collected data directly to the user, however ARERA has planned to upgrade smart meters to second generation ones. This action represents an opportunity for the development of innovative services in the field of smart consumption metering and energy efficiency.

Focusing on the available solutions for data collection in residential environments, we found that the main issue is that, even considering second generation smart meters, all the data collected is aggregated data, meaning that only the overall energy consumption of the household can be obtained. We identified two ways to solve the problem, either relying on smart appliances and smart plugs or on disaggregation algorithms. The first solution has the advantage of providing precise usage for each kind of appliance, on the other hand it requires a higher cost and effort for the user. The second option is far less intrusive and economic for the user, although it doesn't ensure 100% accuracy in appliances attribution.

On the other hand, in 2019, the European Union defined a regulatory framework for the energy communities. Energy communities are a way to organize collective and citizen-driven energy actions. They contribute to increase public acceptance of renewable energy projects and make it easier to attract private investments in the clean energy transition. Besides, they can help to optimize the electricity distribution system through demand-response and energy storage. In this environment, our project mainly focuses on virtual energy communities which assume the collaboration of citizens also geographically distributed. This concept is not explicitly defined yet. Still, it belongs to the general framework of citizens energy communities.

Looking at the developing technologies in today's context, we discovered four products that aim to ease and digitalize the relationship between the user and their energetic consumption behaviors: OhmConnect, Eesti Energia, Ned and Robo. OhmConnect is a mobile application that aims at reducing the total energy consumption during peak times by rewarding the user for actively reducing their power utilization. Eesti Energia is a smart assistant given by the energy provider that helps the user to better understand hourly house consumption and provides graphs and statistics about the electric bill. Ned goes a step further and, using a device connected to the home electric system, provides the user with insights about their power utilization across their appliances. Robo is a product similar to Ned, which helps the user to keep track of their energetic use.

All the products described have one of two flaws: either they do not take into account the existing habits and behaviors of the users or they provide them with general guidelines that cannot be easily turned into clear and understandable actions, and are not personalized. Our solution, on the contrary, shows an innovative approach as it takes users by hand on the path toward a more sustainable energy consumption thanks to the provided personalized suggestions.

Exploring the opportunities

After having collected information on the context surrounding the area of work of our project, we needed to explore the needs of our target users and turn them into requirements, we carried out two phases of user research. The first phase aimed at collecting data. A survey was made to gather quantitative data, enabling us to identify patterns in the usage of domestic appliances, awareness of energy consumption, propension to change and more. We also carried out phone interviews to collect qualitative data, going more in depth into the topics of the survey. In the second phase, we took advantage of design thinking tools to organize the data from the previous phase. We created four mindsets (image 3), archetypes that helped us emphasize our target users' attitudes and emotional responses, and defined their respective user journeys, identifying the strengths and weaknesses of their experiences.

After analyzing the research data, we concluded that users that are eco-conscious tend to be more motivated to go out of their way, while users that are more driven by their own personal benefit are usually less motivated to sacrifice their comfort.

Generating a solution

The main components of the proposed solution are a physical hub, needed to collect energy consumption data, an underlying algorithm to elaborate them, and an app to interact with the users.

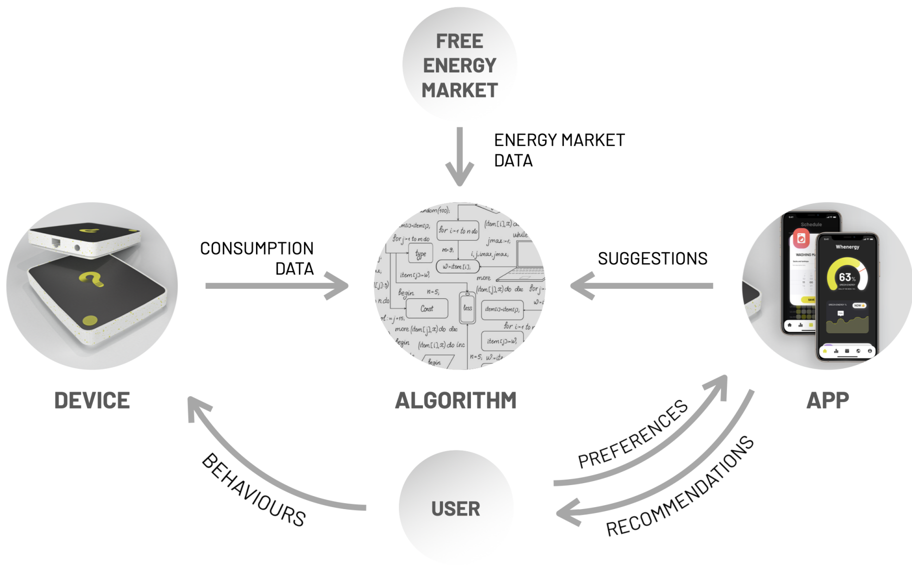

Image 4: The Whenergy system.

The added value of Whenergy with respect to the existing solutions is that it not only gives a complete and clear overview of the energetic impact of the user, but it also guides them by suggesting simple and concrete actions that can immediately be performed, such as "do the laundry at 8:00 pm instead of 9:00 pm". Moreover, nobody is left alone in the process. Depending on their personal goals and consumption behaviors, users are sorted in different communities, thus accessing a supportive and encouraging environment that motivates them to strive and reach their goal together: each community sets its consumption goals and the user is nudged to stay within the boundaries of such goals by getting notified on how both the community as a whole and the single persons are performing.

The physical hub needs to be plugged in and connected to the Internet through an ethernet cable or Wi-Fi. Since the only data easily obtainable from the grid is the overall energy consumption, an algorithm disaggregates it giving in output the consumptions for each single appliance of the house. Consumption data is the key ingredient to understand the tenants' habits. Once they are disaggregated appliance by appliance, the algorithm analyzes them. After extracting the weekly frequency of usage of each appliance and a probability distribution of the usage of each appliance over the day, i.e. at what hour the residents are more likely to use a certain appliance, the device provides suggestions that respect the tenant's habits.

The second building block to better consume energy is the metrics used to judge what kind of consumption can be considered "good." In our work, we identified as crucial the usage of renewable versus non-renewable energy. Therefore, the adopted metric is the percentage of renewable energy in the grid over the whole energy offer. The higher this percentage, the better the consumption. This quantity needs to be forecasted in advance and this is possible thanks to a shallow artificial neural network.

On the base of users' habits and forecasted percentages of renewable energy, the algorithm suggests to the users when to use appliances. Suggestions are computed aiming on one hand to move energy consumptions to moments of the day rich in renewable energy, but on the other hand keeping in mind users' habits and hours of sleep. More specifically each user or virtual community of users sets a goal: a minimum percentage of renewable energy consumption to be achieved over the weekly or monthly total. By solving an optimization problem, suggestions are generated in order to achieve the fixed goal with a limited impact on users' habits.

To make sure all this useful information does not get lost, we designed a user-centered system with the main touchpoint in the mobile app. Through their personal device, residents can clearly understand the best moment to use their appliance and arrange their activities.

As soon as the user downloads the app, an onboarding experience helps Whenergy to collect basic knowledge and routine info about them. The app has a dashboard section to check a house's consumption footprint, and improvements and achievements based on personal goals. A community section allows to set and monitor shared goals with groups of people with similar habits and intents. The calendar can be used to schedule energy usage following a visual heat map of all the time slots in the day.

The app allows for different flows of use, adapting to the user and making the implementation of Whenergy in the routine friendlier and easier: they can check on the spot if it's the right time to use a certain appliance and the system provides them with a multiple choice of optimal moments, or schedule daily use or plan the whole week using the suggestions of the algorithm. The system always checks which suggestions are followed or not by the user, in order to learn their behavior and how keen they are to change their habits to consume better.

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