PRINCIPAL ACADEMIC TUTOR
Franca Garzotto, DEIB, Politecnico di Milano
Andrea di Salvo, DAD, Politecnico di Torino

ACADEMIC TUTORS
Mathyas Giudici, DEIB, Politecnico di Milano
Pietro Crovari, DEIB, Politecnico di Milano

EXTERNAL INSTITUTIONS
Edison S.p.A., RD&TI department

EXTERNAL TUTORS
Stefano Ginocchio, Edison S.p.A.

TEAM MEMBERS

Flavio Baroni,
Politecnico di Milano,
Management Engineering

Mattia Ghibaudo,
Politecnico di Torino,
Electronics Engineering

Dario Mazzola,
Politecnico di Milano,
Computer Science and
Engineering

Giulia Monchietto,
Politecnico di Torino,
Mathematical Engineering

Gabriele Munafò,
Politecnico di Milano,
Computer Science and
Engineering

Ekim Güney Öztürk,
Politecnico di Milano,
Integrated Product Design

Carlo Zucchelli,
Politecnico di Milano,
Electronics Engineering

ECTIS
Exploring Conversational Technology to Improve Sustainable behaviours

Executive summary

In a world where climate action is becoming increasingly urgent, our project introduces an AI-integrated device designed to inspire sustainable behaviors in home environments. Homes, as the epicenter of daily life, present a powerful opportunity to foster lasting change. This innovative solution not only enhances smart-home interoperability, ensuring seamless communication between devices, but also emphasizes comfort and ease of use. By incorporating Generative AI, the device personalizes user interactions, making sustainability effortless and rewarding.

Backed by a multidisciplinary team of students and researchers from Politecnico di Torino and Milano, and in collaboration with Edison SpA, the project follows a structured, three-phase approach: problem analysis, requirements definition, and prototype development. Our research highlighted how AIoT (Artificial Intelligence of Things) has revolutionized households' operations, offering advanced capabilities that optimize energy consumption while delivering a more personalized, adaptive, and interactive experience for users. In this context, we argue that these technologies are instrumental in promoting greener practices within the home environment.

Preliminary analysis identified critical gaps, which this project seeks to address. Generative AI remains under-used in smart home systems and offers no universal solution that fits all needs, lacking true interoperability across diverse home appliances. Moreover, existing approaches often neglect user-centered design principles that are essential for fostering sustainable-driven behavioral changes.

Key to our approach is the integration of gamification and nudge theory, effectively encouraging users to adopt greener habits through subtle, engaging interactions without compromising their lifestyle. We created a physical prototype, a smart vase, which not only functions as the hub of a household's smart ecosystem but also fosters continuous engagement through plant care. Equipped with smart sensors, a touchscreen, and AI features powered by Home Assistant, ChatGPT, and NodeRed, the vase delivers ecological tips, progress reports, interactive challenges, educational content, real-time feedback and even more!

Initial feedback shows promise, though further iterations are needed to perfect accessibility and system performance. Our goal is to present the potentialities of this innovative product, able to encourage sustainable living while maintaining comfort, convenience, and engagement in daily routines.

Key Words

Sustainability, Generative AI, Smart-home, Interoperability, Gamification, Conversational technologies, Internet of Things (IoT)

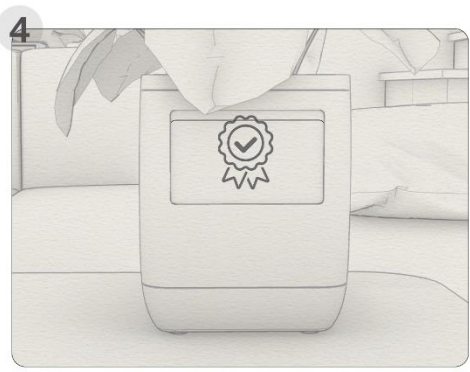Figure 1: Sustainable Development Goals addressed
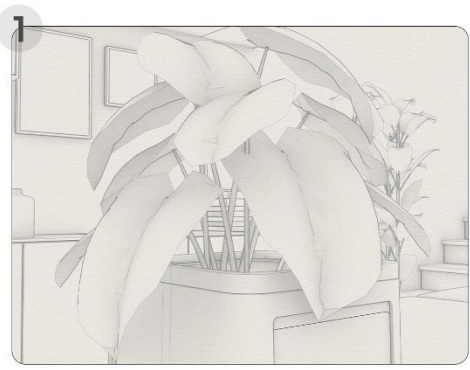
1. Take care of the plant

2. Check the last month consumes and graphs on the screen

3. Control the other smart home devices

4. Do some challenges, earn a badge and enter a leaderbord/ level up

5. Speak with it and receive sustainable recommendations

6. Become sustainable even outside home!

Project description written by the Principal Academic Tutor

The Intergovernmental Panel on Climate Change argues with about 95% certainty that climate change is anthropogenic. In 2019, World leaders at the Sustainable Development Goals (SDG) Summit defined the 2020s as a Decade of Action in which nations must collaborate in the development of scientific knowledge and cutting-edge tools to achieve sustainability goals.

Only a collective effort can tackle this urgent challenge: *everyone must implement sustainable behaviors and contribute as individuals to a "greener" world.*

In 2022, the presentation of generative Artificial Intelligence to generate text (like in ChatGPT) or images (as in Midjourney) disrupted the technological panorama, automating processes and tasks that were not imaginable even a few weeks before.

Sustainability is a complex challenge requiring the cooperation of many disciplines and stakeholders to obtain tangible results.

The aim of this project is to explore how the power of generative technologies can support the design of new products or services to help people in a shift toward more environmentally sustainable behaviors.
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Team description by skill

The ECTIS team is composed of seven members from diverse academic and technical backgrounds, which allowed to approach the project's ambitious goal of creating a device capable of influencing user decision-making in smart homes from zero.
The team includes:

- **Flavio Baroni**, Management Engineering
- **Mattia Ghibaudo**, Electronics Engineering
- **Dario Mazzola**, Computer Science and Engineering
- **Giulia Monchietto**, Mathematical Engineering
- **Gabriele Munafò**, Computer Science and Engineering
- **Ekim Güney Öztürk**, Integrated Product Design
- **Carlo Zucchelli**, Electronics Engineering

The project's complexity and innovative nature demanded a collaborative approach throughout all phases, except for the prototype realization, where the team adopted specialized roles.

The project kicked off with a comprehensive state-of-the-art and market analysis to understand the current landscape of generative AI in smart homes and to identify room for innovation. Afterwards, we performed a survey on customer perception to gain a deeper understanding of potential user needs and expectations. This phase provided critical data, which was validated with existing literature and market results to ensure the consistency and reliability of the gathered information. This resulted in the extraction of the essential features and functionalities needed for the envisioned smart home system.

We then engaged an in-depth analysis of gamification and persuasion techniques, exploring methods to include behavioral motivation strategies into the system. The following step involved the conceptual design evaluation and selection, where the team brainstormed multiple design ideas for the project solution. Each design was assessed against specific criteria: user experience, feasibility, integration with existing systems, and cost-effectiveness.

Once the design was finalized, the prototype proposal was prepared, outlining the technical specifications, design identity, and interface elements.

The team then split into specialized roles for the prototype realization phase. Mattia and Flavio, putting together their technical and managing background, were responsible for analyzing and selecting the required components.

Gabriele and Giulia focused on model training.

Dario and Carlo worked on interface development and implementation.

Ekim took charge of the physical design of the vase.

Eventually, Gabriele and Dario completed the assembly of the prototype.

Even if in this phase the tasks were split, the team continued to perform regular brainstorming to assure that the solutions proposed reflected the expectations of the whole team.

Lastly, the prototype testing was conducted. The team collected feedback through surveys and user testing sessions, focusing on usability, performance, and alignment with user expectations.

Goal

The main goal of the ECTIS project is to develop a product or service that seamlessly integrates into the home environment and daily habits of users. The primary objectives are to **raise awareness of individuals' environmental impact and to encourage proactive steps toward more sustainable living**.

To enhance this process, the product will be integrated with a conversational agent employing Generative AI. Within this promising technology, the challenge is to provide personalized, interactive guidance, helping users understand their ecological footprint, while making it easier and more rewarding to adopt sustainable habits in their everyday routines.

To achieve the presented goal 3 main subgoals were decided:
- Problem Framing and State-of-the-Art Analysis:
  Understanding the scientific and commercial context of generative AI techniques and their existing application in smart home environments.
- Requirement Definition and Solution Design:
  Extensive user research to elicit needs and requirements. Collection of data through surveys, and interviews, to gather insights into possible users expectations and challenges related to both sustainable behaviors in smart homes and generative AI usage. Definition of a conceptual design.
- Prototyping:
  Development of a prototype of the proposed solution and feedback gathering

Understanding the problem

The project addresses a critical global issue: the significant rise in CO_2 emissions. Italy, as the 19th largest producer of greenhouse gases worldwide and the third highest in the European Union, plays a key role in this environmental challenge. With annual emissions of approximately 0.35 billion tons, Italy contributes around 10% of the total emissions in the EU. This makes the need for urgent action clear.

In response, the United Nations introduced the 2030 Agenda for Sustainable Development, with 17 goals aimed at fostering a more sustainable and resource-efficient world by 2030. Italy has embraced these goals and is working to integrate them into national policies. This project aligns with this global effort by focusing on three specific Sustainable Development Goals (SDGs) that are particularly relevant to Italy's environmental challenges: making cities and human settlements more sustainable (SDG 11), ensuring sustainable consumption and production patterns (SDG 12), and taking urgent action to combat climate change (SDG 13).

The **home environment is a key space for change**, as it is where people spend most of their time. Homes offer an opportunity to promote sustainable habits, and modern technology—particularly smart-home devices—can help by improving energy efficiency, reducing waste, and encouraging sustainable behaviors. However, for these devices to work effectively, they need to communicate and function seamlessly together. Additionally, many individuals lack the motivation to adopt sustainable practices at home, where external pressures are minimal. This makes it essential to raise awareness and create incentives that make eco-friendly habits easy and appealing.

In this context, the integration of **Generative AI in smart-home environments offers a promising solution**. AI-powered conversational agents can engage users more naturally and personally, helping to embed sustainable behaviors into everyday life.

Exploring the opportunities

The state-of-the-art analysis of this project highlights the gaps in current research and solutions, focusing on three main pillars: Generative AI, Smart Home technologies, and sustainability. Generative AI is rapidly evolving, offering sophisticated models capable of generating content and predicting patterns, but its integration into smart homes, particularly in fostering sustainable behavior, remains largely underexplored. Smart home technologies, while advanced in terms of energy efficiency and user convenience, often suffer from a lack of true interoperability across devices and platforms, limiting their potential to create a seamless, energy-conscious environment.

Moreover, the project explores the application of behavioral theories, such as gamification and nudge theory, to encourage sustainable actions within households. Gamification strategies can engage users by applying game-like elements, while nudge theory emphasizes subtle changes in decision-making environments to guide users toward more sustainable choices without restricting their freedom. Despite these advances, **existing research shows a gap in fully integrating** these **behavioral strategies with AI-powered smart homes, particularly in creating systems that both motivate and simplify sustainable behavior**.

Building on the insights from the state-of-the-art analysis, the user requirements for the project emphasize key areas that align with both stakeholder expectations and market needs. Technically, the solution must integrate seamlessly with existing systems, leverage generative AI for personalized interactions, and ensure a user-friendly interface that prioritizes privacy and security. Economically, affordability and sustainability are crucial, with the solution designed to be cost-effective and scalable, appealing to users who seek both value and eco-friendly products.

From a societal perspective, the project aims to foster sustainable behaviors through gamification and education, encouraging users to adopt environmentally responsible habits. Environmentally, the focus is on resource efficiency and product longevity, ensuring minimal environmental impact. Lastly, the user experience must be intuitive and engaging, offering features like voice control and automation while fostering a sense of community and shared sustainability goals.

Generating a solution

The conceptual design process centered around creating an interactive device that supports users in making eco-friendly choices, grounded in a literature review of persuasion techniques. We structured our approach by identifying three general target areas: Awareness, Interest, and Assistance. These areas served as benchmarks for evaluating existing solutions and as guidelines for the development of our own design, with particular emphasis placed on the Awareness and Interest stages, often underdeveloped in competitor solutions.

Recognizing that achieving behavioral change requires fostering habits, we established that a physical implementation would serve as a concrete reminder, especially given the prevalence of smartphone applications in the market.

In defining the high-level technical requirements, we explored household locations that would maximize user interaction, spaces that are non-intrusive, common, and associated with idle times. We also considered various reference objects for the device. Four main options were analyzed: an **e-ink painting**, a **smart side table**, a **centerpiece**, and a **suspension lamp**. The e-ink painting offered energy-efficient, visually appealing qualities, but some technical complexities, while the smart side table functioned as a centralized control hub but was less suited for action-oriented engagement due to its placement in living rooms where people typically relax. The suspension lamp, though innovative, posed high installation costs and complexity in incorporating visualizations. Ultimately, we selected the centerpiece as our high-level design due to its balance of aesthetic appeal, functionality, and versatility in fostering engagement.

The **centerpiece**, **designed as a smart vase** with a touchscreen, stood out for its ability to blend seamlessly into daily routines. It provided sustainability insights and monitored plant health, while also acting as a decorative and interactive piece in any room. Integrating a plant into the design further enhanced user interaction, as caring for the plant naturally prompted engagement with the device. The vase's versatility meant it didn't require replacing existing household appliances, and its aesthetic ensured it would be both original and visually appealing. In this way, the device was designed to involve both users who were less environmentally conscious and those already conscientious about sustainability, providing an inclusive solution to support eco-friendly habits.
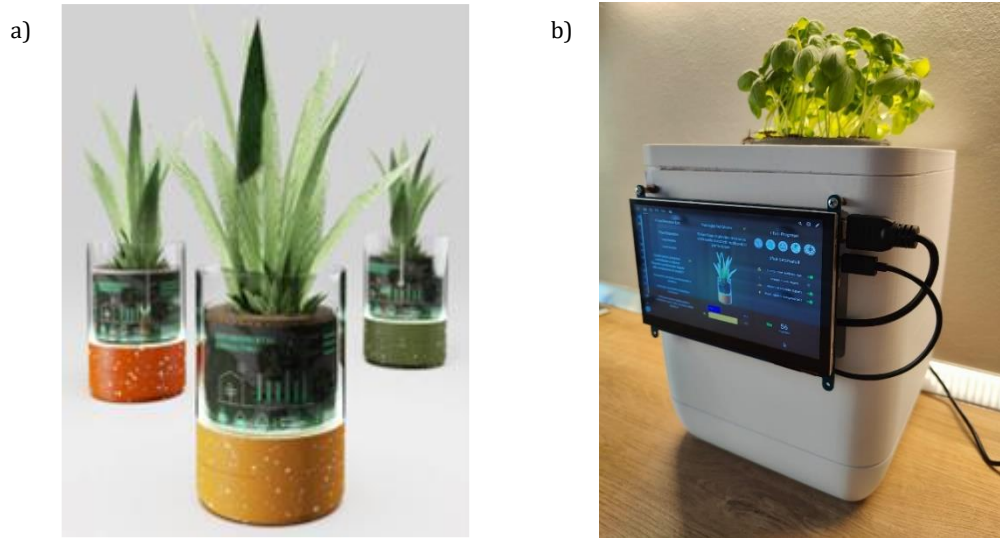
Figure 3: Solution device integrated with generative AI.
a) Conceptual design visualization. b) Final device prototype

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