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VALUES

ENERGY CULTURES & BEHAVIOURAL CHANGE

Re-Crafting Energy-Related Household Routines

The Integration of Design Methods in Behavioural Change Theory to Foster More Sustainable Routines

Giovanni Profeta
SUPSI
Orcid id 0000-0002-2420-0037

Francesca Cellina
SUPSI
Orcid id 0000-0003-4425-4750

Desirée Veschetti
SUPSI
Orcid id 0009-0002-2878-4348

Evelyn Lobsiger-Kägi
Zurich University of Applied Sciences
Orcid id 0000-0003-4104-6016

Devon Wemyss
Zurich University of Applied Sciences
Orcid id 0000-0003-1615-7515

Pasquale Granato
SUPSI
Orcid id 0000-0001-7395-5682

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Abstract
The shift towards the adoption of sustainable practices in energy consumption has been boosted by the unprecedented diffusion of digital technologies, such as smart meters and other monitoring devices, that support households in changing their daily behaviour. However, more than just information and communication technologies are needed to foster long-lasting behaviour change toward the energy transition. Current theories suggest that behaviour changes involve multiple phases, requiring motivational systems to support progress between phases and long-term maintenance of the desired behaviour.
Social Power Plus is a mobile application that guides a community of more than 200 Swiss households towards more sustainable energy consumption routines at home. The app adopts the Model of Action Phases (MAP), which identifies four phases of behaviour change (predecision, preaction, action and maintenance). Through a participatory design process, we identified app features that, using proper data visualisation techniques, focus on providing as much actionable feedback as possible. The app also offers social network-like features that have the potential to leverage transition processes by fostering the sharing of experiences and knowledge around energy saving.

1. Introduction

Worldwide, energy consumption is constantly raising due to population growth and rapid urbanisation. Coupled with current dependency on fossil fuels, this resulted in ever-increasing carbon emissions. A large body of research has been undertaken to support efficiency in energy provision infrastructures (Shu & Zhao, 2023; Maghsoudi et al., 2022). Taking advantage of the unprecedented diffusion of digital technologies, such as smart meters, sensors, and other monitoring devices, and of the related development of information and communication technologies (ICT), researchers have also widely explored novel feedback-based strategies aimed at supporting individuals in the transition towards sustainable behaviour in the residential domain (Fraternali et al., 2019; Wemyss et al., 2019). However, more than just sensing and ICT technologies, providing quantitative feedback on the amount of consumption is needed to foster a long-lasting energy transition. Recent reviews of app-based research experiments, in fact, showed that, although feedback-based interventions have high behaviour change potential at the individual level (Chatzigeorgiou & Andreou, 2021), they fail to address the systemic level, where infrastructures, social networks, and other social practices can act as both enablers and constraints on changes in households' energy demand (Raven et al., 2021). Furthermore, reviews highlighted that not only does the design of energy feedback systems have to provide insights on energy consumption levels, but it also has to offer sufficiently concrete and actionable information to assist target users in energy-saving behavior (Karlin et al. 2015; Geelen et al., 2019).

In the Social Power Plus (SPP) interdisciplinary research project, we guided more than 200 Swiss households towards adopting more sustainable energy consumption routines via a mobile application (app). The SPP app, developed through a participatory design process, is grounded on a phase model of behaviour change: using persuasive design principles and feedback systems based on data visualisation, its features allow users to progress along the phases of behaviour change and also support the maintenance of the behaviour in the long term.

2. Design Interventions Grounded in Behaviour Change Theories

Within technical tools, users might perceive automation as a lack of choice, which could decrease their willingness to adopt more sustainable behaviours. Additionally, without feedback on the cause-effect relationship, users might not learn and adapt their behaviour in a long-lasting way (Lilley, 2009). Thus, specific design solutions, namely the practical responses to specific user needs and desiderata, must be incorporated into the technical tools to actively support users' behaviour change. The possible design solution range reflects a spectrum of behaviour change strategies, from targeting fully conscious processes to fully unconscious processes, or a combination of both. Strategies targeting conscious processes require cognitive activities triggered by perceivable events and involve awareness, deliberation, and intentionality. They include providing information, fostering individuals to set specific, measurable, achievable, relevant, and time-bound (SMART) goals, promoting self-monitoring, and leveraging personal and social norms and social influence (Marteau, 2017).

Strategies targeting unconscious processes instead require less cognitive processing because they are based on uncontrolled activities, often based on automatic mental associations, connections, and emotions formed in the mind through past experiences and learning triggered by specific design elements. These design strategies, also known as "nudges", include: setting default options, visually highlighting specific options instead of others, exposing individuals to certain stimuli that can influence a subsequent behaviour ("priming" strategy), evoking positive or negative feelings, aligning behaviours with individuals' self-perception or ego (Dolan et al. 2012). Usually, behaviour change interventions tend to adopt more than one of such strategies.

Research has shown that the most effective interventions are those whose design is explicitly grounded in behavioural theories. To support such a process, researchers developed several theoretical models. They are typically grounded on the isolation and identification of specific target behaviours and encompass a wide range of operational process phases and activities to ensure a broad acceptance and usage of the final artefact. The Design with Intent method (Lockton et al., 2010), for instance, identifies for an individual target behaviour a subset of the most applicable design patterns among patterns derived from architecture, cognitive science and other disciplines related to human behaviour. Similarly, the Behaviour Wizard method (Fogg & Hreha, 2010) selects the target behaviour among 15 behaviour types, combining five behaviour flavours (five behaviours provided of a certain degree of familiarity and intensity) and three durations (one-time, short-term duration and permanent). According to how the target behaviour is triggered it adopts specific design solutions. The Behavioural Design method (Cash et al., 2017) identifies not only behavioural trends and triggers but also defines measurable behavioural solution requirements via extensive prototyping, to ensure there are no significant negative effects and to quantitatively and iteratively verify the impact of the proposed design solution compared with the baseline data from the field study.

With a more pragmatic intent, a recent extensive review of articles about energy-saving home applications (Tongsubanan & Kittichai, 2024) highlighted that most of them lack a clear understanding of users' needs and expectations. Because of this, the article suggests implementing the User-Centred Design (UCD) methodology. UCD is a design process that originated in Donald Norman's research laboratory at the University of California San Diego in 1986, where end-users influence how a design takes shape (Abras et al., 2004). UCD focuses on identifying and emphasizing user needs and preferences comprehension throughout the design process. UCD includes the following steps: 1) understand user characteristics and needs; 2) define the problem the design solutions aim to address; 3) generate ideas and explore various design solutions that have the potential to address the identified problem; 4) develop prototypes of the design solutions; 5) test the prototypes with the users; 6) based on the feedback received during testing, repeat the 3-4-5 steps to improve user experience and align the design with user needs and preferences.

Some of the techniques commonly used in the design process includes: user interviews to gather users' needs and desiderata, participatory design workshops, bringing together designers, stakeholders, and users to collaboratively generate ideas and design solutions, and development of low-fidelity sketches and high-fidelity mockups to be tested by users.

3. Research Methodology

The Social Power Plus (SPP) project aims to produce actionable knowledge on how to foster the shift towards the adoption of sustainable routines in energy consumption at home through a mobile app. In particular, it focuses on re-crafting eight specific energy-related routines towards energy sufficiency (space heating, showering, washing, cleaning, cooking, dish-washing, studying and working, recreation) and supporting dialogue between app users and households through an internal social feed. The interdisciplinary project includes competencies coming from the following disciplines: energy management, ITC, interaction design, and sociology.
SPP adopts the UCD methodology. Unlike the original UCD process, SPP applies design methods within a test environment and under uncontrolled, real-life conditions. The process we used to carry on the SPP project consists of the following steps: 1) conduction of a literature review to identify current behaviour change strategies based on design interventions; 2) creation of a community of real-life households, within a "living lab" framework (see for instance Sahakian et al., 2021); 3) design of the mobile app features with the involvement of the living lab participants; 4) development of the mobile app; 5) test of the mobile app by the living lab participants and strict assessment of its capability to induce long-term sustainable habits.

The SPP app was designed through a participatory design process presented in details in Wemyss et al. (2023). The process included three workshops, through which we gathered inputs from 50 voluntary households, which were identified through an open call in three Swiss regions (Schaffhausen, Wil, and Winterthur), with the support of the local utility companies providing energy services. Then, the SPP app was tested by 220 voluntary households living in the same regions for three months (Feb 1st- May 1st, 2022). Results are reported in Cellina et al. (2024). In this article, we focus on the description of the features of the SPP and show how they were designed to implement a specific behaviour change theory, to enhance its effectiveness.

Many behavioural theories suggest that changes involve multiple stages (Ohnmacht et al., 2017; Bamberg, 2013; Prochaska & Velicer, 1997). For the SPP app, we specifically refer to the Model of Action Phases (MAP) by Heckhausen and Gollwitzer (1987), which identifies four behavioural phases: 1) *Predecision*, when individuals start to recognise that their behaviour may be problematic; 2) *Preaction*, when individuals formulate the intention to start a new behaviour in the foreseeable future; 3) *Action*, when individuals start to concretely act and change their behaviour towards achievement of their goal for change; 4) *Maintenance*, when individuals have sustained their new behaviour for a while and try to prevent relapse to earlier phases. We decided to adopt it for the design of the SPP app for two main reasons. Firstly, MAP encompasses the entire sequence of events, from defining wishes for change to evaluating results after goal achievement. Secondly, MAP separates the motiva-

tional processes in the pre-decision phase from the volitional processes in the post-decision phases, making it a working framework that can be applied in real-life conditions.
In the SPP app, we implemented the MAP within a UCD process, to support people in understanding the behaviours that need to be changed, showing the progress through phases, and maintaining the desired behaviour over time.

4. Results: the Design of the Social Power Plus App

The Social Power Plus app was a mobile application released on the major app stores and made available for the community of Swiss households involved in the project. It includes four main sections providing visual feedback on energy consumption and related persuasive features: My home, Goal setting, Challenges and Pinboard. These sections are designed to support householders during the whole transition towards more sustainable energy consumption habits according to the MAP (Tab. 1).

MAP (behaviour change phases)	Social Power Plus features
Predecision	Feedback on the household's energy consumption Feedback on consumption in relation to other households
Preaction	Goal setting Challenge commitment setting
Action and Maintenance	Challenges Energy saving tips Pinboard (in-app social feed) Feedback on goal achievement progress Congratulation for goal achievement Regional energy saving competition Online meetings Notification and reminder system

Table 1. MAP behaviour change phases and Social Power Plus features.

4.1. Predecision Phase: My Home

To stimulate households to start thinking, they should take action to change their daily routines, since its landing page, called "My home," the Social Power Plus app provides daily feedback on the house's energy consumption. Thanks to a direct connection with smart meters automatically recording energy consumption and integrating an energy feedback system based on interactive data visualization, the household receives feedback on the evolution of its consumption, compared to its own historical baseline measured over a comparable period. If consumption is higher than the baseline, the app background is red; if it is lower, the app background is green (Fig. 1).

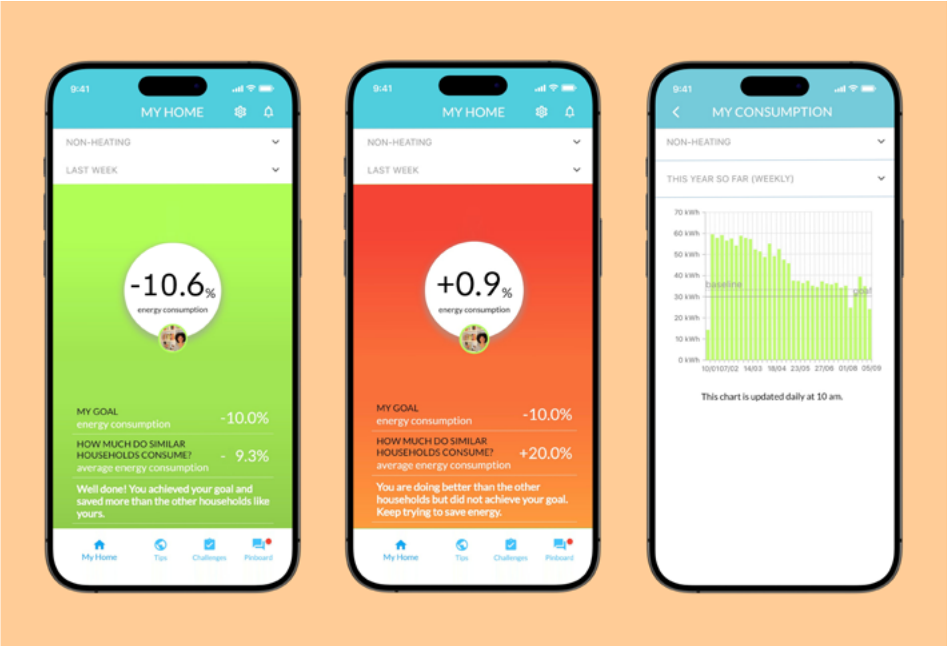

Figure 1. "My home" section pages within the Social Power Plus app show individual energy consumption and saving feedback.

Furthermore, "My Home" provides a comparison with other households by reporting the average change in consumption by similar households of the SPP community. Finally, in a more detailed sub-page, "My home" provides a bar chart reporting the household's consumption in the previous twenty-four hours, the daily consumption in the last week, or the weekly consumption since the start of app use. Through this piece of information, households start self-discovering their daily and weekly consumption patterns by intuitively correlating the periods in which they perform energy-consuming activities at home with the periods when the bars are high and *vice-versa*.

4.2. Preaction Phase: Goal and Challenge Commitment Setting

Once households have decided they will start to actively change their energy consumption, it is helpful to commit to specific goals to be achieved soon. For this purpose, SPP offers the "Goal setting" and "Challenge commitment" features (Fig. 2). Within the "Goal setting" section, households are invited to specify their own energy-saving target, namely the energy-saving percentage they would like to achieve compared to their historical consumption. Through the "Goal setting" section, household members start developing concrete plans for action and commit to stick to them. To support households in achieving their goals, SPP invites them to join "Energy sufficiency challenges" and to set their commitment to change. The challenges aim at modifying dominant behaviours around eight household routines: space heating, showering, washing, cleaning, cooking, dish-washing, studying and working, and enjoying recreation time.

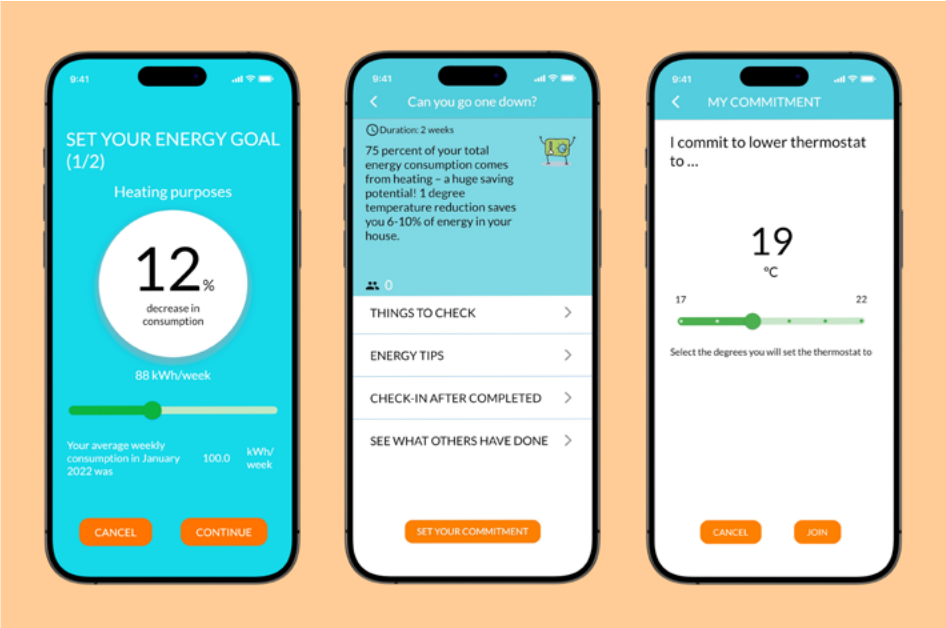

Figure 2. "Social Power Plus" pages provide individual goal-setting opportunities, challenge introduction, and commitment setting.

Each challenge lasts for two weeks, and every two weeks, new challenges are released, dealing with a different household routine. For instance, challenges aim at reducing room thermostat settings by a few degrees, reducing the number of weekly laundry/washing machine cycles, or enjoying digital-detox free time at home without using electronic devices. Households are free to ignore the challenges or to commit to participate in more of them at the same time. Before taking action, namely still in the preaction phase, households are invited to browse the available challenges, select one or more of them, and state their commitment to energy saving. Namely, committing to a challenge is the first step for households to achieve their overall energy-saving goal.

4.3. Action and Maintenance Phases: Challenges, Pinboard and Rewarding Feedback

Once households have set their energy-saving goals and committed to a challenge target, they have to start taking action. All household members can engage in each challenge by contributing to re-crafting the way they behave within the household. Completing challenges is self-regulated and personalised: household members can perform them at the times that best fit their lifestyle, weekly schedule, and the constraints affecting their lives.

To support household members in achieving their target, the challenge section provides a set of general energy tips, which suggest simple, lower-energy-demand ways to perform the related household routine, inspired by a literature search on energy-saving behaviour (for instance, tips suggest wearing warmer sweaters, lowering the thermostat and still feeling comfortable, or cleaning single stains on clothes instead of using the washing machine).

To get further support, households can interact with the other members of the SPP community through the “Pinboard” feature (Fig. 3): an in-app social feed that aims at creating spaces for households to share experiences and collectively support each other in the transition towards more sustainable energy consumption. When they complete a challenge, households are invited to post on the pinboard a short message or picture about their experience when tackling the challenge and how they managed to achieve it. Mainly, the pinboard is designed as a place for households to share comments, suggestions, and successes or failures.

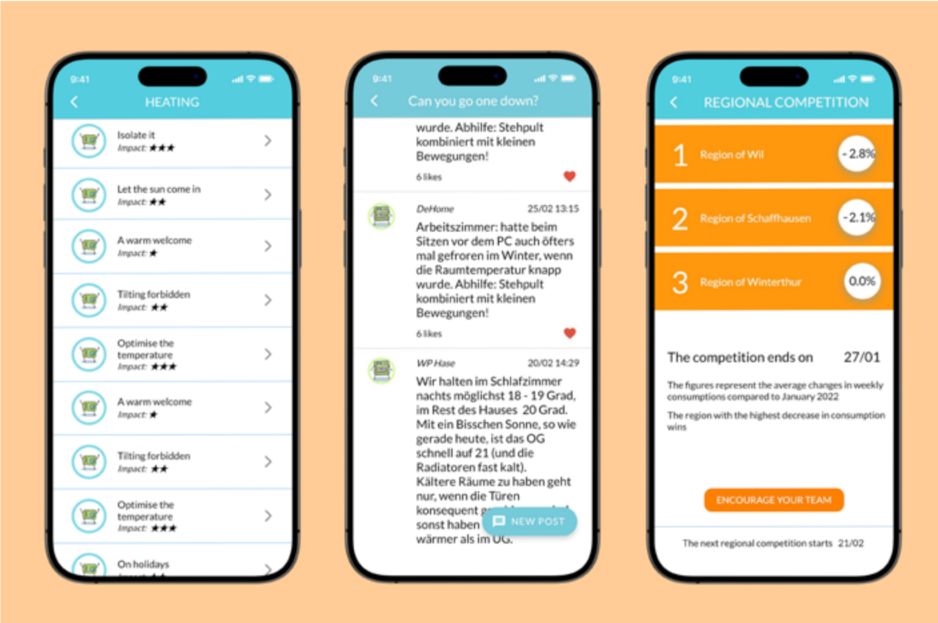

Figure 3. “Social Power Plus” sections provide tips, social interaction possibilities via the pinboard, and the regional energy-saving competition.

Everything posted in the pinboard is visible to any users, and whenever a new message is posted, a notification is shown in the app. App users can also “like” messages or respond to them by activating an asynchronous dialogue with their peers. The pinboard leverages social interactions and activates a social learning process between the peer households of the SPP community. By embedding social support into the app features, the pinboard is expected to create a feeling of “supporting relationships” for new behaviours, that fosters action maintenance over time. To further favour such feelings, pinboard-mediated social interactions are also coupled with more casual interaction possibilities, namely via online monthly meetings, that offer additional opportunities for informal interaction between app users.

A "booster" feature is also periodically activated (monthly, when the SPP app was tested on the field): leveraging the sense of belonging to one's region, a weekly "regional energy saving competition" is launched between households living in the different regions. All households of the same area are automatically put into their region's team. The app computes the amount of energy saved by the regional teams. The region with the highest energy saving wins the regional competition. No real-life prizes are available, though notifications in the regional energy saving competition section and in the pinboard congratulate the winning team, thus providing a virtual reward and public recognition of the obtained results, which are expected to help keep the interest in SPP high.
The app also provides users with regular feedback on the effects of their actions through the goal achievement feedback that is shown in "My Home": if they achieve their energy-saving goal, they are rewarded with a congratulatory message; otherwise, they are incited to keep efforts to save energy.
Finally, to support maintenance of the new behaviour over time, a notification system provides by-monthly reminders about energy-saving topics, such as short news about energy-related events, or additional tips and recommendations. Overall, the combination of challenges, tips, pinboard, regional energy competitions, goal feedback, and notifications is expected to support households throughout the action and maintenance phases, until new behaviours are set and permanently implemented.

5. Discussion

Over the whole SPP project, we aimed to understand which specific design solutions grounded in behaviour change theo-

ries can be used to foster more sustainable energy consumption routines at home. Based on this aim, we ran an intervention in real-life conditions based on the use of the SPP mobile app by 220 households.
We built a system that provided users with features that supported the whole behaviour change process. For the predecision phase, we offered households with app features that support self-monitoring and social comparison processes. For the preaction phase, we provided households with app features to let them set their personal goals for change and explicitly commit to them. For the action phase, we provided the households with app features aimed at stimulating them to actively implement novel behaviours, via energy sufficiency challenges actively, the provision of suggestions towards the target behaviour, and energy consumption feedback coupled with praises and rewards if they performed well. Also, as individuals benefit from community relationships, we implemented specific app features aimed at providing and receiving social support around the new target behaviour, via social interaction features enabling social learning and cooperation. Finally, in the maintenance phase, notifications and reminders helped households to keep implementing the new behaviour, without falling into temptation to relapse to previous routines.

Overall, as reported in detail in Cellina et al. (2024), we estimated the impact of the SPP app by means of a survey sent to all project participants before and after the SPP intervention. About 130 of them answered both the two surveys, thus allowing us to estimate changes in household routines after app use quantitatively. The results showed that 49% of the app users tried at least one of the app-based proposed energy-saving activities at home. Indeed, after the use of the SPP app, most household (self-reported) routines changed in a statistically significant way. Specifically, the use of the oven, the tumble dryer, the dishwasher, and electronic appliances decreased even with a low statistical effect size (Tab. 2). A decrease in the indoor thermostat temperature setting, instead, occurred in a moderate effect size. These results suggest the effectiveness, at least in the short term, of the SPP app. The higher effect size found regarding thermostat setting might be because lowering the temperature is easier than renouncing to a given energy service, and possibly also to the fact that heating was the most frequent discussion topic in the pinboard, thus contributing to both active and passive social learning processes.

Based on the experience of SPP participants, elements from the post-intervention survey provide two key learnings for future research on the design of app-based behaviour change interventions. First, the individual energy feedback system was major in driving the change. Many users, characterised with high personal interest and experience in energy consumption topics, declared their wish for having even more detailed information on their energy consumption (specific appliance responsible for the energy consumption and real-time data), which is supposed to allow them further to optimise their consumption and well-being with minor routine changes. For instance, one of the participants explicitly indicated she wanted “to be able to download the current performance as a csv file with the best possible temporal resolution”. These results confirm that energy feedback systems based on data visualisation are potent tools supporting the shift towards more sustainable routines.

	Pre-intervention survey			Post-intervention survey			Effect size (Cohen's d)[1]	Statistical significance (p value)[2]
	n	mean	SD	n	mean	SD		
At what average temperature (°C) do you heat your living room during the day?	129	21.04	0.95	126	20.52	1.00	0.58 (M)	*** 1.81E-09
How many times per week does your household use the oven?	132	3.89	2.04	132	3.30	1.62	0.32 (S)	*** 0.00038
On average, how many hours per day are computers running in your home?	131	6.84	6.08	128	5.49	5.74	0.30 (S)	*** 0.00080
How many times per week does your household use the tumble dryer?	119	2.50	2.38	116	2.19	2.19	0.25 (S)	*** 0.00783
How many times per week does your household use the dishwasher?	130	5.00	2.70	131	4.63	2.65	0.22 (S)	** 0.01304
On average, how many hours per day are TVs running in your home?	126	2.92	2.10	124	2.56	2.00	0.19 (S)	** 0.03220
On average, how many hours per day are tablets running in your home?	107	3.69	4.87	110	2.77	4.35	0.18 (S)	* 0.07812
On average, how many baths do you take per week?	130	0.492	1.09	130	0.37	0.72	0.13 (S)	0.13170
How many times per week does your household use the washing machine?	132	4.23	2.40	132	4.05	2.48	0.12 (S)	0.16640
On average, how many show-ers do you take per week?	131	5.85	2.75	131	5.97	2.93	0.03 (S)	0.76720

Table 2. Household energy consumption self-reported routines before and after use of the SPP app.

1 The Cohen's d effect size is the value measuring the impact of the intervention: small (S) if the value lower than 0.5; moderate (M) if the value is between 0.5 and 0.8; large (L) if the value is greater than 0.8.
2 The p value is an index of the statistical significance: 0.1 *; 0.05 **; 0.01 ***.

Also, they suggest to design feedback systems in a highly flexible and customizable way that allows app users to get as many insights as possible out of them, based on their own energy and data literacy. For instance, one of the participants suggested that the consumption feedback offered by the app "is too high-level and you have no idea how the use of individual devices affects the energy consumption".

Second, according to the users' evaluation, the pinboard played a marginal role in driving our observed routine changes. Despite it offered both active and passive social interaction features (possibility to write a post and react to other peer households' posts, or read others' posts), only a few app users actively interacted with it. They used it to share their experiences and knowledge around energy saving. For instance, one participant commented explicitly on his interest in the pinboard: "Above all, I want as much data as possible about my house and my use. I don't have time for chats in an app at the moment". We hypothesise that such a limited pinboard use is at least partially since participating households had no previous real-life connections between each other. Future applied research should, therefore, strive to favor as much as possible interventions within the community of households characterized by the presence of pre-existing relationships.

6. Conclusions

This article contributes to the existing literature about design methods and interventions to foster more sustainable routines. We showed a concrete example of a process in which design disciplines contributed to the current efforts by the scientific community, private companies, and policy-makers to provide householders with tools and practical guidance on how to reduce their energy consumption at home.

In the SPP project, we designed an app aimed at reshaping everyday energy-related routines via a set of features that are convenient, contextual, personalised, and designed taking into account the real-life needs of its users. We implemented a co-design process inviting potential app users to develop use cases for the app (Wemyss et al., 2023). This process led to many ideas for app features, from which we sorted out the technically unfeasible features from the most promising ones. This was a decision-making process, involving the research team as well as the utility representatives, based on both technical feasibility and insights from behaviour change scientific literature. Despite the broad consensus among the team and co-design participants, it is not guaranteed that this process resulted in ultimately choosing the most engaging features.

The unexpected feedback we gathered from the users within the real-life experiment, namely the high demand for more data and the rather low engagement with the pinboard, shows the importance of the UCD methodology and specifically of testing the mobile app by the living lab participants. Contrary to our expectations, actual users of the SPP app were much more interested in highly detailed quantitative feedback on their consumption, rather than in sharing experiences with peers. Future research might aim at understanding if and how such an interest is directly dependent on the emphasis we put on getting to know one's household consumption during participant recruitment. If so, future research might leverage different recruitment strategies, to ensure that a more diverse group of participants is involved, including low-energy literate people. Future research might also consider the insights we collected from the real-life experiment of the SPP app and, again adopting a participatory design process, identify novel design features that manage to effectively foster user engagement, peer-to-peer knowledge sharing and interaction. Such a process would result in social learning processes towards the adoption and long-lasting maintenance of novel energy-related household routines, thus tangibly supporting the climate and energy transitions.

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IV

BIOGRAPHIES

Valentina Auricchio
Assistant professor of the Design Department of the Politecnico di Milano. Her research is focused on Design Methods and managing strategic design projects with small and medium industries including Design Thinking processes. Her main interest is in design processes, methods and tools and their application within different sectors for strategic innovation. Member of Polimi DESIS Lab and of the international DESIS Network.
valentina.auricchio@polimi.it

Leire Bereziartua Gonzalez
She is an Industrial Design Engineer, from the Mondragon Polytechnic School (Mondragon Unibertsitatea) and Politécnico di Milano. She is currently part of the Deusto Design Research Group team and teaches at the Faculty of Engineering, at the Bilbao campus of Deusto University. She teaches several subjects related to Technical Graphic Expression in different engineering studies, both at grade level and master level, also "Sustainable Design" and "Laboratory III: Experience and Service Design" in Industrial Design engineering studies. She is also part of the Deusto FabLab team (creativity, innovation and development centre for new products, services and experiences) as FabExpert, she has made FabAcademy during 2018. In addition, since 2018 she collaborates with projects within the Digital Industry Cathedra. In 2014 she holds a master's degree in Teaching Training, which helped develop her teaching skills further, and since the 2019/2020 course she is in PhD adventure, specializing herself in Circular Economy, new technologies and Renewable Energies.
leire.bereziartua@deusto.es

Mario Bisson
Associate Professor at the Department of Design of Politecnico di Milano where he teaches and has taught Industrial design, Visual elements for the project and Color at the School of Design. He is currently Scientific Director of the Color Laboratory of the Department of DESIGN, he is promoter and co-founder of the Interdepartmental Laboratory of Politecnico di Milano EDME (Environmental Design and Multisensory Experience). In 2013 he is co-founder of the MDA Association (Mediterranean Design Association) that deals with topics related to Environmental design.
mario.bisson@polimi.it

Beatriz Bonilla Berrocal
PhD candidate in Design at the Design Department of Politecnico di Milano, member of Polimi DESIS Lab. Her research interests focus on Design for Social Innovation and its application both in business and communities.
beatriz.bonilla@polimi.it

Stefana Broadbent
Associate Professor in the Design Department of Politecnico di Milano. Between 2014 and 2016 she was Head of Collective Intelligence at Nesta, UK's innovation agency. Previously Stefana was a Lecturer in Digital Anthropology at University College London where she led the Master in Digital Anthropology. Her research interests are in the area of digital and sustainable social practices.
stefana.broadbent@polimi.it

Alessio Caccamo
Alessio Caccamo, PhD (1991) is Information Designer and Junior Researcher (RTDA) at Sapienza – University of Rome. He combines theoretical research with applied research in Communication Design - specifically in Data Visualization and Information Design - focusing on pedagogical, sociological and critical aspects, i.e. the human-data interaction. Co-Head of the SID Group – Design for Education, he specializes in Design for Learning, researching through design hybrid projects both analogue and digital for learning environments.
alessio.caccamo@uniroma1.it

Massimiliano Cason Villa
Designer and Ph.D. Student at Iuav Universtiy of Venice, he pursued his education with an interdisciplinary outlook, somewhere between Interior and communication design, attending the environment of makers and digital fabrication.

Since 2019 he has been collaborating with the startup Design Differente, taking care of participatory didactics projects on Circular Design topics, with partners such as the Municipality of Milan, La Triennale di Milano and the SOUx school of Milan. Since 2022 he has been teaching at the New Academy of Fine Arts in Milan; today he is a student at the Doctorate in Science of Design at the Iuav University of Venice, with a research focus on Design and Circularity studied under the lens of product life cycle assessment tools.
mcasonvilla@iuav.it

Francesca Cellina
Researcher at the University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Francesca Cellina has a background in both environmental engineering (master) and social sciences (PhD). She performs trans-disciplinary research activities to foster the transition towards a low carbon society, particularly in the domains of mobility and household energy consumption. She exploits ICT tools and devices in participatory, living lab interventions that leverage co-creation and co-design methodologies to engage individuals and stakeholders in real-life interventions aimed at triggering societal transitions.
francesca.cellina@supsi.ch

Davide Crippa
Architect and Ph.D. in Interior Architecture and Exhibit Design, he attended the masters of Italian design, completing his training with an interdisciplinary outlook. In 2004, he founded the Ghigos studio and since then has been pursuing a wide-ranging research among exhibitions, installations and projects of international relevance. From 2007 to 2021 he taught at the Milan Polytechnic and the New Academy of Fine Arts in Milan; today he is a Researcher at the Iuav University of Venice, where he is investigating the potential of interaction design and new digital fabrication technologies with a view to the circular economy, with a thematic focus on the sustainability of installations.
dcrippa@iuav.it

Marta Corubolo
Researcher at the Design Department of the Politecnico di Milano. Her research interests cover service and strategic design and social innovation, community centered design and collaborative services, with a specific focus on the incubation and growth of local initiatives and their relationship with the private and third sector. She is a member of the Polimi DESIS Lab.
marta.corubolo@polimi.it

Michele De Chirico
He is a PhD student in Design Sciences at Università Iuav di Venezia. His research relates to design of materials, focusing on design for the sustainable management of production waste and on materials as contextual actors and cultural meaning-makers. Since 2020, he has also been engaged as a lecturer in courses dealing with design and materials and design history and criticism.
mdechirico@iuav.it

Barbara Di Prete
Architect and phd in Interior Architecture and Exhibit Design, is an associate professor at the Design Department of the Politecnico di Milano, where she carries out research between urban, exhibit and interior design. In 2004 she founded the Ghigos studio, designing exhibitions, installations and projects for institutions of international relevance (Maxxi, Expo2015, MoMA, Milan Triennale, Venice Biennale). Since 2015 she has been coordinating the Specializing Master in "Design for Public Space" provided by POLI.design. She is currently following funded research for ENEA, CAP, Regione Lombardia, investigating the instances of sustainability in the energy, environmental and social fields.
barbara.diprete@polimi.it

Raffaella Fagnoni
She is full professor of Design at Università Iuav di Venezia, where she teaches design laboratories and civic space design. She also directs the PhD school in Science of Design. She has lectured abroad, in Iran and China, and has coordinated local and international research groups, both public and privately funded. Her research topics focus on design for social impact,

service design for public interests, social innovation, reuse and recycling, and design for sustainability, with the aim of intervening in emerging issues through active stakeholder involvement and the enhancement of local heritage. She is focused on the ongoing role of design in contemporary society, considering environmental emergencies and the state of alert in which our planet finds itself, working on the circular economy, local territory, waste recovery, and care for people and habitats.
rfagnoni@iuav.it

Rossana Gaddi
Designer and PhD. Associate Professor at the Department of Architecture of the University "G. d'Annunzio" of Chieti-Pescara, where she deals with Communication Design and enhancement of local resources and the territory. She took part in national and international seminars and research programs on the topics of innovation for cultural and territorial enhancement, and Communication and System Design for social inclusion.
rossana.gaddi@unich.it

Letizia Giannelli
Research fellow affiliated with the Service Design Laboratory at University of Florence. With a background in video production in the documentary film industry, her current focus is on research on Service Design and its applications in the textile industry.
letizia.giannelli@unifi.it

Debora Giorgi
Phd and Architect, she is Associate Professor in Design (ICAR/13) at the Department of Architecture, University of Florence (DIDA-UNIFI). President of the CdL in Textile & Fashion Design, visiting professor in international Universities, she teaches the Laboratory of Service Design at the CdLM in Design and works on design for services with a particular focus on social innovation and collaborative services.
debora.giorgi@unifi.it

Pasquale Granato
MSc in Computer Engineering, he has built a long career developing complex applications across various domains. He is currently a researcher at SUPSI (University of Applied Sciences and Arts of Southern Switzerland), focusing on renewable energy, particularly solar energy, and sustainable mobility. Pasquale is also an expert in games and gamification, integrating innovative approaches to enhance engagement and learning.
pasquale.granato@supsi.ch

Luca Incrocci
Industrial and UX/UI designer with a background of experience in graphic and service design. He is currently a researcher at the Service Design Lab at the University of Florence, focusing on service design methodologies applied to the textile industry.
luca.incrocci@unifi.it

Carmelo Leonardi
Product designer and Ph.D student in Design Sciences at Università Iuav di Venezia, Carmelo Leonardi graduated from the same university in 2022, with a master thesis titled "Melior de cinere surgo, design of a new ecological material derived from Tephra and its applications" which allowed him to deepen the concepts of social and environmental sustainability in design.
cleonardi@iuav.it

Ami Licaj
Research Fellow at the Laboratory of Design for Sustainability at the University of Florence with a PhD in Design, obtained in 2018, on Data Visualization entitled "Information Visualization. Intersubjective Liquid Discipline." Passionate about processes - and the "designerly" way of dealing with them - applied to all things digital/social/intangible/future. Academic career includes activities as Visiting Professor, national and international seminars by invitation, and design courses in other universities.
ami.licaj@unifi.it

Evelyn Lobsiger-Kägi
MSc Environmental Sciences ETH, she has been researching and teaching sustainable development and energy behaviour at the ZHAW (Zurich University for Applied Sciences) for 15 years and is now co-leading the "Energy Behaviour" Team at the Institute for Sustainable Development. Her main focus is on the participatory development of sufficient and energy-efficient interventions at household and neighbourhood level. She works in a transdisciplinary manner with cooperatives, energy supply companies, municipalities and NGOs to develop and test practice-oriented approaches.
kaev@zhaw.ch

Giuseppe Lotti
Full professor of Industrial Design, is President of the Degree Course in Product, Interior, Communication and Eco-Social Design of the Department of Architecture (DIDA) of the Università degli Studi di Firenze. He is scientific manager of research projects at the European Union, national and regional level. He is the author of publications on the culture of the project. He has been curator of design exhibitions in Italy and abroad. He is the technical-scientific coordinator of the Interior and Design District of the Tuscany Region – dID.
giuseppe.lotti@unifi.it

Marco Manfra
PhD candidate in Innovation Design at the University of Camerino and former research fellow at the University of Ferrara. He was Visiting PhD(c) at the Architecture Faculty of Lisbon University. He is professor of the course "Processi del design per l'impresa sostenibile" in the I and II level Master's degree program in "Design della Comunicazione per l'Impresa" at the University of Ferrara. He carries out research activities mainly in the field of design for social and environmental sustainability - with eco-social approach -, theories and culture of the project, media ecology, and regeneration of marginal territorial contexts.
marco.manfra@unicam.it

Raffaella Massacesi
Architect and PhD. Communication designer. She is Assistant Professor in Design at the Department of Architecture of the "G. d'Annunzio" University of Chieti-Pescara, and sole director of university spinoff SOS-Habitat. Her research interests relate to digital design, webdesign, environmental communication, communication for public utilities.
raffaella.massacesi@unich.it

Luciana Mastrolonardo
Architect and PhD. Assistant Professor at the Department of Architecture of the University "G. d'Annunzio" of Chieti-Pescara where she deals with Architectural Technology and process sustainability. She took part in national and international seminars and research programs on the impact of sustainability at various scales and in different dimensions, through metabolic and qualitative studies.
l.mastrolonardo@unich.it

Michele Mauri
Researcher at Politecnico di Milano—Design Department, he's co-director of DensityDesign Lab. Within the laboratory, he coordinates the research, design, and development of projects related to the visual communication of data and information, particularly those related to born-digital data and Digital Methods.
michele.mauri@polimi.it

Claudia Morea
Architect and PhD in Design for Sustainability, she is currently adjunct professor at BA Textile & Fashion Design, University of Florence. Expert in Life Cycle Assessment, she focuses her research on the spread of sustainability assessment capabilities, with specific regard to engagement and sustainability empowerment.
claudia.morea@unifi.it

Stefania Palmieri
Associate Professor at Politecnico di Milano, PhD in Industrial Design. She is Head of Relations with Businesses and Professions for the School of Design - Integrated Product Design. Her research and teaching activities deal with methods and processes, with particular attention to innovation processes in relation to different productive, organizational and cultural contexts, in which to enhance and strengthen the collaboration between University and business. She is part of the Scientific Committee of the interdepartmental laboratory EDME, which deals with digital technologies, immersiveness, new relationships and synergy of knowledge.
stefania.palmieri@polimi.it

Fabiola Papini
She holds a double degree in Communication Design from the School of Design, Politecnico di Milano, and the Shanghai International College of Design and Innovation, Tongji University. She is co-founder of an independent magazine and digital designer at a Milan-based information design agency. Her interests range from data visualisation to digital design, sustainability, and editorial design.
fabpapini@gmail.com

Adrian Peach
He is a practicioner and teacher, has spent three decades working with a diverse range of international brands from Alessi to 3M, with prestigious architectural practices including Antonio Citterio and David Chipperfield, with artisans and industries. He has collaboration with several research centres and universities in Europe and Middle East, like Academy of Art, Architecture and Design (UMPRUM, Prague), Domus Academy (Milan), German University in Cairo (Berlin and Cairo), German International University (Cairo), Istituto Marangoni (London), KLC (London), Istituto Europeo di Design (Milan), Hochschule Hannover, Hochschule für Technik und Wirtschaft (HTW-Berlin), Hochschule der Bildenden Künste Saar (Saarbrücken), Kunsthochschule Weißensee (Berlin) and Università di Bologna.
info@adrianpeachdesign.com

Silvia Peluzzi
Designer, she graduated with honors at Politecnico di Milano in the Master's deree of Product Service System Design. In 2022, she participated in an international mobility program at FH Salzuburg where she studied Design & Product Management. With a background in Interior Design achieved with distinction in the year 2021, she had a previous mobility at LAB University of Applied Sciences in Finland.
peluzzi.silv@gmail.com

Giovanni Profeta
Giovanni Profeta holds a PhD in Design from Politecnico di Milano, where he completed his thesis titled "Displaying Open Cultural Collections: Design Guidelines for Cultural Content Aggregators" within the DensityDesign research lab. As a researcher at the Institute of Design of the University of Applied Sciences and Arts of Southern Switzerland (SUPSI), he conducts applied research projects focusing on data visualization and algorithmic methods for accessing and analysing cultural collections. Additionally, he is also the teacher of the Interaction Design course in the Bachelor of Visual Communication and the Master of Arts in Interaction Design and the teacher of the Data Visualization course in the Bachelor of Data Science and Artificial Intelligence.
giovanni.profeta@supsi.ch

Grazia Quercia
PhD in Communication, Social Research and Marketing from Sapienza University of Rome and Adjunct Professor of "Laboratorio di Design Transmediale" at University Guglielmo Marconi, she is a member of the editorial board of the "Transmedia" series by Armando Editore and a member of the research unit GEMMA (Gender and Media Matters). Her research interests include cultural and creative industries, media ecology, transmedia design, participatory culture, sustainability communication and gender studies.
g.quercia@unimarconi.it

Lucia Ratti
Designer and Ph.D. student at the Design Department of Politecnico di Milano, her research activity touches different intersections between design and sustainability, ranging from urban biodiversity to circular exhibit design, to the energy transition and its diffusion. Since 2019 she has been an assistant in didactic activities in the Interior Design Bachelor Degree of Politecnico's School of Design, and in 2020 she started working with the association Repubblica del Design, where she takes care of the design and implementation of participatory design-didactic workshop, with partners such as the Municipality of Milan, Milan Triennale, ans SOUx school of architecture for children.
lucia.ratti@polimi.it

Agnese Rebaglio
Designer and Ph.D., Associate professor at the Design Dept. of Politecnico di Milano. Her research activity focuses on designing innovation processes of urban contexts, from a perspective of sustainability and social inclusion. Scientific director of the Specializing Master "Design for Public Spaces" provided by POLI.design. She is currently developing research on design for urban regeneration and energy sustainability promoted by design. Promoter, for the Interior Design Degree Course, of GIDE (Group for International Design Education), a network of European design schools that collaborates in educational programs.
agnese.rebaglio@polimi.it

Chiara Rutigliano
PhD candidate in Sustainability and Innovation for the Design of the Built Environment and Product System at the University of Florence. Designer with experience in graphic and innovative service design, particularly in the study of user experience and relationships in complex systems. Currently his research is focusing on traceability and transparency in the textile industry.
chiara.rutigliano@unifi.it

Carla Sedini
She is an Assistant Professor at the Design Department of Politecnico di Milano and PhD in Sociology. She is a member of the D+S research group at Polimi, where she combines and integrates social research and design. She has been researching and teaching issues related to Territorial Development, Social Innovation, and Quality of Life, with specific attention to fragile populations. She published a book titled "Collectively Designing Social Worlds. History and Potential of Social Innovation".
carla.sedini@polimi.it

Andreas Sicklinger
He is Full Professor in Industrial Design, focuses his research interests on three main fronts: Design as Science (human factors and new human factors), Design Education and Future Aesthetics, Design for Territory and the Mediterranean. He worked for Aldo Rossi on the projects Schuetzenstrasse e Landdsberger Allee in Berlin, covered the role of Product Manager in the retail sector. He has been professor and head of department at the German University of Cairo from 2012 to 2018. He has published books and articles on topics of his research interest. He is member of the Committee of the Institute of Advanced Studie of University of Bologna and Distinguished Visiting Professor at Malaysia Italy Design Institute, Kuala Lumpur.
andreas.sicklinger@unibo.it

Abhigyan Singh
Assistant professor at the Department of Human-Centered Design of Delft University of Technology (TU Delft), The Netherlands. With a background in new media design, anthropology, and IT engineering, his research examines social, cultural, and economic aspects of emergent local energy systems and services. His research makes theoretical, conceptual, and methodological contributions to the emerging disciplines of design anthropology and energy research. Abhigyan's work has earned him awards such as the WWNA Apply Award (2021) from the European Association of Social Anthropologists' Applied Anthropology Network (EASA-AAN) and Cumulus Association's 'Young Creators for Better City & Better Life' Award. In addition to his academic work, he is Co-lead of the Social and Economic Value Sub-task of the International Energy Agency's Global Observatory on Peer-to-Peer Energy Trading (GOP2P).
a.singh@tudelft.nl

Manfredi Sottani
He is a Designer and PhD Candidate (Curriculum in Design) at the Department of Architecture, University of Florence. He carries out research activities at the Design Sustainability Lab (Department of Architecture, University of Florence, scientific supervisor Prof. Giuseppe Lotti), specifically in the field of Digital Design, Sustainability Design, Communication Design and Strategic Design for Territorial Systems. He also participates in regional R&D as well as in international and European projects.
manfredi.sottani@unifi.it

Davide Stefano
Architect and PhD. Researcher in Real Estate Valuation at the Department of Architecture, "G. d'Annunzio" University of Chieti-Pescara, where he deals with cost estimation of post-earthquake reconstruction, relationships between urban quality and real estate values, and price formation of raw materials in the construction sector.
davide.stefano@unich.it

Suzanna Törnroth
She is an Associated Senior Lecturer (PhD) in Design at Luleå University of Technology, Sweden. She researches on the feminist technoscience perspectives of emerging technologies in human and non-human worlds. Particularly, her recent research delves into the ecological and multispecies perspective of solar energy technologies, following a dissertation titled called: "Solarscape: The power of humanity in designing solar imaginaries, entangled worlds, and critical sustainable futures". She also has a practice-based design and urban planning background in Sweden, Singapore, Dubai, Copenhagen and Maldives.
suzanna.tornroth@ltu.se

Anna Turco
She holds a degree in Design, Visual and Multimedia Communication from Sapienza University of Rome. She is the recipient of a research scholarship entitled "Visual Communication Design for Natural Capital and Material and Immaterial Cultural Heritage." Since 2022, she has been pursuing a PhD in Design at the Department of Planning, Design, and Architecture Technology at Sapienza University of Rome and works as a teaching assistant in the Communication Design Laboratory, the Public Space Design Laboratory, and the Design and Representation Laboratory. She has participated in the European project "Conference on the Future of Europe" in Brussels, Strasbourg, and Warsaw, addressing issues related to climate change, environment, and health. Her areas of scientific research focus on Visual Communication Design, specifically Environmental Graphic Design, applied to public space for reactivation and regeneration purposes.
anna.turco@uniroma1.it

Annapaola Vacanti
She is a Research Fellow at Università Iuav di Venezia, where she teaches in design laboratories for the curricula of Product design and Interior design of the master degree design courses. She obtained a PhD in Design at the University of Genoa in 2022. Her research focuses on Interaction Design and the opportunities offered by data-driven tools and Artificial Intelligence for design, exploring the challenges that lie at the intersection between technology, human factors, and sustainability issues. She is working within the iNEST (Interconnected Nord-Est Innovation Ecosystem) project, funded by the National Recovery and Resilience Plan (PNRR). Alongside her academic career, since 2018 she has been art director and organizer of TEDxGenova, an autonomous event operating under official TED license for the local dissemination of valuable ideas.
avacanti@iuav.it

Francesca Valsecchi
She is an Associate Professor at the College of Design and Innovation at Tongji University and director of the Ecology and Cultures Innovation Lab. She develops research on more-than-human design and the challenges of the post-development paradigm. Her research includes published, speculative, and exhibition works about mapping ecosystems, ethnography of waterscapes, ecological data, and urban-nature interaction.
francesca@tongji.edu.cn

Gijs van Leeuwen
PhD Candidate at the Department of Human-Centered Design of Delft University of Technology (TU Delft), The Netherlands. His research is concerned with relations of power and politics, and how these co-evolve with emerging energy infrastructures and technologies. Methodologically, he is developing a transdisciplinary approach that is based on design anthropology. He has a multidisciplinary background with two Master's degrees in Energy Science and Philosophy of Science, Technology, and Society.
g.e.vanleeuwen@tudelft.nl

Desirée Veschetti
Designer and research and teaching assistant at the University of Applied Sciences and Arts of Southern Switzerland (SUPSI), she has been involved in research dissemination projects concentrating on accessibility and cultural heritage. With her background in editorial and interaction design, she incorporates these skills into SUPSI's Bachelor in Visual Communication program, teaching in courses centred on Creative Coding with Machine Learning and User Interface Design.
desiree.veschetti@supsi.ch

Devon Wemyss
PhD Science and Technology Policy Studies, she has been researching in the field of energy digitalisation and behaviour change at the ZHAW (Zurich University of Applied Sciences) for 10 years. Her main focus is on collaborative processes to activate climate-relevant behaviour change, particularly looking at how digital tools can support these changes in the long-term and at large scale to move beyond research.
wemy@zhaw.ch

Chenfan Zhang
PhD candidate of the Design Department of the Politecnico di Milano. Her research interests include design for social innovation, community and community development, and service design. Member of Polimi DESIS Lab and of the international DESIS Network.
chenfan.zhang@polimi.it

Francesco Zurlo
Ph.D., he is Dean of the School of Design of Politecnico di Milano. He is full professor of Industrial Design. His research interests are concentrated in strategic, systematic and creative research through design, focusing to the impact of business innovations and human flourishing. Professor Zurlo is the Director of the Design + Strategies research group, he is a member of the scientific committee of the Observatory of Design Thinking for Business of the School of Management of Politecnico di Milano, and of ADI Index (the most important organization for assessing the best design in Italy).
francesco.zurlo@polimi.it

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AIAP
via Amilcare Ponchielli 3
20129 Milano

www.aiap.it
aiap@aiap.it
biblioteca@aiap.it

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