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0. EDITORIAL #26

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II. MODELS: ENERGY COMMUNITIES & COLLABORATIVE LANDSCAPES

EDITORIAL
#26

Humanizing Energy
Design and Art for Energy Transition

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The energy transition represents today an unavoidable challenge, a necessity and an environmental, social and economic urgency that can no longer be postponed. Institutional actors, governmental and non-governmental bodies have defined strategic objectives to pursue it, yet they have undertaken actions that are still too often of limited impact. International programmes include, for instance, the 7th SDGs of the 2030 Agenda and, in the European sphere, the European Green Deal and the most recent REPowerEU, with which the European Union has set the target of using 42.5 percent renewable energy in its energy mix by 2030 (European Commission, 2022). The plan calls for parallel efforts to reduce consumption, improve the energy efficiency of buildings and production cycles, and invest in energy storage infrastructure.

The climate crisis also prompts a rethink of fossil fuels' environmental and social impact. The transition to more sustainable sources, instrumental in a serious reduction of greenhouse gas emissions, is indeed an important step in the fight against climate change. An increment in energy sustainability also goes in the direction of countering the emergency of energy poverty: whereas in developing countries the latter manifests itself in the inaccessibility to the electricity grid for about 1 billion people, Italy alone in 2021 accounted for more than 2.1 million households experiencing difficulties in acquiring a minimum basket of energy goods and services (8.5% of total households) and in 2023 10% of minors still

Opening photo: Luminous installation *Verso un Lettering Civile* by Davide Crippa and Repubblica del Design. Realised for the Milano Design Week 2022, Bovisa district (photo by Design Differente).

lived in unhealthy, poorly heated and/or cooled, or poorly lit environments (Castellini et al., 2023).

As a matter of fact, the energy transition concerns all fundamental aspects of societal life: health, work, the quality of everyday spaces, mobility, as well as cultural production and the fight against inequality and discrimination. Community, care, technology, culture, identity, education, neighbourhood welfare, behavioural change, urban biodiversity, social and ecological networks, soft mobility and urban resilience are but a few of the themes that converge in a truly sustainable and inclusive energy transition.

With this in mind, it is surely a collective responsibility to identify processes and methods to implement a rapid and effective energy transition. In this process, design and the arts represent strategic levers of action and innovation, for they may stimulate paradigmatic changes in the ways energy is produced and consumed, in the ways it is used and in the behaviour of individuals and communities around it, to experiment with new conceptual and operational models and, in short, to propose paths towards a more sustainable future.

In this vision, design disciplines intervene on the “hard” components of the energy transition but also on its “soft,” more relational, and qualitative components. This dimension is “close” to the people and calls upon the responsibility of individuals without leaving the solutions solely to institutions, companies, and international bodies. Instead, the energy transition is based on the collective participation of all social bodies, formal and informal, and requires sharing themes, scales, and project intentions. Indeed, the transition requires systemic, structural, technological, political, economic, and cultural changes involving individuals, communities, and all local and global actors. It is, therefore, necessary to implement a revolution of the current models, starting from a more widespread energy education towards scenarios – some of which are already visible – of co-creation, co-production, and co-management, of short and circular supply chains, of self-production and digitised and smart processes, to secure a safe, ethical and welcoming future.

Innovative models such as those of Renewable Energy Communities (Bolognesi & Magnaghi, 2020), so-called circular neighbourhoods, and "proximity" energies aim to engage individuals and businesses in the creation of a local energy system, re-establishing a direct relationship between users and production, while creating new jobs, stimulating community cohesion and reducing greenhouse gas emissions, are heading in this direction. Ultimately, it will enhance territorial specificities and promote opportunities for social innovation and new forms of energy democracy (Liberti, 2022).

Issue #26 of PAD, therefore, gathers reflections, studies, and research proposals that highlight the role of design and the arts in promoting systemic innovation, both in terms of practice and cultural and social meaning, to provide new models of sustainable energy production, use and consumption. In particular, the issue explores how art and design actions can lead to a transition toward innovation in values, models, and tools. These three categories also articulate the structure of the journal. Innovation in values leverages culture and knowledge about energy-related phenomena and transforms everyday behavior. On the other hand, an innovation involving models ignites the development of increasingly participatory and collaborative processes in energy production and consumption systems. Finally, sustainability undoubtedly passes through innovation in tools, which are intended as devices and technologies for sustainable energy production but also understood as those supports aimed at increasing awareness about the role of data and information in the overall energy balance.

1. Values: Energy Cultures & Behavioural Change

The first section, *Values: Energy Cultures & Behavioural Change* is dedicated to pieces that explore the role of design in promoting energy sustainability through cultural and behavioural change. This involves spreading new value systems and increasing the knowledge and awareness of individuals and communities. In this context, design, with its interdisciplinary connections, emerges as a powerful ally for individual and collective education. It can generate support for change, raise awareness, engage people and broaden participation in transition processes. Furthermore, design can outline new future scenarios for energy production and consumption, create new formats for managing daily actions, and envision energy-efficient goods and services. It can also promote using sustainable energy sources by adopting technologies and materials with reduced environmental impact.

The essay *Re-Crafting Energy-Related Household Routines: The Integration of Design Methods in Behavioural Change Theory to Foster More Sustainable Routines* by Giovanni Profeta, Francesca Cellina, Desirée Veschetti, Evelyn Lobsiger-Kägi, Devon Wemyss and Pasquale Granato focuses on the promotion of more sustainable household routines in terms of energy consumption using design methods integrated with behavioural change theories. The authors describe the development and implementation of the Social Power Plus (SPP) mobile app, which aims to promote energy-efficient behaviour. The app is based on the Model of Action Phases (MAP), which identifies four stages of behaviour change. It uses data visualisation techniques to provide feedback to users according to their level of data literacy. In addition, the app provides social networking features to facilitate the sharing of energy saving experiences and knowledge.

The contribution by Gijs van Leeuwen and Abhigyan Singh, *Exploring Design Fictions as Tools for Transformation Towards a Human-Centered Energy Transition*, explores how design fiction can be used to support people-centred energy transitions. The authors propose using design fiction as a method of world-building to imagine alternative realities and intervene in the development of energy infrastructures. The emphasis is placed on using design fiction to influence values, mindsets and practices across the distributed networks that shape energy transitions. The authors present seven speculative scenarios to illustrate possible futures of energy infrastructures, aiming to create a comprehensive approach that can influence systemic energy transitions while maintaining a human-centered focus.

The essay *Environment/Data/People: [Eco] Participation Through Data Visualisation as Design Strategic Approach for Engaging, Sensitising, and Educating the Community to Energy Transition*, by Alessio Caccamo and Anna Turco, explores the role of data visualisation in promoting energy literacy and participation in the energy transition. The article highlights the importance of engaging citizens through visual and participatory methods to foster a deeper understanding and commitment to sustainable energy practices. The article discusses different design strategies to make abstract data more tangible and engaging, including visual metaphors, data art, and data physicalisation. It presents several case studies and examples of effective data visualisation projects. By involving individuals and communities in participatory data visualisation, it is possible to create a more emotionally engaging and accessible understanding of complex energy data.

Marco Manfra and Grazia Quercia, in the essay *Design for Temporary and Sustainable Music Festivals: New Values and Informal Educational Systems for Humanising the Energy Transition*, explore the role of temporary and sustainable music festivals as vehicles for promoting new environmental, “energetic” and social behaviours. These festivals can typically address environmental impacts such as energy consumption, fossil fuel use, biodiversity loss, CO2 emissions and waste generation. The authors argue that these festivals can inspire personal responsibility and promote practices of sustainability and circularity. They examine several European music festivals, detailing their sustainability strategies and encouraging responsible behaviour through interactive and engaging methods.

The essay *Talking about Energy: Design and Language for the Energy Transition* written by the editors (Barbara Di Prete, Agnese Rebaglio, Lucia Ratti) concludes the first part. It emphasises the critical role of communication in the energy transition. It argues that design can play a key role in engaging people both cognitively and emotionally in discussions about energy sustainability. By creating a new language around energy, design can, in fact, promote knowledge and awareness to combat the "energy illiteracy" that is currently making the majority seem disinterested in transition-related issues. Starting from the observation that the technical and specialised language currently used in the energy discourse often has an alienating effect on people, the authors suggest that the development of a new everyday vocabulary could help to bridge this gap, making sustainability a more integral part of everyday life and thus encouraging behavioural change. The article outlines different design approaches to help cultivate a culture of sustainability, making energy issues more understandable and actionable for a wider audience.

2. Models: Energy Communities & Collaborative Landscapes

The second section, entitled *Models: Energy Communities & Collaborative Landscapes*, examines alternative and innovative collaborative models of production, management and consumption, mainly characterised by participatory dynamics, community practices and collective empowerment in constructing new economic and social visions. The five contributions offer complementary points of view on methods and tools for raising citizens' awareness, but also on new forms of "proximity" energy co-production and co-management aimed at combating energy poverty (energy communities, short supply chains, self-production models, local renewable sources).

All these analyses point to the strategic role that design can play in promoting the containment of energy demand, guaranteeing access to energy for all, promoting increasingly inclusive, democratic, and conscious processes of community welfare, but also in outlining new scenarios of more sustainable consumption, redefining both individual behavior and collective aspirations.

Debora Giorgi, Claudia Morea, Chiara Rutigliano, Letizia Giannelli and Luca Incrocci, in the essay entitled *Services to Design Change: Gamification Opportunities to Generate Virtuous Behaviours and Design Sustainability Pathways*, explores Design for Behaviour Change (DfBC) practices capable of promoting an energy transition based on more sustainable consumption, more conscious behaviour, the ability to embrace technological advances and the application of user-centered design strategies. The contribution aims to provide a theoretical and methodological framework that combines the skills of design with those of social psychology to make sustainable energy choices and personal desires and not merely social or regulatory constraints perceived as distant and suffered as imposed. The essay presents case studies that testify to the effectiveness of the proposed practices in raising awareness and stimulating a collective commitment capable of determining impacts in terms of energy, environmental, and climate sustainability, even in the long term.

The essay *Energy to Design Communities: Energy Communities and Communities of Practice to Support Marginal Areas in Abruzzo*, written by Rossana Gaddi, Raffaella Massacesi, Luciana Mastrolonardo and Davide Stefano, illustrates a systemic and multiscale design experiment carried out in Taranta Peligna (CH). Here, the construction of a Renewable Energy Community provides an opportunity to support high-quality artisanal resources, recover the excellence of the local industrial history, valorise the great environmental heritage of the area and counteract the growing depopulation. The aim is to define a production model based on proximity, public-private collaboration and the use of an open-access Geographical Information System, in order to develop inclusive, community-centred scenarios for clean energy production that combat energy poverty and, in the long run, generate economic, cultural, social and environmental benefits, starting from the energy lever itself.

Carla Sedini, Francesco Zurlo, Stefania Palmieri, Mario Bisson and Silvia Peluzzi, in their essay *Enhancing Wind Farm Projects: A Systemic and Strategic Design Approach to Community Acceptance and Engagement*, investigate how to increase local acceptance of wind farm projects by integrating landscape knowledge and cultural significance through a systemic and strategic design approach. A case study analysis of fifty energy transition projects was undertaken and a matrix was filled to map the case studies based on user involvement and their relationship to the environment. The study highlights the need for community engagement at both the design and implementation stages to achieve local acceptance. The discusses strategies include educational activities, visualisation of abstract concepts of sustainability and co-design workshops.

The essay by Andreas Sicklinger and Adrian Peach, *Powered by the People: Human-Powered Energy Generation as a Lifestyle Choice*, addresses a crucial issue that is both a constraint and a lever for the energy transition in a society dominated by consumerism and the pursuit of well-being: the need to replace the dominance of waste with a different social vision that does not conflict with the expectations of citizen-consumers, but is capable of asserting itself as a new, desirable, more ethical and also more attractive lifestyle. With this in mind, the essay illustrates an experiment carried out in two university workshops and invites to take advantage of people's growing interest in health and sport as an opportunity for design, using the energy of physical movement to power household appliances and proposing new products to generate decentralised energy, mainly at home or at work. Starting from concrete solutions, the text thus pursues an ambitious and far-reaching goal: to act in the sphere of awareness, responsibility and individual freedom, and to induce a collective change in behaviour for the benefit of society as a whole.

The contribution *Designing Community-Driven Energy Solutions*, written by Valentina Auricchio, Marta Corubolo, Stefana Broadbent, Beatriz Bonilla Berrocal and Chenfan Zhang, proposes a wide-ranging critical and design reflection, developed in the academic sphere, which identifies renewable energies (solar, wind, biogas and other green sources) as the challenge and opportunity for a future capable of reducing CO2 emissions in the most congested areas of the world, while at the same time reducing energy poverty in the most remote areas or among the most vulnerable populations. Electrification is therefore a prerequisite, strategy and objective for the realisation of this inclusive scenario. In particular, the essay examines a number of community energy solutions that allow citizens to become protagonists of change, sharing resources with their neighbours through networks, often autonomous, that envisage different possible infrastructural distribution models. The results of these experiments are the strengthening of the sense of belonging to the community, the construction of social capital and the transition towards an increasingly necessary local empowerment.

3. Tools: Energy Technologies & Digital Awareness

In the third and final section, centred on *Tools: Energy Technologies and Digital Awareness*, the focus shifts to the more "hard" component of the energy transition. The four contributions collected here are concerned with analysing and proposing directions for an infrastructure, process or service innovation that is brought back to the human scale, suggesting reflections on the introduction of new techno-ecological approaches to energy production, horizontal models for its distribution, recalibrated habits around the use of the web and a renewed awareness of the impact of digital behaviours.

Projects and field experiments aimed at investigating the role of design and art in defining a new productive, commercial, distributive, but also conceptual paradigm – reported first-hand or taken from the literature and critically analysed here – find space in this section, along with data-based reflections on the impact of current technological and digital solutions, to stimulate further discussion on the existing need for the use of "better" tools, and at the same time a "better" use of the ones that already exist. The role of art and design here becomes that of "contaminators", capable of identifying alternative strategies to the current ones, gathering clues from different domains of knowledge and grafting between the meshes of technical-technological knowledge the human need to understand and the collective need to be aware of the change we are living.

Suzanna Törnroth, in her essay *Solar Biota: Co-Living with Solar Ecologies*, presents a personal experience of field experimentation in the sphere of alternative solutions for energy production. Challenging the prevailing perception that associates solar energy with the image of large photovoltaic panels located in places that are inaccessible or otherwise distant from the experience of everyday life, the author reports on the results of a five-month multi-species ethnographic study during which she observed her SunSpider – a small prototype of a photovoltaic "organism" – interacting with the ecosystem and other living and non-living entities. Exploring the possibilities opened up by a relational approach to photovoltaic technologies, the essay offers points of departure for a reflection on the complexities and possibilities inherent in the increasingly necessary act of co-living with solar energy-producing devices. Combining an interpretive lens derived from artistic practice and research with a new materialist perspective, Törnroth proposes an original narrative of the ecosystemic, climatic, and relational entanglements that are triggered in these "solar ecologies" by the conscious coexistence with the technology they bring forth.

From the Cloud to the Ground: A Data-Driven Research to Build Informative Heritage on the Internet's Energy Footprint, written by Fabiola Papini, Francesca Valsecchi and Michele Mauri, moves the spotlight onto the impact of a technological area that is extremely close to our lives: the Internet. Contrary to the common understanding of the Internet as an intangible and lightweight "cloud" devoid of any physicality, the authors bring to the fore the significant resource consumption and contribution to global warming that the vast network of digital infrastructures involved in the functioning of the Web implies. To this end, the essay employs communication design, and in particular data visualisation, both as a method and as an output, to address the knowledge gap that currently exists around the energy footprint of digital activities, and of contextually identifying visual strategies suitable for effectively communicating such complex data. The interplay between human behavior, technology, and the environment is central to the authors' discussion, which ultimately aims to raise awareness of the unsustainability of our current relationship with the internet in order to act as a guide to a more responsible digital future.

The essay *Towards Energy Sustainability in the Digital Realm: A Compass of Strategies Between Natural and Artificial Intelligence*, written by Michele De Chirico, Raffaella Fagnoni, Carmelo Leonardi, Ami Licaj, Giuseppe Lotti, Manfredi Sottani and Annapaola Vacanti, also proposes a critical reflection on the digital as a non-immaterial entity and suggests ways forward from the current predicament. In particular, the authors highlight how the use of digital does not automatically reduce the physical footprint of human activity but rather requires dedicated planning and design aimed at promoting sobriety and moderation, sustainability, accessibility, and inclusion. With this in mind, the essay examines several virtuous contemporary strategies aimed at minimising the energy consumption of the digital, analysing them through a dual reading criterion: practices that use artificial intelligence to improve system efficiency, on the one hand, and practices that rely instead on natural intelligence to redefine established consumption paradigms, on the other. Finally, by clustering these strategies according to further parameters, the essay proposes a significant set of actions aimed at promoting the energy transition within the digital realm, in line with an increasingly post-anthropocentric vision of design.

Lastly, Davide Crippa and Massimiliano Cason Villa, in their essay *Understanding the Energy Transition by Analysing the IT Revolution: An Infrastructural Reading to Direct Design Approaches Toward Energy Sustainability,* draw a connection between the more strictly instrumental field of energy production and distribution technologies and the digital world, weaving a parallel between the energy transition and the IT revolution. Using the IT metaphor as a critical-interpretive tool, the authors focus on the similarities between electrical energy transfer systems and data transfer systems, deriving from these observations a series of operational suggestions that could be transferred between the two domains.

Indeed, the issue of optimising the architecture of computer networks has been addressed before, and the lessons learned from its revision can serve as a guide for the reassessment of current energy policies. In particular, the paper explores the peer-to-peer model as a possible approach to horizontal and community-based energy management through the analysis of recent experiments in design and art and pilot projects carried out in European cities, with the aim of identifying design strategies and synergies that can inform present and future energy infrastructure planning.

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I

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

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Design Strategies, User-Centred Design, Feedback Systems, Community Engagement.

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).

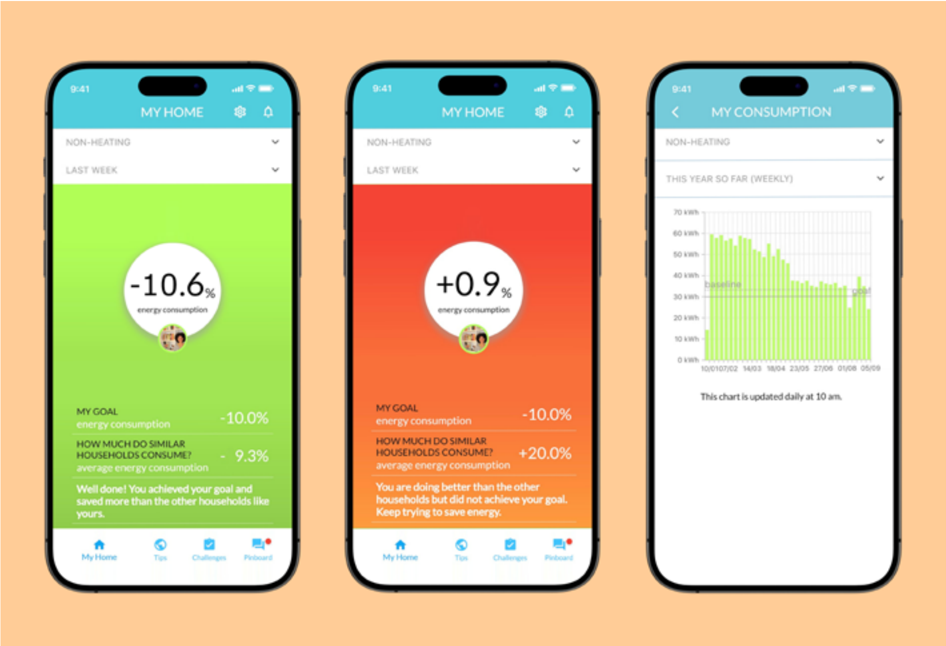

Figure 1. "My home" section pages within the Social Power Plus app show individual energy consumption and saving feedback.

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.

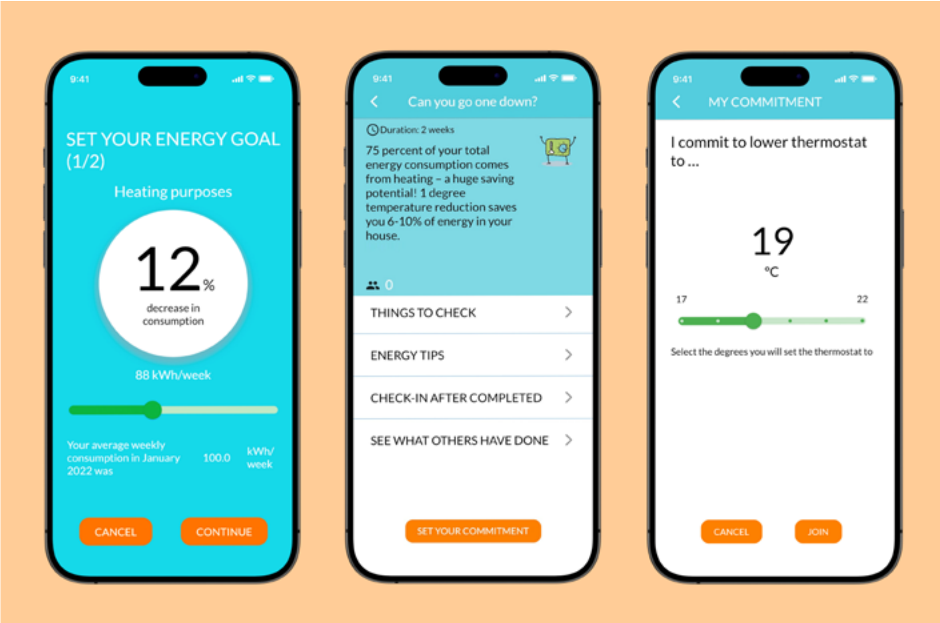

Figure 2. "Social Power Plus" pages provide individual goal-setting opportunities, challenge introduction, and commitment setting.

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.

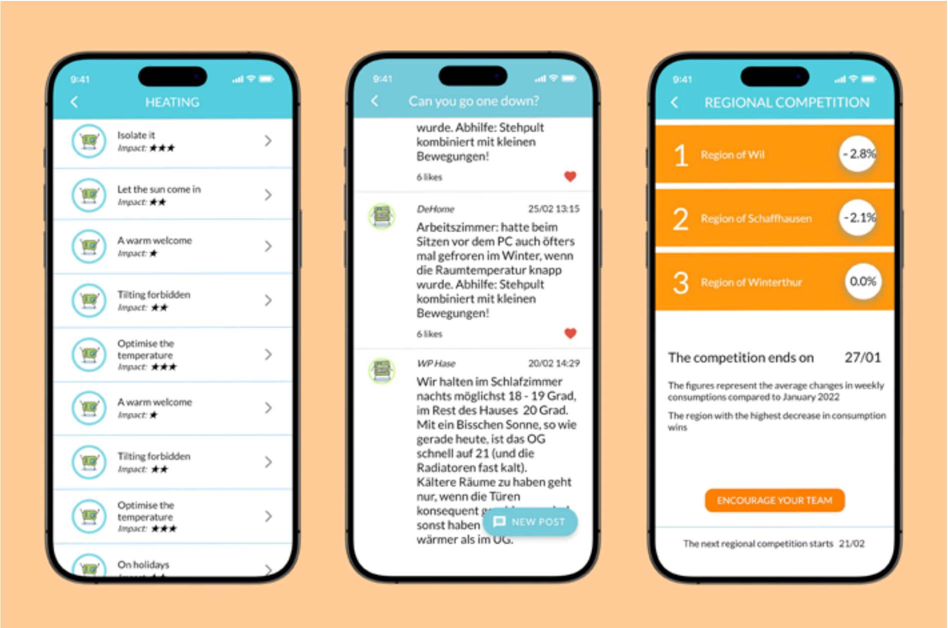

Figure 3. "Social Power Plus" sections provide tips, social interaction possibilities via the pinboard, and the regional energy-saving competition.

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 showers 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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Towards Design Fiction for Human-Centered Energy Transitions

Imagining Infrastructures and Worldbuilding

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Abstract
This article proposes to support human-centered energy transitions through design fiction. Design fiction is conceptualized as a form of worldbuilding in the sense that design fiction not only represents alternative realities but also intervenes in the processes of their emergence. For the context of energy transitions, this article proposes to approach worldbuilding through an understanding of and engagement with energy infrastructures.
The distributed agencies and lengthy time horizons that characterize infrastructural development pose interesting challenges for designers and can be subverted by leveraging the poetic and aesthetic qualities of infrastructure through design fiction.
The article discusses such aspects of energy infrastructures and expected developments in the transition to renewable energy. The approach is illustrated using seven emerging energy worlds, and future steps are identified to develop these into proper design fiction further. Overall, our approach draws together technological, political, and economic trends in the energy sector and provides pointers for designers and artists to intervene and co-shape energy transitions.

1. Introduction

Energy transitions are multidimensional and distributed processes that unfold over multiple decades. This creates challenges for designers who intend to intervene, as a local, human-centered focus is quickly overshadowed by systemic and infrastructural issues (Van Leeuwen & Singh, 2023). Furthermore, energy systems and infrastructures emerge through the distributed agency of many actors, including engineers, policymakers, and administrators, which raises questions about the impact a single designer can make. To address these challenges, this article proposes using *design fiction* to support shifts in values, mindsets, and practices across the distributed networks that shape energy transitions. Through this use of design fiction, the agency and autonomy of all who co-shape energy transitions are acknowledged and respected, as opposed to intervention through political or technological means.

The approach is fleshed out using the concept of *worldbuilding,* which we interpret in two different senses. First, worldbuilding serves to construct representations of alternative and emerging realities. Through worldbuilding, designers and artists can draw the interrelations between emerging technologies, political-economic structures, sociocultural values, and novel forms of community organization, all of which are important aspects of the transition from fossil to renewable energy. Second, by invoking worldbuilding, we recognize and utilize the performativity of design fiction, as it has the capacity to *intervene* in emerging energy transitions. By stimulating the imagination and critical reflection, design fiction can shape sociocultural values and meanings of energy transitions, thereby intervening in the coming about of alternative realities and emerging worlds.

This article proposes to take energy infrastructures as an entry point to characterize how such worldbuilding might occur in the context of energy transitions. Infrastructures draw together technological innovations, political regimes, economic paradigms, and cultural meanings, thus providing a natural underpinning for building an integral vision of alternative futures. Furthermore, infrastructural developments are at the core of the transition to renewable energy. This paper draws from various scholarly perspectives on energy infrastructures, which serves to understand how design fiction can represent various energy transition realities and intervene in emerging infrastructural developments.

Finally, we illustrate our approach by sketching seven *emerging energy worlds* and identifying future steps to turn these into complete design fictions. Overall, this approach to design fiction serves to shift mindsets and value judgments among the distributed actors that co-shape energy transitions.

2. Design Fiction as a Form of Worldbuilding

An early, important work on design fiction is the 2009 essay *Design Fiction* by Julian Bleecker. In his account, design fiction inhabits a middle ground between science fiction and science fact, combining creative speculation with a grounded understanding of real possibilities. He further characterizes this using the term diegetic prototypes, which denotes how speculative technologies, products, or services are experienced by subjects in their idiosyncratic manner. Since then, design fiction has been adopted by the design research community and explored from various perspectives, including user personas and scenarios, narratology and literary theory, and speculative and critical design (Baumer et al., 2020).

This article proposes to understand design fiction through the concept of worldbuilding. We draw from the work of Coulton et al. (2017), who argue that design fiction is a form of worldbuilding rather than a form of storytelling or narrative. They retain the diegetic perspective – i.e., a first-person, subjective view "from within". However, instead of focusing on characters and plotlines, Coulton et al. (2017) emphasize how design fiction can reveal the elements of an imaginary world, as well as the meanings and interrelations of such diverse aspects. This way, design fiction imagines how technoscientific prototypes interact with individual human understandings, situated cultural meanings, and greater societal structures and systems. Design fiction can represent alternative worlds and realities by understanding worldbuilding in this manner.

There is an important second sense in which worldbuilding can be understood, as design fiction can also enact and perform worldbuilding in the social context where it is deployed. This perspective builds on authors like Markussen et al. (2020), who propose that design fiction should be understood through its potential to create social transformation rather than its ontological foundations. Another proponent of this approach is Zaidi (2019), who suggests that designers can support the transformation of cultural meanings and societal structures through worldbuilding practices. Various applications of design fiction show how such transformations can concretely manifest. For example, Wu et al. (2019) use design fiction to stimulate ethical awareness and reflection among professionals, and Blythe et al. (2016) show how design fiction subverts solutionist thinking. Furthermore, the field of design anthropology may provide useful pointers, as it combines an understanding of emergent, alternative worlds with interventionist and performative action (Smith & Otto, 2016; Halse & Boffi, 2016; Singh, 2019). Building on such perspectives, this article proposes to use design fiction to support co-shapers of energy transitions in their judgments, reflections, practices, and actions. It does so by pointing toward alternative realities and possibilities, illustrating the diverse ways sociocultural meanings and values can manifest.

3. Energy Infrastructures as a Starting Point for Worldbuilding

This section argues that infrastructures form an interesting point of departure for worldbuilding due to their interconnective, heterogeneous, and pervasive nature. By discussing various important dimensions of energy infrastructures, including their political, economic, and aesthetic dimensions, a conceptual toolbox is constructed to conduct worldbuilding in the context of energy transitions.

First, we argue that an understanding of infrastructures creates an integral picture of a world that ties together technology, societal structures, cultural values and meanings, and individual, subjective perspectives. Infrastructures can be considered the backbone of modern civilization, as they create the interconnective tissue for the flow of people, materials, and ideas (Larkin, 2013). More than a material network of interconnected technological components, infrastructural ecosystems consist of entangled technologies, administrating organizations, financial techniques, and regulatory structures (Hughes, 1983). As such, infrastructures create the enabling background conditions for society to function.

In particular, energy infrastructures are closely tied to political and economic systems. In his 2011 work, *Carbon Democracy: Political Power in the Age of Oil*, Timothy Mitchell analyzed how the materiality of coal- and oil-based infrastructures co-shaped with the political paradigms of their time. While labor-intensive coal logistics enabled worker strikes and hence socialist politics, oil pipelines and extraction wells centralized control with Western governments and corporations. Dominic Boyer (2019) provided a more present-day perspective, who coined the term *energopower* to show how wind energy development in Mexico co-developed with diverse political and institutional processes, including the interests of local indigenous groups.
Whilst this is only a brief indication of the significance of these works, they show the necessity for worldbuilding practices in the energy context to take matters of power and politics seriously and how infrastructural properties shape these. In the second, interventionist sense of worldbuilding, infrastructures pose interesting challenges for designers. Thomas Hughes' 1983 book *Networks of Power* shows these in two important ways. Firstly, the electrical grid is shown as a fun-

damentally distributed system where no single actor controls its development. While individual entrepreneurs like Edison played an important role, competing systems and models emerged in diverse regulatory regimes and geographical contexts, stabilizing beyond the control of any individual actor. Designerly intervention in infrastructural development must somehow account for this distributed agency. Furthermore, Hughes described how various phases of infrastructural development unfolded over decades. The long development time of infrastructures means there is a fundamental uncertainty about how early interventions will develop over time.

To deal with these challenges, we propose that designers can participate in infrastructural change by supporting informed reflection, decision-making, and judgement for people who are a part of infrastructural ecosystems. Design fiction can support this by leveraging the *aesthetic* dimension of energy infrastructures. This aspect is identified by Brian Larkin (2013), who argues how the materiality of infrastructure – e.g., the concrete of a road or the iron of industrial machinery – produces a certain aesthetic sensibility in the beholder, which shapes the subjective meanings associated with the infrastructure. He also argues that infrastructures have a *poetic* quality, as they are often associated with promises and visions of societal progress. Since infrastructures are so extensive and heterogeneous, Larkin argues that the definition of an infrastructure is a political act. This would make exploring energy infrastructures through design fiction a political project in its own right, as would how designers give shape and form to the aesthetics of infrastructures. This article holds that leveraging the aesthetic and poetic qualities of infrastructures within design fiction is a promising avenue for designers to pursue and co-shape infrastructural developments. This is opposed to traditional forms of product design, which occupy a limited space downstream of an infrastructural ecosystem and are subject to dominant economic and political paradigms.

4. Infrastructural Innovation in the Transition to Renewable Energy

Having established the relevant aspects of energy infrastructures for worldbuilding, this section discusses the infrastructural overhaul required for the renewable energy transition, touching on technological, political, and social dimensions. The current electrical grid is organized in a hierarchical, centralized manner, as it transports electricity from a few centralized power plants to many end-consumers. Renewable energy requires a fundamentally different, more decentralized architecture. Solar and wind energy are geographically dispersed, and new sources of flexibility are required to compensate for the uncontrollability of the weather. Under the smart grid paradigm, digital technologies are expected to play a larger role in data collection, predicting future energy flows, and controlling the grid (Skjølsvold et al., 2015). Furthermore, new end-user-facing technologies are also emerging, such as electric vehicles, smart home energy systems (Geelen et al., 2013), and digital energy platforms (Boekelo & Kloppenburg, 2023).

Existing research provides several pointers for understanding these developments' political, economic, and aesthetic qualities. A common expectation is that bottom-up actors like prosumers and energy communities gain power by practicing *energy citizenship* and *energy democracy* (Wahlund & Palm, 2022). Households and communities can become more autonomous by utilizing locally sourced renewables and energy storage, such as batteries. Hence, the renewable energy transition may not only lead to a more distributed infrastructural architecture but also a more decentralized political system (Funcke & Bauknecht, 2016). At the same time, the increasing reliance on smart technology may centralize control in the hands of a select few actors, as has been the case in other sectors. Since smart technology is associated with technocratic and solutionist forms of governance, its use in energy systems may have a depoliticizing or even *antipolitical* effect (Sadowski & Levenda, 2020). An example of this could be *demand response* practices, which are techniques for grid operators to steer behavior using price signals to secure the grid's stability (Calver & Simcock, 2021).

Similar arguments can be made about novel modes of energy exchange. A common expectation is that households will evolve from consumers of energy to *prosumers* of energy who engage in peer-to-peer (P2P) energy trading on local energy markets. While this is often hailed as a positive and empowering development, it is not difficult to recognize the framing of the *homo economicus* in these perspectives, where end-users of energy are seen as rational individuals who are optimizing for self-interests (Singh, 2019; Singh et al., 2017). This approach may be distinguished from perspectives on energy communities, where access to energy resources is shared collectively (Bauwens et al., 2022), the energy justice framework which prioritizes a just distribution of costs and benefits (Hanke et al., 2021), and alternative forms of energy exchange which prioritize social relations (Singh et al., 2018). While these discussions briefly show what contested aspects of renewable energy infrastructures are emerging, they indicate potential directions designers and artists may explore in their worldbuilding efforts.

5. Seven Emerging Energy Worlds

The above sections discuss what could be the conceptual building blocks for designers and artists to explore the significance of energy transitions through worldbuilding. This section presents early versions of what we take to be *emerging energy worlds*. These worlds are constructed using concepts discussed above and from empirical research conducted in a local energy transition project in Amsterdam South-East. Through ethnographic fieldwork and co-creation sessions, the authors explored tensions between diverse stakeholders, the potential for community involvement, and the design of infrastructural innovations. This research is not further elaborated within this paper, but for more details, readers can refer to Van Leeuwen & Singh (2023) and Van Leeuwen & Singh (2024).

The worlds described here are not exhaustive of all possibilities but indicative of directions that might be pursued in future work. For the present article, these worlds are described at a high level – they are not complete design fiction but provide directions for further development. If sections provide the grounding realities of 'science fact,' the section proposes avenues for creative speculation. Several steps should be taken to further develop these directions into concrete design fiction. For each emerging energy world, suggestions are made about what these steps could look like.

The first step is to consider the *transformative purpose* of the design fiction, i.e., the shifts in mindsets, values, or practices this design fiction should support. The second step is determining the *social context* in which it will be deployed, regarded, and explored. Design fiction may be strategically mobilized within projects, networks, or organizations that make up the process of infrastructural development. The third step is to define the *aesthetic form* the design fiction will take, including the subjective perspective from which the energy world is perceived. This is crucial for creating immersion and imagination beyond present-day constraints and realities.

5.1. A Crumbling Grid

What would the world look like if the electrical grid failed to provide a stable electricity supply and the power went out for days or weeks? Supply chains, digital communications, digital payments, and other systems we have taken for granted could fail and become inaccessible. As a result, authorities might implement emergency measures to reduce and control energy consumption to safeguard the grid's stability.

- **Transformative purpose**: to make people aware of the crucial reliance of our society on the electrical grid and how it enables our daily practices.
- **Social context of intervention:** with end-users of energy, i.e., citizens who are not particularly aware or conscious of how the grid is functioning.

- **Aesthetic form:** a day-in-the-life of end-users of energy to explore how daily life is impacted by a lack of stable electricity supply.

5.2. Techno-Capitalist Monopoly

What if large technology corporations assume complete control over the energy system and own the energy supply and grid infrastructure? Such actors could use advanced technologies like artificial intelligence to predict and control energy flows in the grid, which would be completely invisible to outsiders. Volatility in energy markets could increase corporate profits at the expense of household energy expenditures.

- **Transformative purpose**: to make people aware of the consequences of excessive use and reliance on smart technology and free market mechanisms.
- **Social context of intervention:** with technologists, innovators, and economists in the energy sector, to explore the consequences if a technology-centric, market-based approach is taken too far.
- **Aesthetic form:** a speculative smart energy product-service system or a “job-of-the-future” description for a smart energy technologist working at a large technology corporation.

5.3. Autonomous Energy Community

What if local communities isolated themselves from the rest of the system, aiming to become as independent as possible? Such tight-knit communities might jointly share access to energy resources without a notion of individual ownership. Technical skills in infrastructural maintenance would be highly valued, and social relations could be characterized by in-kind exchanges.

- **Transformative purpose**: to support reflection on an approach to energy systems that prioritizes social relations and values rather than technology and efficiency.
- **Social context of intervention:** with citizens looking to start an energy community, as well as professionals who develop tools, products, and services for energy communities, or who work with energy communities.
- **Aesthetic form:** a day-in-the-life of members of the autonomous energy community, using visuals that represent local community life.

5.4. Smart Energy Household

What if households embraced smart technology, combining household solar energy, batteries, and algorithms to optimize their own consumption? Automated systems could trade this energy on local energy markets to maximize profit and minimize costs. Through apps and other product-service systems, households are engaged through gamification and energy competitions to change their behavior.

- **Transformative purpose**: to explore peoples' preparedness to adopt new home energy systems and services and to support a more user-centric design of such products.
- **Social context of intervention:** in design and innovation processes where professionals are working on new smart energy systems and services, as well as with potential future adopters of these technologies.

- **Aesthetic form:** a day-in-the-life, or other representation, of how end-users of these speculative technologies adapt their daily routines to a home smart energy system.

5.5. National Energy Commons

What if national governments assumed top-down, technocratic control over the energy supply? Expert knowledge and scientific instruments could be mobilized to meet national goals for reducing the energy system's CO2 emissions. Energy budgets could be imposed on end-users, and national campaigns could be organized to educate people about energy use and recruit people for energy-related jobs.

- **Transformative purpose**: to stimulate reflection on the controversial decisions that might emerge around energy governance and the degree to which political control should be centralized.
- **Social context of intervention:** with policymakers, energy policy researchers, and anyone else interested in energy system governance.
- **Aesthetic form:** explore decision-maker's perspective in energy governance and the tensions and dilemmas they encounter.

5.6. Smart Energy Hub

What if businesses and commercial actors worked together to better maintain the stability of the local electricity grid? Businesses could strike special contracts with the grid operator to share access to the grid and use smart technology to jointly optimize the use of solar energy, battery and heat storage, and flexible consumption.

- **Transformative purpose**: to support businesses and other commercial actors in collaborating and exploring joint energy transition solutions.
- **Social context of intervention:** with business representatives who are open to exploring collective energy solutions.
- **Aesthetic form:** a speculative contract or interface that represents how energy resources among different actors are interconnected and interoperate, which shows the social agreements that are in place for local energy governance.

5.7. Local Energy Institution

What if the energy system were governed democratically, with local institutions for political decision-making? Such institutions could govern a particular grid section and impose their own form of energy taxes and regulations. They would make political decisions about how scarce energy resources are distributed, exchanged, and organized.

- **Transformative purpose**: to explore what kind of political decisions and reasonings factor into local energy system governance and what a democratic institution in this regard could look like.
- **Social context of intervention:** with policymakers, citizens, researchers, or other professionals interested in exploring alternative forms of local energy system governance.
- **Aesthetic form:** represents the perspective of local leaders or politicians who are tasked with making decisions about local energy system governance.

6. Towards Design Fiction for Human-Centered Energy Transitions

Transitions and infrastructural developments unfold over decades, and, likely, many future developments in technology, governance, and economy cannot be foreseen. Furthermore, the extensive scale and distribution of agency in systemic transitions is such that local, human-centered interventions are limited in scope. This article provides pointers for how design fiction can serve to intervene at a local level while not losing sight of greater systemic trends.

While this article aims to make steps toward developing design fiction that supports the emergence of human-centered energy transitions, these efforts are far from complete. From the descriptions provided in Section 5, several important steps still need to be taken to develop design fiction, as we have defined in this article. Design fiction should go beyond textual descriptions and consist of visual and material prototypes. Such prototypes should illustrate diverse aspects, including the social, political, and technological, at various scales, including local, national, and global, and through diverse perspectives, including end-users, professionals, or decision-makers. While we intend to explore these in future work, we encourage other designers, artists, and researchers to do the same.

Design fiction can support nuanced perceptions, reflections, and actions among energy transition actors by sensitizing people to these diverse realities and possibilities.

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Environment/Data/People

[Eco] Participation through Data Visualization as Design Strategic Approach for Engaging, Sensitizing, and Educating the Community to Energy Transition

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Abstract
In the face of a polycrisis marked by environmental, social, and economic upheavals, the transition to sustainable energy has become a global imperative. This transition is not only a matter of policy and infrastructure but also hinges on the individual citizen, who initiates and completes the process. Therefore, it is crucial for citizens to possess adequate energy literacy in line with the 2030 SDGs. Information Design plays a significant role in this scenario by creating communicative artifacts that narrate complex topics in an easily understandable manner to a broad audience. Moving from the cold, intangible dimension of data to a warm, tangible, human dimension can be achieved using visual metaphors, the creation of new levels of meaning, and the co-creation and participation in the visualization project. The physical and digital involvement with data can design a unique communicative bridge between people, the environment, and stakeholders. In this context, the participatory visualization and physicalization of data for eco-educational purposes termed [Eco] Participatory through Data Visualization - could be a promising area of investigation in communication design research and practice.

1. Introduction

In the current scenario, promoting the change towards sustainable energy sources requires an approach that actively involves both the individual and the community, including all economic and productive actors, to steer personal choices towards social responsibility (Leonardi, et al., 2023, translated by the Author). While, on the one hand, the role of social and political agencies is evident, on the other hand, it's crucial that the individual citizen who is the beginner and the finisher of the energy transition process and who, therefore, needs proper sustainability and energy literacy (IRENA, 2022) according to the SDGs 2030 (United Nations, 2015). Visual Communication Design, both in Information Design (Kirk, 2019) and Environmental Graphic Design (Calori & Vanden-Eynden, 2015), is able to make a relevant contribution in the energy transition scenario, by designing communicative artefacts capable of narrating complex topics in a quick and easily understandable way to a wide audience (Tufte, 1982).

2. The Importance of Being Energy Literate: the Role of Participation as Driver of Emotional Involvement

Energy literacy is a fundamental aspect in encouraging energy-saving behaviors and fostering sustainability. Energy transition is surely not only about technological change, but it must also reflect socio-cultural and environmental transformations on the local level (Chodkowska-Miszczuk, et al., 2021). In this sense, on the one hand, energy literacy encompasses cognitive, affective, and behavioral domains, influencing individuals' understanding of energy consumption, production impacts, conservation needs, and renewable energy development (Aguirre-Bielschowsky et al., 2015), and, on the other hand, it focuses on the ability to assess energy-related problems, and the adoption of appropriate behavioral strategies (Usman et al., 2021). Energy literacy at all educational levels is crucial for promoting energy-saving practices (Cotton et al., 2016). This is particularly relevant in the "greening" agenda in higher education, where developing students' energy literacy is a key aspect (Cotton et al., 2015).

In the energy transition context, energy literacy is crucial for increasing public awareness and participation in energy-related issues (Hendinata et al., 2022). It is also linked to wider sustainability issues, making it a good proxy for measuring sustainability in educational institutions (Cotton et al., 2017). That's because energy awareness comes down to understanding the basic concepts, rules, theories, energy transfers, transformation processes, and the role that energy plays in everyday life (Chodkowska-Miszczuk et al., 2021). Moreover, energy literacy is considered a minimum required capacity for developing a sustainable society that actively engages in discussions on energy and environmental issues (Akitsu & Ishihara, 2018). The involvement of the education sector in promoting energy literacy is seen as a strategy to build awareness in students from an early age (Rohmatulloh et al., 2021; Putri et al., 2022). Furthermore, an energy-literate individual not only possesses basic energy-related knowledge but also comprehends both the environmental impacts of human energy activities on the ecosystem (Khuc et al., 2023) and the necessity of developing the skills to address energy-related challenges (Puspitasari, 2020; Usman et al., 2021).

To achieve these abilities, participation is an essential key strategy for fostering informed decision-making, promoting sustainable energy practices, and empowering individuals to contribute to energy transition efforts. Research has emphasized the importance of participation in enhancing energy literacy levels and encouraging engagement in energy-related issues (Ryghaug et al., 2018). Actively engaging in energy-related activities and discussions allows individuals to deepen their understanding of energy concepts, contribute to energy citizenship, and support the transition towards renewable energy sources (Ryghaug et al., 2018). Community awareness and participation are vital for driving changes that reduce climate change impacts and greenhouse gas emissions (Mohamad & Osman, 2022). For instance, engaging communities in energy-related discussions and initiatives can lead to collective action toward mitigating environmental challenges and promoting sustainable energy practices (Mohamad & Osman, 2022). Furthermore, involvement in energy literacy initiatives can increase awareness of energy consumption patterns, which is crucial for effective engagement in transitioning energy systems (Zanocco et al., 2022).

Adding to these, participation in the sense of being emotionally involved into the energy issue topic defines a crucial role to foster energy literacy through the design and fruition of data art experience. Information design strategies – such as

Data Visualization[1], Data Art[2] and Data Physicalization[3] – are essential for enhancing energy literacy by effectively conveying complex information in a more understandable and engaging manner, improving decision-making, changing attitudes, and reducing risky behaviors (García-Retamero & Cokely, 2013).Indeed, data art plays a significant role in communicating environmental data by evoking emotional responses and fostering connections with nature, creating empathy for ecological issues, influence pro-environmental attitudes, and encourage pro-environmental behavior (Curtis et al., 2012; Curtis, 2009; Brock et al., 2022). Through data visualization artifacts, individuals can develop a sense of empathy toward environmental concerns and engage in meaningful dialogues about sustainability (Sommer & Klöckner, 2021). Moreover, the emotional engagement facilitated by data art can lead to increased environmental awareness and sensitivity to ecological issues (Wang et al., 2022). Combining science and art opens new avenues for research and discussion on environmental matters, providing emotional and human contexts that enhance the understanding of complex environmental topics (Valentini & Nesci, 2021). To achieve these

1 Data visualization involves creating visual representations of data using common graphics like charts, plots, and infographics. These visual displays help convey complex data relationships and insights in an easily understandable manner.

2 Data Art, or Information Art, is a visual medium that draws inspiration from and integrates data, computer science, information technology, artificial intelligence, and related data-driven disciplines. It leverages data as source material to craft visually captivating and meaningful representations, conveying emotions to the audience by revealing insights, patterns, or hidden stories in an accessible and creative manner.

3 Data physicalization explores the use of physical artifacts to represent data. It intersects with various research domains, including information visualization, scientific visualization, visual analytics, tangible user interfaces, shape-changing interfaces, personal fabrication, graphic design, architecture, and art.

goals, emotional involvement with the data is mandatory because the participation with the content domain is a crucial determinant of the effects of interactivity (Wojdynski, 2015). In this sense, people participate in the visualization because in a dynamic data visualization – dashboard or interface – the result of the visualization is linked with the interaction and determines a custom result.

3. Participation through Data Visualization to Foster Energy Transition: Designing *Affective* Visualization

Through his action, the designer facilitates the co-creation of individual awareness and collective consciousness through the involvement of all actors (Rizzo, 2009) and by addressing personal choices toward social responsibility (Leonardi et al., 2023). The resistance of communities to understanding data – both due to a low level of graphicacy (Cairo, 2017) and relativism towards environmental issues – necessitates data humanization strategies (Bertling, 2023) to instill collective empathy towards the energy transition; a holistic approach that keeps in mind environment, data and people. Let's move from the cold and intangible dimension of data to a warm and tangible – human – dimension that is the result of both the use of visual metaphors and the creation of new levels of meaning (Lupi in Lange, 2019) and the co-creation and participation in the visualization project and ultimately the physical materialization of the information itself. It is possible to design a particular communicative bridge between people, the environment and stakeholders. To enhance energy literacy and support energy transition, participatory design strategies are essential for engaging stakeholders in the design and development of energy-related initiatives. Participatory design involves incorporating end-users, such as community members, in decision-making processes to ensure that resulting solutions align with their needs and preferences Tuhkala (2021). This approach can lead to enhanced quality and usability of energy-related designs, increased acceptance of innovations, improved comprehension of energy concepts, and more effective implementation of energy transition initiatives (Könings et al., 2007). In energy literacy, participatory design can entail collaborative efforts among educators, policymakers, and community members to co-create educational materials, workshops, and programs that deepen understanding of energy production, consumption, and conservation practices (Könings et al., 2010). By involving stakeholders in the energy literacy initiatives' analysis, design, and implementation stages, participatory design can guarantee that resulting interventions are pertinent, engaging, and successful in promoting energy literacy (Könings et al., 2010). In these terms, it is possible to assume that the participatory visualization of data (Moretti & Mattozzi, 2020) applied for eco-educational aims (Bertling, 2023) – a so-called [Eco] Participation through Data Visualization – could be an approach capable of considering thinking, attitudes, emotions, motivations (IxDF, 2016). Indeed, environmental data storytelling can trigger an emotional reaction, harnessing the power of motivation, imagination and personal values, the driving forces behind the most effective and lasting forms of social change (Lack, 2020, Translated by the Author). In this sense, data visualization should be humane, ethical, and do good to society (Lan, Wu & Cao, 2024): in a few words, it should be an effective visualization design.

3.1. Data Visualization and Community Interaction: Environmental Data as Participatory Interface

Integrating participation for building and staging data is key to engaging communities and improving understanding of environmental challenges. Individuals can participate in a tangible and engaging experience beyond traditional data dissemination methods. Participatory methods have been identified as a way to empower the public and prevent the reinforcement of existing power dynamics (Lorenz & Kolb, 2009). This approach democratizes access to information and promotes active involvement in energy-related decision-making processes. Through data visualizations, viewers and participants are immersed in a collective experience that raises awareness and encourages discussions about the energy transition.

Figure 1. Insidius Riding. Sample of the data visualization interface. © Hyphen Labs. Fair Use.

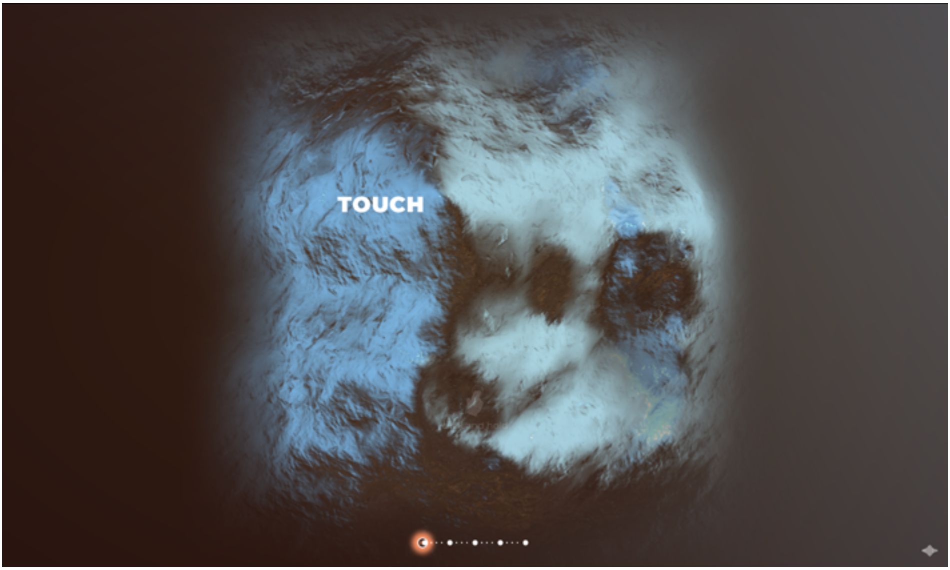

Figure 2. Insidius Riding. Sample of the data visualization interface. © Hyphen Labs. Fair Use.

Heartbeat of the Earth (2009 – ongoing) is a continuous initiative by Google Arts & Culture Lab that brings together artists and scientists in a unique participation, to use technology creatively to interpret, communicate, and expand upon environmental data. A first reference to the Google project is the mobile-first data story titled Insidio*us Riding* (2022) (Fig. 1). This project is the brainchild of the globally recognized artist collective Hyphen Labs, in collaboration with the Union of Concerned Scientists and Allison Akootchook Warden, a renowned poet and Indigenous spokesperson. The interactive narrative invites users to embark on a tactile journey, exploring the multifaceted challenges that our planet currently faces (Fig. 2). These issues are represented through the depiction of a melting glacier, a poignant reminder of the urgent need for environmental action.

One of the key concepts explored in this artwork is the ecological cascade effect. This phenomenon refers to a chain of secondary extinctions set into motion by the primary extinction of a pivotal species within an ecosystem. The loss of such a species can disrupt the balance of the ecosystem, leading to unforeseen consequences and potentially triggering a domino effect of extinctions. *Insidius Riding* delves into the intricate interconnections within our environment, highlighting the potential cascade effects of accelerated global warming, the thawing of the cryosphere, and rising sea levels. The artwork vividly depicts how these interconnected issues could precipitate an ecological collapse. For instance, the thawing of the cryosphere could lead to the emergence of prehistoric viruses locked away in ice for millennia. Similarly, the accelerated warming of our planet and rising sea levels could have cascading effects on our agriculture, leading to the disappearance of essential pollinators like bees and the consequent vanishing of crops. Through its immersive narrative and interactive design, *Insidius Riding* is a powerful environmental education tool. It encourages users to engage with the pressing issues of our time and fosters a deeper understanding of the delicate balance that sustains life on our planet. The story underscores the urgency of collective action and the need for each of us to play our part in preserving our shared home for future generations.

There is also a need to incorporate emotional and storytelling data elements into these visualizations, which can effectively convey complex information and elicit meaningful responses. As highlighted by Kennedy & Hill (2017), emotional engagement with data is essential for making sense of information, emphasizing the importance of incorporating emotional components into data visualization strategies. In this sense, the second case study of the Google Project titled *Plastic Air* (2021) by Giorgia Lupi has surfaced, offering a profound exploration of microplastics' impact on our environment and health (Fig.3). As it turns out, discarded plastic remains. Instead, it degrades into increasingly smaller fragments known as microplastics. These minuscule particles eventually enter our air, becoming an invisible yet pervasive presence in our atmosphere. Through the work, viewers are provided with a unique lens, enabling them to "see" and explore the omnipresent plastic particles that fill the air around us. It incorporates published research from many esteemed institutions, including the University Fernando Pessoa, the University of Plymouth, the University of Georgia, the University of Victoria, the University of Strathclyde, Utah State University, and Université Paris-Est.

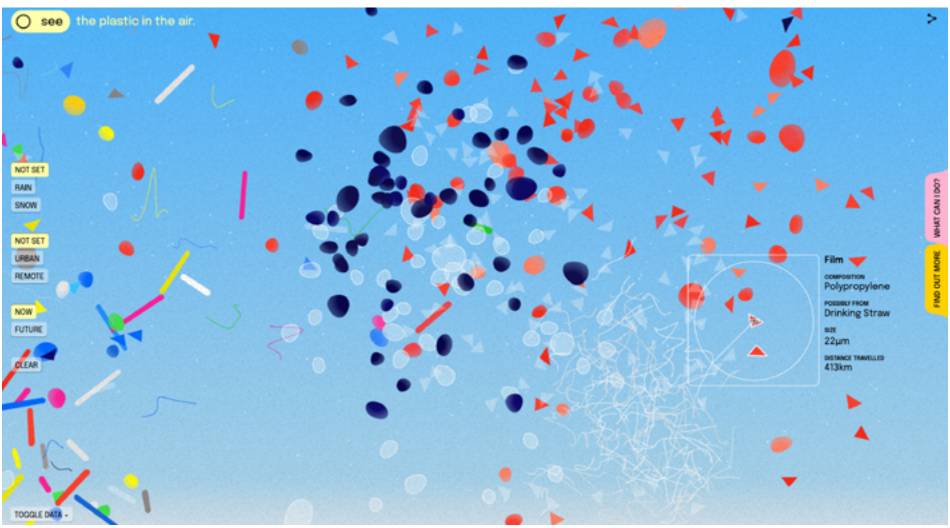

Figure 3. Plastic Air. Sample of the data visualization interface. © Giorgia Lupi. Fair Use.

Figure 4. Plastic Air. Sample of the data visualization interface. © Giorgia Lupi. Fair Use.

Plastic Air is a stark reminder of the far-reaching consequences of our reliance on plastic. It highlights the insidious journey of plastic from our hands to our atmosphere and, ultimately, back to us as we inhale these microplastics (Fig. 4).
The project underscores the urgent need for more sustainable practices and invites viewers to reflect on their consumption habits. Citizen participation, as emphasized by Chitsa et al. (2022), is critical to driving bottom-up transition and policy development, particularly within urban communities. Involving citizens in creating and staging data visualizations can help communities develop a sense of ownership and empowerment, leading to more effective climate change mitigation and adaptation efforts. Indeed, *Plastic Air* is a call to action, a plea for awareness, and a testament to the power of art in conveying complex environmental issues. It challenges us to reconsider our relationship with plastic and to strive for a future where clean air is not a luxury but a right.

3.2. Data Visualization and Community Involvement: Environmental Data as a Participatory Artifact

Adopting data visualization strategies can make otherwise complex and remote information accessible to the public. This process increases energy literacy and promotes concrete action on crucial environmental issues. In an era of widespread climate change denial and pervasive inertia on the part of citizens and governments, the ability to communicate clearly and engagingly through data physicalization becomes even more relevant to translate data into artifacts that are simultaneously tangible, visible, and perceptible with senses other than vision. As a reference, World Primary Energy (2020) is a data physicalization exhibit that blends technology, data, and design. It offers a comprehensive, interactive, and visually appealing perspective on the future of energy consumption. It serves as a reminder of the importance of renewable energy and its role in our future. This exhibit is a collection of 25 meticulously 3D printed pillars, each symbolizing the anticipated future energy consumption (Fig. 5). The data exhibit designers embarked on a journey to scrutinize the global progression of energy consumption. They looked ahead from 2020 to 2100 across five prospective scenarios. But the exhibit doesn't stop there. It goes further by incorporating factors such as population growth and temperature rise. These factors are seamlessly integrated into the exhibit via rear projection through a laser cut. The exhibit is interactive and controlled via an app. The data fueling this exhibit is sourced from a reputable institute dedicated to climate impact research, the Potsdam Institute. The data presents many perspectives and interdependencies, offering a comprehensive view of our energy future.

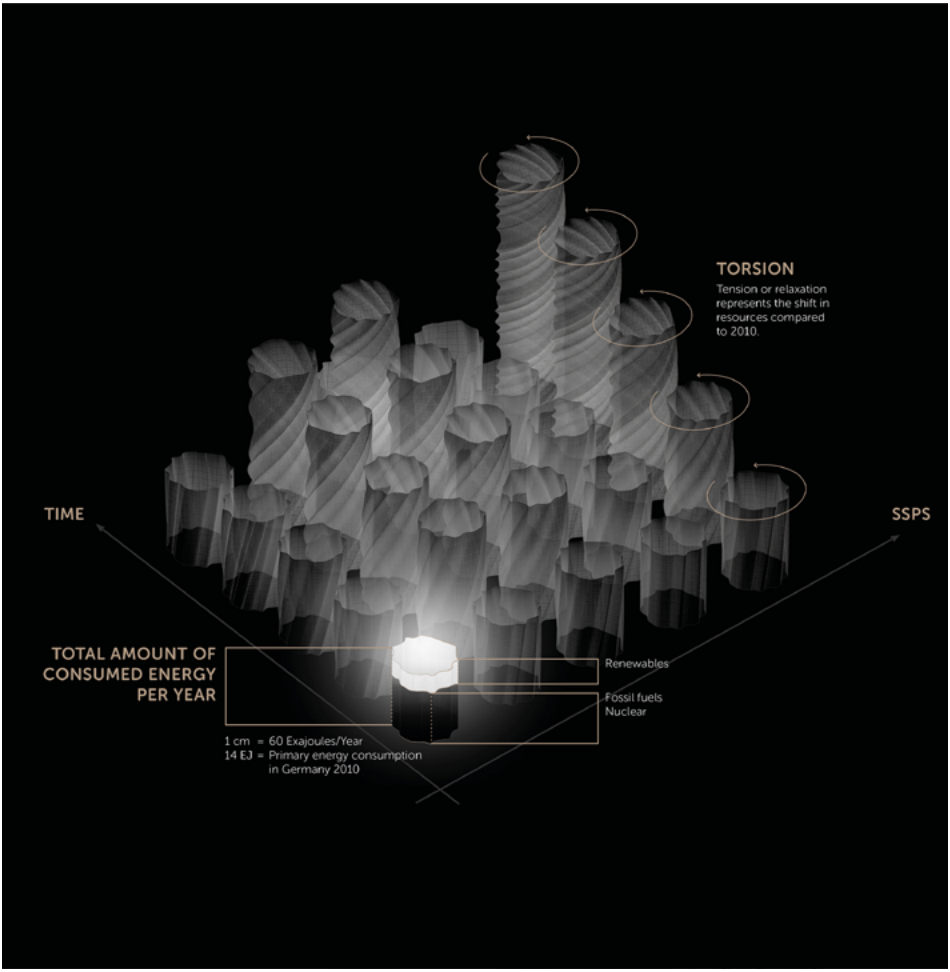

Figure 5. World Primary Energy. Sample of the data physicalization © Katja Budinger, Stéphane Flesch, Roman Grasy, Kathi Veitengruber. Fair Use.

The physical representation of the data aids in the analysis and comparison of database excerpts. Each pillar's height corresponds to the annual global consumption of primary energy. Furthermore, each pillar is bifurcated into two sections (Fig. 6). Renewable energies are depicted in white, while a combination of fossil fuels and nuclear resources is depicted in black.

This color-coded system provides a clear visual representation of the energy sources. The rotation of the form is another intriguing aspect of the exhibit. It illustrates the distortion of energy developments in future scenarios, providing a dynamic view of potential outcomes. The pillars are strategically arranged on a two-dimensional grid. The y-axis represents the timeline from 2020 to 2100, providing a chronological view of energy consumption. The x-axis, on the other hand, represents the Shared Socio-economic Pathways, offering a socio-economic perspective on energy usage.

Figure 6. World Primary Energy. Sample of the data physicalization © Katja Budinger, Stéphane Flesch, Roman Grasy, Kathi Veitengruber. Fair Use.

3.3. Data Visualization and Community Engagement: Environmental Data as Participatory Space

As Rosing and Eliasson (2018) emphasize, one of the most pressing challenges of our time is the sense of alienation and distance that many people feel to major global issues, thus losing a sense of belonging to the worldwide community. Indeed, data are a means to understand a complex world but not the end: we must always maintain sight of what lies behind the numbers, and to design practical tools and stories, we must learn to look through them (Lupi, 2022). In this sense, we could look at Artboat as a case study.

ArtBoat: Magazine Beach (2015-2020) is a unique data-art installation that breathes life into public green-blue spaces. It uses light as a medium and transforms the river into a canvas (Fig. 7). This i-project is powered by SeeBoat, a remote-controlled boat fitted with sensors and LEDs.

Figure 7. ArtBoat: Magazine Beach. Sample of the data physicalization © Laura Perovich, MIT. Fair Use.

Figure 8. ArtBoat: Magazine Beach. Sample of the data physicalization © Laura Perovich, MIT, Ph Neil Gaikwad. Fair Use.Use.

These components measure and visually represent water quality data in real-time. The project is the brainchild of Laura Perovich from the MIT Media Lab. It responds to the "Sky Art Conferences" by MIT's Center for Advanced Visual Studies, which used the sky as an installation site. Now, the water has become the primary site for artistic display. The project aims to make environmental data more interactive and understandable for communities and researchers. During ArtBoat installations, communities gather at riverside public parks. They collaboratively create light paintings on the water using a color-mixing board (Fig. 8). This board helps formulate light palettes, which are then used to control the color of a remotely operated ArtBoat. Essentially, this system serves as a paintbrush, and the river becomes its canvas.

Community photographers capture these moments of shared creation, community development, and public space ownership. They use long-exposure images to offer a fresh perspective of urban space. SeeBoat takes ArtBoat a step further by merging it with water quality sensors. This allows communities to color the river based on water quality data, enhancing their understanding of the environmental and climate challenges we face as a community. The project emphasizes the importance of community understanding of environmental pollution. This is particularly relevant given that many facilities in the US significantly violate their Clean Water Act permits. The initiative explores new ways to engage communities in environmental data and foster meaningful civic conversations. In doing so, it hopes to inspire a new wave of environmental awareness and action. In this context, data physicalization in public space emerges as a crucial tool for creating awareness and understanding of energy use, which is often "hidden" or "not directly apparent" to most people (Broms et al., 2010). By democratizing energy data through physical visualizations such as physicalizations of energy, communities can interact with and understand energy-related information in a more accessible and engaging way (Morais et al., 2021). Overall, incorporating participatory data visualization into public spaces increases public awareness and discourse and enables individuals to contribute to the energy transition movement actively.

4. Conclusion

From the thawing of the cryosphere to the emergence of prehistoric viruses, from the impact of microplastics to energy consumption and water quality, the projects presented challenge us to reconsider our relationship with consumption, highlighting scenarios and perspectives of [Eco] Participation through Data Visualization as a tool for raising awareness and educating on environmental issues. Information design-led approaches, using a visual code that mediates between abstract concepts – data – and concrete objects – visualization – may indeed be able to bridge the gap between traditional and scientific knowledge, arousing interest and motivating concrete actions. However, what emerges is the need for a holistic approach capable of implementing strategies for humanizing data that consider their visualization and physicalization, the storytelling linked to them, improving the process of use and focusing on the active participation of citizens. Despite significant progress – from practice to research – there are some limitations, including making data accessible and understandable to a broader audience, the need for more sophisticated interactive tools, and integrating different data sources meaningfully. In addition, there is a disparity in access to the technologies needed for data visualization, which could increase the gap between different socio-economic communities. To address these limitations, future development areas should focus on creating more inclusive and accessible platforms, developing technologies that facilitate data interactivity and integration, and implementing participatory methodologies that actively involve local communities. In addition, it is essential to foster interdisciplinary collaborations that combine technical, scientific, and humanistic skills to develop more engaging and persuasive narratives. Thanks to the integration of participatory approaches and interaction with data through interfaces, objects, and spaces, users are encouraged to engage with the urgent issues of our time, fostering greater sustainability literacy. A so-called [Eco] Participatory Data Visualization can increase motivation, awareness, and active involvement in addressing complex issues such as energy transition (Rappold et al., 2019; Provenzi & Barello, 2020). Investing in these strategies helps us understand environmental challenges better and brings us closer to achieving a more equitable, prosperous society in harmony with the planet. It is, therefore, necessary for professionals and policymakers to adopt a proactive approach in encouraging the use of data visualization for environmental education by investing in technology and data literacy programs, promoting collaboration between public and private entities to create interactive and accessible platforms, and supporting community initiatives that use data visualization to raise awareness and engage citizens. It is possible only through a collective effort to effectively address environmental challenges and promote the transition towards a sustainable future.

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Design for Temporary and Sustainable Music Festivals
New Values and Informal Educational Systems for Humanizing Energy Transition

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Abstract
Whether today the energy transition is too often expressed with technical-scientific languages and approaches, highly specialised and top-down, appearing hardly comprehensible to common sense, it becomes necessary for the culture of the project to support milder and more suitable strategic levers of action and innovation, to embrace paradigmatic changes from below, certainly more relational, inclusive and qualitative.
In this sense, given their nature as centres of artistic expression and cultural, educational propagation, temporary and sustainable music festivals can take on a dimension of social activism, helping to inspire people towards new environmentally, energetically, and socially preferable trends and behaviours.
In the last decade, in Europe, festival managers, public institutions, design teams of various backgrounds and active citizens' groups, have rethought temporary music events in a sustainable way, fostering and disseminating an awareness of the logic of circularity, water-saving, energy-saving, soft mobility, use of renewable sources, and other interrelated issues. Such festivals, close to individuals, appealing to their personal responsibility, stand as catalysts of good practices for the energy transition, as well as ecological media environments for an autonomous and spontaneous re-education to socio-environmental sustainability. Through the analysis of fitting case studies, this contribution aims to reflect and debate on the role of temporary musical events as accelerators of innovation and as a vessel for new design experimentation, especially in the areas of clean technologies, by an informal educational approach to sustainability.

1. Energy Transition and Informal Education for Cultural Transition

Temporary music festivals more and more often detach themselves from having a purely entertaining role as crowd-gathering event. All over the world, temporary and sustainable music festivals – and the projects associated with them – seem to have embraced their capability to be a large-scale vehicle of diffusion, in fact, given their nature as centres of artistic expression and cultural, educational propagation, such events can take on a dimension of social activism, helping to inspire people towards new environmentally, energetically, and socially preferable trends and behaviours.

Unfortunately, the variety of diverse actors and material flows may have negative environmental impact, in terms of energy consumption, fossil fuel usage, biodiversity loss, CO2 emissions, waste generation, and dispersal (Getz & Page, 2016). However, as will be discussed, these types of events all enjoy the implicit possibility, and opportunity, not only to become more sustainable in themselves, but even to transmit to the local communities that will be temporarily created, the broader eco-social values inherent in them.
In fact, it has been demonstrated that climate change mainly has an anthropogenic nature (Rahm, 2023), since issues as global warming or economic and social inequalities, are the product of deep-rooted consolidated habits, which continue to be adopted uncritically, and, even more often, the result of a short-sighted and poorly imparted education (Fry, 2020).
Although the term *education* is used as a synonym for *instruction* most of the time – as a term that refers to trans-

missive methodology of knowledge – in this context, we are referring to the concept of *education* according to its more purely etymological connotation of an individual process of construction of meaning. Education, so intended, is structured as a mean to understand our selves, other people, and our interactions with the natural and social environment we inhabit (Mortari, 2020). This ability to comprehend, if properly channelled, can become a substantial generating element for the feeling of care towards the world, which is the basis of ecological thinking (Capra, 2022). The radical change of pace for an ecological transition cannot disregard, therefore, an educational and cultural transition, capable of redirecting the human thought and fuelling the dialectical imagination between speculations on the future and prefigurative experiments in real setups (Fagnoni, 2022). Whether today the energy transition is too often expressed with technical-scientific languages and approaches, highly specialized and top-down, appearing substantially extraneous and hardly comprehensible to common sense (Boffi et al., 2023), it becomes necessary for the culture of the project to support - and intervene operationally - on milder and more suitable strategic levers of action and innovation, to embrace paradigmatic changes from below, certainly more relational, inclusive and qualitative (Crippa et al., 2022).

Temporary music festivals have consequently evolved their identity into a pivotal aspect of, especially, youth culture, playing a significant societal role, inspiring individuals, and fostering the need of a shared vision (McGay, 2015), conscious of the environmental impact and their power to disseminate education for counterbalancing and bring it to zero. Empowered by their inherent capacity for communication, such events possess the potential to serve as guiding forces in driving the transition ahead and disseminate a literacy toward environmentally and energy-conscious practices and attitudes (Jones, 2017).

In the last decade, in Europe, with different formats and grades of engagement, festival managers, public institutions, design teams of various backgrounds and active citizens' groups, have indeed fostered and disseminated an awareness of the logic of circularity, water-saving, energy-saving, soft mobility, use of renewable sources, and other interrelated issues (Mancini, 2023).

In terms of design perspective, to diminish environmental impact and instil in the local community a sense of conservation and ecological stewardship, it is imperative to creatively implement environmentally friendly practices, for example envisioning recycling or reuse systems, modular setups and stages, and mitigation of resource consumption and emissions during the entire event production (Vezzoli, 2022). The festival design, however, cannot only be limited to macro-level intervention regarding organizational decisions (Bistagnino, 2011), but needs to involve the community of participants for lowering emissions, requiring greater effort to lower the impact.

Suggesting and giving the freedom of embracing high-efficiency design and technological solutions for energy need, sustainable food and drink consumption, transitioning to digital supports, and promoting upcycling initiatives for attendee-generated waste, can further improve the impact on environment and create a community of festival goers sharing a set of values inside and outside the festival area. Similarly, advocating for more frequent and substantial solutions to address pressing issues of social innovation, often overlooked, aligns with the principles of "Universal Design" outlined in the Stockholm Declaration of the EIDD. This holistic and innovative approach aims to design products, services, and scenarios that champion human participation, enhance diversity, social inclusion, and equality, ensuring equitable participation opportunities across all societal contexts.

If these strategies were to be thoroughly embraced, they would spawn new scenarios of vibrant ecosystems. Within these scenarios, sustainability, intertwined with cultural, artistic and social dimensions, evolves into a dynamic crucible for experimentation with alternative practices (Galeota, 2023). Consequently, music events, serving as hubs for communal interaction and societal resilience, possess the capacity, among other roles, to discern the latent needs of temporary communities. They can introduce grassroots-level efforts to establish fresh regulatory frameworks, catalysing agile processes of eco-social transformation (Bishop, Williams, 2012). This revaluation has supported popular culture, fostering expansive creativity and public reflection through widespread, dynamic, and inclusive participation. Such festivals, close to individuals, appealing to their personal responsibility, stand as catalysts of good practices for the energy transition, for an informal, autonomous, and spontaneous re-education to socio-environmental sustainability.

This demands having a view on sustainability as a cultural and experiential process, organically emerging from the bottom, rather than a set of imposed objectives from above (Caffo, 2017; Manzini, 2018), channelling the principles of a participatory culture (Jenkins, 2009) into a *meta-design framework* (Fischer, Giaccardi, 2006) requiring an active co-creator pool to lower the barriers and facilitate a coral construction of the entire festival experience (Jordan, 2016; Vannicola, 2018). A coherent and unified design of the event, together with its multichannel narration, creates a media system capable of engaging participants and keeping them inside the experience (Quercia, 2022), making temporary music festival ecological media environments (Granata, 2015), eco-systemically disseminating a circular grassroot and top-down re-education to sustainability. Recognizing ecological values as shared and meaningful is crucial for establishing sustainability as the mainstream vision of eco-social prosperity, rather than merely an alternative one.

2. Aims and Methodology

This contribution initiates a broader strand of research on sustainable festivals and their experience design to foster ecological transition and share literacy about environmentally sustainable practices. By analysing particularly virtuous and fitting case studies, this paper aims to reflect on and debate the role of temporary music events as accelerators of innovation and as a container for new design experimentation. This is particularly evident in the areas of clean technologies, informal educational approaches to sustainability, and local policies. The underlying purpose is to understand how the tools of creative disciplines can bring about innovations of meaning and provide new models from below of social and operational value, acting on a multiplicity of scales and domains.

European sustainable music festivals were mapped and analysed using a grid of six dimensions derived from the synthesis of the *Criteri Ambientali Minimi* (Minimum Environmental Criteria) (2022), environmental requirements defined for the design of cultural events, such as: energy, transport, water and/or wastewater use, waste and recycling, architecture and design and event set-up, communication and social innovation.

The mapping process facilitated the identification of the most adherent and exemplary events across various countries, encompassing small, medium, and large-scale festivals, while intentionally excluding mega events due to the significant disparity in available resources and means. The festivals chosen for this study were Northside (Denmark), Terraforma (Italy), We Love Green (France), Green Man (Great Britain), Shambala Fest (Great Britain), and DGTL Amsterdam (Netherlands). Employing a qualitative and heuristic approach, the festivals were analysed utilizing both secondary data sources and official communications from the events themselves.

The discussion section will examine the findings of the analysis, shedding light on festival's sustainability framework employed to disseminate knowledge about eco-friendly practices, re-educating the crowds informally with achievable and replicable solutions to daily needs of energy, intended as material and social necessity.

Through this examination, we aim to contribute to the ongoing discourse surrounding sustainable events and the pivotal role of festivals in driving environmental and social change.

3. New Values and Educational Systems in Temporary and Sustainable Music Festivals

The considered European music festivals have several points of contact, even though each one realizes its festival projects with a distinguishable identity. The common ground on which those events move is being fully independent and free from consumerism to have the chance of offering an alternative vision of society (McKay, 2015) to an engaged and active co-creator crowd. Under the motto “We do want to show you why it is more sustainable to dance with us during DGTL rather than staying at home”, the DGTL Danish electronic music festival suggests the role of environmentally preferable events in boosting the experimentation of new practices, often grassroot.
Each of these festivals concentrated a great part of the effort into transforming themselves in a low-impact temporary event by collaborating with institutions, governments, and providers. Most of them have also been awarded with prizes and awards for the green innovation they move forward, which does not limit to the organizational level, but searches for and actively involves an active and conscious behaviour and contribution, adopting different design and communication strategies.

One of the main issues is the power to make the festival take place, the kiosks function and the stage provide the show. Most of the festivals adopted countermeasures by changing their source by drawing energy from the existent grid and selecting providers of clean energy, installing led bulbs, generators powered by recycled oils and a system, like in Shambala, or compensation by taxing the cafes and food stands participating to the festival for the used energy, with the aim of active increasing their efficiency and integrate the solution in their service. Attendees, likewise, support the compensation strategy with an energy tax donated to *Ecolibrium* included in the ticket price, to encourage them to offset the emissions of their trip and participation. The event partner, a non-profit organization, employ the donations to renewable energy projects like a 4.2 MW solar farm in Bristol, enhancing the production of clean energy and addressing social issue like local energy poverty and community education. According to the festival statement and report, the donation had the power of increase participant awareness toward the impact of their movement and the solution of energetic and social issues by choosing environmental-attentive partners and providers.

To satisfy the individual need of power, other festivals decided to provide with power banks for smartphones, like in Northside with its supplier Volt, or solar powered stages and charging station, choice made by Green Man and Wild Solar, offering an affordable and achievable solution of integrating renewable energy sources in a daily action.
However, the participants consciousness regarding the impact of their choices passes primarily through the planning of the journey to the festival location. Although transportation is, finally, an individual choice, the festival sustainability strategy involves creating alternative to solo car trips, offering services to guide toward low-impact transfers.

The common ideas are to diminish the use of carbon fuelled cars, sometimes not providing parking spaces near the location, like it happens with We Love Green and DGTL festivals, or implementing compensation strategies. Shambala is responsible for founding the *Ecolibrium* initiative to minimize the impact of festival transportation, which was also adopted during Green Man fest. The attendees will find ride opportunities and parking tickets on the Green Man website, provided by the Go Car Share platform, and *Ecolibrium* will be responsible for donating £1 for each car parking ticket sold with the aim of compensating the CO^2 emissions and investing in climate solutions, mostly oriented to reforesting and regeneration projects in Asia.

Participants, indeed, are actively involved in resolving global and local pollution problems, which are handled by festivals through suggesting the use of public transports, offering a free shuttle from and toward the train stations (Terraforma, Green Man), Rail&Entry ticket packages (Shambala), train vouchers to be won in competitions during the event or discounts, or even foreseeing the event ending before the last available bus (We Love Green, DGTL).
Bicycles are the most sponsored way to reach the strategic festivals locations by offering services like the organized trips of Green Man and Red Fox Cycling: the company plans group bike rides to and forth the festival on the day before the opening and on the day after the ending, awarding participants with a free beer and a fast-track entry to the area. All the luggage is transported by the Red Fox team in a low-emissions van, giving the chance to appreciate biking through natural routes and pausing with drinks and snacks along the way.

In Northside, alternatively, cyclers will find a bicycle wardrobe provided by Specialized in which the bikes will be repaired, cleaned and personalized, taking the habit home, outside the festival gates, of using the renewed two-wheels mean to move in cities.
The sustainability literacy for DGTL pass through the gamification of CO2 calculation: the partnership with SkyNRG led to the development of a free tool to calculate the travel emissions to reach the DGTL festival area, available in two different versions, one for visitors and one for other festivals organizers, artists, and fans all over the world. The game-alike feature is broadly known as effective in motivating and engaging, especially in informal learning (Alsawaier, 2018).
A great effort is also implied in tracking the impact of water usage. In each festival report, saving water appears to be a relevant goal, for which organizational and cooperative solutions are developed.
All the festivals drive the crowds toward drinking refillable tap water, sometimes with free stations and always selling refillable drinking bottles, as in Northside, which have more than a water saving role, being reusable outside the festival context and stating the belonging to the festival group and values.
Shambala and Green Man share the partnership with FRANK, a non-profit organization which provides filtered chilled water, and reusable bottles if needed, during the festival by the purchase of a wristband for illimited refills. The earnings support the WASH (water, sanitary and hygiene) campaigns of the organization in countries like India, Nepal, and Kenya, where water scarcity and pollution prevent the public access to drinking and sanitary water.

Most of the water during events is indeed dispersed for sanitary use, for which event organizers adopted shared innovative solutions by installing composting toilets, saving tons of water. Even though compost loos cannot be reproduced in urban routines, their usage helps increasing consciousness toward the litres of sanitary water employed with home devices. Alternatives are possible, used and working during these events, even installing both dry and watery toilets, as DGTL decided to, although the attendees attention is always driven on the importance of water: watery loos are to be used only in case of need and do not employ drinking water, but exploit the flow of the JI river past the festival site, raising the need for a dedicated design project to take the most from the land and give it back without spoiling the area.

Dry toilets, on the other hand, try to resolve both the water and organic waste issue, by transforming urine and feces into reusable materials. Compost loos have the advantage of not using water nor biocide chemicals, which means reducing pollution and consequent sewage treatment, diminishing, in addition, the costs of transportation. The transformation of organic waste into compost creates a circular system, as it is then given to local farmers, benefitting the social community around We Love Green, Green Man, Shambala and DGTL areas. The transformation of urine, full of nutrients, it is considered precious for the soil fertility and helps saving drinkable irrigation water.

Festival goers are not only directly involved in producing compost, but also of taking care of their maintenance by keeping them clean with sawdust to avoid bad smelling and break down (Fig. 1).

Figure 1. DGTL, compost toilets with volunteer attendant, 2023. (https://dgtl.nl/sustainability/).

The change triggered by individuals is also explained on site by volunteers, WaterAid ones in Green Man, re-educating crowds toward sustainability and circularity.
Toilet waste is just a part of the output produced during the event days. Every festival chose to introduce reusable, biodegradable, and recyclable tools to reach the goal of zero grams production of waste per person, as DGTL and Shambala suc-

cessfully managed to, and often ban straws, disposable plastic bottles and envelopments.
The most adopted solution is to actively involve participants in sorting waste. Northside installed eye pleasing trashcans, as part of a complex redesign of their waste management infrastructure, in partnership with local start-ups, with the participation of attendees and their co-design action of the system, shaped on the temporary event needs. The aim is to "facilitate a change of attitude towards disposal of goods […] encourage guests, staff and volunteers to take a stand on recycling and bring behavioural change back home after the end of the festival" (Thim, 2013).

Green Man share the same aim by providing differently coloured plastic bag to festival goers, asking for wisely separating waste, both recyclable and non-recyclable, also pushing cooperation between strangers by sharing rubbish bags and filling them to the top. Some dropping points are arranged all over the campsites and stewards are always available for assistance. Shambala designed and tested during the years different waste management schemes to keep achieving the zero-waste purpose. Under the "we're only as strong as our people" motto, the festival asks to be part of the Recycling Exchange scheme. At the festival ticket purchase, a £20 Recycling Deposit is charged for every order to support the material needed for the recycling activity. At the entrance, attendees will be provided with two bags of different colours for dry recyclables and other kind of waste, which are to be returned when full to the exchange points. In that moment, the deposit is refunded or can be used to buy limited edition festival merchandise, made by sustainable partners (Fig. 2).

Figure 2. Shambala Festival, the Shambala Recycling Exchange area, 2023. (https://www.shambalafestival.org/).

Another waste issue regards food leftovers and unsold meals. DGTL dedicated its effort to transformation, introducing a 24-hour composting machine to the food court, which are processed along with cane sugar cutlery. Unsold meals are, instead, gave away to "Pay what you feel" cafes (Shambala) or given to charities (We Love Green), even though the main warning is to avoid food waste by adopting a responsible behaviour toward consumption.
Reusable bottles are a must in every festival, even though the organizers tried to keep the drink experience the same, by only making small changes. Both DGTL and Green Man preferred to let attendees purchase reusable cups for a little price, that can be used during the festival and handed in to the

bar for cleaning and replacing. The returned ones get washed and reused year by year. They can be also kept as event souvenir and reused at home, bringing away the habit of avoiding single use plastics.
Overall, Shambala introduced the Material Flow mapping for finding weakness in the waste management chain, receiving feedback for the festival community. A similar idea was implemented by We Love Green, that expanded its scope by creating an online recycling platform, where the sourcing materials needed for the festival set-up are put back into market to enhance circularity. They are destined to other events and companies, and every year needed material are collected among local industry leftovers.
The festival keeps great attention to welcoming participants in a sustainable designed setting, also involving artists that, in a past edition, held a scenography workshop which outcome was an eco-co-designed creative scenography ad art pieces made by recycled plastic.
Most of the events' stages are developed with designers specialized in upcycling and reuse, sometimes in-house like at Northside, who developed a storage facility in which build, prepare and repair the festival elements foreseen in the "assembly for disassembly" model.

DGTL and Terraforma partnered with designers to structure stages and other temporary buildings using old construction materials the first, with Nachtlab agency who invented a modular stage with light and mirror components from scratch to be reassembled in different layouts, or natural materials the second. The studios behind the Italian festival designed the

iconic Alpha stage (Fig. 3) and the workshop area with wood, involving students from the Politecnico di Milano in renewal activities every year, holding workshops and co-creation activities to come up with minimal impact set-ups and upcycling ideas for excess materials, building useful festival utilities like benches and tables.
From 2022 is in use a new stage made from wood recollected after an extreme storm that cut down hectares of forest, with the aim of using low impact materials and helping locals collect and manage the high amount of lumber (Colturri, 2019), giving an example of community and environment safeguard through possible uses of such raw material.

Figure 3. Terraforma Festival, the Terraforma Alpha Stage, 2023. (https://www.terraformafestival.com/).

Figure 4. Shambala Festival, Shambala camping tents provided by Vintents, 2023. (https://www.shambalafestival.org/).

Shambala offers to its community the experience of sleeping in camping tents provided by partners like Vintents, which produce upcycled and repaired tents from the '70s, and Camplight, which dedicates to save and recondition tents from other events (Fig. 4). The underlying message to repair and not to discard reparable items gets transformed into a tangible and pleasant experience to be broadly replicated.
Partners proved to play a significant role in festival organization, realization and external communication, generating effects far beyond the re-eco-education of attendees. The network of start-ups, schools, universities, and governmental departments let the festivals promote sustainability in their territory.

Northside created a sustainability model with WorldPerfect to internalize and disseminate eco-practices, including workshops with stakeholders, like employees, participants, Aarhus city officers and local companies, from which a Northsiders group was formed, in charge of holding meeting to rethink the festival. One of the ideas that came out is placing Trash-Talkers in some strategic points of the festival area to instruct on the recycling activities with easy to remember catchphrases upon the waste bag colours and their use.
Workshops are held also during festival, as The Think Tank Lab of We Love Green in which festival attendees discuss about ecological issues with activists, artists, scientists and educators; or the Village Positive Initiatives that welcomes innovative companies and no-profit committed to sustainable development with the task of raising festival-goers awareness about the challenges of eco-citizenship; or, finally, the Start-Up Lab to help starting doing business under the sustainability ethos becoming a changemaker.

Terraforma idea of dissemination pass through activities, events, panels, resulting in the Terraforma Journal and in a series of “Simposio”, an occasion of discussion about the union of sustainability and artistic practices. One of the outputs has been the restoration opera of the event location, Villa Arconati, giving back life to an abandoned area, reliving the historical Labyrinth, reinstating the local flora. The project followed with the reforestation of the camping area, designed by Space Caviar, aiming at involving territorial stakeholders and citizens in returning to an eco-normality of the land and help neutralizing emissions even during the festival days.

Finally, also Shambala and Green Man invest most of the received donations and effort into valorising the hosting territory, by opting for local suppliers and collaborating in improving the nearby communities of young people, mostly to guarantee education and sports access, and scientific, artisanal, and sustainable productive companies. In fact, an environmentally preferable attitude also passes through the care for communities and minorities. Almost all the festivals celebrate diversity, as the Shambala stage flags co-chosen with participants to support causes state, and, alongside, build equals interactions by adding informative pages to their websites regarding inclusivity and cultural appropriation. Likewise, DGTL considers equality and safety a collective effort, "free from harassment, racism, homophobia, transphobia, ableism, and sexism". In case of need, the Awareness Crew is available to support visitors stemming harming behaviours. Accessibility has a central role for all the festivals, listing services for an easy access to the areas, for handling earing and seeing problems, interpreters, and dedicated stewards for granting an equal enjoyment of an environmentally and socially preferable event.

4. Conclusion

All the analysed temporary music festivals place the energy transition and, therefore, the cultural transition at the centre of their activities. This identifying character is not the consequence of normative impositions from above, but rather the product of a collective awareness, with grassroots countercultural and nomadic historical roots (Bottinelli, 2015). Hence, temporary festivals stand as simulacrum of communities of people, mostly young, who make responsible individual choices shared within a tangible, open and active community, capable of humanizing the messages and values of energy sustainability, making them simpler, conveyable, and transferable to other contexts. The design practices inherent in them are all dimensioned to a *human* scale, transforming attendees in a participatory crowd, which co-creates each sustainable act of the festival and, in turn, shares and adopts such practices and behaviours outside and beyond the temporariness of the festival, in the individual daily experience. This study evidences that the energy transition, in this kind of festival, is not only inherent to the environmental preservation and the optimization of re-cycling and up-cycling actions among waste, water, and energy, but rather in a broader idea of care – indeed necessary and experiential – which also passes through accessibility and for all kinds of diversity, whether physical, mental, or gender (Roe, McCay, 2021). In this regard, each festival analysed reflects, albeit in its own way, on the common goal of generating a sense of shared responsibility toward the environment and society, to continuously educate a generation in need to be increasingly aware of and committed to promoting environmentally and socially preferable lifestyles.

The role of design, once again, remains crucial in promoting change and facilitating innovation, this time within temporary music events. The designer's goal is to design *socially interactive* systems that not only directly engage users and facilitate informal education about the energy transition, but also leave a lasting cultural and behavioural imprint after the festival is over.

From this perspective, design intervenes in both key aspects of the energy transition, i.e., the technical, outfitting, product, and *infrastructure* features, and the more relational one as educational, sociocultural and *superstructure* aspects (Manfra, 2022; Tironi et al., 2024). The roles of designers, local producers, stakeholders, and users are therefore revised and innovated through shared responsibilities and sometimes overlapping areas of expertise, expressing themselves from time to time in nuanced and fluid identities, such as the promoter or facilitator, the researcher, the tester, the co-designer or co-user, destined to converge toward a completely open and grassroot idea of the sustainable temporary event.

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Talking about Energy
Design and Language for the Energy Transition

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Abstract
The energy transition is central to contemporary debate and discourse, whether scientific, political, or social. Research, publications, funded programs, and awareness-raising projects are evidence of its relevance. Much is, therefore, being said about it, both from a global perspective, focusing on geo-economic balances and technological innovation, and from a local viewpoint, focusing on energy equity and accessibility and the realm of sustainable behavior. However, communication about energy is not always effective or transparent, and as a result, what communities and individuals perceive and learn seems far removed from their experience, as demonstrated by their resistance to change. Given these premises, it is in the authors' interest to develop a reflection on the potential of design in developing proposals to engage as many people as possible, cognitively and emotionally, in the discourse on energy sustainability. Design, which by its very nature is capable of elaborating innovations of meaning in the everyday environment, can contribute to the development of knowledge, awareness, and critical sensibility to support the development of sustainable behavior through a new language. The article, therefore, reflects on the value of language in promoting sustainability. In particular, the presentation of selected cases in the design field provides an interpretive model for promoting a sustainable energy transition through art, design, and language innovation.

1. Talking about the Energy Transition

The energy transition is at the center of contemporary public debate. Government bodies, politicians, economists, and experts are placing it at the forefront of the programs to be developed, highlighting the need for technological, economic, industrial, and social interventions on a global scale to respond to the environmental and geopolitical emergencies underway (European Commission, 2022; IEA, 2022; WEC, 2021; Rosen, 2021). On the one hand, they act as promoters of new global development pathways, issuing regulations and recommendations, promoting investment in R&D, and negotiating cooperation between the actors involved; on the other hand, they disseminate a new system of standards and reference values. Global policy plans, such as the recent European Green Deal (2019), promote responses to climate change that will transform current economic and production paradigms and social behavioral patterns. A popular search engine for scientific publications, such as Google Scholar, provides around 636.000 results in 0.09 seconds when searching for the words "energy transition" from 2020 onwards (more than 9.000 publications per month). The issues addressed in the energy discourse, both in the political-economic and scientific spheres, are articulated and diverse and have evolved. For example, as Kathleen Araújo reminds us, in the 1930s, the focus was on the changes brought about by molecular dissociation; in the 1970s, the debate revolved around fuel substitution to avert resource constraints and, later on, the possibilities of transforming production forms to reduce carbon emissions (Araújo, 2014). Today, the emphasis is mainly on investigating technical and strategic issues, such as technological and IT innovation, integration of renewable resources, energy security, international policies, measurement of environmental impacts, and so forth. At the same time, references to the issues of universal access, energy justice and equity, social acceptance, and behavior change are significant. These shed light on the strategic, social, and cultural role of energy: in its production, supply, and consumption modes, energy is not merely a technical fact, but it is pervasively linked to culture and the individual and collective behavior of societies (Rainisio et al., 2021).

While many actors are involved in such an *energy dialogue*, others are excluded. If, on the macro level, it is necessary to work towards the sharing of universal values by overcoming the local dimension through an internationally shared means of communication such as language (Zygmunt, 2016), on the other hand, it is precisely at the local scale that the technical and specialistic cut of the syntax adopted in this context fails to be inclusive for a large part of the population. Indeed, most citizens perceive such linguistic complexity as not *close* to their daily lives (Bazzocchi et al., 2023; Cason Villa and Rebaglio, 2023). Yet, any effective energy transition approach needs to start with a change in people's behavior, lifestyles, and consumption habits. In this direction, working towards a broader understanding of sustainability discourses, in general, can reduce the distance of issues that are still perceived as far removed from individual responsibility. It is a matter of promoting the dissemination of a new everyday vocabulary that allows the *domestication* of sustainability to improve both the public perception of new renewable energy technologies and the involvement of individuals and communities in their dissemination. Propensity to change and contentiousness or perceptions of risk and fatigue are key determinants that either drive or inhibit the uptake of energy transitions. At the same time, the narratives around these attitudes and experiences are full of contradictions and are continuously (re)produced and negotiated as people experience them.

Furthermore, it is necessary to foster more profound awareness and critical thinking and to provide tools and methods to help decipher energy-related messages, which are often distorted through the filters of private interests or any other interests than those that would serve the common good. Indeed, the dominant language associated with sustainability and efficiency often runs the risk of not being transparent on crucial ethical issues but rather of expressing the strategies and interests of large corporations committed, in the global transition, to preserving their profits first (Morton 2019).
In this context, at both macro and local scales, language - from a semantic point of view, namely the way sustainability is spoken about (the vocabulary employed, the morphology, syntax, and tone of voice) - is a crucial element. Language is undoubtedly one of the privileged expressions of cultural and social processes, and it can influence how people develop and organize knowledge about their environment, as well as the modalities they use to structure the worldviews and values they express concerning other species (Bang et al. 2007).

Embracing Tomasz Zygmunt's reflections (2016) on the role of language education for sustainable development, we recognize in the multiple functions of perception, thinking, memory, and expression the potential that language holds for providing a more inclusive understanding of sustainability. Language is the basis for processing an initial perception of the reality of things and the environment around us. In particular, it is in naming that language manifests its ontological character: in naming, the phenomena of the world around us, with their challenges and complexities, become present, acquire meaning, and become *speakable* in the sense that they enter fully into public reflection and can therefore be the subject of discussion (Benjamin, 1995/1916). The possibility of elaborating a discourse, or rather a dialogue, is seen as "a common way of understanding the world" (J.S. Dryzek, 1997, p. 8), capable of activating the cognitive dimension through words, especially in those cases where speech is not based on assumptions, prejudices and disputes, but rather on objective data and truths that provide the basic terms for analysis, debate, agreement and disagreement, conveyed in the most transparent, open and comprehensible way possible. Therefore, the intense relationship between language and thought ultimately generates the culture in which we move and help preserve within memory and nurture through progress. Sustainable thought and culture make humans sensitive to the outside world and its needs, simultaneously becoming their own (Pullen, 2015). After all, "the language we use to describe things [signals] how much we care about them and will steward over them" (Beatley, 2011, p. 58). In other words, it expresses how we exist in the world through our conduct, manners, and individual or social behavior.

Indeed, talking about energy sustainability is not an easy challenge. However, as the research by Scrase and Ockwell

(2010) and Isoaho and Karhunmaa (2019) on discursive approaches in the field of energy transition shows, it is essential to recognize, with a multidisciplinary approach, the role of language and narrative in the formulation of energy proposals and policies that will influence the future.
In short, involving as many people as possible in the discourse around energy sustainability raises a number of questions: What language and engagement approaches can be used to make the energy transition more acceptable? What tools and methods should be employed to decipher and critically approach the mainstream lexicon and develop an autonomous and conscious knowledge of it? And consequently, how is it possible to promote a new everyday vocabulary that supports a new *energy culture* and an increasing expression of sustainable behavior?

2. Design and Language for the Energy Transition

Exploring the connection between design and language means, first and foremost, considering the mediating role both play in the contexts of use in which they operate. As seen in the previous section, language is as complex as it is an explicit and overt expression of our way of experiencing, perceiving, and thinking about the culture we are immersed in. It is the privileged mediator of any relationship. Design, a practice that is conversely characterized by tacit and implicit knowledge, nevertheless actively participates in the shaping of our everyday worlds through objects, environments, and services that, with their *language* (Barthes, 1970/2016; Baudrillard, 1970/2014; Kubler, 1962/2002; Sudjic, 2015), interpret and express aesthetics, socio-technical values and cultures of contemporaneity (Griswold, 2012). In this sense, design is also an instrument of mediation between different needs and knowledge, as well as of translation, in an intercultural sense (Baule & Caratti, 2016). The design, seen as a language used to imagine, prefigure, and outline ways of living in the world, is continuously in conversation with the situation it is shaping (Schön, 1983). But that is not all. We are especially interested in observing how the discipline of design can intervene in the *matter* of language, promoting two-way innovation, that is, both in real-life situations and on the lexicon - language that characterizes them. Designing language is disseminating tools of critical reflection, imagination, participation, and resistance; it promotes profound social and cultural changes. The domains of this work are innumerable (from communication design to exhibition design, industrial product design, interaction design, and much more), as are the fields of its application. A new way of speaking is brought about through processes, devices, research, and experimentation. One can activate processes of community engagement and participation in a creative dialogue of social innovation through the adoption of shared vocabularies that strengthen local networks and identities, such as the vocabulary of the NoLO neighborhood in Milan (Tassinari et al., 2023); one can imagine installations and performances revolving around words that, once materialized, penetrate the inhabited space of the city and make themselves present, thereby entering into collective experience and memory, as in Luigi Mainolfi's first luminous tales in Turin and similar ones developed elsewhere, or as in the luminous words of the Illumina-MI collaborative project, developed during the pandemic and later turned into a neighborhood icon-reminder for the community of a Milanese suburb; finally, one can produce narratives that, through storytelling techniques, exhibitions, and verbal and textual installations, become devices for sharing an ethic of sustainability.

In view of the relationship between language, thought, design, and culture (and in particular, a culture of sustainability) described above, it seems increasingly necessary for the cultural sphere and the design disciplines to collaborate in the search for and in the co-construction of a common language that would allow and facilitate the discussion about the energy transition. A language aimed at reconnecting people and resources, technology and culture, thus counteracting the "energy illiteracy" that today makes majorities appear silent, disinterested, and paralyzed in the face of transition issues (Wilkinson & Lowe, 2021) and instead enabling them to participate in the debate with informed and proactive attitudes (Crippa & Ratti, 2023).

Based on these premises, this section aims to offer an insight into an international contemporary design scene that is already committed to the definition of such a language, which has proven to be able to cross and connect different disciplinary fields thanks to the way design's own language is connoted, capable of combining the discursive, the pictorial, the persuasive and the instrumental (Doloughan, 2002). Specifically, a number of possible design approaches have been identified here to define mechanisms, dynamics, and tools of language design and language use that can support the processes of energy transition. Two *auxiliary verbs* indicate two macro-classes of design approaches that support *language actions* with high or low end-user engagement in promoting energy issues. The articulation of the proposed interpretive stance is presented in the table below (Fig. 1).

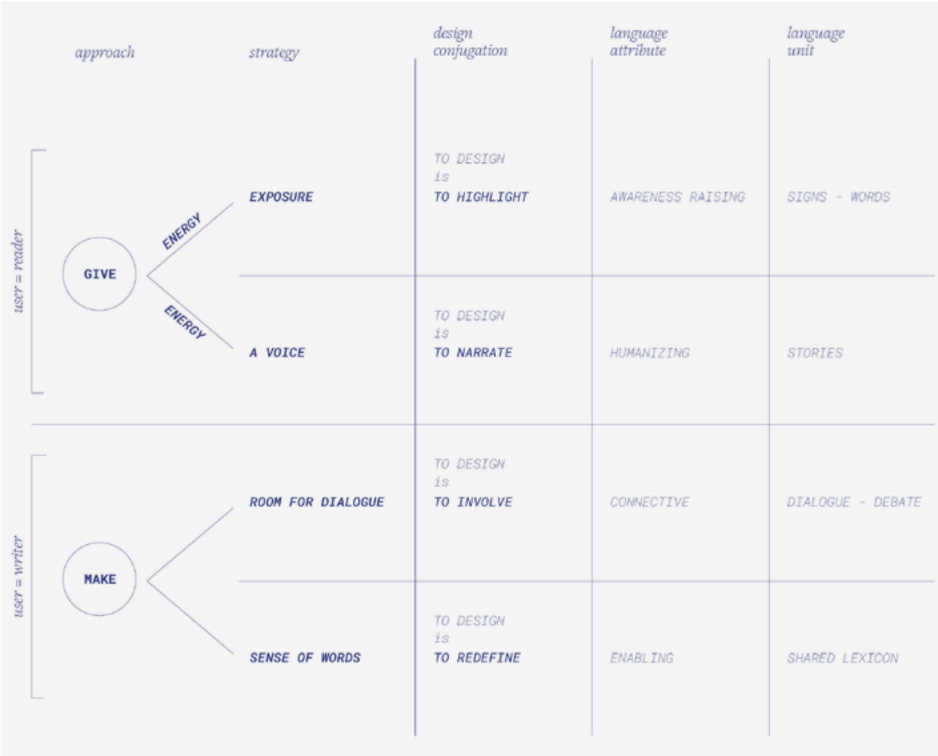

Figure 1. Outline of the relationship between design and language for the energy transition. (Credits: authors).

In the first approach, the user involved in the featured projects takes on the role of reader, first of words and then of stories, directing his or her attention towards the examined experiences without being directly involved. In the two underlining strategies, *design gives*. It gives exposure to energy in projects that play on the semantic level of words, making them the raw material of awareness-raising messages, and it gives voice to energy, designing a recognizable identity for it through storytelling tools.

In the second approach, design *makes*, or rather *makes with*, users – writers who co-author the meaning of their experience through participation. The nature of the language used in these projects changes as the people involved change, in actions that make room for dialogue by creating tools that connect and facilitate the exchange of opinions about energy or help to make sense of words, in an example of co-construction of a shared lexicon for transition.

2.1. Give Energy Exposure: to Design is to Highlight (Awareness-Raising Language)

The first strategy, which sees design and the arts engaged in *giving energy exposure*, emphasizes the capacity of design culture to act and produce innovation not only at the functional level but also at the level of meaning (Verganti, 2009). As suggested by Judith Butler (1993), "precede any willful performance and become embedded in those performances". Working on the significance level is, therefore, a necessary condition to stimulate concrete actions towards sustainable change in the long term.

Language, understood here in its basic units of sign-signifiers and words re-signified through the design lens, is used to raise public awareness of environmental issues through symbolic gestures and evocative messages conveyed through typical communication tools.

An example of this approach is the *A few degrees more* initiative, which the Leopold Museum in Vienna carried out in 2023 in collaboration with the Climate Change Centre Austria. Starting from the observation of a general tendency to ignore the warnings about the world's climate that have been coming from the scientific community for decades, the museum decided to play with the meaning of words, translating in a literal way the minimizing attitude that sees global warming as "just a few degrees more" on the thermometer. Paintings by Gustav Klimt, Egon Schiele, Gustave Courbet, and other masters depicting coastlines, mountains, lakes, and cities have been rehung on the museum walls, tilted by the number of geometric degrees corresponding to the difference in degrees Celsius that global warming would (or will?) make to the areas depicted in the paintings. Working on a semantic level and using language as a tool for creating meaning and modifying reality, the curators have thus managed to transform what for many seems an imperceptible difference into an immediately measurable and uncomfortable contingency. Accompanying the paintings with scientific captions describing the real impact that an increase of 3, 4, or 6 degrees Celsius would have on these landscapes, the Leopold and the Climate Change Centre have certainly succeeded in making visitors ask themselves whether they "still think that more than 1.5 degrees is not too much?".

In the same vein, we note the diffused installation *Climate Signals*, realized in New York City in 2020 by artist Justin Brice Guariglia in collaboration with the municipality and the Climate Museum. The operation consisted of 10 solar-powered illuminated signs, much like the large LED banners used to communicate emergency messages on highways, displaying flashing danger messages, this time to draw the attention of passers-by not to an accident or ongoing maintenance work down the road but to the urgency of the climate emergency. Messages such as "Climate change at work" flashing in Brooklyn's Sunset Park, or "No icebergs ahead" looking out over the water from Governor Island, borrowed not only the physical medium of highway signals but also the lexical forms usually associated with "men at work" or "traffic ahead," successfully bringing the effects of what we tend to ignore into real life, giving them the shape of media we are used to paying attention to, as we are accustomed to reading information on them that can have an immediate impact on our choices.

When design means highlighting and bringing forward the multifaceted issues related to environmental and energy sustainability, we believe language becomes a powerful and transversal medium, capable of spreading awareness messages directed at the most diverse audiences and contexts, whether they are implicit and whispered or pungent and shouted out loud.

2.2. Give Energy a Voice: to Design is to Narrate (Humanizing Language)

Energy, among other issues, has a seemingly trivial problem, but one that is actually crucial in defining our relationship with it: it cannot be seen. Its immaterial nature makes it inevitably elusive, and the impossibility of quantifying it, except through instruments and data of great complexity, makes it distant from the practical experience of everyday life.

The challenge of making energy a *thing* for everyone, in the absence of a *body* to make it visible, requires the effort to *give energy a voice* to make it at least *listenable*.
And with a voice comes a tone to be chosen for it. The choice of the tone of voice to be adopted in design projects that aim to make the energy transition comprehensible and accessible is anything but neutral. Since democratizing the energy discourse requires bringing it closer to people and their lives, it is necessary to find tools capable of overcoming the technical-normative approach commonly adopted in energy communication and instead create new relationships between it and the emotional sphere of those who interface with it.
Charts and tables, numbers and physical quantities, however necessary, are not enough: narratives and stories are essential complements to the usual emphasis on technical data, as they help to translate the abstraction of quantitative and qualitative measures into the described impact of a problem on people's real lives and experiences (Norman, 2023).

In this second strategy, where the user of the projects again plays the role of *reader*, language is thus used in the composite form of stories and narratives.
Narrative structures are in fact, as Trocchianesi (2014, p. 11) suggests, "universal forms through which people understand and move through reality. Narrative allows people to interact with the system of cultural conventions in which they live".
Exhibition design, in particular, with its dynamics and tools of spatial storytelling, is seen here as a potential translator capable of transforming the content it conveys into hypertextual and spatial narratives.

The exhibition that dotdotdot designed for Enel Green Power in 2019 can be seen as an example of this narrative approach. Set in a hydroelectric plant in Trezzo sull'Adda (Milan), the exhibition is divided into four stations exploring different energy production and consumption aspects. In the designers' own words, it proposes "an informative story and an emotional and entertaining journey, characterized by comprehensible language and playful but educational activities" (Pignoloni, 2021). In particular, at one of the four interactive stations, visitors listen to the introductions - tailored to the different audiences – of five digital characters embodying the five sources of renewable energy: Idro, Mariasole, Gaia, Marina, and Levante. This narrative device, activated by the tour operators using screens that respond to speech recognition, creates an immediate sense of familiarity in the audience, who get to know the *good* energy sources as if they were meeting a new friend.

If it is true that "stories make us human," as Johnathan Gottschall reminds us in the subtitle of his *Storytelling Animal* (2012), then if *to design* means *to narrate,* language becomes the evolutionary trigger to humanize cold and intangible concepts, to bring them back to a recognizable level towards which it is possible to empathize through narrative devices that allow each "reader" to

> rethink their own experiences and actions, reconstruct their meaning and highlight their possible developmental prospects, bringing to light the intentions, motivations, ethical and value options implicit in them, inscribing them in a network of culturally shared meanings. (Striano 2008, p. 17)

2.3. Make Room for Dialogue: to Design is to Involve (Connective Language)

Moving on to the second approach constituting the interpretive reading proposed in this article, the role of users shifts and takes on a more active form, seeing them as *writers* co-authoring the plot of experiences in which language changes shape to suit that of its recipient.

The first strategy in this frame interprets language as a connective tool and sees design engaged in the mission of *making space for dialogue* around energy issues.

Thus, Language is implicated in one of its most dynamic and democratic forms: dialogue. Indeed, every language user, including young children and illiterate adults, “can hold a conversation, whereas reading, writing, preparing speeches and even listening to speeches are far from universal skills” (Pickering & Garrod, 2004).

Unlike monologue, dialogue is also inherently interactive and contextualized: in conversation, each interlocutor is asked to both speak and understand (Coates, 1990); each interlocutor interrupts and is interrupted and creates – more or less consciously – balances between words and silences, constructing together with the other the direction of reasoning one exchange at a time. Conversation – turn-by-turn natural language communication – is one of the most common activities humans engage (Hurst et al., 2023), and its potential should not be underestimated. Indeed, recent studies have focused on the educational potential of conversation, finding that it enables learning and the exchange of beliefs and ideas (Huang et al., 2017). Furthermore, Hurst and colleagues (2023) investigated how conversation can influence sustainable behavior, gathering evidence of its effectiveness in influencing knowledge and policy preferences (Brewer et al., 2019; Eveland, 2004), climate beliefs (Goldberg et al., 2019), and self-reported energy use behaviors (Sintov et al., 2019), as well as stimulating meaningful information processing.

These premises were the basis for the design of *Walk the Talk*, a human-scale board game created by Italo Rota and Carlo Ratti Associati for Milan Design Week 2023. Conceived in collaboration with the game design collective Blob Factory Gaming Studio as a giant game of goose composed of colored energy-harvesting tiles, the installation invites players to reflect collectively on sustainable urban mobility. The icons on the tiles represent obstacles or solutions to the challenge of navigating the city, encouraging participants to engage in dialogue to find sustainable solutions to problems such as traffic or lack of pedestrian areas. The playful and performative nature of design is central to *Walk the Talk*: step by step and intersection by intersection, the path within the garden is defined by the choices of the players, who are thus engaged in a collective conversation and shared challenge towards a new way of interpreting mobility in the urban space.

In Lewis's words (1969), dialogue is a game of cooperation in which both participants "win" if they both understand the dialogue, and neither "wins" if one or both do not.
Suppose design equals involvement in the energy discourse. In that case, creating connections between people (and between people and their habitats) based on mutual understanding becomes a central node in weaving new relationships made of real meaning, shared values, and responsible actions of mutual care.

2.4. Make Sense of Words: to Design is to Redefine (Humanizing Language)

The final methodological-practical strategy proposed here focuses on language as an enabling tool.

The ultimate success of human contacts and relationships, as Tomas Zygmund (2016) reminds us, requires a mutually agreed upon and used tool of communication, and thus language, being the primary communicative tool with which we are endowed and thus presenting itself as the primary means of relating to others and the world, must be composed of formulas and structures that are shared by as many people as possible to be effective in its task of enabling relationships. This does not always happen when talking about energy: on the contrary, the use of technical terms and the reference to specialized concepts, together with the many individual interests that interfere in such communication, often and quickly end up making it exclusive, difficult to understand, and therefore overwhelming. However, the creation of an *energy culture*, which would effectively bring it closer to people's lives, must necessarily pass through language since the *simple* use of a conscious language is capable of directing users towards culture and turning them into culture consumers by making them direct participants in culture, with a stake in its creation (Hopfinger, 1985). It, therefore, seems necessary to redefine a common language to talk about energy, one that can truly function as a shared tool for understanding-decision-action, and it therefore seems inevitable that it is the users themselves who should create and shape this language and the ideas it would carry.

In short, participation stands as a necessary condition for the drafting of a new shared *energetic lexicon*. Thus participatory design, with its potential to create open spaces where traditional power structures are suspended, appears as a potentially strategic tool to ensure that everyone's voice is heard in the drafting process and that different views of knowledge do not become mutually exclusive (Robert & Macdonald, 2017).

As evidence of this last strategy, we present the case of a workshop that took place during Milan Design Week 2023 and involved academic researchers, 60 children, their teachers, and families in the co-writing of a "child-friendly energy vocabulary." The workshop, titled *Words&Works* (Figg. 2 & 3), was part of the DE-Sign research project promoted by ENEA in collaboration with Politecnico di Milano, Università degli Studi di Milano, and Università Iuav di Venezia, and brought together different generations of citizens in the search for new words to talk about energy together, at home, at school, and in the city.
To create this new vocabulary, each child was assigned a letter of the alphabet and asked to think of all the energy-related words they could find starting with that letter, write them down, and illustrate them with a drawing before explaining them to the rest of the group.
The approximately 200 words, collected in a large book assembled at the end of the workshop, showed on the one hand – with terms such as Hydrogen, Photovoltaic, KiloWatt – an already deep knowledge of the topic, given the young age of the participants (primary school children); on the other hand, words such as Community, Care, Support and Balance showed how the children see energy concepts linked to a dimension that is not only technological but also human, where the sense of collective responsibility and individual commitment is vital.

Figure 2. *Words&Works*, the young participants of the co-design workshop for a child-friendly energy vocabulary, 2023. (Credits: authors).

Figure 3. *Words&Works*, the moment of the collective writing of the child-friendly energy vocabulary, 2023. (Credits: authors).

By making their voices heard, the children constructed an inclusive terminology. This new vocabulary became a shared asset for work, exchange, reflection, and sedimentation in everyday school and family life.

When making sense of the words we use to describe and understand, energy becomes the object of our action, then *to design* begins to mean *to redefine*. To help connect signs and ideas and to create definitions for the latter that are appropriate to the social group to which they belong; to help grasp the meanings beyond the terms that people use every day – or always hear but never fully understand – by linking them to images and notions that are familiar to those same people; to amplify the resonance of communications about energy, enabling an ever wider audience to hear and evaluate them critically; and finally to help create a common ground for communities to move on, made up of a set of collective principles and a shared way of talking about them.

3. Shaping Possible Worlds with the Stories We Tell

At a time in history so profoundly marked by what Wendell Berry calls the "failure of imagination," when most people live "sheltered from sources toward which they feel no gratitude and exercise no responsibility" (2001, pp. 37-38), working to promote a culture of sustainability means spreading tools and values that foster reconnection.
The disconnection between humans and nature, and the resulting utilitarian and morally detached approach to the resources it offers us, is indeed at the heart of the ongoing environmental crisis (Zylstra et al., 2014, p. 119).

The capacity of art and design disciplines to generate culture, values and shared meanings can act in this sense as a good conductor of collective responsibility. As we have seen, designing a new language for energy transition can be a strategic lever to activate the change we all hope for. The proposed *grammatical* framework is intended to serve as an interpretative outline for potential further work in this direction, for the research and design of processes, visions, and individual and collective endeavors that will activate new perceptions around energy sustainability, greater awareness and, above all, solid changes in behavior. Indeed, changing the way we talk about reality not only changes our inclination towards it but has the power to change reality itself, or rather the future of reality, as Betti Marenko (2023) explains: "Futures can be crafted through the stories we tell, and these stories make and unmake our possible world."

In conclusion, when it *gives energy exposure*, to design is *to highlight* the importance of energy sustainability and the issues related to it, and this mission implies the use of an awareness-raising language; when it *gives energy a voice*, to design means *to narrate* stories in which energy becomes a relatable and approachable character, through a humanizing language.

At the other end of the framework, when design *makes room for dialogue*, it sees its scope to be *to involve* new audiences in the debate around energy through a connective language able to create new relations between them; and when finally it helps *making sense of words*, to design comes to mean *to redefine*, seeing language as an enabling tool, capable - when shared - of making reality adjustable and negotiable.

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II

MODELS

ENERGY COMMUNITIES & COLLABORATIVE LANDSCAPES

Services to Design Change
Gamification Opportunities to Generate Virtuous Behaviors and Design Sustainability Pathways

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Behavioral Design, Education, Awareness, Energy Transition, Key Enabling Technologies.

Abstract
The paper investigates the application of *Design for Behavior Change* (DfBC) practices to promote sustainable energy consumption. By employing user-centered strategies, DfBC fosters the adoption of long-term behavioral modifications that contribute to energy sustainability. This methodological framework leverages real-time data acquisition, personalized feedback, and engaging narrative techniques. The research process fosters positive change and encourages the autonomous adoption of new virtuous behaviors. By strategically applying these tools and combining design-driven methodologies with social psychology research, sustainable energy choices can be transformed from perceived obligations into personal choices desired in everyday life. The article highlights the promotion of activities that contribute to both energy and environmental well-being, emphasizing the positive societal benefits generated by such endeavors, with a particular focus on the potential of technological advancements. It presents two case studies demonstrating the effectiveness of design methodologies and practices in raising public awareness about climate change, particularly regarding energy sustainability. Through analyzing these cases, the paper offers valuable insights into how design can promote an energy transition driven by collective commitment. This radical change requires not only technological interventions but also social, cultural/behavioral, institutional, and organizational change.

1. Research Background: Understanding Barriers to Sustainable Behavior and Opportunities from Technology

Our current energy system is a major driver of global warming, accounting for about 75% of total Greenhouse gas emissions (IPCC, 2023). As a response to the threat of climate change, the transformation of the global energy landscape is therefore of fundamental importance to mitigate climate change and achieve the goals set out in the Paris Agreement (UNFCCC, 2015). According to the International Energy Agency (IEA), achieving these ambitious goals requires significantly faster and more widespread progress than has been seen to date (IEA, 2022). Western cosmology is predominantly anthropocentric, placing humanity at the center of the universe and distinct from nature. Rooted in the historical and social evolution of Western societies, this perspective has fostered a view of nature as a resource for human advancement, neglecting its intrinsic value and need for protection. However, the recent surge in new technologies, such as electric vehicles, solar photovoltaics, batteries, and heat pumps, has ignited optimism for a potential turning point in combating climate change and reducing greenhouse gas emissions (IRENA, 2023). Although the widespread adoption of these technologies represents a significant step forward, it is insufficient for a successful transition. Achieving this transition necessitates a concurrent paradigm shift within the cultural domain towards sustainability, alongside more ambitious and impactful political commitments (IEA, 2022). Moreover, the deployment of these technologies is not without its drawbacks. They also present a range of geopolitical challenges that require further investigation.

Designers play a crucial role in shaping sustainable user behavior and facilitating cultural transitions towards a sustainable energy system. Their influence arises from their twofold role: shaping the production processes and supply chains of their products, as well as influencing how users interact with those products. Understanding and influencing human behavior are therefore becoming critical aspects of the design process for a sustainable future. Climate change awareness campaigns fail to promote long-term behavioral change due to their sole focus on mitigation measures, energy efficiency, and sustainability, neglecting adaptation of the human aspect. This approach can make energy systems seem complex and distant from people's daily lives, leaving them overwhelmed by the vastness of environmental issues or disconnected from the immediate impact of their choices.

Espen Stoknes, a Norwegian psychologist, in his 2015 book "*What We Think About When We Try Not to Think About Global Warming*" identifies five psychological defense mechanisms that impede effective action on climate change: Distance, Doom, Dissonance, Denial and Identity. First of all, the concept of *Distance*, where climate change is perceived as a distant issue. When climate change is framed as an encroaching disaster that can only be addressed by loss, cost, and sacrifice, it creates a wish to avoid the topic (*Doom)*. Furthermore, cognitive *Dissonance*, which arises from the discomfort of holding conflicting beliefs, leads us to deny or feel powerless in the face of information that contradicts our convictions and reality. Even when aware of concerning facts, we tend to act as if we are not (*Denial*). As we filter information through our cultural identity, we often filter away what challenges our existing values and notions. Therefore, if new information requires us to change ourselves, then we experience resistance to calls for change in self-identity (*Identity*). These defense mechanisms collectively hinder individuals from taking action. To address this, Stoknes proposes making climate change more tangible and personal by highlighting its local and immediate impacts. This requires clear and constructive communication of the issue, fostering a shared collective identity, emphasizing membership in a broader group fighting for a common future, and showcasing the solutions and concrete actions individuals and communities can take to make a difference.

Technological innovation is emerging as a key driver of systemic change towards a more sustainable future, smart homes and energy consumption control are clear examples. Specifically, the integration of new technologies like artificial intelligence (AI), the Internet of Things (IoT), and Digital Twins (DT) into change-oriented services can accelerate the energy transition and promote sustainable user behavior.
The Internet of Things (IoT) plays a crucial role in powering Digital Twins, which have the potential to help users understand their energy consumption and improve efficiency. The deployment of smart sensors in buildings, industrial facilities, and power grids facilitates the capture of valuable data on critical parameters like temperature, energy consumption, and operational conditions. This continuous data stream feeds into Digital Twin technology, creating a comprehensive and dynamic virtual representation of the physical system. Beyond

mere replication, the Digital Twin, empowered by this rich data, transforms into a powerful tool for simulation and optimization. Through the creation of hypothetical scenarios, inefficiencies can be proactively identified, and alternative solutions can be tested before real-world implementation. Chevron Corporation, for example, has adopted artificial intelligence to develop digital twins and optimize operations. By using predictive data analysis, the company has significantly reduced the number of required drillings and improved the efficiency of maintenance activities. This approach enables proactive optimization of energy performance, resulting in cost reductions and a minimized environmental impact.

Artificial intelligence can be implemented in sustainable energy by customizing recommendations and providing real-time feedback. Recent studies (Ayan et al, 2020; Li et al, 2020, Chiesa et al, 2020) highlight how these systems, based on microcontrollers such as Arduino and Raspberry Pi, enable automatic adjustment of light intensity, remote control of luminaires and the creation of custom scenarios. The use of motion, light and temperature sensors allows lighting to be optimized according to space occupancy, daylight availability and individual preferences helps users to analyze their energy consumption data, offering personalized and targeted energy-saving recommendations, helping them to understand the impact of their behavior on energy consumption. This approach takes into account users' specific needs, habits and characteristics, suggesting effective actions based on climate, home comfort and energy costs. Machine learning allows AI systems to adapt to user preferences, continuously improving recommendations. Intelligent automation simplifies the process, freeing users from the need to remember energy-saving actions and allowing them to focus on strategic aspects such as communication, engagement and impact assessment. These technologies help design efficient strategies to promote sustainable energy behavior.

2. Research Methodology

This study explores the application of Design for Behavioral Change strategies through two case studies. The first case involved developing a user-friendly interface for a database containing energy audit results from school buildings. This platform aimed to enhance accessibility and comprehension of complex energy data for stakeholders, ultimately promoting informed decision-making regarding energy usage within schools. The second case study showcases a disciplinary workshop about carbon footprint. Students were able to understand and apply the concept of carbon footprint by analyzing their daily consumption habits. This interactive exercise increased the students' awareness of their environmental impact, encouraging them to switch to more sustainable practices.
The "*Design-driven*" approach (Verganti, 2010) to energy production goes beyond merely considering technical efficiency or economic cost. Instead, it places the very meaning of energy and its value for people and communities at the forefront (Badalucco, Chiapponi, 2009). Such an approach demands interdisciplinary and coordinated actions, involving experts from engineering, architecture, design, urban planning, social sciences, economics, and more. It is crucial to overcome disciplinary fragmentation and adopt a systemic view of energy production, considering its social, environmental,

and territorial implications. Engaging the society is a key element, since the energy transition cannot be imposed from above; rather, it must be the outcome of a shared process that engages citizens and other local stakeholders.
Ceschin e Gaziulusoy (2016), Explains about the Design for Sustainable Behaviour evolution of Design for Sustainability. The authors highlight that an ecodesign approach can provide designers with a set of design strategies to reduce the environmental impact of a product throughout its whole life cycle, however, the way in which consumers interact with products can produce substantial environmental impacts.
As noted by Niedderer et al. (2014) there are many different designs for behavior change approaches because there are many different models of behavior change in social sciences. For example: the Design for Sustainable Behaviour model developed at Loughborough University (Bhamra et al., 2011; Lilley, 2009) is grounded on behavioral economics and proposes a set of design intervention strategies based on informing, empowering, providing feedback, rewarding and using affordances and constraints; Design with Intent (Lockton et al., 2010) draws from a variety of fields and proposes eight lenses (Architectural, Error Proofing, Interaction, Perceptual, Cognitive, Security, Ludic and Machiavellian lenses) by which to understand and influence aspects of personal behavior and contexts.

Behavioral design, coupled with collaborative practices, can facilitate the energy transition by fostering spaces for dialogue and exchange. This collaborative approach promotes public awareness of energy issues and aids in identifying user needs and challenges. Consequently, the design discipline assumes a multifaceted role: acting as a collector of user experiences, a social mediator, and a facilitator in the process of assigning new meanings to energy use. By doing so, design enables actions that promote and communicate social innovation. Accessible educational processes are then triggered, shaping citizens' behaviors and incentivizing the adoption of sustainable practices. This design approach aligns with the field of social psychology. Studies have shown that leveraging theoretical frameworks from social psychology allows for the evaluation of user needs and barriers. This evaluation is crucial for implementing interventions aimed at behavior change. The COM-B model (Michie et al., 2011), for instance, facilitates an assessment of the factors influencing the adoption of energy-sustainable behaviors. It also enables the development of targeted interventions to overcome barriers and promote change (Fig.1).

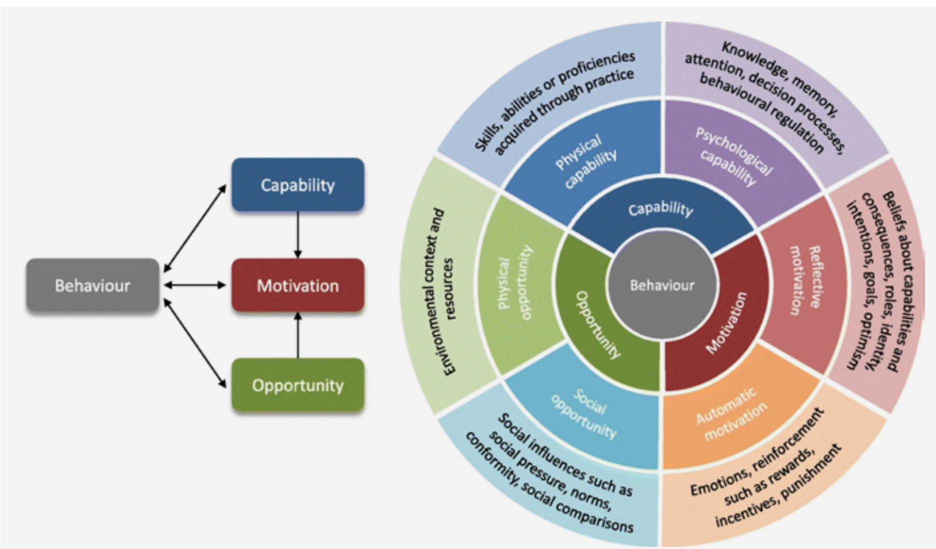

Figure 1. Michie et al., The COM-B model for understanding behavior of the behavior change wheel. 23 COM-B, capability, opportunity, motivation-behavior, 2011.

This behavior change framework proposes three necessary components for any behavior (B) to occur: Capability (C), Opportunity (O), and Motivation (M). By assessing these components, it is possible to understand why a specific behavior occurs and how to create targeted interventions that lead to effective change. For instance, if a lack of capability is identified, training or education interventions can be designed to increase users' knowledge and skills. The COM-B model provides a foundation for the Theory of Change which allows for the explicit articulation of the logical linkages between the identified solutions and their related activities, with the expected mid-term results, long-term goals, and desired impacts throughout the change process. Therefore it works as an effective tool for monitoring and evaluating whether the implemented activities effectively lead to the expected change.

Furthermore, recognizing the limitations of solely disseminating information, Engagement Design strategies were employed to ensure user engagement and maximize the effectiveness of the implemented infrastructures, in order to encourage consumers to adopt sustainable choices:

- *Gamification:* The simplest definition of gamification is 'the use of game features in non-game situations to enhance user experience and engagement' (Deterding et al., 2011). Gamification projects often rely on elements such as points, badges and leaderboards to motivate users and encourage sustained engagement (Huseynli, 2024). Incentives and penalties, as integral components of gamification, have been shown to be powerful tools for shaping user behavior and achieving desired outcomes (Gamma et al., 2021). This fosters a sense of participation and achievement, motivating individuals to strive for continuous improvement. Beeta represents an innovative digital solution that, by exploiting game dynamics, promotes energy awareness among users. Indeed, the application invites users to participate in challenges and competitions, incentivising them to monitor their consumption and adopt more sustainable behavior. The results suggest that gamification can be an effective tool to stimulate behavioral change in the energy field.

- *Personalized Feedback and Insights:* by providing real-time customized feedback on their energy consumption patterns, users can identify areas for improvement and track progress over time, fostering a sense of accountability and awareness. Energy, being inherently abstract and intangible, has traditionally been difficult for users to perceive and understand (Burgess & Nye, 2008). To overcome this challenge, recent studies have focused on strategies that increase the visibility of energy use, such as real-time home displays (Pahl, et al. 2016). These tools have proven to be effective in reducing energy consumption, but their long-term effectiveness depends on the ability to actively engage users. Therefore, the design of these tools requires a careful approach to comprehensibility and interactivity in order to provide personalized feedback and promote lasting behavioral change (Nasrollahi, et al., 2023). Numerous applications are commercially available related to raising awareness of a more conscious use of energy, e.g. Vemer's Energy Wi-Fi app to remotely control your consumption, Energy Consumption

Analyzer to calculate the average rate of energy consumption, MyWatt Plug to remotely monitor electrical outlets and keep costs under control.

- *Storytelling and Emotional Connection:* storytelling can frame sustainability within a compelling narrative and can create a deeper emotional connection to the issue. Storytelling techniques highlight the positive environmental and social impact of energy conservation, inspiring users to become active participants in the solution.

- *Networking and Social Learning* enable users to share experiences, compare results, and learn from each other's successes. These services offer significant scalability, fostering network buildingreaching a wider audience and reinforcing positive behaviors through social interaction. Social interaction strengthens motivation and consolidates sustainable behaviors (Cialdini, 2009). For example, Opower provides users with personalized energy-saving tips and gamification elements, making energy saving fun and competitive. Nest, a smart thermostat, monitors home energy consumption and offers social networking features to share consumption data with friends and family, encouraging conservation through social sharing. Enercities connects local communities engaged in the energy transition, allowing users to share experiences, best practices, and resources, and participate in collaborative projects. This community-based approach promotes energy conservation by providing support and a sense of belonging.

The presented best practices provide examples that can illustrate the implementation of the proposed strategies and demonstrate their effectiveness in promoting sustainable energy behaviors.

3. Case Study 01: User-Friendly Platform for Energy Efficiency in School Buildings

The project, conducted by BexLab (Building Environmental eXperience) and coordinated by Professor Antonella Trombadore, in collaboration with the Service Design laboratory led by Professor Debora Giorgi, developed a user-friendly interface prototype (Fig. 2). This interdisciplinary research is part of the Eni CBC Med program, Mediterranean University as Catalyst for Eco-Sustainable Renovation - Med-EcoSuRe, focusing on cost-effective energy renovation in university buildings with the potential to extend results to the entire public building sector. The methodology is based on a Living Lab approach, creating an innovative physical and virtual research and learning space.

Figure 2. Service Design Lab, UX and UI for Bexlab Platform, prototype of the user interface, 2021.

Here, researchers, stakeholders, and students can collaboratively experiment to improve energy efficiency, indoor quality, and well-being in building retrofit processes, fostering environmental awareness. Advanced technologies such as *Building Information Modeling* (BIM), dynamic environmental monitoring systems with sensors, and the *Internet of Things* (IoT) are used to implement the concept of a *Digital Twin*. This enables data availability through user-friendly ICT platforms, promoting knowledge of environmental issues and conscious behavior. Leveraging Digital Twin technology, predictive virtual scenarios assess the technological and economic feasibility of proposed solutions. Real-time monitoring systems gather data and experiential feedback, enriching the virtual model and providing a solid foundation for further enhancements. In-depth analysis within BexLab involved active stakeholder engagement, including students, faculty, technical staff, and administrators. Data collection through real-time questionnaires and field observations provided insights into stakeholders' perspectives, concerns, and behaviors related to environmental and energy comfort in school buildings.

Our contribution included the design of scenarios (Fig. 3) and storyboards aimed at reflecting real-life situations and actions that users could take to optimize environmental and energy comfort. These scenarios, presented as suggestions based on real-time perception of environmental energy, actively encourage users to participate in the process of environmental and energy improvement. The creation of storyboards were focused on actions and scenarios within the virtual user experience (digital twin), and it facilitated a multi-user and multi-level perspective on the collected data.

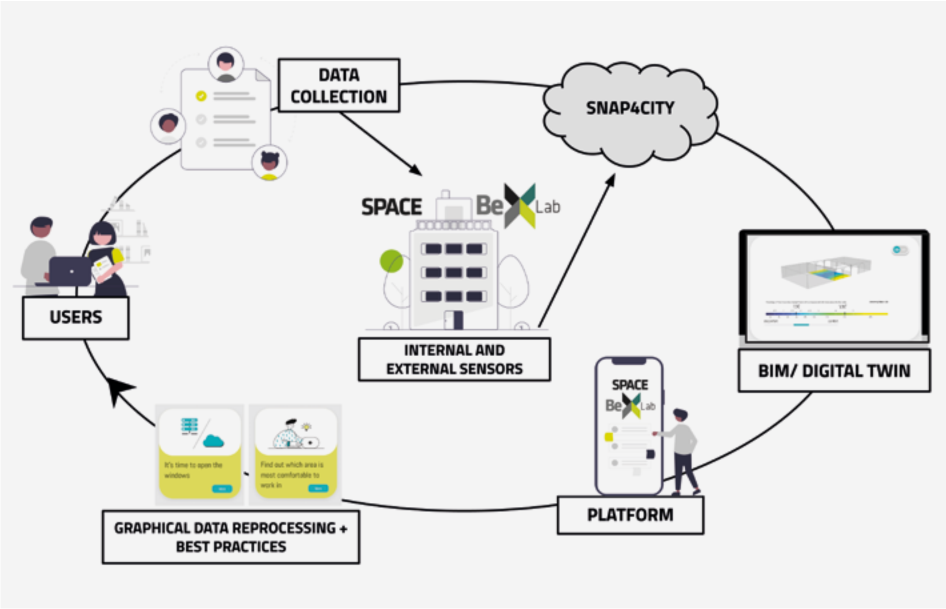

Figure 3. Service Design Lab, UX and UI for Bexlab Platform, construction of interested parties in the project system, 2021.

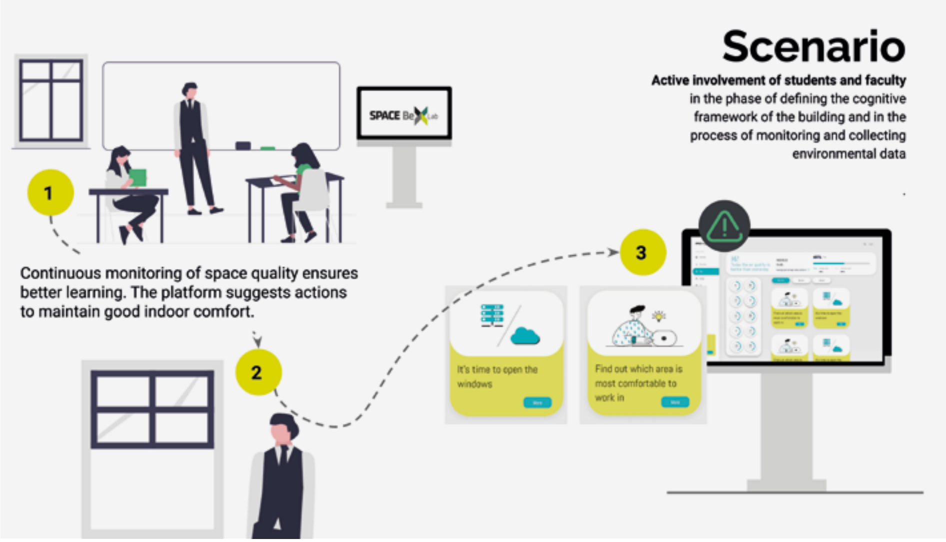

Figure 4. Service Design Lab, UX and UI for Bexlab Platform, example of illustrated scenario, 2021.

This approach enhanced everyone's ability to understand and interpret the information (Fig. 4). The User Experience methodology led to a user-friendly interface tailored to different user groups. Intuitive and eavsy to use, the interface provides clear information on energy consumption and environmental parameters. The final output includes a dashboard with sections for real-time sensor data and overall comfort perception, suggesting actionable steps to improve resource management. Continuous improvement is fostered through user feedback questionnaires, ensuring the platform remains adaptable to emerging needs and provides a progressively better user experience. The interaction between physical and virtual models, mediated by ICTs, transforms into an innovative experience aimed at improving building life quality, stimulating creativity, and encouraging collaboration among users. This data management and communication platform fosters a collaborative environment. Informed by real-time data, administrators and technicians can devise intelligent solutions and test them within the digital model. Residents, empowered with this knowledge, can then implement practical measures and provide feedback, creating a continuous improvement cycle.

The s*martness* of the building, through enabling technologies, enhances innovation, knowledge, learning, and *problem-solving skills*, contributing to raising awareness and changing behaviors towards a culture of sustainability.

4. Case Study 02: The Use of Ecodesign Tools to Raise Awareness of Domestic Consumption and Promote Sustainable Practices

The activities described in this case study illustrate how Design-driven approaches can effectively educate and raise awareness about environmental and energy sustainability, particularly regarding household consumption. This case study emerged from a workshop within the Service Design course for the academic year 2022/23, aimed at equipping future designers with the tools and methodologies necessary for service ideation, definition, and development (Stanford d.school, 2024).

The training was structured around a group project for three participants, tasked with designing and prototyping a social innovation service for the Macrolotto Zero district of Prato. The course focused on understanding household consumption patterns to achieve two main objectives. First, it aimed to raise student awareness of the environmental impact of daily domestic practices, particularly by linking everyday habits to household energy consumption and resulting CO2 emissions. Second, it sought to bridge the gap between theoretical design principles and their practical application. By using tools and methodologies from the Service Design course, students were empowered to define, map, and represent the domestic environment as a complex ecosystem.

The activities involved designing tools based on a Design Thinking approach. Templates were created and shared on Miro's jamboard. For four weeks, students documented their household consumption patterns, logging data on water, electricity, food, transportation, and waste production.

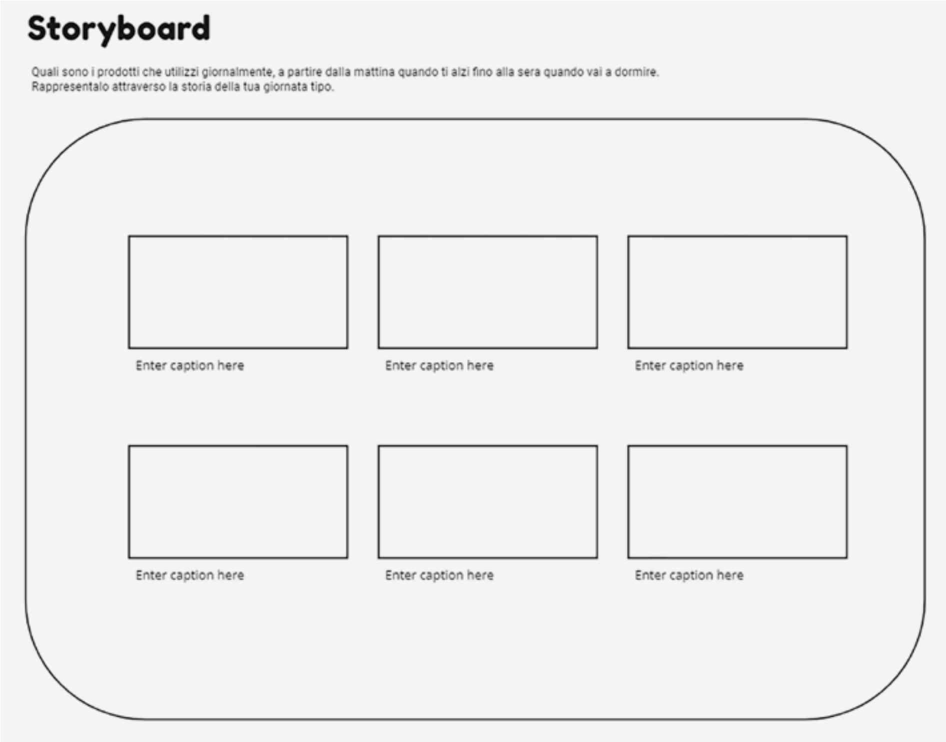

Figure 5. Service Design Lab, Workshop of domestic ecosystem, Example of storyboard used during the first activity, 2024.

They then used storyboards to translate a typical day's consumption patterns into visual narratives. Uploading these vignettes to a shared jamboard allowed collaborative representation of household consumption phases in their daily routines (Fig. 5).

Building on a lecture about ecosystem mapping (Tassi, 2019), students mapped all sources of household consumption into five categories: water, electricity, food, transportation, and waste generation. This helped them identify all elements of consumption within the domestic ecosystem (Fig. 6).

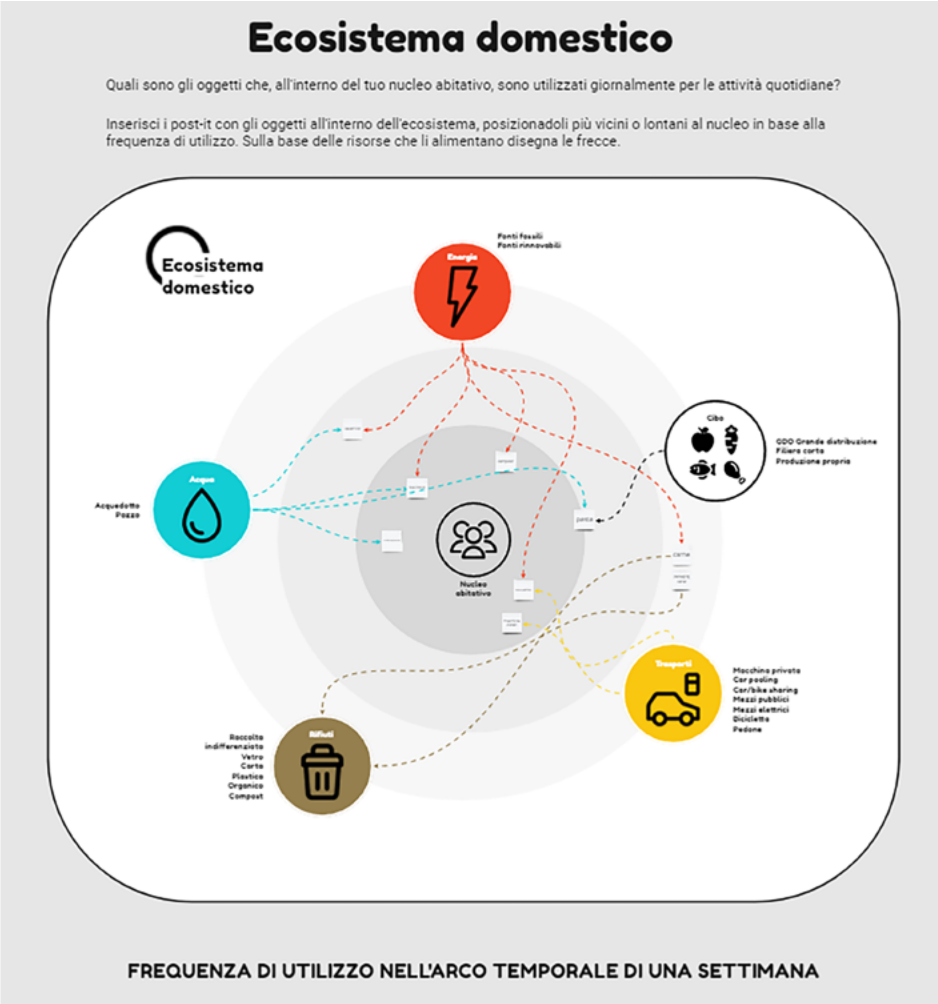

Figure 6. Service Design Lab, Workshop of domestic ecosystem, Example of Ecosystem map used during the second activity, 2024.

After a week, students reviewed their ecosystem maps with feedback from teachers and began creating an "interpretive abacus" to quantify each device's consumption. They conducted online research to find average consumption data for each device and entered these results into the abacus (Fig. 7).

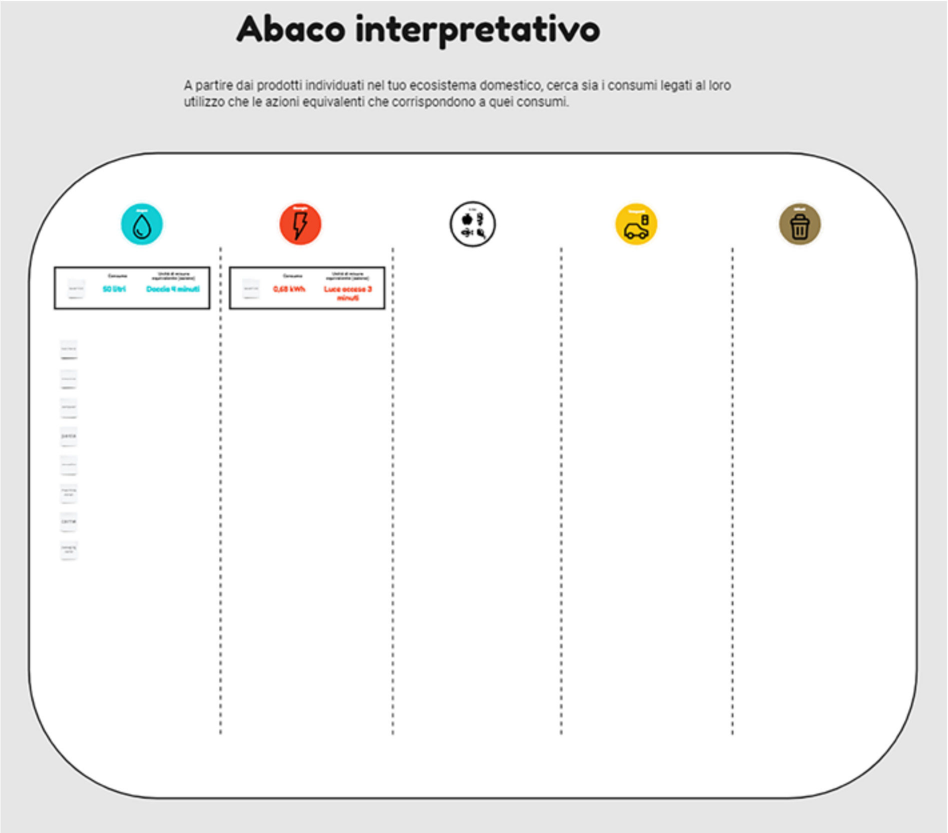

Figure 7. Service Design Lab, Workshop of domestic ecosystem, Example of Interpretative Abacus used during the third activity, 2024.

The next activity, "transform-ations," involved developing solutions to reduce or eliminate consumption problems identified in previous exercises. Students chose three products from their abacus and used a template on the jamboard to outline the object, the resource to be recovered, the resource recovery strategy, and potential solutions to modify family behavior (Fig. 8).
During the final presentation, students shared their "transform-ations" solutions. It was clear that through these activities, students gained a deeper understanding of household

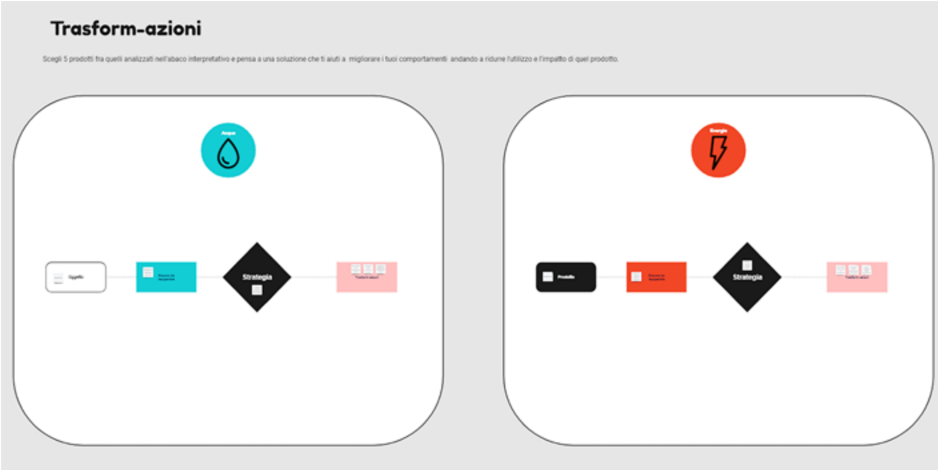

Figure 8. Service Design Lab, Workshop of domestic ecosystem,, Example of Trasform-azioni used during the fourth activity, 2024.

resource consumption and the impact of daily actions on energy use. They recognized the environmental impact of their choices and proposed innovative solutions to reduce consumption and promote sustainable practices.

The case studies that were just showcased are a compelling illustration of how such methodologies can increase environmental awareness and encourage sustainable behaviors. By engaging students in a series of practical activities, a deeper understanding of the impact of their daily habits on the environment was fostered.

5. Conclusions

“Design for Change” results as a compelling approach within the framework of fostering sustainable energy. By actively engaging users, facilitating virtuous behaviors, and nurturing a culture of shared responsibility, this innovative methodology holds immense promise in addressing the pressing challenges of our energy-intensive world. Co-creation is central to Transformation Design in service platform development. When project participants actively contribute to shaping the service, designers must move away from rigid, pre-determined sequences of actions. This allows for greater adaptability and flexibility to meet the evolving needs of the co-creators. When designers are faced with the need to disseminate and scale the promising solutions of creative communities, their contribution takes the form of "enabling solutions", or "a system of products, services, communication and everything else needed to improve the accessibility, effectiveness and replicability of a collaborative service" (Manzini, 2008: 38).

What makes this approach strong is its focus on social psychology, behavioral sciences, and cutting-edge technologies. This synergy allows for the adoption of dynamics in response to the complex and ever-changing variables required by this ongoing transition. Beyond offering immediate solutions, "Design for Change" fosters groundbreaking advancements in how we manage and conceptualize energy resources. This approach ushers in a paradigm shift, where technological innovation and predictive scenarios work hand-in-hand to pave the way for a future with significantly reduced energy waste. By educating participants, the program engenders a critical awareness of the environmental and social consequences of daily routines. This goes beyond simply adopting energy-efficient practices, nurturing a long-term commitment to responsible behavior.

While past experiences offer valuable insights, a critical approach remains essential to avoid deterministic biases and uncritical adoption of *Key Enabling Technologies*. These innovations demand thorough investigation, comprehension, and integration to empower users with knowledge and awareness. This fosters a sense of designer accountability and stimulates critical design thinking, crucial for tackling the ever-growing complexity of achieving sustainability and other ecosystemic goals.

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Energy to Design Communities
Energy Communities and Communities of Practice to Support Marginal Areas in Abruzzo

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Marginal Areas, Renewable Energy Communities, Communities of Practice (CoP), Open Access Geographic Information Systems, Local Supply Chain.

Abstract
This contribution reports on an ongoing analytical experiment aimed at establishing a Renewable Energy Community in Taranta Peligna (CH), a highly marginalised municipality in the Italian Abruzzo region. The aim is to activate a Community of Practice to support local artisanal resources of high quality for the enhancement of energy and productive resources and thus to counteract the worrying depopulation that is taking place. With a systemic multi-objective approach to research, it is planned to define a distributed and collaborative model based on proximity, where the Municipality, with the participation of the community and the patronage of the Maiella Park Authority, can guide the creation of Energy Communities to obtain environmental, social, and economic benefits. In this perspective, a feasibility study based on an open-access geographic information system will provide an overview of the current energy situation, recovering the industrial and environmental heritage to define clean energy design scenarios, overcome energy poverty, generate economic improvements, and promote social awareness. Thanks to the holistic lever of systemic design, the proposed model faces difficulties in overcoming the classical economic approach and the deeply rooted individual culture, designing inclusive community-centered scenarios for social, cultural, economic, and, not least, energetic innovation.
However, the research can only benefit from a local production model within the Maiella National Park, a UNESCO Geopark since 2021, rich in clean energy and authentic communities, witness of a strong manufacturing and industrial history characterized by excellence and authenticity.

1. Introduction. The Centrality of Systemic Design in the Current Polycrisis

In times of polycrisis (Tooze, 2021; Davies & Hobson, 2022), where difficulties intertwine and influence each other at a global level, generating complex effects that amplify existing vulnerabilities, it becomes imperative to adopt innovative solutions that transcend traditional approaches (Lawrence, 2024). These approaches often manage crises in isolation, unable to address their growing interconnections (clearly evidenced by the correlation between the 2030 Sustainable Development Goals).

Despite today's well-defined international regulatory context (Green Deal Plan, UNSDGs 2030, ESG indicators), transversal and unconventional approaches are needed to manage complexity. These approaches challenge cause-and-effect dynamics, shift cultural paradigms, and experiment with community models for sharing technical and social resources within everyday habitats.

To protect environmental complexity and promote economic and community growth towards sustainable, robust, and resilient systems (Norman, 2023), the systemic and unconventional approach of Design can outline new conceptual models and operational processes (Manzini, 2015). It can explore more sustainable future scenarios, enable collective participation involving all social entities (both formal and informal), and engage in common themes, scales, and design intentions through a circular process (Gaddi, Mastrolonardo, 2023). This approach resonates with literature on systemic and transition design (Bistagnino, 2009; Irwin, 2019; Barbero and Ferulli, 2023), where the designer serves as a connecting figure

supporting the understanding of complexity dynamics. This includes analysing connections between parts and consequent reconfiguration of the production system, considering both community and local needs alongside global aspects. It involves narrating planning and future scenarios to create leadership around consensus based on active participation, envisioning possible innovation scenarios through mastery of design tools and technical and creative skills, and promoting the enhancement of the territory through services, products, and communication with a strong relational characterization (Magnaghi, 2020). It also entails connecting stakeholders to broaden the debate beyond the project itself (Design Council, 2021).
The research is about an experiment for the creation of an Energy Community in Taranta Peligna (CH), a very marginal municipality in the Abruzzo region, designated by 9 positive parameters according to the Prime Ministerial Decree 07.23.21. Additionally, it explores the possibility of activating a Community of Practice (Wenger, 2002) to support the enhancement of local environmental and artisanal resources.
The premise of the research stems from an existing agreement between the Municipality and the Department of Architecture of "G. d'Annunzio" University of Chieti-Pescara, aimed at studying design solutions for the enhancement of energy and production resources to counteract the worrying depopulation underway. The first analytical phase, here described, will spot the opportunities offered by the territory and will be followed in the future by an operational phase aimed at the definition of inclusive design solutions to support the local community and foster economic development and energy transition.

2. Energy Communities and Communities of Practice in Support of Abruzzo Fragile Areas and Local Communities

The mountainous regions of Abruzzo are experiencing significant depopulation: from 2015 to 2022, the population in mountain municipalities decreased by 6.2%, surpassing both the regional (3.8%) and national average decline in mountainous areas (4%) (ISTAT, 2022). While not recent, this depopulation trend (OECD, 2020) has direct implications for residents' economy and social well-being (European Network for Rural Development, 2020). This situation is particularly pronounced in Central-Southern Italy, especially in Abruzzo, where the pandemic has further exacerbated the situation, resulting in a 2.4% decline between 2020 and 2022 solely in the mountainous areas of Abruzzo (de Renzis et al., 2022).

Despite this, depopulation is not inevitable. Certain factors can effectively counteract depopulation and facilitate a fair transition (European Commission, 2021; European Commission, 2022), socioeconomic diversification, high female employment, low risk of social vulnerability, preservation of historical-architectural heritage, and the availability of natural resources, including those for renewable energy production (De Santoli, 2024). Establishing energy communities in marginal and rural contexts promotes energy self-sufficiency, reduces CO2 emissions, fosters local innovation, supports local production chains, and encourages entrepreneurship (Bussone, 2024). Consequently, renewable energies and sustainable technologies become instruments for fostering new models of territorial economic development, where participating entities, such as producers/consumers or prosumers (Perger, 2020),

actively engage in creating and developing renewable projects, thereby exercising control over the process and benefiting from the outcomes. This vision aligns with the energy and cohesion policies of the European Union, such as the Circular Economy Action Plan (2020), which aims to reduce disparities among regions by promoting smart specialization, a green economy, and social inclusion. This involves transitioning from a linear production model based on resource exploitation to a circular and regenerative one (Ellen MacArthur Foundation, 2015), promoting short supply chains, investing in renewable energy and the green economy, enhancing heritage to develop sustainable tourism models, fostering digitalization, and strengthening collaboration between institutions, organizations, and citizens (Bolognesi & Magnaghi, 2020).
The integration of Energy Communities and Communities of Practice represents a particularly compelling strategy: by utilizing clean energy and low-impact technologies, virtuous cycles can be initiated to revitalize local economies with high added value, within a circular and sustainable framework. Achieving this requires a systemic approach that integrates energy planning with territories' social, economic, and cultural needs, leveraging extensive collaboration between public and private entities, academic institutions, and the local population (Manhique, 2021).

3. Analysis and Design Methodology. A Design-Driven Approach for Enhancing Energy Resources

The analytical methodology employed a combination of quantitative and qualitative analyses (data and best practices) to compare integrated environmental themes and industrial

symbiosis (Raggi et al., 2018), to define the most suitable processes and technologies for constructing a Renewable Energy Community (REC) in Taranta Peligna. In this context, the environment concept was perceived as a complex and comprehensive system (Butera, 2021) with its own rules and boundaries to which economic and social systems must adhere. This compelled to consider safeguarding the complexity of the environment while promoting the growth of local economies and communities through a circular process in which design, communication, and technology support development, rather than merely serving as tools for development.
Within this application context, the energy transition is based on the collective participation of all social entities, both formal and informal, necessitating the sharing of themes, scales, and design intentions. This offers a perspective on how design can act as a driver of change, promoting creating communities that are aware, resilient, and rooted in their territorial context.

The analytical methodology and design process, which embody the synergy of divergent and convergent thinking, adhere to principles outlined by the Design Council (2021) to develop new design methods and tools:

- Focus on the shared benefits of all living beings (placing people and the planet at the centre).
- Plan from the root cause to the broad vision, from micro to macro, from present to future.
- Create prototypes to understand the functionality and foster further innovation (through continuous testing and iterative verification in the field).

- Establish safe and shared spaces and languages to introduce multiple perspectives.
- Consider a specific project as an element of a broader process of change.
- Focus on existing physical and social resources and explore methods to reuse and enhance them.

The territory of Taranta Peligna (Fig. 1) not only possesses energy resources but also environmental and historical/cultural assets. It is situated mainly within the Maiella National Park (UNESCO Geopark since 2021). It features resources such as the Acquevive River Park (Fig. 2) and the Cavallone Caves (Fig. 3), which houses a multimedia museum and a medieval path carved into the Maiella rock.

Figure 1. Taranta Peligna. Source: Municipality of Taranta Peligna, 2023.

Figure 2. Acquevive River Park, Taranta Peligna. Source: Municipality of Taranta Peligna, 2023.

These historical and cultural assets are intertwined with the economic and social history of the upper Aventine Valley, particularly in relation to the wool processing industry, for which Taranta Peligna was the economic hub. Evidence of this industrial tradition can be found in landmarks such as the Church of San Biagio, the church of the wool workers dating back to the 16th century, and the historic core of the abandoned medieval village overlooking the river. The remnants of pre-industrial machinery from wool mills, which produced traditional Abruzzo blankets and fabrics, further attest to this industrial heritage.

Figure 3. Cavallone Caves, Taranta Peligna. Source: Municipality of Taranta Peligna, 2023.

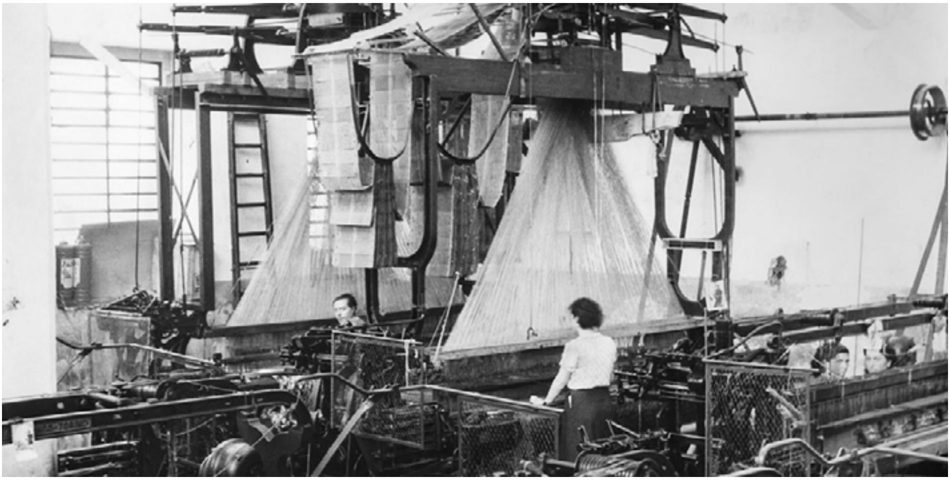

Figure 4. Ancient weaving, Lanificio Merlino. The movement of the warp threads of the Abruzzese Blanket is managed by jacquard machines, the first machines to be driven by a binary system. Source: Lanificio Vincenzo Merlino, www.copertemerlinotaranta.it, 2024.

Figure 5. Jacquard pattern of a traditional Abruzzo blanket, Lanificio Merlino. Source: Lanificio Vincenzo Merlino, www.copertemerlinotaranta.it, 2024.

Despite the textile industry crisis in the 1980s, only one wool plant survived: the Lanificio Merlino, a historic brand with a 150-year legacy (Fig. 4), which remains active, albeit with only one production unit, in the production of blankets and fabrics, including the Traditional Abruzzo blanket made with 3600 threads of twisted wool (Fig. 5). Merlino has historically been attentive to renewable energy dynamics (photovoltaic and hydroelectric), as depicted in Table 2, which will be discussed further in the subsequent paragraph of this contribution.
In the following paragraphs (4 and 5), the analytical methodology will be illustrated as a quantitative analysis of local constraints and opportunities, which indicate the consequent most suitable technologies and tools to support the development of qualitative scenarios based on community advantage, allowing the hypothesis of inclusive design solutions.

4. The Energy Resources of Taranta Peligna. Analysis of Existing Consumption and Potential for Energy Development

For quantitative analysis, Taranta Peligna is estimated to be a small village with a resident population of 291 units and slightly more than 170 families (ISTAT 2022).
Ministerial Decree no. 414 of December 7th 2023 (MASE, 2023), aimed at stimulating the birth and development of renewable energy communities and widespread self-consumption in Italy to pursue the 2030 decarbonization objectives (Goal 7, UNSDG), regulates the incentive methods to support electricity produced by RES (Renewable Energy Sources) plants. These incentives apply to self-consumption and the sharing or sale of surplus renewable energy under market

conditions or through dedicated withdrawal, with economic conditions guaranteed by the Energy Services Manager (Italian GSE). Furthermore, in municipalities with a population of less than 5,000 inhabitants, if the Administration can participate in the REC as a producer or consumer, it could receive a contribution of 40% of the investment cost.
However, an estimate of the village's consumption can be made based on the 2012 Sustainable Energy Action Plan, developed by the Local Agency for Energy and Environmental Development of the Province of Chieti as part of the European Commission's Covenant of Mayors program (2008). According to this study, the Municipality of Taranta Peligna's overall electricity consumption is approximately 1,017 GWh/year.

TYPE OF CONSUMPTION	POWER CONSUMPTIONS (MWH/YEAR)	
MUNICIPAL SECTOR	18,65	1,83%
SERVICE INDUSTRY	221	21,72%
RESIDENTIAL SECTOR	612	60,14%
PUBLIC LIGHTING	166	16,31%
	1.017,65	**100%**

Table 1. Type of electricity consumption in the Municipality of Taranta Peligna. Source: Sustainable Energy Action Plan, 2012.

As seen in Table 1, the most significant element is represented by the consumption of the residential sector. Since estimating this value is fundamental in the context of energy consumption control and verification, it is necessary to carry out real-time monitoring of residential consumption. This activity can be easily carried out by installing electricity consumption meters (smart meters), which, with the assistance of IoT sensors, allow precise monitoring of each household electrical device, collecting data from each appliance, transmitting it to a unified platform with a specific communication protocol (e.g., *Modbus*, *LoRaWAN*, *OpenThread*). These systems, accessible in terms of costs and installation procedures, enable monitoring not only the energy consumed by buildings but also that produced by individual installed systems.

TYPOLOGY RES PLANT		POWER INSTALLED (KW)	ANNUAL PRODUCTION (KWH/YEAR)
PHOTOVOLTAIC	Municipality of Taranta Peligna	20,00	25.600,00
PHOTOVOLTAIC	I.L.A. - Industria Laniera Abruzzese di Vincenzo Merlino & Figli S.n.c.	75,90	97.227,90
HYDROELECTRIC	I.L.A. - Industria Laniera Abruzzese di Vincenzo Merlino & Figli S.n.c.	600,00	
HYDROELECTRIC	Verlengia & De Cecco S.r.l.	9.000,00	1.054.897,70
HYDROELECTRIC	Enel Green Power S.p.A. Centrale ENEL Aventino 1	10.000,00	
			1.177.725,60

Table 2. RES plants in the Municipality of Taranta Peligna. Source: Sustainable Energy Action Plan, 2012.

Table 2 reveals that several RES plants currently exist within the entire municipal territory of Taranta Peligna, producing a total of approximately 1.17 GWh/year: existing and operational plants within the municipal territory cannot become part of the REC (D.M. 414/2023). Therefore, new forms of development must be identified.
Given the characteristics of the area and the availability of water resources, it is possible to consider the reactivation of the old power plant located along the Acquevive River Park; as depicted in Figure 1, the river stretch is indeed suitable for harnessing the water resource for hydroelectric purposes,[1] with a potential withdrawal of 3,455 l/s.

1 Abruzzo Region, Study to support regional planning regarding water resources intended for hydroelectric energy production, 2008. https://www.regione.abruzzo.it/content/risorse-idriche

However, this value is purely theoretical and requires an in-depth hydrological study to verify its validity; therefore, in the hypothesis of a flowing water system with a withdrawal of 1,000 l/s and a geodetic head of 5 meters (within the same structure), a production of approximately 384,018 kWh/year would be achieved. This entirely precautionary estimate does not consider the possibility of greater withdrawal and a larger geodetic drop, which would allow for increased production.

Regarding the development of photovoltaic systems, it will first be necessary to conduct a census (Carbonara & Stefano, 2016) of all municipal real estate assets to identify properties and areas suitable for constructing photovoltaic systems. However, following the census activity, a "real estate due diligence" (Carbonara & Stefano, 2020) will be required to verify said assets to provide an accurate description and evaluation of the assets under analysis.
In addition to the public potential, it is possible to estimate the potential that can be installed on individual private residential homes by assuming that each resident family (173 families according to ISTAT 2022) creates a modest-sized system equal to 3 KWp. From this perspective, a production of approximately 648,750 kWh/year could be achieved.

As for RES plants deriving from the exploitation of wind resources, the municipal territory falls within a multi-restricted area (as shown in Figure 7: Site of Community Interest - SCI, Special Protection Area - ZPS, Maiella National Park, Zones A1 and A2 of the Regional Landscape Plan), effectively inhibiting the installation of large-scale wind turbines.

The greatest energy potential of the area, with production greater than 2500 MWh/MW, as shown in Figure 8, is located only in the mountainous part of the municipality of Taranta Peligna. This makes the realization of any project unsustainable (both financially and in terms of landscape) due to the steepness of the area and the presence of highly protected areas. Nevertheless, there remains the possibility of installing small-scale wind power systems with reduced power up to 3 KW on the premises of buildings, which, albeit with a minimal contribution, still represent a form of renewable energy with low impact.
In summary, the hypothesis of establishing and developing a REC in Taranta Peligna envisages that the proposed RES plants (hydroelectric for 384,018 kWh/year (Fig. 6) and photovoltaic for 648,750 kWh/year) could ensure, with the aid of storage systems, the energy balance of the entire municipality, providing production of 1.033 GWh/year, compared to a consumption of 1.017 GWh/year.

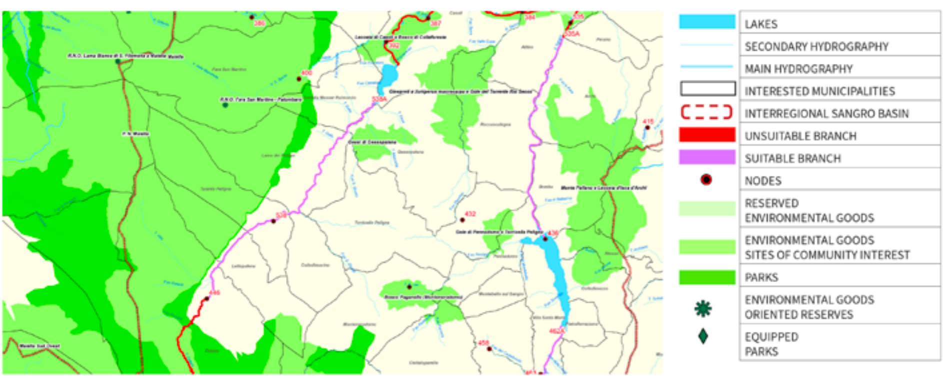

Figure 6. Section suitable for the exploitation of the hydroelectric resource. Source: Abruzzo Region, *Study to support regional planning regarding water resources intended for the production of hydroelectric energy*. 2008, available online.

Figure 7. Constraints: A) Site of Community Interest (SCI); B) Special Protection Area (SPA); C) Landscape Plan. 2024, available online.

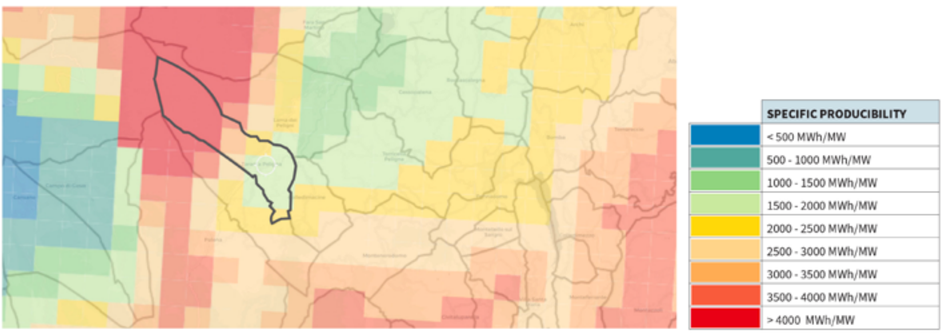

Figure 8. Specific onshore producibility at 100 m above sea level, expressed in MWh/MW – Source: RSE Italian Wind Atlas, available online.

5. Technologies and Tools to Support the Renewable Energy Community

To facilitate the creation of the REC and support its development, the project proposes the construction of a web-based digital platform integrated with a geographic information system and with functions capable of providing the energy analysis of the territory, facilitating interactions and the circulation of information between people and support the community in communication actions, energy management, and decision making.

The numerous projects aimed at creating energy communities constitute a point of reference for understanding good practices and acquiring a broad repertoire of information materials, technologies, and software specifically developed to support the development of communities (European Union, 2023). Citing examples, European projects such as H2020 *CREATORS*[2] provide software, applications, and services to help cities set up, plan, and manage community energy systems.
H2020 *BEcoop*,[3] allows the consultation and use of a toolkit of technical tools, business models and community models, and self-assessment tools. The H2020 *BENEFFICE* system[4] suggests technologies and incentives to improve home energy efficiency.

In the specific Italian context, the Legambiente Renewable Communities portal[5] reports on numerous case studies of energy communities that have been created, offering, through a WebGIS portal, a map of their location and a summary filing of each community's objectives and characteristics. From the study of the references and the preliminary analysis of the territory in question, the structure of the web platform emerges, and three main functions are outlined: the instrumental function, necessary for the measurement and monitoring of the energy balance; the dissemination function, for the

2 https://www.creators4you.energy/
3 https://www.becoop-project.eu/
4 https://cordis.europa.eu/project/id/768774/results
5 https://experience.arcgis.com/experience/40737f090e95471aa87a300a43700bec

growth of the energy community, and the collaborative one, which allows the development of ideas and favours the decision-making process. In Table 3 it is possible to schematically identify the expected results that applying these three functions to a WebGIS portal and web platform (detailed in the following paragraphs) could bring to Taranta Peligna, activating the advantages of building an energy community.

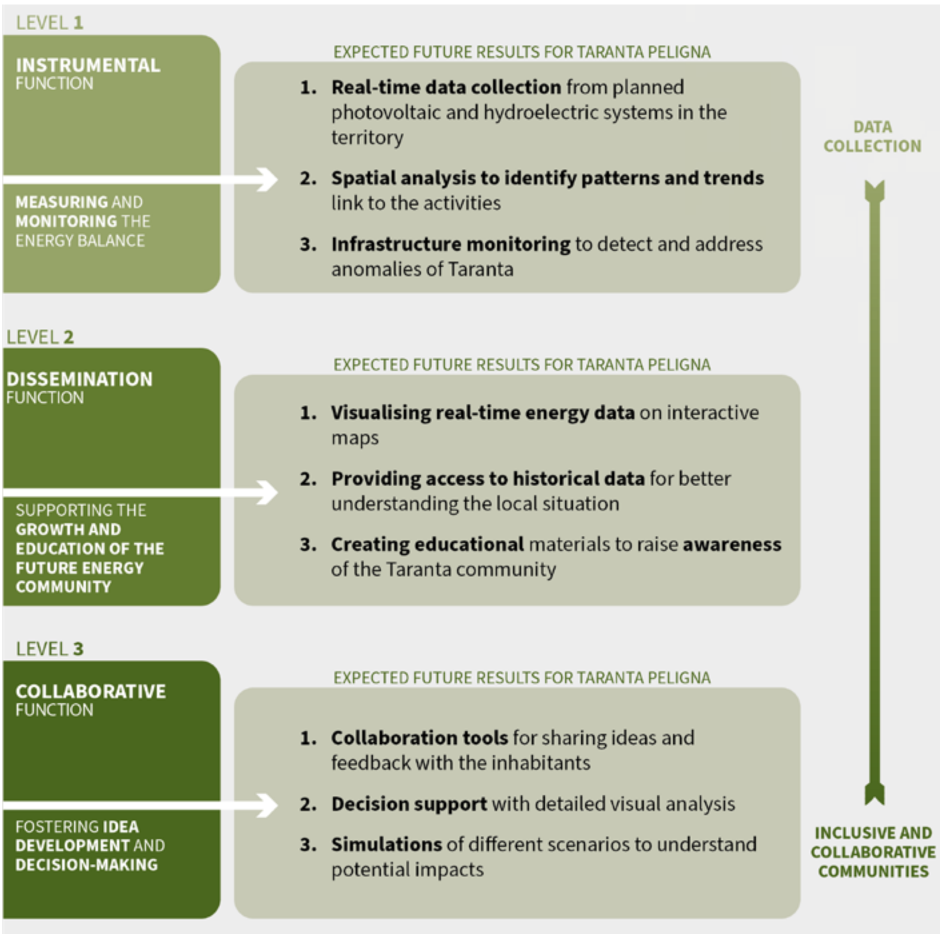

Table 3. Structure of the web platform: main functions and expected results for Taranta Peligna.

5.1. Communicating the Energy Balance to Communicate Opportunities: the Instrumental Function

A part of the web platform is dedicated to the visualisation and querying of geo-referenced virtual maps that provide precision monitoring (Fusero et al., 2018) through a WebGIS portal. The system allows real-time mapping of residential and non-residential energy consumption, storage, and localisation. The portal also allows to:

Monitor renewable energy production plants from renewable sources, allowing real-time intervention in case of anomalies.

Monitor residential and non-residential consumption and related CO_2 emissions to study the most suitable interventions and strategies for energy saving and emissions reduction.

Collecting data such as radiation and exposure can help deduce the best siting opportunities for new RES plants (Canessa, Masini, Lanzetta, 2012).

Allow community members to geo-reference their activity and build collaborative networks by supporting the exchange of surplus or underutilized energy resources through a peer-to-peer mechanism.

The creation of periodic summary maps is envisaged to support the information system. Using Data Visualization tools, these maps describe the evolution of monitoring and the visual history of the energy community's quantitative data.

5.2. Making Data Understandable, Involving, Training: The Dissemination Function

An energy community is made up of groups of people with different skills and interests. Private citizens, technicians, and administrators of public entities must be able to access

the information; understanding its contents is a crucial aspect of the initiative's success and growth.
The community was created to optimize the use of energy resource but can "expand its attention also towards distribution, storage and electric mobility" (Boulanger et al., 2021), generating unexpected synergies and technological innovation. To foster these processes and encourage the involvement of residents in the community, there needs to be an exchange of knowledge, circulation of ideas, and explanation of the purposes, services, and reward systems provided for those who embrace renewables and commit to reducing CO_2 emissions. For this purpose, the web platform is the ideal tool to reach, through multimedia means such as videos, images, texts, social feeds, serious games, reports and downloadable guides, the plurality of subjects interested in the activity (Mastrolonardo & Clementi, 2024).

5.3. Promote the Organizational Structure and Decision-Making Process: The Collaborative Function

A collective energy project is based on collegial decisions, collective energy purchases at advantageous rates for use in common areas and choices relating to investments in RES plants in which private citizens and businesses participate, whose utilities fall within the same transformer substation (Robinson et al., 2022). These activities require collaborative and participatory forms of consultation and decision-making that the web platform can facilitate by implementing an open-source tool, such as *Your Priorities*[6], designed to enable community members to

6 https://yrpri.org/domain/3

collaborate on decision-making processes. It provides features for posing questions, proposing ideas and solutions, voting, moderating responses, conducting surveys, and linking to social media. This tool, hosted by the project's web platform, is a Progressive Web App (PWA), a software application used through a web browser and allows optimal operability on mobile and desktop computers.
In summary, the digital platform to be designed for the energy community of Taranta Peligna is a multimedia and collaborative WebGIS tool to support decision-making: it connects producers, consumers, and self-consumers towards the transition to renewable energies and encourages the development of specific skills and the enhancement of local resources with high added value. In this context, the web platform asserts itself as a crucial replicable model tool, not just for energy monitoring but also to promote active and educational participation, transforming every participant into a proactive element in the context of community management and environmental sustainability. This approach is important within a broader vision that enhances territorial resources as dynamic systems, capable of countering depopulation through technological innovation and the valorisation of local traditions, integrating zero-impact production processes and the redevelopment of local resources, with the goal of fostering a radical shift towards a circular and sustainable economy (Manzini, 2015).

6. Conclusions. Energy to Design Communities

Recognizing the importance of the territory in the processes of socio-economic and cultural development, and considering local resources as dynamic micro-systems capable of generating

value and resources (productive, but also cognitive, organizational and relational), the analysis has focused on the definition of a future vision for Taranta Peligna based on an authentic, local and innovative value system that can counteract depopulation with technological additions, for a community focused on local manufacturing with zero impact compared in wool-textile supply chain. This chain still showcases products with a strong identity tied to local tradition, contributing to the redevelopment of existing tourist and environmental resources.
Indeed, delving into the root of a problem, whether hidden within governance structures, regulations, or deeply ingrained social assumptions or beliefs, an essential aspect of the design process considers connections, relationships, leadership, and narrative surrounding that require evolving resources and time. This process also needs to connect with other similar initiatives (local, national, community, etc.) to spark a movement for change. In this sense, the contribution of design discipline concerns both the methodological process and the product/service system: the web platform, designed not only to monitor but also to involve and connect users and stakeholders, is specifically designed to grasp possible growth opportunities, support the creation of a community of practice to establish, in a participatory manner and with a bottom-up approach, the skills that the territory of Taranta Peligna has seen arise and develop throughout history.
A pilot analytical experience like the one underway in Taranta Peligna (that will be tested in the future project phases) allows us to acknowledge the limits and obstacles to overcome, such as the classic economic model and prevalent individual culture, and to consider the ecological transition not as a linear passage

but as a true paradigm shift. The pursuit of limitless growth, whether applied to national GDP or individual profit, has led to exceeding the resource extraction limit. The consequences of this are becoming increasingly severe, including growing inequality. Conversely, reversing the energy transition negates the principle of limitless growth, replacing it with the circular economy. This is intrinsically at odds with the decoupling between economic growth and resource extraction, a myth that has never been demonstrated and is incompatible with the second law of thermodynamics (Butera, 2021).

Aknowledgments

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Enhancing Wind Farm Projects

A Systemic and Strategic Design Approach to Community Acceptance and Engagement

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Wind Farms, Strategic Design, Case Study Research, Community Engagement, Sustainability Transition.

Abstract
This study explores the local implications of increasing renewable energy production, with a focus on wind energy. Drawing on landscape knowledge and cultural significance, it employs the Territorial Capital concept to inform strategic design processes, considering factors such as local context and ongoing transformation dynamics. Landscape justice and energy democracy are highlighted as crucial concepts, alongside systemic perspectives, to address the research question: How can wind farm projects be innovated to enhance local acceptance? Through case study research involving fifty projects, various strategies are proposed to align wind farm installations with their surroundings' cultural and sensory fabric, promoting community acceptance and sustainable energy practices.

1. Introduction

The EU Green Deal decarbonization objectives have been influencing the development of policies at the local level, foreseeing the increase in the production and use of renewable energy and resources, especially as far as the wind sector is concerned (Sperati et al., 2022).
Drawing upon principles of landscape knowledge, historical context, cultural significance, and ongoing transformation dynamics, resumable with the Territorial Capital concept (Zurlo, 2003; Parente & Sedini, 2018), the discussion here presented seeks to inform the strategic design process with a multidimensional understanding of the environment and its potentialities in relation to its inhabitants. Defining landscape justice (Mason & Milbourne, 2014) and energy democracy (Wahlund & Palm, 2022) as crucial concepts to be attentive to and adopting systemic and strategic perspectives to the matter (Chilvers et al., 2018), the article addresses the following general research question: How might we innovate wind farm projects to make them more accepted by local communities, being aware of contextual limits and possibilities?

A case study research and analysis was carried out to give a first answer to this question. We selected fifty projects dealing variously with the energy transition, some specifically working in/for the wind power sector. In conclusion, we will anticipate the critical issues these strategies can answer related to the community's acceptance of wind farm installations that resonate with the cultural and sensory fabric of their surroundings, enriching the experience of both residents and visitors while promoting sustainable energy practices.

2. Understanding Complexities in Wind Farm Acceptance

The limits in the acceptance of wind farms installation cannot be reduced to NIMBY (Not in My Backyard) reactions because this concept simplifies and flattens the complexity of the reasons against them (Hagget, 2011; Pasqualetti, 2011; Castiglioni et al., 2021). Based on what Pasqualetti (2011) proposes, the critical factors identified are briefly presented here in a reasoned order. The first critical factor is "Imposition" because the installation is experienced as an imposition from above. Linked to the physical installation of turbines is the "Density" factor; being wind a localized resource, it does not allow the spread of turbines equally on the territory, and some places are therefore more impacted than others. One of the major requests of the inhabitants is "Respect" (the third critical factor) and attention to the relationship between land and the life on it. Moreover, the conservatory approach of inhabitants toward the landscape takes us to the fourth critical factor, which is "Immutability" and it represents the difficulty in accepting changes in a familiar landscape; this also leads to the consideration that wind turbines are seen as an attack on "Place identity" (fifth critical factor). Paraphrasing what is stated in the *Manifesto per le Energie Rinnovabili in Basilicata* (*Manifesto for Renewable Energy in Basilicata*) (March 9, 2021) written by Legambiente Basilicata, Alleanza per il Fotovoltaico in Italia and Rete degli Studenti medi Basilicata and the literature review, the most common believes and sentiment toward renewable energy, with specific attention toward wind energy, includes a negative perception of its impact on the landscape because of the installation of wind turbines and wind farms; moreover, inhabitants are often skeptical on the effectiveness of wind turbines which have been often questioned about their sustainability, because of the need of large amounts of materials and energy to be installed and to function. Other issues are related to the actual benefits that inhabitants can receive, which are defined as mainly economic and environmental.

Starting with the discussion around the landscape, it is important to highlight that landscape and panorama are different concepts (Garibaldi, 2023). The European Landscape Convention (2000)[1] defines the landscape as an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors; moreover, the landscape is recognized as "being with us but also beyond us, spatially and temporally"; and as involving "multiple trajectories and a simultaneity of stories so far" (Brace & Geoghegan in Mason & Milbourne, 2014, p. 107). All these definitions make clear that given the importance of human actions in the processes that characterize the landscape, it is evident how it should be regarded as constantly changing and evolving; the landscape (whether natural or man-made) is not static but is in constant transformation. As a result of the installation of clean energy infrastructures, such as wind turbines, local communities experience a landscape transformation that can lead to uneven development, squeezed landscapes, and place identity transformation phenomena (Bridge et al., 2013). We have identified the concept of landscape justice as helpful for shifting the framing of climate change to spatial, temporal, and relational scales.

1 Council of Europe Landscape Convention (ETS No. 176), opened for signature at Florence on 20 October 2000.

Indeed, the application of the landscape justice concept to evaluate change allows one to take under control risks of exclusion, the creation of public space, and antagonism and pluralism dynamics (Mason & Milbourne, 2014). Therefore, wind farm development should use the concept of justice to define various possibilities of recognition and participation going beyond the assessment of economic benefits to the community. Landscape governance (Görg, 2007) is needed to facilitate broad participation in public discussion and give space to local knowledge decision-making.
As far as the concept of benefit is concerned, its definition has to include more than just economic advantage, which can be acquired thanks to taxes, payments to landowners (where the wind turbines are installed), and shared management of wind farms (Copena et al., 2019; Rand & Hoen, 2017). There are potential indirect benefits (*fringe benefits*) that the installation of wind farms can generate, in addition to environmental (if the energy produced is used in favor of the area that produces it) and economic benefits. Similarly, critics were moved toward the sustainability transition initiatives regarding the real sustainability of wind farms. Also, in this case, a systemic perspective is needed when sustainability has to be evaluated. Indeed, sustainable development requires specific attention to several interconnected environmental (Planet), social (People), and economic (Profit) elements.

For all these reasons, the social acceptance of landscape changes due to wind farm installation should be the result of learning (and participatory) processes (Wolsink, 2010; Rand & Hoen, 2017).

We talk of processes because adopting a systemic strategy to the matter is needed. Complex transition processes, indeed, should go beyond the idea of participation as a single event but intend to understand how multiple engagement practices interact in/with larger systems where different forms of participation must be grounded in social, normative, cognitive, and material elements (Chilvers et al., 2018). As Chilvers & Kearnes (2015, p. 52) highlight, an ecological conception of participation suggests that is not possible to properly understand any collective participation without understanding its relational interdependence with other collective participatory practices, technologies of participation, spaces of negotiation and the cultural political settings in which they become established.

Co-creation practices are recognized as more inclusive forms of involvement, even if difficult to implement. These participatory strategies make it possible (Suboticki et al., 2023) to give marginalized groups a voice and broaden the diversity of participants involved (human and non-human); provide for more equitable decision-making; open up to possible new and unexplored alternative solutions; allow for a wider understanding than just identification of problems, valuing diverse expertise; and produce narratives that can ensure openness and inclusiveness. However, as several pieces of research highlight, the participants in co-design and co-production activities are usually highly educated women in good socio-economic conditions living in easy-to-access areas (Gheduzzi et al., 2021). For these reasons, in the following section, we present case studies from urban contexts, because of the greater ease with which participatory strategies are adopted in highly urbanized places due to a greater tradition/experience due in part to the higher population density of higher schooling populations, greater availability of resources (time and economic), and the more concentrated presence of research and development institutions on site.

3. Research Objectives and Methodology

The research question, *How might we innovate wind farm projects to make them more accepted by local communities, being aware of contextual limits and possibilities?* is significant in the current energy and urban development sectors. A comprehensive case study research and analysis was carried out to answer this.
We meticulously selected fifty projects dealing with various aspects of the energy transition, some specifically working in/for the wind power sector. As previously explained, we also included case studies from different areas of interest (e.g., urban regeneration) to ensure a comprehensive understanding.
In the comparative table presented in Annex 1, each case study selected is described by its name, location, and implementation period; a short description highlighting the project goal is also presented. Finally, the analysis focuses on two levels of engagement, considering first the involvement during the project development and then the public involvement in the project's delivery phase, which has been analyzed through the classification in the Pine and Gilmore matrix (2011). Based on Pine and Gilmore's (2011) theoretical model, we defined a matrix to map the case studies and identify possible project scenarios.
The model developed by the two authors is particularly useful in this research since it focuses on the perceived experience by considering the active or passive participation of the public

and its relation with the surrounding environment. This model goes beyond services and places experience as the culmination of economic value. The different experiences according to the presented model are classified concerning two dimensions: on the horizontal axis is placed the users' participation (extending from passive to active) and answer to the question *What kind of experience does the case study offer the user/community?* The vertical axis describes the users' perception of their surroundings (extending from absorption to immersion), answering the question: *What kind of physical presence does the intervention have in the context?* From the intersection of the two axes, four quadrants are generated (Pine & Gilmore, 2011):

- Entertainment: Users are led to see or hear but are not actively involved;
- Education: Users are actively involved while not being necessarily immersed in the environment;
- Escapist: Users immerse themselves in the environment while performing an action;
- Esthetic: Users contemplate the landscape and the works of art.

In the following section, we present the analysis of case studies using the developed matrix.

4. Case Study Analysis and Scenarios

The matrix helped us answer what kind of physical presence and engagement the case studies describe. As previously said, the crossing of the two axes allows the identification of four different quadrants representing four experience types.

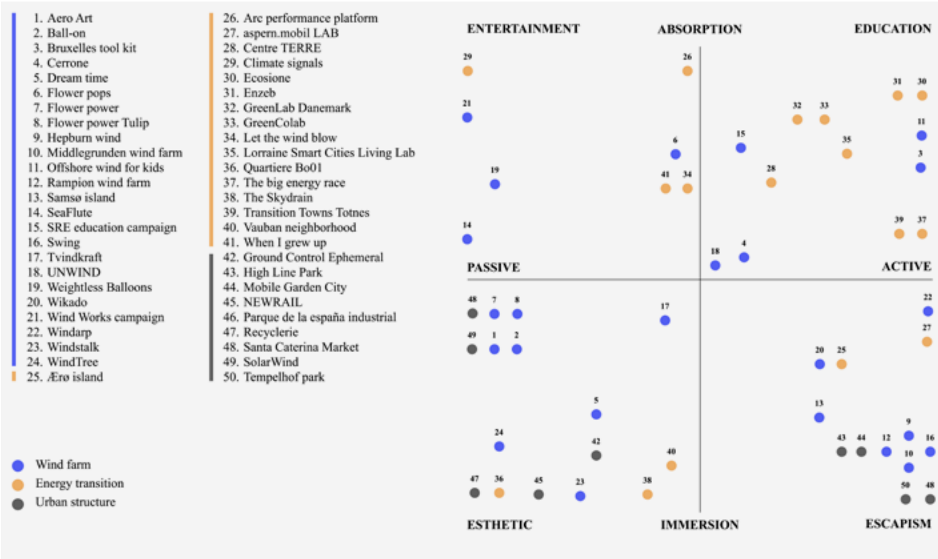

Table 1. The authors, adapted from Pine and Gilmore 2011, Case studies mapping.

The *Entertainment* quadrant corresponds to a passive involvement of the public with absorption from the surrounding environment (Pine & Gilmore, 2011); this may happen when watching, reading, or listening to something while out of the scene. *Flower pops* (6) is an example fitting this quadrant. The project aims to make offshore wind farms more attractive for people by creating an anthropomorphic landscape that recalls the flower's shapes. Working on the offshore wind farms' aesthetic provides the public with the experience of admiring, with binoculars, the created unique landscape. Other examples that can be placed in this quadrant are the ones regarding campaigns and messages such as *Climate signals* (30). This installation invites people to acquire information regarding the ecological transition on big street screens powered by solar panels.

Figure 2. Bricece Guariglia J. Climate signals, outdoor installation presented by the Climate Museum in NY, 2018, The Climate Museum © 2017.

The *Education* quadrant, still describing the physical absorption from the environment, involves active participation by users (Pine & Gilmore, 2011). This suits all the cases that provide awareness but engage the public in direct activities such as workshops and labs. An example is *Offshore wind for kids* (12), an association that aims to raise consciousness on the wind energy topic by targeting young people through small turbine construction workshops. In this quadrant are also all the projects designed to make people understand the abstract concept of green transition, giving physical elements with which to interact. Examples are the *Ecoesione* (31) and *Enzeb* (32) board games and the *Brussels tool kit* (3).

Figure 3. Teachers' toolkit, Pilot project run by WindEurope in Brussels to foster learning about wind energy by co-design a teaching tool kit, 2021, © WindEurope.

The *Escapism* quadrant describes the experiences where the public is engaged through active participation and is also immersed in the environment (Pine & Gilmore, 2011). Fit in this quadrant the case studies where people can discover the sites as protagonists of the experience. An example would be the *Windarp* (22) project, in which by reshaping the outlook of the wind turbine, the designers create an installation where humans can actively contribute to energy power production. The same idea is behind the *Swing* (16) project, where people have fun on wind turbines shaped like swings and contribute to energy production. The *Escapism* experience also has an educational role, in which people become the main actors due to their relation with the surrounding environment; the *Rampion wind farm* (12) is suited to this explanation: visitors here get closer to the wind energy production topic thanks to an immersive VR experience provided by the wind farm museum. Other examples regard public spaces dedicated to the community, designed by the reuse of dismissed material. This concept is behind the *Wikado* (20) park, where a disassembled wind turbine creates a children's playground, but it is also the driving idea of the London *Mobile Garden City* (44) in which the no-more-used spaces and materials of the Olimpic site were used to create a community movable garden.

Figure 4. Superuse Studio, Wikado, playground in Rotterdam designed by reusing wind turbines, 2008, photo by Denis Guzzo, Copyright: http://www.denisguzzo.com/info/#acquire.

Figure 5. Flower turbines, Flower power team in front of their turbines, 2018, photo by de Groen J.

Finally, people participating in *Esthetic* experiences are immersed in the environment without active participation. The case studies located in this quadrant work on the aesthetic and the overall design outlook to improve the environment and allow people to be immersed in it. Examples are the *Dream Time* (5) and the *WindStalk* (23) projects. The first is rethinking the traditional wind turbine by creating an installation that recalls the northern lights in a public space. The latter improves the environmental qualities and creates a unique landscape that people can explore by redesigning the traditional turbines.

5. Insights from Case Studies

The case study research underscores the crucial role of community engagement, particularly in the design phase, for successful project outcomes. Notably, with a few exceptions, most of the cases examined only involved community engagement in the delivery phase. This finding highlights the necessity of both levels of engagement for achieving local population consensus. The case studies enabled us to envision general outlines to follow in order to meet the local community's acceptance. The state-of-the-art shows that the success of a project is possible without community engagement during the design phase. As it happened in the *Santa Caterina Market* (48) in Barcelona, an effective result would be reached through punctual and grounded research that respects the local environment while considering the place's cultural identity. The following output would have a positive indirect impact, generating new cultural identity hotspots and providing also indirect economic income. Similar results can be reached when general awareness is raised by designing museums, installations, parks, or events. Successful cases of those elements are for example, *Rampion wind farm* (12),*Climate signals* (30), *Mobile Garden City* (44), and *Middlegrunden wind farm* (10).

However, the current global scenario reveals a significant gap in community involvement, which is largely limited to the delivery phase. Shifting this focus to the design phase could lead to a more positive community response. The current situation only sees community involvement in specific activities such as co-funding and passive forms of participation like interviews, forms, and surveys. Active engagement, such as co-design and co-production, is a rarity.

Figure 6. Rampion Visitor Centre, VR experience inside the wind farm Museum, 2020, photo by © Southern News & Pictures Ltd.

Such a change would require a gradual evolution by implementing different integrated strategies. The research highlights that positive results can be achieved through people's literacy on the topic. Education is a fundamental step to reaching local acceptance: actions in this direction are needed, targeting both children and adults. The abstract concepts of sustainability and energy transition should be visualized through physical elements to facilitate people in understanding the importance of green energy (*Arc performance platform* (26)). The game dynamic has also been identified as an effective solution for visualizing those concepts and raising aware-

ness (as it happens for *Ecoesione* (31) and *Enzeb* (32) board games and in *The big energy race* (37)).
Different outputs could also be useful for visualizing green energy's direct and indirect advantages and details of wind turbines' workings and impacts. Workshops would not only be helpful for what just mentioned, but they would also provide occasions to co-design with the local community the experiences around the wind farm (similar to what is happening in *Hepburn wind* (9) and in *Tempelhof park* (50)).

5. Conclusion

In this conclusive discussion, some strategic answers to the critical statements previously introduced are proposed according to the Pine & Gilmore (2011) model used for the case study analysis.
To this end, the fifty case studies were clustered according to the defining themes that emerged from their analysis. In particular, we can divide them according to the goals addressed (aesthetics, sustainability, and identity), which activities were put in place to pursue and address these goals (tourism, information, education), and - the last category, as a relevant element of understanding of the wind energy topic - identifies parks as specific places were both goals and actions can take place. The different themes interface with each other, often generating overlap.

This classification helps visualize possible strategic directions to achieve community acceptance. In line with what has already been mentioned, the overview shows areas that can still be implemented where to foster innovation.

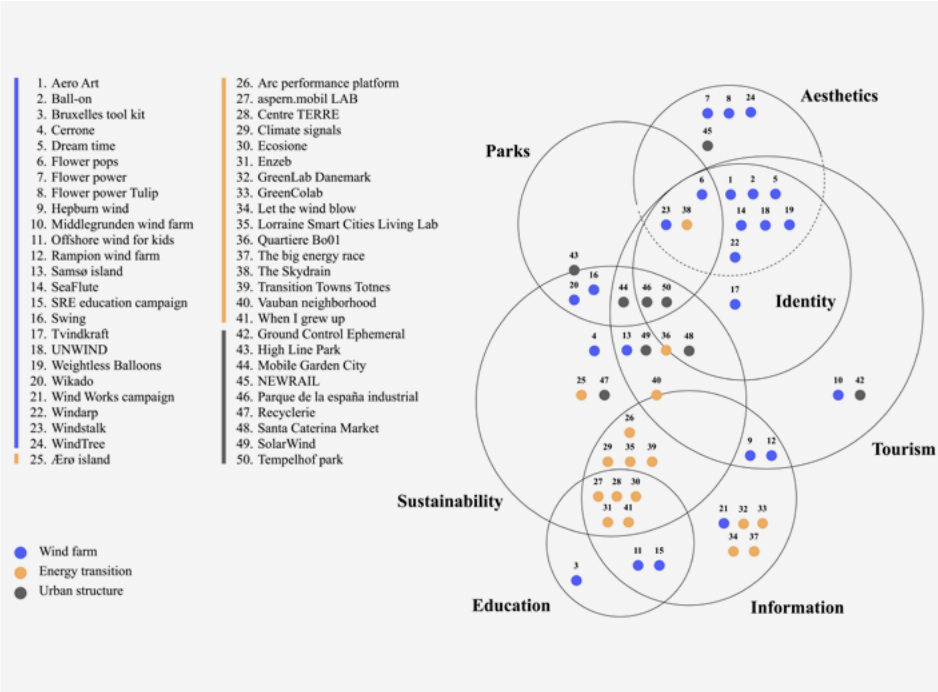

Figure 7. The authors, Case studies themes classification.

A way would be to design sustainable tourism solutions that act on the wind farm aesthetics while preserving and pointing out the place's identity. This would affect sustainability by considering the energy transition and providing indirect advantages such as economic income and social public spaces. As previously explained, those actions should be integrated with educative activities and information campaigns to engage the local community readily. In the following subsections, we will briefly overview strategic answers to the critical statements mentioned at the beginning of the contribution.

5.1. "Wind Farms Have a Strong Impact on the Landscape"

Entropic landscape[2] is a concept developed by Smithson and taken up by Careri in his book *Walkscapes* (2017) that we can adapt and interpret based on the wind power domain and context of interest (rural landscape). An entropic landscape dissipates energy through the inactivity of its structural elements. The shift from an entropic landscape to an energy landscape could be possible by applying strategies to make manifest and topic of conversation new landscape elements. The role of art and design can be crucial to act on elements such as:

- remembrance and (new) memory
- encourage active and contemplative life of/on the landscape
- foster the emotional participation of inhabitants (and others)
- helping/guiding inhabitants in understanding change.

Strategies to work on this specific issues should be focused on the integration of wind farms into the landscape through the construction of scenarios capable of promoting emotional involvement; wind farms could become places to be discovered and experienced where wind turbines could even become art installations, redefining the concept of "park". Moreover, wind farms should respect the local and cultural identity of the place (intended as Territorial Capital) to integrate and enhance the landscape through a careful study of the local identity.

2 Entropology is a term proposed by Claude Lévi-Strauss resulting from the union of entropy and anthropology.

5.2. "We Don't Benefit from Wind Power"

As mentioned, wind energy can have fringe benefits beyond direct economic ones. It can be a great opportunity to

- revitalize rural areas and counter depopulation,
- fostering the diversification of the local economy and the creation of jobs,
- improve local infrastructure,
- promote sustainable tourism,
- develop technology and innovation.

These can result from a strategic exploitation of wind farms as places to visit and enjoy, as discussed above. Participation is crucial to contrast a poor recognition of the advantage that local populations received by developing the wind power economy. Indeed, local attitudes toward wind farms follow a "U-shaped" pattern (Wolsink, 2007). Studies show mixed results; some individuals express increasing appreciation over time for wind farms near them, while others express unchanged or decreasing appreciation. These differences are due to different experiences, very much linked with the direct involvement and engagement of inhabitants during the planning and construction processes (Hallan & González, 2020).

5.3. "Wind Energy is not Really Sustainable"

Broadening the common definition of sustainability allows one to look at the ecological transition as bringing environmental, economic and social benefits, in line with the New European Bauhaus (European Commission) approach (Rosado-Garcìa et al., 2021). Indeed, the NEB aims to facilitate and guide the transformation of our societies along three values:

- aesthetics (*beautiful*): quality of experience and style (beyond functionality);
- sustainability (*sustainable*): from climate goals to circularity, zero pollution, and biodiversity;
- inclusion (*together*): from valuing diversity to ensuring accessibility and participation.

To gain trust, it is essential that information is accessible to everyone and that designers strategically facilitate the communication between inhabitants and other stakeholders, such as policymakers and entrepreneurs. Also, in this case, scientific dissemination can become an opportunity for benefit, favoring tourism, as in the case proposed by Smith et al. (2017). Through the involvement of different subjects (researchers, journalists, energy experts, designers, and architects, etc.) and use of different media, relevant topics could be explored (e.g., energy policies and their perception at the local level, risks and opportunities of energy in the local economy, the relationships between green energy and local communities).

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Annex 1

n°	Name	Location	Period	Short description	Goal	Engagement type during the design	Matrix quadrant
WIND FARM							
1	Aero Art	Germany	2012	A visionary project where the wind farm becomes a modern art site	Acceptance of wind farms (metabolisa-tion) through the artistic rendering of the turbines	-	Esthetic
2	Ball-on	Melbourne, Australia	2018 (LAGI contest)	Floating aerial turbine (BAT) with horizontal axis covered with bright reflective fab-ric. Addition of organic photovoltaic cells (OPV)	Improving the wind farm scenarios by levering local weather condition	-	Esthetic
3	Brussels tool kit	Brussels, Belgium	2021	Generation of a wind energy learning pro-gramme, with the output of a replicable toolkit to be used in differ-ent contexts	Explaining to 12 years old children the wind energy	Passive participation - Consultation (co-design)	Education
4	Cerrone	Gubbio, Italy	2022	The biggest collective wind turbine in the Italian territory pro-moted by the cooperative ènostra	Contributing to the energy transition by including the population	Active partici-pation - Share actions Based on the idea of citi-zens as pro-sumers (both promoters and consumers)	Education
5	Dream time	Melbourne, Australia	2018 (LAGI contest)	Fabric with triboelectric yarn, with an insulating part made of recycled plastic, into which silver threads are inserted. The energy is gen-erated by the meeting of the two materials with opposite charges	Providing an artistic output of wind-gen-erated energy using a different technology by shaping public spaces	-	Esthetic

6	Flower pops	Santa Monica, California	2016 (LAGI contest)	An unusual offshore wind farm designed as an anthropic garden made of different wind turbines to admire: each technology has a different "flower" form.	Creation of new scenarios and the related experiences	-	Entertainment
7	Flower power	Amsterdam, Holland	-	A metal tree with vertical-axis wind turbines.	Giving organic shapes to the wind turbines	-	Esthetic
8	Flower power Tulip	Holland and US	2018	Vertical wind turbines shaped as tulips	Placing of wind turbines in urban contexts	-	Esthetic
9	Hepburn wind	Hepburn, Australia	2011	A self-managed energy community that offers tours of the wind farm and houses artists' houses and an energy school. The wind farm has become a venue for art installations	Implement the energy transition	Bottom-up	Escapism
10	Middle-grunden wind farm	Middle-grunden, Danemak	2018	A wind farm that organises boat tours for different types of groups (experts, schools, tourists, etc.). Once every two years, it organises open days where it is possible to climb the turbines	Education of the vast public on wind energy	-	Escapism
11	Offshore wind for kids	Belgium	2021	A non-profit organisation that organises activities and events targeted to children and young people focused on wind energy	Educating and raising awareness of wind energy among children and kids	-	Education

12	Rampion wind farm	Rampion, UK	2018	An offshore wind farm with a museum dedicated to wind energy and the wind farm, where people can explore the topic through VR.	Educating and raising awareness of wind energy, specifically on the farm	-	Escapism
13	Samsø island	Danemark	From 1998 In 2020 it gained the title of the most sustainable island in the EU	A self-sufficient island that uses renewable resources only.	Ecologic transition while fostering local economic growth and proposing sustainable tourism solutions	Active participation - Shared action (co-funding)	Escapism
14	SeaFlute	Melbourne, Australia	2018 (LAGI contest)	An unusual wind farm with generators shaped as bottles which works thanks to the D-WEG technology (Direct Wind to Electricity Generator)	Changing the scenario of wind farms by changing the aesthetic of the turbines while working on the sound	-	Entertainment
15	SRE education campaign	Taiwan	2022	An education campaign in the libraries of the country promoted by SRE (Synera Renewable Energy)	Educating and raising awareness of wind energy among children	-	Education
16	Swing	Melbourne, Australia	2018 (LAGI contest)	An unusual wind farm where the turbines are swing, producing energy through both the air movement and human interaction	Changing the scenarios of wind farms by shaping public spaces	-	Escapism
17	Tvindkraft	Tvind, Danemark	1975	A Wind turbine designed and handcrafted by locals	Powering the Tvind school	Bottom-up	Esthetic

18	UNWIND	Melbourne, Australia	2018 (LAGI contest)	An unusual wind farm composed of kites	Changing the scenarios of wind farms by creating public spaces where to learn about wind energy	-	Education
19	Weightless Balloons	Santa Monica, California	2016 (LAGI contest)	An unusual offshore wind farm composed of fluctuant spheres that produce energy through waves		-	Entertainment
20	Wikado	Rotterdam, Holand	2008	A children's park made by the reuse of dismantled wind farms.	Reducing the environmental impact of post-dismantledg wind farms	-	Escapism
21	Wind Works campaign	London, UK	2012	A campaign for offshore wind farms levering on people's sentiments and referring to the Romanticism	Acceptance of offshore wind turbines	-	Entertainment
22	Windarp	Conhagen, Danemark	2014 (LAGI contest)	An unusual wind turbine, shaped like an arp and designed to play sounds through human interaction and air passage.	Making the wind farm sound pleasant for humans	-	Escapism
23	Windstalk	Abu Dhabi, United Arab Emirates	2010 (LAGI contest)	An unusual wind farm composed of 1203 poles of carbon fibre.	Changing the scenario of wind energy by designing less impacting wind farms for the landscape and environment	-	Esthetic
24	WindTree	France	2013-2016	A metal tree with vertical-axis wind turbines.	Integrating the wind farm in the cities context	-	Esthetic

ENERGY TRANSITION

25	Ærø island	Danemark	2021 (EU Responsible Island Prize)	An island that promotes the use of renewable resources for more than 30 years	Fostering green transition	Active participation - Shared action (co-funding)	Escapism
26	Arc performance platform	US	2018	A digital display for LEED - certified buildings that enable people to visualize the consumption and the quality of life	Encouraging positive behaviour and change to achieve the energy transition by reducing waste	-	Entertainment
27	aspern.mobil LAB	Vienna, Austria	2014 - ongoing	Started by the Vienna University of Technology (TU Wien), the LAB is an open ground that engages citizens in developing mobility green solutions through innovatively designed tools	Raising awareness on green mobility and climate protection	Active participation - Shared action (co-design)	Escapism
28	Centre TERRE	Canada	2019	A centre focuses on co-creating sustainable energy solutions to meet the needs of groups not served by the national electricity grid.	Designing and improving sustainable energy solutions for rural areas of Canada	Passive participation - Consultation (co-creation)	Education
29	Climate signals	New York, US	2018	An Outdoor installation made by light street panels located in public spaces that project messages regarding the energy transition.	Warning people regarding the energy transition	-	Entertainment

30	Ecosione	Pisa, Italy	2020	A board game designed by the University of Pisa with energy transition as a focus	Education for young adults about the energy transition	-	Education
31	Enzeb	Italy	2023	A collaborative board game dedicated to adults	Making education related to energy efficiency more accessible	Active participation - Shared action (co-design)	Education
32	GreenLab Danemark	Spøttrup, Danemark	2012 - ongoing	A research platform focused on green energy development	Contribute to the development of sustainable energy systems while informing people and companies	Passive participation - Information (co-creation)	Education
33	GreenColab	Portugal	2018 - ongoing	Non-profit organisation focus on solutions based on algae	Fostering innovation and economic diversification in the algae biotechnology field	Passive participation - Consultation (co-creation)	Education
34	Let the wind blow	Worldwide	2019	An illustrated open-source book for children about removable resources and energy transition	Educating children about the energy transition	Bottom-up	Entertainment
35	Lorraine Smart Cities Living Lab	France	2008 - ongoing	Collaborative research project	Engage in user-driven co-creation for the green transition	Passive participation - Information and consultation (co-creation)	Education
36	Quartiere Bo01	Malmo, Sweden	2001	Residential neighbourhood born from the regeneration of a port area some Archistar	Shaping the sustainable solution through the aesthetics	-	Esthetic
37	The big energy race	London, UK	-	A collective game shaped as a challenge between different citizens	Reducing waste generation and fostering the energy transition	Bottom-up	Education

38	The Skydrain	Gulf of Mexico, Mexico	-	A public space where the green energy solution creates a unique ambient.	Envisioning a new scenario for the green energies solution while shaping public spaces	-	Esthetic
39	Transition Towns Tones	UK	-	A non-profit organisation led by the local community which proposes activities and events about energy transition	Educating and raising awareness regarding the energy transition	Bottom-up	Education
40	Vauban neighborhood	Freiburg, Germany	1996	An energy neighbourhood born from the requalification of an ex-French army quartier	Neighbourhood ri-qualification	Passive participation - Consultation (co-creation)	Esthetic
41	When I grew up	Worldwide	2021	An open-source book that shows the stories of some illuminated people related to the energy transition	Educating people about the energy transition	Bottom-up	Entertainment
URBAN STRUCTURES							
42	Ground Control Ephemeral	Paris, France	-	Abandoned public spaces become the location for exclusive events	Temporary requalification of public spaces	-	Esthetic
43	High Line Park	New York, US	2003	Park generated from the requalification of the ex-railway station	Preserving a city symbol	Passive participation - Information and consultation (co-creation)	Escapism
44	Mobile Garden City	London, UK	2015-2018	An itinerant garden available for citizen	Re-using and recycling the materials and the spaces of the Olimpic village	-	Escapism

45	NEWRAIL	Dronten, The Netherlands	2020-2024	Installation of solar panels and noise barriers on the railway lines	Improving the environmental landscape	Passive participation - Information and consultation (co-creation)	Esthetic
46	Parque de la españa industrial	Barcelona, Spain	1985	A park arose from the spaces of an ex-fabric company building	Creation of a public space dedicated to citizen	Active participation - Shared decision-making (co-design)	Esthetic
47	Recyclerie	Paris, France	-	A multifunctional space in an ex-station	Creating a common space for locals	Bottom-up	Escapism
48	Santa Caterina Market	Barcelona, Spain	2005	Roofs inspired by the local culture	Have a positive impact on the landscape, respecting local culture and identity	-	Esthetic
49	SolarWind	Calabria, Italy	2011	A bridge with wind turbines and solar panels	Re-qualification of an urban site with the improvement of green energy solutions	-	Esthetic
50	Tempelhof park	Berlin, Germany	2010	The biggest open-air area of the city, generated by the requalification of the dismissed airport	Requalification of the airport area providing a collaborative space	Active participation - Shared decision and action (co-design and self-management)	Escapism

Powered by the People

Human-Powered Energy Generation as Lifestyle Choice

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Abstract
The problem of energy consumption, resource depletion and global warming has moved in fifty years from a fringe campaign to the mainstream of politics, scientific research and the media. However, the need to reduce consumption conflicts inexorably with the lifestyle demands of consumers who continue to buy more, use more and waste more, and who are growing in number in the world's emerging economies.
This paper documents an investigation into the following research questions: How can we as designers turn the need to reduce energy and resource consumption into an attractive lifestyle proposition? Could we exploit the increased interest of consumers in health and sporting activity by harnessing their body energy to drive appliances? Could we turn this into a win-win proposition?
The investigation took the form of two design development workshops at the University of Bologna in 2022 involving 60 participants. Drawing inspiration from the wake-up calls of 20th Century Modernism and the designer activist Victor Papanek circa 1970, concerned with provoking mass behavioral change for societal benefit, participants were tasked with developing product proposals to generate decentralized energy and store it for use in the home, office or community. The activities culminated in a panel discussion of experts in the field, who expressed their own view based on the workshop input, offering their own speculative reflections. The challenge for designers within such a process is to propose the initiative as a positive lifestyle choice, to be embraced willingly by consumers and citizens in order to bring about a shift in awareness and habits.

1. Introduction

> Tempting as it is to think of the transition to a clean economy as a huge leap, it is in fact a trillion tiny steps – the steps that each of us take, many times a day, all around the world, when we decide how to live and what to buy. (Harford, T., 2022)

In the light of impending environmental catastrophe, now almost universally recognized as resulting from global resource consumption, a research project was conducted at the University of Bologna to examine ways of mitigation the problem by converting human-generated energy for certain tasks.
A design-led approach was taken in order to imagine ideas for products and systems that could be promoted as positive lifestyle choices that consumers could willingly embrace. The project was entitled 'Energy Consumption and Lifestyle' and ran during March 2022, just as, coincidentally, the price of energy was more acutely felt following the previous month's invasion of Ukraine by Russian forces.
Participants in the project were drawn from the Industrial Design department. They comprised digital native students with an age range between 20 and 25 years, by and large unfamiliar with the hand-powered appliances that were once typical of daily life in Western societies pre-1960. Any lack of acquired wisdom would be offset by a fresh outlook in the ideation process.
The design concepts, created in two separate workshops, were put in discussion in a round table with three practicing professionals who have their own connection the topic, examining and provoking further reflection for an ongoing debate.

In the light of “innocent” design approach of young generation designers, a panel discussion with particular critical approach to the real-world situation has brought up a counter vision to an idealized, and by virtue of inexperience, a very simplified vision of the problem during the workshop.

1.1. The Conceptual Starting Points for the Project

Firstly, the problem of energy consumption, resource depletion and global warming has moved in fifty years from the fringes to the mainstream of politics, scientific research and media. the Intergovernmental Panel on Climate Change has stated that today’s levels of global emissions must be halved by 2030 in order to limit temperature rises to 1.5°C, yet current emission rates are increasing (Shukla, P.R. & Skea, J., 2022).

The message is clear: a significant change in policies and practices is needed for humans to survive on Earth. However, the need to reduce consumption conflicts directly with the lifestyle demands of consumers who continue to buy more, use more and waste more, and who are growing in number in emerging economies.

Design has been punctuated historically by occasional wake-up calls, such as the birth of the Modernist movement in the 1920s and Victor Papanek’s 1971 book Design for the Real World a half century later, both of which sought to use design to address the real social and environmental problems of their times. Both demanded the abandonment of applied style in favour of honesty, empathy and long-term problem solving. 50 years later, what might today’s wake-up call be that designers should respond to?

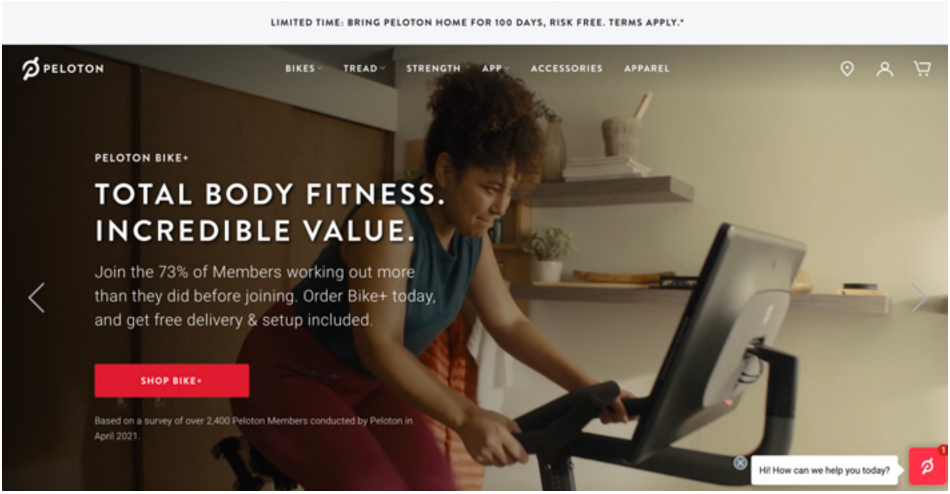

Figure 1. Peloton homepage (2022). https://www.onepeloton.com.

Figure 2. Demonstration of cyclette driving foodmixer, Berlin, 2017. Photo: Adrian Peach (2017).

The 2008 book Nudge by Richard Thaler and Cass Sunstein (Thaler & Sunstein, 2008) investigated the phenomenon of mass behavioural change for societal benefit and how it is stimulated. According to Tim Harford, the authors inspired a new behavioural science movement that found its way into government policy (Harford, 2022). The authors of this paper intended to explore how design can be employed as a stimulant for change.

Vaclav Smil (2017), cited in the article "Our World in Data" by Ritchie et al. (2020), calculates that world energy consumption from all resources increased exponentially from 5000 TWh in 1800 to 170,000 TWh in 2017 – a factor of 34, with renewable sources supplying around 20,000 TWh of today's total consumption.

In Figures 1 and 2, individuals are seen generating energy on machines that are linked, in one case to a food mixer, in the other to the world wide web. Could the desire of these individuals to use their own body energy for the purpose of personal (even selfish) fulfillment be employed to mitigate in small measure our problem of energy consumption?

1.2. Project

The project was designed to view the problem through two prisms, exploring both the physical science of energy generation and the behavioral science behind human stimulus for change, to identify new opportunities that benefit society and the environment in the long-term.

The core task was to investigate how we can turn the need to reduce energy and resource consumption into an attractive lifestyle proposition. Would it be possible, for instance,

to capitalize on consumers' increased interest in health and sporting activity by harnessing their body energy to drive appliances, thereby creating a win-win proposition?
The investigation embraced the science behind energy consumption and generation methods (including mechanics and storage in fuel and electricity) as well as the social and psychological factors related to physical activity and lifestyle. Historical precedents as well as new technologies were to be taken in consideration. The new product concepts were required by the briefing to combine *usefulness* and *function* with *lifestyle* and *desire* to create an effective, attractive, commercially viable product concept.

1.3. Project Guidelines

The project briefing stipulated the generation of imaginative but realistic solutions to generate energy through the movement of the human bodies, energies that can then harness at home, at work, in the private sphere and in the community, to reduce the overall burden on the energy infrastructure. Various contraptions and techniques already exist, ready to be applied, but they remain on the fringe of the mainstream consumption model because they often do not correspond to current aesthetic and lifestyle trends nor to consumers' different expectations of cultural, social, personal fulfillment.

Sport and physical activities are considered by many to be attractive and fashionable. Fitness is a standard driver of personal and social fulfilment, as evidenced in the media and clothing built around such activities. The project required a bridging of the gap between this pleasure principle and the

duty to reduce resource consumption. The project participants, 104 individuals ranging in age between 20 and 25 years working in groups of 4, were encouraged to be idealistic, provocative, humorous, and to push accepted boundaries. The workshop activities were carried out quickly over the course of two days, leaving little room for deep research into viability or for detailed design development, so as to encourage imaginative, original thinking around the problem.
The concept ideas were to be presented internally before being passed on to three professionals practicing in architecture, design for industry, research and academia, for comment and discussion. Additionally, these professionals were asked to offer their own views and experiences related to energy generation, resource conservation in the light of pressing environmental issues.

2. Project Results

2.1. Input

The project coordinators facilitated the early fact-finding efforts of the participants in order to establish some basic historical and scientifically proven facts regarding energy consumption. In this way, the ideation process would build upon solid foundations. The bulk of the benefits and comforts enjoyed by the individual in a developed industrial society are derived from processes requiring a high level of energy consumption, far greater than humans could hope to match with their own physical strength. At small scale, for example, the energy required to boil a kettle for making a cup of tea is equivalent to that expended by a human performing a half hour fitness run.

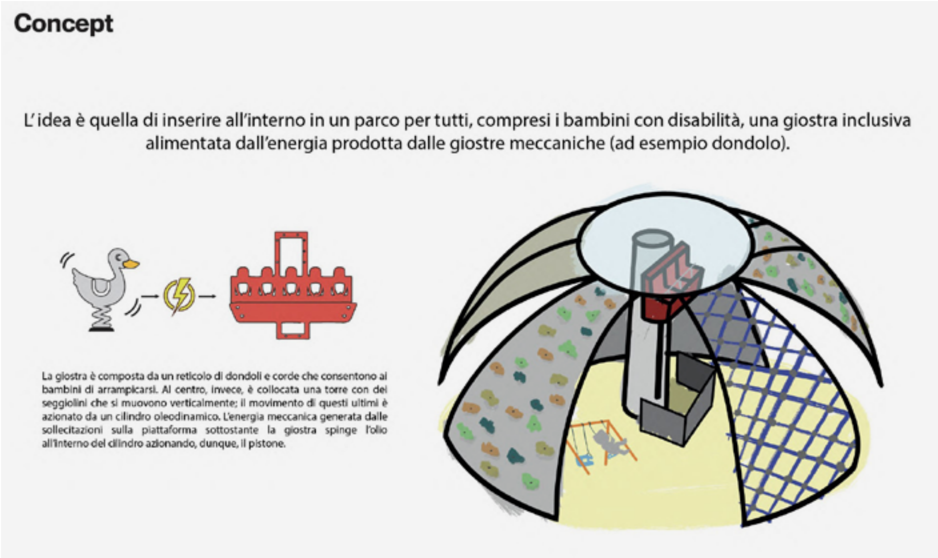

Figure 3. Concept. Authors: Marella de Santis, Maria Sabrina Losito, Davide Magi, Lavinia Marinelli.

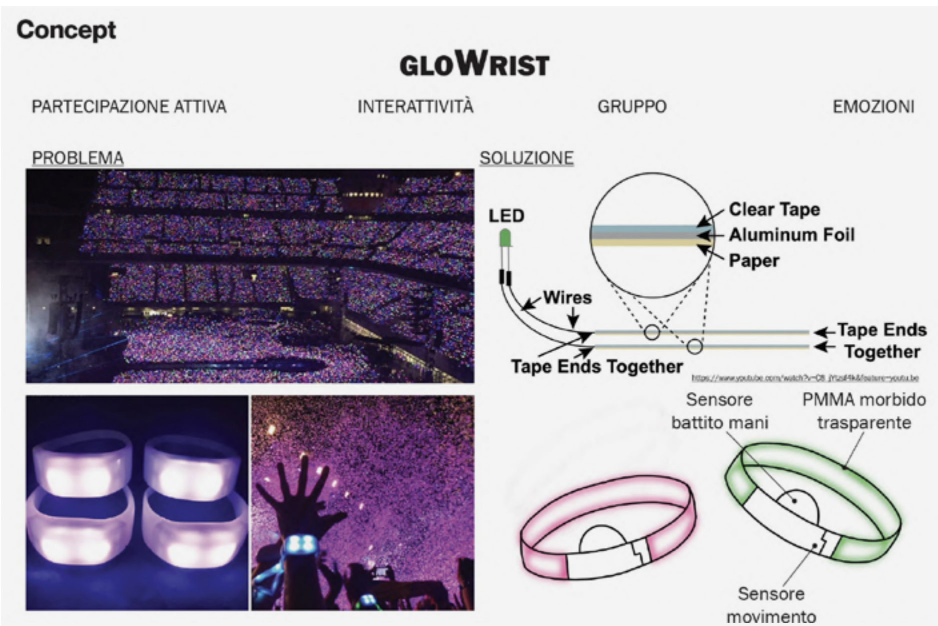

Figure 4. gloWrist. Authors: Maria Giulia Camillo, Martina Conforti, Benedetta Gaeta, Erica Potesso.

At large scale, in Europe, households consume just under 30% of all energy from various sources (renewable and non-renewable), as does transport, with industry consuming just over 25% (Eurostat, 2021). From these and other related facts, participants could build a picture of energy consumption in perspective and in proportion, and envisage the potential contribution that human power could make to overall consumption.

2.2. Project Elaboration and First Findings

The results of the two days of workshops revealed, as could be expected, different levels of critical thinking ability and design development performance between the different age groups, resulting from the respective levels of study experience.
The fast nature of the workshops meant that the results achieved would emerge mainly from the existing knowledge and understanding of the student participants, and less from new research they could perform.
The authors sorted results into four groupings, for the purpose of interpretation, and sample projects from each category include:

- Daily use for the community. Societal/environmental benefit (Fig. 3-4)
  - A railway station escalator whose downward movement (under the mass of the users) is used to power the station information boards;
  - Bracelets illuminated by kinetic arm-movement worn at stadium events for audience participation (initially judged as “new application” but proven part of existing socially useful functions);

- Children's playground equipment used to illuminate/irrigate the park area.[1]

- Daily use for the individual. Partial societal/environmental benefit (Fig. 5-6)
  - Desk lamp powered by foot-bellows under the desk;
  - Jogging pants that generate light through leg movement (for safety at night).

- New Application. Surplus energy is captured but used to drive a new product (no overall saving in energy consumption)
  - A reading seat with pedal-powered cooling fan.[2]

- Low/negligeable energy yield (Fig. 7-8)
  - Piezo energy generated by typing at the keyboard;[3]
  - Energy converted from a fiddling action in the fingers;
  - Fan installed in ski-tips to produce electrical energy.

The results must be seen holistically in the context of educating contemporary designers to understand the world of energy and consumption. It was noted that some hand-operated household appliances hypothesized at the ideation stage were inadvertently reinvented to imitate pre-1960 products. Another misconception emerged that the only means for storing energy was via electrical battery.

1 A number of groups identified children at play as a boundless source of energy to be exploited.

2 Only one group found its way into this category, as the consultation process successfully steered most participants away from such results.

3 A number of students identified "fiddling" type activities as potential energy sources. The concern of this author is that they could never generate sufficient quantities of energy.

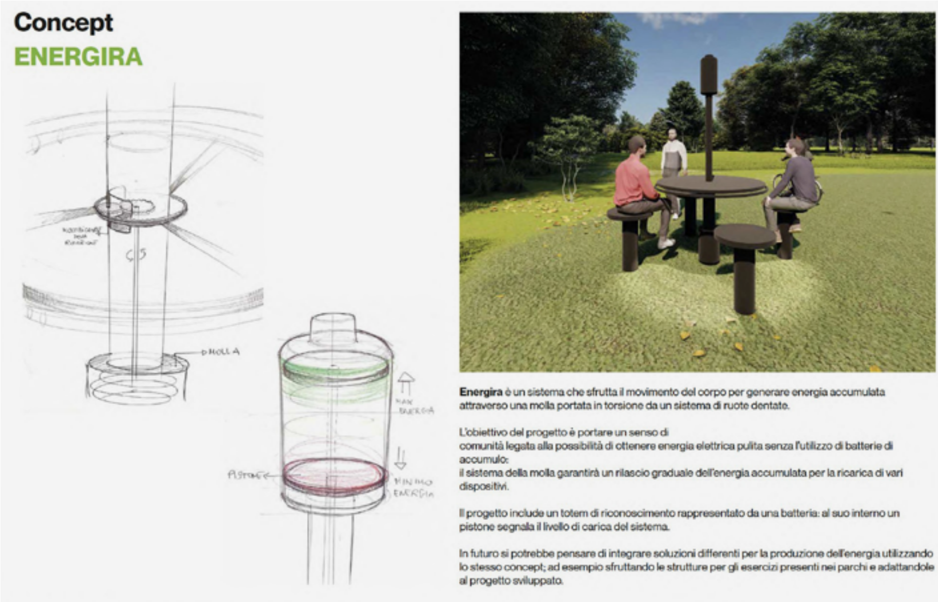

Figure 5. Energira. Authors: Luca De Scisciolo, Giacomo Pala, Elena Rossi.

Figure 6. Yellow Girello. Authors: Emanuele Brighi, Sara Camporesi, Marco Giangrandi, Cristiano Merlin.

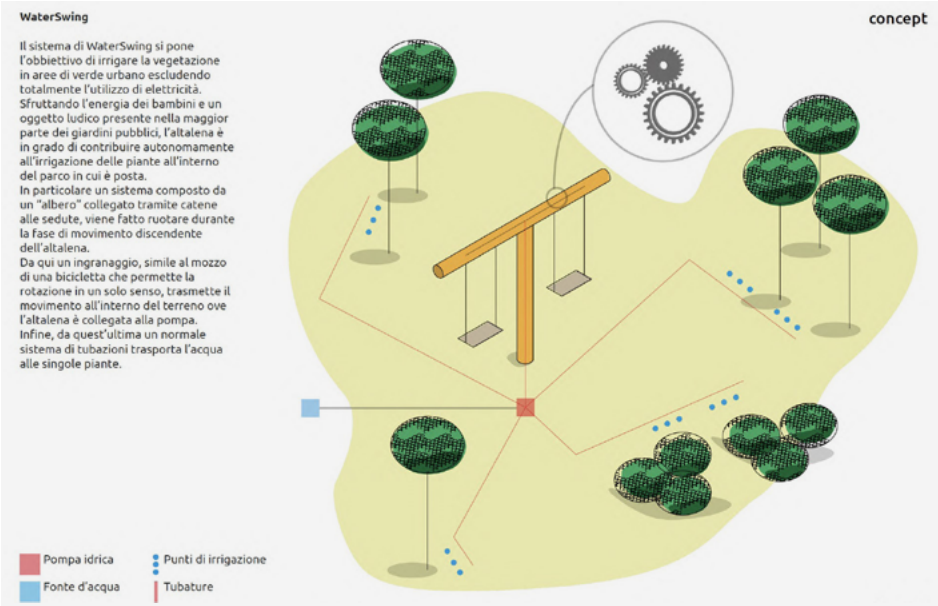

Figure 7. WaterSwing. Authors: Alberto Bonazzi, Anna Fedele, Tommaso Gabrielli, Giacomo Ghelfi.

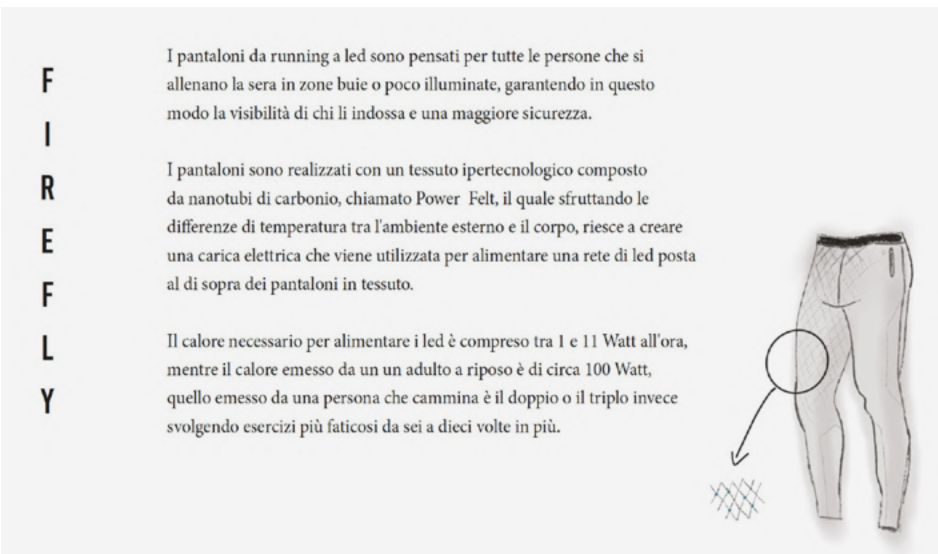

Figure 8. Firefly. Authors: Emanuele Agresti, Alexandra Bucciarelli, Alice Gagliardo, Ludovica Gentili.

The participants' generation has grown up in the digital age, in a highly automated world. It has developed a different understanding of the basic physical principles of energy transfer, mechanics, action and result because their experience of the physical world is dominated by a minimal physical action instigating a battery-driven result (i.e. touch screen command by pressing or swiping).

3. Discussion

3.1. Round Table Discussion and Projects' Evaluation

The project results were shared with three practicing professionals, and a roundtable event entitled "Powered by the People" was held at the university, and workshop participants were present. The practicing professionals brought in to analyze and comment on the project were carefully selected to explore the opportunities this project could have opened up beyond just the workshops in a critical vision.

The analysis yielded some unexpected new insights, which departed radically from the initial concept of the workshops, whose aim was to achieve an overall reduction in energy consumption. The audience received a stark reminder from the panel that the promotion of energy-saving initiatives[4] places itself in direct opposition to an ever-present trend throughout history. Human evolution has been characterized by the harnessing of technological resources outside the body to generate energy and to improve the efficiency of energy conversion. Design-led solutions to avoid the impending environ-

4 See possible references for an optimistic approach in: Lamb et al., 2020; Abrahamse & Steg, 2011.

mental catastrophe must adopt a speculative and, above all, realistic approach to this problem.
The first, Lucy Salamanca[5] drew upon her experiences as a designer working from the early 2000s in the "Fair Trade" movement, which has shifted its focus from fairness towards human stakeholders in the global supply chain (workers, women, children) towards a broadly holistic approach which looks to protect natural habitats as well, which in turn benefits the inhabitants.

> Design has moved away from its original definition "Industrial Design" (of attractive products to induce consumption) to a hybrid profession uniting diverse poles.

Referring to the project ideation, she affirmed a shift in Western consumer's consciousness towards an understanding that individual benefit is intrinsically linked to social and environmental benefits, citing the diffusion of bio-products into the mainstream marketplace.
However, she warns that the ideas in Western consumers' minds about what constitutes ecologically and ethically sound consumption can often be misguided, as exemplified by the demand for soya, which led producers in Brazil to fell large swathes of forest, radically altering the agriculture in favor of a mono-culture cash crop.

5 Lucy Salamanca is a designer from Colombia, based in Milan since the 1980s. Art Director and designer for several Italian companies, she has participated in the development of projects in different craft companies in Latin America, Asia and Africa. Her project research ranges in many fields: design, art and traditional craft techniques, identifying the harmony between the roots of the past and the look to the future.

Salamanca believes that to find the answers to the future energy challenge, we need to draw on the lessons above and avail ourselves of interdisciplinary studies and professions that can address the complexities of systemic change.

In the second interlocution, Simone Giostra[6] began by stating his intention to challenge the project's premise. In his view, we should not aim to consume less energy.
Historical energy consumption statistics reveal a flat line up until 20 thousand years ago with the arrival of agriculture, followed by a steady increase in reserves of energy obtained from sources outside the human body until the industrial revolution, which led to a near-vertical graph of increased energy production and usage. This ability to harness surplus energy afforded us, according to Giostra, the opportunity to think and deliberate and ultimately develop our civilization. Despite the resolutions of the 2005 Kyoto Protocol, the consumption line has remained vertical, and "we don't want to change this for an important reason: that we consume so much more energy than other species has determined our success on the planet […] the more energy we capture and burn, the more we consolidate our presence."
He cited the Jevons Paradox from William Stanley Jevons' 1865 book The Coal Question, which addressed an apparent shortage of coal at a crucial point in the Industrial Revolution.

6 Simone Giostra is an architect and associate professor with Tenure at the Politecnico School of Architecture in Milan, where he leads the Energy/Form Lab. At the intersection of design, technology, and the environment, his research work explores the relationship between the use of energy and the notion of form in architecture at 3 distinctive scales: construction component, building and landscape.

> There has never been an increase in efficiency that has brought a reduction in energy consumption – we just do more. Every time a machine consumes less, we buy two machines. And every time we have an energy crisis, we find new ways to procure energy and then consume even more of it.

Giostra notes that so-called green technologies bring ecological and socio-economic problems into the equation. Having embraced solar technology 25 years ago, he realized it could not be produced "cleanly". Procurement of the necessary resources has led to "two wars recently".
So, in addressing the student projects, Giostra concludes that two important themes are emerging: Firstly, capturing dissipated energy for further use. "This is what nature does – it leaves energy to be used in the next cycle until it eventually leaves the planet as radiation". Secondly, energy is an ornament. Again, in the natural world, animals and plants use energy first for metabolism (survival), then as an ornament. In our evolution, "who had more ornament? The chieftain". The Renaissance turned surplus high energy into high culture, thus elevating us from essential metabolic function.
Giostra was drawn to those projects that combined real energy efficiency with a strong message to their user, noting that the small excesses of energy that would otherwise go to waste can be used to send information, as in the participant proposal for an office chair that signals periodically to its user to take a break, thus inciting the user to use their energy for wellbeing. Examples are the proposal that suggested harnessing the energy from body heat that would otherwise be dissipated and lost and the bracelets worn by concert-goers

that enable audience participation (the latter belonging to the surplus-signal-ornament-culture camp).

This last point conveniently leads to the third participant, Mario Fedriga[7], head of design of a leading Italian sports equipment brand, whose products conform in many ways to the principles identified by Giostra. As a practitioner in the production of fitness equipment for individual as well as community use, Fedriga was able to offer valuable insights into the project's themes, as seen from the cutting face of the production industry and the market.

> We get people to move while standing still, to lift weights without constructing, and we have passed from the concept of fitness to well-being, from individual to social benefit.

If before, as individuals, we "ran around the filling station to burn off our energy, then filled up, and continued to repeat the cycle", now our focus is on a holistic, balanced vision of well-being comprising exercise, diet and positive mental attitude. If we can get this balance right, we reduce "social damage", such as the burden on health care systems. In this sense, the ethos of the company, along with the perception of fitness in the public imagination, has moved from the individualist, the "hedonistic", towards an understanding that the individual lives in a social and environmental context.

7 Mario Fedriga is visiting lecturer and industrial design manager at Technogym. He co-ordinates "look and feel" of products, formats, customer touch points, ensuring the appropriate level of design innovation through the identification and analysis of consumer trends and market needs.

> Our consumers are ambitious, concerned about their appearance in the mirror, and therefore about the impression they make in their social context. From this understanding we derived our advertising slogan "Let's Move for a Better World".

Fedriga illustrated a fitness product launched already in 2010 under the slogan RRR:

- Reduce – energy consumption by 30%;
- Recycle – an integrated dynamo returns energy to the machine;
- Renew – harvest energy to reintegrate into the electrical grid.

The equipment informs the user of their achievements and sets challenges "in an entertaining way" using gamification principles. This information is mapped and shared, thereby creating a community of users and a "virtuous cycle." In this case, the action of humans using the machines is motivated by an information signal, the low-energy impulse setting a higher-energy action in motion, as defined by Claude E. Shannon in 1948.

3.3. Discussion Findings

In forecasting future solutions to the current energy problem, all participants recognized the inevitability of certain behavioral tendencies, driven by evolutionary development, that have manifested themselves in history, even those that fly in the face of common sense or environmental expedient. These can be defined as follows:

- Humanity will continue to explore procuring more (surplus) energy from new resources using new technologies, so that the reaction (feedback) from a machine or service will always use more energy than the human impulse provided. Where historically the source of extra energy was visible to the user (for instance, an open fire or a steam boiler), today the energy is increasingly imperceptible (the whirring server storing data on another continent or the near-silent electric vehicle). Any contribution from humans using their bodies will be symbolic only.

- The drive for efficiency will lead to more consumption not less. History has shown that societies, producers of goods and services, and consumers will always demand more. We will continue in the direction of complexity not simplicity in our energy infrastructures. There will be no turning back. Information will be integral to new technologies, processes and products. The message will be the driver of development, just as it always has been.

While some of the project work by participants followed the course prescribed in the proposal and briefing, some unexpected results led the project into new territory, broadening the scope even further for the round table discussion. This freedom of scope allowed participants to recognize some basic unavoidable truths about human evolution, the human condition, and our future relationship with energy and the planet.
The direction of discussion is supported in scientific literature and in the media. Tim Harford, writing on governmental energy policy in 2013, states:

> The broadest version of the Jevons paradox is that energy efficiency, in a very general sense, makes economic growth possible, and this in turn creates new demands for energy that swamp the initial energy saving. (Harford, 2013)

Simon Kuper also reinforces the observations made about consumers' demand for energy:

> […] as William Jevons pointed out in 1865, when fuels become cheaper and more efficient, we use more of them. Note the global rise in car sales, increased ship speeds and the growing numbers flying each year. About four out of five people on earth have never taken a flight. Many of them cannot wait. (Kuper, 2019)

> No electorate will vote to decimate its own lifestyle. (Kuper, 2019)

4. Conclusion

4.1. Observations on the Findings

In the light of invaluable contributions to this project from participants and practitioners in architecture and design, a clear directive emerges. What sounds like a mere provocation turns into truth based on evidence: humanity must steer its vision of a sustainable future away from a low-tech, "return to green" model towards a hi-tech, high consumption model that will be more efficient, cleaner and safer than those in current use. The future solutions that emerge will embrace human desire for more yield, for even where in Western economies the idea of consuming less and wasting less has been embraced in certain quarters of society, developing economies are busy increasing their wealth, the wellbeing of their citizens and consequently their resource consumption (Kuper, 2019). We will continue to behave as social animals, motivated by a deep desire to procure and communicate. If we can find a solution that halts global warming in time, we will survive as a species. If we fail, the planet may well find a way to regulate itself to survive, as the well-known proponent of the Gaia theory, James Lovelock (2019) points out, but there may not be a place reserved for us on it.

Since at no point in history has there been a reduction in energy consumption, instead only an insatiable demand for the benefits and comforts afforded by energy conversion, then viewing our current (and still increasing) consumption as "over consumption", to be somehow capped or reduced is surely a dead-end avenue of research. The aversion to catastrophe will lie in a new technology-based yield that meets humanity's insatiable need while proving to be more efficient and environmentally cleaner.

4.2. Relevance of the Project

Despite the minimal contribution that human power can make to our future energy generation needs, the symbolic relevance of this endeavor remains strong for the flowing reasons:

- The introduction of more physical exercise into daily life can increase overall physical fitness in the population, leading to more effective performance at work and in family life, less strain on health infrastructure, and a greater sense of well-being.

- The introduction of a decentralized system of energy generation at the domestic or small community level can effectively relieve a small proportion of the burden from natural resource consumption at this scale. More importantly, it can increase the individual's sense of agency and autonomy in society, as well as that of the small community within the greater collective. Human-powered energy generation, therefore, becomes a tool of empowerment.

- Ultimately, by fostering a holistic understanding of our place as humans in the environment, human-powered energy generation fosters a greater respect for the precious planet we depend on for survival.

Finally, this project, in effect a thought experiment, has shown the importance of certain baseline arguments and the fact that they must be addressed in the education of a new generation of designers who will, in the future, shape our society and environment in their professional practice.

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Designing Community-Driven Energy Solutions

Reflecting on Design for Future Social Systems and the Ability to Shape Change

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Abstract
Electrification is a promising strategy to reduce CO2 emissions by 2050 as solar, wind, and other renewable sources substitute fossil fuels. It is also a significant way to reduce energy poverty in disconnected areas. Electricity can be produced from different sources and by individuals or communities. Community energy solutions allow citizens to participate in the energy transition by pooling resources with their neighbours and community for larger-scale installations, bringing cheaper and cleaner energy and economic and social benefits to households and businesses. Community energy projects enhance the sense of belonging, build social capital, and improve well-being by involving renewable energy technologies that feed existing grids and networks or are autonomous local grids and networks with different distribution infrastructure ownership models. A master class of international students tasked with designing product-service systems for energy communities has developed concepts aimed at communities with limited resources undergoing pressure due to heat waves or massive tourism or providing support to vulnerable populations. Challenges and complexities in finding innovative solutions for radical infrastructural changes have emerged in addressing community solutions and the transition toward local empowerment.

1. Introduction

One of the most challenging demands to engage design students is to ask them to imagine systemic transformations that affect the current or future social systems. Due to the major social and environmental challenges we are facing, there is a growing need to build a design culture through the education of future designers for radical transitions (be it social, digital, technological, ecological, energetic, etc.) and to significantly contribute to the design of social systems as a future-creating, collective human activity (Banathy, 1996). This requires embracing new methods and approaches and deeper reflections on how it is possible to rethink design education when addressing global challenges that deal with complex sociotechnical systems (Banathy, 1996; Pizzocaro, 2000; Friedman, 2012; Norman & Stappers, 2015; Mayer & Norman, 2020).

The project challenge given to design students of the master course Innovation Studio[1] in the first semester of 2023 was to develop a service system and one physical touchpoint for an energy community. Students could focus on developing countries or areas with limited energy resources, but there was a preference for existing or future communities in Europe. The question was to envision product-service systems that could benefit from the possibilities of locally produced energy potentially managed by the community of users.

The students of the Master's course come from all over the world and from different bachelors. Hence, each group defines

1 The course Innovation Studio is a design studio of the Master in Product Service System Design of the School of Design of the Politecnico di Milano where 87 designers coming from 14 different countries have developed 15 ideas for an efficient energy consumption future.

a methodology based on the different project cultures and contexts they will address. Exercises are given to support research, such as Bodystorming, a specific method designed for the course (Broadbent et al., 2023), and *Scaling*, taking inspiration from the work done by Hunt (2020). The main aim of the course is to test ideas rather than develop perfect solutions, and it is structured in cycles of iteration with moments of confrontation and proof of concept through peer-to-peer feedback. Students also learn how to prototype services and touchpoints, developing *Desktop Walkthroughs* (Auricchio et al., 2022). Students had also gone through a phase of desk research in which they examined existing cases and a phase of primary research in which they interviewed members of energy communities in Italy, individual households that had installed solar panels for their consumption, or simply communities that were considering new forms of collaboration, especially considering the cost of energy crisis in the past years. The results of the master course were exhibited in the museum of the main energy provider of the city of Milan – AEMuseum,[2] where a final narrative of the class results was designed by a group of selected students.[3] According to this narrative, projects were divided into the following macro-categories:

- *Power For Optimising:* projects that face the current challenges and adapt to a transforming reality. The projects proposed efficient energy use by fostering a sense of unity and innova-

2 https://fondazioneaem.it/aemuseum/

3 Curators of the exhibition were: Alessandra Coppola, Alissa Sara Zaouali, Büşra Yeliz Karaoğlu Balcı, Camilla Cristante, Elena Buccelli, Federica Francesca Pancari, Sara Faustini, Zhenqi Xu. For more details see https://www.uncertaintimes.polimi.it/powerfor-2024/

tion within communities, reflecting on the power of collaboration and how community-led and community-driven initiatives can lead to sustainable and practical energy solutions.

- *Power For Inventing:* projects to explore new technologies by imagining the future. Solutions that look at tomorrow introduce opportunities and innovative approaches to redefine the concept of energy, as well as visionary and transformative approaches, showing how today's creativity can be directed towards shaping uncertain but potentially revolutionary futures.

In the following paragraphs, projects describe some issues encountered in this coral experimentation in designing for autonomous and self-organised communities. This paper aims to create a bridge between education activity and research through three main reflections on challenges related to: 1) imagining radical social transformations, defining a community and delimiting its boundaries; 2) designing the infrastructure and the social systems as materials (Blomkvist et al., 2016), bringing into the design process both the whole and the single elements of the service to be designed and deeply understanding what needs to be designed, from tangible touchpoints to intangible community interactions; 3) understanding design methods needed to address community engagement and to achieve social impact. The economic and legal implications that socio-technical systems are bound by were not a constraint given to the class. However, they were considered in project discussions and debates related to the feasibility and critical assessment of concepts.

Overall, the main hurdle was to imagine how a community could create a system of governance for the common good. While many projects intended to serve a community, the issue is to define a service that can be self-managed and regulated. It is, in a sense, much easier to think of services "for" a community – solutions that benefit a community but are managed by a third party (a traditional centralised model or the old approach to development projects) –, than to rethink systems made by services "growing within" and "led by" a community.

2. Imagining Radical Social Transformations

When addressing electrification and energy communities, we enter not only a technical realm but, more significantly, a redefinition of institutional and economic structures that define the organisational models of energy production and distribution. From a centralised model in which energy utilities produce energy through carbon, hydro, nuclear or wind power, and energy distributors convey the energy to households and businesses, the new distributed electrification models envisage individual or local production. Energy communities, household solar panels, or local alternative energy networks all reduce the role of the utilities and push onto communities and the individual the efforts and benefits of energy production. This is a very major transformation of resource management from the social perspective. How radical this change could be is well illustrated by the analysis of some feminist researchers, who point out the profound political implications of the current fossil fuel and energy systems. Sheena Wilson, who leads the *Feminist Energy Futures* project, suggests that decarbonizing our energy supply

> […] could provide opportunities to develop more socially just ways of living that put the concerns of those most exploited – women, people of colour, and the global 99 percent - at the core of energy transition politics. (Wilson, 2018)

A feminist perspective on energy offers an important framework to understand why moving away from unsustainable energy cultures seems so difficult. In their introduction to *Petrocultures*, Wilson, Carlson, and Szeman (2022) point out, as other researchers before them (Smil, 2017), the profound cultural transformations and identities that have accompanied the recent decades of fossil fuel consumption and the cheap and plentiful availability of high-density energy. The centralisation of production, distribution, and governance, which characterises the energy industry, has significantly reduced participation in the decision-making processes, the distribution of benefits and costs, and representation of the people and entities concerned and made people dependent on utilities. Warren (2000) suggests rethinking energy production with four objectives: a) a political objective, ensuring democratic, decentralised, and pluralistic systems; b) an economic objective, which prioritizes human well-being and biodiversity over profit and unlimited growth; c) a socio-ecological objective which engenders relationality over individualism; d) a technological objective, which requires an approach that privileges distributed and decentralised fuel power and people power. These principles do not suggest a unique model of energy production and distribution but invite a pluralistic approach:

> A commitment to democracy goes hand-in-hand with a commitment to pluralism. In terms of energy, this means that instead of advancing a single, universal energy solution for everyone, feminist energy analysts would support the blossoming of multiple ways of designing and living with energy. While there are many benefits to decentralised and distributed fuel production and consumption, feminist energy approaches do not rule out in advance that larger, democratically coordinated systems may be appropriate for certain regions, or that longer-distance energy sharing and gifting (as opposed to buying and selling) may also play a role. (Bell et al., 2020, p. 5)

In light of such analyses, we can see why energy communities are emerging as loci of considerable social transformation and how they are being used to subvert structural inequalities in some regions of the world. Some interesting examples of radical systemic approaches are, for instance, programs that focus on women as the main actors of energy projects. They start from the realisation that in many societies, women are bearing the consequences of the climate crisis more than men, and this will continue to increase existing gender inequality and challenge women's livelihoods, health, and safety. In many rural areas, women have also traditionally been the purveyors of fuel and water for their families, tasks that are becoming more challenging when environmental conditions are modified. Energy community projects that target women offer, therefore, multiple benefits by providing an essential resource such as energy, by providing training and an income to women, by building a system of governance that allows women to control the production and distribution of energy and the decision on how to use it, by designing a system that will enable women of the community to appropriate for themselves the technology and infrastructure. A significant project in this domain is *The Barefoot College*, started in Rajasthan and now present in 95 countries, an organisation that trains women in rural communities to assemble, install, and maintain solar equipment. These women, who have little-to-no formal education or literacy, receive hands-on education in installing and managing solar panels and on the economic value they can produce (Minnini, 2022). As Solar Mamas, they not only gain a sustainable income and financial independence but go on to distribute clean, sustainable energy for their communities.

The project combines design solutions that address sustainable energy, governance, knowledge transfer, and economic gain. What seems particularly significant is the combination of strategies, knowledge training, income, distributed systems, and access to an essential resource. While this combination can be seen as the hallmark of modern development programs, Barefoot College offers a systemic approach to the energy transition that can inspire projects in many other contexts. A similar philosophy has been followed by *Solshare* in Bangladesh (Dumitrescu et al., 2023), which helps set up peer-to-peer microgrids for households and small businesses. While not uniquely centered on women, they are particularly attentive to enabling women to create sources of income through the resale of energy.

3. Defining a Community and Delimiting Its Boundaries

The first task students gave themselves was identifying the communities that would transform.

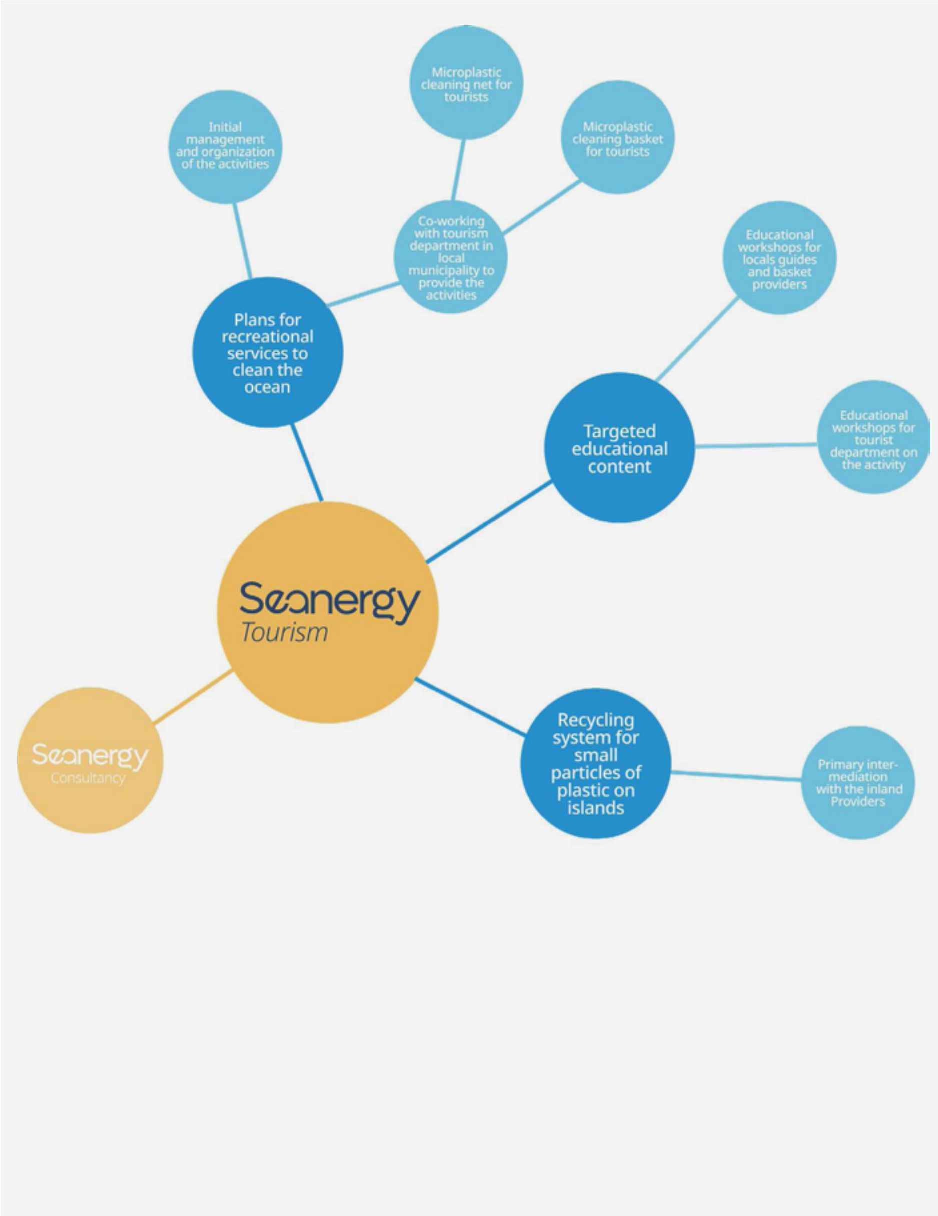

Figure 1. *SeaEnergy*. Project developed by Daniela Achury, Kimia Chavoshi, Alessandra Coppola, Chiara Corti, Yexin Jin. SeaEnergy collects plastic fragments from the sea and provides sustainable tourism services on the island, introducing cooperation and respect into the travel experience.

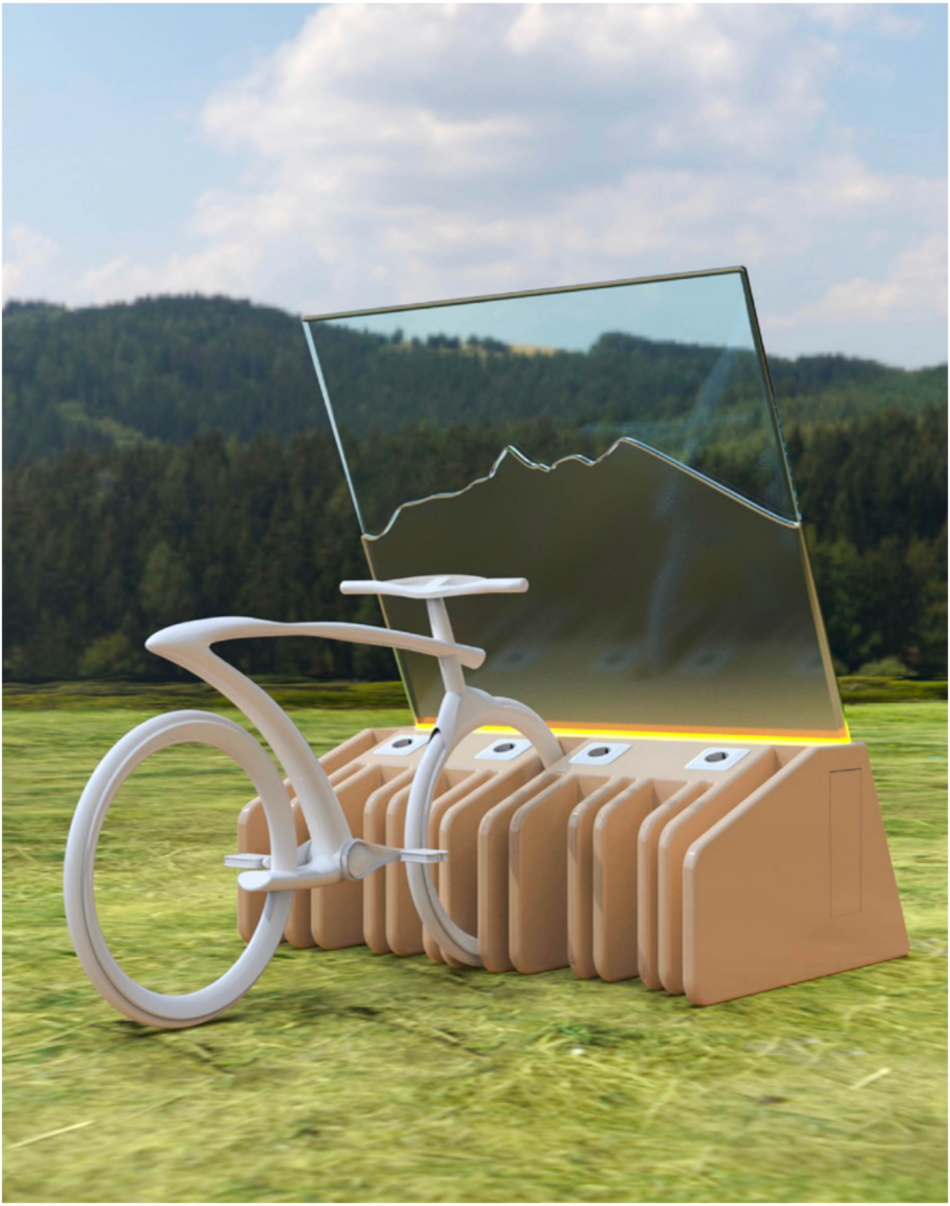

Figure 2. *Sunday.* Project developed by Ingrid Berre, Eleonora Gasparino, Chiara Mazzeo, Federica Pancari, Yaxin Ran, Zhelin Yan. Sunday transforms the energy produced by idle, second-hand real estate in small tourist villages into public economic resources for the community, contributing to local sustainable tourism.

Transitory and temporary communities. A first cluster of product-service systems explored the fluidity of community boundaries, envisioning their potential expansion or contraction over time, acknowledging, for example, temporary inhabitants as tourists, remote workers, and city users as likely new members of such a community. This transient nature led to a deeper investigation of the potential motivations and visions that could trigger the contribution of both permanent residents and temporary users to the community in terms of engagement, shared governance, and user experience. For example, the project *SeaEnergy* (Fig. 1) engages responsible tourists in island communities' energy production by involving them in collecting microplastics from the sea. While considering the impact of traveling in small and fragile ecosystems, this solution makes explicit the trade-off between tourism, sustainability, and energy production. It reveals the challenge of going beyond mutual exploitation.
Conversely, the project *Sunday* (Fig. 2) envisions an energy community fostering trust and collaboration between residents of remote areas and second-home owners. Operating on principles of mutual and shared responsibility, this service promotes a cooperative model and a series of touchpoints and landmarks for a solar energy co-production and management system. This approach cultivates a symbiotic relationship between diverse groups, emphasising accessibility, collaboration, and sustainability for all involved.

Potential and prospective communities. A second group of projects worked on building solutions that reveal potential or build prospective communities through infrastructure by supporting users in using eco-efficient services and sites. Here, the community comes into being by sharing the convenience and efficiency of energy systems and products that retrofit shared spaces, renew abandoned or underutilized areas, and recover undervalued competencies and professions. *Revita* (Fig. 3) repurposes neglected spaces and second-hand clothes by involving local artisans in creating eco-efficient furniture. These products optimise the heating and cooling systems of co-working spaces and handicraft production areas. At the same time, a service focuses on strengthening relationships fostered by working in and utilising such locations.

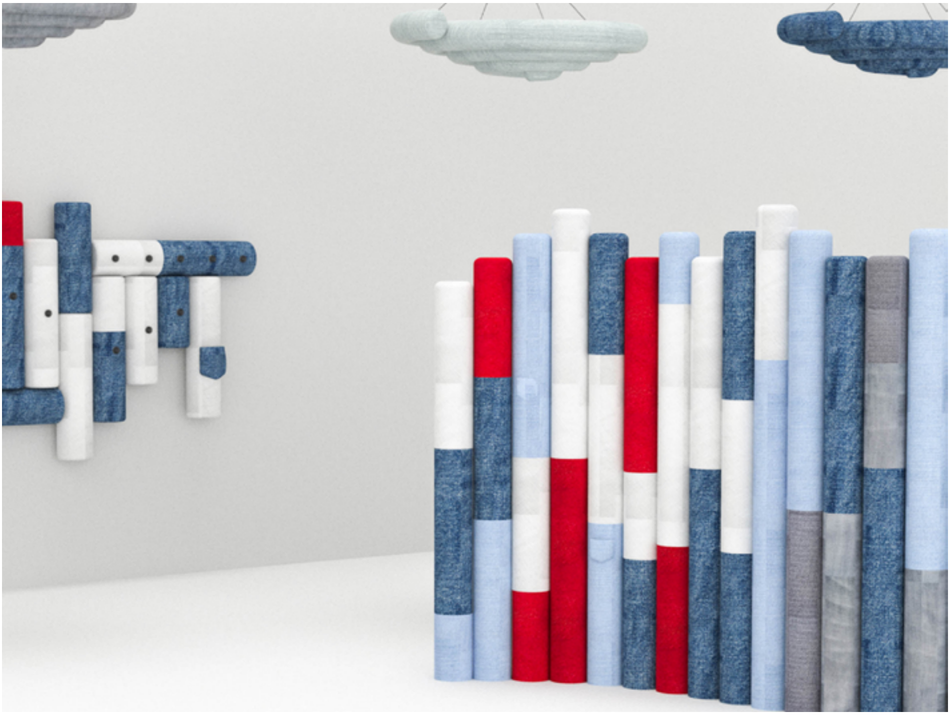

Figure 3. *Revita*. Project developed by Luisa Valentina Arosa Cely, Junyan Lu, Elisa Pinizzotto, Kezia Jane Rivan, Erika Vuthoj. Revita tackles the problem of discarded second-hand clothes by transforming them into various materials needed for energy-saving facilities.

Figure 4. *Netnook*. Project developed by Giulia Badocchi, Jin Deng, Gorkem Er, Sara Faustini, Ada Hatipoğlu, Xilian Liu, Caterina Polese. Netnook provides energy-efficient hubs in underutilised residential areas, promoting a sustainable work environment.

Similarly, *Netnook* (Fig. 4) envisions a future where a widespread remote workforce will still require shared and temporary offices while confronting the challenges of climate change in outdated and energy-inefficient settings. *Courtile* (Fig. 5) develops solar-powered shared spaces in condominiums, facilitating neighbour interactions and supporting local associations in their initiatives for community development.

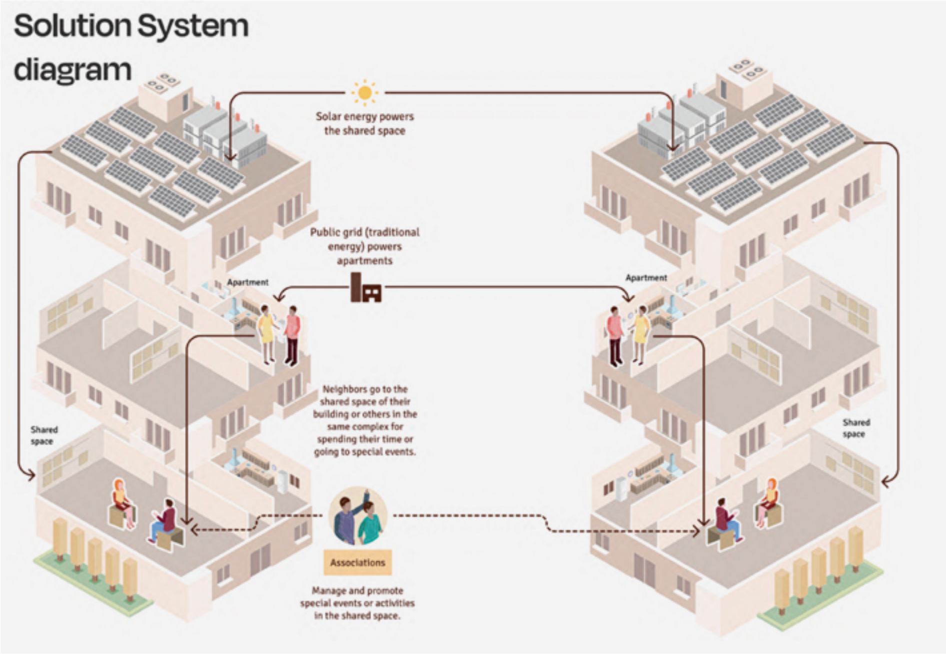

Figure 5. *Courtile*. Project developed by Miriam Cianci, David Martinez, Tita Nikolopoulou, Emanuela Ruggeri, Zebin Yin, Alissa Zaouali. Courtile is a centralised energy and knowledge centre for community well-being.

Although they refer to collaborative models, these services mostly adopt a top-down approach and rarely empower the community in the governance of the system, understanding the community itself as an outcome of a service governed by third parties.

Communities in crisis: A third cluster moved in a scenario where uncertainty is deeply intertwined with emergency situations such as blackouts, earthquakes, and floods. In these extreme circumstances, solutions proposed by students aim to offer support and assistance, reactivating and nurturing social ties while working on the theme of access, management,

Figure 6. *Occa*. Project developed by Tomás Barros, Beatrice Cinquepalmi, Chiara Lualdi, Lorenzo Mangilli, Laura Vieira, Zhenqi Xu. Occa provides an innovative and reliable emergency drinking water service during extreme heat waves and water shortage.

and distribution of common goods, particularly in contexts where community cohesion is weak. This perspective can offer new avenues for strengthening not only social bonds but also resilience within communities facing emergency situations. For example, by providing access to common goods like electricity and water, initiatives such as *Occa* (Fig. 6) can serve as emergency drinking water filtering and distribution services, utilising water from public swimming pools during prolonged blackouts, or by rethinking emergency rescue objects as in *Ecos* (Fig. 7), a radio as a service for communities in danger during blackouts due to major earthquakes.

Figure 7. *Ecos*. Project developed by Elena Buccelli, Andrea Di Lenardo, Naz Derin Sahin, Yaren Seval Yilmaz, Linwei Yu. Ecos, as a radio communication platform, improves earthquake preparedness, fostering community resilience in emergencies.

Communities beyond humans: Another group of projects delved into the concept of "more-than-human" energy communities, recognizing the interconnectedness of all living beings. These solutions seek to integrate animal and plant species into the fabric of renewable energy systems. These communities aim to promote biodiversity, enhance ecological resilience, and foster symbiotic relationships between humans and the natural world. *Litus* (Fig. 8) empowers remote coastal communities through an algae farm lab run by local fisher communities, which cultivates bioluminescent species capable of absorbing sunlight and emitting natural blue light at night.

Figure 8. *Litus*. Project developed by Chiara Colombo, Daniele Landi, Valentina Phung, Elizaveta Pustovit, Maryam Roozbehi, Nicoló Vespini. Litus introduces bioluminescent buoys for coastal communities as a new innovative local co-produced service.

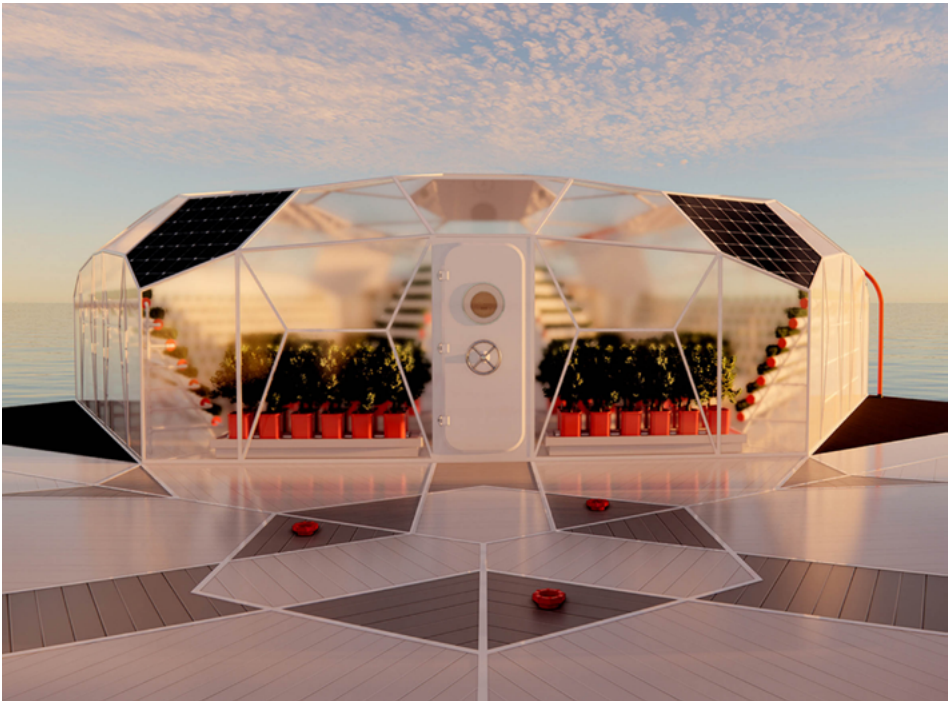

Figure 9. *Atholou*. Project developed by Yaru Bao, Selene Garresio, Kyeongmin Han, Marzieh Khoramabadi, Marcello Mariotti, Nandini Mehta, Sandra Quintana Echemendia. *Atholu*, a floating farm in the Maldives, supports sustainable aquaculture for communities confronting sea-level rise.

Communities as geographical locations: Other groups of students considered that a geographical location could define the needs of its inhabitants and started from specific challenges that the region would be facing. In this category, three projects addressed climate change. In *Atholou* (Fig. 9), the effects of sea rise on agriculture of the archipelagos of the Maldives were addressed through a system of floating agriculture powered by waves and solar panels. A speculative and futuristic solution that attempts to reduce the dependency of the islands on imported food and limit the risk of depopulation and the preservation of skills and local culture.

Figure 10. *Coolwaves*. Project developed by Camilla Cristante, Nastaran Kalvandi, Sana Farooq Khan, Cecilia Pizzagalli, Camilla Porrini, Chi Yuanlong. *Coolwaves* faces the climatic challenges of Milan, reshaping the urban landscape through sustainable cooling solutions in public spaces.

Finally, *Coolwaves* (Fig. 10), a project for the city of Milan, starts from the current and expected significant rise in temperature during the summer months. By proposing communal cooling spaces in the city squares, it wants to address the urgent need to find alternatives to residential air conditioning technology and ensure that outdoor spaces in the city remain accessible and used.

Figure 11. *Nexu*. Project developed by Aashka Dhebar, Chiara Laudonia, Letizia Perico, Marco Gugliuzza, Ruth Asfaw, Zahra Mazrouei. *Nexu*, as a new decentralised data centre system, provides services for the fast-paced digital world. Collaborating with communities, it aims to achieve truly sustainable realms.

Figure 12. *Hom.e*. Project developed by Maria Camila Diaz, Catarina Landim, Sirui Lu, Valentijn Raes, Paola Rapino, Bianca Selvatici. *Hom.e*, by providing devices as touchpoints for people living in the apartments, enhances energy awareness assisting the Housing First Associations and their beneficiaries.

4. Designing Infrastructures as a Material and Social System

When looking at the projects from the lens of the proposed system of services and materials, we can see the emergence of different models of infrastructural transformation. Three main categories emerged: *solutions to control energy consumption, solutions to share energy,* and *solutions to harness energy.*

Solutions to control energy consumption. The first category encompasses projects that seek to raise energy consumption and management awareness while providing practical, readily adaptable tools to translate this consciousness into tangible actions and services. As an example, *NexU* (Fig. 11) is a project that addresses the energy consumption of our digital activities and aims at bringing data storage closer to the end users. A decentralised edge data centre system integrated within energy communities, aiming to encourage people to achieve a more sustainable digital world. Working on a similar theme but involving a completely different target, *Hom.e's* (Fig. 12) touchpoint focuses on Housing First Association's beneficiaries, often individuals with a history of chronic homelessness. Addressing challenges in comprehending abstract energy concepts, the touchpoint delivers intuitive feedback on the daily energy usage of four groups of appliances. Its primary goal is to enhance knowledge on the subject and ultimately reduce energy bills for these associations.

Solutions to share energy. In the second category physical spaces become the means to share energy creating common spaces of energy consumption for cooking, working, and leisure. These projects rethink existing public and private spaces as physical facilities that allow communities to reduce energy consumption while creating new encounters, such as the projects described above *Coolwaves* (Fig. 10) and *Courtile* (Fig. 5) respectively in public parks and in residences for social housing, or *Hygge Hub* (Fig. 13) which instead unites neighbours in a communal kitchen in Denmark to reduce energy consumption when cooking. This last solution addresses inequality due to energy poverty in vulnerable areas by facilitating communal cooking.

Figure 13. *Hygge Hub*. Project developed by Büşra Yeliz, Karaoğlu Balcı, Silvia Emuli, Emilia Galli, Suofeiya Nanxi, Li Zihan. *Hygge Hub* provides a shared community kitchen to reduce energy consumption and enhance communities in disadvantaged neighbourhoods.

Figure 14. *Stelo*. Project developed by Yang Cen, Marta Grauso, Julienne Joven, Giovanni Malausa, Kangling Qin, Benthe Schümmer. *Stelo*, reestablishing the relationship between children and nature, provides a breathable, healthy learning environment powered by plants.

Solutions to harness energy. Energy harnessing is capturing available energy and converting it to electrical power. This challenge requires a deep knowledge of past, recent and future technologies. The projects in this field either stand on the shoulders of existing solutions and replace (or displace) them in new contexts of use, such as the touchpoints of the projects described above *Ecos* (Fig. 7) and *Sunday* (Fig. 2), or they imagine the use of future technologies, based on desk research and data available, for example, *Litus* (Fig. 8) or *Stelo* (Fig. 14) an indoor plant-based air purifier for schools.

Figure 15. *Novomodo*. Project developed by Chiara Mele, Ayano Osawa, Ganjar Satrio, Francesco Tomio, Xinyi Zhu. *Novomodo* aims to solve food issues and provide a new eating solution by using freeze-drying techniques on surplus vegetable products.

In the project *Novomodo* (Fig. 15), instead, the whole concept of what we will be eating in the future changes to avoid energy consumption in food preparation, proposing a diet based on dried food and preparing on-the-go nutritious snacks using a shaker. This project is based on a food preparation methodology used in Japan for making rice balls.

5. Conclusions: Community Involvement and Social Impact

The transformative shift to distributed energy production models also asks for a deeper reflection on how we design, which are the appropriate methods, approaches, and creative constraints, and if we need to envision new ways of thinking and making (Görnsdotter et al., 2023). After desk research, students defined their specific context of action. Still, one crucial question emerged when moving into the concept definition phase: Are we designing a speculative solution, or should we solve a real problem? Interestingly, answering this question opens up two separate design directions: the first aims at envisioning and placing the project in a possible future (Dunne & Raby, 2024), and the second aims at solving a problem by analytically understanding the complexities of the present situated challenges within the transition, we could call the first *paradigm shift* projects and the second *transitional* projects. Students were free to choose any direction and define how far into the future the solution could be developed, basing their assumptions on technological and social projections found in the desk research. In general, speculative design was mainly chosen by groups looking at geographically distant[4] realities (Maldives, Ventotene Island, Catania). At the same time, a more problem-based approach was preferred when looking at nearby and known communities in the region where we were physically working. This decision was mainly determined by the level of access and relationship a designer may have with a community, whether one works for, in, or with a community (Villari, 2021; Selloni, 2017). The decision will determine how creative thought gives shape to solutions, such as building utopic or dystopic hypotheses of a faraway future or making sense out of on-field research and interviews with experts and stakeholders

4 Distant here is intended as a place that is physically far away from the designer, so, since the course was in Italy we are considering here places that were difficult to visit or reach for on-field research in the time span and economy of the educational project.

within a specific community. The scope of the projects will also differ in terms of impact; while a speculative project aims at igniting critical reflections on the present state of the art and the consequences of decisions we might take today, a problem-solving approach aims at finding real solutions to existing challenges - the first imagines paradigm changes in the way we see the future of energy production and consumption while the second gives shape to innovative ideas within the present world and the infrastructural constraints described above.

The most successful cases of energy communities, such as the *Barefoot College*, are characterised by a deep embedding of the design process in the social environments for which solutions are being developed. Participatory approaches in design are even more crucial in this field because the actors can only indeed decide the models of access and governance of energy resources, who, how, and especially for what energy will be used needs to emerge from a dialogue with the interested parties. The nature and duration of student projects make it difficult for them to embed themselves in their imagined target communities, and they must rely on desk research, interviews, and case studies. This means the available data may not provide them with enough information to drive their creative process fully. The iceberg model illustrates this issue well. Just like the portion of the iceberg above the water's surface is limited, so is the visible information about the community (Vink & Koskela-Huotari, 2021). Discovering regulative, normative, and cultural-cognitive qualities of a community is difficult based only on secondary research (Zhang & Auricchio, 2023). As the design process moves forward, it requires enhanced calibration of the details to ensure that the design outputs are self-consistent within the context of the chosen community. The challenges students face, however, are not dissimilar from many development projects that have attempted to serve communities in top-down initiatives and that have met with resistance or failure. A case in point is numerous off-grid projects (Jeuland et al., 2023) in which the well-intentioned energy actors, after building a local energy production system, are shocked to see that the inhabitants of the area that previously lacked access to electricity, underuse the service. It often takes redesigning the main tools and diesel-powered machines for agricultural processing (fundamental for their livelihood) to finally see an uptake of electricity and a change in daily practices. Participatory design approaches in something as fundamental as energy access and use are simply a precondition for a successful project. In educational terms, for students to realize this firsthand and understand that participatory techniques are the drivers of their creativity is a major step.

Interestingly, the more speculative-driven projects, which endeavour to craft a fresh narrative and subvert existing models and organisations, are more generative of creative leaps, such as the project of floating agriculture, the recuperation of water from swimming pools in extreme blackouts, or the luminescent algae. During the final exhibition, speculative solutions inspire visitors to interpret and fill some gaps.
As students embark on the journey of designing sustainable energy solutions, it is crucial that they integrate future thinking into the design process, envisioning alternative futures

and exploring different scenarios to identify potential risks and opportunities and develop robust and future-proof strategies. "From the dialectic of past and present come the situations that determine the possibilities for the future. To plan effectively in the present requires a vision of what the future could and should be" (Margolin, 2007). However, in so doing, their awareness of the role of the participatory process will allow them to address complex projects that are transformative in their objectives.

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A full list of students in the different years can be found on the official websites with project details and student names:
https://www.uncertaintimes.polimi.it/powerfor-2024/
https://www.instagram.com/uncertaintimes_/

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TOOLS

ENERGY TECHNOLOGIES & DIGITAL AWARENESS

Solar Biota
Co-Living with Solar Ecologies

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New Materialism, Artistic Research, Technoscience, Multispecies, Solar Energy.

Abstract
Solar energy (technology) has often become synonymous with the solar photovoltaic (PV) panel within global decarbonisation efforts, leading to a disproportionate focus on the anthropogenic and techno-economic benefits of solar energy use within modern consumption patterns. However, solar PV could otherwise be understood as a technoecological phenomenon – broadly conceived as indeterminate associations of living and non-living ways of being. Through the lens of artistic research combined with the new materialist tradition, this article elaborates on a multispecies ethnographic study which was conducted over a five-month long period. The study is based on a multispecies (co)living with the SunSpider: a prototyped, small-scale, solar PV *thing*, installed in the outdoor context of an intimate domestic environment. The results of the study offer poetic insight into the entangled ecological, weather and climatic narratives that ensued in place, explained through a medium of multispecies storytelling. Importantly, the discussion relates to the notion of care, and how the SunSpider's form and function fostered an emotional attunement between the human and non-human study participants. The central question to this study is thus – *How might a relational adoption of solar PVs increase multispecies flourishing?* The article culminates in the explanation of 'solar ecologies', which offers a point of departure in exploring relational complexities in co(living) *with* solar PV – and solar energy symbolically, at large.

1. Introduction

Due to the nature of the study (its intimate proximity and epistemological standing), I adopt a first-person perspective and voice to the narration of this study. *Solar Biota* is a multispecies ethnographic research study carried out over five months within an intimate domestic context (i.e., the personal setting of my home). *Biota*, as part of the project's name, signifies a direct focus on the (co)constitutive ecology of flora, fauna and fungi that live and flourish *with*, and alongside, the SunSpider – a temporarily installed solar photovoltaic (PV) prototype – on the Thuja tree in the front lawn. The study seeks to understand and appreciate the tensions and alignments between *things* and naturecultures, while seeking to disintegrate the binary separation of the two – specifically in relation to solar PVs. The central question to this study is thus – *How might a relational adoption of solar PVs increase multispecies flourishing?* The resulting storytelling of the experiences from the study is based upon my human positionality, as I embrace my human ethico-onto-epis-tem-ology (Barad, 2008); the inseparability of my ethics, ontology and epistemology in scientific knowledge production. Thus, in the Method section, I clarify my journey from sensitising the body to the visceral sensorial confrontations with the SunSpider in order to aid in the understanding and storytelling of its co-constitutive surrounding solar ecology.

Concerning the SunSpider prototyping, its form solidified over a process of iterative tinkering, which is explained further in the section on Prototyping. After which, I continue to explain the installation of the SunSpider in the Thuja tree on the front lawn, and document its unfolding, entangled narrative with weather and seasonality, and with its multispecies companions (such as the Great Tits and the Eurasian Magpie birds). These findings lead to reflections upon the theme of care, its accompanying tensions and politics, states of "*living*" in reference to technologies, and discussion on an emergent sense of responsibility *to care*. Finally, I elaborate on the term *solar ecologies* and conclude why studying its (un)formation processes is essential to providing richer meaning to the future of PV design and global decarbonisation efforts.

2. Being (More-Than-)Human: A Method in Itself

> The human body, with its various predilections, is, to be sure, our inheritance, our rootedness in an evolutionary history and a particular ancestry. Yet it is also our insertion in a world that exceeds our grasp in every direction, our means of contact with things and lives that are still unfolding, open and indeterminate, all around us. Indeed, from the perspective of my bodily senses, nothing appears as a completely determinate or finished object. Each thing, each entity that my body sees, presents some face or facet of itself to my gaze while withholding other aspects from view.
> (Abram, 1997, p. 49)

In *The Spell of the Sensuous*, David Abram (1997) discusses ecological philosophy emerging from the human senses' reflective, intimate, and sensitive use. Such intentional use of the senses resonates with the art of "noticing", as coined by posthumanist thinker Anna Tsing, who posits a method and mode for how society might descale our senses and our thinking to embrace the power of observation and natural history

to grasp better the fragility and contingency of human and nonhuman survival (Latour et al., 2018; Tsing, 2015).
The human body – with all our senses – remains certain as a starting point for more-than-human sensibilities and awareness, which is a necessary tool in multispecies discovery and storytelling. The boundaries between the human and nonhuman are, as Abram (1997) expounds above, "unfolding, open, and indeterminate", and in this particular occasion, the making and interactions with the SunSpider is part of this evolving process.

This study utilises such posthumanist thinking as a bedrock, upon which a multispecies ethnography is performed to gather data. Multispecies ethnography as a method, represents a more-than-human approach to sociocultural anthropology that asserts that we cannot adequately understand humanity in isolation from nonhuman species entangled in human life (Locke, 2018). It is concerned with the limitations of anthropocentric thinking, and recognises the agency of nonhuman species in how they are socially, historically, and ecologically intertwined with the environments moulded and shared by humans and other earthlings; what Kohn (2013) defines as "anthropology beyond the human." In other (simpler) words, "humans cannot survive by stomping on all the others" (Tsing, 2015, p. vii).

This multispecies ethnography study with the SunSpider is rooted in a four-year doctoral journey on understanding the relationality of solar energy. The dissertation explored embodied, sensorial and emotional perspectives on human-solar relationships (Törnroth, 2023). This more-than-human approach was drawn from the will to appreciate things and materials as more than isolated, static items – rather, to be lived with and experienced. Diverse theoretical perspectives also recognises such vitality of materials (Bennett, 2010; Ingold, 2007) and also the significance of *things* in framing and participating in everyday experiences (Miller, 1987). Things, here, being referred to as active objects of engagement as opposed to passive objects of fascination (Ehn, 2008). These perspectives raise important epistemological and methodological questions on how the non-verbal, latent, and tacit properties of things (in relation to the social and biophysical worlds around them) may be experienced, captured, and studied (Woodward, 2016).

The multispecies ethnography of this SunSpider was, in practice, carried out daily over the span of approximately five months (December 2023 to April 2024). I practiced undisturbed observation from my kitchen window every morning ranging between the times of 8am to 10am, and approached the Thuja tree to perform direct sensorial confrontations – if weather and conditions permitted – around noon daily. In the night, I would often visit the tree once again between the times of 6pm to 10pm, to check if the SunSpiders' lights have lit up. When days with longer daylight approached (beckoning the Summer months), I had to increasingly delay my visitation until it was completely dark outside (i.e approximately 10pm). I would often photograph, film and audio record moments and situations I found particularly interesting, fascinating, or poignant in some way. For example, I filmed the SunSpider as it swayed, detached and broken, in the blistering winds of Storm Ingunn. I audio-recorded The Great Tits' song on numerous occasions and documented temperature readings from the local thermometer. I wrote field notes to immediately document how I was feeling, the weather, what I saw, smelled, heard, touched, and the conditions of the tree, and other multispecies companions. In line with qualitative traditions, *thick* and *rich* descriptions within the study, was considered key (Merriam, 1988). For a detailed overview of the observations, refer to Table 1.

	December 2023	**January 2024**	**February 2024**	**March 2024**		**April 2024**
Morning observation	9 to 10am (Sunrise ranged between 9.09 to 9.55am)	8 to 9am (Sunrise ranged between 9.50 to 8.29am)	8 to 9am (Sunrise ranged between 8.25 to 6.45am)	8 to 9am (Sunrise ranged between 6.41 to 4.52am)		8 to 9am (Sunrise ranged between 5.45 to 3.54am)
Afternoon observation	11am to 12pm	12 to 1pm	12 to 1pm	12 to 1pm		12 to 1pm
Night obser-vation	6 to 7pm (Sunset ranged between 1.30 to 1.04pm)* *Winter solstice occurred on 22nd December	7 to 8pm (Sunset ranged between 1.19 to 3.05pm)	7 to 8pm (Sunset ranged between 3.04 to 4.43pm)	7 to 8pm (Sunset ranged between 4.47 to 6.20pm)		9 to 10pm (Sunset ranged between 7.27 to 9.04pm)
Monthly temperature	High: 2 °C Low: -20 °C	High: 6 °C Low: -37 °C	High: 5 °C Low: -30 °C	High: 6 °C Low: -20 °C	**Daylight savings time shift**	High: 9 °C Low: -19 °C
Main data collected	Photographs of SunSpider's prototyping process, placement in the tree, and illumination in the darkness. Field notes: Reflections on the tinkering process and on the daily sensorial con-frontations.	Attempts at capturing the Eurasian Magpies and the Great Tits on photograph, film, and audio recordings. Field notes: Reflections on the harsh winter conditions and how the snow and ice build-up affected the SunSpider's operation and inhibited op-portunities for daily sensorial confrontations.	Filming the affects of Storm Ingunn on the Thuja tree and SunSpider. Field notes: Attempted res-torations and maintenance of the SunSpider in place, after destruction from the storm.	Photograph, film, and audio recordings for early compari-sons from when the SunSpider was initially placed. Field notes: Daily sensorial confrontations, particularly over the health of the Thuja tree due to low temperatures and heavy snow build-up.		Photograph, film, and audio recordings. Field notes: Daily sensorial confronta-tions and final reflections on the changes that occurred in the SunSpider and its situated ecology.

Table 1. Detailed overview of observations, weather conditions, and data collection.

Figure 1. SunSpider form and placement within the Thuja tree.

3. Prototyping the SunSpider

Humans have, over time, co-evolved with things – that we are "prosthetic creatures" so tied to technology, matter, and nonhuman beings that these are essential parts of our identity, culture, and behaviour (Wakkary, 2021; Wolfe, 2010). The making of the SunSpider was thus motivated by a combination of considerations (Fig. 1):

- to mimic a recognisable earthling by form to create a parallel to the state of "living";
- to design something discrete that could blend into the pre-existing and situated (solar) ecology;
- something accessible and tangible to the everyday human (myself);
- to show the basic functionalities of the solar panel (i.e., the LED lights that turn on and off);
- a form that provokes a question of how solar energy technologies might exist in our living environments.

To build the SunSpider, I followed iterative rounds of *tinkering* (Mol et al., 2010) with aluminum metal wires, LED lights, and basic electrical engineering within the solar panel device, which I had purchased as a ready-made solar module giving 2W. Tinkering is a practice of "attentive experimentation" (Mol et al., 2010, p. 13) that focuses on making things work on a day-to-day basis – to *do* while thinking so that materials might *talk back* to us (Schön, 1983) and that we might learn from them; iteratively stumbling forward. Persistent tinkering is a messy yet creative process, especially suited to "a world full of complex ambivalence and shifting tensions" (Mol et al., 2010, p. 14).

It is often utilised as a form of exploration and discovery within technoscience topics due to the necessary initial process of familiarisation, learning, adapting, and attuning to seemingly detached and strange technologies (Kirksey et al., 2014; Lindtner & Avle, 2017).

Tinkering was necessary for this process as well because I iteratively experimented on the form of the SunSpider – its function,

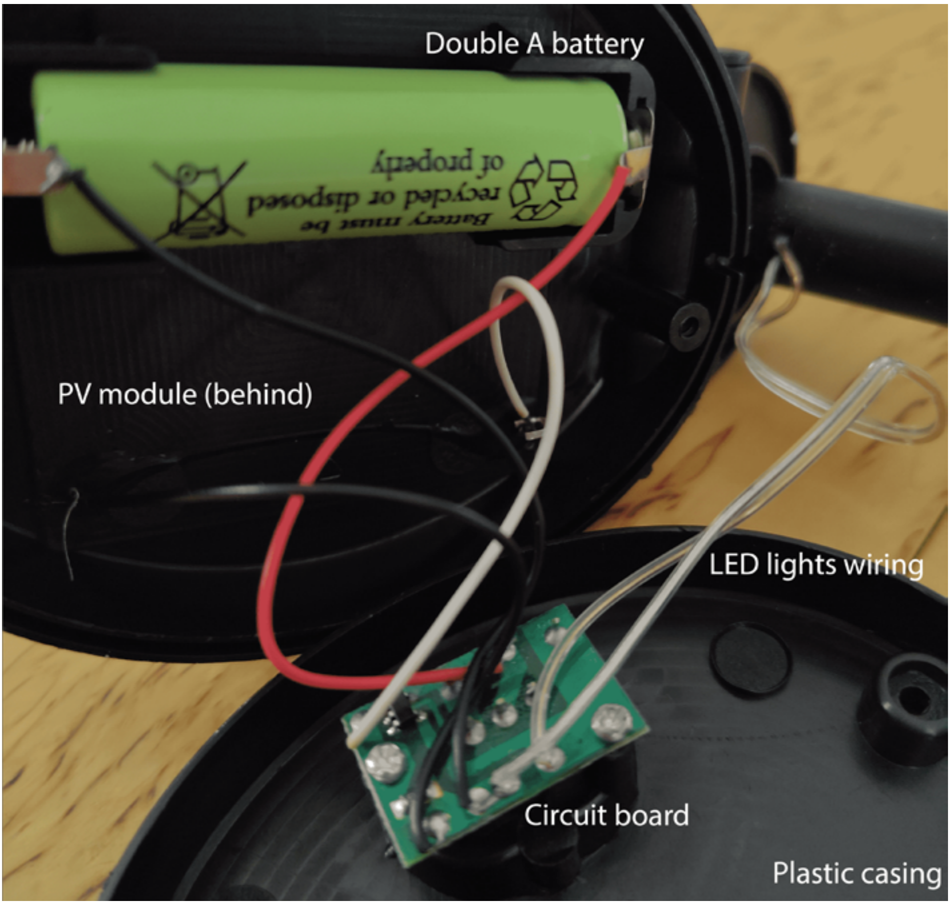

Figure 2. Detailed PV system set up within the computing body of the SunSpider.

however, was clear to me from the start; the underlying intention was to symbolise a state of "living" through the LED lights turning on after a day of solar access. After some time, I finally understood how to secure the solar module to the LED lights and aluminum metal legs. The solar module was connected to a double A battery, and the wiring for the LED lights was via a circuit board (Fig. 2). I then successfully tested the SunSpider's operation with artificial UV lamps I had at home. The process took two days to design and test before it could be installed outside in the Thuja tree. I then created a second SunSpider and installed both prototypes in the Thuja tree, close to one another, to increase the chances for a longer survival of either one. The SunSpider invited its name through its form, with a central computing body with eight malleable metal "legs".

4. (Co)Living with the SunSpider: A Storytelling of Experience

In this section, I describe, through storytelling, the results of the five-month-long experience. I attempt to build a vivid imagery of the process through thick descriptions, in order to situate the reader in place. I do not, however, attempt to speak for my multispecies companions, for fear of running the risk of being a ventriloquist – a consistent debate within multispecies storytelling (Kirksey et al., 2014). Therefore, I situate the multispecies storytelling from my own sensorial experiences borne from this ongoing relationship.

4.1. "Together We Are Weathering the World"

I lived with the SunSpider for over five months, between December 2023 to May 2024. The seasons changed, from the darkest night, the winter solstice, to when daylight becomes longer at the spring equinox. Living in the subarctic, according to the Köppen Geiger climate classification system, meaning that the coldest month averages below 0°C or – 3°C and only a mere 1-3 months averaging above 10°C. The coldest recorded temperature where the SunSpider was installed was – 35°C, and that was in February 2024. Precipitation in the form of snow had the largest impact on the tilt and exposure of the SunSpider to solar access. On days with high snowfall, the SunSpider would often be covered with snow, so it does not receive any solar access, and therefore, its LED lights would not illuminate at night. The branch that the SunSpider's "legs" wrapped around would also tilt downwards due to the weight of the snow, and the SunSpider – already covered in snow – would receive negligible solar energy due to the position of its solar panel (Fig. 3).

In the colder winter months, I was forced to resort to window-watching for extended periods of time, where I would then film and capture moments through the transparent glass barrier, in the comfort of my own home. The relationship to the prototype here was purely visual, juxtaposing the background of warmth and light of my home to the biting cold and darkness outside. On the 20th of February, at –25°C and after a week of temperatures below –25°C, the LED lights on the SunSpider had not lit up for over a week. It was difficult to locate the prototype in the dark to watch it, and the prototype continued to remain hidden among the tree branches for another week until warmer temperatures and sunnier days arrived. In this period, I found myself watching the Thuja tree instead, where the SunSpider resided on.

Figure 3. Snow build-up on the Thuja tree affecting tilt of the SunSpider and access to sunlight.

How it swayed in the wind, how it captured snowflakes where their branchlets were densest, how its branches fractured under the weight of heavy snow, and how its morphology fluidly shifted between a cone-shape to the shape of a blossomed flower as snow collected, drifted away, or melted. Such visual appreciation of the SunSpider's living environment was important understanding the entangled existence in which the SunSpider, the Thuja tree, and my multispecies neighbours, live in.

Figure 4. SunSpider illuminating in the darkness.

When Storm Ingunn hit in January, the SunSpider was put to a different meteorological test: strong winds. One of the two prototypes of the SunSpider expectedly lived a much shorter life than the other; the winds had dismembered it. The attached solar PV panel fell to the ground while the LED "legs" continued to wrap themselves on the tree branch. I tried retrieving the broken panel but was blocked by a wall of snow and ice. When the warmer months approached, with some days providing temperatures above 0°C, the snow began to melt quickly. This allowed the solar panels to be exposed to sunlight again and began illuminating at night (Fig. 4). The snow wall between myself and the broken prototype began melting – yet not enough to access the broken panel. It was clear that the weather and climatic factors played an essential role in determining the electricity production for the LED lights to illuminate and how I could approach and interact with the prototype.

As warmer months followed, I could conduct my ethnographic activities up close, through sensorial confrontations. These sensorial confrontations included approaching the tree daily to smell it. It would often carry the identifiable smell of fresh, crisp winter air, hinted with musky undertones. I would also approach the tree to gently examine its branches and leaves, particularly looking at the health of the branches on which the SunSpider was wrapped on. Through this, I appreciated its hardened skin and robust bounce on which birds and the SunSpider would make their homes. Running my fingers on the bumpy branches, I noticed the leaves are arranged like a flattened fan, decorated with miniature cones, which, upon researching, are identifiable traits of the Thuja tree.

The season's warmth afforded me this privilege: to stand outside for extended periods, to *notice*, linger and appreciate. Akin to Neimanis and Walker's experience, "we are not masters of the climate, nor are we just spatially "in" it. As weather-bodies we are thick with climatic intra-actions; we are makers of climate-time. Together we are weathering the world," (2014, p. 558).

4.2. My Multispecies Neighbours

My multispecies neighbours, as I call them, were many. I focused my observations on three species of earthlings that emerged and were present most visibly throughout the five-month study. The *Great Tit (Parus major)* family takes residence in the Thuja tree in front of my house, on which the SunSpiders were installed. The Great Tit is a small passerine bird in the tit family Paridae, and they commonly do not migrate except in extremely harsh winters. I learned that they are mainly insectivorous in the summer but will consume a broader range of food types in winter. The *Thuja* tree, on which the Great Tit resides, is a genus of coniferous tree or shrub in the Cupressaceae (cypress family). Thuja species are used as food plants by the larvae of some Lepidoptera species, which includes the autumnal moth and the juniper pug – both of which exist in subarctic Sweden. Occasionally, the *Eurasian Magpie* or common magpie (Pica pica) visits the Thuja tree, asserting dominance by aggressively confronting the Great Tits that reside in it. The Eurasian Magpie is one of several birds in the crow family (corvids), and they are known to be intelligent – it is believed to be one of the most intelligent of all non-human animals (Prior et al., 2008). Magpies are often sedentary and spend winters close to their nesting territories. However, those that live near the northern limit of their range, such as in Sweden, Finland, and Russia, might move south during harsh winters.

With a longer study period, I would have liked to *notice* a little deeper – additionally, the vast microbiome that makes up the Thuja tree. On the morning of the installation of the two SunSpider prototypes (December 20th 2023), the family of Great Tits (Parus major) that live in the Thuja tree on my front lawn exuded apprehension. They dispersed in their usual fashion, watching me from afar as I walked towards the Thuja tree and installed the SunSpider prototypes, carefully wrapping each branch with the SunSpiders' legs. They did not return to the tree for a few days after that, which was unusual for them. I had feared that my installation – no matter how seemingly inconspicuous – had caused a disruption and disturbance to their everyday lives. Finally, after five days of watching and waiting every morning, they returned to the tree. They were noticeably hesitant; they did not hop around as easily as they usually did and stayed far away from the affected branches. After 20 minutes, one brave Great Tit slowly approached a SunSpider, one small hop at a time. Upon nearing it, it paused and then pecked cautiously on the SunSpider's malleable metal legs. Soon after, the bird relaxed and continued its usual routine. This distinctive realization changed the course of the Great Tit's life for months to come – almost every day after that, the Great Tit sought something amongst the SunSpider's metal legs. I suspect that the SunSpider's legs had provided a feeding ground of larvae for the Great Tit to feast on, as the birds often spent extended periods with their beaks down, rummaging between the legs of the SunSpider. Unexpectedly, the metal legs that consist of tiny cracks and crevices might serve as protective spaces against the harsh winters, thereby creating local microclimates in which microbiomes (such as the Lepidoptera larvae) might flourish. Additionally, it appeared as if the SunSpider's legs provided a good grip for the Great Tit to cling to as it sat, watching, from the tree (Fig. 5).

Figure 5. A Great Tit perches on the SunSpider's legs.

Apart from spotting the territorial behaviour of the Eurasian Magpie family that often visits the Thuja tree during the first week of the SunSpiders' installation, I had not seen them for the following four months. I believe they have migrated south to avoid the harsh winter – temperatures in February 2024 dropped as low as -40,8°C in the Sápmi mountain regions, with average temperatures being the coldest since ten years ago (SMHI, 2024). However, in the final week of April 2024, I heard them singing as I stood in my kitchen. I looked outside, and alas, they had returned. The snow was melting, the temperature was an average of above 0°C that week, and the sun had come out. Their bird song was identifiable: a low but loud and harsh, repetitive chattering, not unlike someone viciously shaking a rattle. *Chak-chak-chak*, they go. Sometimes followed by a higher-pitched descending squealing sound. These were not necessarily pleasant sounds, but I greeted and welcomed the birds back anyway into our situated solar ecology. They, however, remained ever cautious of the SunSpider – never approaching it.

5. Discussion: Interventions of Care? Centralising Relationality in PV Design

The distinction between lively biological and intrinsic processes of the Thuja tree, the Great Tits, and the Eurasian Magpies was in stark contrast to the rigid, dual states of the SunSpider's "living." Its LED lights illuminated at night and showed successful solar energy absorption during the day – or the simple opposite, where its LED lights did not light up. These two states were synchronised to daylight and the night's darkness, drawing parallels to a biological circadian rhythm. "Living", for the Sun-

Spider, was purely functional – it did not fear predators, it did not feel hunger or thirst, and did not reproduce. Yet, it continued to survive, alongside complex earthlings, by the whim and instruction of the human – in this case, myself. There has been a sentimental dimension of needing to care for it – I needed to perform activities to ensure its "living". There was a clear emotional investment, not unlike the feeling one gets to protect and care over something valuable. For example, I brushed off snow from the solar panels on days of heavy snowfall to facilitate solar access and picked up pieces of the prototypes that fell on the ground and restored them (when possible). It was the continuous process of tending to the SunSpider that I noticed was in direct contrast to the naturally occurring, robust survival of the other multispecies companions. Human *care* and intervention seemed necessary to keep this technology alive. Technologies, in a broader sense, can get lost, break, and deteriorate – in the words of Mattern (2018), "[n]ow breakdown [of technologies] is our epistemic and experiential reality" (np.).

However, I reflected on the intrinsic yearning to care – was it my *responsibility* to care? At the very least, I recognise and acknowledge the traditions of care that normalises invisible labour – women's work, domestic and reproductive labor, and all acts of preservation and conservation, formal and informal (Mattern, 2018). Beyond that, romanticising maintenance and repair is also dangerous, because:

> Care is a selective mode of attention: it circumscribes and cherishes some things, lives, or phenomena as its objects. In the process, it excludes others. Practices of care are always shot through with

> asymmetrical power relations: who has the power to care? Who has the power to define what counts as care and how it should be administered? (Martin et al., 2015, p. 627)

But care, in this scenario, went both ways. It was a bidirectional sense of duty: the SunSpider absorbed solar energy and gave life to the LED lights, provided a feeding ground and a gripping surface for the Great Tits, and offered a sense of warmth and solace during cold and dark winter nights. Thus, to respond to the central question to this study – *How might a relational adoption of solar PVs increase multispecies flourishing?* – the SunSpider took lead from the Thuja tree: it did not impose itself. It was malleable and inconspicuous, weaved delicately across branches so as to not impede solar access to the Thuja's leaves. Its gentleness and fragility were perhaps a direct contrast to the rather large and rigid solar PVs often seen around human living environments, thereby presenting a more relational way of designing PV. It is also perhaps this gentleness and fragility that had invited the fostering of a sense of care – for myself to care over its sustainable use and life, and for the SunSpider to, in turn, care for its situated ecology by enabling ecological flourishing through its sensitive embeddedness. It belonged to an environment larger than itself. Scaling up, this could inspire larger solar PV systems to be adaptable, approachable, and sensitive to flourishing: designed with relational thought in the centre. For example, agrivoltaic systems – solar parks that combine agricultural food production with large-scale solar PV production, signal a step forward in this direction. However, much more creativity, innovation and sensitive thought is required in developing this trajectory.

The SunSpider is a humble prototype preaching an appreciation and awareness of the interconnectedness of a solar ecology, its design open for re-development in different forms and scales according to the situated ecological context.

6. Conclusion: The (Un)Formation of Solar Ecologies

Unformation is not a word but signals something evolving– the potential formation and unformation of solar ecologies. It signals something temporary and ordered, even within a messy and chaotic context (i.e., solar ecologies). The word reflects an inherent relationship: as easily as the prefix *un-* is tagged on to indicate dissolution, can the central term *"formation"* still exist in a seemingly dichotomous parallel. It is this indeterminate association of living and non-living ways of being (Lorenz-Meyer, 2017) that make up the solar ecology. Solar ecologies are thus:

- a celebration of the vitality of materials (SunSpider's malleable LED legs);
- an invitation for multispecies interaction (e.g. The Great Tit);
- a microclimatic sanctuary and habitat (e.g. The Great Tit feeding off a SunSpider's leg);
- a light in the dark;
- a facilitator of circadian rhythms;
- an active collaborator *with* weather and seasons;
- and a participant in the human politics of care (e.g., emotional relationship with the human in context).

Engaging with the SunSpider attentively and longitudinally revealed the meaningful nuances in which solar PVs might offer human and non-human living environments, such that they are attuned to multispecies flourishing – as opposed to decontextualised and detached megastructures (i.e solar parks) (Wilhite & Wallenborn, 2013). An appreciation for solar ecologies is necessary for the latter to reorient production practices. A consequent question that logically follows is: *What powers might I – and society as a whole – as humans, have in influencing the narrative of solar ecologies in place?* It is the continued study of the (un)formation of situated solar ecologies, beyond this article, that will thus aid in the breaching of boundaries of current traditional PV design.

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From the *Cloud* to the Ground
A Data-Driven Research to Build Informative Heritage about Data Centres' Energy Footprint

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Abstract
By adopting a critical stance towards our technocentric times, the article reflects on the impact of contemporary digital transformation and infrastructures in the broader environmental and climate crisis debate, analysing the Internet's energy footprint. The Internet is often perceived as an intangible and weightless service, as represented by the popular *Cloud* metaphor. This common belief has generated a knowledge gap in users' minds: no correlation exists between digital activities and their footprint on our planet. However, the Internet is a massive network of infrastructures consuming vast resources, contributing significantly to global warming. The article aims to bridge this gap using data visualisation as a research method and design output. It summarises data-driven research with a two-fold output: mapping the known and unknown aspects of the Internet's energy footprint to support transparency and future reflections and identifying visual strategies in the design field for communicating complex information. The research promotes an open-data approach, highlighting the pivotal role of data in understanding the connections between human behaviour, technology, and the environment. Additionally, this type of research has the potential to influence public awareness, engagement, and policy-making, emphasising its broader implications for fostering a more sustainable digital future.

1. Introduction: The Hidden Weight of Digital Transformation

Societies of developed countries are currently experiencing profound digital empowerment, driven by the advent of 5G technology, the pervasive implementation of artificial intelligence (AI) and machine learning, and the extensive deployment of Internet of Things (IoT) devices. This transformation continuously increases data generation and traffic. However, the associated surge in energy consumption is largely overlooked. While networked technology promises to lead to more efficient use of resources, it concurrently masks the operations of an extensive physical infrastructure. This scenario shapes a society where humans become increasingly dependent on data while the connection between digital services and their material aspect is obfuscating. People use the Internet constantly and expect it to be accessible 24/7. However, many people fail to realise that their digital habits are linked to massive digital infrastructure systems that make the Internet possible and functional. In contrast to prevailing narratives and digital metaphors surrounding the Internet, such as the *Cloud*, our contribution explores the physical side of the Internet to materialise its connotation. Reflecting on the material implications of today's digital transformation and inquiring about the climate crisis from a systemic perspective, this article presents a data-driven project that aims to assemble an informative heritage about the Internet's energy footprint.

2. Research Context: Decoding the Internet's Energy Dilemma

In the world of unlimited data, people's lifestyles are increasingly characterised by online operations: businesses, governments and individuals are all persuaded to mass-migrate to an online lifestyle. People may think this is good for the planet, perhaps because they move less, but this does not mean that digital activities are without environmental impact. Whenever we do anything online, such as storing data, watching a movie, participating in a video call, or sending an email, we use resources, consume energy, emit CO2, and leave behind environmental footprints. According to the issue *The Real Climate And Transformative Impact of ICT: A Critique of Estimates, Trends, and Regulations* (Freitag et al., 2021), global greenhouse gas (GHG) emissions from the Information Communication Technology (ICT) sector are between 2.1–3.9%. This wide range considers the divided forecasts published by the most reliable studies on the future trend, as shown in Fig. 1, that reveal the uncertainty around the phenomenon.

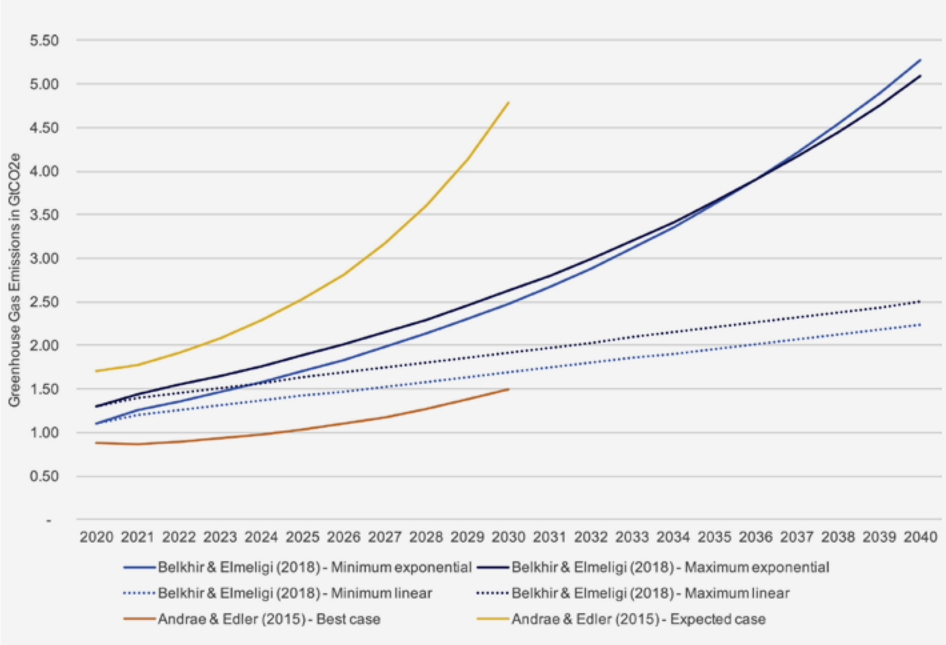

Figure 1. A comparison of different projections of ICT GHG emissions from 2020 according to current literature (Freitag et al., 2021).

The data visualisation project *Dirty Cloud* (Simonetta et al., 2021) is an effective information artefact that makes the current GHG estimates more familiar to the public. By visualising data from the *Global Carbon Atlas* (*Global Carbon Atlas*, 2022), it compares the GHG emissions of the Internet to countries, pointing out that if the Internet were a country, it would fall in the top five after China, the United States, India and Russia. How are the tonnes of CO2 produced when people use digital products and services? The connections between actions and consequences when using digital products are well communicated by Joana Moll's projects titled *CO2GLE* (Moll, 2014) and *DEFOOOOOOOOOOOOOOOOOOOOOREST* (Moll, 2016). In a minimal interface, these digital products show in real-time the amount of CO2 generated by Google requests and the number of trees needed for their compensation. They explore how to trigger thoughts and actions, highlighting the invisible connections between the uses of digital communication technologies and their consequences. In this article the authors exploit the capacity of data to provide an outlook into complexity by adopting a data-driven perspective on an uncertain and unexplored phenomenon. As said by Jussi Parikka in his book *A Geology of Media* (Parikka, 2015), to understand contemporary media culture, we must look for those material realities that precede media themselves, such as the energy on which media depends. An online purchase, a WhatsApp message, a streaming movie, or a chat with chatGPT are examples of online services that respond to our requests via the Internet. When users make a request, a network of infrastructures is activated, allowing it to travel across links and nodes to the source that contains the answer.

The data capable of satisfying the request is stored in special computers, called servers, that send back a response based on the personal account, data and content. The server involved in the request is located in buildings called data centres and thousands of others. In addition to the servers, these contain various components designed to operate and monitor them: power systems, uninterruptible power supplies, ventilation and cooling systems, fire suppression systems, and connections to external networks. Due to anonymous architecture and missing standards, their polluting qualities are far less visible than the billowing smokestacks of coal-fired power stations. However, according to the International Energy Agency (IEA), the data centres industry consumes around 1-1.5% of global electricity use (IEA, 2023). It is growing steadily, driven by the high demand for computing power, especially for artificial intelligence, but there is no complete picture of its dimensions. Data centres are the new bedrock of our digital economy and society, and they are playing a silent and crucial role in the Internet's energy consumption: they are one of the most energy-intensive building types, consuming 10 to 50 times the energy per floor space of a typical commercial office building. Data centres as energy-hungry facilities are the framework of our research. The high energy footprint of the Internet calls for a redefinition of the topic based on a shared value system and new forms of communication and awareness. In this perspective, data visualisation can be a lever for action and innovation: the fragmentary and scarcity of data represents a research opportunity to investigate the current level of available data and contribute to increasing knowledge of the Internet's energy footprint.

3. Research Workflow: A Data-Driven Methodology

This research adopts a Research-Through-Design (RTD) (Gaver, 2012) approach to address the underexplored phenomenon of the Internet's energy consumption, an emerging and underexplored phenomenon, engaging stakeholders from various backgrounds. Given the complex networked infrastructure, including the challenging assessment of energy consumption, a proxy observation is necessary. Therefore, this study focuses on data centres, which are highly energy-intensive and core to the Internet's infrastructure. The study aims to identify design strategies to create visual artefacts that raise awareness among young adults, especially those in higher education disciplines heavily reliant on the Internet or directly involved in its development at various levels. Examples include design students whose work is significantly influenced by the digital realm. The research is structured into two primary methodological approaches due to the fragmented and unevenly documented nature of the subject. The first approach is data-driven, assessing the current knowledge and availability of data on data centre energy consumption. This phase seeks to answer the question, *How much data about data centres' energy footprint is available globally?* The findings from this stage are crucial for establishing a baseline of existing data and are detailed in Section 4, *Unveiling Physicality*. The second approach analyses how data centres are represented in digital media. Understanding how data centres are portrayed online required a data design phase in which suitable methods were necessary to capture this wicked phenomenon. *Digital Methods* (Rogers, 2023) are emerging approaches rooted in media studies and sociology, increasingly adopted in the design field, which views web platforms as societal proxies. In other words, when events or innovations impact society, their effect on the public debate leaves traces on the web, and therefore, it is possible to collect this data as a source of knowledge about the topic. This approach acknowledges the biases related to web platforms as ephemeral media and as economic actors interested in the topics they promote. We drew inspiration from studies on image circulation (Colombo & Niederer, 2021) by examining which images news articles use to depict data centres. Due to the need for a visual compendium to promote news on social media, news outlets are compelled to illustrate each article with an image.

But what kind of image is appropriate when discussing data centres? Photos of infrastructure, sci-fi collages, or portraits of people owning such infrastructure? The research question guiding this second exploration is, *How do Google News' top 100 sources visually represent the data centres' energy footprint?*. The results of this phase are described in Section 5, *Framing Dilemma*. The combination of these two data collection phases informs the design of printed visual artefacts aimed at the target audience. These artefacts, discussed in Section 6 and illustrated in Fig. 2 and 3, are intended for dissemination in academic settings or exhibitions to spur scholarly discourse and encourage proactive engagement with the environmental impacts of digital technologies. By integrating data-driven insights and media analysis, the research not only sheds light on current understandings and gaps but also lays a foundation for future investigations into the environmental entanglement of the digital age.

Figure 2. Cover of the printed artefact (Authors, 2022).

Figure 3. A section of the booklet showing the energy consumption of data centres in different countries (Authors, 2022).

4. Unveiling Physicality: How Much Data about the Data Centres' Energy Footprint is Available Globally?

This section introduces a visual strategy designed to map and understand the global data availability and distribution of data centres. It aims to reveal the physicality behind the digital veil that often obscures our understanding of the Internet, starting from the following research question: *How much data about the data centres' energy footprint is available globally?* In a world where digital infrastructure plays an increasingly critical role, the environmental impact of data centres remains a complex and controversial issue. As outlined in the introduction, the focus on data centres provides an entry point for a better understanding of this vast and intricate phenomenon characterised by the need to ground abstract digital phenomena in tangible, measurable terms. Despite digital corporations' lack of obligation to publish data about data centres, this research leverages the *Datacente.rs world map* – a comprehensive infrastructure dashboard with information on 6,242 data centres – to gather valuable insights. Key metrics such as white space (space allocated for information technology equipment) and gross power (total electrical output) are identified as recurrent and closely linked to the energy consumption of buildings. By adding a geographical component to these two metrics, the first strategy maps the available and unavailable data across countries and regions, generating a final dataset that includes region, country, the total number of data centres, available and unavailable white space and gross power data. Two visual outputs are generated: a scatter plot representing global data availability by region and a multi-set stacked bar chart illustrating data availability by country.

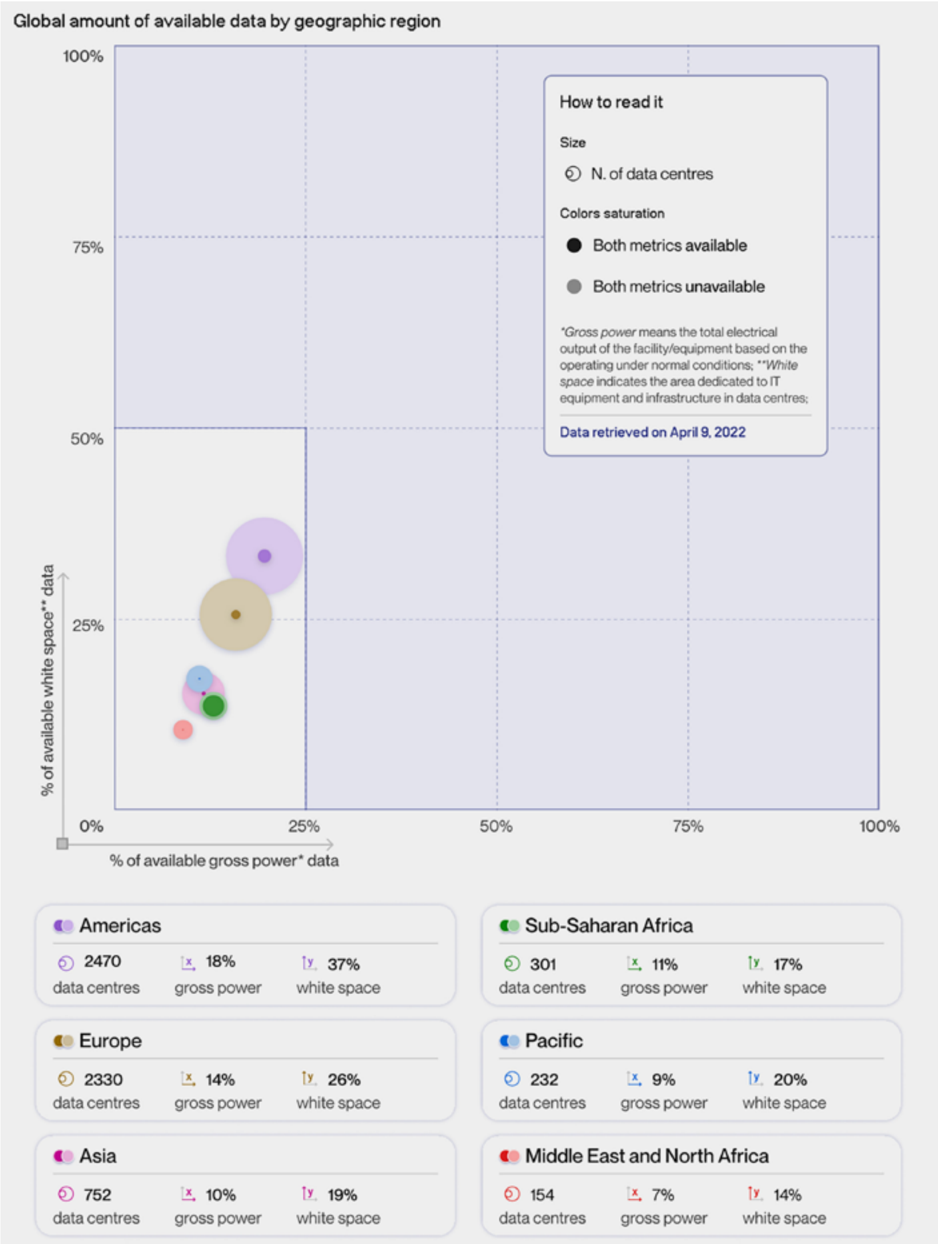

Figure 4. Visualisation correlating the number of data centres and the data availability in terms of white space and gross power per geographic area (Authors, 2022).

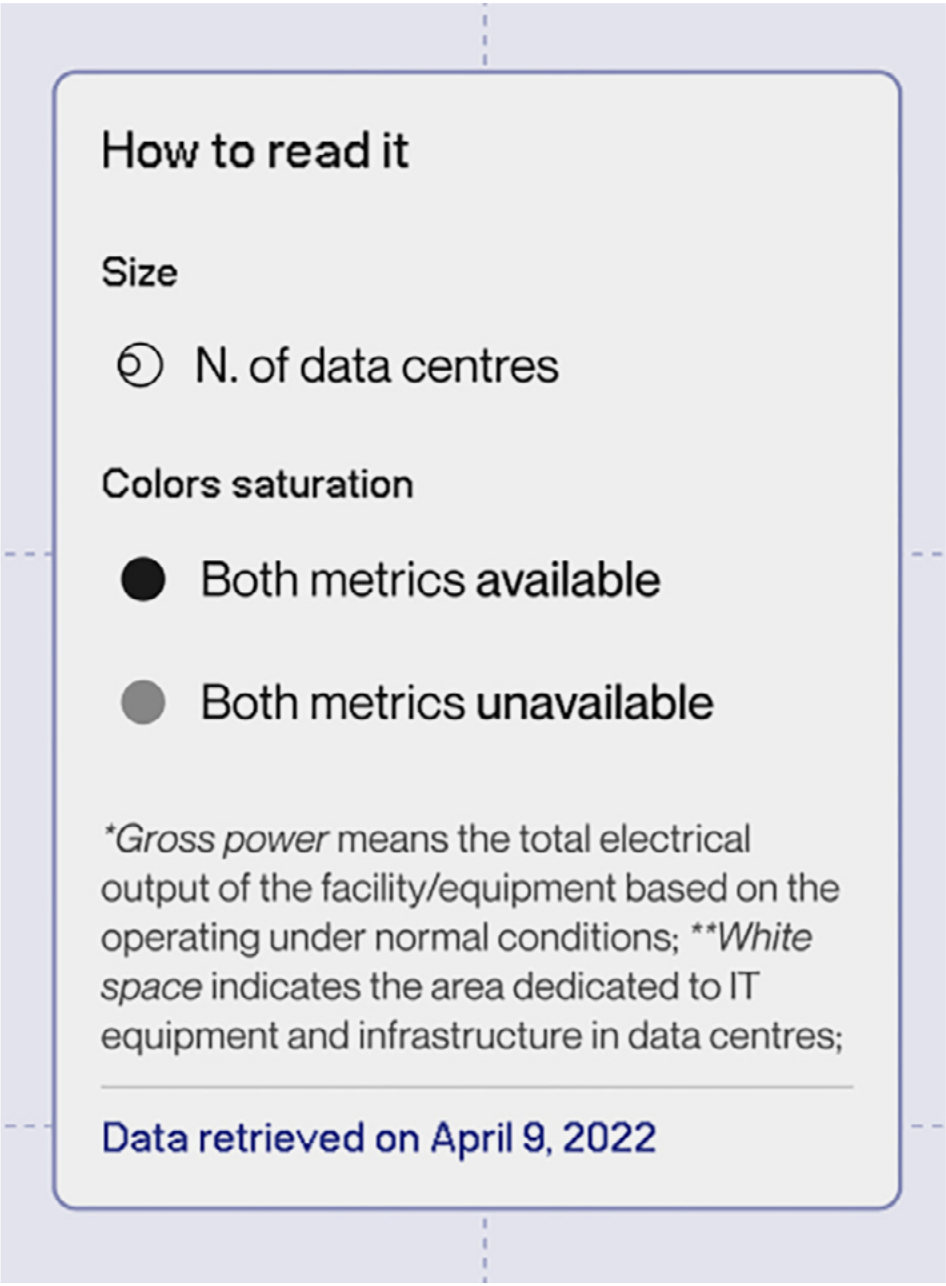

Figure 5. Close-up of the visual model legend (Authors, 2022).

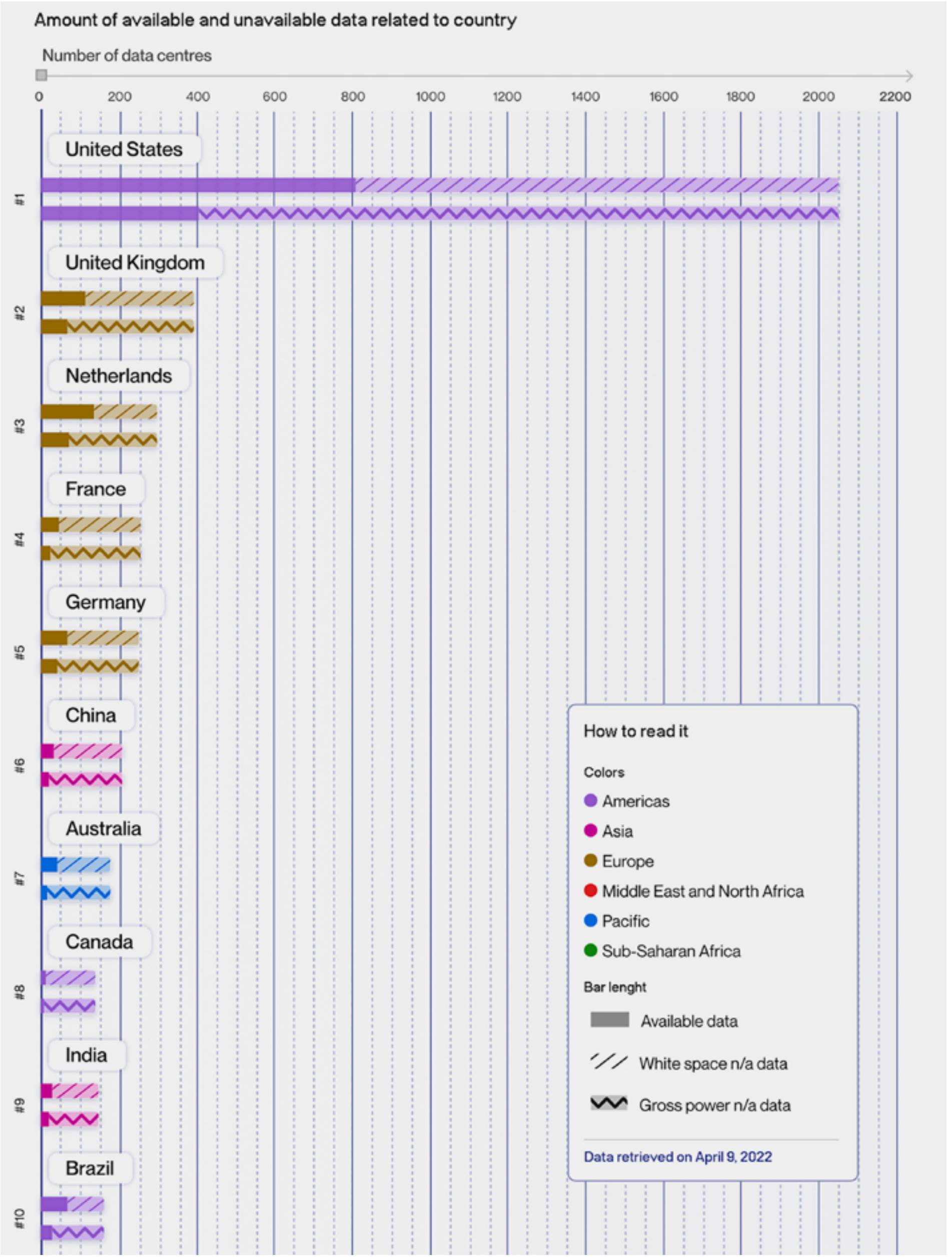

Figure 6. Section of the booklet showing the available and unavailable data in terms of gross power and white space per country (Authors, 2022).

Fig. 4 visualises the global amount of available data by geographical region. The six regions' names follow the Inter-Parliamentary Union (IPU) standards, each associated with a colour. To offer a macro-view of the phenomenon, the chosen visual model is a scatterplot. As visually explained in Fig. 5, each dot represents a region whose colour saturation changes according to the availability or unavailability of white space and gross power data. The dots' size changes according to the number of data centres located, and their position is the result of the correlation between the percentage of available gross power (horizontal axis) and white space (vertical axis) data. The linear grid below the scatterplot is divided into two sections: a white background highlights the area where region shapes are located, while the grey area is empty and does not host any data. The second visualisation in Fig. 6 shows the available and unavailable data related to the country. The chosen visual model is a multi-set stacked bar chart that visualises the number of data centres (horizontal axis) and the country name (vertical axis). Countries are ranked according to the number of data centres in descending order. The bar chart highlights the relationship between available and unavailable data for each metric, as detailed in Fig. 7, through different textures and colours. The information related to white space and gross power is divided into two bars to optimise readability.

This first visual strategy shows over 6,000 data centres across regions and countries. Still, the visualisation can only show a limited view as most data are unavailable. This snapshot is valuable because it highlights the urgency of accurately measuring the sector's impact.

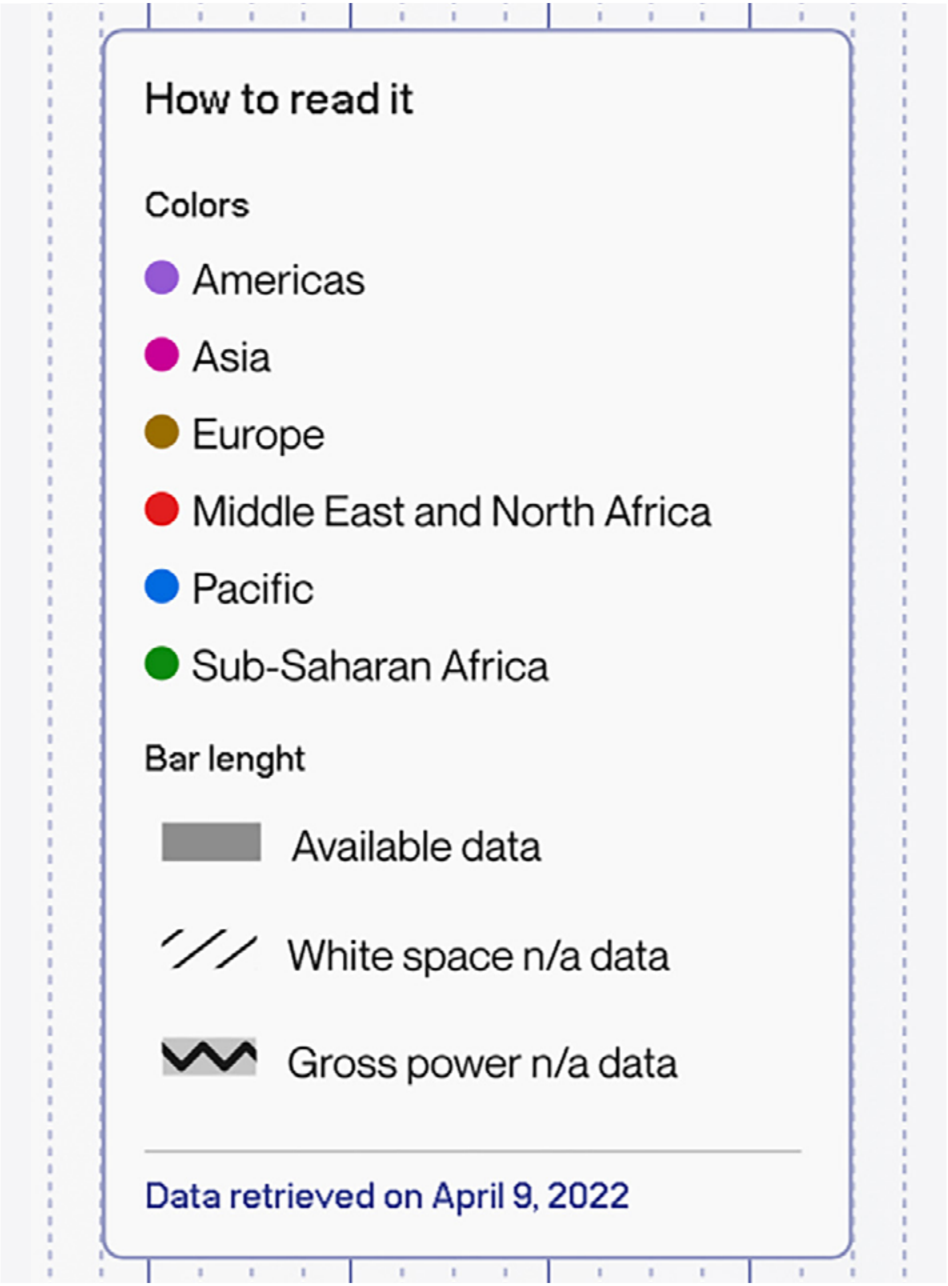

Figure 7. Close-up of the visual model legend (Authors, 2022).

This is consistent with the current concern among researchers and experts who believe it is difficult to measure the energy impact of these infrastructures, which are considered the core of the Internet itself. The output designed by authors serves as tools for unveiling the physicality of data centres, transforming abstract data points into tangible representations of their global distribution and environmental impact. By linking data centre metrics to physical locations, this research establishes a concrete connection between digital performance indicators and their real-world implications. While the visualisations offer valuable insights into data centre energy consumption patterns, they also underscore the challenges and gaps in data availability and the fragmented nature of the current landscape. From the authors' perspective, this visual strategy contributes to a more comprehensive understanding of the Internet's environmental footprint, laying the groundwork for future research and policy initiatives to promote sustainability and transparency in the digital age.

5. Framing Dilemma: How Do Google News' Top 100 Sources Visually Represent the Data Centres' Energy Footprint?

The second visual strategy delves into the challenges and complexity associated with representing the data centres' energy footprint to uncover patterns that shape the visual narratives surrounding the issue. With the escalating significance of data centre's energy consumption, digital media had emerged as influential platforms shaping public perception and discourse on the subject since 2018, when the first article was published on the Nature website under the title *How to stop data centres from gobbling up the world's electricity* (Jones, 2018).

The research involves a meticulous process of collecting and categorising visual content accompanying the articles sourced from Google News. Google News was chosen as the primary source due to its comprehensive coverage and accessibility. By querying “data centres’ energy footprint” on Google News in incognito mode, the authors selected and mapped the top 100 results according to the May 15, 2022, ranking, based on Google News’ algorithms that prioritise factors such as relevance, freshness, and user engagement. The incognito mode was employed to ensure unbiased results, free from personalisation and system preferences. The authors scraped online sources and collected information such as the sources’ links, typology, and depicted subjects. Automated tools, such as Cyren APIs, were utilised for website categorisation. However, the same approach was not feasible for identifying and clustering images’ subjects due to the inherent complexity and nuances in the visual content. This inability to recognise and categorise subjects consistently reveals the intricate nature of the framing dilemma faced in representing the data centres’ energy footprint visually.

In Fig. 8, the final visualisation reveals the relevance of images in this visual strategy. The main visual model is a photographic bar chart, with each bar representing a type of subject depicted in the cover images. In addition, each bar comprises stacked rectangles, the number of which determines their descending order. Each rectangle contains the cover image, converted to greyscale to give them all the same visual relevance, and a bar whose colour identifies the type of source from which the image was taken. This bar can be single or double, depending on the type identified by the API used.

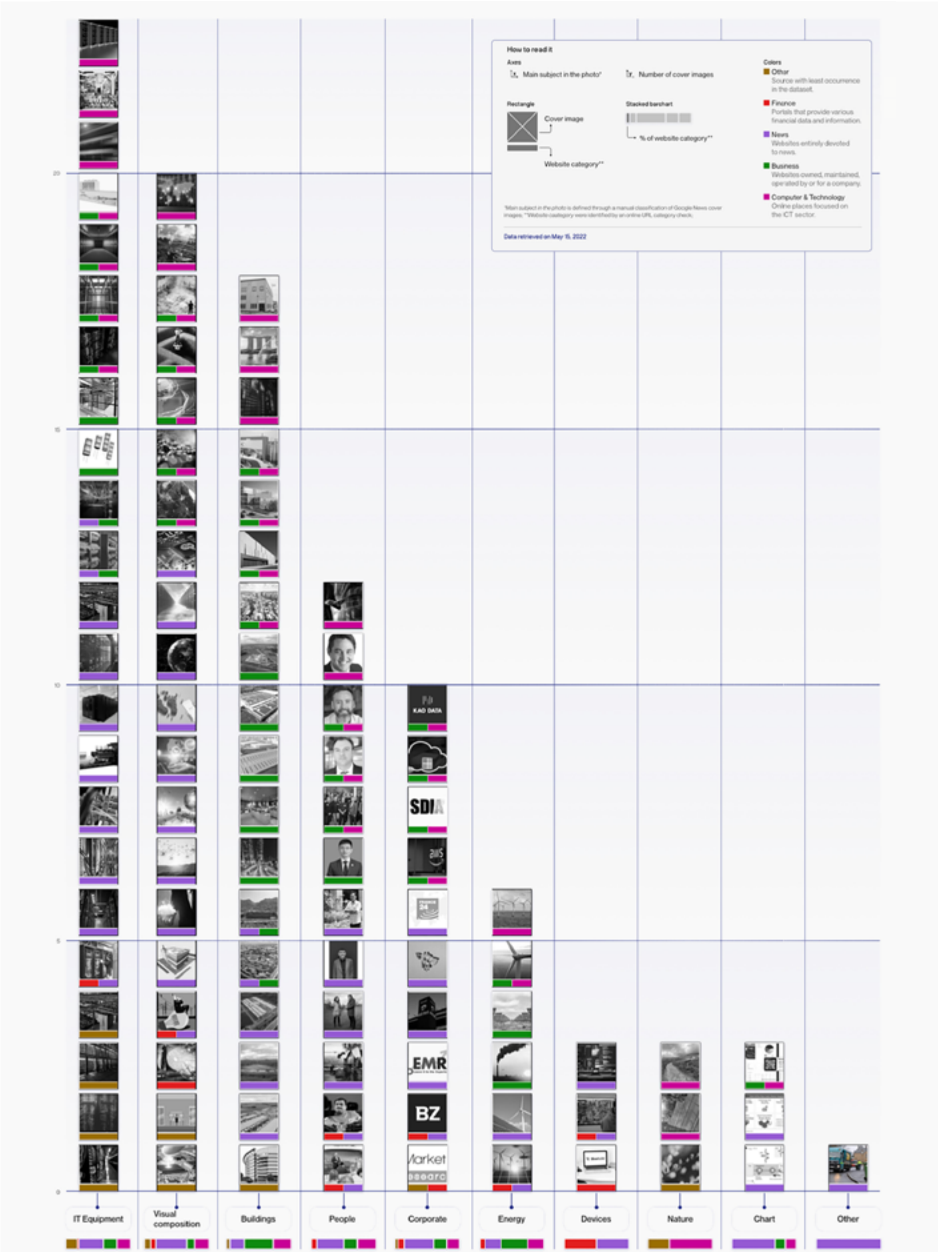

Figure 8. Visualisation of the distribution of Google News source typology and main topics according to cover images (Authors, 2022).

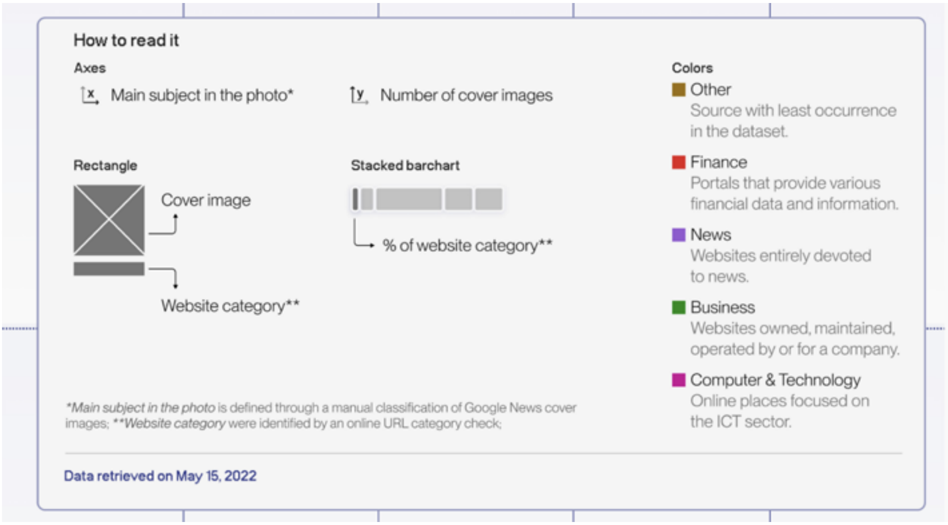

Figure 9. Close-up of the visual model legend (Authors, 2022).

The colour association is shown in Fig. 9, which details the legend. The legend also explains the meaning of the bar chart at the bottom of each bar, which shows the distribution of resource types according to the subject group identified. The second visual strategy provides a comprehensive overview of the recurring themes related to the energy footprint of data centres and the corresponding resources proposing solutions to address this issue. The findings reveal a heterogeneous scenario where visual compositions occupy the second position in the ranking after photographs portraying information technology equipment, such as the interior of server rooms or technical equipment. The first two columns of the analysis indicate a preponderance of resources related to the *News* category, highlighting the significance of the material-abstract contrast in reality. The proposed imagery is diverse and lacks a cohesive view of the phenomenon under consideration.

Unexpected clusters, such as *People* and *Corporate*, assume a prominent role and are very focused on individual subjects, while clusters more inherent to the query, such as *Nature* and *Energy*, collect a small number of images, indicating a potential gap in the visual representation of these aspects.

6. Discussion: A Cultural Shift in Data Centres Energy Awareness

This article discusses an ongoing research project aiming to understand the energy implications of our digital infrastructure. It does so through visualisations, as a design contribution to the understanding of the energy transition, not only as the issue of accessing better energy resources: in a *humanised* energy transition perspective, clarity and awareness of energy consumption is necessary both at individual and system levels. Through visualisation, the research offers insights into the challenges and complexity of visually representing the data centres' energy footprint and the *framing dilemma* faced in striking a balance between physical and abstract connotations of the technology systems we utilise every day. The findings contribute to the existing body of knowledge, highlighting the influence of visual narratives on shaping public perception and discourse on sustainability issues, of which Internet energy consumption is a case.

Future research may extend to visual narratives for public awareness, engagement, and policy-making. Through data collection and analysis, a lack of information about energy consumption related to digital activities emerges. The visualisations advocate for an open-data approach within the data centres and digital services industry as a necessary contribution to the knowledge about the phenomenon of our hyper-connected lifestyles and global energy footprint. By emphasising the interconnected relationship between people, technology and the environment, the project promotes a redefinition of digital dependencies through the lens of environmental responsibility. Such responsibility ought to be built collectively, and visual narratives can complement discursive and textual approaches by introducing accessibility and readability to data.

The research uses data visualisation to inform behavioural change through two distinct strategies to deepen understanding of the phenomenon. The first gateway focuses on unveiling the physicality behind the seemingly intangible world of data. By dispelling the myth of the non-physicality of data, the research reveals the tangible infrastructure that underpins the Internet, highlighting the crucial role data centres play in our digital ecosystem. The project maps data centres' global distribution and environmental impact through data collection and visualisation, clarifying the fragmented landscape of available information and highlighting the need for comprehensive data. The second gateway delves into the challenges and complexities of visually representing the energy footprint of data centres in the digital media landscape.

The research uncovers the prevailing themes and tendencies that shape public perception and discourse on the subject by analysing visual narratives across top Google News sources. This exploration underscores the *framing dilemma* faced in striking a balance between conveying the physical and abstract connotations of the issue and revealing the gaps and inconsistencies in current visual representations. In doing so, it highlights the role of design as an agent of change in promoting awareness and shaping cultural perceptions.

By humanising the energy transition and emphasising the collective sensitivity required for sustainable action, designers can leverage the creative potential of data visualisation to bridge the gap between data, technology, and human behaviour. This approach contrasts technocracy, urging us to move beyond mere resource access to a deeper awareness of consumption patterns and their implications. Whilst the energy transition is an unavoidable challenge and is understood as an environmental, social and economic necessity, more widespread education and information about energy scenarios is needed. By bringing dissonant points of view to the forefront and challenging prevailing narratives, as designers, we can cultivate a culture of sustainability grounded in informed decision-making and collective responsibility.

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Fabiola Papini: Conceptualization, Methodology, Data curation, Visualization, Writing (Original Draft).
Francesca Valsecchi: Supervision, Writing (Original Draft), Writing (Review & Editing).
Michele Mauri: Supervision, Writing (Review & Editing).

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Towards Energy Sustainability in the Digital Realm

A Compass of Strategies between Natural and Artificial Intelligence

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Abstract
The digital is not an intangible entity. Contrary to the belief that the digital world reduces the physical footprint of human activities, its environmental impact is far from minor. To foster sustainability, accessibility, and inclusion requires the creation of complex and multidimensional strategies to encourage long-term behavioural change. In this scenario, concepts such as sobriety and moderation emerge as an alternative sustainable model. The article critically overviews concrete practices for balancing digital energy usage. An analysis of contemporary strategies is presented through two main parameters: firstly, a distinction is made between solutions that use artificial intelligence to optimise efficiency and solutions that use natural intelligence to rethink traditional consumption paradigms. Secondly, design strategies are categorised into three drivers: reducing digital activities by resorting to low-tech or analogic alternatives, adapting resources through artefacts responsive to energy availability and quality, and replacing traditional technologies with biobased and bioinspired solutions. The results highlight the necessity for a post-anthropocentric vision in design and provide a compass of strategies to apply to the energy transition in the digital realm.

1. Introduction

Humanity faces a critical global emergency due to climate change and biodiversity loss, impacting both the environment and societal structures. This crisis requires a paradigm shift from solely technological solutions to profound changes in thought models and lifestyles. Essential is the development of new relationships between humanity and nature, emphasising an interdisciplinary approach and the crucial role of design. Indeed, design emerges as a pivotal catalyst for change, synthesising complex environmental challenges into actionable, visionary strategies. This new design paradigm aims to integrate technology purposefully and strengthen the bond between humanity and nature, driving innovation for the benefit of the entire planet. Ultimately, design helps individuals and communities adapt to change, overcome challenges, and move towards a sustainable future (Lotti et al., 2022).

> [Design] can make revolutions in science, technology, history, or politics visible and bring them to life. When design is used well, it changes lives and, with it, the narrative. It can be top-down, bottom-up, or infiltrated from the side, but in all of these different strategies, and especially the bottom-up strategy, design is very powerful because it can help the infiltration. (Antonelli, 2022, p. 95)

The practice of "giving form" is challenged to grapple with the realities of living on a compromised planet, inspired by the work of pioneers like Victor Papanek, Tomas Maldonado, and Yona Friedman. Since then, the landscape of design has transformed: objects are now designed not only for aesthetic or functional needs but also in response to environmental sustainability and circularity. The shift from tangible products to intangible services marks a significant dematerialization in design practice. Moreover, design has broadened its scope, aiming to affect behavioural change and tackle complex societal challenges. Yet, these changes are initial steps; the full impact of these shifts will emerge only through a radical break from past practices and by engaging deeply with the local contexts. The task of conceiving and constructing alternatives grows increasingly challenging, even as design capabilities have advanced to a point where they can craft futuristic scenarios with cutting-edge technologies and artificial intelligences, pushing the limits of what is conceivable (Fagnoni, 2022).

Amid the global challenges associated with the circular transition, digitalisation and its associated technologies have emerged as key enablers for sustainable development and integration. This marks a shift toward more sustainable practices, highlighted in the framework of the "twin transitions" where digital transition acts as a facilitator for efficiency and innovation. This synergy between ecological transition and digital transformation fosters enhanced sustainability across diverse sectors (Muench et al., 2022). Yet, the role of digitalization in addressing the interconnections between energy transition and climate change has been inadequately addressed in investment policy formulation (UNESCO, 2015). Furthermore, the concept of circularity remains underdeveloped in the digital sphere, and the environmental impacts of escalating digital usage are frequently underestimated (OECD, 2022).

While digital technologies are instrumental in analysing climate data and enhancing planning and efficiency – thereby conserving energy and minimising resource consumption (World Bank, 2016) – the pervasive "myth of digital" conjures an illusion of limitless power and absence of boundaries (McGovern, 2020). This illusion masks the significant environmental impacts of digital ecosystems, including their substantial direct energy consumption. The concept of digital sustainability necessitates a paradigm shift from the tangible to the intangible, recognizing that the digital realm, often perceived as an ephemeral cloud, indeed consumes significant amounts of energy, materials, and space.

The article proposes a critical overview of concrete practices for balancing the energy usage of the digital. The disciplinary context is developed in the dedicated section, where the first reading parameter is defined: a distinction is made between solutions that leverage Artificial Intelligence to optimise the efficiency of devices and platforms, and solutions that use Natural Intelligence to rethink traditional paradigms of consumption in the digital realm. It follows an overview of design strategies, categorised into three main drivers: reducing digital activities by resorting to Low-Tech or analogic alternatives; adapting the use of resources through artefacts that are responsive to energy availability and quality; replacing traditional technologies with biobased and bioinspired solutions. In the discussion section, such strategies are critically analysed, assessing their effectiveness, limitations and potential impact on long-term sustainability. Conclusions outline the goals and next steps of the authors' joint research activities.

2. AI & NI for Promoting Sobriety in the Digital Realm

The sustainability challenges of today call for a departure from the norms of continuous expansion and acceleration. Concepts such as moderation and sobriety are emerging as viable alternatives, proposing a radical downscaling of resource exploitation, not as a compromise but as a fundamental principle (Franz, 2022). Aiming for a more balanced, moderate, and sober life is the only possible answer to the multiple crises of the contemporary world. Degrowth is thus understood as a new scenario, freeing human identity from economic representations (Seibert et al., 2021), developing an ethic of low consumption, and "finding reasons for elegance in scarcity" (Lynch & Southworth, 1994).

Specifically, this study promotes digital sobriety and moderation as a paradigm shift that positions designers to significantly influence the environmental footprint of digital content through its creation, accessibility, and consumption, necessitating the extension of eco-design and circular principles to the digital realm, which, despite its intangible perception, has substantial environmental impacts (McGovern, 2020; Paoletti, 2021).
Sustainable strategies in the digital domain include enhancing energy efficiency, modifying regulatory constraints, encouraging sharing, designing for decarbonisation, and managing usage growth (OECD, 2021; The Shift Project, 2024). Key actions involve establishing a quantitative framework for digital strategy redirection, optimising deployment to minimise electricity consumption, restricting data-intensive uses to control data growth, and educating stakeholders on developing lean and

resilient infrastructure (The Shift Project, 2024). The concept of sobriety by design plays a pivotal role in this context, reflecting an ethical commitment to environmental sustainability and earth-centric design. This approach influences the development of digital goods, ensuring they are crafted with a focus on resource conservation and an energy-saving approach.
Our investigation focuses not on calculating energy and resources consumption, or quantitative negative impacts – which falls outside the scope of design discipline expertise – but rather on identifying specific issues through the research of good practices for digital sustainability, conveyed by design choices that embody the concepts of sobriety and moderation and that define their aesthetics and usability.

The world we inhabit is more a product of human creation than natural evolution, where every aspect of our environment bears the imprint of human ingenuity (Simon, 1996). Human influence is categorised into four degrees of "naturality" (Proserpio, n.d.): from entirely natural, like forests and oceans, to human-designed but naturally-produced, such as farms, to fully human-made objects and systems like democracy, and finally to technologies like machine learning, which can independently create, as demonstrated by AI-generated media (Manovich & Arielli, 2024). In today's technological panorama, designers can exploit both Natural Intelligence (NI) and Artificial Intelligence (AI) (AIColabs, 2024) to produce artefacts that are energy efficient and more sustainable. This study considers these opposite approaches as one of the parameters available for critical reading of design strategies for sustainable digital goods.

NI, the cognitive capacity inherent in biological entities, is characterised by an ability to perceive, reason, and adapt organically, influenced by genetic, environmental, and experiential factors. NI evolves through slow biological processes, shaped by evolutionary pressures over millennia. An established design trend ascribable to biophilic design emphasises the value of reproducing the functioning of dynamic and complex natural systems in order to design in balance with planetary cycles and temporalities.

Conversely, AI represents the zenith of human technological endeavour, leveraging algorithms and machine learning to process and analyse large datasets. AI is propelled forward by continuous research and technological updates, evolving rapidly in capabilities and applications across various industries like healthcare, finance, and transportation. The inherent capability of AI to process enormous amounts of information and find patterns within it at an inhumanly fast rate offers the opportunity to seamlessly manage and control the energy consumption of digital artefacts.

This shift towards digital sobriety and moderation sets the stage for exploring specific design strategies that can effectively reduce, adapt, and replace digital practices to promote sustainability.

3. Design Strategies: Reducing

Reducing digital consumption involves implementing minimalist design principles that directly impact energy usage. Over the past decade, the growing energy consumption of computing systems, from large-scale supercomputers to personal laptops, has become a significant concern driven by

economic, environmental, and implementation practicalities (Beloglazov et al., 2011; Belkhir et al., 2018).
In 2020, the Information and Communication Technology (ICT) sector contributed from 1.8 to 2.8% of global greenhouse gas emissions, with projections indicating an increase of up to 830 million tons of CO^2 by 2030 (Andrae & Edler, 2015; Belkhir et al., 2018). Even mobile phones, despite their relatively low energy impact, are part of an infrastructure that requires considerable amounts of electricity to function. In 2018, the global impact of mobile communication technologies was estimated at around 2,135 million tons of CO^2, highlighting the need to adopt strategies to reduce the environmental impact of our digital activities (GSMA & Carbon Trust, 2021).

Considering the broad impact of digital technologies on daily activities and the ongoing digital transition in public organisational integration, an evident contrast arises between the urgent demand for transformation and its relative impact on the documented environmental crisis. The paradox is evident in the breadth of media resonance regarding the energy required for the activation and sustenance of our technological devices, as well as for the operation of data processing centres (Diguet & Lopez, 2019). This paradox also manifests concerning issues related to the extraction of metals and materials used in the production of our digital tools (Pitron, 2018). In recent years, various proposals have been put forward to resolve this dichotomy. These proposals pursue different objectives, including the pursuit of balance in promoting sustainable development initiatives through adopting new technologies or optimizing existing processes, as well as considering ecological issues as a driving force for broader reflection on digital society (Fing, 2019). This approach is commonly known as Low-Tech and entails exploring the conditions of an information society within a crisis context (Tomlinson et al., 2012), promoting sobriety, understood as the adoption of Appropriate Technologies (Schumacher, 1974), and low impact, characterised by simplicity that makes them potentially less efficient but richer in resources, as well as the local management of resources (Bihouix, 2014).

4. Design Strategies: Adapting

Adapting digital practices to energy availability is crucial for advancing sustainable methodologies. This alignment is not only necessary but imperative as almost all human and non-human activities depend on energy, primarily derived from the Sun, which fuels photosynthesis, structures our days, and delivers essential nutrients (Van Aubel, 2022).

The contemporary scenario of ever-increasing energy demand is dominated by technology and poses sudden challenges that are increasingly fraught with pitfalls. It is therefore particularly significant to urge an in-depth reflection on the energy issue in relation to the digital realm that is capable of driving change and proposing alternative visions (Lotti, 2022) in an attempt to stimulate a paradigm shift in the Earth vs. Sun dichotomy. Interaction with the Sun and its energy possibilities become central; in contrast to fossil fuels, limited and polluting energy sources (Earth), it represents a potentially unlimited source of energy (Sun). Solar energy is to be interpreted with a double valence: on the one hand, as a source that generates energy, and on the other hand, as a Natural Intelligence approach, such as solar technology like NI. In this view, solar energy effectively responds to current energy challenges by proposing adaptable, scalable and sustainable models. It plays a crucial role in the energy transition to a fully renewable supply, ensuring not only the availability but also the quality of the energy needed. This kind of energy is not limited to its most common uses: the long-term goal is to naturalise the resource, fully integrating it into the realm of digital sustainability.

Solar energy is inspirational because it also suggests a model of an adaptive approach that, in the pattern of regenerative design, renews and restores materials and resources to ensure resilience by counteracting the concept of a linear and degenerative economy that involves the use of resources that are then discarded after only one use. Considering time in a circular, rather than linear, manner leads us to imagine alternative methods for re-new, re-store, re-source. The ability of design to reframe the narrative on complex topics is essential to fit this alternative energy reality into a shared vision, facilitating the transition to a post-fossil fuel future and preventing solar energy from becoming as problematic as asbestos in the 21st century (Van Aubel, 2022).

5. Design Strategies: Replacing

Embracing biologically inspired alternatives in place of traditional technologies marks a profound shift in our design paradigm.

This strategy of replacing begins by redefining the relationship between humanity, nature, and technology: where design

through a post-anthropocentric vision shifts from a human-centred perspective to a relational view, where it becomes an intermediary between "the life of the form" and the "form of life" (Goodwin, 1994, 2007). In this context, nature takes on the role of co-designer, highlighting the need to move beyond the use of simple ecological tools, leading to new design processes and methodologies based on biological principles, where nature is not relegated to a marginal or final role but is integrated from the beginning of the design process, actively operating as a co-designer. This approach emphasises a deep and functional integration between natural systems and human innovations, promoting solutions that are not only sustainable but also intrinsically connected with the living fabric of our planet, perfectly in line with the regenerative design model.
This model aims to create design systems that not only minimise the negative impact on the environment but actively improve and regenerate natural resources. Regenerative design goes beyond sustainability, aiming for an integration that restores, renews, and enriches ecosystems and communities, where designers are invited to consider nature not just as a source of inspiration or a resource to be preserved but as an active partner in the design process (Mang & Reed, 2012).
Moving towards this paradigm shift, co-designing with nature means not only drawing inspiration from it, as in biomimicry, but also exploring new Biobased solutions that can replace materials or even processes as in the case of bio-HCI (Biological-Human Computer Interaction), namely the use of microorganisms as Living Media Interfaces (LMI) and Living Bits that integrate living organisms, such as algae, bacteria, and fungi, into the digital world (Karana et al., 2020).

The use of living organisms as interfaces for digital systems introduces a revolutionary approach leading to significant innovations, including a drastic reduction in energy consumption linked to digital interfaces, offering a more empathetic and engaging user experience, and paving the way for new design paradigms that integrate natural elements in replacement of processes that have been 100% digital until now (Licaj & Matteucci, in press).

6. Discussion

To further analyse and make sense of the three principal strategies in digital sustainability (reducing, adapting, replacing) we elaborated a diagram (Fig. 1) that illustrates the intersection of Artificial and Natural Intelligence in relation to the former. Our analysis is based on relevant exemplary cases that – although being for the most part experimental practices – push forward the design discipline with regard to the impact of digital artefacts.

The first axis showcases how AI and NI can be leveraged to reduce digital consumption. Formafantasma[1] portfolio focuses on offering both a bright and dark colour scheme, preferring the second as it reduces screen brightness and energy consumption of OLED screens. It also uses system typefaces and a simple structure to avoid unnecessary HTTP requests, and informs the user on the weight of the images before downloading them (Fig. 2).

1 https://formafantasma.com/website.

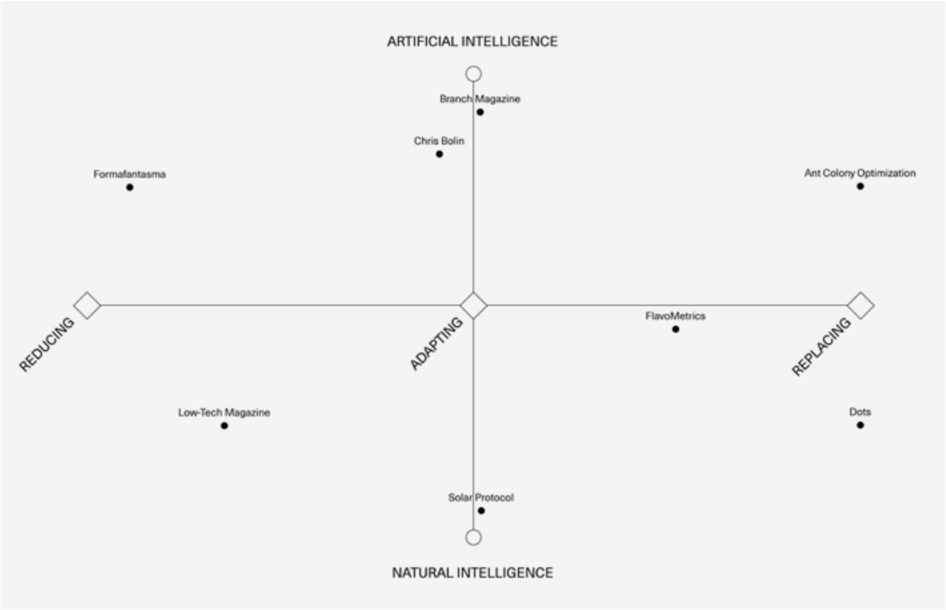

Figure 1. Diagram showcasing the relationship between the main drivers for sustainable digital design; AI and NI are on the vertical axis, while three design strategies are on the horizontal axis, i.e. reducing, adapting and replacing.

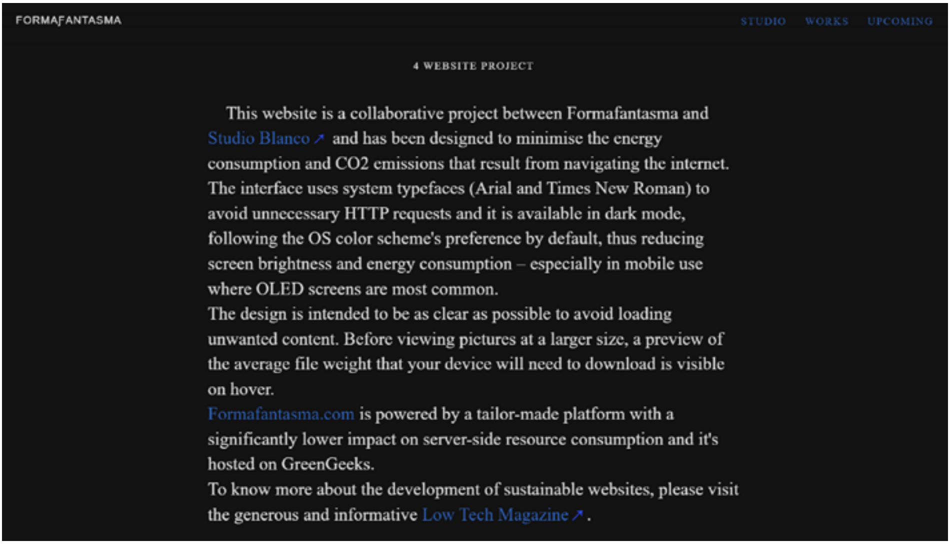

Figure 2. Screenshot of Formafantasma website [accessed on June 19, 2024].

Figure 3. Screenshot of Low Tech Magazine [accessed on June 19, 2024].

Moving from left to right, Low-Tech Magazine[2] uses a similar approach about UI choices. Also, it is solar-powered (a battery indicator visually shows the energy available and informs of the chance that the website may go offline). As the server is located in Barcelona, this territorial integration highlights the importance of designing and implementing energy infrastructure and digital services considering local specificities, a key approach in addressing environmental challenges and optimising resource efficiency (Fig. 3).

These cases adopt minimalist design principles that directly reduce energy consumption. While effective in raising user awareness and having an immediate impact, they need to improve scalability and acceptance. Their success depends heav-

2 https://solar.lowtechmagazine.com.

ily on broad user engagement and behaviour change, which can be challenging to secure. Moreover, low-energy websites' aesthetic and functional constraints may not be suitable for all digital applications, particularly those requiring high data throughput or rapid interaction.

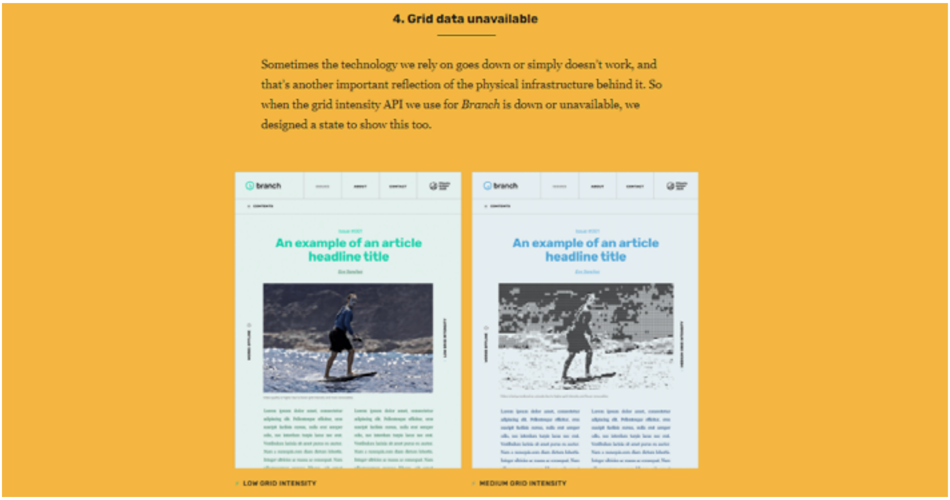

Figure 4. Screenshot of Branch online magazine [accessed on June 19, 2024].

Adapting the appearance and user experience of digital artefacts to energy availability is a central strategy to align more closely with sustainable practices (Vacanti et al., 2023). Both AI and NI are extremely useful in these examples. AI is leveraged by Branch Magazine[3], which adapts its UI to grid intensity, through a grid intensity API and the user location. As the intensity grows, the experience of navigating the magazine changes, with images being hidden by default, and the logo and background highlighting the state of the grid (Fig. 4).

3 https://branch.climateaction.tech

Figure 5. Screenshot of Chris Bolin experimental website [accessed on June 19, 2024].

Chris Bolin[4] uses another strategy to offer a critique of the contemporary excess of connectivity, fostered by social media. The content of his website is hidden unless the user goes offline (Fig. 5).

As opposed to these examples, Solar Protocol[5] uses NI to complement and adapt the website's fruition: by placing servers in sun-optimal locations, Solar Protocol monitors their activity and builds an open network active in eight countries and six continents, directing data traffic to the server receiving the most sunlight at that time (Fig. 6).
These innovative approaches could struggle in areas with unpredictable solar energy availability or underdeveloped infrastructure. Adapting user interface elements based on energy availability is a progressive step towards sustainability, but it might lead to inconsistent user experiences, potentially affecting user engagement and satisfaction.

4 https://chrisbolin.co/offline
5 http://solarprotocol.net

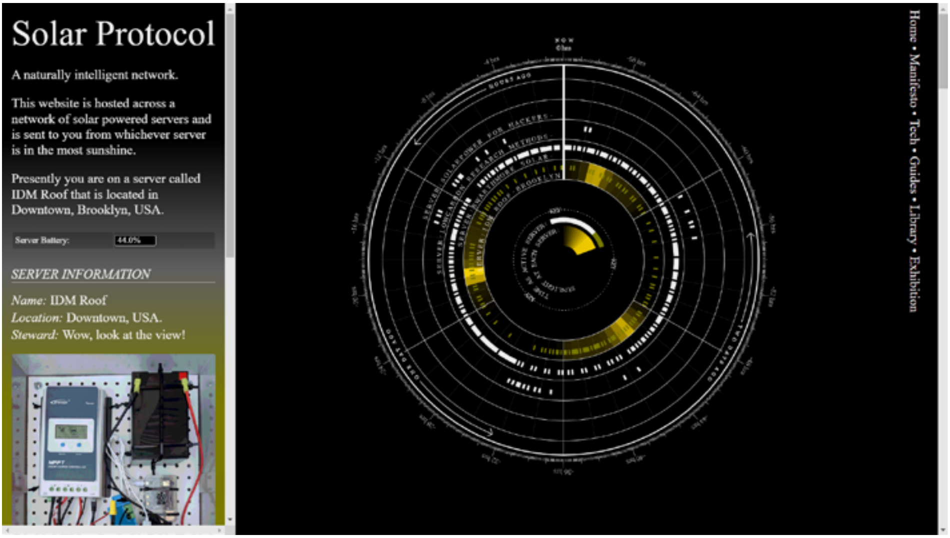

Figure 6. Screenshot of Solar Protocol website [accessed on June 19, 2024].

Replacing is a strategy in which traditional technologies are substituted with innovative, often biologically inspired, alternatives. FlavoMetrics (Risseeuw et al., 2023) uses computer graphics and simulations to aesthetically represent Flavobacteria, a type of microorganism known for its iridescence and reactive behaviours. This tool allows users to adjust various environmental parameters such as growth, humidity, and lighting conditions to observe how these changes affect the appearance and behaviour of the Flavobacteria, opening up new possibilities for using living organisms in interactive designs, providing a foundation for developing new functions and modes of interaction between the biological and digital worlds.

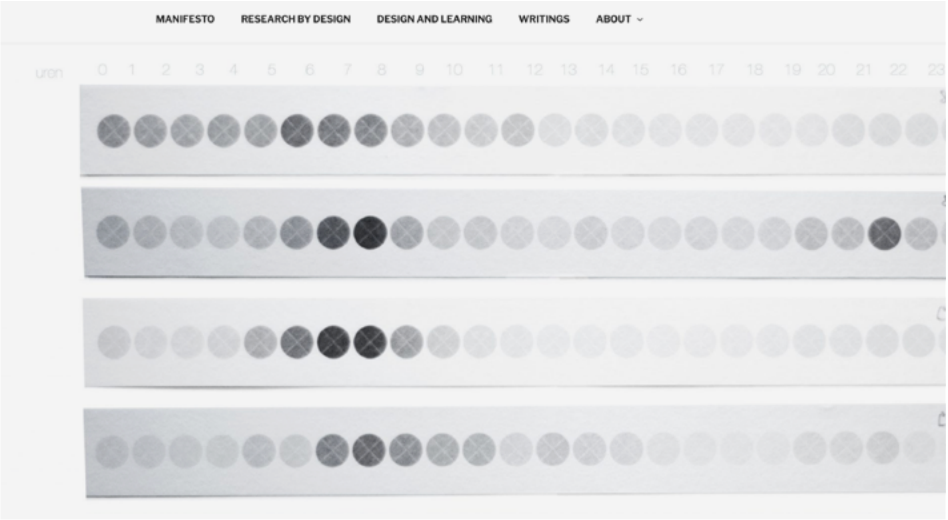

Figure 7. Screenshot of Dots Project website [accessed on June 19, 2024].

Figure 8. Ant behaviour as inspiration for the metaheuristic optimization technique (credits: Wikimedia Commons, 2007).

The Dots project[6] by Studio Dust, showcased at the 2015 Rotterdam Stadsmakerscongres, visualises the invisible matter of air pollution. It uses a device to capture fine dust particles on paper, providing quantitative data through light reflection analysis. The resulting dots on the paper vary in shades of grey depending on location and timing, offering a visual comparison of air pollution levels in various areas, such as the northern Netherlands and the traffic-heavy zones of Rotterdam (Fig. 7). Ant Colony Optimization (ACO) is an algorithm inspired by the behaviour of ants searching for food. Ants lay down pheromones to mark paths that should be followed by other members of the colony, leading to efficient routes being reinforced and inefficient ones diminishing. ACO has been used successfully in solving the travelling salesman problem, routing of vehicles, and other optimisation tasks (Dorigo et al., 2001) (Fig. 8).

7. Conclusions

Design generates proposals to tangible and (seemingly) intangible problems – digital sustainability – through the discipline of design, here understood with the concept of "to act". This requires a critical and radical rethinking of the designer's role, which extends beyond the creation of objects or spaces to the design of adaptive and sustainable digital systems. In its role as mediator, design must consider the complexity of interconnected crises, developing solutions that not only respond to the climate emergency but also guide society toward more democratic, responsible and conscious values. Raising consciousness and informing the community are essential

6 https://studiodust.nl/?page_id=612

to activate sustainable, meaningful and accessible practices. Social aspects play an active role in this cause, and design can help build a more conscious society, where energy is seen not only as a technical resource but as a fundamental element in our relationship with the Planet.

The integration of AI and Natural Intelligence in design aims to minimise the environmental impact of digital technologies through a blend of theoretical and practical strategies. This approach promotes a multi-dimensional model of digital sustainability. However, overcoming resistance to minimalist or adaptive designs requires engaging users through educational initiatives and incentives that encourage energy efficiency.

The next steps of our work aim to structure a path of research and experimentation on the integration of the concepts of sustainability, energy consumption, and design that are developed within two specific laboratories: CTRL+JUNK LAB from Università Iuav di Venezia[7], and Sustainable Design Laboratory from Università di Firenze[8]. The shared goal of involving communities and stakeholders in promoting sustainable and circular design practices highlights the need to develop innovative methods to reduce environmental impacts and improve resource efficiency.
Specifically, in the next steps, the research will focus on advancing sustainability, energy efficiency, and design through a series of hands-on experiments via a series of workshops

7 https://sites.google.com/iuav.it/iuav-centro-studictrljunklab/ctrl-junk-lab
8 https://www.designforsustainabilitylab.com/

exploring strategies to reduce, adapt, and replace digital design paradigms with more sustainable ones while assessing their energy impacts. Also, a further upcoming goal is to identify a more specific area of experimentation where energy impacts are at their highest, such as public events.

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Understanding the Energy Transition by Analyzing the IT Revolution

An Infrastructural Reading to Direct Design Approaches Toward Energy Sustainability

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Abstract
The paper compares the IT revolution and the energy transition, analyzing the former's infrastructural evolution and drawing parallels with the latter. It aims to strategically reinterpret design projects in the context of energy sustainability.
The comparison between the electrical energy transfer system and the data transfer system offers insights and operational suggestions potentially transferable from one field to another. Thus, the analysis aims to analyze the limitations and potentials of the logical architecture models of the computer network, which have already been addressed and solved in the past, to reread the macro-strategies of current energy policies, based on the one hand on a technocratic vision that works on sources and infrastructure (that we can define as client server) and on the other hand on cooperation between actors and society (that we can define as peer to peer). Focusing mainly on this second approach, the paper investigates projects introducing an experimental model – communitarian, collaborative, horizontal, near –, using the IT metaphor as a critical-interpretive analysis capable of opening new reading and development scenarios. The essay intends to systematize the most recent experiments, sometimes still prototypical, conducted between design and art and pilot projects initiated in some European laboratory cities to identify possible strategies and contaminations in light of their energy infrastructure and thus outline a framework of operational strategies for the discipline of design.

1. The Infrastructural Issue of the Energetic Transition

In the different meanings identified by the 17 Sustainable Development Goals of the UN 2030 Agenda, the Energetic Transition is an open challenge that several productive sectors are only beginning to address. In particular, it is one of the central themes of the European Green Deal (European Commission, 2019). It seems urgent in light of the current energy crisis and the depletion of raw materials and finds ample space in the debate within the project disciplines.
One of the biggest challenges to achieving the Energetic transition is facing the issues connected to the energy transmission grid (Solomon et al., 2023).

The energy transmission grid faces several challenges that hinder its efficiency and effectiveness. The U.S. Department of Energy (DOE) has identified interconnection challenges on the transmission grid, which need to be addressed to improve the integration of clean energy sources (DOE, 2023). The current grid infrastructure cannot adequately support the integration of new clean energy sources and the increasing electricity demand. This is further exacerbated by the growing amount of renewable energy sources, which challenge the grid's stability and reliability (FUERGY, 2023). One of the significant issues facing the power grid is the transmission losses that occur during electricity distribution.

These losses impact the grid's efficiency and increase costs and energy wastage. Additionally, the outdated infrastructure of the transmission system is a significant problem as it is not equipped to handle the energy systems of the future

(Bushnell, 2013). This outdated infrastructure poses a threat to the expansion of renewable energy sources, in fact, a mass adoption of them impacts the electricity infrastructure. Bottlenecks or grid congestions may occur when the existing transmission and/or distribution lines, or transformers, are unable to accommodate all required load during periods of high demand – such as simultaneous charging of thousands of EV – or during emergency load conditions, such as when an adjacent line is taken out of service (Gielen et al., 2019).

Most existing power systems infrastructures feature large-scale generating plants, with demand traditionally considered uncontrollable and inflexible. However, with the increasing integration of distributed energy resources, traditional energy consumers will become prosumers who can both generate and consume energy. The generation of DERs is unpredictable and intermittent, and prosumers who have surplus energy can either store it with energy storage devices or supply it to others in an energy deficit. This energy trading among prosumers is called Peer-to-Peer energy trading (Zhang et al., 2017)

Other concerns regard the instability of electricity supply and, in particular, the reduction of the reserve margin during peak demand periods and the interconnection of national grids at the European level: at present, the European energy infrastructure consists of some 27 loosely connected grids, whereas the interconnection between the different areas of the internal market would play a key role in improving the reliability and resilience of the entire system, even in fragile contexts (TERNA, 2023).

Thus, modernization is crucial for ensuring the grid's reliability and resilience in the face of increasing demands and evolving energy systems. In conclusion, the problems of the energy transmission grid are multifaceted and require comprehensive solutions to ensure the grid's sustainability and efficiency. These solutions must address interconnection challenges and transmission losses and, more importantly, accommodate a new, more distributed energy flow throughout the grid.

2. The Paradigm of the IT Revolution, from Client to Server to Peer-to-Peer

Analyzing the issues and challenges connected to the energy transmission grid allows a comparison with another type of grid, the World Wide Web, whose evolution over the years has encountered similar problems, which in some cases have found solutions potentially transferable from one field to another.
Specifically, in the context of the aforementioned shift from centralized energy supply models to peer-to-peer energy sharing caused by the development of new renewable energy sources, the revolution generated by the change from *client-to-server* (C2S) to *peer-to-peer* (P2P) network models in the IT field appears to be of interest.
From a network standpoint, the primary difference between these two terms is that, in a peer-to-peer network, every node can ask for assistance and deliver services. In a client-server network, the client nodes demand services, and the server node answers with assistance (Fig.1).
Historically, peer-to-peer file sharing exploded into the public consciousness with the release of Napster in 1999, which sparked a revolution in computer-mediated communication.

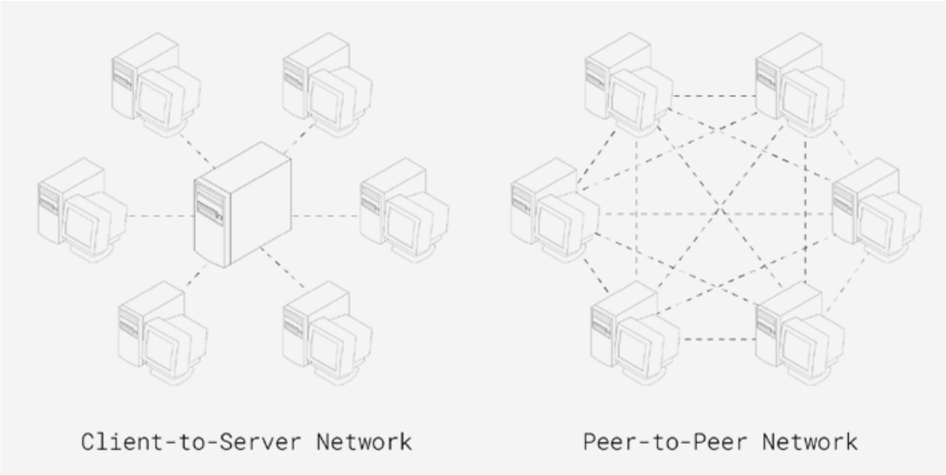

Figure 1. Diagram of Client -to-Server networks compared to Peer-to-Peer networks (credits Massimiliano Cason Villa).

Within a few years, peer-to-peer communication replaced client-server communication as the dominant communication paradigm of the Internet. Peer-to-peer has also redefined the role of home users, empowering them to produce and distribute content free from control by third parties (Huges et al., 2008; Liu et al., 2010).

The main characteristic of P2P networks is that they are decentralized, distributed systems that enable to share and integrate their resources, data, and services, free users from the traditional dependence on central servers, and will allow them to easily share resources (e.g., music, movies, games, and other software). Furthermore, existing P2P file-sharing networks can be divided into three categories according to the degree of network centralization: centralized P2P networks, decentralized P2P networks, and hybrid P2P networks. (Vu et al., 2009)

> Although P2P is often seen as an opposite model to the centralized client-server paradigm, it is essential to state that the first-generation P2P systems (e.g., Napster) started with the concept of centralization. However, in contrast to traditional client-server systems, the servers in centralized P2P networks only keep the meta-information about shared content (e.g., addresses or ID of peer nodes where the shared content is available) rather than storing content on its own. (Sifferd, 2002)

Fully decentralized peer-to-peer networks, which do not rely on any central server, later became widely used to address the problems of centralised P2P networks such as scalability, single point- of-failure and legal issues.

Finally, to avoid the problems observed in the centralized and decentralized P2P networks discussed above, hybrid P2P networks later emerged to provide trade-off solutions with a hierarchical architecture.

From an infrastructural standpoint, peer-to-peer grids feature a wide range of benefits. They distribute the responsibility of providing services from centralized servers to each peer node in the network, with the result of eliminating the bottleneck of centralized servers, optimizing the exploitation of the available bandwidth, processor, and storage across the entire network, and improving the availability of resources as if one peer node is overloaded or experiences a hardware failure, other peer nodes in the network can still handle requests.

2.1. Extending the IT Paradigm to Energy, Parallels, Insights and Possible Solutions

Suppose the paradigm of peer-to-peer versus client-to-server networks is extended to the energy transmission grid. In that case, some of the benefits of peer-to-peer networks can be looked at as useful insights and even possible solutions, particularly towards fostering the integration of new renewable energy sources.

As it was discussed above, in Italy the infrastructure necessary for the distribution of electricity is based on a high-voltage transmission network that allows the energy produced in power plants to be brought to local substations, where it is then converted to low voltage for distribution to individual consumers. Within the metaphor of the IT revolution, this model can be compared to client-to-server networks, where all resources (energy) are supplied by a single server (power plants), this comes at the cost of several issues, such as bandwidth limitations in period of high demand, that are directly translatable to the power transmission grid issues that this work wants to address.

Extending the metaphor to a peer-to-peer network, a new type of power infrastructure can be envisioned, one where all nodes in the grid are connected, and they both consume and produce energy from various sources. Just like on the Net, energy requests can be answered by more than one source, lowering bandwidth usage and the possibility of failures. The European Union is experimenting with such a model, but it is difficult to achieve for multiple reasons. On the one hand, because of the aforementioned infrastructural shortcomings of the grid. On the other hand, the current regulation for the production and consumption of energy in the European Union prevents users on the grid from freely exchanging energy and currently needs to be updated to allow more decentralized networks (European Commission, 2021c).

Moreover, for these models to be feasible, the technical, economic, social, and behavioral challenges need to be considered. From a behavioral standpoint, sociologist Michel Bauwens describes peer-to-peer models as bottom-up models whereby agents in a distributed network can freely engage in common pursuits without external coercion (2017).

This description portrays peer-to-peer as a primarily social dynamic based on voluntary participation in the creation of common goods that are made universally available.

From a Socio-economic perspective, the peer-to-peer model can be compared to the *Collaborative commons* model, which is the first economic system that stands as an alternative to capitalism and socialism to make the global economy more democratic and ecological (Rifkin, 2014, p. 3).

To further describe this perspective, the American economist and sociologist Jeremy Rifkin also recalls the shift caused by peer-to-peer sharing networks to foreshadow how the companies with the greatest chance of success will be those able to restructure themselves according to a non-vertical, but horizontal management: "I am optimistic because I remember that the very powerful music and media majors collapsed because of millions of Lilliputians like Napster, and because I see that in the energy sector, the large vertically integrated companies are unable to scale the small markets created by green energy" (Romeo, 2014).

In a context where both technical and socio-behavioral challenges must be tackled, the discipline of design can mediate knowledge and needs (Bistagnino, 2008), taking knowledge from one area and transferring it to another to envision trajectories and strategies for innovation.
As such, the insights suggested by the analysis of the IT revolution and the advent of peer-to-peer models become a lens to reread the macro-strategies of current energy policies, based on the one hand on a technocratic vision that works on sources and infrastructure – that we can define as client-to-server—and on the other hand on cooperation between actors and society – that we can define as peer-to-*peer*.
The analysis will focus on the second approach, investigating projects that introduce an experimental model - communitarian, collaborative, horizontal, *near* - that is innovative compared to the established ones.

3. Peer-to-Peer Models to Face the Energetic Transition, Experiments for *Near* Infrastructures

At present, fully decentralized and off-grid peer-to-peer energy communities are mainly found in developing countries. They are born in conditions of strong energy poverty to compensate for the lack of a proper centralized energy grid, and they are usually connected to a number of other socio-economic challenges.
In Italy, people do not directly and locally exchange the energy they produce, whereas experiments in central Europe are based on decentralized social energy networks, whereby the energy consumed is internally and autonomously produced by increasingly self-sufficient communities, although not fully decentralized and off-grid.

In the context of this essay, these cases can be interpreted as primordial 'peer-to-peer' explorations of energy,
Following the metaphor built by the essay, the cases will be categorized by following the typologies of peer-to-peer networks that have been presented. The aim is to categorize the current experimentations of peer-to-peer energy sharing models within their efficacy to address the issues of bandwidth shortage and connection of the existing energy supply grid.

The centralized P2P category will not be used. In fact – as it has already been stated – it was born to address issues connected with the laws and regulations on the distribution of content on the Net. In contrast, the decentralized and hybrid P2P networks categories are adapted to addressing the technical issues linked to the transmission of data and energy alike. Inside the decentralized peer-to-peer category, both some of the most ambitious and the most recent energy communities will be analyzed, with a focus on off-grid energy production technologies and their feasibility within the current regulations. In the Hybrid peer-to-peer category, some of the most recent politics and experiments for the creation of energetically sustainable neighborhoods will be analyzed, focusing on how the integrations between the autonomous energy production technologies and the Centralized energy grid play into the efficiency of these experiments.
Towards more democratic and inclusive scenarios, the cases analyzed envisage greater individual empowerment, collaborative formats of energy co-production and co-management, strategic public-private alliances, and neighborhood social participatory actions that enhance the neighborhood scale.

These experiments can provide some indications that can be replicated in other urban contexts.

3.1. Decentralized Peer-to-Peer models, Off-Grid Experiments and Energy Communities

Access to energy is a key element for socio-economic development and human well-being. However, millions of people around the world, especially in developing countries, still live without electricity or have to rely on traditional and unreliable energy sources.
In this context, models based on off-grid energy production and consumption, such as energy communities, are emerging as a promising solution to ensure sustainable and reliable access to energy in rural and remote areas.

Energy communities represent an innovative form of community organization in which community members actively participate in the production, distribution and consumption of renewable energy. These models can be considered fully decentralized peer-to-peer models and offer an alternative route to centralized, monopolistic energy systems, with the aim of creating energy-self-sufficient communities and managing local energy resources more efficiently.

One of the earliest examples is the Auroville community in the southern Indian state of Tamil Nadu (Kapoor, 2007). Founded in 1968 by Mirra Alfassa and French architect Roger Anger, Auroville aims to be a place of peace, harmony, and human unity. The community lives in harmony with nature and practices sustainability principles in all aspects of daily life.

The community has historically been actively engaged in renewable energy production and consumption, minimizing the use of fossil fuels and promoting sustainable technologies such as solar, wind, and biomass. The goal is to achieve energy self-sufficiency and minimize the environmental impact of human activities within the community.
The first solar panels were installed in Auroville in the early eighties. Currently, Auroville has more than 150 houses fully powered by photovoltaic panels and about 50 houses that use solar power in conjunction with a grid connection. Some communities run solely on solar energy. The total standalone photovoltaic energy capacity of Auroville is more than 15% of the total photovoltaic capacity in India.

In recent years, energy communities have also started to sprung up all over the most remote regions of Italy, with examples such as the CER of Roseto Valfortore in Apulia (Eroe, 2021), Magliano Alpi in Piedmont (Turco, 2021), and Villanovaforru in Sardinia (Liberti, 2022).
Among these, an analysis of the latter highlights the issues connected to a true implementation of off-grid communities in Italy.
Founded in 2022 by Mayor Maurizio Onnis, the CER of Villanovaforru bases its production on a photovoltaic system built on top of the roof of a school gym. The system has a power output of 54.5 kilowatts and is connected to forty private and commercial consumers.
In the context of this analysis, the issues with Villanovaforru's model are twofold. On the one hand, the model is not based on actual self-consumption. Still, in exchange, the legislation stip-

ulates that the energy produced is fed into the grid, and those who are part of the energy community receive an incentive commensurate with their consumption during the hours the plant is active. In short, the users pay the bill, and the energy community receives money from the energy services manager. Furthermore, the 2021 decree on energy communities (European Commission, 2021a, 2021b) imposed a maximum power output limit of 200 kilowatts and required that the users connected to the energy community depend on the same secondary substation, that is, the plant where the electricity passes from medium voltage to low voltage. To understand the influence of these limits on the model's scalability, one only has to consider that a small town like Villanovaforru has three secondary substations.

The cases analyzed show the shortcomings of fully decentralized peer-to-peer energy consumption models. Even though decentralized models would greatly benefit the issues connected with the power supply grid infrastructure by allowing exchanges between nodes in the grid, said models still face application and scalability issues due to the evolution of the existing norms and – as such – appear feasible only in contexts with a lack of control and regulations on the subject.

3.2. Hybrid Peer-to-Peer Models, European Policies and Energy Neighborhoods

In recent years, the transition towards a more sustainable and decentralized energy system has become increasingly important on the political and social agenda, both globally and at the European level.

In this context, the peer-to-peer energy consumption model has emerged as one of the most promising solutions to address the challenges of energy production, distribution, and consumption. Several experiments are being carried out at the neighborhood and community levels (Stremke, 2022).
These models can be described as Hybrid peer-to-peer as they combine a mix of production models based on the insertion of small production cores in the form of neighborhoods within the city. The energy produced is partly used internally and partly shared with the centralized city grid.

Among the most notable examples the Kronsberg district in Hannover can be mentioned (Fraker, 2013), which covers approximately 150 hectares and was created in a participatory form to create new housing for EXPO 2000; the project, which includes residences, services, schools and a center dedicated to culture and the arts, envisages housing diversification with three different types of buildings based on energy consumption: "NEH" buildings with consumption below 55 kWh/m2a, "PH" buildings with consumption below 15 kWh/m2a and "SH" buildings with zero consumption, capable of producing more energy than they consume.

Within the district, the *SolarCity* project is an emblematic case: it is a social housing complex (supported by various bodies, including the Göttingen Energy Agency) that has benefited from European, national, and local funding. The flats are heated thanks to 1,350 m2 of solar collectors, and the excess energy produced in summer is stored in highly insulated tanks for winter use. This system is very efficient but relies

on the district's centralized grid to cover the entire share of housing needs (Guarini, 2011, pp. 8-9).
Furthermore, the Schoonship neighborhood in Amsterdam can be cited. Schoonschip is a floating residential neighborhood in a side canal of the River IJ in the Buiksloterham area of Amsterdam North (Leclercq, 2023). The initiators' ambition was to develop the most sustainable neighborhood achievable. Energy plays a central role, as it is generated locally and exchanged with neighbors via a smart grid.

After 10 years of making and implementing plans, 46 households comprising over 100 residents live on the houseboats. These goals were then translated into an ambitious urban design plan, in which the various houseboats are connected by shared jetties. All the homes are connected to a smart grid so that energy is generated collectively, exchanged, and settled between themselves. The 46 house-holds have a single connection to the national energy grid.

From an infrastructural point of view, these cases are functional but not fully decentralized, as they partly rely on the city's grid to be energy efficient, showing that a mixed approach between centralized and decentralized energy production models could be an alternative to an application of feasible peer-to-peer scenarios, in which citizens collaborate to shape a *revolution* of current production and consumption models, based on practices of co-creation, co-production and co-management of resources and goods.

4. Conclusions

The experiments described here cannot be understood as optimal or resolving solutions nor be considered better models in absolute value. Still, they open up alternative and complementary scenarios to the centralized energy production/consumption system, unprepared to face the great contemporary energy challenges.
When read through the lens of the IT revolution, these experiments allow us to see how the criticalities associated with economic-productive structures have been codified for years, enhancing citizens' role in the energy transition.

These models will have to be monitored shortly to fully understand their potential and limitations, margins of effectiveness, and inherent risks: their suitability for use must be assessed concerning the specificities of the territorial context, considering, for example – concerning codified centralized systems – the level of initial economic investment and expenses when fully operational, the pervasiveness and capacity for more or less capillary diffusion even in peri- or extra-urban contexts, the adequacy in satisfying both medium-low and discontinuous energy demands and high energy demands, but episodic and unpredictable.
In this interpretative hypothesis, the "peer to peer" model might be better when there is a capillary spread of many demands, with medium to low and discontinuous energy demands (e.g. in residential districts). In contrast, the "client-server" model would be better with stable energy demand, with a very high flow (e.g., in industrial areas), i.e., in contexts with high concentrated energy demand.

The hypothesis to be pursued should therefore envisage a hybridisation of the two systems, with an overcoming of the approach typically derived from the industrial revolution (linear vision) towards a more contemporary scenario, proposed instead by the information technology revolution (reticular and systemic vision): the digital paradigm of the electronic age can thus help us outline more sustainable urban and energy innovation scenarios, complementary if not alternative to those prevailing - but also abused and sometimes oversimplified - typical of the contemporary debate on sustainability (circular vision).

It is up to us to imagine and then promote radical changes, affirming new development trajectories and new value systems that can overcome the current ones at the root of contemporary economic, energy, environmental, and climate crises.

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