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PAD

HUMANIZING ENERGY

PAD. Pages on Arts and Design
International, peer-reviewed,
open access journal
founded by Vanni Pasca in 2005

Publishing Consultant
Vincenzo Castellana, Architect, Italy

Art Direction
Francesco E. Guida

Web Site
Pietro Forino, www.pietroforino.com

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Publisher
Aiap Edizioni
via A. Ponchielli 3 – 20129 Milano – Italy
aiap@aiap.it – www.aiap.it

PAD © ISSN 1972-7887
#26, Vol. 17, June 2024
www.padjournal.net

0. EDITORIAL #26

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Towards Energy Sustainability in the Digital Realm

A Compass of Strategies between Natural and Artificial Intelligence

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Keywords
Digital Sustainability, CO2 Emissions, Energy Centred Design, Artificial vs Natural Intelligence.

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 sus-

tainability 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.

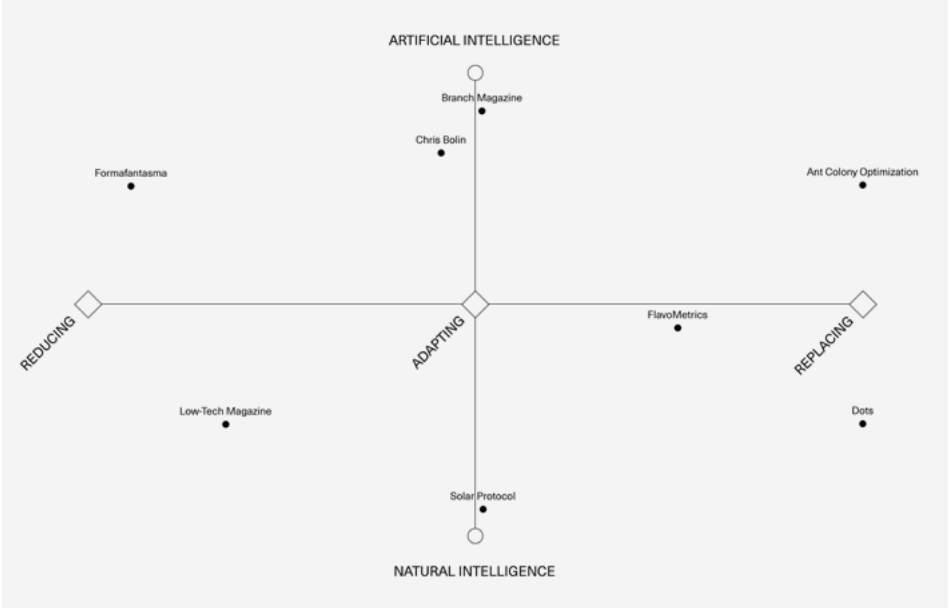

Figure 1. Diagram showcasing the relationship between the main drivers for sustainable digital design; AI and NI are on the vertical axis, while three design strategies are on the horizontal axis, i.e. reducing, adapting and replacing.

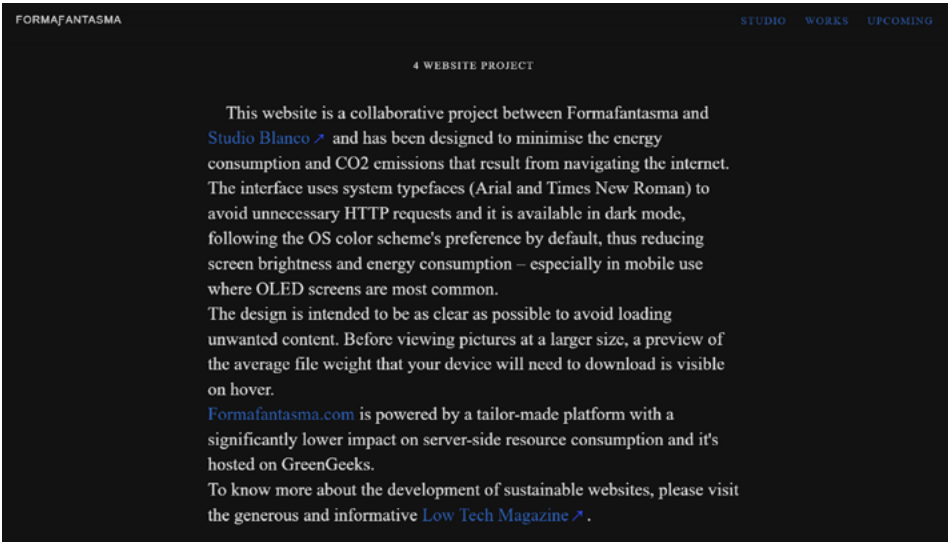

Figure 2. Screenshot of Formafantasma website [accessed on June 19, 2024].

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.

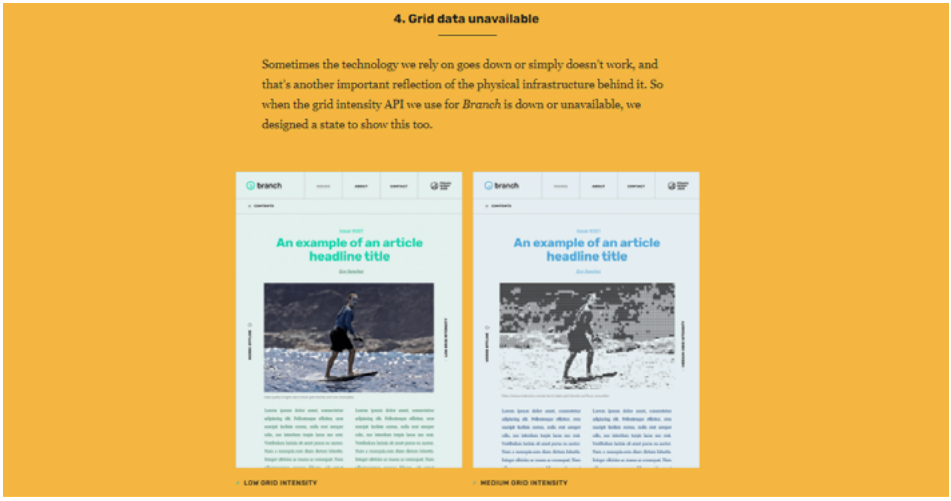

Figure 4. Screenshot of Branch online magazine [accessed on June 19, 2024].

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

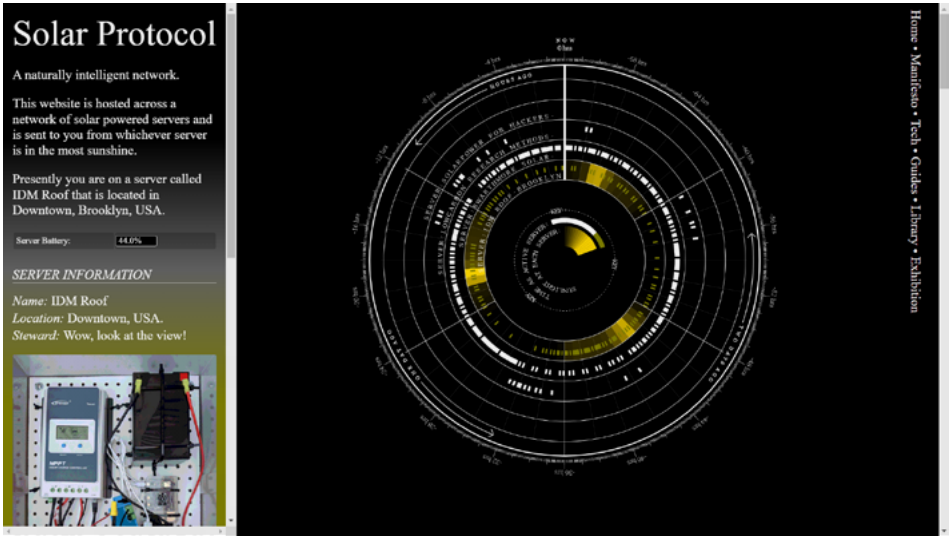

Figure 6. Screenshot of Solar Protocol website [accessed on June 19, 2024].

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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IV

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PAD. Pages on Arts and Design
International, peer-reviewed,
open access journal
ISSN 1972-7887

#26, Vol. 17, June 2024

www.padjournal.net

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della comunicazione visiva