RIVISTA ITALIANA DI

ERGONOMIA

ORGANO UFFICIALE DELLA S.I.E. - SOCIETÀ ITALIANA DI ERGONOMIA

N.27 - 2023

Poste Italiane S.p.A. – Sped. in Abbon. Post. DL 353/2003 conv. in L.27/02/2004, n.46, art.1 comma 1 DCB Milano – rivista quadrimestrale – anno 12 – n. 27, 2023

- ERGONOMICS FOR A BETTER USE AND CONSUMPTION OF RESOURCES
- ENERGY RESPONSIVE DESIGN
- ERGONOMIC DESIGN FOR PUBLIC TOILETS FAUCET
- EU GREEN DEAL
- ASSESSING PEAK EXPIRATORY FLOW RATE HEALTH RISKS NEAR CEMENT FACILITIES
- SMART INLAND WATERWAYS TRANSPORT SERVICE AND THE IMPACT OF DIGITALIZATION ON HUMAN RESOURCES

RIVISTA ITALIANA DI
ERGONOMIA

RIVISTA QUADRIMESTRALE
NUOVA EDIZIONE
NUMERO 27 - 2023

Organo ufficiale della
SOCIETÀ ITALIANA DI ERGONOMIA
www.societadiergonomia.it

SEDE LEGALE REDAZIONE, AMMINISTRAZIONE, ABBONAMENTI, PUBBLICITÀ
Segreteria SIE c/o R.M. Società di Congressi srl
Via Ciro Menotti 11, 20129 Milano
tel. +39 02 70.12.63.67 – segreteria@societadiergonomia.it

PROGETTO GRAFICO E IMPAGINAZIONE
Frush [Design sostenibile] – www.frush.it

PREZZO PER L'ITALIA € 10,00
ABBONAMENTO ANNUALE € 25,00
ABBONAMENTO STUDENTI € 20,00
ABBONAMENTO BIBILOTECHE E ISTITUZIONI € 30,00
L'abbonamento comprende 3 numeri della rivista

Autorizzazione del Tribunale di Milano n. 484 del 30 Ottobre 2009
Poste Italiane S.p.A. - Sped. in Abbon. Post. DL 353/2003 conv. in L.27/02/2004, n.46, art.1 comma 1 DCB Milano
ISSN 2531-8845, 2/12/2016, Rivista Italiana di Ergonomia

RIVISTA ITALIANA DI ERGONOMIA

THE RIVISTA ITALIANA DI ERGONOMIA, *of the* S.I.E. *- Italian Society of Ergonomics, is a scientific journal that operates nationally and internationally for the promotion and development of ergonomics and the study of human factors, and the dissemination and systematization of knowledge and experiences related to the ergonomic approach, in close relationship with the social, environmental and productive realities where human beings, operate and live, coherently with the goals of the* SIE.

Supported by an international scientific committee and using a double-blind reviewing process, the journal publishes original contributions from research and applications on ergonomic issues, in its various aspects and related to the different contexts and human activities.

The RIVISTA ITALIANA DI ERGONOMIA *is aimed at ergonomic professionals and all those interested in applying the principles and methods of ergonomics / human factors in the design, planning and management of technical and social systems, in work or in leisure.*

INDEX

Energy responsive design: a novel paradigm for human – technology interaction

ANNAPAOLA VACANTI, MICHELE DE CHIRICO,
CARMELO LEONARDI, MASSIMILIANO CASON VILLA
Università Iuav di Venezia

Keywords: eco-ergonomics, energy-centered design, responsiveness, energy responsive design

Abstract

The complex relationship between humanity, technology, and energy is a defining characteristic of modern life, shaping our environment and experiences. The paper aims to explore the evolution of this relationship, highlighting the need for novel solutions and practices in the design field that can drive the transition to energy efficient artifacts and sustainable lifestyles. Building on the concepts of eco-ergonomics and green economics, we highlight the necessity to take into account the connection between energy-efficient solutions and the behavioral dimension of human nature. Introducing the term energy responsive design, we extend the concept of responsiveness from web design to energy usage, advocating for a design approach that integrates energy efficiency with user-centered experiences. A case studies section then illustrates and discusses the application of such an approach to diverse design domains (digital, product, and interior). The case studies

show how both natural and artificial intelligence can be leveraged to design responsive artifacts that do not necessarily need human cognition, but rather operate autonomously in shaping the environment, experience, and resource consumption of users' daily practices, while also making energy more visible, and understandable. Ultimately, we aim to encourage further exploration in this field, proposing the expansion of energy responsive design to new areas and assessing its potential in the design practice.

Humanity, technology, energy

The modification and artificialization of the environment is what defines the human, by – inevitably and at the same time – detaching him from nature (Caronia, 1996); indeed, Gehlen (1988) effectively describes humans as technological beings by nature. Such a peculiar characteristic has driven the evolution of technology to the extent of becoming so deeply intertwined with the environment, that it became what Morton describes as an *hyperobject* (2013), a massive entity that shares space and resources with humanity.

Our living, working, and social environments are increasingly adapting to incorporate technology. This includes considering the need for constant Internet access, accommodating the infrastructure for servers, designing spaces to facilitate the movement of autonomous robots, and updating public transportation systems. Meanwhile, our bodies are becoming more integrated with technology through the use of prosthetics and wearable devices, enhancing our natural senses with artificial stimuli. The same energy sources that we use to warm and brighten our spaces are being heavily utilized to support an ever-growing digital infrastructure.

Indeed, the evolution of energy sources has been closely tied to technological advancements. Historically, energy was derived from organic sources such as wood, water, and muscle power. The industrial revolution then marked a significant shift with the adoption of coal, oil, gas, and electricity. The transition to these fossil fuels made energy cheaper and more accessible, facilitating global industrialization and urbanization, while leading to environmental challenges, such as greenhouse gas emissions and climate change. This evolution not only made energy more economical but also transformed its distribution, shaping modern society and economy (Wrigley, 2016). Today, a growing shift towards sustainable and renewable energy sources like solar and wind power, is driven by the need to balance

energy availability with environmental stewardship. This ongoing evolution reflects the continuous interplay between technological progress and energy use, and highlights how the complex relationship between humans and technology requires both of the actors to partially adapt to one another.
In this context, as a discipline that bridges the gap between products and human behavior, design plays an important role in incorporating technology into everyday environments, both digital and physical. Specifically, inside of the design approach, ergonomics is traditionally the field that ensures that the human factor is incorporated into design choices, by helping the designer assess the consequences of said choices in terms of safety, health, comfort, and efficiency (Chapanis, 1995). The term *eco-ergonomics* (Hanson, 2013; Hedge, 2008) has also been used, appearing as early as 1998 (Charytonowicz, 1998), to take into account the needs of the natural environment with which humans interact, and Thatcher and Groves (2008) used the related term *green ergonomics*, highlighting the design of low resource systems and products, the design of green jobs and achieving systemic behavior change, as areas where ergonomics could contribute to conserving and restoring nature and allowing humans to benefit.
Thus, a form of *energy ergonomics* can be imagined as a design approach that bridges the technologic aspects of energy-based solutions with the behavioral dimension of human nature. In fact, as a result of the distance between our living environment and the remote places where energy is produced, people tend to lack firsthand experience with energy as a tangible entity (Leonardi et al., 2023). The processes of its generation, which used to be a significant part of social, material, and cultural life, are now less visible. In modern times, electricity is consumed extensively, yet the labor required for its production and distribution happens in distant, often unknown locations. Advancing towards sustainable energy sources necessitates efforts to enhance individual awareness and collective consciousness, and requires designers to focus on the balance of user comfort, design features, and energy efficiency.

Energy responsive design

As of today, the most popular approaches to effectively support sustainable behaviors and practices in everyday life include both the effort of making technology more efficient, and the attempt of making energy visible (Javaid et al., 2022). The latter is often achieved through the implementation of devices and interfaces that provide visual data, thereby enabling users to consciously adjust their behavior in response to real-time energy availability. These approaches are not only instrumental in reducing energy consumption but also serve an educational purpose, fostering awareness about the environmental impact of our artificial infrastructures. However, it is arguable that a valuable turn of perspective would be that of making technology autonomously adapt to energy consumption, without the need for an active involvement of human cognition. This concept advocates for a seamless adaptation of technology, aimed at simplifying human experiences and minimizing friction, rather than imposing the cognitive burden of resource usage issues on individuals. Such an approach would ensure that technology functions within sustainable parameters without requiring constant human oversight or decision-making, as the technology itself becomes a proactive agent (Latour, 2005) in energy optimization.

In this sense, we intend to introduce the concept of *energy responsive design*, building on the well known concept of *responsive web design* (Marcotte, 2011), which refers to the dynamic adjustment of the digital space to the screen boundaries of different devices. Web responsiveness is a characteristic of the digital artifact, and does not need users to be aware of it; nevertheless, it has a huge impact on user experience.

Within the field of web development, two distinct methodologies are employed to optimize website responsiveness across a range of browsers, from the latest versions to older ones (Heilmann, 2009). *Graceful degradation* builds web functionalities to provide a high-level user experience in modern browsers, while ensuring a basic but functional experience in older browsers. The goal is to maintain core functionality without disruption, even though the experience may be less engaging on less advanced platforms. *Progressive enhancement*, on the other hand, starts with establishing a basic level of user experience, accessible by all browsers, and then layers more advanced features that are activated in browsers capable of supporting them. This method focuses on building from a simple, functional base and progressively adding more sophisticated capabilities as technological advancements permit.

Essentially, while graceful degradation focuses on adapting downward from a current standard of complexity for lesser experiences, progressive enhancement begins with a minimal, functional foundation, allowing for continual expansion to accommodate future technologies. The former looks backward to ensure backward compatibility, whereas the latter looks forward, maintaining a solid foundation for future enhancements.

Energy responsive design involves designing products and systems that can adapt their functionality in response to the type or quantity of available energy, much like how websites adapt to different browsers. In this approach, the role of the designer becomes pivotal in pre-planning various operational states of a project, contingent on the energy resources at hand. This means designing for multiple scenarios, where a device or system can operate at different levels of functionality based on the energy available.

Graceful degradation in this context would mean that a device or system is designed to deliver optimal performance when energy is abundant but still maintains essential functionality in low-energy scenarios. This ensures that the basic purpose of the technology is fulfilled, even under constrained energy conditions. Conversely, progressive enhancement in energy responsive design would involve creating a basic, energy-efficient operational mode that all devices can maintain. As more energy becomes available, additional features and functionalities could be activated, enhancing the user experience without compromising the basic utility. Also, a key aspect of this design approach is empowering users with the choice to intervene and manually adjust the energy consumption state of a device, thus bringing back the concept of making energy consumption visible and tangible to the user. By providing clear feedback on energy usage, users can decide whether to allow the technology to operate autonomously or to take control, consciously managing their energy consumption.

In the following section, we will delve into existing case studies across various design domains that are already employing this concept of energy responsiveness. These examples will illustrate how the principles of energy responsive design are being practically applied and integrated into real-world solutions, providing valuable insights into the application and impact of this approach.

Case studies

Having defined the concept of energy responsive design as a dynamic adjustment of the aesthetics and/or functionality of an artifact to the availability of the energy source, this section aims to give an overview of projects that implement such approach into real-life scenarios.

Digital domain

The energy consumption of computing systems, ranging from large-scale supercomputers to personal laptops, has become increasingly significant due to economic and environmental considerations. In 2020, the Information and Communication Technologies (ICT) sector contributed to 2.8% of global greenhouse gas emissions, with projections of 830 million tons of CO2 by 2030 (Freitag et al., 2021). Today's amount and duration of online activities, facilitated by smartphones and tablets, leads to higher energy demands. Two key factors contribute to this: the rising data intensity of services, like high-definition video content, and the growing amount of automated data traffic between computers, significantly driven by software updates (De Decker, 2022). To address this, responsiveness can be leveraged both in hardware design, and web design.

With regard to hardware (smartphones, laptops, tablets, ...), several approaches aim to extend battery life. For example, most devices autonomously adapt screen brightness to the situation, being brighter when plugged in and darker when using battery – of course, the user can actively intervene in changing the setting.

A recent advancement in this approach is Optimized Battery Charging[1], a feature being introduced by Apple in iOS 13, designed to prolong battery lifespan by minimizing the time an iPhone remains fully charged. This feature prevents the battery from charging beyond 80% under certain conditions. It employs on-device machine learning to adapt to individual charging routines, activating only during extended periods of charging. This approach ensures the iPhone is fully charged when needed, while reducing battery wear. When Optimized Battery Charging is in use, a notification on the Lock Screen indicates the estimated time when the iPhone will be fully charged. For urgent charging needs, users can override this feature. This functionality represents a balance between maintaining battery health and ensuring device readiness.

In web design, two case studies have become mostly influential in the field of energy driven design, and makes use of responsiveness through different strategies.

The case study of Branch magazine, a digital publication about sus-

[1] https://support.apple.com/en-us/HT210512

[2] https://branch.climateaction.tech/issues/issue-1/designing-branch-sustainable-interaction-design-principles/

tainability, aligns with the goal of a greener web through the design introduced by Tom Jarrett, who focused his UI and UX choices on energy demand and grid intensity. Grid demand refers to the fluctuating requirement for electricity, with suppliers adjusting their output based on demand levels. Carbon intensity, measuring the greenhouse gases emitted per unit of electricity, varies with the proportion of renewables in the energy supply. Renewable sources, being intermittent, often require baseload generation from fossil fuels, especially during peak demand times. Branch's interface showcases this approach by changing its design based on grid intensity, utilizing a grid intensity API and user location. At low carbon intensity, indicating higher renewable energy output, the full magazine cover and media content are displayed. Medium intensity leads to lower resolution displays, and high intensity, with increased carbon emissions, results in images and other media being hidden by default, only accessible upon user request.

Solar Protocol[3], instead, is a solar-powered network, created by a group of artists and New York University professors, which challenges conventional digital design by controlling traffic through the "logic of the sun" (Brain et al., 2022). The network comprises solar-powered servers located worldwide, strategically set up across different time zones. These servers prioritize locations with the most sunlight at any given time, in contrast to the typical internet model where requests are directed to the geographically nearest server for faster responses. This approach, while potentially slowing down websites load times, optimally utilizes naturally available energy. The network currently hosts a few websites and is being developed into a broader digital space for essays and artworks. The creators see this project as a platform to explore themes like designing with natural intelligence, designing for intermittency, and reevaluating the necessity of high-resolution and constant availability in digital design.

[3] https://www.dezeen.com/2022/09/27/solar-protocol-network-explores-potential-solar-powered-internet/

Product Design domain

A notable aspect of household energy consumption in Western homes is that approximately 10% of it is attributed to electronic appliances in standby mode. This phenomenon, often referred to as vampire load, surprisingly contributes to 1% of the total CO_2 emissions (Mullai & Sivasamy, 2017). Standby mode, particularly in computers, exemplifies this issue. Even when turned off, these devices maintain a low level of power consumption, typically around 2 watts, primarily for maintaining quick startup procedures. This seemingly insignificant power usage accumulates over time, leading to a substantial energy drain. The imperative is then to rethink product design from an energy-conscious perspective, not only improving the energy efficiency of devices during active use but also addressing their energy consumption when idle. Designing products that intelligently manage power, transitioning seamlessly between active and standby modes, and possibly even eliminating standby power requirements altogether, is essential.

The case study of Nisshoku[4], a lamp designed by Yuichiro Morimoto, is a valid example among several case studies that leverage solar power to dynamically change the aesthetics and amount of light emitted by lighting devices. Nisshoku, named after the Japanese word for eclipse, is a lamp that operates without electricity, absorbing light from its environment and emitting a warm glow, reminiscent of a solar eclipse (Morimoto, 2023). The design also incorporates a layer of milky white opalescent acrylic placed atop the condensing plate, which helps to diffuse the light effectively. The lamp utilizes a special acrylic material known as a condensing plate, engineered to collect light rays and release them along the edges of a circular form, creating an eclipse-like effect that grows stronger in relation to the amount of sunlight it receives. Differently from other products, Nisshoku is designed to function and look appealing both when being fully lit and when emitting just a small amount of light, reproducing the natural effect of an eclipse by responsively reacting to the solar energy available, in complete autonomy from the choices of the user.

A similar approach is followed in the design of Ra[5], a solar-powered tapestry designed by Marjan van Aubel to be hung in windows, named after the ancient Egyptian sun god (Hahn, 2022). It is made from transparent photovoltaic cells arranged in a geometric pattern, less than one millimeter thick. During the day, Ra captures sunlight, but is not inert, because it changes the interior by casting vivid shadows on surrounding walls; at night, it glows with an embedded ring of electroluminescent paper, powered by the energy collected throughout the day. It is designed as a thin, portable wall hanging that can be rolled up like a scroll. The glowing center is made from electroluminescent paper, similar to those used in watch displays, powered by an integrated battery. The tapestry uses organic PVs printed using light-absorbing ink covering nanoparticles of titanium

[4] https://www.designboom.com/design/nisshoku-captures-light-surroundings-exude-eclipse-like-glow-yuichiro-morimoto-01-31-2023/

[5] https://www.dezeen.com/2022/01/26/ra-marjan-van-aubel-tapestry/

oxide on a polyethylene terephthalate (PET) plastic sheet, allowing them to be flexible, lightweight, and versatile. Unlike traditional silicon-based solar panels, organic PVs are much lighter and thinner, offering efficient material use and ease of transportation.

Interior Design domain

The term responsive in the context of architecture (Aziz et al., 2021) refers to the interaction and response between natural and artificial systems, ensuring the building's ability to automatically adapt and learn over time. Since the latter half of the last century, architectural envelopes are evolving their role from mere protection to energy accumulation and generation, thanks to advancements in materials and energy-efficient system design. In addition to this, there is a growing necessity for systems capable of autonomously managing the energy consumption of interior spaces, which involves the integration of low-energy consumption appliances and products, and sophisticated control systems. Incorporating these elements into interior design not only enhances the sustainability of buildings but also improves the comfort and well-being of occupants.

For instance, the Lunar System[6] is an all-in-one solution designed for optimal energy capture and management in homes. It's a compact system that includes a battery, bridge, and app, allowing homeowners to use, store, and control their energy, adaptable to various conditions. The Lunar Bridge forms a crucial link between the home and the external grid, automatically managing power when sensing a flicker on the grid, to keep the power flowing through an outage. The system also includes stackable battery modules that can expand with demand, ensuring scalability for different energy needs and an accompanying Lunar App, which employs predictive AI to optimize energy use, tracking weather patterns and energy costs for efficient power management, and shows at a glance the current and predicted autonomous activity of the system.

[6] https://www.lunarenergy.com/lunar-system

The case study of Soft House[7], instead, is a unique architectural project from a Massachusetts Institute of Technology (MIT) team, led by Sheila Kennedy and showcased at the International Building Exhibition (IBA) in Hamburg, which highlights green innovations in construction. The Soft House features a dynamic facade with textile strips integrated with photovoltaic cells for solar tracking and maximizing energy capture while also acting as a natural shield. The design incorporates a light wood frame to create a flexible living

[7] https://www.kvarch.net/projects/soft-house

space, while the energy produced by these solar curtains is used for LED lighting, reducing carbon emissions. Similar projects involving dynamic facades and other solutions showcase a systemic responsive approach that allows designers to control and improve the living conditions within interior spaces by leveraging renewable energy sources and natural intelligence.

Takeaways and further developments

In this paper, we have advocated a shift in the concept of responsiveness from the digital realm to the domain of energy consumption. Our proposal underscores how this approach is closely tied to ergonomics, fostering more satisfying user experiences along with greater energy efficiency. However, it has to be acknowledged that the case studies presented may not be exhaustive, as the "energy responsive" label is a term applied by the authors. Yet, the selection provides a snapshot of current design practices, demonstrating the application of responsiveness across various fields and projects. The majority of these cases are strongly linked to solar energy, suggesting a future trend, but also raising questions about the application of this approach to other energy sources. Also, it can be noticed how web development's key concepts like graceful degradation (as seen in Branch's website) and progressive enhancement (as in the Nisshoku lamp and Ra tapestry) are evident in some (but not all) case studies.

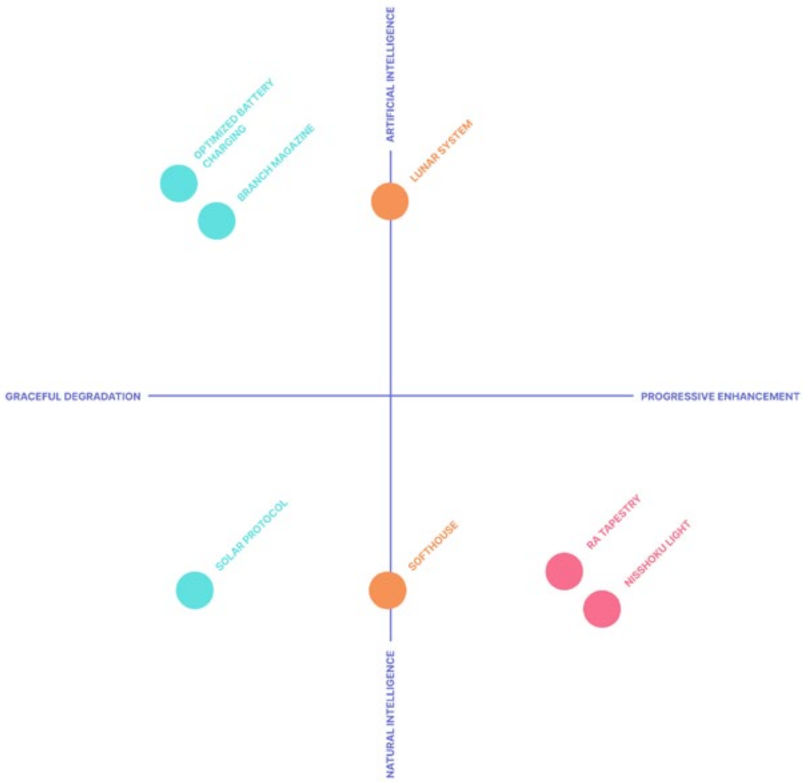

Figure 1. The scheme showcases how the 7 case studies leverage artificial or natural intelligence, and whether they use graceful degradation, progressive enhancement, or neither. At a glance, it is evident how digital case studies tend to adopt a degrading approach, while product case studies are bound to solar natural intelligence and progressive enhancement. A gap is also visible in the domain of progressive enhancement case studies powered by artificial intelligence (credits: A. Vacanti, 2023).

Relevantly, we found both metamorphic artifacts that adapt in response to daily energy changes (as seen in Solar Protocol) – thus recreating a sense of connection to natural intelligence – and smart artifacts whose state changes are activated by the implementation of algorithms and artificial intelligence (as seen in Lunar System). Many case studies also undergo aesthetic modifications along with functional changes. This aspect of energy responsive design is significant as it offers visual feedback and transforms the user experience, enhancing the understanding and the connection between people, technology, and energy, ultimately supporting a positive shift in the way we manage and consume our resources.
To sum up, our study indicates that energy responsive design holds substantial promise for advancing sustainable design practices, following a novel energy ergonomics approach. Future research will focus on identifying novel application areas for this concept, examining its viability across different design fields, with the objective to achieve a more balanced and environmentally conscious usage of energy in daily practices, thus reflecting a pragmatic and thoughtful approach to sustainability.

ACKNOWLEDGEMENTS
The sections are to be attributed as follows. Section 1 is a joint reflection of the authors. Sections 2 and 3.2 are to be attributed to A. Vacanti; section 3.1 to C. Leonardi; section 3.3 to M. Cason Villa; section 4 to M. De Chirico.

References

- Abbing, R. R. (2021). 'This is a solar-powered website, which means it sometimes goes offline': a design inquiry into degrowth and ICT. In LIMITS Workshop on Computing within Limits. https://doi.org/10.21428/bf6fb269.e78d19f6

- Aziz, H. N. A., & Abdelall, M. I. (2021). Responsive façades design using nanomaterials for optimizing buildings' energy performance. Ecology and the Environment, 253, 397-408 https://doi.org/10.2495/sc210331

- Brain, T., Nathanson, A., & Piantella, B. (2022). Solar Protocol: Exploring Energy-Centered Design. In Eighth Workshop on Computing within Limits 2022, LIMITS.

- Caronia, A. (1996). Il corpo virtuale. Dal corpo robotizzato al corpo disseminato nelle reti. Franco Muzzio Editore.

- Chapanis, A. (1995). Ergonomics in product development: a personal view. Ergonomics, 38(8), 1625-1638.

- Charytonowicz, J. (1998). Ergonomics in Architecture. In Human Factors in Organizational Design and Management, VI: Proceedings of the Sixth International Symposium on Human Factors in Organizational Design and Management Held in The Hague, 357. The Netherlands, August 19-22.

- De Decker, K. (2022). Why we need a speed limit for the internet. Low Tech Magazine https://solar.lowtechmagazine.com/2015/10/can-the-internet-run-on-renewable-energy/

- Freitag, C., Berners-Lee, M., Widdicks, K., Knowles, B., Blair, G., & Friday, A. (2021). The climate impact of ICT: A review of estimates, trends and regulations. arXiv preprint arXiv:2102.02622.

- Gehlen, A. (1988). Man, his nature and place in the world (Vol. 3). Columbia University Press.

- Hanson, M. A. (2013). Green ergonomics: challenges and opportunities. Ergonomics, 56(3), 399-408.

- Hedge, A. (2008). The sprouting of "green" ergonomics. Human Factors and Ergonomics Society Bulletin, 51(12), 1-3.

- Heilmann, C. (2009). Graceful degradation versus progressive enhancement. Dev. Opera. https://web.archive.org/web/20121220062725/http://dev.opera.com/articles/view/graceful-degradation-progressive-enhancement/

- Javaid, M., Haleem, A., Singh, R. P., Khan, S., & Suman, R. (2022). Sustainability 4.0 and its applications in the field of manufacturing. Internet of Things and Cyber-Physical Systems, 2, 82–90. https://doi.org/10.1016/j.iotcps.2022.06.001

- Latour, B. (2005). Reassembling the Social: An Introduction to Actor-Network-Theory. Oxford University Press.

- Leonardi, C., Crippa, D., di Prete, B., & Pasteris, P. (2023). Designing for the energy transition from INtuition to INtention. TECHNE - Journal of Technology for Architecture and Environment, 26, 53–60. https://doi.org/10.36253/techne-14479

- Marcotte, E. (2010). Responsive Web Design. A List Apart. https://alistapart.com/article/responsive-web-design/

- Morton, T. (2013). Hyperobjects: Philosophy and Ecology after the End of the World. University of Minnesota Press.

- Mullai, B. D., & Sivasamy, R. (2017). Impact of vampire power and its reduction techniques — A review. In 2017 International Conference on Intelligent Computing and Control Systems (ICICCS) (pp. 404-405). IEEE.

- Thatcher, A., Groves, A. (2008). Ecological Ergonomics: Designing Products to Encourage pro-Environmental Behaviour. In CybErg 2008: The Fifth International Cyberspace Conference on Ergonomics.

- Wrigley, E.A. (2016). Energy and the English Industrial Revolution. Cambridge University Press.

ANNAPAOLA VACANTI

Researcher at Università Iuav di Venezia since 2023, Annapaola Vacanti focuses her efforts on Human - Technology Interaction, exploring the intersection between human factors, technological development, and the social and ecological impact of the latter. She gained a Ph.D in Design from the University of Genova in 2022. Alongside her academic career, since 2018 she organizes and curates TEDxGenova, an autonomous event operating under official TED license for the local dissemination of valuable ideas.

MICHELE DE CHIRICO

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

CARMELO LEONARDI

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

MASSIMILIANO CASON VILLA

Exhibit designer and Ph.D student in Design Sciences at Università Iuav di Venezia, his research focuses on strategic design approaches that bridge the gap between Life cycle Assessment tools and Ecodesign processes. Since 2021 he is teaching Technology of Materials at NABA Milano.