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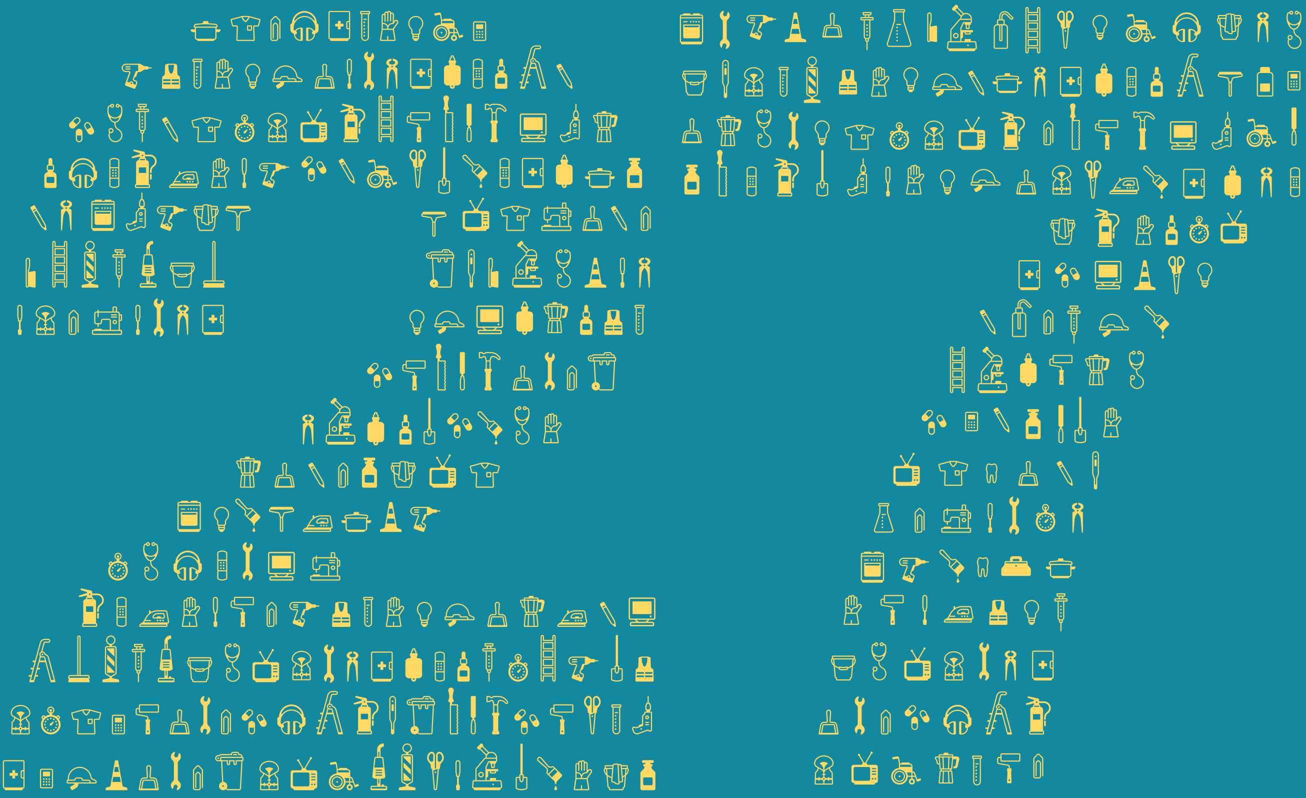

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# RIVISTA ITALIANA DI ERGONOMIA

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.

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# EDITORIAL

ERMINIA ATTAIANESE

## Resources sustainable use. Which implications for ergonomics?

A resource (from the French ressource) is a means, i.e. an available capacity, consisting of a tangible or intangible reserve that expresses an aptitude for adequately responding to difficulties, synonymous with something that resurrects, that embodies the sense of continuity. This meaning suggests that the concept of resource includes the idea of a continuous evolution, closely related to the evolution of man's needs, and his ability to meet them through the identification of means that from time to time adapt to needs, in this assuming the role of resources (Attaianese, 1997).

Even if a lot of people would argue that they can live by with very little, the reality is that resources, both natural and man-made, are essential to human life, growth, development, and advancement. Materials, water, energy, minerals, services, personnel, information, and other means that can be changed to create advantages are among the resources used by humans (Chang, 2016).

The concept of resource is closely linked to those of environment, considered as the natural framework in which vital phenomena take place, because it clearly reflets a sense of necessity: in fact, living beings are linked to the environment through the resources it offers them, in such a relationship that an irreversible stoppage of these would necessarily cause their death (Ciribini, 1984)

From a human perspective, a resource is obtained from the environment to satisfy human needs and wants. From a broader biological or ecological perspective, a natural resource satisfies the needs of a living organism. If we consider systems

as “organisms”, then they too have needs for resources that are needed to sustain them.
Particularly, the natural resources represent a fundamental link between humans and their environment, and the issue related to their sustainable management is an important point in about all global strategies and practices as one of the most relevant challenges of our times.
From the first UN initiatives (UN, 1972) to the 2030 Agenda for Sustainable Development (UN, 2015) and beyond, the right of people to adequate living conditions has been linked to the responsibility to protect and improve the environment by safeguarding its natural resources, and to the increasing need of more conscious consumption and production models.
Nevertheless, today more than ever, we continue to extract, process, consume, and waste resources at every stage of a product or service lifecycle, much faster than how the Planet can regenerate. The environmental long-term impacts due to the ecological deficit and the drawing down local resource stocks drive the three planetary crises we are currently facing: climate change, biodiversity loss, and pollution.
This critical scenario requires a paradigm shift toward not-linear production and consume models (Ellen MacArthur Foundation, 2023), in relation to which Ergonomics and Human Factors methodologies and applications may play a significant role (Richardson and Thatcher, 2023), e.g.:

- by rethinking how to design using less, for an efficient materials use, without decreasing products effectiveness and usability for different users' needs (Mugge and Bakker, 2018).
- by extending the life cycle of products, increasing the effectiveness and acceptance of practices for sharing, leasing, reusing, repairing, refurbishing and recycling, taking in account the local identities and day-to-day experiences of communities (Lumbreras, 2021).
- by supporting decisions making taking into account the system as a whole over a longer period of time, and structuring interventions by adopting systematic eco-socio-technical approaches, inclusive and context-sensible, capable to act at different levels, from macro to micro scale (Thatcher, 2017).

- by increasing sustainable products manufacturing, capable for transforming raw materials using processes that do not affect the environment, while saving energy and other resources, but assuring, at the same time, human safety and wellbeing (Lin et al, 2019).

But, above all, inclusion and participation practices typical of human-centred approach, contribute to the development of accepted circular models, involving people not as passive recipients of politics or strategies, but as leading actors adopting sustainable life-styles and behaviors (Sinclair, 2021), capable to progressively decrease human footprint on the environment through conscious shared choices.

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# Ergonomics for a better use and consumption of resources

ERMINIA ATTAIANESE[1] AND EMILIO ROSSI[2, 3]

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Since the publication of 'Blue Marble', one of the most famous photographs of Earth taken in 1972 by the crew of the Apollo 17, the public opinion has gained an indisputable awareness that world's resources are no limitless and that preserving the environmental balance must have been a global imperative. Fifty years later, issues related to the efficient use and the sustainable consumption of human and natural resources are more crucial than ever (Glavič, 2021). Accordingly, studies on how to prevent the waste of resources have been developed in many fields such as Engineering, Economics, Architecture and Design, and in the domain of Social Sciences (Wang et al. 2019). However, the current picture of what the world is facing in this historical period suggests that much more must be done (WEF, 2023). Despite the huge number of studies in the field, there is a public consensus that the entire scientific community needs to further dig into this complex and multidisciplinary research framework. Thus, with the growing concern about environmental degradation and climate change, it is imperative to explore innovative approaches to conserving resources while ensuring optimal utilizations for present and future generations. There is a close tie between the issue of how to use and consume resources – human, natural, economic, industrial, cultural, etc. – and the discipline of Ergonomics and Human Factor (HFE) (Bolis et al. 2022), which was historically designated to provide proactive insights on how to foresee effective and enjoyable 'conditions of wellbeing' for the whole populations. In fact, the way we use and consume the planetary resources deals with how we design a living scenario where people and anthropic actions can coexist with natural features, in a condition of mutual respect and interdependency – re: sustainability (Sinclair et al. 2021).

It is known that HFE is an interdisciplinary research field that focuses on designing and arranging products, service, environments, and systems of solutions that are well-suited for human use in an efficient, effective, and satisfactory way. The contribution of the discipline is recognised as pivotal in ensuring that the utilization of resources is optimized to promote human comfort, efficiency, and overall well-being by minimizing unnecessary physical strain or cognitive overload (Wilson, 2000). However, HFE cannot be only linked to correction approaches and interventions; instead, HFE can play a significant contribution to discover innovative and proactive fields of explorations useful for future industrial and scientific developments. For example, by incorporating ergonomic principles, products can be optimized to require fewer resources during production while still meeting the needs and expectations of users (García-Acosta and Lange-Morales, 2019); in the transportation sector, ergonomic principles can be applied to develop more fuel-efficient vehicles that minimize energy consumption and emissions while ensuring driver comfort (Rajesh et al. 2023); similarly, HFE can guide the design of energy-efficient buildings that promote user well-being and reduce energy wastage (Norton et al. 2021); HFE studies can trigger the development of standards and rules; it also can underscore the importance of ergonomics in the context of human-computer interaction and digital technology for resource management (Frejus, 2021).

The analysis of current societal, economic, and industrial scenarios suggests that the research community must reinforce its efforts in digging into this topic, which is strategic for the prosperity of the society in the present and the future, so that people can benefit of pleasant conditions that respect both human and the environmental sides

(Thatcher et al. 2018). To strengthen our understanding and foster the scientific debates about possible innovations in this cross-disciplinary research area, the Volume 27 of the Rivista Italiana di Ergonomia [Italian Journal of Ergonomics] promotes a reflection on the topic '*Ergonomics for a better use and consumption of resources*' through a first collection of works coming from different fields. Volume 27 intends to address the pressing need for innovative approaches to tackle the complex issues of resource scarcity and environmental degradation. Both environmental and human aspects are critically discussed and presented through some innovative studies and interdisciplinary reflections linking artefacts, societal targets, and people. Through this collection of scientific essays, the editors intend to stimulate a reflection on the role that HFE can play at the societal level by the analysis of contributions that discuss how resources, both human and environmental, are better managed and consumed, and what is the role of such inspirational research lines at the societal level. Lastly, the Volume 27 aims to highlight the role of HFE in shaping consumer behaviour towards more sustainable choices, as also proposed by SDGs. The Volume 27 is the first in its kind for the history of the Rivista Italiana di Ergonomia [Italian Journal of Ergonomics], but it will not be the last volume that gathers a set of original contributions about this research topics. Specifically, Volume 27 gathers five high-quality contributions mainly focused on the interactions between humans and resources at different levels, and then the analysis on the value expressed by resources at different levels using different angles.

The first contribution presented in this Volume, authored by Vacanti et al. and entitled '*Energy responsive design: a novel paradigm for human–technology interaction*' proposes an interesting discussion on the evolution of the relationships between humanity, technology, and energy, and highlights the need for novel solutions in the design field that can drive the transition toward energy efficient artifacts and sustainable lifestyles; through a selection of case studies and discussions, authors introduces the term 'energy responsive design' to include user-centred experiences in addition to the ones already discussed by current studies, such as responsiveness, energy efficiency, and human behaviour. The contribution proposed by Setayesh et al., entitled '*Ergonomic design for public toilets faucet: an approach on water consumption management*' presents an interesting project on the correct management of water in public contexts; sanitary facilities are one of the places where water is consumed mostly, then authors proposes an ergonomic design of public faucet based on water consumption management; in this essay, both quantitative and qualitative data are proposed, including simulations and tests with users. The work presented by Vacca, entitled '*EU Green Deal: can the legislation on energy efficiency of buildings be effective fighting climate change, overcoming the energy crisis/resources scarcity and improving occupants' health*?' introduces a novel perspective on the role of HFE for resource management from a judicial perspective; specifically, the work explores the topic of energy efficiency of green buildings as a valid research area where to improve promote user well-being whilst reducing energy wastage and resource scarcity; the author also proposes an comprehensive analysis of legal normative from an EU perspective to provide completeness and useful references for future uses in the field. Consistent with the design domain and the human wellbeing, the work of Musa et al. entitled '*Assessing peak expiratory flow rate health risks near cement facilities: predictive modeling and insights*' explores the value of human wellbeing in high-risk work environments; specifically, authors research into Peak Expiratory Flow Rate (PEFR) in residential living areas near a cement manufacturing facility in Africa; the work is interesting because uses a comprehensive dataset encompassing anthropometrical variables and individual-level data on PEFR measurements, alongside statistical techniques to establish a relationship between PEFR values and anthropometrical variables of the individual. Finally, the work of Cipressi introduces a novel perspective on the value of correct transportation service design as a valid research field where to improve the management of human and natural resources; specifically, the work entitled '*Smart Inland Waterways Transport Service and the impact of digitalization on human resources*' examines how digitalization, when applied to services and autonomous vessels, enhances human resources in the IWT sector; the author uses a four-level themed analysis to discuss both strategic and HCD-related topics with impacts on the service design domain. Editors of the Volume 27 of the Rivista Italiana di Ergonomia [Italian Journal of Ergonomics] are aware that the contributions presented in this manuscript are not exhaustive of the whole picture of contributions that the research community is carrying on at the present times; however, the intention of this Volume is to collect and present a first set of fresh international contributions to feed the debate on the effectiveness of ergonomic interventions in relation to a better use and consumption of resources.

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# 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.

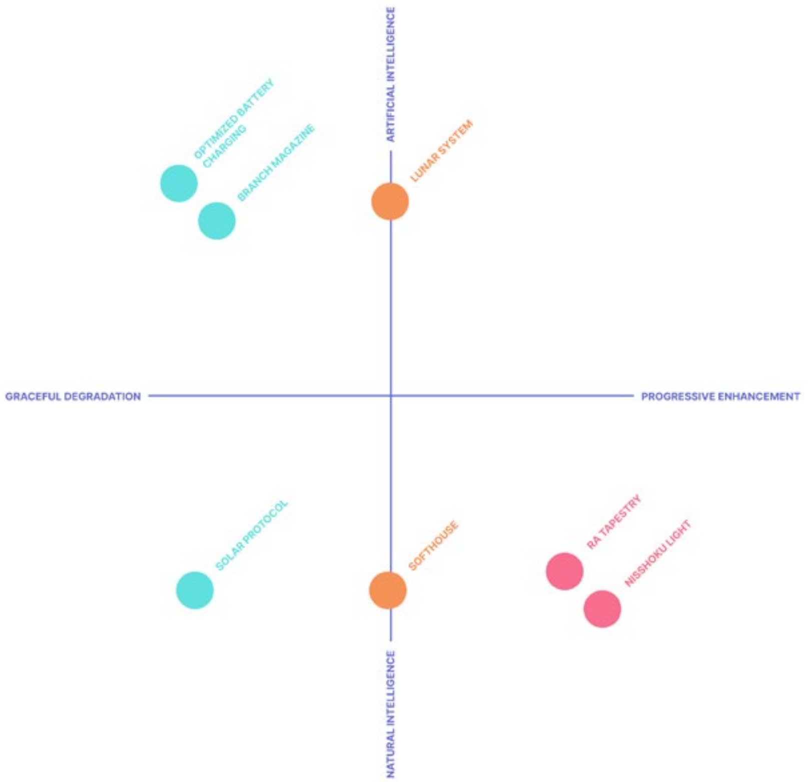

*Figure 1. The scheme showcases how the 7 case studies leverage artificial or natural intelligence, and whether they use graceful degradation, progressive enhancement, or neither. At a glance, it is evident how digital case studies tend to adopt a degrading approach, while product case studies are bound 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.

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# Ergonomic design for public toilets faucet: An approach on water consumption management

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Keywords: Ergonomics, Water consumption, Faucet, Sustainability, Public toilet

## Abstract

**Ergonomics design for public areas plays a crucial role in terms of sustainability. Designing public sanitary facilities and amenities is part of urban utilities and equipment design. Water is our most valuable natural resource and water scarcity has become a prominent problem. Since public sanitary facilities are one of the places where water is consumed, attention should be paid to their faucet design, in terms of hygiene, comfort of use, and controlling excessive water consumption. This study aims to ergonomic faucet design based on water consumption management. In this cross-sectional study, the primary data were obtained through library studies, questioning, and user centered design process (UCD), in which 50 participants completed the questionnaire and 10 participants participated in the UCD process as volunteer samples. Our**

**findings show 77% of participants do not show much desire to use the existing public sanitary faucets. Participants also emphasized the need for accessibility and comfort of using faucets. Given the importance of water conservation, participants found the use of scenarios and metaphors effective. Participants also stated that the proximity of the faucet's lever and spout is effective in understanding how the faucets work. Considering the gathered data lack of hygiene in the existing faucets reduces the desire to use them. Also, lack of comfort and improper usability are other reasons that should be considered in the faucet design process. Attention to the criteria of cognitive aesthetics and the use of curved forms are other things that should be used in the design.**

## Introduction

Ergonomics as a multidisciplinary science concerns human health, sustainability, and quality of life (Sadeghi Naeini & Arabshahi, 2019). Ergonomics interventions don't limit to industrial workstations, in fact, public areas, daily products, and street furniture are also assessed by ergonomics. Furthermore, ergonomics plays a crucial role in design for sustainability (Sadeghi Naeini, 2020; Sadeghi Naeini et al., 2022). Public Toilets and their amenities are one of the most complex and important elements of urban furniture (Na'was & Fakhoury, 2018). Designing sanitary faucets for public toilets is important in terms of user satisfaction, reducing the risk of disease transmission, and minimizing water consumption. Besides, water is referred to as the source of life, and it is our most valuable natural resource, making its preservation of utmost importance. Therefore, public hygiene fixtures are recognized as essential sanitary facilities in building infrastructure, with the responsibility of controlling water flow. Also, citizens' negligence towards public property can lead to serious mismanagement of water resources.

Studies have shown that designing faucets using a creative system for water reclamation and purification can help reduce water consumption and increase water efficiency (Kalbusch & Ghisi, 2016).

Water conservation was identified as a fundamental factor in demand management, offering an effective solution for ensuring sustainable urban water supply. This encompasses two categories of behaviors: water-saving behaviors and water-use efficiency behaviors (Shahangian et al.,2021). Overall, the use of water-efficient faucets and equipment is one of the most common and effective measures for reducing water consumption (Maleki Nasab et al., 2010). Water-saving faucets have less environmental impact compared to regular faucets. Based on the results, the use of low-consumption faucets is recommended. Reducing water consumption through changes in the faucet mechanism and visual shape will be possible (Kalbusch & Ghisi, 2016). This paper aims to show the rules ergonomic in optimizing water consumption.

## Research background

Greater confidence in users taking actions to conserve resources correlates with stronger negative emotions toward the waste of water such as guilt, upset, embarrassment, and annoyance. However, users' perceptions of aesthetics, usefulness, and overall quality of designs correlated more with positive emotions toward resource conservation like satisfaction, pride, fondness, and happiness. Therefore, evoking negative emotions in users may be an effective strategy for spurring immediate sustainable behaviors while nurturing positive emotions may be more important for engaging users with eco-feedback products in the long-term. Two styles of eco-feedback designs, quantitative (which emphasized quantitative resource usage info) and figurative (which used animal faces as reminders of environmental sustainability), were tested against neutral designs (which had little or no feedback info). In this experiment, older participants (age 37 and above) reacted very differently to the figurative designs compared to younger participants (under 37 years). Actually, the figurative designs worked better for the younger participants. This finding is useful for forming guidelines for designing more inclusive eco-feedback products or designing eco-feedback products for different generational groups (Bao et al., 2019).

Sustainable design places the rule as an intentional tool for behavior change. The conventional goal of sustainable design was initially to design products that require minimal energy and recycling. Currently, the idea of sustainable design is evolving toward altering user behavior. Results indicate that auditory information plays an important role in the assessment of water flow rate. Unconscious perceptual judgments can be embedded into habitual behavioral patterns, such as hand washing in public places, which may ultimately reduce excessive water consumption. Introducing faucets that amplify the sound of the water flow and keep the flow constant has the potential to be an effective way to facilitate environmental behavior (Golan

& Fenko, 2015). Washing hands after using the toilet is socially desirable, so consistent with this hypothesis, compared to the neutral control condition, a significant increase in hand hygiene compliance has been demonstrated when viewing eyes are presented in the toilet (Pfattheicher et al., 2018). In the idea of unifying the faucet's lever and water outlet, the hand contact surface is at the end of the water outlet, which can be easily washed. This allows the faucet to be cleaned directly while washing hands, saving the amount of water that users have to collect with cupped hands to wash the faucet, in addition to significantly increasing hygiene, it also reduces consumption (Shieh et al., 2017).

Persuasive display design (displaying consumption numerically and metaphorically of a traffic light) encourages public awareness and sustainable behavior regarding water conservation. Remarkability, aesthetics, noticeability, and persuasiveness in the long-term deployment of the water visualization were able to effectively motivate reduced household water use for all participants (Kuznetsov & Paulos,2010). Changes in cognition caused by dementia can significantly alter the way a person perceives familiarity and affect cognition and usability of everyday products. When faucets are more familiar to users visually and mechanically, fewer operational errors occur. Users can control water temperature and flow without needing assistance, resulting in a more aesthetically pleasing product and improved usability for elderly individuals with cognitive decline (Boger et al.,2013). Emotions are a water-saving factor for users to attract the attention of users and cause their emotional reactions. Attractiveness in the design of water-saving equipment is placed in the priority of influence and leads to an increase in awareness of water-saving and a change in the attitude of people using water-saving facilities (Chiu et al., 2019).

## Research method

This work employs analytical sources found via literature searching methods to trace a set of questions to be submitted to a sample of users for later data collection and analysis. In the initial questioning, 50 participants (55% female and 45% male) participated in the age range of 18 to 57. In using the User Centered Design (UCD) method, 10 participants including 6 women and 4 men in the age range of 14 to 53, of whom 9 were Iranians and 1 was Afghan, all of whom had experience using public toilets, were evaluated.

Using UCD which focuses on users of a product, we evaluated it.

UCD employs various investigative techniques and captures end-user needs and emotions to drive each stage of the design and development product. UCD also heavily emphasizes iteration - ideas are tested and redesigned to arrive at usable, satisfying, emotional impact. Typically, after a discovery phase, there are five phases: research, analyze research, design solutions, test solutions, and repeat across designs.

## Results

In the initial questionnaire, 77% of participants use public toilet faucets rarely only in emergencies (Fig1-A), and lack of hygiene and concern about water outages as the reason for this (Fig1-B), respectively. 14% of participants do not feel worried about water waste and 21% are somewhat worried (Fig1-C). Most participants use toilet faucets less than 2 times a day and during consumption open and close the faucet 2 to 3 times, and this use is mostly for washing hands and then taking ablution (Fig1-D).

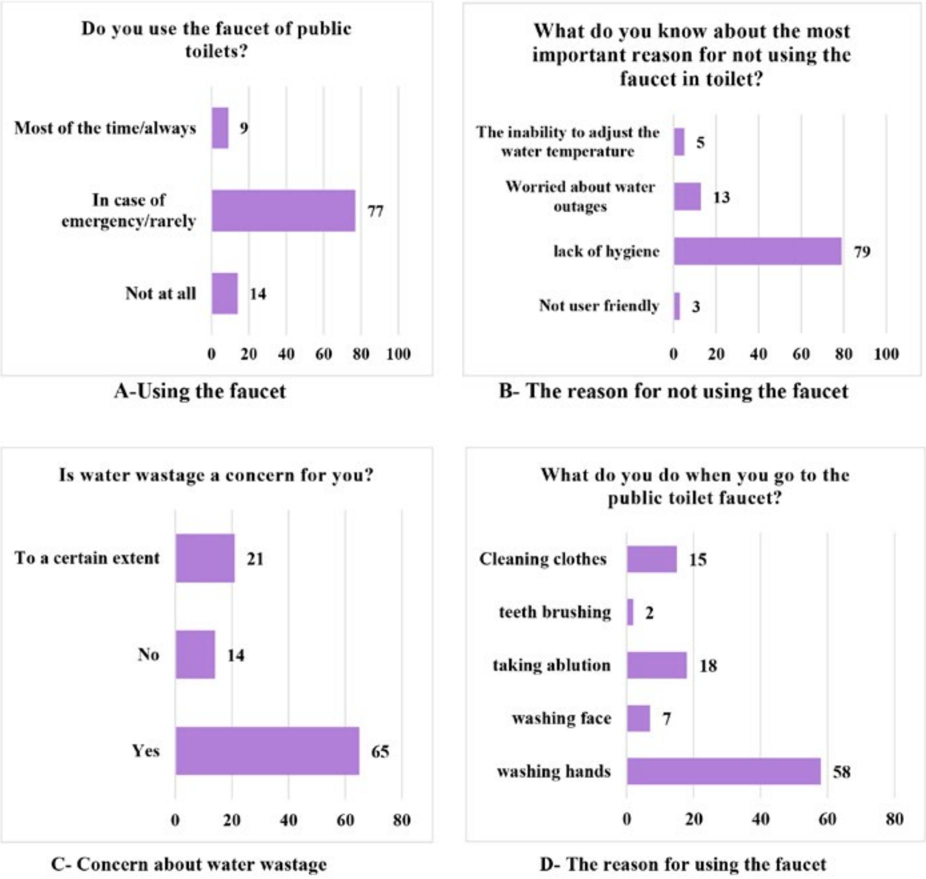


*Figure 1. Some parts of the questionnaire-based results.*

Based on the results obtained from initial questionnaire of users, among the 5 initial designs (Fig. 2), design number 1 was approved using the Analytical Hierarchy Process (AHP) evaluation method.

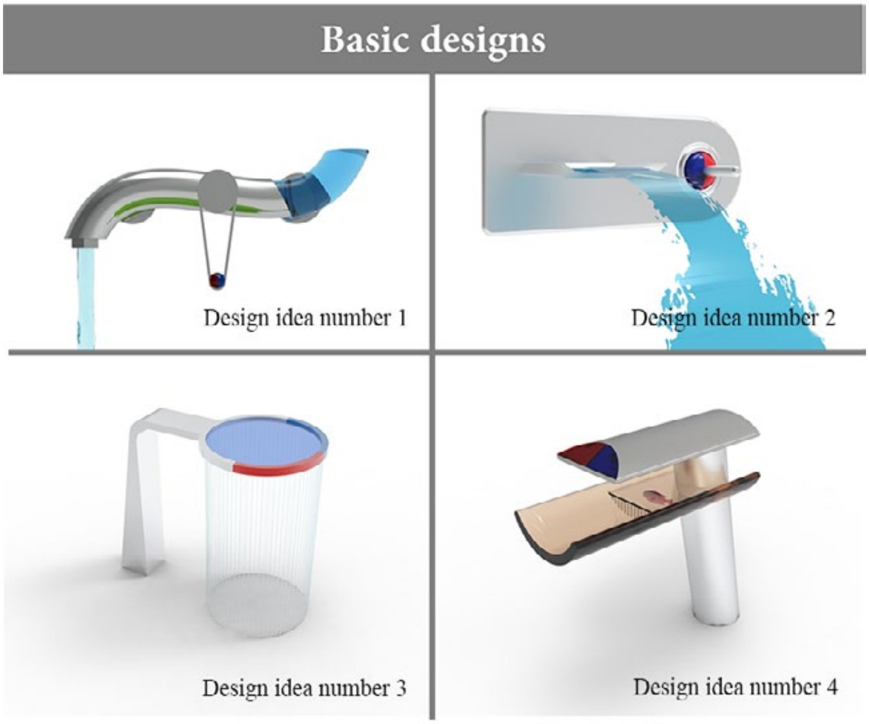


***Figure 2.*** *Initial ideas using questionnaire results.*

73% of participants use public sanitary facilities less than twice a month, 18% of participants use two to four times a month, and 9% of participants use between five to seven times a month. The initial 3D model design as a preliminary design (Fig. 2-No.1) was shown to users and they were asked to complete the designed questionnaire, and after that the prototype was made available to them for evaluation as a tangible product and they were asked again to fill out the questionnaire (Fig. 3). During working with the prototype, the performed Tasks were observed using the Usability Testing method. The results are as follows (Tab. 1):

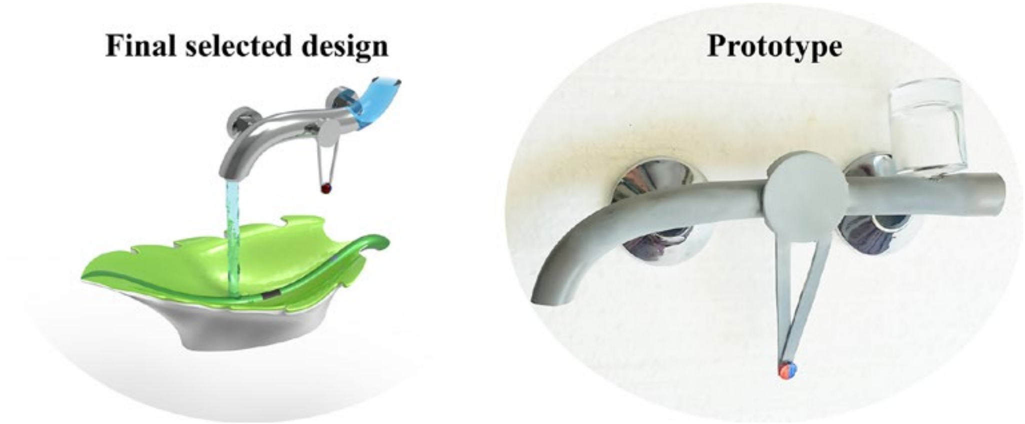


*Figure 3. The first design.*

| QUESTIONNAIRE RESULTS | INTERVIEW RESULTS | USABILITY TESTING RESULTS |
|---|---|---|
| Creating a sense of cleanliness, interest, and excitement through the form | Confusion at first encounter | The movement of users' eyes between the tank and the Watershed Because of the distance |
| Acceptable satisfaction of the form | Understanding the performance of water supply in case of failure from the designed tank | Pouring water on the faucet's lever after closing it |
| Dissatisfaction with the form and function of the faucet's lever handle | Dissatisfaction with hand hygiene after use | Failure to create a sense of responsibility in reducing water consumption |

*Tab. 1. The results of the first design.*

Based on the results, idea generation, 3D modeling, and prototyping of the second design were performed (Fig. 4). In the revised design to make some feelings for users toward decreasing water consumption, the fish figure was used to create a scenario. Another revision brings the tank and faucet's lever closer together and increases the faucet's lever surface area. After that like design number 1, it was evaluated.

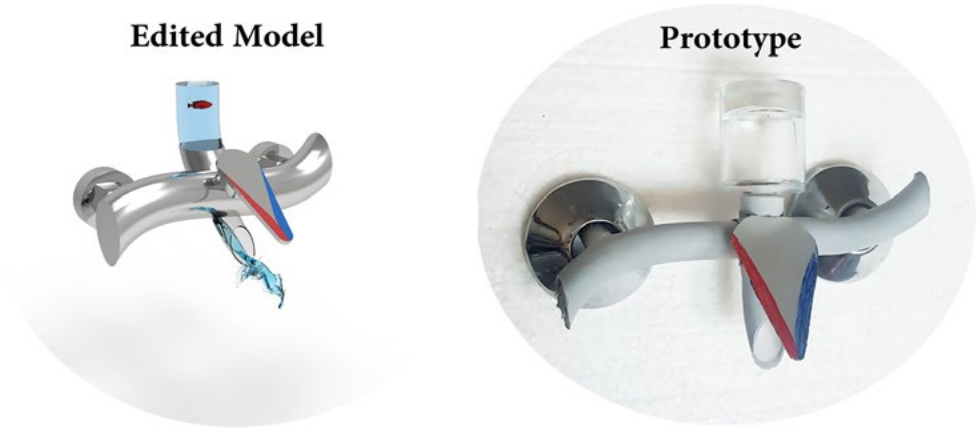


*Figure 4. The second design.*

| QUESTIONNAIRE RESULTS | INTERVIEW RESULTS | USABILITY TESTING RESULTS |
|---|---|---|
| Dissatisfaction with the form and function of the faucet's lever handle | Dissatisfaction with hand hygiene after use | Improper position of the faucet's lever handle |
| Satisfaction with the overall form of the product | Creating a sense of saving water on average | Pouring water on the faucet's lever after closing it |

*Tab. 2. The results of second design.*

Based on the results obtained, idea generation, 3D modeling, and prototyping of the third design were performed (Fig. 5). In the revised design an added traffic light metaphor and combining the faucet's lever and water outlet, was re-evaluated. The results indicated complete participant satisfaction, and as a result, the third design was selected as the superior design.

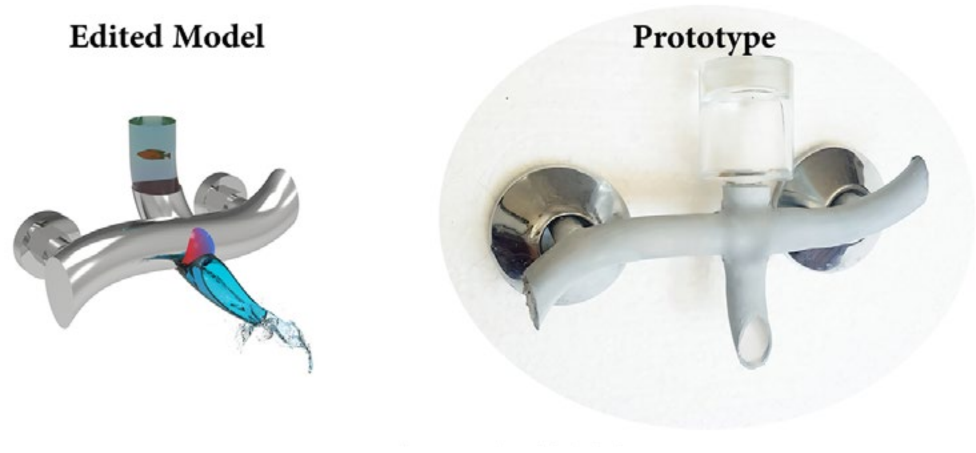


*Figure 5. The third design.*

In the designed faucet, the water flow opens by moving the spout upwards. Also, the water temperature is adjusted by moving the spout to the right and left. When opening the faucet, first the tank is emptied (gradual mixing of tank water with the main cold and hot water flow) and after it is finished, the main flows are used directly. Due to the internal mechanism and gravity, if the users forget to close the faucet, the faucet's lever automatically closes after a short period (Fig. 6).

*Figure 6. The way of using the designed faucet.*

## Discussion and conclusion

Water is known as one of the prominent fundamentals in urban resilience and sustainable development (Meng, 2023). Water Conservation Programs (WCP) are defined as optimizing water consumption that can be achieved through demand management by planning and implementing actions to Improper use and losses (Kalbusch & Ghisi, 2016). Population, household size, and growth affect water consumption (DEFRA, 2013). Furthermore, tap water quality is interconnected to some different factors such as economic and social factors. (Weisner et al., 2023)

Water Demand Management (WDM), emphasizes water conservation as a fundamental factor in demand management and refers to any policy, solution, or program that encourages consumers to reduce water consumption through behavioral changes (Cook et al.,2018). Besides, there is an association between water sanitation and sustainable development. (Li et al., 2023)

"Efficient use" pertains to management practices that ensure the optimal utilization of water, preventing waste, and avoiding unreasonable or inefficient methods of use. Water efficiency involves reducing the quantity of water used to accomplish specific functions, tasks, or outcomes. The focus of water use efficiency lies in improving water consumption through advancements in fixtures and equipment technology. Conversely, water conservation involves taking various measures to enhance the overall efficiency of water utilization, which may include behavioral modifications such as reducing the frequency of using fixtures and appliances (A.W.W., 2006).

Also, there is a connection between urban spaces and health, in this regard, urban health which concerns the health of citizens is known as one of the important factors in terms of city planning and management. Therefore, in terms of community health, all aspects of public and individual health should be considered in washing hands is important (Kim et al., 2023).

Hand washing is the most effective and inexpensive way to prevent many illnesses. Hand washing is often part of water, hygiene, and cleanliness programs along with other hygiene interventions. The main purpose of hand washing medically is to clean the hands of pathogenic agents (bacteria, viruses, or other disease-causing microorganisms) and chemicals that can cause harm or disease. This is especially important for people working in the medical field, althou-

gh hand washing is also an important practice for the general public (Larson & Committee, 1995).
One of the places that provides the possibility of handwashing is public areas, offering this function through the provision of faucets. Considering the importance of the hygiene of faucets in creating a desire for use and optimizing water consumption, the faucets were designed for installation in public places based on the results obtained from field studies and research. These faucets, using a curved form achieved the highest satisfaction in terms of aesthetics and sense of cleanliness in users. Also, this form causes it not to stain if water drops come into contact with the faucet's body and drops slip off the body as a result does not discourage the desire to use it.
Displaying the water flow to users in use also played a significant role in reducing consumption and increasing the sense of cleanliness. Amplifying the sound of water flow increases environmental behavior, so in order to achieve a stable faucet, the water outlet form was designed to amplify the sound so that users can stop the flow faster. The tank was designed to supply water during lack of water shortages. In such a way that when the faucet is opened, the water stored in the tank with a low output flow is mixed with the cold and hot water set by the user and is available to him, and after the user closes the faucet, the flow of hot and cold water in the tank. It is recharged and done. In addition, using a fish scenario and traffic light metaphor created the greatest sense of responsibility to save water. In such a way that users see the death of fish and the red color of the body of the tank during heavy use. The fish figure will have a significant impact on changing the behavior of the younger generation in the long term (Fig. 7). Designing the faucet's lever as a derivative of the lever faucet creates more familiarity, especially for older users. Combining the faucet's lever with the water outlet also cleans the faucet's lever of contaminants each time it is used, saving the amount of water that users have to collect in cupped hands to wash the faucet, in addition to significantly increasing hygiene (Fig. 8).

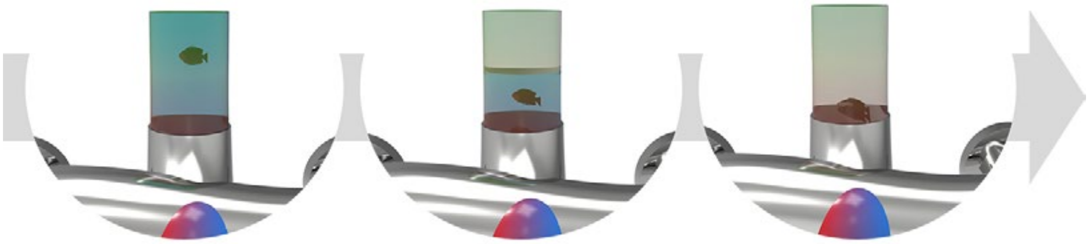

*Figure 7. Scenario & water supply in times of interruption.*

*Figure 8. View of the installed sink faucet.*

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# EU Green Deal: can the legislation on energy efficiency of buildings be effective fighting climate change, overcoming the energy crisis/resources scarcity and improving occupants' health?

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Keywords: legislation, energy efficiency of buildings, sustainability, ergonomics, Renovation Wave Strategy, New European Bauhaus.

## Abstract

**Ergonomics can guide the design of energy-efficient buildings that promote user well-being and reduce energy wastage tackling climate change and the complex issues of resource scarcity. Energy efficiency means using less energy to perform the same task eliminating energy waste. Improving energy efficiency is the cheapest way to reduce the use of fossil fuels, consequently, there are several benefits for the environment. It is linked also with occupant health and well-being (better air quality, reduction of damp conditions, psycho-social factors). There is a synergy between ergonomic considerations, occupant comfort and the optimization of energy consumption. In the EU several Directives regarding the Energy Performance of Buildings have been adopted: Directive**

**2002/91/EC, Directive 2010/31/EU Directive 2012/27/EU, Directive 2018/844/EU, the last one includes measures that accelerate buildings renovation also making them smarter. The Commission has introduced a renovation wave of public and private buildings, as part of the European Green Deal and this trend will also enhance the quality of life for people living in. There are still technical, financial, and informational barriers preventing improvements to the energy performance of buildings. As part of the Fit for 55 package, the Commission adopted a legislative proposal to revise the EPBD. The soul and the spirit of the European Green Deal is the new European Bauhaus, ergonomics plays a crucial role creating functional, aesthetically valuable, and inclusive designs that fit the needs and comfort of individuals. Also transparency and occupants' behaviour are significant as a catalyst for energy efficiency of buildings.**

## Introduction

Sustainability issues have been explored and dealt with by ergonomics for environmental sustainability (Hanson, 2013). Ergonomics can guide the design of energy-efficient buildings that promote user well-being (Allen et al., 2015) and reduce energy wastage tackling climate change and the complex issues of resource scarcity. Energy efficiency means using less energy to perform the same task eliminating energy waste. Improving energy efficiency is the cheapest way to reduce the use of fossil fuels, consequently, there are several benefits for the environment. Behaviour adaptation also plays a critical role in reducing energy demand. Integrating ergonomic design principles with energy-efficient strategy can lead to smart buildings that promote occupant well-being, enhance productivity, and reduce environmental impact by conserving resources and minimizing energy consumption.

Human health and protection of the environment are closely linked. Indeed, climate change has serious consequences since it worsens a variety of health hazards, respiratory problems caused by air pollution, vector-borne infections, and waterborne diseases. Climate change affects vulnerable populations including low-income communities, indigenous peoples, and those living in developing countries. These communities frequently lack the healthcare and resources to deal with the health consequences of climate change. This phenomenon is called "environmental racism" (Taylor, 2014).

Environmental rights are linked to human rights, this fact was underlined by the Stockholm Declaration on the Human Environment of 1972 in Principle 1: «Man has the fundamental right to freedom, equality and adequate conditions of life, in an environment of a quality that permits a life of dignity and well-being, and he bears a solemn responsibility to protect and improve the environment for present and future generation». In 1983 the World Commission on Environment and Development (WCED), known as Brundtland Commission, was created to pursue sustainable development. The Brundtland Commission released «Our Common Future», also known as the Brundtland Report, in October 1987, this document defined the meaning of the term «sustainable development»: "Sustainable Development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs ("Our Common Future", also known as the Brundtland Report, from the United Nations World Commission on Environment and Development (WCED, 1987).

The European Convention on Human Rights (ECHR) does not include the right to a decent environment (Vacca, Onishi 2018); however, the case law of the ECtHR shows how environmental protection is important, for example Lopez-Ostra v Spain ECtHR, Case 41/1993, 9 December 1994 and Guerra v Italy (116/1996/735/932), 19 February 1998. It can be based on article 2 ECHR (right to life). The human right to a healthy environment until recently has never been adopted in a United Nations treaty or declaration, however, many countries, even in the past, have included this right in their national Constitutions and international bodies considered environmental issues (Knox, Pejan 2018).

The right to a heathy environment was finally acknowledged recently by the United Nations Human Rights Council during its 48th session in October 2021 in HRC/RES/48/13 and subsequently by the United Nations General Assembly on July 28, 2022 in A/RES/76/300. This article is aimed to underline the link between ergonomics and the recent European legislation regarding energy efficiency of buildings and their paramount importance in fighting climate change, overcoming the energy crisis/resources scarcity and improving occupants' health. Energy ratings must be prominently displayed consequently also transparency and occupants' behaviour are significant as a catalyst for energy efficiency of buildings. Educating occupants about energy-saving practices and providing them with tools like smart readiness that enable them to regulate energy use can further contribute to the energy efficiency of a building without compromising comfort.

## EU Framework: overview

Buildings account for 40% of global energy demand today and are responsible for 36% of $CO_2$ emissions in the EU (Boo, Dallamaggiore, Dunphy, Morrissey 2016); they are the largest source of energy demand globally and are of paramount importance addressing climate change. Sustainable buildings use less energy, have reduced environmental impact, and improve the life of those who work or live in these buildings. Ergonomics interventions such as optimizing daylighting, thermal comfort and workspace contribute to energy savings by reducing the reliance on artificial lighting and heating, ventilation, and air conditioning systems.

New technologies that make buildings more energy efficient are gaining momentum, for example: effective insulation, double frammed walls, structural insulated panels, high performance windows, smart glasses, tight construction and ducts, efficient heating and cooling equipment with proper home ventilation, light colored cool roofs, planting gardens on rooftops, efficient products (lighting, appliances), active solar heating. Important design elements are: house orientation, trees for shading and wind breaks. Passive solar construction design allows the sun's rays to heat through strategic placement of windows. Active solar system is related to solar panels which absorb the sun's radiation to warm air or water. Zero energy buildings provide their own power through renewable energy like solar or wind power.

A smart residential building refers to any form of residence equipped with devices and related services allowing home automation, and remote monitoring, accessing or controlling of the building (Balta-Ozkana, Boteler, Amerighi 2014; Statista 2022). The aim of smart home is to provide homeowners with convenience and cost savings.

Disclose building energy data is also of paramount importance to reduce greenhouse gas emissions, have smarter government, energy efficiency, consumer transparency. Indeed, white economy is growing since energy efficiency reduces energy costs thanks to savings in fuel consumption, less severe environmental impact, and lower dependence on imported energy: improving the energy efficiency of buildings is the cheapest way to cut greenhouse emissions and improving health for occupants of energy efficient buildings (Houser 2009). If a country wants to be more energy efficient one of the simplest tools is the energy disclosure law. By making the information public and setting up a rating system for ranking, it provides an additional incentive for building owners to make efficiency upgrades. If a building purchaser considers two comparable buildings and discovers that they have huge different energy efficiency ratings, he or she will be influenced. Investing in energy efficient measures can offer significant returns. Green buildings improved marketability.

In case of no actions regarding energy efficiency of buildings the energy demand might rise by 50% by 2050 (Bisello, Antoniucci, Marella 2020).

In the EU several Directives regarding the Energy Performance of Buildings have been adopted: Directive 2002/91/EC, Directive 2010/31/EU Directive 2012/27/EU and EU Directive 2018/844 which is part of the package "Clean Energy for all Europeans" and includes measures that accelerate buildings renovation also making them smarter.

The Energy Performance of Buildings Directive (EPBD) 2002/91/EC was the main EU policy instrument to create better conditions for the energy performance of buildings. It introduced a framework for energy performance certification and called for energy performance legislation in each of the EU's member states. This Directive required development of performance and inspection standards as well as energy performance certification for commercial, residential, and government buildings. Energy ratings must be prominently displayed in public buildings.

The EPBD comprised the following themes: certification of buildings, inspection of boilers, inspection of air-conditioning systems, methodologies for calculating the energy performance of buildings, implementation of minimum energy performance requirements for new buildings and for major renovations. A deadline of 4 January 2006 was set for all member states to bring into force the necessary laws, regulations, and administrative provisions. This deadline was subsequently extended to 1 January 2009 because of a shortage of trained certification experts in most member states but, even for the new deadline, several member states did not have functioning certification programs, because they lacked sufficient trained and certified experts to implement them (Ries, Jenkins and Wise 2009).

Some Member States made some progress, but the majority had po-

tential for improvements. For this reason, Directive 2010/31/EU has been adopted. The aim of this revision was to clarify and simplify certain provisions, extend the scope, make the rules more effective and provide for the leading role of the public sector (Vacca 2013).
Under this Directive Member States must establish and apply minimum energy performance requirements for new and existing buildings, ensure the certification of building energy performance and require the regular inspection of boilers and air conditioning systems in buildings. New buildings were required to be nearly-zero energy by 2020 or 2018 in the case of buildings owned and occupied by public authorities. Nearly-zero buildings means buildings that have a very high performance. The nearly-zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.
The recast of the EPBD in 2010 strengthened the role of energy performance certificates by demanding publication of the energy performance indicator of the energy performance certificate at the time of advertising a building for sale or rental rather than only at the time of signing a purchase agreement or rental contract. Member States should lay down the necessary measures to establish a system of certification of the energy performance of a building and reference values such as minimum energy performance requirements to make it possible for owners or tenants of the building or building unit to compare and assess its energy performance. Member States must ensure a good quality of the certificates and inspections. The public sector should show a leading example investing in such buildings and therefore the national plans should set more ambitious targets for the buildings occupied by public authorities.
In 2012 the EU adopted the Directive 2012/27/EU on energy efficiency. This Directive establishes a common framework of measures for the promotion of energy efficiency within the Union to ensure the achievement of the Union's 2020 20% headline target on energy efficiency (2020 Climate and Energy Package, known as 20-20-20 package). Measures include the legal obligation to establish energy efficiency obligations schemes or policy measures in all Member States, an exemplary role to be played by the public sector and a right for consumers to know how much energy they consume. Reduction of energy consumption and the use of energy from renewable sources in the building sector constitute important measures

needed to reduce the Union's energy dependency and greenhouse gas emission.

Each Member State should set an indicative national energy efficiency target based on the parameters set in the Directive and shall notify those targets to the Commission. This Directive also stipulated that the Commission has to assist Member States in setting up financing facilities with the aim of increasing energy efficiency.

Despite many funding instruments available at EU level, the complexity and bureaucracy of the application procedures and a lack of awareness about funding opportunities, especially at local level, discouraged to take advantage of these opportunities. There were technical, financial, and informational barriers preventing improvements to the energy performance of buildings.

The European Commission in 2013 published a report on financial support for energy efficiency in buildings stressing that the EU needed to improve the financial support in this sector.

The European Commission in 2013 also published a study on "Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries". The study showed a positive impact of the Energy Performance Certificate under the Energy Performance of Buildings Directive (Directive 2010/31/EU) on sales and rental prices indicating that better energy efficiency is rewarded in the market. Higher energy ratings result in higher sales or rental values of buildings on average in most of the Member States under scrutiny.

## EU Green Deal

About 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is not energy efficient. In the Clean Energy for all Europeans package a new directive (EU 844 of 2018) has been adopted, according to this directive, renovation of existing buildings can lead to significant energy savings, can create economic, social, and environmental benefits, and stimulate the economy, underlining the paramount role of renovation of buildings. EU countries can set mechanisms to help finance renovations that make buildings energy efficient and smarter, fighting "environmental racism". Better and more energy efficient buildings can improve citizens' quality of life while bringing down their energy bills and alleviating energy poverty. Also this legislation was not enough to achieve the hoped goals since several barriers remained.

The European Green Deal is the plan to make the EU's economy sustainable by turning climate and environmental challenges into opportunities and making the transition inclusive for all. The Commission has introduced a renovation wave of public and private buildings, as part of the European Green Deal. This also includes new rules on smart readiness of buildings.

The European Commission has published its Renovation Wave Strategy to improve the energy performance of buildings, it is a significant economic opportunity which can generate several jobs in different sectors. The Commission aims to at least double renovation rates in the next ten years and make sure renovations lead to higher energy and resource efficiency. This will enhance the quality of life for people living in and using the buildings, reduce Europe's greenhouse gas emissions, foster digitalisation, and improve the reuse and recycling of materials promoting circular economy principles to minimize waste. Integrating ergonomics and energy efficiency principles can create spaces comfortable and functional for occupants but also energy efficient, for example well-placed windows are able to provide natural light reducing the need for artificial lighting during the day or smart building technologies like smart sensors and automated controls can optimize both comfort and energy consumption. Also, occupant behaviour plays a critical role in reducing energy demand, educating occupants about energy-saving practices, and providing them with tools that enable them to regulate energy use can further contribute to the energy efficiency of a building without compromising comfort. Only 1% of buildings undergo energy efficient renovation every year, so effective action is crucial to making Europe climate-neutral by 2050. The reluctance to retrofit existing residences are due to several reasons such as costs, conversion challenges, mess, disruption.

There are many barriers that today make renovation complex, expensive and time consuming, consequently action is needed. Also the Renovation Wave strategy faces several challenges, including financial barriers, the need for skilled workforce, and different national regulations consequently a coordinated approach among member states is compulsory accelerating financial incentives, grants and innovative funding mechanisms.

As part of the Fit for 55 package, the Commission adopted a legislative proposal (COM/2021/802) to revise the EPBD on 15 December 2021. This proposal underlines the tools for achieving a zero-emission building stock by 2050, introducing a new definition of zero-emission building and refining existing definitions such as 'nearly-zero energy building' (nZEB) and 'deep renovation', triggering an increase in the renovation rate of the worst-performing buildings. Financial measures should prioritise deep renovations, especially of the worst-performing buildings, and targeted grants and subsidies made available to vulnerable households.

The recast Energy Efficiency Directive (EU) 2023/1791 has been published in the EU Official Journal in September 2023. The energy efficiency first principle implies adopting a holistic approach, which considers the overall efficiency of the integrated energy system, security of supply and cost effectiveness and promotes the most efficient solutions for climate neutrality across the whole value chain. This new directive obliges Member States to prioritise vulnerable customers and social housing within the scope of their energy savings measures. The recast directive further strengthens the exemplary role to be played by the public sector in enhancing energy efficiency practices. The EU's security of supply must be boosted consequently also EU dependency on Russian fossil fuels will further decrease, in line with the REPower EU Plan.

The New European Bauhaus initiative is inspired by the iconic Bauhaus movement established in the aftermath of World War I which was considered a revolution in the architecture. The New European Bauhaus is an evolution aimed to adapt its core values to address the contemporary challenges of climate change, social inclusion and sustainable development embracing concepts like circular economy, energy efficiency, and the use of eco-friendly materials, minimizing ecological impact of buildings and public spaces, combining functionality with beauty, acknowledging that well-designed spaces can influence the quality of life, evoking cultural significance and reflecting local identities and traditions. It fosters social cohesion, accessibility and a sense of belonging involving actively communities, citizens, and stakeholders in the design process.

The 8th action programme (EAP) aims to speed up the transition to a climate-neutral, resource-efficient economy, recognising that human wellbeing and prosperity depend on healthy ecosystems. It forms the EU's basis for achieving the United Nation's 2030 Agenda and its Sustainable Development Goals. Energy efficiency of buildings is linked especially to Goal 11 (sustainable cities and communities), Goal 9 (industry, innovation, and infrastructure), Goal 7 (affordable and clean energy), Goal 13 (Climate action), Goal 3 (Good health and well-being).

Energy efficiency is linked with occupant health and well-being (better air quality, reduction of damp conditions, psycho-social factors). Ergonomics plays a crucial role creating functional, aesthetically valuable, and inclusive designs that fit the needs and comfort of individuals.

## Conclusions

Disclose building energy data is of paramount importance to reduce greenhouse gas emissions, have smarter government, energy efficiency, consumer transparency, green economy.

Transparency is a cornerstone for strengthening the ability of citizens to govern them effectively, efficiently, and equitably and consequently to ensure good public sector governance 'advertising' decision-making, especially now that most of the governments are committed to play a paramount role in socio-economic development to try to survive from the recession (Vacca 2012). Transparency is of paramount importance in saving energy resources, in fighting corruption and overcoming the resource course.

There is a link between energy performance labelling and property values. According to multiple studies, energy-efficient buildings achieve higher occupancy rate, rental rates, and sales prices than comparable, less efficient buildings, increasing their property value, better energy efficiency is rewarded in the market.

Buildings use more energy than any other sector, making up 40% of total energy consumption. Consequently, they are important to achieve energy savings targets, to combat climate change contributing to energy security. More energy efficient buildings provide better living conditions and save money to all citizens. The best moment for energy improvements is when buildings are constructed, or they are anyway renovated.

This proliferation of directives in the EU is symptomatic: the EU demonstrates that this area is a strategic one and that the original plans were not so successful thus further action is needed.

In the EU, several Directives on energy performance of buildings created important guidelines which must be implemented in all member states; however, some states can decide to go beyond the directives with the result that the member states can still implement a different standard.

The Renovation Wave Strategy represents a holistic approach aimed at reshaping the built environment, by targeting the retrofitting and renovation of existing buildings the EU goals are aimed not only to mitigate the environmental impact championing the principles of the circular economy but also create socio-economic benefits.

The technical aspects of renovation are important but also the improvements in living conditions. Ergonomics is relevant since, enhancing the quality/efficiency of a building, this strategy seeks to promote comfort, health, and well-beings for occupants.

The European Commission stressed the fact that the EU needs to improve the financial support in this sector, simplifying compliance requirements, increasing access to financing and fostering harmonised approaches. There were technical, financial, and informational barriers preventing improvements to the energy performance of buildings. The reluctance to retrofit existing residences are due to several reasons such as costs, conversion challenges, mess, disruption.

Despite many funding instruments available at EU level, the complexity and bureaucracy of the application procedures and sometimes a lack of awareness about funding opportunities, especially at local level, discouraged to take advantage of these opportunities.

Energy efficiency is linked with occupant health and well-being (better air quality, reduction of damp conditions, psycho-social factors). Markets are moving to differentiation not based on cost savings but on comfort, well-being, security.

The energy efficiency of buildings goes beyond technological innovations and design solutions since involves also addressing occupants' behavioural adaptations (Schweiker 2017).

Occupants' behaviour is gaining momentum (Ghisi, Forgiarini Rupp, Fernandes Pereira, 2021). It influences energy consumption in buildings since factors like comfort perception, heating and cooling preferences, hot water, the use of clothing, lighting and appliance usage can affect energy demand (Faitão Balvedi, Ghisi, Lamberts, 2018). Window opening behaviour has significant influence on the energy consumption and it could be as important as thermal insulation (Salim, Al-Habaibeh, 2021). Many studies have investigated the effect of occupants on energy consumption in buildings. Having knowledge regarding occupancy and being able to check usage patterns may allow significant energy-savings (Erickson et al., 2009). Understanding the human-building interactions in residential buildings has a high potential of energy saving (Faitão Balvedi, Ghisi, Lamberts 2018). The engagement of the occupants with smart thermostats or energy monitoring systems can incentivise positive changes consequently feedback mechanisms and education/informational campaigns can foster conscious energy-saving habits. Smart meters are designed to monitor, record and manage energy consumption in real-time and can impact user behaviour, they intersect technology with human-centred design principles.

Green buildings are gaining momentum due to documented returns on investment, occupant satisfaction and willingness to protect the environment. Ergonomics can be integrated into the life of a building to promote sustainability goals for both the human factor and the environment (Miller, Dorsey, Jacobs 2012).

Integrating ergonomic design principles with energy-efficient strategy can lead to smart buildings that promote occupant well-being, enhance productivity, and reduce environmental impact by conserving resources and minimizing energy consumption.

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# Annex

- Energy Performance of Buildings Directives

- Directive 2002/91/EC
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- Directive 2010/31/EU
https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF
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- Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC on eco-design requirements for energy related products and 2010/30/EU on energy efficiency labelling of energy-related products and repealing Directives 2004/8/EC on the promotion of cogeneration and 2006/32/EC on energy end-use efficiency and energy services, [OJ L315 p.1]

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# Assessing peak expiratory flow rate health risks near cement facilities: predictive modeling and insights

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Keywords: PEFR, Cement Facility, Air Quality, Environmental Health, Predictive Modeling, Industrial Pollution.

## Abstract

**This study delves into the critical concern of Peak Expiratory Flow Rate (PEFR) in residents living near a cement manufacturing facility. As industrial expansion continues, the focus on air quality and its impact on public health grow. The study's aim is to create a predictive model for estimating PEFR values in individuals living close to the cement facility. To accomplish this, a comprehensive dataset was utilized; encompassing anthropometrical variables like standing height, weight and individual-level data on PEFR measurements are gathered from a representative sample of the study population. The study employs advanced statistical techniques, including regression analysis and predictive modeling, to establish the relationship between PEFR values and anthropometrical variables of the individual. The findings highlight potential health risks associated**

**with residing near cement facilities, offering valuable insights for policymakers and healthcare professionals. This research's outcomes targeted interventions to reduce health risks and enhance the well-being of residents near industrial facilities. Ultimately, this study contributes to the broader conversation on environmental health and underscores the importance of proactive measures to protect public health in industrialized areas. Ultimately, this study contributes to the broader discourse on environmental health and underscores the importance of proactive measures to safeguard public health in industrialized regions.**

## Introduction

Assessing peak expiratory flow rate in the vicinity of cement facilities is imperative due to potential health hazards associated with exposure to air pollutants emitted in these settings. Cement production releases particulate matter, volatile organic compounds, and other pollutants that can negatively impact respiratory health. Monitoring peak expiratory flow rate offers valuable insights into lung function, aiding in the early detection of respiratory impairment. Individuals residing or working near cement facilities may face an elevated risk of respiratory conditions such as asthma, chronic bronchitis, and other lung diseases. Understanding the correlation between air quality and peak expiratory flow rate enables the timely identification of respiratory issues, facilitating intervention and preventive measures.

Cement manufacturing using raw materials like limestone, clay, and gypsum is consistently associated with dusty and unclean conditions. This poses an air pollution risk to all living creatures in proximity to cement plants and the production process generates substantial levels of particulate matter. Amah et al. (2020) stated that cement factories often release significant amounts of particulate matter (PM) 2.5, which can adversely impact respiratory health. Such particulate matter can lead to respiratory issues like asthma, bronchitis, and emphysema. Cement manufacturing has been linked to decreased peak expiratory flow rate (Ismaila et al., 2015), a respiratory function measurement often employed for diagnosing and tracking respiratory illnesses. This suggests a potential risk of obstructive airway disease (Moharana, 2018).

Air pollution is a pressing concern due to its substantial effects on human health and the environment. Growing industrialization and

the accumulation of harmful gases have intensified air toxicity (Soni et al., 2019). However, air pollution can begin in a closed or semi-closed system, which is known as indoor air pollution. Air pollution is caused by various factors. A primary factor is the burning of fossil fuels, including in vehicles, airplanes, and power generation (Donahue, 2017). Also, industrial activities release pollutants into the air through chimneys (Singh, 2018). Roughly 7 million premature deaths are attributed to air pollution annually (Institute for Health Metrics and Evaluation, 2017). Numerous global environmental pacts have been developed to curb rising air pollution and its detrimental impact on both the environment and human health. These agreements are legally binding for countries that have officially endorsed them.
In Nigeria, inhabitants of the Ewekoro local government have reported elevated instances of respiratory ailments due to the excessive emission of nitrogen dioxide, carbon monoxide, and sulfur dioxide as a result of the area's industrialization level. Oguntoke et al. (2012) discovered PM 10 and PM 2.5 concentrations considerably surpassing allowable levels within and around cement plants in a Nigerian local government region. The levels of PM around cement plants in Nigeria have raised concerns. The cement manufacturing sector in Nigeria significantly contributes to air pollution, releasing pollutants such as PM 2.5 and PM 10, as highlighted by Etim et al. in 2021. PM2.5 are atmospheric aerosol particles with diameters less than or equal to 2.5m that can penetrate deeply into the lung when inhaled. The peak expiratory flow rate (PEFR) is defined as the maximum or peak flow rate attained after taking a deep inspiration during a forceful expiratory effort. It's measured in liters per minute. Peak expiratory flow rate (PEFR) is one of the most useful and straightforward parameters in the field for assessing lung function in the general population, as well as diagnosing and monitoring patients with bronchial asthma and chronic obstructive pulmonary disease. As outlined by Münzel et al. (2021), air pollutants impact the cardiovascular system through mechanisms including oxidative stress, systemic inflammation, endothelial dysfunction, autonomic imbalance, and thrombogenicity. PM has been linked to the emergence of metabolic conditions like obesity and diabetes mellitus, both of which are cardiovascular disease risk factors (Solomonica, 2017).
According to the World Health Organization (WHO), air pollution is now the world's single greatest environmental health risk, making breathing clean air an important public health priority. Peak expira-

tory flow rate is useful for monitoring the progression of respiratory diseases because it provides useful information about the condition of the airways. Children who live in polluted areas are more likely to develop pneumonia and asthma. Peak expiratory flow rate (PEFR) can be used to reduce the impact of air pollution by diagnosing and monitoring the treatment of residents living near cement areas. The purpose of this project is to investigate and model the Peak expiratory flow rate (PEFR) of residents in the Lafarge Ewekoro cement plant area such as Akinbo village, Itori, Ewekoro local government area of Ogun State Nigeria.

Long-term exposure to pollutants emitted by cement factories and other industries necessitate the cause Chronic Bronchitis, Heart Disease, Asthma Attacks, and even premature death (Hamanaka et Mutlu, 2018). Laniyan and Adewunmi (2020) evaluated the contamination and ecological risk of heavy metals associated with cement production in Ewekoro, where three prominent cement factories are located. The findings revealed elevated levels of heavy metals in the cement dust released into the air. Pollution can lead to the buildup of heavy metals in soil, water, and air, ultimately causing contamination of these environmental components.

Cement factories emit various pollutants, including nitrogen oxides ($NO_x$), sulfur dioxide ($SO_2$), carbon monoxide (CO), carbon dioxide ($CO_2$), particulate matter (PM), and gaseous substances like hydrochloric acid (HCl) and hydrofluoric acid (HF) (Richards, 2017; Voicu et al., 2020). Moreover, heavy metals such as arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni), and lead (Pb) are also released into the air (Hassan et al., 2020). These emissions give rise to health issues, ranging from eye and skin irritation, headaches, and respiratory problems to cardiovascular ailments and even cancer (Dhinu et al., 2019).

This study recognizes the broader impact of industrial activities on residents' quality of life in affected areas. Policymakers often need a comprehensive understanding of the multifaceted impact of industrial operations. Research integrating environmental and health perspectives provides a stronger foundation for crafting effective regulations and guidelines. Identifying potential health risks through peak expiratory flow rate assessments serves as a preventive measure. Integrating environmental considerations ensures measures taken to protect human health also contribute to sustainable environmental practices. Optimizing processes in cement

facilities through the application of ergonomic principles can yield dual benefits by improving health outcomes and enhancing resource efficiency.
By underscoring the significance of evaluating peak expiratory flow rate, our study contributes to the overarching objective of safeguarding public health in areas exposed to industrial emissions. It establishes a foundation for devising strategies to mitigate health risks and enhance the overall well-being of communities affected by cement production.

## Research Methodology

A descriptive cross-sectional study was conducted among local residents comprising both males and females who were randomly chosen in the Lafarge Ewekoro cement plant area Akinbo village, Itori, Ewekoro local government area of Ogun State Nigeria, Given the evident sex-related variations in Peak Expiratory Flow Rate (PEFR) observed in the literature, a cross-sectional study was carried out among residents of Lafarge Ewekoro cement plant area, specifically in Akinbo village, and Itori, Ewekoro.
A total of two hundred (200) residents participated, comprising 120 males and 80 females. Each individual underwent testing in a standing position, holding the peak flow meter (PFM) horizontally by its handle; ensuring fingers were away from the scale, slot, and holes at the device's end. the respondents took a deep breath and blast the air out hard and as fast possible in a single blow through the mouth piece of the PFM. The operation of peak expiratory flow (PEF) was performed three times and the highest reading was recorded as PEFR.
Similarly, the participants' height and weight were also measured and recorded in centimetres and kilogram respectively. Subjective measurements were also employed to assess the age and health status of the respondents.
The following criteria were observed for acceptances of participants;

1. Participant had no history of disease that could affect lung function.
2. Participant never smoked
3. Participant had no asthma or recurrent bronchitis during their childhood
4. Participant has ability to cooperate appropriately during the tests

The main materials used are mini-Wright Peak Flow Meter (PFM) with different mouthpiece, measuring tape, and digital weighing scale.

- **Peak Flow Meter:** A Peak Flow Meter is a small plastic device featuring a measuring gauge on its side. It gauges the speed at which you exhale air forcefully from your lungs. This measurement, known as peak flow or "PF," is quantified in Liters per Minute (LPM). Peak flows assess the openness of the larger air passages in the lungs. The device comprises a spring-loaded piston sliding within its body along a rod. The piston possesses an indicator aligned with a slot marked by a graduated scale in liters/min. The indicator records the piston's maximum movement and remains in that position until reset by the operator. There are two categories of peak flow meters: the low range, measuring 50-350 L/min for children aged 4 to 9 and adults with significantly limited lung function, and the high range, spanning 60-800 L/min, intended for older children, teenagers, and adults.

*Figure 1. Mini-Wright Peak Flow Meter (PFM).*

- **Measuring Tape:** A measuring tape is a flexible tool designed to measure lengths, distances, and heights of objects or bodies. Here, it was employed to determine the height of the residents.


*Figure 2. Measuring tape (10m).*

- **Digital Weighing Scale:** The Digital weighing Scale was used to measure the weight of the resident selected at random in Lafarge Ewekoro cement plant area.

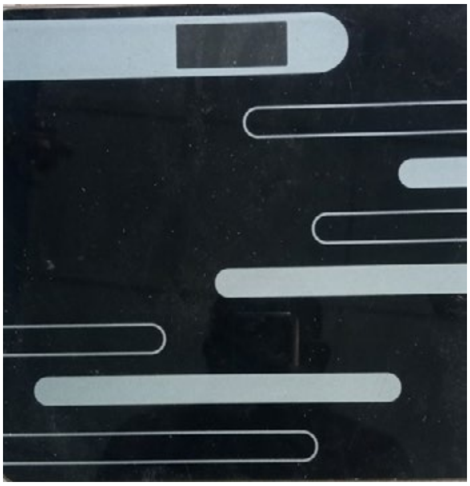

*Figure 3. Digital weighing scale.*

## Statistical Analysis

A statistical analysis was performed using IBM SPSS Statistics version 25 software. The relationship between the Peak Expiratory Flow Rate (PEFR) and the anthropometric parameters of the respondents was used to design a model where the Peak Expiratory Flow Rate (PEFR) was the dependent variable and the anthropometric parameters (Age, Height, and Weight) were the independent variables. The Multivariate Linear Regression was used to analyze the data collected from the study area.

The expression for the Multivariate linear regression equation is;

$Y = a + bX1 + cX2 + dX3 + zXn$ -------------------------------------- 1

Where:
X1, X2, and X3 ....Xn - Independent variables (age, weight, and height)
Y - Dependent variable (PEFR)
b, c, and d ......z - Slopes
a – Intercept (constant)

## Results

This section discussed how the data collected were analysed. The result was analyzed separately for both male and female as sex is an established factor for variation in PEFR.

| VARIABLES | MALE (N= 120) | $SD_M$ | FEMALE (N= 80) | $SD_F$ |
|---|---|---|---|---|
| Age (years) | 38.33 | 9.50 | 37.50 | 8.78 |
| Weight (kg) | 62.35 | 10.80 | 59.90 | 8.35 |
| Height (cm) | 168.35 | 7.73 | 162.90 | 8.67 |
| PEFR (L/min) | 185.16 | 29.60 | 174.50 | 20.75 |

*SD: Standard Deviation; n: number of respondent; M: Male; F: Female*

*Tab. 1. Descriptive Statistics of both Male and Female.*

Table 1 shows the descriptive statistics (mean and standard deviation) for both male and female participants. The result revealed that male participants were of 38.33 (± 9.50) years while females were 37.50 (± 8.78) years. The result further revealed that male averaged weight was 62.35 (± 10.8) kg, while females weighed 59.9 (± 8.35) kg respectively. Similarly, males and females had average heights of 168.35 (±7.73) cm and 162.9 (± 8.67) cm respectively. However, PEFR of the participants were taking three times and the highest value was recorded. The result shows that male participants has a mean PEFR of 185.16 (± 29.60) L/min and females had 174.50 (± 20.75) L/min. The result revealed that PEFR for male respondents were higher than that of female counterparts.

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| Model | B | Std Error | Beta | T | Sig. |
| 1 (Constant) | 296.468 | 85.419 | | 3.471 | 0.001 |
| Age of subject | -0.353 | 0.407 | -0.113 | -0.867 | 0.390 |
| Height in cm | -0.835 | 0.538 | -0.218 | -1.552 | 0.126 |
| Weight in kg | 0.716 | 0.502 | 0.202 | 1.426 | 0.159 |

*a. Predictors: (Constant), weight in kg, Age of subject, Height in cm*
*b. Dependent Variable: PEFR*

*Tab. 2. Regression Analysis of PEFR and Anthropometric Parameters for Male Subject.*

Table 2 shows the regression analysis of the PEFR against the anthropometric parameters of age (years), height (cm) and weight (kg) respectively for the male participants. A model equation was formulated to determine the PEFR for male respondent. Below is the formulated equation in line with multivariate linear regression.

$$PEFR_{predicted} = 296.47 - 0.35(Age) - 0.84(Height) + 0.72(Weight) \ldots\ldots\ldots\ldots 2$$

Equation 2 shows the model equation for the male $PEFR_{predicted}$ respondent. This equation can be use to validate the PEFR of the resident of the area.

| Model | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|
| | B | Std Error | Beta | | |
| 1 (Constant) | 273.080 | 63.510 | | 4.300 | 0.000 |
| Age of subject | 0.038 | 0.427 | 0.016 | 0.088 | 0.930 |
| Height in cm | -0.648 | 0.430 | -0.271 | -1.508 | 0.140 |
| Weight in kg | 0.088 | 0.369 | 0.046 | 0.238 | 0.813 |

*a. Predictors: (Constant), weight in kg, Age of subject, Height in cm*
*b. Dependent Variable: PEFR*

*Tab. 3. Regression Analysis of PEFR and Anthropometric Parameters For Female Subject.*

Table 3 shows the regression analysis of the PEFR against the anthropometric parameters of age (years), height (cm) and weight (kg) respectively for the female participants. Similarly, a model equation was formulated to determine the PEFR for female respondent. Below is the formulated equation in line with multivariate linear regression.

$$PEFR_{predicted} = 273.08 + 0.04(Age) - 0.65(Height) + 0.09(Weight) \ldots\ldots\ldots\ldots 3$$

Equation 3 also shows the model equation for the female PEFRpredicted respondent. This equation can be use to validate the PEFR of the resident of the area. Equation 1 and equation 2 shows the predicted PEFR from the anthropometric parameters (Age, Height, and Weight) using linear regression analysis.

| Sex | Model Equation | Measured PEFR (L/min) | Predicted PEFR (L/min) |
|---|---|---|---|
| Male | PEFR = 296.47 − 0.35(Age) − 0.84(Height) + 0.72(Weight) | 185.16 | 172.41 |
| Female | PEFR = 273.08 + 0.04(Age) − 0.65(Height) + 0.09(Weight) | 174.50 | 166.63 |

*Tab. 4. Validation of PEFR Models.*

Table 4 shows the validation of the model equations with the measured PEFR and compared same with the predicted PEFR of the respondents.

## Discussion of the Findings

This study delves into the concerning issue of Peak Expiratory Flow Rate (PEFR) among individuals living near a cement manufacturing facility, shedding light on the escalating worries about air quality and its impact on public health due to industrial expansion. To address this concern, the research developed a predictive model estimating PEFR values in residents near the cement facility. The results of this study carry significant implications for public health and environmental policy. By uncovering the intricate relationship between industrial emissions and respiratory health, the study underscores the urgency of proactive measures to protect the well-being of communities residing near industrial facilities. The research methodology involved meticulous collection of a diverse dataset, including key anthropometric variables like height and weight. PEFR measurements from a representative sample were combined with individual-level data. Sophisticated statistical techniques, such as regression analysis and predictive modeling, established a nuanced relationship between PEFR values and individual anthropometric variables. The developed model equations were in consonance with the research conducted by Ismaila et al., 2015.

The study's outcomes highlight potential health risks for those near cement facilities, emphasizing the intricate connection between PEFR values and anthropometric factors. These findings have significant implications for policymakers and healthcare professionals, offering valuable insights into the health risks associated with industrial proximity. This research further underscores the concept of environmental justice, emphasizing the disproportionate impact of industrial emissions on vulnerable communities. Residents near cement facilities often face socioeconomic challenges, making them more susceptible to the adverse health effects of pollution. Addressing this disparity is crucial for promoting social equity and ensuring the well-being of these communities. The research underscores the urgent need for targeted interventions to mitigate health risks for residents near industrial facilities. Policymakers can use this knowledge to create evidence-based policies regulating industrial emissions and safeguarding public health (Moharana, 2018). Stringent regulations and emission control measures can notably reduce adverse health effects for communities near industrial zones.

Healthcare professionals, armed with this awareness, can tailor medical interventions to address specific health concerns in these communities (Etim et al., 2021). Regular health check-ups, early detection of respiratory issues, and specialized care can effectively manage health challenges caused by industrial pollutants. The findings emphasize the importance of health education and awareness campaigns in these communities. Educating residents about the potential health risks associated with industrial proximity empowers them to take preventive measures. Community workshops, informational sessions, and accessible educational materials can play a pivotal role in enhancing awareness (Musa et al., 2017). Informed individuals are better equipped to protect themselves and advocate for their rights, fostering a healthier living environment.

This study significantly contributes to the broader environmental health discourse by highlighting the intricate link between industrial proximity and respiratory health. It emphasizes the need for proactive measures to safeguard public health in industrialized regions, serving as a call for stringent policies to curtail industrial emissions and protect vulnerable populations. Long-term health monitoring programs are essential to track the health outcomes of individuals residing near industrial facilities. Regular health check-ups, especially focusing on respiratory health, can aid in early detection of illnesses related to environmental exposure (Musa et al., 2016). These monitoring initiatives can provide valuable data for researchers and policymakers, guiding evidence-based interventions and ensuring the effectiveness of implemented policies over time.

## Conclusion

This study advances our understanding of the complex relationship between industrial emissions and respiratory health. By establishing a predictive PEFR model and revealing associated health risks, this research provides a robust foundation for evidence-based policymaking and targeted healthcare interventions. Moving forward, it is crucial to heed these findings, enforce stringent regulations, and foster collaborative efforts among the healthcare professionals, and communities to create healthier environments for the respondents. The complexity of environmental health issues necessitates interdisciplinary collaboration between scientists, policymakers, healthcare professionals, and community representatives. By fostering collaboration, researchers can gain comprehensive insights into the multifaceted challenges faced by affected communities. Interdisciplinary studies can lead to holistic solutions that address not only immediate health concerns but also broader social and economic factors contributing to vulnerability.

The implementation of ergonomic principles serves to mitigate physical strain and occupational risks for workers, diminishing the probability of work-related injuries and musculoskeletal disorders. The adoption of ergonomic design cultivates a safer and healthier work environment, contributing to employee well-being and boosting productivity. This, in turn, has the potential to decrease absenteeism and enhance overall workforce health. Ergonomic enhancements result in a more resource-efficient utilization of energy and materials in production processes. Ergonomic integration principles align with corporate social responsibility objectives. Demonstrating a commitment to the habitant living within the vicinity of the cement facility, employee welfare and sustainable practices enhances the company's reputation and supports long-term viability. By incorporating ergonomic principles into the optimization of cement facility processes, the industry can foster a healthier environment, diminish environmental impact, and bolster overall operational sustainability. This approach underscores the interconnected nature of human well-being and resource efficiency in industrial settings.

This study further concluded that, not only illuminates the existing health disparities but also serves as a catalyst for informed action. By incorporating these findings into policy frameworks, fostering community engagement, and promoting ongoing research, society can move closer to ensuring a healthier, more equitable future for all residents, regardless of their proximity to industrial facilities. Building upon this study, future research endeavours could explore the effectiveness of specific interventions in reducing respiratory health risks among affected populations. Comparative studies across different industrial settings and regions can provide a nuanced understanding of the varying impacts of industrial emissions. Additionally, research focusing on innovative technologies for emission reduction and community-based participatory research approaches can further enrich the knowledge and inform sustainable environmental policies.

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# Smart Inland Waterways Transport Service and the Impact of Digitalization on Human Resources

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Keywords: Digitalization, Smart Inland Water Transport, Services, Human Resources, Human Centred Design

## Abstract

**Inland waterway transport (IWT) services play an important role on the implementation of the Sustainable Development Goals (SDGs) outlined in the 2030 UN Agenda, since more eco-efficient ways of living and consuming rivers are promoted through innovative ecological solutions that are better from the environmental, technological, and social point of view. This work examines how digitalisation, when applied to services and autonomous vessels, enhances human resources in the IWT sector. Themed analyses that consider both technological and design aspects offer opportunities for discussing the set of research implications that directly and indirectly account the human factors (HFE) domain. Technological advances employed in such vehicles offer various benefits like reducing accidents, improving fuel efficiency, and increasing cargo capacity, as well as reducing the workload of crew members (onshore and offshore). Additionally, digitalisation offers several environmental benefits, including increased work-related safety, more efficient routes, and reduced emissions in river transport.**

## Background

Europe and the whole world are facing new challenges, especially in the urban environment, due to unstoppable population growth (70% of the world's population is expected to live in cities by 2050), climate emergency, and societal changes. Most issues involve improving quality of life in cities within a sustainable and inclusive vision. Therefore, an imminent challenge for the development of cities will be how to improve urban transport services in a more environmentally, economically, and socially sustainable way. Among different systems and services operating at the urban scale, transportation is getting higher attention due to its capability to influence daily human routines as well as the design of urban settlements. It is indeed known that the shape of future cities and transportation lines can be developed from and around services.

In the perspective of operating within a smart-led city design, services and digitalisation become paramount and ubiquitous paradigms to be adopted in the design of all urban-related systems, including those for transport. Hence, the digitalisation of transport service chains could be assumed as the most crucial element in this process because it would allow better use, quality, and safety. In urban areas crossed by waterways, inland waterway transport (IWT) is certainly one of the best and most promising alternatives to the road networks for passenger and freight transport; for instance, it promotes low emissions alongside eco-efficient and reliable solutions, and zero-emission urban areas can be created (Sustainable Development Goals, 2030 Agenda). According to Jan and Nepveu (2020) IWT refers to the use of ships to transport goods from origin to transit points by the urban waterway network of a city, whilst enabling more economic growth in Europe's waterborne regions, so that prosperity and quality of life increase. Besides, IWT is the only known transport modality that uses pre-existing natural routes – re: rivers and canals – which in principle defines a sustainable and economically reliable modality to correctly use an existing resource.

Although Europe is globally recognised for its expertise in the development, production, and management of eco-efficient waterborne transport services, the supply chain urgently needs for solutions to be developed and implemented quickly. Only in this way the sector can properly align to better use and consumption of available resources. An increasing number of initiatives aim to varying automation levels

and small purpose-built vessels as the key to achieve desired system qualities such as high availability, redundancy, flexibility, and cost efficiency, (Reddy et al. ,2019). In the report "*Towards future-proof inland waterway transport in Europe*" (European Parliament, 2021) it is stressed the importance of autonomy for increased use of IWT. Looking at these needs, trends, and initiatives, the rise of a new mobility segment based on electric, autonomous urban ferries is clearly apparent. Back in 2016, the European Commission's "DG MOVE *Project*" explored the potential of digitalisation in the IWT sector and defined a concept for the Digital Inland Waterway Area (DINA). DINA aims to interrelate information on infrastructure, people, operations, fleet, and cargo in the IWT sector and to link this information with other transport modes – re: multimodal transportation.
The digitalisation and automation of IWT has a significant influence and provides huge opportunities. They promote improved door-to-door trips by making them user-centric, adaptive, and integrated across modes, while respecting data privacy and ensuring cybersecurity. They also optimize the safe operation of assets and the efficient use of available space and infrastructure through the whole life cycle management of assets and equipment via constant monitoring. This enhances business and policy decision making (European IWT Platform, 2019).
The scenario of studies around digitalization and IWT opens to considerations that cannot be disjoined by considering together workers in the sector, environment, and enabling vehicles. Digitalization can therefore support the transition toward more eco-efficient ways to use inland waterways as well as to trigger more aware consumption models of environmental assets. In this perspective, the primary areas within which to address the above-identified challenges are the followings:

- people should strive to establish attractive workplaces with higher social, qualification, safety and security standards;
- fleet should enable the transition to zero emissions and decarbonisation of fleets while ensuring competitiveness and safety;
- infrastructures must ensure that the trans-European inland waterway network is navigable on a continuous and reliable basis and provides fast connections to other modes of transport, while ensuring the sustainability of the infrastructure, protecting the environment and adapting to climate change;
- digitalization should be assumed as an enabling key driving force

to support innovations towards smart and sustainable jobs, fleet, and infrastructures connected to other transport modes and sectors (re: inter-modality) (European IWT Platform, 2019).

Consistent with the research scenario of sustainable IWT and digitalization, and using the four challenges synthetically presented before, this work examines the effects of disrupting digital technologies and automation services in the maritime industry of vessels for IWT. Four themed investigations are provided to stress the impact that these technologies have on employees' work and well-being, as well as on environmental features in relation to human-centred domains. The main idea behind this work is to show the hidden and sometimes less considered endogenous and exogenous aspects that should suggest a better use and consumption of human and natural resources in the marine industry. In terms of operative method, a desk-based methodology was used to detect relevant sources and to provide qualitative insights. The analyses provided in this work have the potential to open unexplored aspects that are relevant for the HFE domain as they will uncover links that echo the scientific and cultural domain where HFE studies take place.

## Four themed investigations

Four themed analyses on automated vessels for IWT provide a new interpretative framework useful to clarify the links between environmental and human resources. Within the IWT concept, this analysis contributes to open reflections on novel touchpoints that may trigger sustainability and inclusivity in the sector. Specifically, these analyses are intended as a cascade model (the first one introduces the second one, and so on) that at end will allow to define a design-oriented framework within which pertinent examples can be found.

### Autonomous passenger transport

Autonomous vehicles are transforming the transport industry. However, in the shipping sector, when associated with international waterborne transport, they prospect the reconfiguration of urban infrastructure and mobility (Gavanas, 2019; Milakis et al., 2017; Thomopoulos & Givoni, 2015).

The notion of "autonomous ship" is currently under discussion within the maritime community. The concept of "Smart Shipping", as promoted by authors such as Martin Stopford, emphasises the incorporation of digital elements into ships through the introduction of new

sensor systems to monitor performance and prevent future failures through data analysis (Gunay, 2022). Automated driving systems were introduced to replace human drivers in response to the common problem of human error as a major cause of vehicle accidents (Crayton & Meier, 2017). While acknowledging human failure as a significant accident cause, it remains vital to appreciate the constructive role of humans on ships. Autonomy does not eliminate human error, but reallocates it to other areas, such as shore-based controllers and the design of hardware and software systems. Autonomous Vehicles (AVs) have the potential to revolutionise the way a work is performed by the integration of artificial intelligence and machine (Davidson & Spinoulas, 2015). Accordingly, the retraining of on-board transport workers' skills will be required. Alongside rail and aerospace, the maritime sector is moving further towards automation. Introduced in 2012, the MUNIN project has fostered new technologies for autonomous ships (AS), including advanced decision support systems and remote operation capabilities. Norway is a pioneer nation in the development of technology-renovated and safe autonomous ships (Høklie, 2018).
Here, greater operational flexibility is provided for routes with varying passenger numbers. The primary driver for their deployment is the reduction of emissions, while the introduction of autonomous ferries highlights an expanding trend in maritime transportation. The utilization of advanced technology in battery-powered ferries that maintains on-board crew marks a transition to potentially autonomous conventional passenger ferries. The Trondheim electric ferry project demonstrates the potential cost-effectiveness and operating efficiency benefits of autonomous vessels. This urban ferry acts as a test of technical feasibility and public acceptance, influencing the possible progress of recently commissioned ferries towards a limited autonomous status with remote control from shore stations. Studies suggest that smaller ferries also offer greater benefits in terms of autonomy. Thus, it proves necessary to modernise the entire inland waterway fleet with smaller, autonomous, and sustainable vessels. This mirrors an increasing of expense for local public administrations. The integration of automation in ferries offers considerable advantages in terms of cost reduction (e.g.: construction, personnel on board) and energy consumption (Kretschmann et al., 2017). The implementation of such technology will be crucial for gathering and monitoring data pertaining to ferry operations, which can be used to mitigate risks and human errors.

## Levels of Automation

The Level of Automation (LoA) is an essential framework for discussing unmanned and autonomous operations (Sheridan and Verplanck, 1978) within the sustainability of services for IWT. However, different taxonomies related to LoA have emerged over the years (Sheridan and Verplanck, 1978). In the context of vehicular autonomy, multiple scales exist, such as those from Lloyd's Register, Society of Automotive Engineers (SAE), Verband der Automobilindustrie, and the Norwegian Forum of Autonomous Ships (Sheridan and Verplanck, 1978). Additionally, the Maritime Safety Committee of the International Maritime Organization (IMO) has formulated a scale that concentrates on autonomous surface ships in the maritime industry. This scale ranges from ships with automated processes accompanied by seafarers to fully autonomous ships (Sheridan and Verplanck, 1978). The committee defines three degrees of autonomy:

- Degree one: The ship incorporates automated processes and decision support. Seafarers are on board to operate and control shipboard systems and functions. Certain operations may be automated, occasionally without supervision, but seafarers remain on board and can take control.
- Degree two: A remotely controlled ship with no seafarers on board.
- Degree three: The vessel is controlled remotely with no seafarers on board. The ship operates at a degree three level of autonomy, where its operating system can make independent decisions and take actions.

The implementation of autonomous or unmanned vessels requires sophisticated technology, including sensors, AI, IoT, and automated navigation as stated in the findings of the Research in Maritime Autonomous Systems project. These technologies, used at various levels, allow for the generation and processing of data to support both manual analysis and autonomous decision making (MUNIN, 2013). However, it is crucial to note that digitalised applications are not synonymous of autonomy; they rather denote a transformation in the digitalisation of the industry (MUNIN, 2013).

## Impact on wellbeing of seafarers

The introduction of electric motors and simplified operating procedures through automation raises questions about the future of seafaring jobs, especially on short-distance passenger ferries, where tasks such as navigation and engineering may be reduced (Porathe, 2014). Such reductions of human participation could also neglect the importance of human-centred design (Cook and Shipley, 1980; Main et al., 2017). This transition to navigation that is increasingly oriented towards the use of the latest technologies (Adamson et al., 2018) has consequences for the physical and mental well-being of the crew. It is crucial to prioritize the mental health and well-being of seafarers to achieve optimal safety and performance, as emphasized by IMO (1997; 2003). Crew resilience, which refers to the capacity to maintain performance within safe limits, is influenced by several factors, including individual capabilities, working environment, training, and stress levels (IMO, 1993b; Tam and Jones, 2019b).

This theme has opened a debate within the maritime community, where worries have arisen about possible loneliness, depression, and the impact on minimum manning levels. Developing countries that depend on maritime employment are particularly affected by this concern. The possibility of losing jobs due to automation is a major preoccupation for current and future generations of seafarers wishing to pursue a maritime career.

While crew size is expected to decrease, full autonomy on all ships is unlikely to be achieved for another decade or two. A growth in employment is expected in shore-based positions, which not only offer more predictable working hours, but also the possibility of a more diverse employee base, potentially encouraging greater participation of women in maritime careers (IMO, 2020; Kim et al., 2018). Consequently, it will be necessary to modify training methods and improve the digital skills of existing seafarers (ICS 2019; Johns 2018). Further research is required to achieve an equilibrium between technological implementation, cyber risk mitigation, and the assessment of the societal implications of autonomation for workers, including the potential for isolation and increased workload (Tam and Jones, 2019b). By enabling the participation of all individuals, including those afflicted by disabilities, the employment of remote-control systems and autonomous technology has the potential to diversify the workforce (Takeuchi et al., 2020).

## Human centred design approach

The latest technological solutions will enable the shipping industry to respond effectively to the need for greater safety and efficiency in the transportation of people and goods by improving human and organisational capabilities. The introduction of tools based on artificial intelligence will act as enabling technologies rather than driving technologies. This perspective fundamentally shapes the system design and redefines its success criteria. This paradigm shift goes beyond individual projects focused on technological feasibility and considers technology as a tool for maritime knowledge management. The objective of this approach is to improve quality, sustainability, agility and, above all, process safety. When utilising smart technologies, a holistic approach is required to address the human element, including social and technical aspects, in line with European objectives (IMO, 2003).

Designing ergonomic working environments and keeping up with new technologies on ships pose important challenges and questions for designers. These include identifying and implementing the best practices in work design and ergonomics, which are crucial for achieving the optimal performance of ships (Nordby, Gernez & Mallam, 2019). In maritime transport, it is crucial to create advanced, self-managing automated systems that are easy to understand and provide users with ergonomic functionality (Wild, R. J., & Lützhöft, M., 2020). By identifying and addressing the elements necessary for accessibility and usability of new technologies, innovative solutions should be developed. Essential elements to be considered in workplace design from an ergonomic perspective include work task assessment, documentation and system context analysis, and automation of repetitive or hazardous tasks. Using prototypes and evaluating systems with representative users in the intended context, combined with a user-centred design strategy, ensures that ergonomic considerations are incorporated at every stage of work transformation (Lützhöft, M., 2020).

Ergonomic design (i.e.: HCD) prioritises the wellbeing of people, with the aim of optimising performance, reducing errors, and ensuring the safety and well-being of crews. To create a supportive, efficient, and adaptable working environment, it is essential to understand needs, capabilities, and responsibilities of seafarers within the system. Creating a comfortable working environment requires a comprehensive approach. Nordby et al. (2019) highlight the importance of HCD, which requires a new approach and perspective. It is essentially a human-centric design concept that underlines the importance of keeping humans at the centre of the workspace. In this regard, it is important to offer a workspace that is not only safe

and comfortable, but also fosters efficient and satisfying user interaction. This ensures a positive user experience, which is necessary to improve both the physical performance and the psychological aspects of navigators (Nordby, Gernez & Mallam, 2019). Therefore, it is necessary to create an ideal ergonomic context by considering flexible workstations that remain accessible despite changing conditions, providing technology that supports the seafarers' work tasks, providing computer systems that provide information and execute commands (design of control centres, control stations and user interfaces), which are essential to ensure a fluid and stress-free work experience. The aim of this methodology is to create dynamic and supportive environments that enable optimal human performance and compensate for weaknesses (Nordby, Gernez & Mallam, 2019).
Automation systems can be seen as elements that support human work on ships, ensuring greater safety and efficiency. For such systems to have a tangible positive impact on seafarers' work, it is necessary to develop and integrate them into the whole workspace system with a human-centred approach.

## Conclusions

This study presents a comprehensive and systematic exploration of the multiple impacts of digitalisation and automation in the maritime industry, particularly in the context of services related to IWT in urban areas that are consistent with the idea of sustainable mobility and eco-efficient ways of moving people and goods along rivers in the respect of their environmental qualities and features. It offers an initial understanding of the potential effects, implications, and opportunities arising from the integration of digital technologies and automation of navigation aids. The achievement of a balanced approach that addresses these technological developments, environmental sustainability, workforce adaptation, and HCD principles is emphasised to reach a harmonious integration of new technologies in the maritime sector, which ultimately promote sustainability and inclusiveness. The study tries to clarify the complex relationships between environmental resources, technological advances, and human aspects within the inland navigation model. These investigations explore the complex use of autonomous passenger transport, the level of automation, the impact on seafarers' welfare and the HCD approach.
Firstly, the implementation of automated vehicles, especially in the

shipping industry, is emerging as a potential accelerator for redesigning urban infrastructures and revolutionising sustainable mobility. Despite their significant benefits in terms of improved work quality, enhanced safety, and reduced environmental impact, the massive introduction of autonomous transport could have a significant impact on employment opportunities. Therefore, it is crucial to take proactive steps to address these changes and ensure a fluid transition, considering retraining and upgrading the skills of the workforce. In other words, whether such systems have the power to lowering the environmental impact of mobility, they can also produce a negative pressure on the human capital deployed for its daily implementation. The investigation into autonomous passenger transport highlights the changing landscape in the shipping sector by emphasising the role of intelligent vessels and the gradual integration of autonomous ferries. These developments aim to reduce emissions, improve operational efficiency, and modernise fleets, though considerable financial implications for local authorities. The potential advantages in terms of lower costs and energy efficiency underline the importance of integrating such technologies. However, when discussing intelligent shipping, it is essential to consider the levels of automation, which offer three different scales and degrees of autonomy. The significance of advanced technology and digital applications in data collection, analysis and decision-making is highlighted, thus highlighting an evolving phase in the digitalisation of the maritime industry. The transition to automated navigation has an impact on seafarers' welfare, making it a central topic within the maritime community. The debate has raised questions about possible job displacement, changes in crew size and the impact on the psychological and physical well-being of workers. It is essential to balance technological advancements with considerations for workers' mental health, training, and social implications.

The HCD approach to service and vessel design is a crucial aspect of designing artefacts that address the needs of users and the integration of intelligent technologies. The focus is on creating ergonomically satisfying (re: usable) working environments that put seafarers' well-being, efficiency, and safety at the core. This strategy includes an understanding of the needs and capabilities of workers and ensuring that technology is well integrated into the workspace, improving human performance and compensating for weaknesses.

It must be noted that this contribution is essentially based on research carried out using data and information provided by other researchers and lacks direct field experiments. However, the lack of documented case studies is mainly due to the novelty of this emerging research field. Despite this documental limitation, it was possible to define the ideal balance between vehicle automation levels that can guarantee optimal conditions for seafarers' well-being. Obviously, a level two range of automation should be considered. These new devices are designed to minimise risks on board, ensure greater efficiency and improve the working environment, where the human contribution to vehicle management remains important. The implementation of new technologies should not be regarded as a threat to the workforce but will certainly lead to a transformation and renewal of some professional roles. Based on current studies, we can state that it is be possible to find a satisfactory compromise between technology and well-being. Tests and experiments would help to establish a precise framework for the design of a product-service system (PSS: a service in connection with vehicles) that integrates the right technologies to define it as smart, allowing at the same time improved psychophysical well-being, work performance, and occupation in terms of employment opportunities.

Overall, the analysis of the smart services and solutions for IWT puts the emphasis on the dichotomy between the idea of resources themselves, which sway between environmental aspects and human skills. It was observed that these two realms do not progress simultaneously, and the search for a balance is needed to progress and maintain higher, altogether, environmental goals in terms of maximum eco-efficiency of PSS, and human resources in terms of skilled workforce that are asked to maintain the system prosper over time, which ultimately reflects in economic power and dignity of people operating in the field.

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