

Cybernetic avatars for energy transformation: regulating the digital revolution for enhancing sustainable attitudes of energy consumers

Fumio Shimpo, Maciej M. Sokołowski, Piotr Mikusek, Yash Chawla and Roberto B. Figueroa Jr

Abstract

Purpose – This study aims to fill the gap in the literature and to explore the potential of using cybernetic avatars as tools for climate and energy transformation within the context of public policies, demonstrating their role in heightening awareness and fostering positive attitudes towards sustainable energy among individuals, as well as enhancing the efficiency and communication of public administration.

Design/methodology/approach – In the context of disseminating knowledge about the climate impacts of day-to-day human activities, the authors address main elements that constitute the specific basic terms of reference for a draft framework aimed at using cybernetic avatars as tools for climate and energy transformation.

Findings – The symbiosis of consumer awareness, technological innovation, and educational endeavours, facilitated by cybernetic avatars, constitutes the linchpin for an environmentally responsible and sustainable energy future. As the energy sector adapts to the evolving preferences of the new generation, the integration of avatars and advanced technologies emerges as a pivotal factor in sculpting a conscientious and ecologically sustainable energy landscape.

Social implications – Energy 4.0 technologies transform the energy sector. Industry 4.0 drives digitalisation, which brings various means, such as Internet of Things, artificial intelligence, blockchain and the metaverse, that reshape energy markets and enable distributed energy transactions. These technologies combine to create the concept of avatarisation, which imagines a digital representation in a virtual world, driving us towards Society 5.0.

Originality/value – The authors propose a draft framework for the implementation cybernetic avatars in climate and energy policy (“Nexus Avatar Platform for Sustainable Future”), consisting of three main elements: vision, tool scope, and policy coherence.

Keywords Artificial intelligence, Cybernetic avatars, Energy transition, Metaverse, Consumer awareness, Society 5.0, Energy 5.0, Digitalisation, Sustainable energy

Paper type Conceptual paper

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1. Introduction

The concept of using cybernetic avatars as a cognitive facilitation has been around for a while. There is now an increasing role and number of fields of application for avatars, a form of representation and mirroring of users in a digitised environment (Nakamura, 2002). Cybernetic avatars can exist in a digitised and dematerialised form, but they can also take the form of physical, teleoperated robots (Hagita *et al.*, 2024). Same is true for autonomous robots. In what follows, the term “cybernetic avatars” will refer to categories of avatars occurring on digitised platforms.

A number of postulates relating to the use of cybernetic avatars can be found in the literature, including teaching children with autism (Konstantinidis *et al.*, 2009) and supporting ethical education of students (Hu *et al.*, 2023). The preceding discussions and referenced literature have underscored the significant role avatars can play in heightening awareness and fostering positive attitudes. Nonetheless, a notable void exists in the literature concerning their application in the context of implementing energy policies.

There is a recognised need to systematically incorporate cybernetic avatars, as tools for climate and energy transformation, into state policies. This structural integration encompasses both the paradigm of avatarising politics and the necessary regulatory shifts within state administration in this domain. Such a comprehensive approach aligns with the concept of e-administration, denoting modern methods of wielding state authority through digitised tools, resulting in enhanced task efficiency (Cahlikova, 2021, pp. 5–8). This is particularly evident with regard to improved communication with citizens (Hoffman and Cseh, 2020, p. 200).

The indication of the potential of using cybernetic avatars or avatars more broadly as one of the tools for decarbonisation and strengthening sustainability in the energy field has already taken place in the literature. There have been several studies on the implementation of cybernetic avatars for cost optimisation in the energy sector (Ye *et al.*, 2024). The need to develop sustainability criteria for artificial intelligence within the emerging framework of “green artificial intelligence” has been increasingly recognised (Sokolowski, 2024). To build upon and extend existing research and to answer how cybernetic avatars can be modelled into the state’s climate and energy policy, in the context of disseminating knowledge about the climate impacts of day-to-day human activities, it is necessary to properly define three main elements constituting the specific basic terms of reference (TOR). These elements serve as a draft framework for the implementation of such a tool, offering universality, regardless of the legal system to which they would be implemented. In this article, we define in detail these four elements and lay the groundwork for comprehensive regulations for cybernetic avatars in energy transformation.

In this light, this study uses a qualitative approach to explore the integration of cybernetic avatars into climate and energy policies. It includes a literature review on avatars in education and sustainability (see Boudet, 2019; Sokolowski, 2024), the development of the Nexus Avatar Platform for Sustainable Future (NAPSF) framework based on policy coherence principles (see European Commission, 2019), and case study analyses of avatar applications in public sectors (see Naqvi, 2023). These methods collectively address the potential for cybernetic avatars to enhance public engagement with sustainable energy practices.

The structure of the article is divided into three main sections on: the role of consumer awareness in the energy market, the role avatarisation plays and can play in the energy market and the theoretical framework for the implementation of an energy data aggregation platform, ending with our conclusions and recommendations. It reflects the verification of the research hypothesis: consumer awareness of the advantages of operating a sustainable energy system can be increased and strengthened through the use of avatarisation technologies, and the appropriate design of public policies could provide a tool for building a standardised platform providing an environment for building this consumer awareness. In the context of the research hypothesis presented in this way, the motivation for choosing the research topic seems obvious. The increasing amount of data provided by modern energy systems should not be used solely to improve the technical aspects of transformation processes. It is also necessary to reflect on what opportunities exist for their use as part of the process of increasing public acceptance.

2. Sustainable energy attitudes: the consumer awareness factor

Amid the digital revolution and the pressing need for sustainable energy consumption, understanding the role of consumer awareness in shaping energy attitudes becomes

paramount (Carmichael *et al.*, 2021). As advancements in technology offer new opportunities for energy transformation (Chawla *et al.*, 2022; Hainsch *et al.*, 2022), the emergence of cybernetic avatars introduces an exciting dimension to it (Kuru, 2023). In this context, this section explores the significance of consumer awareness in the formation of sustainable energy attitudes, exploring how cybernetic avatars can facilitate and enhance this process.

2.1 Consumer awareness: a catalyst for sustainable energy choices

Consumer awareness plays a pivotal role in shaping attitudes and behaviours within the energy market (Owens and Drifill, 2008). When examined with regard to energy consumption, it goes beyond mere comprehension of individual usage patterns. It involves a deeper understanding of energy-related issues. Informed consumers are better equipped to make responsible decisions about their energy usage (Karytsas and Theodoropoulou, 2014). This is particularly important, considering the global significance of energy transition (Sokolowski, 2022).

The impact of consumer awareness extends to the formation of sustainable energy attitudes. Consumers who possess a high level of awareness are more likely to adopt energy-efficient practices and embrace sustainable energy sources (Brounen *et al.*, 2013). They actively engage in reducing energy wastage and supporting policies that promote a sustainable energy future (see Li *et al.*, 2021). Recent scientific studies have corroborated the strong association between consumer awareness and the adoption of sustainable energy practices (see Ha and Janda, 2012; Pothitou *et al.*, 2016). In recent years, emerging technologies have opened new possibilities for engaging consumers in sustainable energy practices (Chawla *et al.*, 2022). By incorporating these such technologies, stakeholders can enhance educational efforts and empower consumers with the knowledge they need to make informed decisions towards sustainable energy choices (Boudet, 2019).

2.2 Assessing consumer awareness in the energy market

To ensure a smooth transition to sustainable energy practices, effectively measuring consumer awareness in the energy market becomes crucial (Claudy *et al.*, 2013; Kowalska-Pyzalska, 2018). Using a multifaceted approach, with quantitative and qualitative techniques like surveys and interviews offer valuable insights into consumer attitudes and preferences related to energy consumption (Csutora *et al.*, 2021). These methods address the comprehension of energy concepts and perceptions of sustainable energy practices.

Qualitative research on consumer awareness has shed light on specific factors that influence attitudes towards sustainable energy choices. A study by Sony and Mekoth (2018) explored consumer perspectives on sustainable energy usage, revealing that individuals with higher awareness levels were more likely to have a more positive energy attitude. Furthermore, Haque *et al.* (2021) uncovered how information dissemination and educational programs played a key role in increasing awareness among consumers, leading to positive shifts in energy attitudes. Complementing qualitative methods, quantitative metrics such as energy literacy tests and awareness indices provide objective measures of consumer awareness across diverse demographics and regions (see Chawla *et al.*, 2020; Martins *et al.*, 2020; Neves and Oliveira, 2021).

2.3 Factors influencing consumer attitudes towards sustainable energy

Several factors influence consumer attitudes towards sustainable energy practices. Education and information dissemination significantly impact consumer behaviour (Li *et al.*, 2017). Informed consumers are more likely to embrace eco-friendly behaviours and advocate for solutions like renewable energy or energy conservation. Apart from that socio-

economic factors also play a role, where financial constraints may hinder access to energy-efficient technologies, creating disparities in sustainable energy adoption. Socio-cultural factors are equally influential, with social acceptance driving wider adoption of sustainable energy practices.

Government policies and incentives are critical drivers of consumer energy attitudes (Sun *et al.*, 2020). Supportive policies, such as feed-in tariffs and tax incentives, can sway consumers towards better choices (see Sokołowski, 2016). Technological advancements also impact consumer attitudes, as access to innovative and user-friendly energy technologies can inspire consumers to adopt cleaner energy sources (Siksnyte-Butkiene *et al.*, 2023). Same is true for the practices that the corporations can adopt in this regard (see Sokołowski and Taylor, 2023).

2.4 Empowering the future: enhancing consumer awareness among children and youth

Recognising the significance of early intervention, it is imperative to integrate energy-related topics into school curricula. By incorporating age-appropriate content on sustainable energy concepts, environmental impacts and climate change, educational institutions can nurture a generation of environmentally conscious and well-informed active individuals. Various studies (Hoque *et al.*, 2022; Otto *et al.*, 2019) have shown that early exposure to sustainable energy concepts significantly influences attitudes and behaviours in the long term.

Promoting interactive and engaging energy education programmes tailored to children and youth can stimulate interest and participation (van de Wetering *et al.*, 2022). These programmes use hands-on activities, experiential learning and digital simulations to create lasting impressions and instill sustainable energy attitudes in the minds of the young (Kirby and Chilcote, 2014). Empowering youth to take an active role in community-based energy projects (see Cassotta and Sokołowski, 2022; Sokołowski, 2020, 2021), that together with awareness campaigns can be a powerful catalyst for change. By involving young individuals in initiatives that demonstrate the benefits of sustainable energy practices, they are encouraged to become vocal advocates for a more sustainable energy future. Research suggests that engaging in real-world energy-related activities fosters a sense of ownership and responsibility among youth, leading to sustained positive attitudes towards energy conservation (van de Wetering *et al.*, 2022).

As we progress into the digital age, the integration of cybernetic avatars provides a unique opportunity to enhance energy education for children and youth. These avatars can act as personalised mentors, offering real-time information, interactive learning experiences and tailored guidance on sustainable energy choices. Cybernetic avatars facilitate greater engagement and knowledge retention among young individuals, ultimately leading to more informed and sustainable energy attitudes.

By harnessing the power of cybernetic avatars in educational efforts, we can strengthen the impact of sustainable energy initiatives among children and youth. These avatars serve as dynamic interfaces, connecting young minds with cutting-edge innovations and offering insights from the broader energy landscape. By associating the findings from the existing literature and forthcoming research on the potential of cybernetic avatars, stakeholders can empower the next generation to become proactive agents of change in achieving a greener and more sustainable future.

While the new generation of future energy consumers relies on new technologies and solutions like artificial intelligence (AI) in their everyday lives, the energy sector must find its answers for accommodating their preferences. This concerns adaptation to consumers' needs, given the discussed growth of their eco- and climate-friendly awareness, also

steered by the virtual world, as we predict. How can the energy sector adapt to the changing demands and expectations of the new generation of future energy consumers?

3. The influence of modern energy technologies and avatarisation on the energy sector

Energy sector has a significant role in the energy transformation which is striving to reduce greenhouse gas emissions, promote renewable energy sources and enhance energy efficiency. With the convergence of energy system and modern technologies, energy markets, which were previously restricted to incumbent distributors, may now consider liberalised and opened, not only due to laws and policies but also new technologies and solutions. Among them we list cybernetic avatars.

3.1 Digitalisation of energy sector for the needs of energy transition

The digitalisation, being a technology-driven modernisation trend, has been a significant influencer on various facets of the energy sector (see [Akberdina and Osmonova, 2021](#)). This brings transition from the physical to the digital world ([International Energy Agency, 2017](#)), a move from analogue data to digital form, followed by its storage on digital data repositories ([Wallmüller, 2017](#)), with the utilisation of digital technologies to enhance business operations, policy-making or decision-making in a broader sense, aiming to optimise efficiency, cost, security and sustainability ([Światowiec-Szczepańska and Stępień, 2022](#)). Digitalisation has a close correlation with information and communication technology (ICT), as [Weigel and Fischechick's \(2019\)](#) examination highlighted.

In the 21st century, when the world saw the swift evolution of digital technologies and faced the emergence of the fourth industrial revolution or Industry 4.0, digitalisation has rapidly accelerated ([Aman et al., 2013](#)). With Industry 4.0, the energy sector also aims to achieve Energy System 4.0 which is signified by the distribution of digital infrastructure in the energy sector ([Ghobakhloo, 2020](#)). This covers key technologies for Energy System 4.0, which include the Internet of Things (IoT), AI, edge computing, blockchain, big data, extended reality, digital twins and the metaverse ([Singh et al., 2022](#)). With further advancement in these areas, mainly driven by the recent boom in AI, this can very soon become Society 5.0 (the super smart society) – the new society created by transformations led by scientific and technological innovation ([Shimpo, 2018](#)).

Apart from AI, one of the critical enabling technologies for the realisation of Society 5.0 is IoT. Using IoT shifts energy systems towards efficiency, sustainability and resilience. [Singh et al. \(2022\)](#) argued that IoT is crucial for the success of smart grids and their generation, distribution and transmission systems. Through IoT, real-time energy consumption measurement and reporting improve billing and usage patterns, boosting interactions between different stakeholders ([Kashef et al., 2023](#)) and due to IoT sensors on turbines and solar panels can predict equipment failure and maintenance (see [Sampurna Lakshmi et al., 2023](#)). Another enabling technology that usually works synergistically with IoT is blockchain technology. Its potential in energy markets has been extensively studied, with a particular focus on facilitating decentralised energy trading (see [Mengelkamp et al., 2018](#); [Andoni et al., 2019](#)).

Edge computing is a key enabler for distributed and widespread deployment of other technologies in the modern ecosystem. It is defined as a new technology that provides IT services and cloud computing capabilities near mobile customers within a radio access network ([Abbas et al., 2018](#)). The introduction of edge computing could improve network latency and conserve bandwidth resources for faraway cloud data centres by bringing processing capabilities closer to tasks ([Cui et al., 2021](#); [Zhao et al., 2018](#)), enabling real-time data analysis and quick decision-making in smart energy systems.

Further enhancing the performance of current and future energy infrastructures are big data and AI. The convergence of AI with other enabling technologies is said to further enhance the efficiency of smart grids as well as contribute to the automation of democratised energy markets. IoT data is one of the richest sources of big data and requires novel analytics to fully profit from it. AI, which also relies on the abundance and accuracy of big data can greatly boost the efficiency of smart grids by enabling autonomous decision-making in IOT systems and execute smart contracts between agents of decentralised energy markets (Atlam *et al.*, 2020).

Another set of enabling technologies are Immersive technologies like Augmented Reality (AR) and Virtual Reality (VR) (Singh *et al.*, 2022). Immersive technologies span a range of devices and software that provide immersive experiences and environments to users. The combination of virtual and real environments as well as the human and machine interactions generated by immersive technologies are broadly referred to as extended reality (XR). Thus, VR and AR are both immersive technologies and extended realities. VR is a combination of hardware and software that provides multisensory stimuli to simulate real or imagined worlds, which participants having a perceived self-location can interact with (Figueroa, 2023). AR overlays digital objects on physical objects or locations to enhance interactions with physical environment. The metaverse is a persistent multi-user-interconnected virtual environment that can be accessed by a combination of immersive technologies. It is a virtual environment that allows for real-time, embodied user conversation and dynamic interactions with digital objects (Mystakidis, 2022). The metaverse can be made up of elements that are digital representations of physical objects. Such an object is called a digital twin. A digital twin is conceptually defined as “a virtual representation of a physical system (and its associated environment and processes) that is updated through the exchange of information between the physical and virtual systems” (VanDerHorn and Mahadevan, 2021). Among the immersive technologies, the metaverse and digital twins are believed to further accelerate the advancement of the energy sector towards Energy System 5.0 through a concept called avatarisation.

3.2 Avatarisation of energy sector

The impact the aforementioned enabling technologies on the energy market can even be enhanced by their convergence. Avatarisation of the energy market is another fascinating area where these enabling technologies can make a significant contribution. This concept refers to the digital representation of energy resources and their interaction in a virtual marketplace.

Profoundly envisioned in Kuru's (2023) paper, a convergence of key future technologies has been proposed. Kuru introduces a concept he has termed *MetaOmniCity*, depicting a hyper-connected, sustainable and intelligent virtual city. He vividly elucidates how the principles of the metaverse and digital twins can bolster smart cities through IoT connectivity and blockchain-based transactions (see Lytras *et al.*, 2021). The idea of digital twins, widely acclaimed to have been initially articulated by Grieves (2017), has been used in the industry as a virtual counterpart to a physical-world entity, which boasts bidirectional near real-time data streaming. With the Society 5.0 framework, this moves further towards digital twin cities (Sokołowski and Shimpó, 2025).

The energy market within this cityscape is revolutionised, driven by state-of-the-art low-emission infrastructural technologies and smart meter solutions. As Kuru (2023) delineates, the rise of these tech solutions reduces the carbon footprint significantly, while simultaneously offering unprecedented efficiency and control over energy consumption and distribution. Moreover, Kuru's (2023) paper outlines principles for creating tools for the *MetaOmniCity*'s energy market. These principles guide the development of technology that is user-friendly, scalable and adaptable, with a strong emphasis on data security and privacy. The defining characteristic of these tools, as Kuru (2023) explains, is their ability to

transform complex energy market dynamics into easily understandable information for the average household.

While we have yet to see a fully functional instance of the MetaOmniCity, some benefits of avatarisation can be readily implemented in through the field of education's operationalisation of digital twins. Most smart city literature would agree with the definition posited by [Kuru \(2023\)](#) which seemingly requires the bidirectional influential relationship between the physical and virtual entities. However, education scholars may be more concerned about the simulative affordances of digital twins and the metaverse.

[Camposano et al. \(2021\)](#) reported seven metaphors of digital twins as described by professionals in the fields of architecture, engineering, constructions and facilities management.

Among these metaphors, three stand out as especially relevant for educational applications:

1. being a process or modelling method;
2. a visualisation tool; and
3. a shared concern between different communities of practice.

These metaphors provide a framework for understanding how cybernetic avatars can be used as educational tools in the energy market. They allow for the creation of virtual models of energy systems, providing an accessible and engaging way for consumers to understand the complexities of energy production and consumption.

Moreover, the concept of cybernetic avatars as “digital human twins” suggests a more interactive and personalised approach to education. In the energy market, this could manifest as virtual representations of consumers and prosumers in the educational metaverse, enabling individuals to experiment with different energy use behaviours and observe the potential impacts in a risk-free environment. There has been an exponential increase of educational metaverses which would enable learners to interact with digital twins of real-world instruments or objects through easy-to-learn Web-based platforms like Frame VR, Sansar and Edify. With these tools, science communication projects involving the development of metaverses for educating consumers and prosumers on how various components of a smart city or a liberalised microgrid could work and how they could affect the system through their cybernetic avatars. This approach can also be easily replicated in less developed countries and cities that are still preparing for or do not have infrastructural support for smart cities. Initiatives on avatarisation for educating energy market consumers in the metaverse can be included in government funded technology-enabled science communication projects.

One example from the Philippines is the recently approved immersive science communication open laboratory, which aims to use immersive technologies like VR, AR and the metaverse to promote environmental and sustainability science in the country. Its objectives include the development of a digital twin of its campus and nearby communities for simulating various concepts of sustainability including the concept of a sustainable smart campus.

4. Implementation of a standardised training platform based on cybernetic avatar technology

To answer how cybernetic avatars can be modelled into the state's climate and energy policy, it is necessary to properly define three main elements constituting the specific basic TOR of such a project. They constitute a draft framework for the implementation of such a tool and can be used in a universal way, regardless of the legal system to which they would be implemented. These elements are the following:

- Vision – a clear definition, preferably using measurable indicators, of what goals are to be achieved by the implemented tool.
- Tool scope – how the tool is to be constructed.
- Policy coherence – highlighting areas within planned state policies and applicable regulations that require changes to ensure the effectiveness of the constructed tool.

The above elements will directly influence the shape of the implemented tool. To facilitate further discussion, we propose to call such a platform the working name “Nexus Avatar Platform for Sustainable Future” (NAPSF). As the name suggests, NAPSF would be a VR based on the use of cybernetic avatars intended to increase the awareness of its users regarding the impact of energy use on the environment and the benefits resulting from conscious consumer attitudes on the energy market. Like other VR platforms, it would be focused on cooperation and interaction ([Aseeri and Interrante, 2021](#)), but to a very specific extent, because this interaction would take place mainly with the data feeding VR and only secondarily with other users. It is the data that constitute the core of the designed tool and they constitute its essence and being the subject of visualisation, the perception of this data is to be easier to assimilate ([Erickson, 1993](#)).

4.1 The vision that defines the boundaries of Nexus Avatar Platform for Sustainable Future

The vision of using cybernetic avatars by public administration is not something that is no longer confirmed in reality. They are pioneeringly used by public entities in their activities, e.g. in Colombia, where the first trial in the metaverse using cybernetic avatars took place or in Saudi Arabia, which used cybernetic avatars to celebrate a national holiday ([Naqvi, 2023](#)). Therefore, if issues of court proceedings or the state's activities in the promotion of its own culture can be the subject of the use of cybernetic avatars, then such a broad issue as the implementation of more sustainable policies provides space for the implementation of cybernetic avatars. In the opinion of the authors of this paper, it is not only possible, but even necessary, to implement NAPSF as a systemic tool supporting the implementation of climate and energy policies. Modern technologies have significant potential to be used to reduce human impact on the climate ([Chawla et al., 2022](#)).

The implementation of NAPSF must be preceded by defining a vision of the goals to be achieved. The methodology for setting goals should be two level. The first level should refer *per excellence* to the strategic transformation assumptions specified in the strategic documents of implementing countries, which are tools for guiding decarbonisation policies ([Jeudy-Hugo et al., 2021](#)). An example of such a document and a tool for defining strategic goals may be the “European Green Deal”, which is a strategy aimed at achieving net zero emissions in the European Union by 2050 ([European Commission, 2019](#)). The zero-emission goal includes detailed partial goals, including: increasing the share of the use of renewable energy sources or improving energy efficiency ([Schlacke et al., 2022](#)).

Defining strategic goals is fundamental from the point of view of determining the main directions, but it is not sufficient. The second level of goals should specify in detail what medium-term goals (e.g. up to five years) this tool should support. The catalogue of such goals will result from strategic goals and will depend on the particular needs of a specific country. Examples include an increase in the number of renewable energy prosumers, an increase in the number of energy cooperative agreements concluded, an improvement in the energy efficiency of residential buildings, an increase in the share citizens using low-emission public or individual transport or increasing the number of consumers using dynamic energy tariffs. Each of these elements can play a positive role in the country's climate and energy transformation. The mentioned catalogue is, of course, not closed and its shape may change over time. However, from the point of view of the implemented

mechanism, it is important that these goals are defined numerically, e.g. an increase in the share of renewable energy prosumers by 20% during a given period.

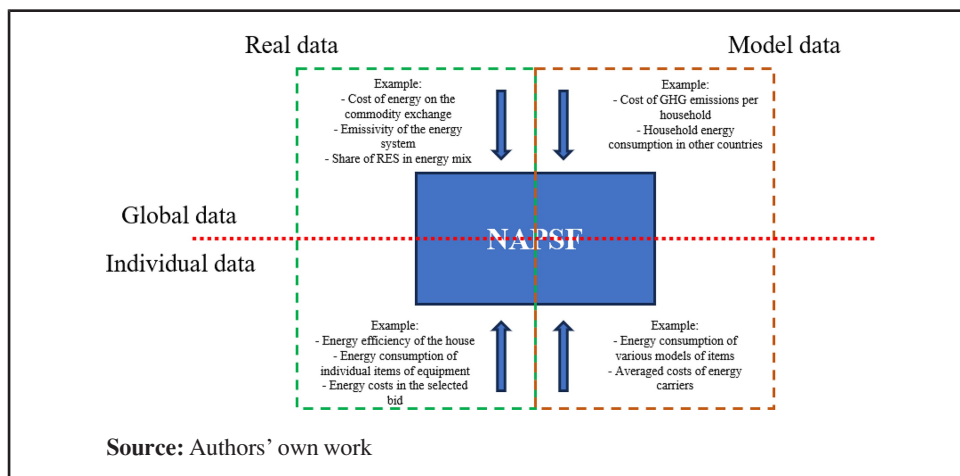
The area in which the use of NAPSf seems natural and easiest is schools, where this platform could be used as an element of education about climate or energy. Avatars can be an effective tool for multi-stimulus engagement of students (Alam and Mohanty, 2022; Sheth, 2003), through active participation, in shaping conscious consumer attitudes of themselves for the future, as well as of their loved ones in the present. Gamification tools could be used (Alsawaier, 2018), in which the students' goal would be to optimise their own virtual household in terms of greenhouse gas emissions and the costs of its operation. However, the designed tool cannot be limited only to educational institutions. Access to NAPSf should be based on open access, where any interested consumer could download the platform, access it after registration, and then use it to virtually verify how their attitude in the energy market affects the energy system, the climate and the total costs of running his household. NAPSf can be used regardless of the individual characteristics of its potential users, although these characteristics, such as the user's age, must influence the solutions used in the interface (Paleczna and Szmigielska-Siuta, 2020).

4.2 Determining the shape and stakeholders in NAPSf implementation

After determining the main goals to be achieved by NAPSf, we define its boundaries. NAPSf would be based on metaverse using cybernetic avatars to reflect phenomena occurring in material reality in VR. Cybernetic avatars constitute the digital twin reflecting the user (Dwivedi et al., 2022) by the virtual representation, even a simplified and symbolic one, and the user's immediate environment (Koohang et al., 2023). As the concept of cybernetic avatars encompasses the configuration where a single teleoperator controls multiple avatars, an individual can participate in various areas of the metaverse simultaneously using multiple avatars. This enables users to experience and test different energy-related scenarios at the same time, for improved comparative analysis. The data that would feed the NAPSf can be schematically presented using the Figure 1 below:

As one can see in the Figure 1 above, the data feeding NAPSf can be divided into two main categories related to their source: real and model, and global (system) and individual. Real data refers to information obtained directly from NAPSf users, e.g. available thanks to smart metering technology, which is a set of interconnected network infrastructure solutions integrated with advanced ICT tools (McHenry, 2013), operating in close to real time. They can also be obtained not from the user, but from public administration bodies providing access to

Figure 1 Model depiction of sample data feeding the NAPSf



aggregated data on the energy market, e.g. the share of renewable energy in the grid in a given time period (Mostafa *et al.*, 2022) or the costs of a given energy carrier on the commodity exchange. Instead of real data, model data can be used, which does not fully correspond to the market behaviour, but reflects it based on historical data or forecasts. The use of model data may be necessary for several reasons: lack of access to real data, too high cost of its aggregation or the user's lack of willingness to disclose data under NAPSf.

4.3 Policy coherence

The issues of consumers' awareness on the energy market and factors influencing their behaviour are undoubtedly the subject of interest of energy policy and energy regulations (Czarnecka, 2018; Immonen *et al.*, 2020). NAPSf requires a systemic approach to be effective, including state actions in the field of, among others: energy, information obligations of suppliers of goods and services, shaping educational policy and promotional activities.

In terms of energy, the main role that the state has to play is the digitisation of the energy market and the development of smart meter, smart grids and IP-based tools Utility Networks (Varela, 2018). These tools not only allow the consumers to be more active in the energy market (Hampton *et al.*, 2022), but also, to increase awareness of the processes in which they participate, including in terms of climate and economic challenges (Veskiöja *et al.*, 2022). It is the implementation of data digitisation tools that is a key element from the point of view of providing input material to feed NAPSf with information. Another element relating to data is the creation of information obligations on energy market participants. This concerns the scope of information that can be fed into the NAPSf, both as individual information about a given consumer that could be used by him within the NAPSf, as well as non-individualised and publicly available information that can be used as model information, e.g. on the energy consumption of individual home appliances (Pierce *et al.*, 2010).

In addition, energy companies operating on the market should be obliged to provide offers to consumers based on a digitised template, which would allow for easy translation of offers into data feeding VR. The next element is for the public administration to take action and implement the use of the NAPSf platform as part of compulsory school classes. Such action, depending on the legal model adopted in a given country, may not require changes to regulations at all, but only taking the initiative at the level of shaping the school education program. Similarly, in the case of promotional activities, countries should undertake informational activities regarding the possibility of using NAPSf by consumers on the energy market, and not only by students.

An important element of the implementation of NAPSf, like other tools in the field of climate and energy policy, is the proper identification of stakeholders who will shape and engage in this policy and who will be influenced by this policy (Sprengel and Busch, 2011). This is one of the tools to prevent the failure of the implemented policy (Sokołowski and Heffron, 2022). Therefore, depending on the implementing country, identification of stakeholders should be a key element. These are not only consumers and public administration but also enterprises operating on the energy market, third sector organisations participating in shaping climate and energy policy, educational institutions and suppliers of goods and services. Properly collecting them in the implementing country may allow these entities to be involved in the process of preparing the platform at the stage of NAPSf creation and thus facilitate its subsequent implementation.

5. Conclusion and recommendations

The role of consumer awareness takes precedence as a decisive factor in the context of advancing sustainable energy practices and shaping attitudes and behaviours within the energy market. A discerning comprehension of diverse energy sources, environmental ramifications and market policies by consumers substantially influences their choices, with

heightened awareness correlating strongly with the adoption of sustainable practices and energy-efficient sources, thereby contributing to a more environmentally responsible energy landscape.

The imperative of assessing consumer awareness becomes apparent for a seamless transition to sustainable energy practices. A comprehensive approach, amalgamating qualitative and quantitative methodologies, yields invaluable insights into consumer attitudes and preferences. Research underscores the significant impact of pro-environmental identity, values and awareness, emphasising the necessity for bespoke communication strategies tailored to promote sustainable energy behaviours.

Various determinants, encompassing educational paradigms, socio-economic considerations and governmental policies, play crucial roles in shaping consumer attitudes towards sustainable energy. Technological facets, particularly the advent of AI and the evolution of industry, energy and society accentuate these influences. Moreover, empowering the succeeding generation entails the integration of sustainable energy concepts into educational curricula and leveraging cybernetic avatars for interactive and immersive educational initiatives. Avatars, functioning as personalised mentors, deliver real-time information, interactive learning experiences and tailored guidance, fostering well-informed and sustainable energy attitudes among children and youth.

The impact of modern technologies, inclusive of avatarisation, transmutes the energy sector towards Society 5.0 and Energy 5.0. Digitalisation, propelled by Industry 4.0, introduces an array of technologies that drive us towards Industry 5.0. This includes IoT, AI, blockchain and the metaverse, redefining energy markets and fostering decentralised energy trading. The amalgamation of these technologies introduces the concept of avatarisation, envisioning a virtual representation within a digital world.

To effectively implement these technological advancements, the proposed NAPSf presents itself as a standardised training platform grounded in avatar technology. Articulating a clear vision, defining the scope, ensuring policy coherence and engaging stakeholders emerge as essential components for the efficacious implementation of NAPSf. This virtual reality platform, rooted in avatars, seeks to enhance user awareness regarding the environmental impact of energy consumption and stimulate conscious consumer attitudes within the energy market. The NAPSf can undoubtedly serve as a tool to build and raise consumer awareness of the energy transition, while putting modelled and real data in the spotlight as input components for building virtual energy models of, for example, real households. The inclusion of virtual avatars to present and interact with this data by consumers can facilitate familiarisation with the data, as well as being a useful tool to encourage use of the platform. However, the present study may be limited by its data. The concrete impact of NAPSf can still be empirically tested through a mix of experimental and longitudinal studies. This would be a great opportunity for future research. Nevertheless, the practical potential of the NAPSf steams from the effective integration of two main areas. The first is the development of a virtual environment to enhance data immersion. Within this context, avatars are employed to enrich the experience, facilitating improved interaction with the data and raising awareness, e.g. with respect to climate issues (Erisen *et al.*, 2024). The second area involves the aggregation of data pertaining to broadly defined energy usage that can be used to generate different scenarios that illustrate the consequences of changes in the energy-oriented behaviours of avatar users (Hsu *et al.*, 2020).

In conclusion, the symbiosis of consumer awareness, technological innovation and educational endeavours, facilitated by cybernetic avatars, constitutes the linchpin for an environmentally responsible and sustainable energy future. As the energy sector adapts to the evolving preferences of the new generation, the integration of avatars and advanced technologies emerges as a pivotal factor in sculpting a conscientious and ecologically sustainable energy landscape.

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