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Digitalisation in Local Housing Energy Systems: Co-Creation and Digital Literacy in the Dutch Context

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Abstract

This article critically reflects on the digitalisation of local housing energy systems. It looks at two Netherlands-based cases and their implementation, combined with the use of digital tools. From a socio-technical angle, it is crucial to provide energy-consumption dashboards with a two-fold feedback loop for residents about their energy consumption. That enables users to make informed decisions and behavioural adjustments in daily energy usage. By proposing a framework, the article introduces two new analytical categories: digital literacy and co-creation applied to the use of interactive digital tools. The aim is to unpack new challenges of the digitalisation process and the use of dashboards in relation to the two analytical categories. To do so, the article compares two different configurations of local socio-spatial contexts. The analysis draws upon an archive of correspondence, official documents, survey results, participant observations, multiple rounds of group interviews from the funded projects, and new in-depth expert interviews. The results reveal that inhabitants should accept the underlying technology that revolves around decentralised energy systems and be willing to pay their share of the investment costs. Furthermore, the authors discuss the reach of digital literacy and co-creation as emerging urban planning dilemmas. The empirical evidence is that the scale of implementation, the type of engagement with residents (tenants vs. owners vs. communities), the degree of digital literacy, and the opportunities for co-creation activities are essential features for a more inclusive digitalisation outcome.

Keywords

co-creation; digital literacy; digitalisation; housing energy system; The Netherlands

1. Introduction

The deployment of technologies such as sensors and energy consumption (Lock et al., 2020) at the citizen level has garnered considerable attention for their potential to unveil and track environmental impacts (Coenen & Hoppe, 2022). These technologies are intended for optimal systems, such as heating systems, electricity grids, or integrated systems encompassing electric vehicles, mostly from a technical engineering perspective (Hoppe et al., 2016). This perspective predominantly focuses on technical considerations, including energy utilisation and production, CO_2 emissions, and, at times, a technical-economic analysis aimed at cost optimisation. Despite the wealth of information garnered, the efficacy of these tools in driving substantive changes in environmental policy and individual behaviour is brought into question (Kitchin & Dodge, 2014). This scepticism is further compounded by the observation that, over time, consumers may disengage from these dashboards: Familiarity breeds a sense of complacency (Kramer & Petzoldt, 2022; Timm & Deal, 2016). The normative views about the implementation of technologies that present seemingly objective assessments due to their technical capabilities (Mattern, 2021) are debatable because they underscore the paradoxical reality that these seemingly eco-conscious digital tools often rely on energy-intensive infrastructures like data centres. This raises questions about their net environmental benefit. While these technologies excel in quantifying data related to pollution levels, tree coverage, and air quality, the translation of such data into meaningful policy alterations or tangible action remains a subject of contention, as articulated by Broussard (2018). Although technologies like sensors and dashboards for energy consumption at a citizen level have proven effective in recognising and tracking environmental impacts, there is evidence highlighting their environmental cost, given their reliance on energy-intensive infrastructures (Edwards, 2013).

With the recent advancements in data visualisation and AI technologies, some critical scholars argue that there are alternative ways of understanding the digitalisation process and its spatial articulation which are overshadowed by the dominance of smart city discourses and computational and algorithmic perspectives (Alvarez Leon, 2024; Dekeyser & Lynch, 2024). By embracing this critical approach, the article explores the following research questions:

> RQ1: How is the digitalisation process affecting the configuration of local housing energy systems?
>
> RQ2: What kind of digital tools are implemented, and how in relation to socio-technical features (actors and technologies) in two cases?
>
> RQ3: To what extent do digital literacy and co-creation activities play a role in optimising the use of the systems, and how are they enabled?

The comparison between two cases in the Dutch context is to maintain rigour in the same kind of regulation in energy transition projects in local housing systems at a national level. The purpose is twofold: theoretically and analytically, to introduce two emergent categories and potential dilemmas in urban planning and in a broader research context; empirically, to draw evidence from these two projects and the new research which contributes to how community members, researchers, and digital experts together can realise a more inclusive digitalisation process preventing spatial unevenness. The common ground of the analysis is the use of dashboards and similar technologies to enable citizens to play their role as agent of change in local energy

systems (energy demand control in relation to their technical skills) and adapt their behaviours accordingly (their degree of digital literacy). Digitalisation is a process in which co-creation is the component that facilitates the acquisition of an adequate degree of digital literacy to ensure optimal use of the local housing energy systems within communities.

The notion of digital literacy is operationalised as a mutually inclusive element together with the technical set of skills to use the system. In other words, understanding the energy system and using the dashboards by final residents determines the behaviour adjustment and, therefore, the reduction of CO_2 consumption. This article draws on cases from two separate research projects in which the authors were involved. The first case, the Oude Weverij – Het Indië-terrein, in Almelo, was the demo housing project within the broad research project funded by the Netherlands Enterprise Agency (RVO). The second case, Aardehuis, in Olst, was the Dutch pilot housing project in the European Horizon 2020 project SERENE – Sustainable and Integrated Energy Systems in Local Communities. In the first demo housing project, the research group developed and tested management for decentralised energy systems, including battery storage (RVO, 2024). In the second pilot, the research group observed participation in local energy communities in relation to sustainability goals and the socio-economic aspects of the roll-out of new energy technology niches in the demos (SERENE, 2024).

Based on the abovementioned prior research project results obtained through the RVO and Horizon funds, the operationalisation of the concept of digital literacy adds novelty and relevance to the deliverables published from the two projects. The selection of the two use cases is based on both commonalities and dissimilarities to emphasise how these instances in the same geographical area (province Overijssel, Twente region) can have a very different impact in terms of effectiveness in the use of specific technologies. Regarding the scale of projects, both are local small-scale implementations, and, in terms of geographical scale, the Oude Weverij – Het Indië-terrein in Almelo can be defined as urban, and the Aardehuis, in Olst, as rural. The main difference between the two Dutch use cases is that Almelo involves tenants renting apartments who not keen to adapt their behaviours, while Aardehuis is a cohesive community driven by eco-centric values. In the latter, they emphasise sustainability with self-managed energy systems, benefiting from higher community involvement and mutual trust. Besides the diverse community vision and sense of belonging more present in Olst, the scale and the aspect of co-creation remain central factors. The critical insight is that mere monitoring does not inherently influence energy consumption behaviours, particularly when the user's interest declines or financial incentives fail to provide tangible benefits that are readily perceived. To optimise the use of these systems, inhabitants need to contribute through their specific behaviour, either in their energy use or willingness to invest in a savvy use of energy technology at a local scale. Findings indicate that there are challenges in terms of planning and spatial unevenness. For instance, access to advanced energy systems is limited and often perceived as a privilege. The main common findings highlight that digital literacy, co-creation, behavioural motivation, and community sense of belonging are key to the adoption and optimal use of sustainable technologies. What plays a role here is the different scales of spatial developments which face regulatory hurdles, especially with older grid infrastructure.

The article is structured as follows: the next section is about digitalisation in local housing energy systems, focusing on dashboards, digital literacy, and co-creation; the third is a brief methodological note; the fourth is the presentation of the two use cases. The fifth and the sixth are sections dedicated to the discussion of results and conclusions.

2. Digitalisation in Local Housing Energy Systems

Smart technologies do not only pertain to technological elements or economic benefits—they also interact with a human factor and behavioural dynamics by final users (Coenen & Hoppe, 2021). According to Parra et al. (2017, p. 739), local housing energy systems in combination with smart technologies might "increase the amount of renewable energy generation consumed locally, they provide opportunities for demand-side management and help to decarbonise the electricity, heating and transport sectors." The digitalisation process of housing energy systems entails mainly the use of smart technologies, such as interactive dashboards designed for consumers. Scholars in environmental psychology review and evaluate the effectiveness of interventions designed to encourage households to reduce energy consumption, categorising them into antecedent and consequent strategies. These studies provide valuable insights into how social norms can influence energy conservation behaviours by offering insights from behavioural economics and psychology to explore the cognitive biases and motivational factors that may explain why energy-related behaviour often fails to align with consumers' personal values or material interests. The factors of urgency, knowledge, motivation, and investment capability are often linked to social norms as influencing reasons (Abrahamse et al., 2005; Frederiks et al., 2015). In this article, the relationship between digitalisation and the use of dashboards and these behavioural components are taken into account. The objective is to analyse the factors that compose the social part of the system along with the digital tools, which are the technical components. The combination of both is to obtain the desirable use of these socio-technical systems; thus, a certain degree of digital literacy is expected from the final users. Co-creation activities might certainly enhance and increase awareness and, therefore, improve the degree of digital literacy and corroborate existing technical skills. The article argues that the combination of these elements is the condition sine qua non to assure effectiveness at a societal level and to reduce the carbon footprint in energy consumption.

2.1. Digital Literacy and Co-Creation: Towards a Framework

In an increasingly digitised world, the concept of literacy extends beyond traditional reading and writing skills to encompass digital literacy, which is crucial for navigating the complexities of the digitalisation process (Van Dijk, 2012). Digital transformations in the urban environment put digital literacy and technical skills in a central and significant role in shaping socio-economic dynamics and behavioural patterns of individuals in our society (Townsend, 2013). Studies in pedagogical design are pioneering in introducing the concept of digital literacy in relation to learning and educational activities, which affect directly behavioural factors. Digital literacy, as highlighted in scholarly discourse, stands as a pivotal challenge in the seamless integration of technology within academic realms (Blau et al., 2020). Its essence is encapsulated by defining it as the repertoire of competencies and skills indispensable for navigating the labyrinthine and multifaceted information landscape fostered by digital media. Eshet-Alkalai (2012) defines digital literacy as a multifaceted concept in which three distinctive categories can be identified. First, there is the realm of photo-visual thinking, which pertains to the adept understanding and proficient utilisation of visual and data represented in graphs and captions. This is about decoding and encoding messages conveyed through images and multimedia presentations, an essential skill in today's visually-driven digital environment. Second, real-time thinking comes into play, necessitating the ability to process a myriad of stimuli simultaneously; this skill is particularly crucial in dynamic digital contexts where information bombardment is commonplace. Last, information thinking involves the critical evaluation and synthesis of data sourced from diverse digital

outlets; in an age of information overload, the capacity to discern credible sources and amalgamate disparate pieces of information is indispensable. Moreover, Heitin (2016) defines digital literacy as "the ability to use information and communication technologies to find, evaluate, create, and communicate information, requiring both cognitive and technical skills," emphasising the trifecta of finding and consuming digital content, creating digital content, and communicating or sharing digital content.

Within contemporary debates in urban studies, the concept of digital literacy is not under the radar yet. The first attempts mainly focussed on disparities in digital skills and how these affect technology use, discussing the digital divide in urban and social contexts (Hargittai, 2001; Selwyn, 2004). More recent works suggest that the definition of digital literacy and its relation to contiguous concepts such as digital citizenship remains nebulous and often divergent (e.g., Helsper & Eynon, 2013; Nichols & Stornaiuolo, 2019). Thus, with the emergence of the concept of digital literacy and different skill pathways that lead to digital engagement, there is an urge to grasp the complexities and divergences in digital literacy among individuals and in synergy with the notion of digital citizenship. For instance, digital literacy serves as a gateway to accessing housing opportunities and welfare benefits in today's digital age. Individuals proficient in utilising online platforms can explore a wider range of housing options, conduct thorough research, and engage in virtual tours or online applications. This access empowers individuals to make informed decisions about housing, potentially enhancing their socio-economic standing. Conversely, those lacking digital literacy may face barriers in accessing housing information and services, exacerbating existing inequalities. In essence, the discourse surrounding digital literacy underscores its multifaceted nature, intertwining various technical and non-technical elements. By framing digital literacy in these analytical dimensions, this section provides valuable insights into the effectiveness of digital tools and real-time feedback in promoting energy conservation behaviours.

The article introduces digital literacy adapted to decentralised housing energy systems and consumption. This functions as an operationalised concept in terms of the ability to access, manage, understand, integrate, communicate, evaluate, and create information safely and appropriately through digital technologies for energy consumption. The adopted theoretical background includes competencies that are variously referred to as computer, ICT, information, media, and energy literacies, by acknowledging all these distinctions in one definition applied in the two use cases (see the discussion in Section 5). In particular, dashboards are an object and a digital tool in which a certain degree of digital literacy is required to optimise their use. Tools are the connection points between using information, demanding response reaction, and seeing the effect of the demand response behaviour. To do so, there is a need to include physical, social, economic, and environmental principles concerning urban planning, such as community engagement activities and co-creation. These activities guide the development, design, and leverage of technology to improve urban management, infrastructure, and services (e.g., smart grids, decentralised energy usage), as well as use data-driven approaches to enhance efficiency and responsiveness. In the proposed digital literacy framework (see Figure 1), co-creation activities and collaboration among stakeholders are taken into account to generate functional and inclusive environments.

Co-creation is a term used by many fields to refer to either a "theory of value" focusing on how entities co-create value with users through collaboration, a set of practices that function as design methods, or both (Jukić et al., 2022). Co-creation involves a cooperative effort between public and private stakeholders to address a common public issue or objective. This process includes sharing different resources to

collaboratively initiate, design, and/or implement ideas, strategies, policies, regulatory structures, or technological innovations (Hofstad et al., 2022). Recent work on co-creation demonstrates how co-creating urban data dashboards with community partners can lead to insights and actions grounded in residents' experiences, aiming to achieve social change: "Co-creation of urban data and informatics with community partners facilitates the development of insights and actions that are grounded in residents' experiences and aimed at achieving social change" (Nidam et al., 2024).

Conversely, the study by Jones (2019) examines the role of participatory urban dashboards in urban planning and decision-making processes. Jones (2019, p. 59) claims that "it is to co-create dashboards with communities that are portrayed by, and potentially affected by decision-making that occurs in response to, urban dashboards." On one hand, under these conditions, practices of co-creation have become notably prominent as successful governance arrangements (Rodriguez Müller et al., 2021) for leveraging local knowledge and perspectives to forge innovative approaches (Torfing et al., 2019). On the other hand, using Steen et al.'s words (2018, p. 293), there is a critical side of it which pertains "the darker aspects of co-creation and co-production, particularly in the context of public services and citizen engagement." However, this evolving approach presents challenges and paradoxes, particularly because it involves the participation of diverse stakeholders, each with their own unique backgrounds and perspectives. Such diversity can lead to increased conflict, necessitating advanced conflict resolution strategies, and may even result in the co-destruction of established norms and structures. Insights into the dynamics of co-creation and co-production in public services emphasise the need for effective conflict resolution strategies and the potential for innovative approaches through citizen engagement (Tappert et al., 2024).

Building on the abovementioned work and starting with the assumption of the embeddedness of digital platforms with an urban character and participatory features for citizens (Chiappini, 2020; Chiappini & de Vries, 2022), this article situates digital literacy in the context of energy consumption and residents' behaviour adaptation. As a theoretical tool, the framework analyses energy-oriented projects rooted in urban studies epistemology. In applied terms, it shows how to optimise energy usage through a combination of technology, collaboration, and behaviour adjustment. As Figure 1 illustrates, the central component is related to the concept of digital literacy, conceived as the ability of residents and stakeholders to effectively use and understand data visualisations provided by digital tools, such as dashboards and technical affordances. Practical examples of technical affordances are choices made by software developers and engineers, for instance, the function of scrolling, visual graphs, and swiping right or left.

These dashboards present insights into daily energy consumption and provide functions (i.e., technical affordances—see Figure 7) to help adjust behaviours in a specific socio-spatial context in which the scale of implementation plays an important role in the success or failure of the project.

To break down the key components and their vectorial relations in Figure 1, the digital tools (top box) as dashboards are emphasised as tools that provide functions that enhance usability, functionality, and decision-making. These tools rely on design and technical features that make data intuitive and actionable. The tools act as a medium to improve digital literacy by making energy consumption patterns visible and understandable. The stakeholders (left corner) include municipalities and other organisations responsible for housing energy systems. Their role is to design, implement, and provide technological and infrastructural support for digital tools. The residents or citizens (right corner) represent the primary users of the

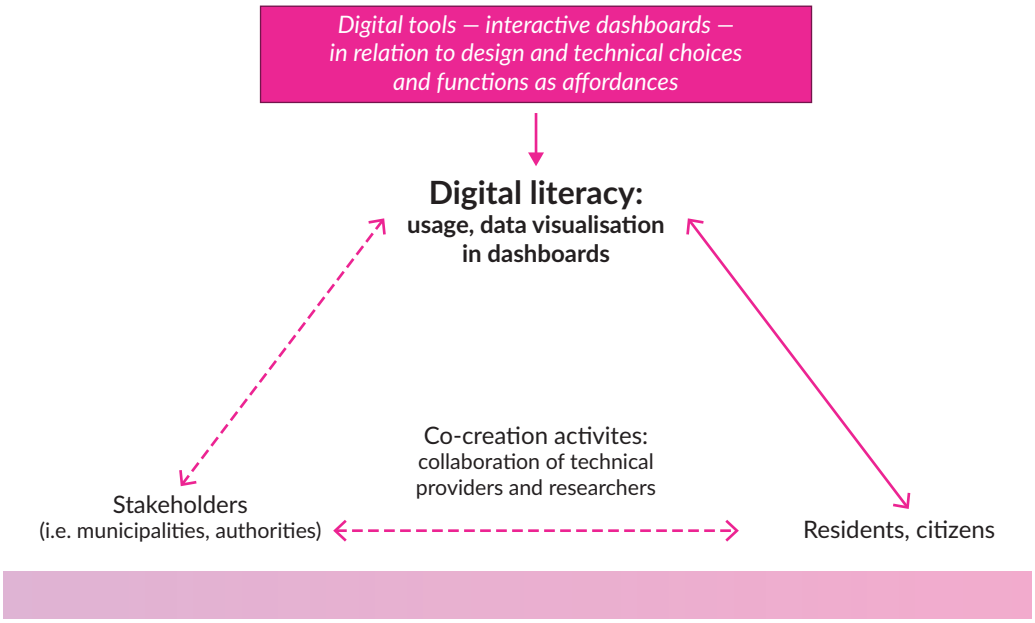

Figure 1. Digital literacy towards a framework.

dashboards. Hence, their role is to engage with these tools to understand their energy usage and make adjustments to align with optimal energy consumption behaviours. The co-creation activities (bottom box) refer to the potential collaboration between technical providers (i.e., developers of dashboards and energy systems) and researchers. This is vital to ensure that the tools are user-friendly, effective, and responsive to the needs of both stakeholders and residents. While co-creation involves collaborative approaches among stakeholders for developing solutions, digital literacy is essential at an individual level for the effective understanding of the use of these tools. In the discussion section, the framework functions as a heuristic tool in the analysis of the two use cases and situated in a broader debate in urban studies.

3. Methodological Note

The methods employed are rooted in a qualitative approach and integrate multiple rounds of primary and secondary data collection. To explain the steps of the research, there are two main phases in which data were gathered through different rounds and techniques. The first phase of primary data collection happened within the two funded projects in which the authors were involved as university partners: Oude Weverij (funded by RVO) and Aardehuis (funded by Horizon 2020-SERENE). From 2018 to 2022, residents have been participating in surveys and face-to-face rounds of individual and group interviews. Participant observations have been conducted during offline and online official meetings between stakeholders. The first phase enquired about socio-technical elements, namely, how the different elements in the local housing energy system (PV, heat pumps, storage, users) can be optimised and how the residents are keen to adapt their behaviours according to them (RQ1 and RQ2). In 2024, the second phase of data collection started, in which the prior material was revised in light of the new analytical categories of digital literacy and co-creation (RQ3). Specifically, the prior collection of primary source data allowed for first-hand access to an extensive archive of empirical data and documents to re-contextualise the two use cases. To collect new empirical material, in which digital literacy and co-creation are the new elements to include in the framework, four in-depth expert interviews were conducted. Finally, the article uses digital ethnography

notes and multimedia material (e.g., screenshots), capturing real-time interactions and socio-spatial dynamics in the two cases. Table 1 illustrates the operationalisation of the area of inquiry linked to the deployed methods and the multiple rounds of data collection and how the research questions tackle the different aspects of the analysis.

Table 1. Overview of the type of methods and rounds of data collection linked to the research questions.

	Methods and rounds of data collection		RQ
	Oude Weverij	Aardehuis	
Local housing energy system and configuration	Prior survey. Two rounds of official document analysis, meetings with partners and stakeholders (mostly in Dutch 2020–2022).	Prior survey. Two rounds of official document analysis, meetings with partners and stakeholders (mostly in Dutch 2020–2022).	1
Type and use of digital tools (digitalisation features: decentralised energy system, dashboard)	Two rounds of group meetings/interviews with tenants of the six units (from 2018—interrupted in 2020 by the Covid-19 pandemic). Participant observation of meetings and digital ethnography (2022–2024).	Two rounds of individual interviews with 12 residents (2018–2022). Participant observation, digital ethnography of meetings (2022–2024).	2
Enabling digital literacy and co-creation activities (during and after implementation)	Secondary data analysis based on prior data collected during the Oude Weverij (RVO project) and Aardehuis (Horizon 2020-SERENE) in 2024. One round of four expert in-depth interviews in 2024 (conducted in English)*.		3

Note: * The four experts (two researchers and software developers at Saxion University of Applied Sciences; one business advisor, director of the Sustainable Innovations Academy in the Netherlands; and one policymaker and consultant in the Innovation Section of the Municipality of Amsterdam) were selected with criteria based on their function in the representative organisation; the in-depth interviews were structured to gather new empirical material on the analytical categories of digital literacy and co-creation; the experts are, to a different extent, directly involved and have knowledge of both of the use cases.

4. Two Use Cases in the Dutch Context

Prior management studies which focused on energy systems indicate that digital tools which aim at behaviour change interventions can lead to an average reduction in energy consumption of 4 to 12 percent, with maximum savings surpassing 20 percent (Nachreiner et al., 2015; Tiefenbeck et al., 2018). As mentioned in the introduction, this article draws on two separate funded research projects—in which different phases of research were conducted from 2020 to 2024. While digital literacy was not the primary focus of either project, it emerged during the research as a key factor influencing the effectiveness of the interventions in both cases. In both cases, the residents of the housing energy system had the opportunity to reduce their carbon footprint and contribute to making homes and their energy systems more sustainable and more based on renewable energy through the use of an interactive dashboard. The Aardehuis case, as part of a European project, aims to demonstrate cost-efficient and consumer-oriented approaches to merging various energy system providers (Bak-Jensen et al., 2024). This merging is crucial for the sustainable growth of regional communities by enabling them to fulfil their energy requirements using local renewable sources and push for a shift towards a more sustainable housing system (Koirala et al., 2016). This shift also promotes a more decentralised configuration of the electricity system and the deployment of digital tools, aiming at a combination of principles between sustainability and digitalisation. Hence, we ask: How is the

digitalisation process affecting the configuration of local housing systems? The objective of the Oude Weverij – Het Indië-terrein housing demo project in Almelo is the experimental development and application of a user-centred housing energy system, including battery and heat storage through smart energy management and behavioural incentives (Riezebos, 2024). In the Oolst case, residents are familiar with the energy system and understand the need for (information from the) dashboards. In the Almelo housing project, the problem begins with understanding the overall energy housing system. Participation and user co-creation can be on the level of the system and the level of the dashboards. As a result, this was the initial problem which was exacerbated because the citizens eventually were not involved in creating the system (which included the dashboard and related demand control measures). Hence, it has been selected by the authors to study the implementation and functioning of the dashboard as well as its social and spatial implications and the benefits of wider application. In both cases, the dashboards offer real-time feedback loops and data visualisations through graphs to promote energy conservation behaviours.

4.1. The Use Case of the Oude Weverij: A Decentralised Energy Housing System With Its Constraints

The use case of the Oude Weverij – Het Indië-terrein is located in Almelo, Overijssel (see Figures 2 and 3). The project presents a decentralised housing energy system (see Figure 4) and the connected dashboard, which seeks to demonstrate the environmental sustainability and feasibility of these systems. The total of the eight houses are rented with a heat pump and solar panels to power up the system in which the heat is delivered for a market-conforming tariff. Moreover, there is a collective battery to store the surplus of solar electricity on sunny days and used for the heat pumps. Thanks to this system, in principle, the residents reduce their carbon footprint, which implies a behavioural change in energy use rewarded through financial incentives. In 2022, the RVO research team started to examine the sustainable energy system's technical functioning and social and economic implications. The economic implications are strickly related to the capacity of residents to adapt their behaviours and benefit of the financial incentives within the Dutch national regulatory setting.

Figure 2. The Oude Weverij – Het Indië-terrein houses, Almelo: Rendering of the project. Source: Riezebos (2024).

The main stakeholders and partnerships in this project are Ter Steege Bouw Vastgoed Hardenberg and Ter Steege Advies & Innovatie, as well as the battery supplier (Contour), installation consultant (Loohuis Energie & Installatie-advies), grid operator (Coteq), and the University of Twente (RVO, 2024). The residents of the eight houses are all new tenants who find themselves primarily as energy consumers, with limited involvement in the implementation of the dashboards. The heat consumption is connected to the use of the dashboard. Although residents have been blandly pushing to collaborate and share information with neighbours and surveys about

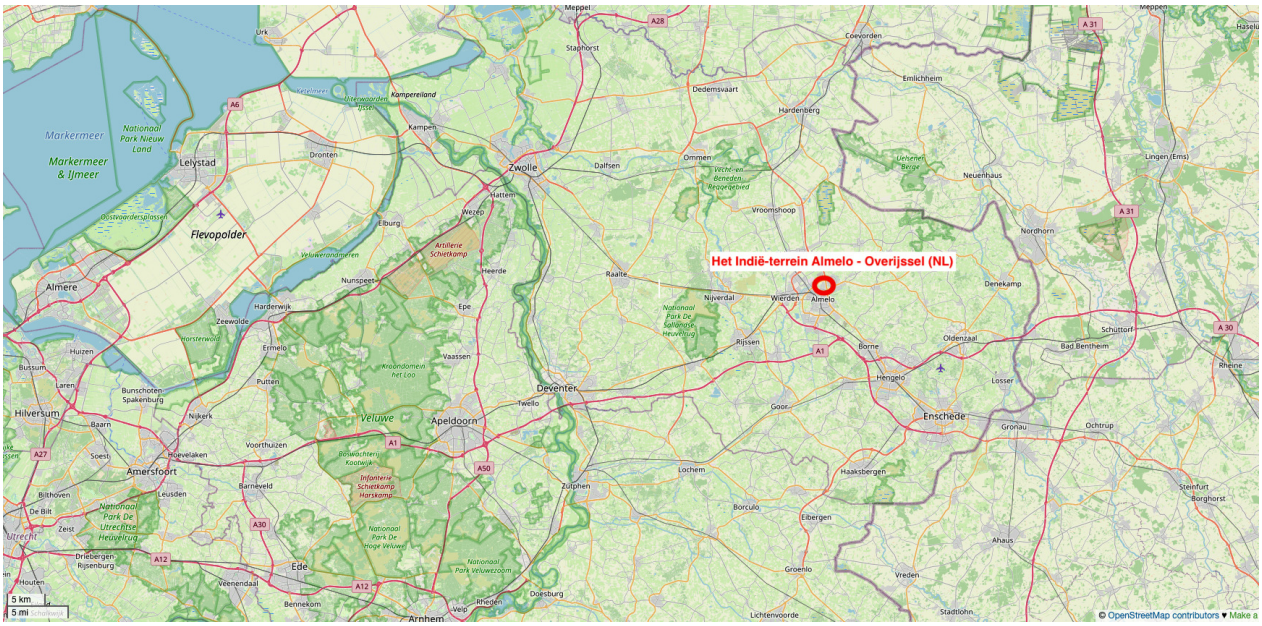

Figure 3. Map and location of the Oude Weverij – Het Indië-terrein, Almelo.

their daily energy consumption the desirable win-win situation did not work out as expected. While they benefit from access to renewable energy via the technical system, residents are encouraged to learn from each other and exchange know-how and tips and tricks about the use of the dashboard. However, they face challenges in how they interact with the system and adapt their behaviour accordingly. The project's advanced energy grid offers new possibilities, but it also introduces obstacles in understanding and adapting to the housing energy system. For this type of energy use that has to flow to the inhabitants and to the project owner to correct the bills, it is crucial to ensure the proper reading of the data on the dashboard according to the use of the system. When these decentralised issues are not disentangled by tenants, it leads to split-incentive problems, which are extra challenges to tackle.

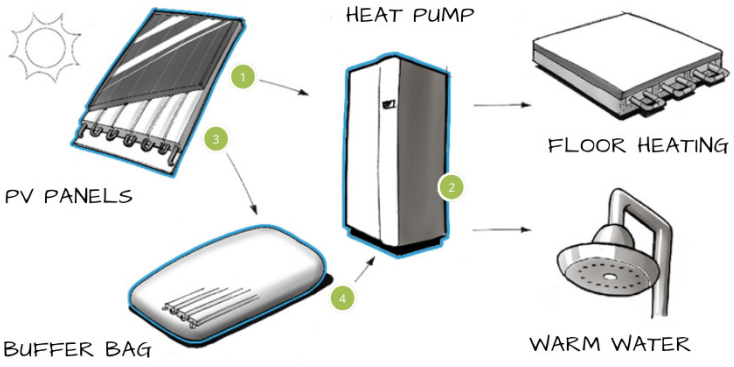

Figure 4. The decentralised energy housing system in Almelo. Source: Riezebos (2024).

4.1.1. The Split-Incentive Problems and the Lack of Collaboration Among Tenants

The split-incentive problem and lack of collaboration among tenants in local housing communities present significant challenges to implementing sustainable housing practices and improving the use of dashboards.

The split-incentive issue arises when the costs and benefits of energy-efficient investments are divided between landlords and tenants, reducing the motivation for either party to act. For instance, the Almelo case shows how tenants are reluctant to adapt their energy behaviours without recognising the reap translated into financial benefits. During the testing phase, "co-creation" could have been implemented as part of both "collaboration" and "shared activity" such as workshops or tutorials with the tenants and the owners. As a result, tenants have little incentive to initiate or fund such improvements, as they do not own the property and may face uncertainties about the duration of their tenancy. Although the degree of digital literacy is not directly measured, as a proxy, the use of the dashboard indicates that it was not effective. This misalignment of incentives is compounded by the lack of collaboration among tenants, often due to diverse interests, socioeconomic backgrounds, or transient residency. Without a collective voice or cohesive effort, tenants struggle to advocate for shared improvements, further perpetuating inefficiencies and suboptimal housing conditions. Addressing these challenges requires innovative policies, such as split-incentive programs, tenant education initiatives, and community engagement strategies to foster collaboration and align interests between landlords and tenants, all of which which have been lacking in this specific use case.

4.2. The Use Case of the Aardehuis Project: An Eco-Centric Community and Its Dashboard

Michael Reynolds' Earthship architectural concepts served as the inspiration for the innovative ecological housing project known as Aardehuis/Aardehuizen (or in English Earthship community). Located in Olst, Overijssel (see Figures 5 and 6), the housing project and its specific architectural style integrates power, water, and heating into the design process and places a high priority on using sustainable and recycled materials during construction (Aardehuis, 2024). The building of the houses, for a total of twentythree units, started in 2011 and concluded in 2015. The plan for the project consists of an investment of €5,500,000 for the realisation of the housing (Aardehuis, 2024), with solar panels to supply 32 percent of the whole electricity demands (de Graaf, 2018). The local housing system is controlled by an interactive dashboard, which has been designed and implemented with the support of a team of researchers and technical experts

Figure 5. The Aardehuis eco-centric community, Olst. Source: Aardehuis (2024).

(Schillinger et al., 2022). The project gathered considerable traction with the help of community volunteers and environmental enthusiasts. It is an example of what digitalisation and eco-friendly living might entail, incorporating garbage recycling, renewable energy, and rainwater collection through the use of digital tools. The realisation is a result of cooperation between three main constellation of actors: the first, the Aardehuis' Collective Private Commissioning project which was accepted by the municipality of Olst-Wijhe, the second, SallandWonen social housing cooperation together with the construction of three rental homes within the community; and the third as BAM Woningbouw which assisted in sourcing building materials and safety instructions (Aardehuis, 2024).

The recent collaboration between the Aardehuis project and the SERENE project has expanded the production of knowledge around this project, which was included as part of the Dutch pilot coordinated by the University of Twente and the research group Ambient Intelligence at Saxion University of Applied Sciences (AMI). This second use case of local housing energy system includes photovoltaic installations, hybrid heat pumps, battery storage and management systems, smart grid control, energy trading with neighbours, and electric vehicle charge-sharing systems (SERENE, 2024). To track their energy usage, the AMI research group gave the owners within the community an interactive dashboard that would further motivate and support long-term energy-conscious behaviours. The group of researches expected behaviour modification techniques via the use of digital tools to accomplish the mission of reducing energy consumption through smart technologies—such as the dashboard. The researchers designed the layout, technical affordance, and navigation of the dashboard as well as the user interface design, relying on sensors on a local scale with a discrete number of users. All these components are defined as a smart systems. These sensors, for instance, detect movement within the house, or they could be used as ambient sensors that are installed in the homes of the residents to measure electricity usage and share data among inhabitants. The collaboration with users and co-creation activities with the researchers produced a single dashboard design that shows the outputs and insights of the recently smartened electrical grid and offers useful feedback to encourage consumers to spend less energy.

Figure 6. Map and location of Aardehuis project, Olst.

4.2.1. The Interactive Dashboard

The researchers were in charge of creating an interactive energy analysis tool that is user-friendly and accessible, as well as embedding all necessary functions and technical affordances to visualise information for communities (e.g., graphs for the weekly level consumption). The deliverable for this project was a prototype with a dashboard in connection to energy consumption (Aukes et al., 2022). The primary goal of this project was to construct a dashboard that could be used for further development. Throughout the implementation of the dashboard, desk research, literature review, testing, prototyping various iterations, and surveys were conducted by the universities involved (see Figure 7).

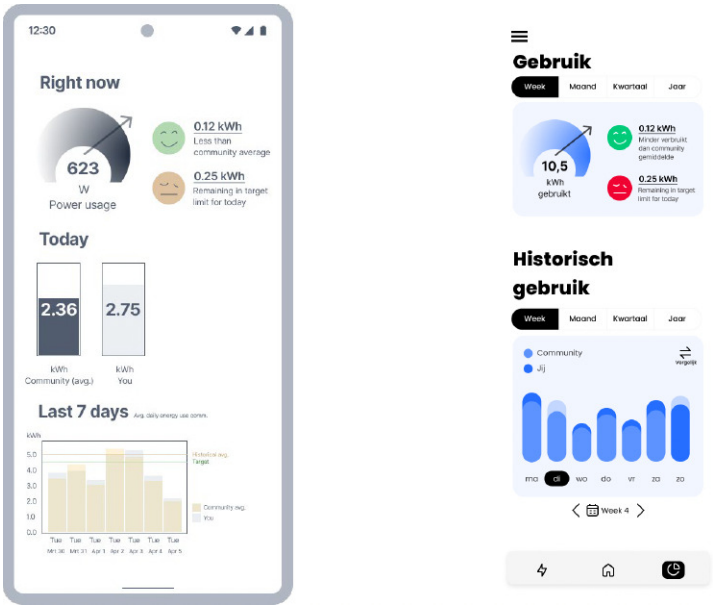

Figure 7. These are the different windows and viusalition of the interactive dashboard used on a smartphone. The first on the left indicate the daily and weekly energy, the second image on the right is the version in Dutch. Both images are taken from the second round of iteration and testing. Source: Bornebroek (2023).

The dashboard was designed with the expectation that it would provide a solid basis for the whole research. Thus, the project's overall outcome offers a robust set of feedback and insights for future implementations. The Olst community is engaged with frequent co-creation activities and direct contacts with the designers and software experts. The following section discusses similarities and differences between the two cases with respect to the categories of co-creation and digital literacy. The crucial reflection is on how these emerging categories can exacerbate dilemmas in urban planning and spatial unevenness.

5. Discussion: Digital Literacy and Co-Creation as (New?) Dilemmas in Urban Planning

Before proceeding with the discussion of the results, it is important to acknowledge the limitations of comparing these two use cases based on the different sets of actors, scale and spatial patterns, as well as the chronological dimension of the development of the two projects. One of the main differences is the type of communities for the two use cases: The former is a group of tenants who rent the apartments from landlords, and the latter is a more cohesive community that decided to live according to eco-centric values. The second use case is particularly compelling as a community-driven sustainability initiative due to its

self-managed energy service. Yet living in these houses and with these systems can be considered a privilege, as not every neighbourhood or portion of a residential area has access to these benefits. One can significantly lower their carbon footprint, but there is a requirement which is a high degree of digital literacy that goes beyond the basic technical skills (e.g. using a commercial app for purchasing products), motivation in behaviours, and sense of belonging to a certain community, either for ecological or solidarity values in a rural setting. As Viano (2024) claims, local and urban communities increasingly rely on digital technologies. There are many examples of the urban and cultural-symbolic economy and its effect in terms of gentrification and spatial inequalities, in a fashion of the "hipster economy" (Gerosa, 2024) or in the "cappuccino city" (Hyra, 2017). Therefore, the two maps (cf. Figures 3 and 6) are not merely about the location of the use cases but show where this potential spatial unevenness might start, which has to do with the lack of participation by tenants in the first use case and, on the contrary, with a semi-rural community that benefits and has the privilege to live sustainably in the second case. The acceptance of a certain technology is strictly related to a path-dependency, and the attainment of permits for new construction endeavours, especially in cities or nations characterised by a less robust grid infrastructure such as inner-city developments, proves to be an obstacle.

One of the main challenges that co-creation activities with digital technologies for climate change adaptation can face is the level of engagement with users. Co-creation activities are needed, but the effectiveness might differ based on the type of community. In Almelo, tenants were not engaged from the beginning due to a lack of resources to organise these moments of participation. If one does not feel part of a community, there is no intrinsic motivation to attend any activities related to it. In terms of acceptance and dilemmas in planning at any scale, the split-incentive problem (see Section 4.2.1) is an example of how co-creation practices might address these obstacles. For instance, in the first use case, the tenants were not properly informed and guided due to Covid-19, which significantly impacted the project for two years. In other words, no co-creation activities or participatory meetings were organised. The interviews with tenants reveal that only a PDF manual was given with technical instructions and pictures. Conversely, in the Aardehuis community, there were several moments in which the residents felt part of the implementation of the technologies and there was no split-incentive problem as the owners paid themselves, although sometimes collectively, for only a few shared bills. As in the last workshop conducted, the inhabitants do not want more advanced technology or new apps—they want to reduce their digital footprint and keep the essential digital tools. Formally, a collective private commissioning agreement has established a robust foundation that fosters mutual trust within the community and encourages the integration of new members. This could open up a dialogue with the community to manage expectations and build their willingness to adapt to certain levels of inconvenience and flexibility in using the digital tool. Due to several reasons and the contingency of the pandemic in 2019–2020, in the Oude Weverij, tenants were not involved in the decision-making process. In the first round of interviews, one tenant declares:

> I always open the window during the day, I do not really check the dashboard. There were no moments in which they explained how to use it. Besides these group meetings, we don't have any assistance. (group interview with tenants—translated by the authors from Dutch to English)

A few of them confirmed that they did not see the collective purpose of using the system properly. If an expert had educated them on the benefits of these behavioural adjustments, the project could have improved in terms of overall system efficiency:

> The sustainable energy system and the fact that the houses are well-insulated ensure that heat is retained for a long time and that there are hardly any temperature fluctuations. They often do not understand or consider the effort to keep the temperature stable and do not open any windows during the day. Rather in the morning or evening when it is necessary. As tenants, they did not receive enough support during the implementation. A PDF manual was delivered to them. (business advisor—in-depth expert interview in 2024)

In the second use case, it is evident how the co-creation activities have prevented the failure of the project and have strengthened community building amongst owners. The researchers confirmed that the iteration phases are crucial to adapting the technology and helping the users. Some feedback after the co-creation activities was the following:

> We received comments, such as it is not smart to implement that function right now. Some people ask for graphs and size over numbers and catchy visuals. Also, to see the symbol of euros, more green imagery, and funny "stickers." They say that helps. (researcher—conducted in English—in-depth expert interview in 2024; "stickers" translation by the authors)

It's not merely about mastering digital tools but also about cultivating critical thinking, creativity, and social adeptness in navigating the complex digitalisation process and in relation to energy consumption reduction. In this article, the notion of digital literacy also encompasses the daily use of smartphones, such as emojis and stickers. As the above quote from the interview displays, the requests are quite mundane and concern the visual and aesthetics of design choices and technical affordances used in the dashboards. Furthermore, the requests can indicate a tech-savvy approach from the communities. For instance, the co-creation activities and workshops organised by researchers indicate that in Olst there is a desire for fewer digital tools, which does not mean less digital literacy but more awareness:

> Let's say just like a little tablet on the wall yeah where like a smart hub where you could see the information, but you don't need to have your phone. During the regular meetings with the community, they said that they want less and less complicated affordances in the digital tools they use….These iterations are very important to adjust the dashboard and to avoid new apps on their phones. (researcher—conducted in English—in-depth expert interview in 2024)

As one of the Saxion University researchers involved in the implementation of the dashboards claims:

> [In Olst]…we are working specifically with the community here in the Netherlands, which is a very small community, where all of them have like this vision of how you should live about energy-conscious behaviour, no footprint and all these kinds of things. It is not an average community. (policymaker—conducted in English—in-depth expert interview in 2024)

This prompts consideration of whether these projects could delve into the public's discussion on how to educate the Alemelo use case to embrace the use of technology, whether at a community or individual level, fostering greater adaptability within the system. It is important to specify that it is difficult to find training programs or policy interventions to improve the degree of digital literacy at an urban or national scale. Smaller and more cohesive communities in which there is trust among dwellers are the ideal conditions that

could enhance participation and a collective understanding of digital tools. For instance, collective and mutual support from neighbours is the most caring manner to improve the degree of digital literacy. Not top-down with digital education programs but solidarity and small-community activities. Thus, the opportunities for scaling up these projects are co-dependent on the type of communities, the capabilities to organise co-creation activities at a collective level, and digital literacy enhancements at an individual level. Digital literacy requirements and co-creation activities are crucial to maintaining these projects beneficial at a societal level. The discussion of findings helps to refine the digital literacy framework. The key takeaway is visually represented in Figure 8, which indicates how fostering digital literacy through tools like interactive dashboards can create a feedback loop between residents and diverse stakeholders to optimise the final use.

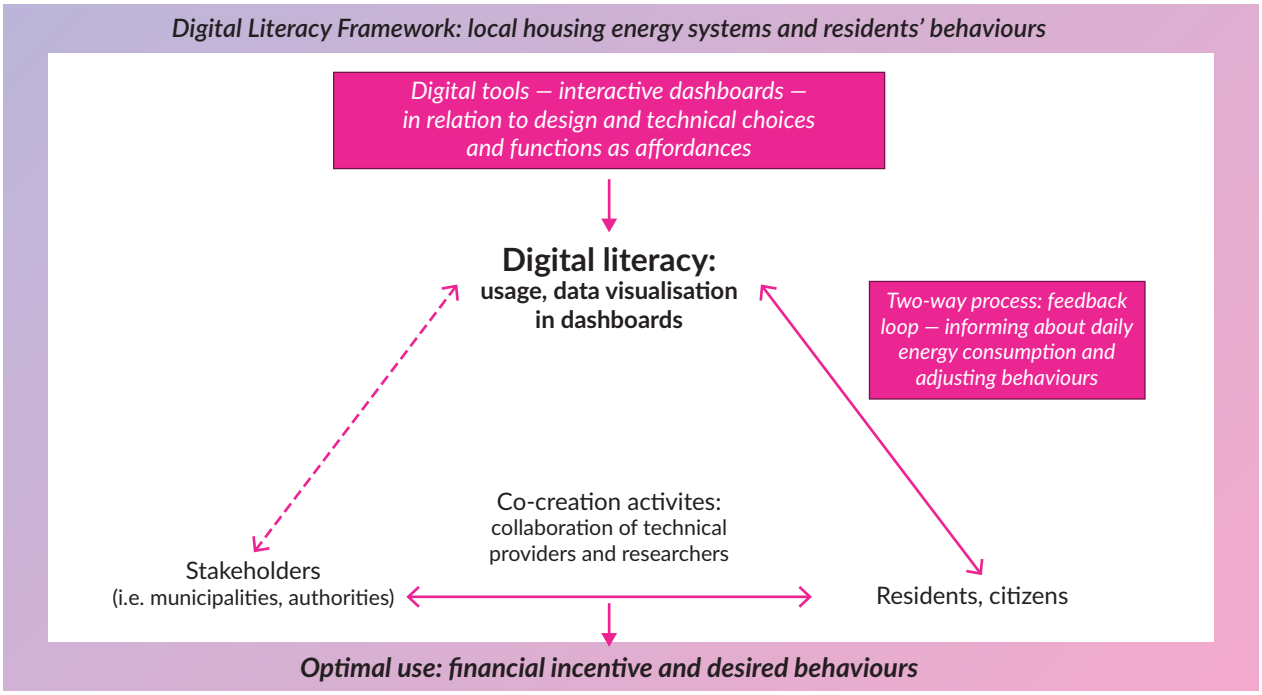

Figure 8. Digital literacy framework—adaptation to local housing energy systems and resident behaviours.

While Figure 1 is based on the theoretical foundations, Figure 8 is the adaptation of the framework to the use cases. The adaptation represents the optimal use of the local housing energy system, the role of digital literacy in relation to desired beahviours. By showing energy consumption and the implicit financial incentives through data visualisations (see Figure 8), this process encourages collaboration, informed decision-making, and behaviour change to optimise energy use in housing systems. The two-way process (right arrow) implies that a feedback loop is established between residents and the system, in which the degree of digital literacy allows the residents to be informed about their energy consumption patterns through dashboards, which helps them adjust their behaviours in real-time. The vectorial interaction between stakeholders ↔ residents indicates that stakeholders receive feedback from residents, which can guide improvements in design and functionality. This interaction is supported by common levels of digital literacy in the communities, enabling both sides to communicate effectively using data insights. It is logical to argue that if a co-creation approach is adopted, digital literacy might be increased after the collaborative activities. From an analytical perspective, the various degrees of digital literacy are potentially conceived as a social struggle over access to and control of space, place, territory, region, and resources. Co-creation activities are intended as a privilege in terms of resources from the stakeholders of money and time (e.g., participation fatigue), to organise a session of

co-creation, one need to find a space, a facilitator, etc. thus it requires both effort from the whole set of actors. From the comparative analysis, dilemmas in terms of urban planning emerged. More resources to organise co-creation activities and fewer time constraints due to Covid-19 would have been beneficial for the Almelo case. However, it is quite challenging to assess how the Aardehuis project can inform improvements in projects like the Oude Weverij. The real question is how technology can be useful when the involved users are not interested in the collective use of it. Finally, results included in the framework demonstrate that to ensure optimal use, financial incentives and desired behaviours act as motivating factors, in which the incentives encourage both stakeholders and residents to adopt and use the tools effectively.

6. Conclusion

After the discussion of similarities and disparities between the two cases located in the Dutch context, it is clear what the challenges of small-scale projects using interactive dashboards are. The relationship between the digitalisation process of house energy systems and the context/community/scale is co-shaped by the level of digital literacy and co-creation activities organised between stakeholders involved in this process. The scale in particular is crucial in determining the level of trust and cohesion during the digitalisation process; namely, local and rural scales seem ideal for a more effective impact. The digitalisation process entails an individual set of technical skills and a degree of digital literacy of the inhabitants who are expected to comprehend and choose technical affordances—monitoring and steering tools—like dashboards and different data visualisation techniques. The degree of digital literacy is a pivotal factor in shaping socio-economic dynamics within decentralised systems applied to individual households. Overall, it determines access to opportunities, economic outcomes, and community engagement. However, it is essential to recognise that digital literacy operates within a broader context of socio-economic factors, including income inequality, housing affordability, social dynamics, and consequent spatial unevenness. By recognising the interrelation of co-creation activities, digital literacy, and socio-economic dynamics, policymakers and stakeholders can work towards creating a more equitable and inclusive pattern, which should be specific for each case: Digitalisation for whom and for which purposes?

Future research agendas might consider charting new directions for urban-ecological relations guided by alternative ways of knowing challenges and obstacles. There is an urgent need to steer away from the current emphasis on smart technologies and decentralised systems without considering behavioural factors, co-creation activities, and collective learning, as well as the degree of digital literacy within different communities. Moving into a state-of-the-art sustainable house is, for a citizen, "like going from a horse carriage to a Tesla, to cite a colleague in the project" (Riezebos, 2024) in terms of digital literacy—and definitely, if all the co-creation activities would have been conducted in Almelo, the tenants would have been more engaged. To overcome these challenges, there are a few contingencies to consider. It is unmistakable that when there is a community behind any project of technological implementation, the individual degree of digital literacy can be transformed into a common ground and therefore into a digital commons which helps to solve problems in a collective way. This might be a call to reclaim a more collective and public use of technology (Terranova, 2022) to resist big-tech and individualisation forces proclaimed by Californian ideology. To conclude, it must be kept in mind that not everyone has the economic privilege and time to attend participatory activities or co-creation practices. Instead, there is an urgent need to understand the degree of digital literacy in different communities and its consequential spatial uneveness.

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Conflict of Interests

The authors declare no conflict of interests.

References

Aardehuis. (2024). *Vereniging Aardehuis*. https://www.aardehuis.nl/index.php/en

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2005). A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology*, *25*(3), 273–291. https://doi.org/10.1016/j.jenvp.2005.08.002

Alvarez Leon, L. F. (2024). AI and global climate change: The political economy of data and energy in geographic perspective. *Geo: Geography and Environment*, *11*(1), Article e00134.

Aukes, E., Coenen, F., Daskalova, V., Gercek, C., Helfrich, F., Lee, D., Lier, G., Sanderink, L., Schillinger, J., Votsis, A., & Willemse, J. (2022). *Conditions for socio-economic development and citizen engagement in energy islands* (SERENE deliverable 3.2). Aalborg University.

Baack, F., Aukes, E., Votsis, A., Hoogsteen, G., Helfrich, F., & Coenen, F. (2024). *Approaches for consumer-centric local integrated community systems* (SERENE deliverable 7.1). Aalborg University.

Bak-Jensen, B., Giuffrida, R., Gonzalez, A. B., Bjerregaard, H., Bogucka-Kykuc, K., Bordo, L., Coenen, F., Domke, E., Giovanni, S., Hoogsteen, G., Laffont, K., Nordlund, H., Radziszewska, W., & van Leeuwen, R. (2024). *SERENE, LocalRES, SUSTENANCE: A multi-disciplinary approach to increase the local adaption of energy-efficient solutions*. Aalborg University. https://vbn.aau.dk/en/publications/serene-localres-sustenance-a-multi-disciplinary-approach-to-incre

Blau, I., Shamir-Inbal, T., & Avdiel, O. (2020). How does the pedagogical design of a technology-enhanced collaborative academic course promote digital literacies, self-regulation, and perceived learning of students? *The Internet and Higher Education*, *45*, Article 100722. https://doi.org/10.1016/j.iheduc.2019.100722

Bornebroek, G. (2023). *UI/UX design of an energy consumption dashboard for carbon-neutral communities* [Graduation thesis]. Saxion University of Applied Sciences. https://hbo-kennisbank.nl/details/saxion_scripties:F1AA95B7-F8A7-4407-82D9CB16E99B00FA

Broussard, M. (2018). *Artificial unintelligence: How computers misunderstand the world*. MIT Press.

Chiappini, L. (2020). The urban digital platform: Instances from Milan and Amsterdam. *Urban Planning*, *5*(4), 277–288. https://doi.org/10.17645/up.v5i4.3417

Chiappini, L., & de Vries, J. (2022). Civic crowdfunding as urban digital platform in Milan and Amsterdam: Don't take pictures on a rainy day! *Digital Geography and Society*, *3*, Article 100024.

Coenen, F., & Hoppe, T. (Eds.). (2021). *Renewable energy communities and the low carbon energy transition in Europe*. Palgrave Macmillan.

Coenen, F., & Hoppe, T. (2022). Renewable energy communities as a new actor in home energy savings. *Urban Planning*, *7*(2), 108–122. https://doi.org/10.17645/up.v7i2.5088

de Graaf, F. (2018). *New strategies for smart integrated decentralised energy systems*. Metabolic.

Dekeyser, T., & Lynch, C. R. (2024). Control and resistance in automated shops: Retail transparency, deep learning, and digital refusal. *Antipode*, *57*(1), 53–74.

Edwards, P. N. (2013). *A vast machine: Computer models, climate data, and the politics of global warming*. MIT Press.

Eshet-Alkalai, Y. (2012). Thinking in the digital era: A revised model for digital literacy. *Informing Science and Information Technology*, *9*(2), 267–276.

Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015). Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. *Renewable and Sustainable Energy Reviews*, *41*, 1385–1394. https://doi.org/10.1016/j.rser.2014.09.026

Gerosa, A. (2024). *The hipster economy: Taste and authenticity in late modern capitalism*. UCL Press.

Hargittai, E. (2001). Second-level digital divide: Differences in people's online skills. *First Monday*, *7*(4). https://doi.org/10.5210/fm.v7i4.942

Heitin, L. (2016, November 8). What is digital literacy? *Education Week*. https://www.edweek.org/ew/articles/2016/11/09/what-is-digital-literacy.html

Helsper, E. J., & Eynon, R. (2013). Distinct skill pathways to digital engagement. *European Journal of Communication*, *28*(6), 696–713. https://doi.org/10.1177/0267323113499113

Hofstad, H., Sørensen, E., Torfing, J., & Vedeld, T. (2022). Designing and leading collaborative urban climate governance: Comparative experiences of co-creation from Copenhagen and Oslo. *Environmental Policy and Governance*, *32*(3), 203–216. https://doi.org/10.1002/eet.1984

Hoppe, T., Coenen, F., & van den Berg, M. (2016). Illustrating the use of concepts from the discipline of policy studies in energy research: An explorative literature review. *Energy Research & Social Science*, *21*, 12–32.

Hyra, D. S. (2017). *Race, class, and politics in the cappuccino city*. University of Chicago Press.

Jukić, T., Pluchinotta, I., & Vrbek, S. (2022). Organizational maturity for co-creation: Towards a multi-attribute decision support model for public organizations. *Government Information Quarterly*, *39*(1), Article 101623.

Kitchin, R., & Dodge, M. (2014). *Code/space: Software and everyday life*. MIT Press.

Koirala, B. P., Koliou, E., Friege, J., Hakvoort, R. A., & Herder, P. M. (2016). Energetic communities for community energy: A review of key issues and trends shaping integrated community energy systems. *Renewable and Sustainable Energy Reviews*, *56*, 722–744. https://doi.org/10.1016/j.rser.2015.11.080

Kramer, J., & Petzoldt, T. (2022). A matter of behavioral cost: Contextual factors and behavioral interventions interactively influence pro-environmental charging decisions. *Journal of Environmental Psychology*, *84*, Article 101878.

Lock, O., Bednarz, T., Leao, S. Z., & Pettit, C. (2020). A review and reframing of participatory urban dashboards. *City, Culture and Society*, *20*. https://doi.org/10.1016/j.ccs.2019.100294

Mattern, S. (2021). *A city is not a computer: Other urban intelligences*. Princeton University Press.

Nachreiner, M., Mack, B., Matthies, E., & Tampe-Mai, K. (2015). An analysis of smart metering information systems: A psychological model of self-regulated behavioural change. *Energy Research & Social Science*, *9*, 85–97.

Netherlands Enterprise Agency. (2024). *Leader uitvoering projecten overijssel*. https://www.rvo.nl/subsidies-financiering/leader-uitvoering-projecten-overijssel

Nichols, T., & Stornaiuolo, A. (2019). Assembling "digital literacies": Contingent pasts, possible futures. *Media and Communication*, *7*(2), 14–24. https://doi.org/10.17645/mac.v7i2.1946

Nidam, Y., Gibson, R., Houston-Read, R., Picard, M., & Gavin, V. (2024). Practicing data inclusion: Co-creation of an urban data dashboard. *Environment and Planning B: Urban Analytics and City Science*, *52*(1), 7–25. https://doi.org/10.1177/23998083241245759

Parra, D., Swierczynski, M., Stroe, D. I., Norman, S. A., Abdon, A., Worlitschek, J., O'Doherty, T., Rodrigues, L., Gillott, M., Zhang, X., Bauer, C., & Patel, M. K. (2017). An interdisciplinary review of energy storage for communities: Challenges and perspectives. *Renewable and Sustainable Energy Reviews*, *79*, 730–749. https://doi.org/10.1016/j.rser.2017.05.003

Riezebos, J. (2024). *Het Indië-terrein: Een slimme buurtbatterij in de oude Weverij*. Topsector Energie. https://projecten.topsectorenergie.nl/projecten/het-indie-terrein-een-slimme-buurtbatterij-in-de-oude-weverij-35214

Rodriguez Müller, A. P., Casiano Flores, C., Albrecht, V., Steen, T., & Crompvoets, J. (2021). A scoping review of empirical evidence on (digital) public services co-creation. *Administrative Sciences*, *11*(4), Article 130. https://doi.org/10.3390/admsci11040130

Schillinger, J. M., Coenen, F. H. J. M., Aukes, E. J., Daskalova, V. I., Gercek, C., Helfrich, F. L., Lee, D., Lier, G., Sanderink, L., Votsis, A., & Willemse, J. (2022). *Obstacles that currently hinder the development and operation of local integrated energy systems* (SERENE deliverable 3.1). Aalborg University.

Selwyn, N. (2004). Reconsidering political and popular understandings of the digital divide. *New Media & Society*, *6*(3), 341–362. https://doi.org/10.1177/1461444804042519

SERENE. (2024). *Demonstrators—Dutch case*. https://h2020serene.eu/#dutchDemo

Steen, T., Brandsen, T., & Verschuere, B. (2018). Co-creation and co-production in public services. In T. Brandsen, T. Steen, & B. Verschuere (Eds.), *Co-production and co-creation: Engaging citizens in public services* (pp. 1–16). Routledge.

Tappert, S., Mehan, A., Tuominen, P., & Varga, Z. (2024). Citizen participation, digital agency, and urban development. *Urban Planning*, *9*, Article 7810. https://doi.org/10.17645/up.7810

Terranova, T. (2022). *After the internet: Digital networks between capital and the common*. MIT Press.

Tiefenbeck, V., Goette, L., Degen, K., Tasic, V., Fleisch, E., Lalive, R., & Staake, T. (2018). Overcoming salience bias: How real-time feedback fosters resource conservation. *Management Science*, *64*(3), 1458–1476.

Timm, S. N., & Deal, B. M. (2016). Effective or ephemeral? The role of energy information dashboards in changing occupant energy behaviors. *Energy Research & Social Science*, *19*, 11–20.

Torfing, J., Sørensen, E., & Røiseland, A. (2019). Transforming the public sector into an arena for co-creation: Barriers, drivers, benefits, and ways forward. *Administration & Society*, *51*(5), 795–825.

Townsend, A. M. (2013). *Smart cities: Big data, civic hackers, and the quest for a new utopia*. W.W. Norton & Company.

Van Dijk, J. (2012). The evolution of the digital divide: The digital divide turns to inequality of skills and usage. In J. Bus, M. Crompton, M. Hildebrandt, & G. Metakides (Eds.), *Digital enlightenment yearbook* (pp. 57–75). IOS Press.

Viano, C. (2024). Context-based civic blockchain: Localising blockchain for local civic participation. *Digital Geography and Society*, *6*, Article 100090. https://doi.org/10.1016/j.diggeo.2024.100090

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