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List of Abbreviations

AEC: Amelander Energie Coöperatie

API: Application Programming Interfaces

CBA: Cost-Benefit Analysis

CFOAT: Aran Islands Energy Cooperative

cVPP: community Virtual Power Plant

DER: Distributed Energy Resources

DSM: Demand Side Management

ECU: Energy Community Utility

EMS: Energy Management System

ENCI: Energy Citizenship

ESS: Energy Storage System

FME: Friesland association of tech-companies

GHG: Green-House Gas emissions

ICT: Information Communication Technology

IES: Integrated Environmental Solutions

IoT: Internet of Things

IEMD: Internal Electricity Market Directive

LEF: Loenen Energy Fund

LEN: Loenen Energy Neutral

LoRaWAN: Long Range Wide Area Network

P2P: peer-to-peer

RED: Renewable Energy Directive

RES: Renewable Energy Strategy

SECs: Smart Energy Communities

VRE: Variable Renewable Energy

VPP: Virtual Power Plant

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Summary

This deliverable examines the role of ICT (platforms) in shaping community-level self-consumption, demand-response, peer-2-peer energy trading within energy communities and market trading. Research into the role of Information and Communication Technology (ICT) in Energy Citizenship (ENCI) is understudied and underdeveloped. D4.2 aims to fill this gap by investigating the contribution of ICT in the goals and achievements of ENCI cases. The central research question of this deliverable is: *what is the role of ICT in shaping energy citizenship?*[1] Data on the role of ICT has been collected in 40 detailed case studies across nine partner countries and 596 mapped cases across Europe (D3.3 and D3.4).

The results indicate that Information and Communication Technologies are used in various initiatives in many ways, but that effective ICT use is subject to limitations and conditions. These barriers take various forms. For example, collective citizen energy storage systems (e.g., neighbourhood batteries) face challenges because they are costly and subject to complicated institutional rules. On the more technical side, the need for interoperability (the ability of computer systems or software to exchange and make use of information) can create additional difficulties. Interoperability can manifest, for example, in the lack of standards for application programming interfaces (API) of Distributed Energy Resources (DER).

The form of ICT most common within the 596 ENCI cases studied is 'community self-consumption' (22% of the ENCI cases). This ICT form captures technological systems that allow a community or a group of people to generate and use their own renewable energy locally. The second most used type of ICT encountered in the ENCI cases are 'ICT platforms' and 'Digital smart meters' (both technologies appear in 14% of the ENCI cases). Examples of ICT platforms in the cases studied are the online energy dashboard in dormitories adopted by 'Student Switch off Campaigns in Bulgaria' and 'Somenergia-opendata' which organises information about the Som Energia energy cooperative. EMS technology is used in the community Virtual Power Plant (cVPP), 'DE-centrale', in Loenen energy cooperative and the 'Energy Transition of the City of Burgas' ENCI case, wherein the municipality of Burgas adopted a building EMS in the main municipality building.

'Digital smart meter' technology was adopted in 14% of the ENCI cases. This form refers to energy meters that use advanced digital technology to measure and record electricity consumption and communicate with other systems in the energy grid. Unlike traditional meters, which require manual readings and can only measure overall energy consumption, smart meters can provide real-time data on energy use and can communicate that data to utilities and energy consumers. Digital smart meters were used

1 D3.3 elaborated the research questions for the EnergyPROSPECTS deliverables. D3.4 consists of the data collection for the purpose of these research questions. The detailed methodology used is elaborated in D3.3. and D3.4.

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by the Som Energia energy cooperative to help households monitor and save on their energy bills ('SomBots'). Smart meters were also used as part of country-wide national programmes. For instance, in Ireland, the 'Energy Communities Tipperary Cooperative' reports the national roll-out of smart meters in domestic residences, as potentially beneficial for the case and their aims if residents can be sufficiently educated about the technology.

In order for ICT to enhance ENCI, competent people are needed as well as a sensible approach, in which the details of potential systems are scrutinised. For achieving scaling, an evolutionary (modular) strategy appears sensible for dealing with emerging bottlenecks and achieving buy-in from commercial actors and citizens alike.

The empowerment of ENCI actors by ICT requires a wider scoped analysis. If ICT empowers dominant actors more than citizens and citizen groups, then the energy system will not become more democratic and just. The focus of this deliverable is on the shaping aspects of ICT on ENCI, instead on the degree empowerment.

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1 Introduction

The energy system is evolving from one which is characterised by large-scale centralised power plants, to a hybrid system with an important role for local (decentralised) energy networks featuring small, weather dependent renewable energy sources (RES) (Bell & Gill, 2018; Gui & MacGill, 2018; Verbong et al., 2013). Three ongoing forces are identifiable in this transition: decentralisation, decarbonisation and digitalisation (Martirano & Araneo, 2022). Digitalisation captures the technological innovations which are being applied to the energy system. It is a process which affects all stakeholders from utility companies to energy consumers and it is leading to the creation of new business models and new roles in the electricity grid (Martirano & Araneo, 2022). Most importantly, digitalisation is opening opportunities for the increasing engagement of citizens in the energy system, on which this deliverable will focus. Our purpose here is therefore not to account for all the controversial aspects of the digitalisation of the energy system, neither to assume a critical approach on energy-dedicated ICT (Information and Communication Technology) - as illustrated for instance by Strengers (2014) - but to ascertain empirically how ICT contributes to the emergence and anchorage of certain forms of ENCI. Attention will also be given to what factors govern effective use of ICT by ENCI actors (as conditions and issues for attention and action). Consequently, this deliverable answers the following research questions:

To what extent are different types of ICT tools used by ENCI actors?
What benefits can ICT tools bring to ENCI actors?
What barriers impede the use of ICT tools by ENCI actors?
How can the application of ICT in ENCI be better enhanced?

The deliverable consists of qualitative and quantitative analysis using data from 596 ENCI mapped cases across Europe (see D3.2). In the quantitative analysis stage, the frequency of different ICT types was measured and compared to identify the more and less common ICT types used in the ENCI cases. During the qualitative analysis information on the use and benefit of ICT for the cases was studied to reveal qualitative insights about the use of ICT tools. In addition, the deep dive case studies presented in Chapter 3 provide detailed insights for the purpose of this deliverable. This deliverable reviews existing related literature to explain the meaning of ICT, its forms, and the diverse factors which impact its role in ENCI. Final conclusions are offered in Chapter 4.

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2 Unpacking the role of ICT with regard to ENCI

ICT is a broad term which does not have one commonly accepted definition. It is generally accepted as referring to all technologies that in combination with each other, allow actors to interact in the digital world. The components of ICT include cloud computing, software, hardware, transactions, communications technology, data, and internet access. ICT for ENCI can manifest in different forms (e.g., software, hardware), with different functions (e.g., peer-2-peer trading, smart metering), and serving different purposes (e.g., demand-side response, flexibility).

There are many ICT applications that play a role in the energy transition. Forms of ICT vary in the extent to which they involve dedicated appliances/devices (both hardware and software) and the extent to which the ICT is user-oriented or not. This Chapter elaborates different forms of ICT, giving examples for illustration.

2.1 Plurality of ICT and related uses

2.1.1 Examples of ICT tools used by ENCI actors

ICT tools used by ENCI actors with a strong software element are applications for energy awareness, energy informatics (Klein et al., 2023), ICT platforms (Energy Management Systems - EMS), Virtual Power Plants (VPPs) and blockchain technology (Martirano & Araneo, 2022).

An EMS consists of "a central controller comprising a highly efficient computing system along with secure, dedicated network communication for managing energy use. This controller can either be an aggregator or a utility that gathers all information, like energy consumption pattern of the load/consumer, energy production of the Distributed Energy Resources (DER), and so forth, of each node to run optimization programs toward achieving their goals, for an effective operation" (Meliani et al., 2021).

The Virtual Power Plant (VPP) is a type of smart-grid type which aggregates/coordinates Distributed Energy Resources (DER) (e.g., solar PV, batteries) into a combined portfolio using software systems (Asmus, 2010; Saboori et al., 2011; Shaukat et al., 2018). VPPs incorporate diverse DERs and their characterisations into a single operating profile that can respond to spatial network constraints, thereby acting as a single virtual entity in the energy system (mimicking conventional power plants) (Asmus, 2010; Plancke et al.,

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2015; Pudjianto et al., 2007). VPPs emerged in the 1990s as a response to challenges arising from the integration of RES into the electricity grid (van Summeren et al., 2020; Wainstein et al., 2017) and illustrate how ICT can remotely control and coordinate energy flows from DER (Asmus, 2010; Saboori et al., 2011). VPPs can be distinguished into different types depending on certain factors, such as the function it provides (van Summeren et al., 2020). Typically, VPPs provide a technical function (solving grid issues) or commercial function (trading energy or flexibility on the market).

Other more hardware-based forms of ICT tools used by ENCI actors are, cyber-physical systems, physical microgrids, batteries, digital smart meters. For example, microgrids are energy systems that are physically integrated with the main electricity grid. They fulfil 'smart grid' functions, like VPP, but through hardware technology (Asmus, 2010).

2.1.2 Variation in uses of ICT

ICT tools can be distinguished based on the functionalities / aspects that they provide to ENCI activities. Most common are energy sharing, peer-to-peer (P2P) trading (trading energy within communities), demand-response (altering energy demand in response to supply), community self-consumption of energy, aggregating flexibility, real-time energy pricing, and management of energy flows. These uses are explained below.

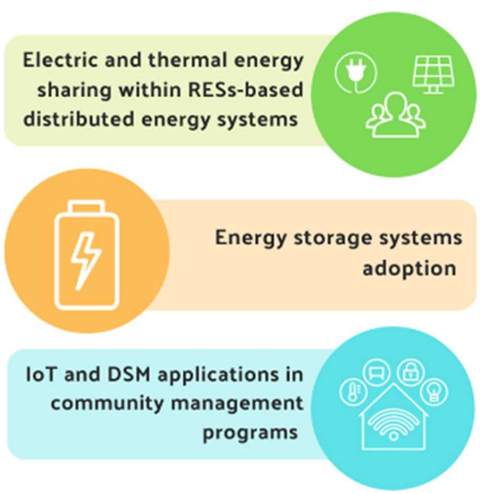

Figure 1: Functions of ICT in smart energy communities[2]

Ceglia et al. (2022) distinguish between three commonly applied uses of ICT in smart energy communities (Figure 1). First, ICT plays a role through microgrids for electric and thermal sharing and management in RES-based distributed energy systems (Giordano et al., 2020; Martirano et al., 2021; Yan et al., 2018).

Second, Smart Energy Communities (SECs) often use Energy Storage Systems (ESSs) to solve issues caused by energy supply and demand mismatches. Hence, community energy storage shows how ICT facilitates the expansion of RESs and communities' self-consumption of energy by storing unconsumed energy for when supply is low, or demand is high (Ceglia et al., 2022). These tools can deliver the scale necessary to make energy storage an economically viable solution for ENCI actors and improve the profitability of energy generation as a result (Barbour et al., 2018; Liu et al., 2019; Tan et al., 2021). One example is the use of battery storage for

[2] Adapted from Ceglia et al., 2022.

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multi-unit residential buildings (Martirano & Araneo, 2022). Some studies even investigate the potential for SECs to benefit from drawing on energy storage technology in electric and hydrogen vehicles (Liu et al., 2021).

Third, SECs can use the Internet of Things (IoT) and Demand Side Management (DSM) applications for achieving flexibility. DSM uses ICT to manage grid congestion by communicating with the energy grid to shift consumption to non-peak hours (e.g., using blockchain technology) (Van Cutsem et al., 2020). These demand-response programmes rely on virtual aggregation by a third-party entity connected to the grid (aggregator) (Di Silvestre et al., 2021). Smart meters are one of the most common ICT devices in this area. They are meant to facilitate lower energy bills by allowing users to interact with their energy consumption patterns (Reka & Dragicevic, 2018), as far as those patterns can be modified – which is doubted by some authors (Klopfert 2011). Overall, this form of ICT (IoT-based devices and DSM) is enabling for ENCI because it enhances actors' efficiency, resilience to unreliability from grid issues, reduces energy costs and maximises self-consumption (de São José et al., 2021; Ford et al., 2021; Nižetić et al., 2020; Reka & Dragicevic, 2018). These uses of ICT can be divided into three main categories (Ceglia et al., 2022):

- Technical: Decreasing global energy consumption through using DERs and reducing the carbon footprint (Ceglia et al., 2022), improving grid stability and energy supply or service reliability, expansion of RESs and optimal use of local RESs for self-consumption (Bartolini et al., 2020).
- Economic: Reducing costs through economies of scale, load aggregation and shifting (Giordano et al., 2020; Martirano & Araneo, 2022; Radl et al., 2020).
- Social: shifting benefits, governing power, and responsibilities from centralised to decentralised entities and contributing to innovation and local value creation (Espe et al., 2018; Roby & Dibb, 2019).

2.1.3 Empowerment by ICT?

EnergyPROSPECTS defines energy citizenship as: "forms of civic involvement that pertain to the development of a more sustainable and democratic energy system. Beyond its manifest forms, energy citizenship (ENCI) also comprises various latent forms: it is an ideal that can be lived up to and realised to varying degrees, according to different framework conditions and states of empowerment." (Pel et al., 2021:64, D2.2). In practice, however, the extent to which this ideal is lived up to can vary, and some previous research argues that the use of the term 'energy citizenship' in political discourse, often is really referring to merely energy consumership (Lennon et al., 2020). This envisions energy consumption and purchasing patterns as the extent of citizens' political interaction with and participation in energy markets, thereby promoting a neo-liberal,

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market-based view wherein energy is merely seen as a commodity, not an ecological resource or social necessity (Lennon et al., 2020). By applying energy citizenship in this way in political discourse, citizens may be boxed into a false choice narrative wherein responsibility for the energy transition is transferred to the citizen, yet they lack the empowerment and agency to make the changes needed because they are positioned within the existing energy system which is inherently structured to favour large corporate players, not energy users (Lennon et al., 2020). This neo-liberal, market-based approach to ENCI is also harmful in that it surpasses issues of inequality in access and differentiated levels of control over citizens' circumstances (Lennon et al., 2020). Moreover, the sum of private-sphere individual actions (e.g., turning lights off) will not bring about the changes necessary in the broader energy system, such as in policy, grid infrastructure etc.

ICT allows for decentralised governance through dispersed RES. It also allows for collective decision-making in the socio-technological energy system wherein citizens are not merely consumers of energy. Importantly, a lot of elements of the energy system cannot be changed by individual actions alone, and ICT can play a role in facilitating the collective action that is necessary. On a practical level, ICT can help to change routinised behavioural patterns and allow citizens to engage more closely with their energy, making it less of an abstract concept in their lives.

As noted, the dominant neo-liberal consensus uses a framing of 'energy citizenship' which simultaneously places too much responsibility on the citizen-level while also locking them into an incumbent system which does not give them agency to make the changes necessary. ICT can help to avoid this scenario by facilitating the empowerment and agency of citizens and their collective action (e.g., community power) in the socio-technical energy transition.

The ideal of 'energy citizenship' includes elements of collective action, democracy, rights, collective ownership, and acknowledges the fact that humans are socially situated, intersectional beings which are not merely concerned with personal gain. While ICT can help in pursuit of political ideals of ENCI, there is still the risk that ICT may be mobilised in a way which reinforces the dominance of for-profit energy corporations who are primarily interested in making money and not in a more democratic, just and sustainability-oriented energy system. Hence, it is important to ask to what extent the ICT in question, incorporates and serves these elements of ENCI. This can be done through questioning the underlying purpose behind the ICT and how it shapes the way in which different actors interact with each other and the energy system at large. If ICT empowers dominant actors more than citizens and citizen groups, than the energy system will not become more democratic and just. The answer to this question requires a wider scoped analysis as we were able to do.

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2.1 Emerging opportunities and key actors for ICT in the energy transition

The previous Section described how ICT could play a role in either perpetuating the citizen-as-consumer view, or in facilitating ENCI in its various forms. This Section explains how ICT is emerging in response to challenges and opportunities in the energy transition, as technological, economic and institutional opportunity.

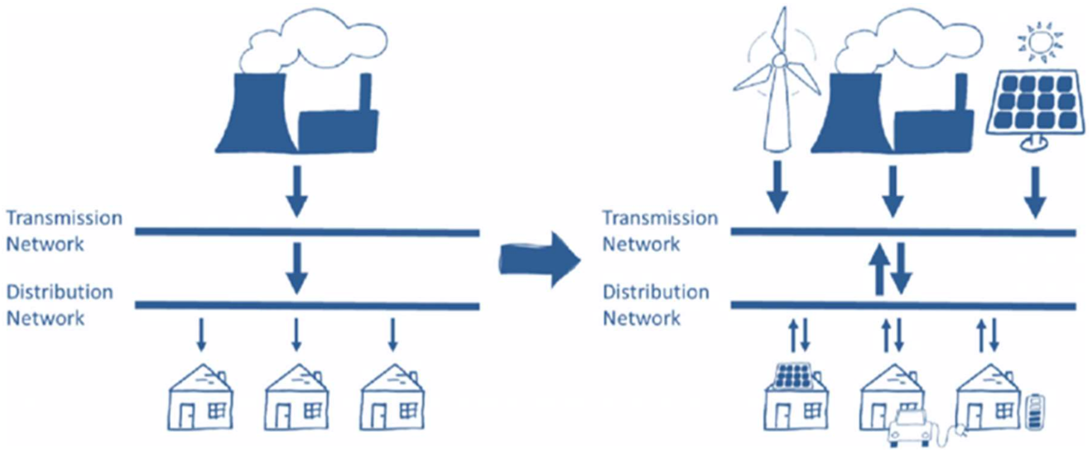

Figure 2: Shift from centralised (left) to decentralised electricity system (right) with bidirectional energy flows from and towards prosumers[3]

Technological opportunity. The incumbent energy system is under pressure due to changes such as liberalisation of the energy market, decarbonisation of energy sources, the rise of distributed energy resources (DER), electrification and digitalisation. This pressure stimulates reformative and transformative change in the technology system and creates a need and opportunity for ICT as one potential solution to managing the pressure (Van Summeren et al., 2021). Figure 2 below by Van Summeren et al. (2021) illustrates the shift in the electricity system currently taking place and can help to explain the role of ICT in this shift. For example, ICT plays a role in managing DER in such a way that mitigates volatility and capacity issues in the energy system through P2P energy trading and demand-response services such as shifting demand to off-peak hours (Klaassen & Laan, 2019). In this way, ICT enables the organisation of an increasingly decentralised and distributed energy system (Figure 2) (Van Summeren et al., 2021).

Economic opportunity. Rising energy costs also stimulate the use of ICT in ENCI, as a tool to make economic savings on energy bills.[4] For instance, smart meters are a tool for small energy consumers in monitoring their consumption and minimising usage. This can have

[3] Adapted from Van Summeren et al., 2021.

[4] In D5.1 and D5.2 we have analysed - through PESTEL analysis - how ENCI evolves through changing technological factors. In contrast to that analysis of distant factors, this analysis focuses on the ICT technologies as proximate factors, i.e. their role as possible 'tools' for ENCI.

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beneficial impacts on peak load reduction as a result (Lovell et al., 2017; Van Summeren et al., 2021). However, everyday-life rhythms are highly anchored in social life constraints (worktime, schooltime, etc.) and therefore only enable minor shifts of the load curve.

Institutional opportunity. Institutional change in the form of new policy acts is creating opportunities for the emergence of ICT within the energy transition. This is evident in two recent EU directives, a) the Renewable Energy Directive (REDII) (re-casted in 2018, currently revised under the Fitfor55 legislative package) and b) the Internal Electricity Market Directive (IEMD) of 2019 (also currently revised). Both directives recognise the role of citizens in the energy transition and acknowledge the importance of ICT to facilitate their involvement. These directives formulate strategies on the expansion of RESs, energy sharing within DER, congestion management, demand-side flexibility, real-time energy pricing, and aggregators as actors (Directive (EU) 2018/2001 and Directive (EU) 2019/944; van Summeren et al., 2020). The directives also recognise the central role of renewable energy communities (RECs) and citizen energy communities (CECs) in the energy transition towards a low-carbon society in line with the European Union's climate targets of 80-95% reduction in green-house gas (GHG) emissions by 2050, compared to 1990 levels (Ceglia et al., 2022). As defined in REDII, renewable energy communities are controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity and whose primary purpose is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits (European Parliament, 2018, p. 103). ICT can play an important role in the operations of such initiatives (see Chapter 3.2).

ICT for reducing energy use and energy management is developed, promoted and pushed by government. ICT companies and scientists are interested in this, which constitute the main advocates for it. The role of ICT for energy communities is investigated by social scientists examining how ICT tools may be shaped to better fit the interests and objectives of energy communities. An overview of the main actors and their roles in the energy system is given in Table 1.

Table I: Overview of main actors and their roles in the current energy system

Energy market roles	Responsibilities and activities
Electricity producer	Generate electricity
Supplier	Source, supply, and bill energy to consumers
Balance Responsible Party (BRP)	Balance demand and supply on behalf of the TSO

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Distribution System Operator (DSO)	Operate and maintain the distribution network to distribute electricity to consumers
Transmission System Operator (TSO)	Operate and maintain the transmission network to transport electricity over long distances
Aggregator	Aggregate electricity or flexibility and trade this on the energy market
Software developers	Develop ICT systems that enable monitoring and active management of DER
Energy consultants	Offering advice about energy matters (including energy management systems) to clients
Consumer	End-users of electricity, which can be residential end-users, small and medium-sized enterprises, or industrial users
Prosumer	Distributed RES (e.g. solar PV) enable consumers to become prosumers who both consume and generate electricity
Energy community	A collective of e.g. citizens and/or small and medium enterprises engaged in activities like generation, distribution, supply, consumption, aggregation and the provision of various energy services
Energy market regulator	Regulating energy markets
Innovation agencies	Responsible for the implementation of innovation policies
Policy makers tasked with promoting green energy and sustainability	Creating policies, targets and interacting with stakeholders in systems of governance
Energy scientists	They educate students, do research on energy markets and smart grid issues. Some of them are advising policy makers about such matters. Social scientists study actor-system dynamics and justice in relation to the energy transition as a political and economic project

Smart energy fits with visions of a smart city (Evans et al., 2019). Smart energy is not explicitly aimed at achieving a more fair, just and sustainable energy system, although such effects are oftentimes mentioned, obscuring the underlying tensions between efficiency, equity and democracy (Evans et al. 2019).

The role of citizens and energy cooperatives in smart grid development is examined in technical studies and in socio-technical studies. The focus of the first type of studies is on the technologies and the economic, and environmental implications of these technologies, with less attention being paid to social aspects (Kojonsaari and Palm, 2023). In socio-technical studies such as Naus et al. (2015) and Skjølsvolda and Lindkvist (2015) the preferences and views of households are examined in focus groups meetings. Discussions with people revealed various privacy and autonomy concerns, but not a straight rejection of smart meters and smart grids (Naus et al., 2015, p. 132).

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A study into the preferences for flexibility technologies (e.g. Variable Renewable Energy (VRE), batteries, hydrogen), electricity generation technologies and system architecture in Germany revealed important differences between actors favouring a centralised system and those favouring a decentralised, more democratic system (Dahl Andersen et al. 2015). Flexibility technologies (used in smart grid configurations) are favoured by all, because they avoid costly expansion of the grid and help to optimise local energy systems, with the help of ICT.

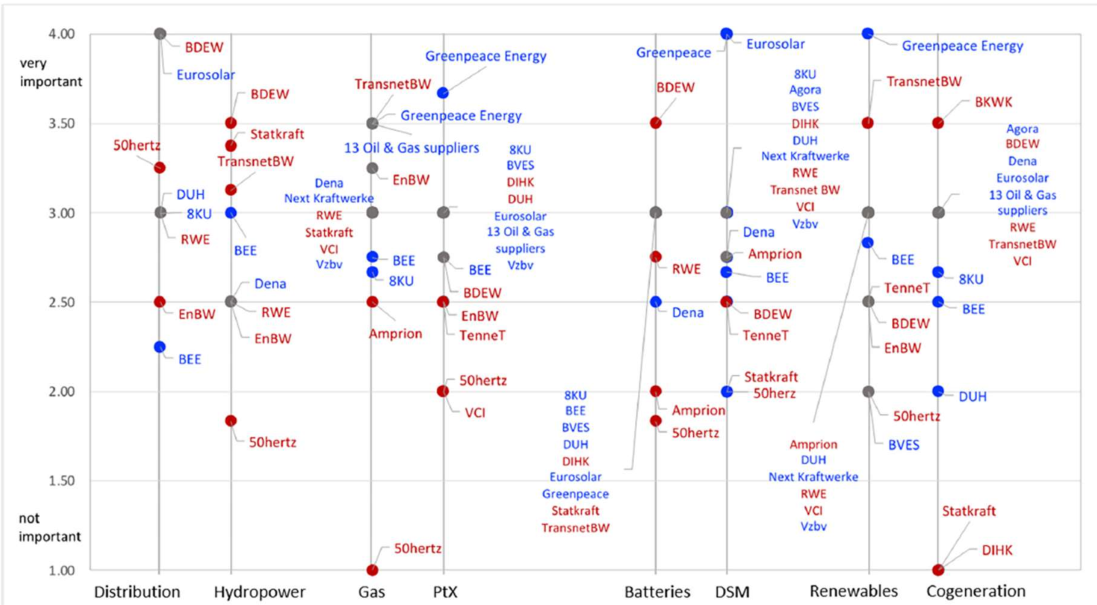

Figure 3: Preferences for eight flexibility options amongst energy incumbents and challengers in Germany. Incumbents are marked in red and challengers in blue colour; when both types of actors are in same place grey markers are used (Dahl Andersen et al. 2023)

Incumbents have a strong preference for centralized architectural technologies but, because the centralised system is difficult to expand (owing to resistance against the expansion of transmission lines and high costs thereof) they reluctantly accept a role for emerging decentralized alternatives (Dahl Andersen, et al. 2023). They are interested in collaborating with energy cooperatives, especially those that that are willing to stabilise the net. The system is in a flux, which is reflected in the diverging preferences amongst incumbents and challengers for different flexibility technologies (Batteries, DSM, Renewables, Co-generation, PtX, Gas, Hydropower and Distribution) (see Figure 3).

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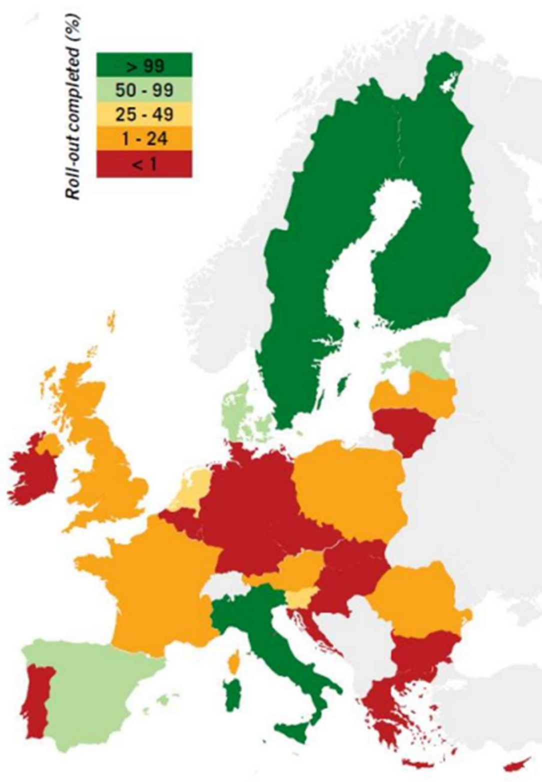

Figure 4: Share of household customers equipped with smart meters for electricity in 2016[5]

Next to utilities and ICT companies, the EU and governments act as advocates of the use of smart meters and grids. Member States of the EU are required to ensure the implementation of smart metering under EU energy market legislation in the Third Energy Package. The EU Directives concerning common rules for the internal market for electricity and gas (2009/72/EC and 2009/73/EC) and the EU Directive on energy efficiency (2012/27/EU) require Member States to ensure the implementation of 'intelligent metering systems' that shall assist the active participation of consumers in the energy market.[6]

This implementation may be subject to a long-term Cost-Benefit Analysis (CBA). In cases where the CBA is positive, there is a roll-out target of 80% market penetration for electricity by 2020. Across the EU, there are big differences in the deployment of smart meters, as can be seen in Figure 4.

Science is involved in this in many different ways. Scientists are heavily involved in the modelling of smart grid applications. Examples are Kuehnbach et al. (2022) and Zahar et al. (2018). Socio-technical studies put the local socio-cultural and institutional centre stage, drawing attention to social, financial and governmental interventions that are necessary to make grids smart (Kumar, 2019).

There is also a growing literature, which is critical about smart grids as empowering energy cooperatives, by noting that smart grids are very much controlled by incumbents (Goulden et al., 2014). Empowerment of citizens in smart grids is very much an ascribed effect: “notions of participation and engagement typically feature as discursive frames, rather than being applied in actual practice” (Naus et al. 2015). Part of the problem lies

5 Source: The EU Building Stock Observatory and ACER, De Groote et al., 2017: https://icaen.gencat.cat/web/.content/10_ICAEN/17_publicacions_informes/11_altres_publicacions/arxius/SmartEnergyCommunities.pdf, accessed 12.05.2023

6 Source: https://www.cencenelec.eu/areas-of-work/cen-cenelec-topics/smart-grids-and-meters/smart-meters/, accessed 12.05.2023.

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with engineers and policy makers who approach smart grid as technological interventions, instead of as socio-technical systems.

We also want to note that in the database about energy citizenship developed in this project, we came across examples of resistance to ICT. These included resistance to (government) campaigns to push smart meters or the compulsory smart meter rollout – like with the Linky smart meter in France, where it resulted in a lot of violent situations of forced installation and many trials (Chamaret et al 2020; Lamb 2022). Public protests to smart metering stem from fears of misuse of private information, suspicions of household surveillance and suspected health impacts of electro-magnetic radiation (Hess, 2014, quoted in Naus et al. 2015). The majority of people and energy cooperatives are not hostile to smart meters and local energy markets with energy management. Micro grids and smart grids involve technical matters which are quite bewildering to most people, including policy makers.

2.3 The role of ICT in enabling ENCI

This Section describes how the potential role of ICT can enable ENCI, dividing the role of ICT into three main categories: economic, social, technological / institutional. We put the emphasis on ICT potentialities for enabling ENCI. More critical issues and challenges that might emerge in relationship to ICT are addressed in Section 2.4.

2.3.1 Economic role of ICT

Adams et al. (2021) study decentralised energy business models and show that ICT can deliver economic value to ENCI actors based on the savings, revenues, and services of peer-to-peer energy trading, community self-consumption and transactive energy models. For instance, the use of smart meter technology in domestic buildings, can help private ENCI actors achieve economic savings on their energy bills.

2.3.2 Social role of ICT

ICT can also play a social role for ENCI actors. Namely, ICT technology can be helpful in transforming knowledge into a more understandable, accessible, and usable form for every-day purposes. For example, ICT tools can help households in understanding their energy consumption patterns better (Klein et al., 2023). Similarly, digital platforms can help energy communities in navigating the complexities of renewable energy projects through providing guidance/assistance (Minuto et al., 2022).

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Another way ICT plays a role in ENCI is in changing social norms around energy consumption (Klein et al., 2023). Previous literature has demonstrated the value of blockchain-based ICT tools for improving democratic perceptions and social acceptance (Martirano & Araneo, 2022). Similarly, it can enable increased participation/engagement from the community-level by providing the ability for end-users to participate in energy markets (Van Summeren et al., 2021). Moreover, ICT tools can also be used in ENCI for strengthening collaboration and collective agency (Van Summeren et al., 2021). For instance, ICT tools can enable actors to collectively engage in institutional work, energy management and trading. Open-source software can be collectively owned (as in the case of EnerGent's cVPP) to achieve the large scale necessary for participation in the energy market.

As discussed in the previous subsections, ICT can facilitate a shift in perception from 'energy as commodity' to 'energy as social necessity / ecological resource', and give agency and control to citizens, thereby facilitating collective action and a move away from the neo-liberal, market-based system in which citizens are only seen as consumers (Lennon et al., 2020).

2.3.3 Technological / institutional role of ICT

In a technological sense, ICT can enable ENCI by enhancing energy efficiency. This is achieved through ICT tools which enable monitoring and control of energy generation, consumption, and distribution. ICT tools can stimulate sustainable consumption, improve market efficiency, reduce transmission losses, and improve electricity grid resilience and management (Klein et al., 2023; Van Summeren et al., 2021).

Smart grids can be used to integrate DER into the centralised energy system by imitating conventional power plants. In this way, ICT can increase the resilience of ENCI actors within the energy system by helping them to adapt to the socio-technical regime. But smart grids can also be used in micro-grid configurations, with a reduced role of distribution system operators and transmission system operators.

The experiences with the cVPPs in Loenen Energy Cooperative show that there are many barriers to such systems: economic barriers such as high costs, interoperability problems and barriers for controlling DER by an EMS. The unfavourable economics of cVPP have various sources: the high costs of batteries, fixed tariffs for grid connection (which are non-negotiable), high prices charged for EMS and the presence of energy taxes (which have to be paid when the neighbourhood battery is charged and discharged) (van Summeren et al. 2021). It is evident that ICT can enable institutional change within the energy system, but the system is pulled in different directions, with incumbents favouring centralised systems and challengers decentralised systems. None of the systems will achieve total dominance, because there are good reasons for the existence of both

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systems. The next Section examines the factors that influence the use of ICT (for ENCI purposes).

2.4 Questioning the effective use of ICT for enhancing/supporting ENCI

2.4.1 Drivers and barriers for ENCI-oriented ICT

ENCI cases vary widely in terms of their internal characteristics, and the external context/circumstances to which they are subject. This Section discusses various barriers to ICT use by ENCI actors and institutional and policy factors that can play an important role in influencing the role of ICT (Mourik et al., 2020), characteristics of the ENCI case, and the scale of the ICT.The barriers which limit the potential role of ICT for ENCI actors are grouped in 4 categories: institutional, technical, economic, and social factors.

Institutional barriers are particularly present as barriers for ICT. For example, lack of funding for ICT developers limits their ability to scale up. Moreover, fixed tariffs for household grid connections prevent the use of ICT for private ENCI, and the taxation of collective energy management and local energy trading prevent the use of neighbourhood batteries (Van Summeren et al., 2021). These factors illustrate the high level of complexity in ICT-based systems for ENCI. For example, collective citizen energy storage systems (e.g., neighbourhood batteries) face difficulties because they are 'behind the meter' and subject to complicated institutional rules.

On a more technical side, interoperability issues can be limiting for ICT (Muto, 2017). This is particularly preventative for attempts by ENCI actors to externalise the control of DER by an EMS (smart grids). Interoperability can manifest, for example, in the lack of standards for application programming interfaces (API) of DER which therefore limits the ability of ICT tools to work together (Plancke et al., 2015). This was experienced by the Loenen Energy Cooperative in their attempt to use an EMS to control a diverse portfolio of DER in the area wherein connection certain DER brands was too costly.

Other technical issues include: over-prevalence of PV-based projects (lack of hybridity, SECs not making full use of local RESs), over-emphasis on electric energy sharing (lack of multi-vector energy sharing), lack of multi-user types for energy sharing, lack of diversified ESSs adopted (Ceglia et al., 2022).

From an economic perspective, barriers are often linked to a lack of financial means for ENCI actors to engage with certain ICT tools. For example, the European Commission's Renewable Energy Directive (REDII) tends to incentivise only electric energy sharing within most EU countries and there is a need to incentivize thermal energy sharing by using 'programmable' RESs (Ceglia et al., 2022).

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There are also social barriers limiting the potential for ICT to play an enabling role in ENCI, such as the lack of energy literacy in society. Another barrier is that ICT developers face challenges in scaling up the technology due to factors such as lack of meaningful involvement of citizens (Van Summeren et al., 2021). Another social barrier is the lack of acknowledgement for the social benefits of ICT in ENCI (Ceglia et al., 2022).

Overall, the barriers limiting the role of ICT for ENCI can be understood as a product of the fact that energy markets have evolved with the structure of centralised large power plants, so they are inherently unfavourable for the new and emerging structures of decentralised energy systems. This is seen in the way that energy market participation is most accessible for large-scale actors. This has implications for the way ICT is used by ENCI. Namely, ICT tools are designed to help ENCI actors operate on a large-scale and in accordance with the incumbent system (e.g., energy communities selling flexibility as or via an aggregator who acts as a large-scale actor in the market).

Previous studies show that even though ICT helps ENCI actors to collaborate with other actors in the energy system in order to achieve the scale necessary to participate in the energy market, this collaboration with regime actors can be hindering for ENCI because it often requires actors to deviate from initial values and innovative ambitions or 'get lost in mainstreaming' (Marletto & Sillig, 2019; Naber et al., 2017). Hence, achieving scale comes with the trade-off of a reduced 'community-logic' (van Summeren et al., 2020). An example is illustrated in the way energy cooperatives have to comply with the incumbent energy system in cVPP projects and cannot keep their own needs, values and goals as a result (van Summeren et al., 2020). This is known as 'fit and conform' in transition literature by Smith and Raven (2012). On the other hand, ICT can be used to enable institutional change through enhancing decentralised ways of consuming/ producing/ trading energy ('stretch and transform').

Previous literature shows that strategies of ENCI actors can combine both approaches into a hybrid 'fit and transform' strategy in which they fit into the incumbent system in the short-term, while also contributing to its transformation over the longer-term (Van Summeren et al., 2021).

VPP is an example of how ICT can fit and conform to the incumbent energy system, because it allows actors such as community energy initiatives to play a pre-defined role in the centralised energy system which is similar to that of conventional large scale power plants (in trading energy and providing services to system operators) (van Summeren et al., 2020).

However, community VPP technology can also be used to challenge or 'stretch and transform' the energy system by enabling decentralisation and decarbonisation through local RE generation and trading. Moreover, the ICT can be used to democratise the energy system through community ownership and inclusivity in governance. This is often seen from the use of cVPPs by energy cooperatives (van Summeren et al., 2020).

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The following strategies help to deal with identified barriers. A protected space / regulatory sandbox' approach can be used involving rule exemptions to enable experimentation / innovation in ICT for ENCI (Lammers & Diestelmeier, 2017). This has been seen with the 'Experimenteerregeling' between 2015 and 2018 in the Netherlands (RVO, n.d.). Through this strategy, an institutional barriers removed and technical learning is being facilitated. However, the temporary nature of this solution was found to be unappealing for ENCI actors such as Energy Cooperative Loenen (Van Summeren et al., 2021).

A second strategy is to collaborate with others in a way that avoids mission drift, the use of ICT in ways which are not in line with their distinctive, transformative goals. This may not be easy. Loenen Energy Cooperative collaborated with DSO Liander and its subsidiary Qirion to achieve their community VPP project. This made the institutional context more favourable for energy management by the cooperative and allowed them to draw on the partners' resources and lobbying powers. However, collaboration is not always achievable. For example, EnerGent energy cooperative attempted to collaborate with DSO, Fluvius, because their grid management practices were a major barrier for the cooperative. However, the DSO was not enthusiastic to collaborate. Instead, the case turned to using small-scale individual batteries to mimic a collective virtual neighbourhood battery and achieve energy management as a result. This shows how without the collaboration of incumbent actors, ENCI actors can use ICT to perform institutional work themselves.

This example also illustrates the issue of needing scale to participate in the energy market. This means that a high number of DER need to be involved, or one large cooperative entity must be responsible for operating the ICT or participating on behalf of multiple communities or actors. In this way, ICT enables ENCI because it enables aggregation which allows ENCI actors to achieve the scale necessary to participate in the energy market. An example of this is using ICT to form a cooperative aggregator to sell flexibility on the market on behalf of energy communities (e.g., Loenen Energy's EMS enables the externalisation of control of DER to a third party) (Van Summeren et al., 2021).

The use of open-source software in ICT is a third strategy to enhance the potential role of ICT for ENCI. This is because it allows greater partnership / collaboration between actors and hence, increases the resources available to help develop the ICT. Moreover, an open-source design may strengthen the collective agency and connectivity among ENCI actors. Collectively, these actors can achieve more by replacing institutions and therefore disrupting and transforming the system. The use of open-source software is in line with the decentralised trend of the energy transition and represents a move away from top-down control architectures which are traditional to the incumbent energy system.

For dealing with social barriers for ICT for ENCI, a number of social measures can be adopted. Klein et al. (2023) show that strategies to improve energy literacy and reduce

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barriers to the accessibility of energy information, would enhance the potential positive impacts of ICT. Energy informatics can be designed in a way for ease-of-use, with intuitive visualisations and the simplification of complex technical information by addressing subjective / qualitative constructs. Better informatics may enhance ENCI actors' capabilities. Moreover, citizens as co-investors / owners of ICT may improve its potential for ENCI because it enables a more diverse involvement in the design of the energy system of the future which may be beneficial for achieving a broader range of functions with a broader range of stakeholders involved and gives more agency to ENCI actors directly.

2.4.2 Exploring justice and the role of ICT in Energy Citizenship?

In examining the role of ICT on ENCI, it is important to pay attention to various aspects of justice (Hicks & Ison, 2018; Walker & Devine-Wright, 2008). Some literature criticises ICT as potentially reducing agency and justice (Van Summeren et al., 2021). Four ways through which this is possible are discussed below.

1. Perpetuating income-inequality? In terms of affordability, some people cannot afford certain ICT technologies and must engage with data or information in a more demanding / effortful way as a result and this can be a factor which is dissuasive for ENCI (Klein et al., 2023). Questions rise whether ICT developers account for matters such as energy poverty, marginalized groups and geography in developing their technologies.

2. Creating vulnerabilities? Previous literature also suggests other ways in which ICT may give rise to new challenges for ENCI actors. For instance, ICT systems create vulnerability due to their reliance on working internet, security, software, and interoperability standards (Van Summeren et al., 2021). Equity concerns may be raised over the fact that it is often too costly to integrate all DER brands in an EMS, and hence energy communities must discriminate between which brands can and will be integrated, thus having implications for the ICT developers and DER owners (Van Summeren et al., 2021).

3. Perpetuating dominant power models? There are also concerns over the potential for ICT to be mobilised by powerful actors in a way which reduces agency by restricting political and social freedom (Rød & Weidmann, 2015) or which commodifies personal data in a market for managing and foretelling human behaviour (Zuboff, 2015). Another justice-related concern is that ICT may be enabling the decentralisation of the energy system in a way which ultimately increases the privatisation of energy provision (Kloppenburg & Boekelo, 2019). There is a similar risk that power could unfairly accumulate in the hands of the ICT developers, such as blockchain operators (Buth et al., 2019). There is a field of literature which speaks to this concern, focusing on the evolution of power dynamics in sustainability transitions in general (Avelino, 2017). On a broader level, there is still debate around the extent to which energy communities contribute to a

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fairer and more just transition both within their community and in society at large (van Bommel & Höffken, 2021).

4. Justice aspects of Energy Sharing by ENCI actors. ICT is often used by ENCI actors for the purpose of sharing electrical energy from renewable energy sources. Diestelmeier and Kuiken (2022) aim to conceptualise this often-ambiguous term and investigate whether it is contributing to an inclusive energy transition. The authors note how 'energy sharing' is not clearly defined or explained in EU directives, raising concerns over matters of rights and responsibilities. The Renewable Energy Directive and the Internal Electricity Market Directive state that Member States must:

> '[...] ensure that [renewable/citizen] energy communities are entitled to arrange within the [renewable/citizen] energy community the sharing of [renewable energy/electricity] that is produced by the production units owned by the community, subject to other requirements laid down in this Article and subject to the community members retaining their rights and obligations as final customers' (2019/944, Art. 16(3e) and 2018/2001, Art. 22(2b)).

This provision describes how energy sharing must not infringe on the rights and obligations of final customers (e.g., households in the case of P2P sharing). However, it does not specify what is meant in this regard through specific stipulations. Exactly what the criteria might be remains ambiguous and have implications for justice and inclusivity. For instance, there could be a model of each member 'getting the same' or one in which energy received depends on the share of the actor's income spent, meaning lower-income households would be supported. This latter approach would be most in line with the directive's social aims of an 'inclusive energy transition'. Nevertheless, whichever criteria would be implemented for energy sharing, there would be further consequences that may adversely affect other rights and obligations of customers in other areas. On a wider perspective, there are also questions around the extent to which energy sharing may contribute to broader societal goals (Diestelmeier & Kuiken, 2022).

Different countries have different rules for energy sharing, and research is needed into whether they maximise fairness/justice. Often the rules involve enforcing the distribution of energy in an ex-ante way e.g., through sharing energy on a per capita or per sqm basis. This might not be fair because the rules might not accurately reflect each members' individual contribution (Gjorgievski et al., 2022).

Gjorgievski et al., (2022) studied the financial fairness of energy sharing and found that a Virtual Net-Billing (VNB) method was found to be the most equitable by the authors, based on fairness indicators. VNB uses dynamic distribution in real-time and/or at the end of the billing period. It distributes the jointly generated economic benefit among the members of the community, based on the imports and exports of the members at each time-step.

Other potential measures to make energy sharing more equitable include enforcing e*x-post* rules for energy sharing that are based on actual energy contributions by members. However, this can be mathematically complex for the average energy user so there is a

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need for better explaining this to users to ensure that the complexity does not act as a barrier in itself. Fairness and equity thus rely more on the ability to enhance actors' capabilities to deal with these ICT-based systems and to decide the extent to which their energy practices can be monitored and managed by ICT devices (Gjorgievski et al., 2022). This insight is also put forward by Klein et al. (2023) who promote the importance of the design of energy informatics as a key measure for enhancing energy literacy in a just way.

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3 An analysis of ICT in EnergyPROSPECTS case studies

3.1 Research methodology

To answer the research questions, a mixed-data collection methodology was applied combining, desk-research, in-depth interviews with key informants and a statistical analysis of the data on ICT use from the 596 data base cases of EnergyPROSPECTS . Below we elaborate on the methods applied during the data collection.

We analysed the data gathered from questions about ICT use in 596 cases for which we collected information in the first stage of the project (see Appendix 1 for the research template questions).

The nature of ICT use and experiences therewith are examined for 40 cases (for which we did a deeper case study analysis). Out the sample of 40 cases we initially subjected three cases for deeper analysis. Descriptions of those cases are included in this report. We also included a fourth case (Ameland), as a case of successful collaboration between the Ameland Energy Cooperative, the Municipality of Ameland, academic and commercial partners, with an important role for democracy and fairness.

For the detailed case selection criteria, we refer to D3.3 (Pel et al., 2022). Data were collected using a Research Template that is presented in D3.4 (Vadovics et al., 2022).

3.2 Overview of the role of ICT and determinants for its contribution to ENCI

This Section contains the results of the role of ICT and determinants for its use and the contribution to a fair, just and sustainable energy transition.

3.2.1 Quantitative analysis of 596 cases

As part of the Energy PROSPECTS research, data was collected and reported for 596 ENCI cases. This deliverable draws on this data to reveal insights into the role of ICT in the ENCI cases. Figure 5 presents the distribution of the main forms of ICT in the ENCI cases.

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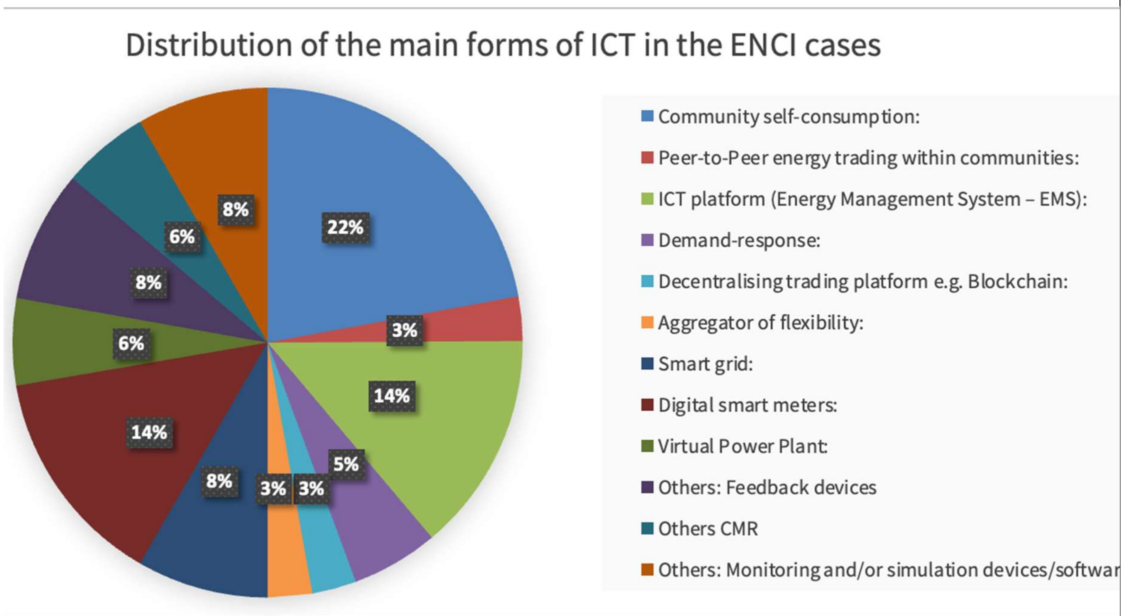

Figure 5: Distribution of the main forms of ICT in the ENCI cases

The form of ICT most common within these ENCI cases was in relation to 'community self-consumption' (22% of cases). This form of ICT captures technological systems that allow a community or a group of people to generate and use their own renewable energy locally. In these systems, ICT is important for the purpose of management and optimisation of energy distribution and consumption. Certain ICT tools are adopted to achieve this aim, such as smart meters, energy management systems, and data analytic software. If surplus energy is generated, ICT tools play a role in either storing the surplus energy in a battery or feeding it back into the grid. Aside from carbon emission reduction, 'community self-consumption' ICT benefits ENCI cases by enabling energy cost reductions, energy independence and resilience. One example of 'community self-consumption' type ICT is feedback devices/platforms (e.g., the 'Naturstrom AG' case uses a feedback portal/application, 'Naturstrom vor Ort' for monitoring energy production and consumption information). A second example is energy sharing technology (e.g., the 'GoiEner' case uses distribution network technology and the 'From the Community Energy Programme to Community Energy Service' case is working on an internal distribution system for sharing energy generated from their solar panels).

The second most common type of ICT used by the ENCI cases were found to be both 'ICT platforms' and 'Digital smart meters' (both technologies appear in 14% of cases). In this typology, 'ICT platforms' refers to tools such as an EMS which an ENCI case can use to manage their resources more efficiently and effectively. The functions of EMS tools can include the monitoring and management of energy production, consumption, and storage. These systems can also provide real-time data and analytics, helping ENCI cases to optimize their energy use and reduce costs. EMS technology is adopted in the Loenen

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energy cooperative, who have implemented a community Virtual Power Plant the 'DE-centrale' which draws on EMS technology to manage supply and demand of energy in Loenen.

EMS technology is also adopted by the 'Energy Transition of the City of Burgas' case, wherein the municipality of Burgas adopted a building EMS in the main municipality building, among others. This technology allows for the optimisation of solar panels, heating, lighting and ventilation systems. On a broader scale, the case uses IoT for smart energy management in other buildings in the city.

Other examples of ICT platforms used by cases are the online energy dashboard in dormitories adopted by 'Student Switch off Campaigns in Bulgaria' and 'Som Energia-opendata' which organises information about the energy cooperative, Som Energia. Another example is the global CMR software solution used by the GoiEner case. This is an application in which a single database captures interactions with all partners, with the aim to improve and manage internal organisation and development.

'Digital smart meter' technology was also adopted in 14% of cases. This form of ICT refers to energy meters that use advanced digital technology to measure and record electricity consumption and communicate with other systems in the energy grid. Unlike traditional meters, which require manual readings and can only measure overall energy consumption, smart meters can provide real-time data on energy use and can communicate that data to utilities and energy consumers. This form of ICT was used by 'Som Energia' energy co-operative to help households monitor and save on their energy bills ('SomBots').

The 'Naturstrom AG' case also used smart electricity meters in tenant electricity projects as part of the LoRaWAN (Long Range Wide Area Network). Project, which enables energy-efficient transmission of data over long distances. With LoRaWAN it is possible to manage several hundred sensors within a network and to process sensor data from digital smart meters. In other cases, smart meters are being installed as part of country-wide national programmes. For instance, in Ireland, the 'Energy Communities Tipperary Cooperative' reports the national roll-out of smart meters in domestic residences, as potentially beneficial for the case and their aims if residents can be sufficiently educated about the technology.

The EnergyPROSPECTS project distinguishes different forms of Energy Citizenship in a typology (D2.2), and ICT will have different roles and effects on different manifestations of these ENCI forms. The typology ranges from more invisible/latent/mundane forms of participation in the energy system (e.g., reformative private-based ENCI) to more visible/manifest forms of ENCI (e.g., citizen- and hybrid based initiatives). Table 2 below illustrates the applications of ICT which are most applicable to different ENCI types.

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Table II: Mapping ICT according to the EnergyPROSPECTS typology

<table>
<tr><th rowspan="3">OUTCOME ORIENTATION</th><th colspan="5">AGENCY</th></tr>
<tr><th colspan="3">Individual</th><th colspan="2">Collective</th></tr>
<tr><th>Private</th><th>Organisationally embedded</th><th>Public</th><th>Citizen-based and hybrid</th><th>Social movements</th></tr>
<tr><td>Reformative</td><td>• Smart meters
• Feedback devices
• Auto-consumption of power or hot water supply by solar panels, Engagement in P2P energy trading or sharing
• Use of car/bike sharing apps</td><td>• ISO50001 management system (ICT parts i.e., monitoring and feedback devices)
• e-cars and bikes pools at the organisation level and related management devices</td><td>• ICT-based polls,
• Social media and influencing platforms,
• Online civil initiatives towards referendum´s organisation</td><td>• P2P energy trading and sharing,
• Blockchain
• VPP</td><td rowspan="2">• Usual" use of ICT for activism events, demo, networking activities</td></tr>
<tr><td>Transformative</td><td>• Autarch or plus-Energy houses
• Building monitoring,
• Community-based car/bike sharing</td><td>• Energy ICT start-ups such as flexibility aggregators
• Or ICT specialist for the conception of energy sharing or trading P2P platforms</td><td>• Online voting operation related to energy transition issues</td><td>• cVPP</td></tr>
</table>

One example is the role of the cVPP in citizen-based and hybrid ENCI types (type 8). Some community energy actors are experimenting with ICT-based tools to achieve their aims and practice in actively managing electricity systems, and thereby entering the incumbent energy system. cVPP technology is an ICT configuration that enables ENCI actors by helping them to manage community-generated energy and to earn revenue from energy trading and offering network support and balancing services (Bakari & Kling, 2012; Verkade & Höffken, 2019). van Summeren et al. (2020) provide the following conceptualisation of cVPP:

> "A cVPP is a portfolio of DER aggregated and coordinated by an ICT-based control architecture, adopted by a (place- and/or interest-based) network of people who collectively perform a certain role in the energy system. What makes it community based is not only the involvement of a community, but also the community-logic under which it operates" (van Summeren et al., 2020:6).

This cVPP allows community energy initiatives to act as a player of various roles in the energy system (subject to applicable regulations). The technological and economic aspects of this technology as well as the potential functions it can provide have been studied by Okpako et al. (2016), Koirala et al., 2016; Wainstein et al., 2017).

Table 2 above illustrated the typical and most common ICT tools for the 10 ideal-types of ENCI. This points to the variation in the scale of ICT tools. Technology can be used to enhance ENCI from the local level (e.g., using cVPP to enhance local RE generation by the Loenen case study), to a more national level (e.g., democratising the national energy system by using an open source cVPP to supply and trade energy within and between energy communities).

This also ties in with the underlying intention of the ICT developer. This can range from the intention to give more agency to individuals, to the intention to achieve economic gains. Three categories may be identified accordingly. First, ICT can be explicitly targeted for ENCI actors. This type is often directly related to the energy uses and energy users, wherein participation is made possible and/or required. Second, ICT can have main purposes other than supporting ENCI. For this type, the impact on ENCI may be measured by the importance given to citizens and how it is balanced with the main purpose. Third, ICT tools may even not consider ENCI at all, but rather indirectly affect it. This unexpected consequence may be either positive or negative. These examples show how the intentions of the ICT developer matter for the role of ICT on ENCI. Appendix 2 displays a list of the other ICT aspects to be found in the mapped cases.

3.2.2 Qualitative analysis of 40 cases

The qualitative data of the 40 cases revealed details about the use of ICT in the detailed ENCI cases and factors responsible for this. In terms of ICT for 'Community self-consumption', several ENCI cases are working on systems for fair distribution and accounting for energy sharing. This indicates that certain actors are attempting to ensure

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that energy sharing technology is just and fair. Similar motivations were found to underlie the use of smart grid technology and digital smart meters. These tools enhance the transparency and accessibility of energy-related information for users. Other tools are being investigated for these purposes but are still in early phases of development (e.g., blockchain technology for peer-to-peer energy trading by GoiEner).

Achieving scale was a key issue for ENCI cases in attempting to play a role in the energy market, and ICT was found to be helpful in addressing this barrier. Specifically, 'aggregator of flexibility' ICT helped Loenen Energy Cooperative to pool energy produced by cooperatives and thus access the energy market by achieving scale. This is part of their Wattflex pilot study[7], which is a succession of their cVPP project. The findings revealed that the complexity and lack of direct contact with the community led to a lack of interest in the VPP technology. The case also reveals how it is important that all residents can participate in some way regardless of whether or not they have RE technology installed domestically.

The use of demand-response technology points to the potential benefits of artificial intelligence systems in ENCI cases by enhancing energy efficiency and energy savings. For instance, one case adopted automated technology on a greenhouse roof in order to open/close windows depending on temperature and sunlight.

The results also revealed a large quantity of 'Other' ICT tools used by ENCI cases. These included CMR (customer relation management) software, and feedback, monitoring and/or simulation devices and software (provide users with real-time information on their energy consumption patterns). All cases also featured the use of communication and media platforms (e.g., Zoom, social media etc.), for the purpose of communication, outreach, legitimacy, collaboration, feedback, and participation. Protesters organise themselves and communicate via modern media.

In the following, we describe the role of ICT in three Deep Dive cases of smart technology applied by energy cooperatives, which have been studied during the detailed case study.

3.3 Highlights from some in-depth analysis of case studies

3.3.1 Aran Islands Energy Cooperative

Background. The Aran Islands Energy Cooperative (CFOAT) is based on the three Aran Islands, located off the west coast of Ireland. The cooperative was founded in 2012 with the aim of creating a sustainable energy system for the islands that is owned and managed

7 For more details: https://flex.energiesamen.nu/pagina/129/wattflex-naar-een-cooperatieve-aggregator, accessed 12.05.2023.

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by the local community. The cooperative's mission is to transition the Aran Islands to a low-carbon energy system that is based on renewable energy sources and is both socially and economically sustainable. The cooperative achieves this by developing and implementing a range of energy projects and initiatives that are designed to reduce the islands' reliance on fossil fuels and increase their use of clean, renewable energy.

CFOAT is focusing primarily on the implementation of smart grid technologies to achieve efficient management of energy distribution and consumption. The cooperative also engages in energy efficiency initiatives such as home retrofit programs and promotes the use of electric vehicles and other forms of sustainable transportation.

Members and stakeholders involved in CFOAT include local residents, businesses, and organizations. The cooperative model entails the cooperation between different societal groups in working together to develop and implement energy projects and initiatives. In comparison to other ENCI actors in Ireland, CFOAT is a pioneer of community leadership in the Irish energy transition and engages heavily in knowledge and skill sharing to assist newer energy cooperatives in their operations.

Smart micro-grid ambition. CFOAT aims to establish a smart micro grid for local residents. Although it has not yet been realised, the ENCI case has acted toward achieving this aim. CFOAT collaborated with IES (Integrated Environmental Solutions) and MPOWER in the sECUre project to investigate the viability of an "Energy Community Utility" (ECU) on the island. An ECU would constitute a community grid made up of local "prosumers" (proactive consumers and participants in the electricity market) that buy and sell electricity among themselves. This would be facilitative for the case in achieving its aim of energy independence. According to a representative of the ENCI case, they would ideally like to set up a micro-grid on the island in order to achieve self-consumption of energy produced.

The sECUre project involves the use of smart meters for informing the P2P trading network software, on the current state of the local network. P2P software is needed for redirecting surplus energy, storing it, or selling it to the grid. However, to achieve the P2P trading ambition, the grid infrastructure needs to be adapted with stabilizers. Currently, the islands receive electricity through a cable from the mainland, however 52% is lost in transmission. Therefore, generating and consuming their own energy on the islands would mean that every unit consumed would replace more than two which would otherwise be imported.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022492.

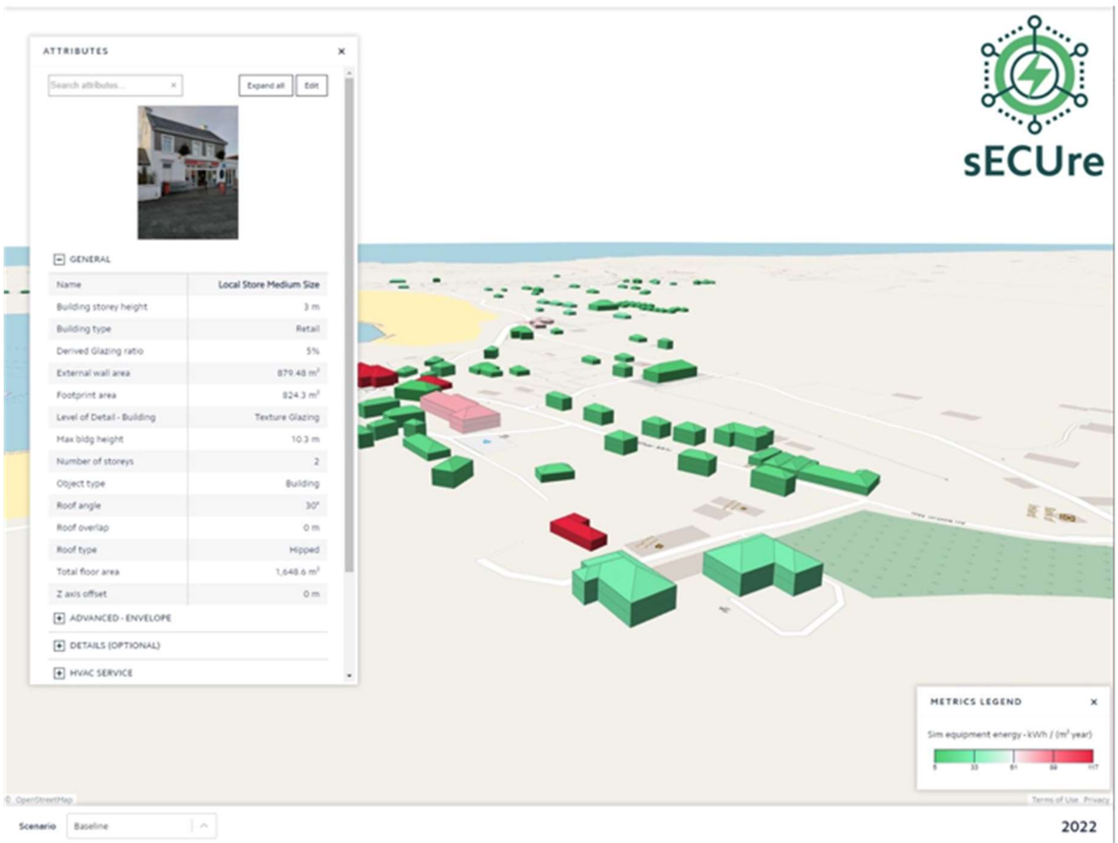

Figure 6: sECUre project platform using the Digital Twin Model[8]

As part of the development of the micro-grid, CFOAT partnered with IES to conduct a research study, using smart Digital Twin technology (IES, 2020), to make a dynamic energy profile of the Inishmore island. The Digital Twin model was recently completed and is providing a comprehensive baseline of Inishmore's energy consumption (see Figure 6). The model uses data on building archetype and construction/renovation statuses of buildings, as well as data from installed smart meters. The model enables the cooperative and island inhabitants to make decisions about their energy usage and production, and to test hypothetical situations against the baseline. The following quote from IES Project Manager illustrates the value of this ICT model:[9]

8 Source: https://www.iesve.com/products/case-studies/27353/irishmore-community-microgrid. accessed 12.05.2023.
9 Source: https://www.iesve.com/products/case-studies/27353/irishmore-community-microgrid, accessed 12.05.2023.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022492.

> *"I hope that IES can help facilitate this transition by showing them the benefits of generating clean, green energy and how they can reap the rewards if they have excess to sell on. You can't improve what you can't measure, and with the Digital Twin model up and running, it is providing a comprehensive baseline of the island's energy consumption."*
>
> Niall Buckley, IES Project Manager

The CFOAT sECUre project is an example of how ICT tools are developed for creating peer-to-peer trading networks of microgrids. The pilot project is still ongoing, and the aim is to maximise the use of self-generated energy on the island.

Other examples of the role of ICT for CFOAT. The use of ICT for energy monitoring has played a role for the CFOAT energy cooperative in other ways. The case collaborated with the University of Galway in the RESPONSE project, in which 20 homes on Inishmore, had devices installed on the washing machine, the dishwasher, and other devices to measure the energy usage and send it back to a central computer. This use of ICT has been facilitative in improving energy efficiency on the island. Moreover, the project established a paid position within the cooperative through the availability of funds. This was central to the viability of the ICT project because it reduced the burden placed on volunteer workers.

Communication technology has also been important for the cooperative. Given the geographical location of the cooperative as island-based, communication software tools, such as Zoom, have reportedly been vital for participation and operation within the cooperative. This is evident from the following quote from a representative of the case:

> *"The opportunity to do zoom meetings in huge. [...]. Because we want to have better representations of the other two islands so that it's not just all about this island. And having zoom meetings has made this much more possible. We do have membership from the two other islands, but it is very hard for them to be involved [...]. [As the] logistics of that is pretty awful and expensive. [...]. We're lucky that we have good internet here. If we hadn't, it would be dreadful".*
>
> EnergyPROSPECTS interview with CFOAT representative

The case study of the Aran Islands Energy Co-operative illustrates the increasing importance of ICT in ENCI. ICT tools are increasingly accessible to ENCI forms such as cooperatives as mechanisms which can help them in achieving their goals. Scaling the use of these tools is a process which appears to take considerable investment of time and money still. Moreover, given the unprecedented nature of the use of these tools (such as in their sECUre project), there is a clear need to consistently question and investigate the

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extent to which they are ensuring justice and equity in economic, environmental and social ways.

3.3.2 Loenen Energy Cooperative - community Virtual Power Plant (cVPP)

Background and the Energetic village. The Loenen Energy cooperative is located in the village of Loenen, east of the Netherlands. Loenen Energy's journey started in 2013 when the municipality of Apeldoorn launched a competition for the best sustainable village idea, called: "the Energetic Village". To accelerate the transition to an energy-neutral village, a group of residents from Loenen came up with a plan for the 'Energetic villages' competition and they won the prize of 200,000 Euros as part of an EU subsidy from the 'Academy of Champions for Energy' (as part of the European Interreg Programme). The approximately 50 declarations of intent to participate contributed to winning the prize of the "Energetic village'. Around this core of residents was a second layer of enthusiasts, so that soon became just under ten percent of the village had knowledge of the project. This was reflected in the final phase of the competition in Apeldoorn, where Loenen was represented by more than 100 people. In the years 2013-2015, the village team, together with various stakeholders inspired and invested in raising awareness about the energy issues, saving energy and generating energy sustainably as the village is aiming to achieve energy-neutrality in the long term.

As a result of the Energetic village prize (part of EU subsidy), it became clear that as a condition of implementation of the EU subsidy, the community needed an entity to distribute the fund (rather than with individual citizens). Therefore, the community group established a board and later the Loenen Energy cooperative was created as an organization entity.

The Loenen Energy Neutral (LEN). The one-off subsidy of 200,000 Euros has triggered a long-term process for the village of Loenen via the Loenen Energy Fund (LEF). The aim of this fund is to achieve 'full energy neutrality for Loenen by 1-1-2050' and to making the energy supply of Loenen more sustainable and to become independent of the use of fossil fuels in the long-term. These include: 1) to decrease energy consumption and to reduce energy costs; 2) participants can contribute annually to the Fund and so more households and businesses can be made sustainable using this fund; 3) the contribution to the Fund is equal to the EU subsidy received upon completion; 4) participants only have to pay 50%+VAT on completion; 5) allows residents to re-finance other residents.

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research and innovation programme under grant agreement No 101022492.

Figure 7: The first major project of Loenen Energy Cooperative[10]

First Project. In August 2020, the first major project of the cooperative, the solar roof distribution centre Thomassen Kanaal-Zuid was completed (Figure 7). 2404 solar panels were installed on the roof of Thomassen's distribution centre at Kanaal Zuid in Loenen, generating around 800,000 kWh of electricity annually. This can power more than 300 households and is one of the largest solar roofs in the province of Gelderland.[11]

DE power station. The DE power station is a virtual power plant (VPP). Traditionally, large power plants are used to generate electricity using gas and coal. A VPP consists of many small plants (solar panels, wind turbines, biogas, hydropower) that together can generate as much power as one large plant. DE power station is actually a smart energy management system that brings together supply and demand of power in Loenen. If you have solar panels, there are situations where you produce more than you use. This is not a problem now because you can sell this back, net, to the power company. However, this arrangement will not continue in the long run. In the future, you may not get anything for the electricity you feed back into the grid, or you may even have to pay for it. It is then advantageous if you can supply that power to someone in Loenen at a better price.[12]

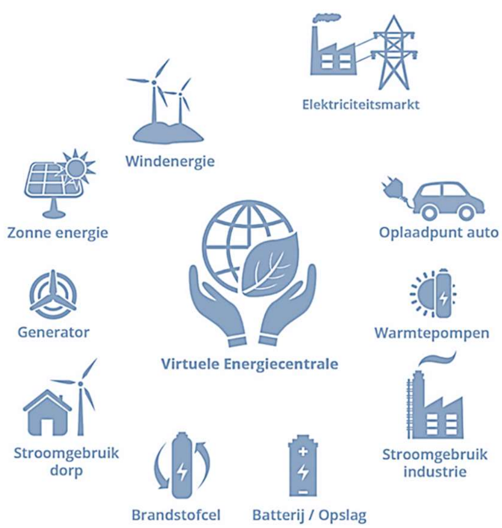

Figure 8: Virtual Power Plant[1]

The cVPP. To develop the cVPP, Interreg North-West Europe made available a grant of 850,000 Euros. Besides the European grant, the Province of Gelderland in the Netherlands also contributed financially to the implementation of the project.

The virtual power plant (Figure 8) consists of multiple interconnected small renewable energy sources (usually solar panels) and consumers (usually households) through an energy management system (EMS). The EMS makes generation and consumption transparent and influenceable. Consciously influencing consumption and generation

10 Source: https://loenenopdeveluwe.info/zonnedak-thomassen-levert-eerste-stroom/ accessed 11.05.2023.

11 The solar roof involves an investment of EUR 690,000, of which 80% is financed by Rabobank and 20% (EUR 138,000) via bonds by ECL members. They are providing a loan (bond) for the duration of 15 years with a part of loan being repaid each year. The annual return on the bonds is set at 4.0%.

12 Source: https://loenenenergie.nl/de-centrale/ accessed 26.09.2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022492.

leads to a different grid load. This has benefits for the energy system and is called "flexibility". This flexibility of (the participants of) the VPP can be used for various activities. For example, offering it centrally to a grid operator to prevent overloading of grids. The "c" of cVPP stands for "community" (everyone involved and affected) that determines how the EMS is used (Figure 9): what values does the community consider important and for which activities is the flexibility deployed.[13]

In 2018, the cVPP project was launched under the leadership of TU Eindhoven and the energy cooperative 'Loenen energy' was established towards the end of this project to ensure continuity. In 2021, the Energy Management System (part of the cVPP) of Loenen Energy was launched and the cooperative won the prestigious EU Sustainable Energy Award.[14]

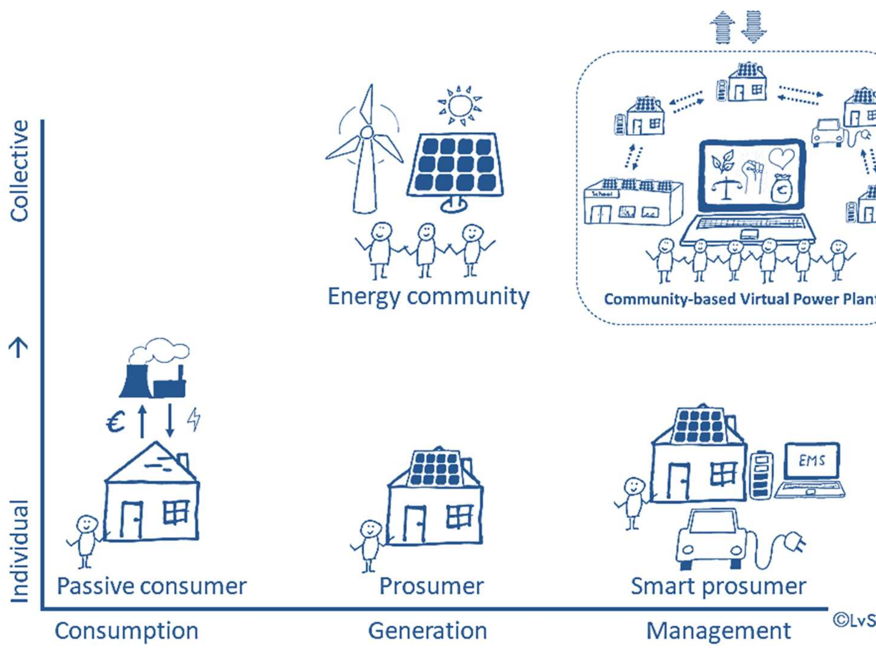

Figure 9: community Virtual Power Plant[15]

Description of the cVPP realization and capitalization. In the first project phase (2017-2020), the cVPP pilot was developed and tested a socio-technical concept in 3 communities in Ireland, the Netherlands and Belgium and developed a Mobilisation and Replication (MoRe) model to help 9 other communities developing their own cVPPs. Loenen cooperative ran a cVPP pilot project with around 100 residents from Loenen (van Summeren et al., 2020). The second phase (2020-2022) supported the capitalization where cVPP goes from replication, doing more of the same, towards upscaling,

13 Source: https://loenenenergie.nl/de-centrale/, Accessed 16.05.2023
14 Source: https://flex.energiesamen.nu/verhalen/39/community-based-virtual-power-plant-loenen accessed 02/12/2022 Accessed 16.05.2023
15 Source: https://www.nweurope.eu/projects/project-search/cvpp-community-based-virtual-power-plant/?tab=,&page=2#tab-3 accessed 11.05.2023

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taking cVPP to the next level. Specifically, this phase focused on: (i) technical upscaling of the EMS by adding assets and experimenting with trade and flexibility and (ii) social upscaling of the business cases through connection of new target groups such as SMEs, industries and rental sector, and territories. The MoRe model is now picked up by Rescoop, a European federation of over 1500 cooperatives, and using insights from cVPP upscaling and the transposition of Winter Package the model is getting upgraded.

The purpose of the cVPP was/is manifold. First, it aims to achieve technical solutions for increasing local RE generation in a way that is feasible given the constraints of the electricity system (accounting for current and future grid issues). Second, it can give the community more independence, control, and ownership within the energy transition by optimizing local self-consumption of energy. Third, it can serve as a financial function by reducing energy bills and increasing local revenues from surplus energy generated to be sold on the market (through a third party supplier) or from peer-to-peer trading and the sale of flexibility. Finally, it can help with imbalances in the local electricity grid through peak shaving (van Summeren et al., 2020). The ability of the cVPP to achieve these functions relies on many factors including, the volume and characteristics of the DE in Loenen, energy market requirements, limitations of the local grid, and institutional developments (van Summeren et al., 2020). Hence, the exact role of cVPP Loenen is still uncertain. In response to this, the cooperative aimed to design it in such a way that it can give the flexibility to play numerous roles in the future (e.g., aggregator, supplier).

cVPP and community participation. The cVPP gives the chance to strengthen the participation of the community, thereby contributing to the democratisation of the energy system. For example, participation of the local residents took place within a series of workshops organized by Qirion. During these workshops the community came together to discuss what they want to achieve as a group (the cVPP was part of this discussion). For example, do they want to invest in another solar panel farm, to invest in biogas system, or shared cars? What type of financial return would that yield? Within the cooperative, these issues are frequently discussed and members can cast a vote. The role of community participation in cVPP is evident from the following quote: '*it (participating via the cVPP) is also just plain fun and educational, and you are participating in this innovative project on the energy system of the (near) future. Indeed, it is expected that, with all the local renewable sources, it will increasingly be designed this way. Also with delivery from consumer to consumer: we will become "prosumers" (producer as well as consumer). You have the opportunity to participate in this innovation so that we can all learn together'* [Interview with a representative from an ICT firm].

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> *'We started with residents' evenings [to] inform residents about [a potential] problem that's coming up [...] In the end, once we knew what the participants wanted as a solution because it was obviously very important that it was community-based and a virtual power station, the residents could indicate which things they thought were important and which they didn't, and then we put the call out to the market to actually build it. .... We translated the wishes of the participants into what you would need in terms of ICT.'*
> *EnergyPROSPECTS Interview with a representative from an ICT firm*

The cVPP pilot in Loenen provides an insight into the level of justice inherent in ICT for ENCI. The cooperative aimed to engage the whole community, and their needs/desires, in the development of the cVPP. They invited inhabitants from the area to workshops to achieve this (van Summeren et al., 2020 and own interviews).

The later stages of operating the cVPP were also subject to the involvement of the wider community in governance and decision-making using democratic voting on all matters in the cooperative. In this way, the nature of the case study as an energy cooperative (with a supervisory board, democratic voting process, cooperative ownership etc.) can enhance the level of justice embedded in the use of the cVPP for ENCI.

The cVPP technology has helped the cooperative in achieving its goals in an indirect way. According to the secretary of LEN, ICT projects such as the cVPP have not per se helped Loenen Energy to achieve its goals. This project had a more technical element and not so much of achieving the goals of the cooperative. According to the secretary of LEN: 'Well, no, I see it more instrumentally. It is something you may need, especially at the CVPP. We hired an ICT firm to build this platform. So, it builds us an app and make sure it can be read. We needed to do this as part of the project design. The proposal we developed ourselves.' Loenen's ICT projects played an instrumental role in the achievement of their technical goals, owing to special circumstances which are not widely replicable. Interestingly, the MoRe model is picked up by Rescoop for fostering cVPP upscaling. The interview with the LEN secretary indicates that the technology of the cVPP is "something you may need" to overcome infrastructural/technical challenges.

3.3.3 Weert Energy Cooperative - Neighbourhood Battery

Weert Energy is an energy cooperative operating in the municipality of Weert in the Netherlands. Founded in 2013, the goals of this cooperative have been to contribute to the sustainable energy in the Weert region, generate and supply electricity locally at

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affordable prices for its residents and also support citizens in taking measures to save energy in their living environments.

Weert Energy owns a 1.5 MWp solar park, a 30,000 MWh wind park and a 614 kWh battery for power storage and exchange. Especially the neighbourhood battery and software for managing the battery and trading electricity is special. The battery helps the cooperative to store electricity generated at the day time and make this available to its members in the evening (when the sun is not shining). The battery was also used for trading electricity, frequency stabilisation and peak shaving. Peak shaving reduces the need for heavier cables and avoids the loss of locally generated VRE when the grid is at maximum capacity. Partners in the project are Weert Energy, TNO/ECN/SEAC, Scholt Energy Services, Soltronergy and Weert Energy.

The project was co-funded by the Dutch government (via RVO), through a heavy subsidy. Peter Ramaekers from Weert Energy was involved in the project as project leader on behalf of Weert Energy. Peter Ramaekers (a founder of Weert Energy) is a retired professional with first-class technical expertise about energy matters and a lot of experience with writing funding proposals owing to his work as associate professor at the Technical University in Eindhoven and employee of TNO (the biggest independent research organisation of the Netherlands). After retirement, Peter Ramaekers wanted to apply the knowledge gained to the cause of a (local) energy transition, a topic to which he is very committed. Next to working for Weert Energy as an unpaid professional, Peter is part of the Hydrogen Coalition Limburg, where he is responsible for the creation of a hydrogen academy, in the form of knowledge modules on hydrogen applications at the higher education institutes (Zuyd, Fontys and HAN) and lower education institutes (Gilde, Vista). Next to possessing technical expertise on energy matters and experience with writing grants, he is an active networker and very effective in that capacity.

The battery project (called COOP-Store) is the largest battery project of an energy cooperative in the Netherlands, it also was the first one. The battery project started in 2015 and in 2016 Weert Energy entered into a partnership (battery consortium) with SEAC/ECN/TNO, Scholt Energy Services, Soltronergy and Chematronics. A subsidy was obtained from RVO (the Dutch agency responsible for the implementation of innovation policy) for testing and running a "neighhourhood" battery in combination with large-scale power generation. The demo phase for the solar park and the battery unit started in September 2018 at the Altweerterheide site (a local meadow). In 2019 the solar park with 5,200 panels (more than 1 MWp) with "neighbourhood" battery of 612 kWh (costing 450.000 Euros) went into operation (Figure 10). The Lithium-Ion battery was put in a sea container. A second sea container contained the converter and a third container was used as a visitor center. Cyclists can charge their electric bicycles for free with green energy from the solar park. Hikers and cyclists can take a break at the picnic table. At a display they can see what the solar park is currently yielding.

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Figure 10: The 612 KWh battery of Weert Energy and solar park[16]

The goals of the project were: to learn about the operation of the battery, the money to be made from peak shaving and frequency stabilisation and to gain operational experience with getting all the right permits. The task of peak shaving and energy trading was outsourced to a commercial partner (Enpuls), who uses an algorithm for this. The experiences revealed that frequency stabilisation makes the most money.[17]

Knowledge issues are dealt by Weert Energy via a knowledge platform that meets every two weeks. The people involved are people with a technical background who are presently retired. The knowledge is being shared with other cooperatives via REScoop Limburg (created by Weert Energy, Leudal Energie, Peel Energie and Zuidenwind). Thanks to lobbying of (mainly) REScoop Limburg, the Province of Limburg adopted the

16 Source: COOP-STORE 2019.
17 Source: https://www.enpuls.nl/media/cjib33nd/eindrapport-peakshaving-pilot-altweerterheide.pdf accessed 16.05.2023.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022492.

following two principles: that wind farms should preferably be developed and operated cooperatively and that the majority of the returns should remain in the local economy. Weert Energy (via Windpark Weert bv) is adhering to this principle: it will pay 1 Euro for every MWh generated at the new wind park which was completed in 2022. This amounts to a sum between 25.000 and 30.000 Euros per year. The wind park is a joint undertaking of Weert Energy and Eneco a large (commercial) energy distributor and producer in the Netherlands (who is also active in Belgium and Germany.) Weert Energy also sells power via OM New Energy, a renewable energy start-up.

Figure 11: Weert Energy's wind park[18]

As member of the Hydrogen Coalition Limburg, Peter Ramaekers is investigating the role of hydrogen in the local energy system of Weert and beyond. He is also looking into tax issues in relation to distributed power generation. He considers the existing tariffs for grid connection and tax treatment of energy cooperatives unfair. He feels that energy that is being created by and for members of a non-commercial energy cooperative should not be taxed.

In general, ICT for the energy system is very much oriented towards the big players and it is hard to change this. ICT for Smart Grids are heavily pushed by technology suppliers and utilities, with support of science and government. The Weert Energy battery project is not going to change this. Transformative impact is achieved not so much via ICT but via the efforts of people who organise themselves and undertake local projects of power generation and energy reduction advices, who engage in lobbying and knowledge sharing for local energy systems. In terms of the types of citizenship developed in D2.2, Weert Energy consists of a mix of ideal-types 7 (*Do their Share*), 8 (*Do their Job*) and 9 (*Go Ahead*). It also empowers individual citizens to *Do their bit* in the household (ENCI type 1). It is amazing what Weert Energy managed to achieve in terms of going to scale in the 10 years of its existence. Starting as a small cooperative in 2013 with members offering energy saving advisory services to citizens of Weert through energy coaches, it developed into an organisation owning a 1.5MWh solar park with a big battery, a 30,000 MWh Windpark and all kinds of collaboration in the Netherlands (Figure 11). In Weert, it operates the Warm Wonen Winkel, an information centre in a building owned by the Municipality.

18 https://www.enpuls.nl/media/cjib33nd/eindrapport-peakshaving-pilot-altweerterheide.pdf https://www.enpuls.nl/media/cjib33nd/eindrapport-peakshaving

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Special ICT is being purchased for the battery. The trading of energy via special software and smart metering technology is contracted out to a company (Enpuls).

3.3.4 The energy roundabout in Ameland

This case is where a large energy cooperation on the Dutch island of Ameland is working with the municipality and various knowledge institutes and commercial parties to create a more sustainable island based on distributed energy resources, with the help of a smart grid (Called the energy roundabout) and a long-term political strategy of phasing out the use of natural gas.

Ameland is one of the five Wadden Islands (see Figure 12, located in the North of the Netherlands). With 2.2 million overnight stays per year, it is an important tourist attraction. The island has near 600,000 visitors a year and many of its people (3600 inhabitants) are working in the tourist sector. The island has a successful history of energy citizenship actions (thanks to various organisations) and has expressed the goal of being a frontrunner in the energy transition.

In Ameland, 300 households are member of the Ameland Energy Cooperative, which has 1000 customers. AEC owns a big solar park with 23,000 panels, together with Eneco. The deal was co-financed through bonds held by 80 AEC members. The 6 MW solar park was realized despite restrictive legislation from the province of Friesland that only allowed solar energy on roofs. The plan reflects an interest in becoming energy autonomous and phasing out natural gas.

Figure 12: Ameland island, The Netherlands[19]

The following civil society organisations played an important role in the commitment of Ameland to shift to sustainable energy: AEC (Amelander Energie Coöperatie) and Dorpsbelangen. Both organisations organise meetings about making Ameland sustainable, with special attention to sustainable energy. In 2007, the Covenant Duurzaam Ameland was being signed, involving the following partners: AEC, Hanzehogeschool Groningen/EnTranCe, TNO, Liander, NAM, Gasterra,

-pilot-altweerterheide.pdf //en.wikipedia.org/wiki/Ameland" https://en.wikipedia.org/wiki/Ameland, accessed 12.05.2023

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Municpality Ameland and Interreg Deutschland-Nederland and SAVE. The smart energy vision is portrayed in Figure 13 and details about the smart grid are offered in Figure 14.

With the help of AEC, Ameland embarked on an Island-wide campaign to reduce energy use in houses and shift to low-carbon energy. The following statistics reveal what has been achieved:

- 1200 households received energy advice from energy coaches.
- 120 savings measures for municipal rental properties;
- 45 methane fuel cells are being installed;
- the Amelander Energie Coöperatie has 300 members and 1,000 customers (serving the majority of the households)
- the solar park Ameland BV has 80 bondholders
- the Sustainable Construction Desk offered 350 home recommendations

At special meetings, called "charettes", energy options and ambitions were discussed. This helped to create support for large techno-economic projects such as the solar park and the creation of an energy roundabout, a smart grid system which helps to deal with irregular supply of renewable energy and irregular demand over the year.

Figure 13: Ameland Energy Network: Future-proof, implementable energy network with smart management[20]

The energy roundabout is a test case for energy self-sufficiency and includes a 3 MW battery, a digester to produce biogas and a 1,5 MW electrolyser to produce hydrogen. Original plans for the production and use of hydrogen faltered, leading the actors to look for an alternative plan. The (revamped) hydrogen project is an official innovation project called H2Watt, undertaken with the active support from FME the national association of

20 Source: https://ec.europa.eu/programmes/erasmus-plus/project-result-content/c8b2e685-fa45-4e2d-b3c6-c03ef2ee7f1d/O12%20ameland%20presentation%203%20june%202019.pdf accessed 17.05.2023

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tech-companies. Risk issues were discussed and proactively dealt by FUMO and the fire brigade.

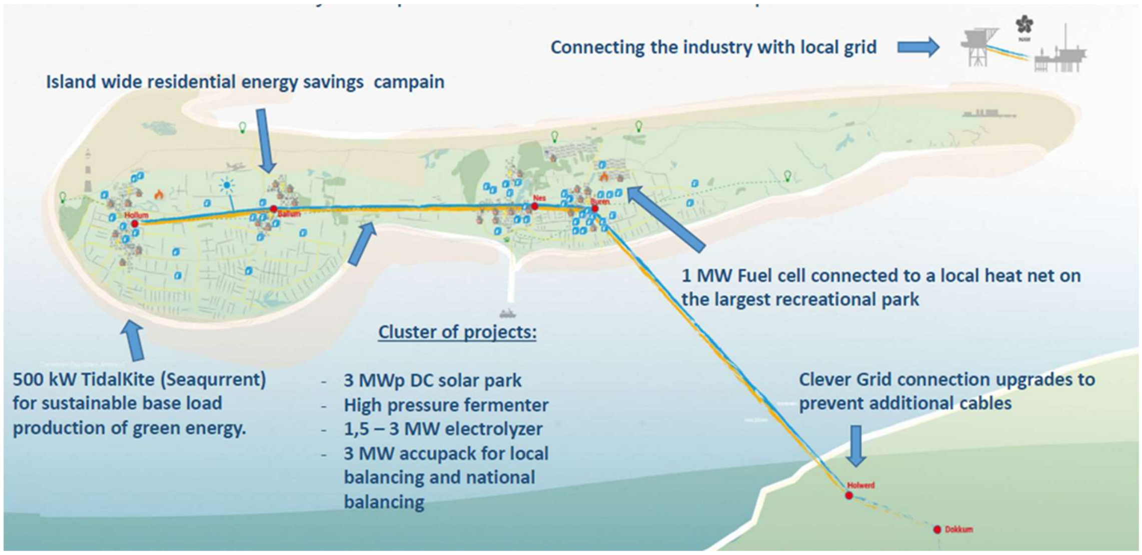

Figure 14: The Ameland energy system[21]

Jakob Dijkstra from Borndeep Energy played an important role in getting different parties to collaborate. In several ways, he can be considered an energy citizen. Dijkstra worked for many years for the Municipality of Ameland as energy expert, which resulted in a civil service mentality. At his lecture, he said he is very devoted to sustainable energy and that he would never work for commercial companies, because 'they are primarily interested in making money from their own products'. He played an important role in the realisation of the energy roundabout, which required the cooperation of many actors. Cooperation was achieved with the help of an energy input and output model for the use of hydrogen, created by Dijkstra.

A model for hydrogen projects served as a boundary object for discussions about costs (an issue on which different parties held diverging beliefs) and the need for balancing the net and matching demand with supply (through hydrogen and other options). The deliberations about costs and volumes during model-based sessions fostered collaboration and collective decision making, thanks to a collective action frame, which was created in the process. This shows the importance of direct deliberations with key stakeholders and the crucial importance of a model for experts and a knowledgeable intermediator.

The energy roundabout, based on ICT for measuring and managing energy demand and supply, obfuscated a costly expansion of the grid following the (planned) creation of a second solar park in 2023. Hydrogen was valued for its ability to store electricity, stabilise the grid and for meeting peak demands. It can also be mixed with natural gas, thus

21 Source: Jacob Dijkstra presentation for WCL meeting "Agenda formation about uncertainty" on 13-4-2023.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022492.

reducing the need for natural gas. For the province of Friesland and the association of tech-companies (FME) the hydrogen pilot is an important pilot project. It was subsidised via various sources.

On Ameland, all 1,600 permanently-inhabited houses of 3600 inhabitants received a heat scan. “Kitchen table talks” were held at 1,200 households, involving a genuine conversation. Households who undertake measures generally fall into the do their bit category (type 1 of ENCI) but in a strongly facilitated way. An important ENCI organisation is the Ameland Energy Cooperation (AEC). With 1,000 customers and 300 members AEC is a relatively large energy cooperation.

The activities were more than energy projects. People from Ameland are proud of their solar park, which was for many years the largest solar park in the Netherlands. They were opposed to the use of wind power, because of visual issues (the solar park was situated next to the local airport), which led them to opt for a solar park and the creation of energy roundabout. Fact sheets were created for energy options and citizens were consulted on big plans and to discuss issues of safety and costs and individual and joint responsibilities for the energy transition.

The presentation by Dijkstra included the following do's about interacting with citizens:

- Not only involve people but really listen to them
- Create a viable business case for business organisations
- Enrol colleagues into new ways of thinking and doing
- Do not claim success for yourself, but give everyone credits for successes achieved
- Don’t invent everything yourself
- Avoid complicated language and do not use thick reports
- Really do it together (small projects wherever possible, and big projects which are necessary)
- Create space for imaginative thinking, dare to do something bold.
- Give chance a chance in dealing with problems and opportunities (surprises are unavoidable)

He also had the following tips (pointers) for (technical) professionals:

- Get the facts of would-be systems right, put them on a ‘cheat sheet’[22] and use them when negotiating with suppliers.
- In making the biggest impact possible, start with the smallest meaningful unit (often a household) and scale upwards.
- Think big, act small, scale fast in an endurable way. Have a big appealing vision, but take a modular approach for moving forward. Make sure you can connect systems. Do not put all eggs in one basket.

[22] A cheat sheet is an excel file which can be ’manipulated‘ (used for doing technical calculations). The word cheat is not to be taken literally!

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- To solve problems, define the right problems to focus on. Attention to the first bottleneck will avoid cost overrun and loss of valuable time.

The above lessons may not apply (in the sense of being relevant) for all cases. In the transformative agency workshops (organised for Task 4.4), we hope to compare these with the lessons drawn by others and the institutionalisation of various lessons by (through intermediaries and trainings and documentation).

Smart grids are often viewed as technological interventions, overlooking that a critical aspect of smart grid is to secure the cooperation of many actors. In Ameland this was achieved via the help of a model, the political wish to become more energy independent and changes in energy generation and use (such as a new solar park). Citizens can develop into opponents or bystanders if their concerns are not taken up. The broad deliberation process in Ameland and the actions of an active energy cooperation (AEC) and Ameland municipality helped to create support for the energy transition process, which, as a result of this, became more democratic and fair. Various key individuals played an important role: a previous Maire who acted as a strong advocate for the solar park built in 2015, several civil servants and Jacob Dijkstra, each of which possessed energy citizenship qualities, next to problem-solving capacities.

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4 Conclusions

The research conducted as part of the Energy PROSPECTS project, reveals a number of interesting conclusions. The data gathered and analysed highlights how smart grids based on ICT may enhance the transformative agency of energy citizens, but the IT part of ICT is lacking widespread prominence in ENCI cases. ICT infrastructure has sharply risen in terms of its application within ENCI in recent years, even when it was not specially oriented towards energy cooperatives. Smart grids offer opportunities for renewable energy generation and energy sharing to energy citizens. The state of the energy sector could radically change with the ever-increasing adoption of supply-demand matching ICT tools (e.g., smart grids) and data management tools (e.g., smart meters/sensors), coupled with the use of battery storage technologies.

The Smart Grid according to the IEEE "is an automated, widely distributed energy delivery network characterized by a two-way flow of electricity and information, capable of monitoring and responding to changes in everything from power plants to customer preferences to individual appliances".[23]

The results presented in this report also highlights how smart meters and network sensors are an integral aspect of smart grids, together with algorithms for energy system management. The form of ICT most commonly used within these ENCI cases is for 'community self-consumption' (22% of 596 cases featured this form). This form of ICT captures technological systems that allow a community or a group of people to generate and use their own renewable energy locally. In these systems, ICT is important for the purpose of management and optimisation of energy distribution and consumption. Certain ICT tools are adopted to achieve this aim, such as smart meters, energy management systems, and data analytic software. If surplus energy is generated, ICT tools play a role in either storing the surplus energy in a battery or feeding it back into the grid.

The second most used type of ICT encountered in the ENCI cases are 'ICT platforms' and 'Digital smart meters' (both technologies appear in 14% of cases). In this typology, 'ICT platforms' refers to tools such as an energy management system (EMS) which an ENCI case can use to manage their resources more efficiently and effectively. The functions of EMS tools can include the monitoring and management of energy production, consumption, and storage. These systems can also provide real-time data and analytics, helping ENCI cases to optimize their energy use and reduce costs. Examples of ICT platforms in the cases studied are the online energy dashboard in dormitories adopted

23 Source: https://www.incite-itn.eu/blog/an-evolution-towards-smart-grids-the-role-of-storage-systems/ accessed 16.05.2023.

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by ‘Student Switch off Campaigns in Bulgaria’ and ‘Somenergia-opendata’ which organises information about the energy cooperative, Som Energia. EMS technology is used in the community Virtual Power Plant, ‘DE-centrale’, in Loenen and the 'Energy Transition of the City of Burgas’ case, wherein the municipality of Burgas adopted a building EMS in the main municipality building. The Burgas case also involved IoT for smart energy management in other buildings in the city.

‘Digital smart meter’ technology was mentioned in 14% of the 596 cases. This form of ICT refers to energy meters that use advanced digital technology to measure and record electricity consumption and communicate with other systems in the energy grid. Unlike traditional meters, which require manual readings and can only measure overall energy consumption, smart meters can provide real-time data on energy use and can communicate that data to utilities and energy consumers. This form of ICT was used by ‘Som Energia’ energy co-operative to help households monitor and save on their energy bills (‘SomBots’). Smart meters were also used as part of country-wide national programmes. For instance, in Ireland, the ‘Energy Communities Tipperary Cooperative’ reports the national roll-out of smart meters in domestic residences, as potentially beneficial for the case and their aims if residents can be sufficiently educated about the technology.

One of the most interesting ICT cases encountered is the battery project of Weert Energy, an energy cooperation in Weert. It is the largest battery project of an energy cooperative in the Netherlands. The battery project began in 2015 and gained speed in 2016 when Weert Energy entered into a partnership with various battery/energy companies and institutes. A subsidy was obtained from RVO for testing and running a “neighbourhood” battery in combination with large-scale power generation. In 2019 the solar park with 5,200 panels (more than 1 MWp) with “neighbourhood” battery of 612 kWh (costing 450keuro) went into operation. The goals of the project were to learn about the operation of the battery and money to be made from peak shaving and frequency stabilisation and to gain operational experience with getting all the right permits.

We were unable to study several aspects of ICT aspects in greater detail , due to the (very) wide scope of the case study analysis. However, the evidence indicates that ICT use is often associated with various institutional and techno-economic problems that have to be dealt with. These barriers take various forms. Collective citizen energy storage systems (e.g., neighbourhood batteries) face difficulties because they are costly and subject to complicated institutional rules. On a more technical side, the need for interoperability can create difficulties. Interoperability can manifest, for example, in the lack of standards for application programming interfaces (e.g. API) of DER. This was experienced by Energy Cooperative Loenen in their attempt to use an EMS to control a diverse portfolio of DER in the area wherein the connection to certain DER brands was too costly. Other technical issues include: over-prevalence of PV-based projects (lack of hybridity, SECs not making full use of local RESs), over-emphasis on electric energy

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sharing (lack of multi-vector energy sharing), lack of multi-user types for energy sharing, lack of diversified ESSs adopted (Ceglia et al., 2022). In addition to the technical, institutional and economic barriers observed, social barriers too are limiting the potential for ICT to play an enabling role in ENCI. ICT is quite bewildering to people, in particular the IT software and hardware require special competence, calling for user-friendly applications (as a target for innovation). Energy informatics can be designed in a way for ease-of-use, with intuitive visualisations and the simplification of complex technical information by addressing subjective / qualitative constructs, enhancing ENCI actors' capabilities. Another barrier is that ICT developers face challenges in scaling up the technology due to factors such as lack of meaningful involvement of citizens (Van Summeren et al., 2021).

Overall, the barriers limiting the role of ICT for ENCI can be understood as a product of the fact that energy markets have evolved with the structure of centralised large power plants, so they are inherently unfavourable for the new and emerging structures of decentralised energy systems. This is seen in the way that energy market participation is most accessible for large-scale actors. This has implications for the way ICT is used by ENCI.

Previous studies show that even though ICT helps ENCI actors to collaborate with other actors in the energy system in order to achieve the scale necessary to participate in the energy market, this collaboration with regime actors can be hindering for ENCI, in forcing them to accept the terms set by others (in the form of prices and taxes to be paid). An example is illustrated in the way energy cooperatives have to comply with the incumbent energy system in cVPP projects and cannot keep their own needs, values and goals as a result (van Summeren et al., 2020). In the transition literature this is known as 'fit and conform' (Smith and Raven, 2012). On the other hand, ICT can be used to enable institutional change through enhancing decentralised ways of consuming/producing/ trading energy ('stretch and transform'). A third possibility is also possible. Strategic action on the part of ENCI actors could result in a hybrid 'fit and transform' strategy in which they fit into the incumbent system in the short-term, while also contributing to its transformation over the longer-term (Van Summeren et al., 2021). Some initiatives are working toward this aim. As an example, Loenen Energy collaborated with DSO Liander and its subsidiary Qirion to achieve their community VPP project. This made the institutional context more favourable for energy management by the cooperative and allowed them to draw on the partners' resources and lobbying powers. However, collaboration is not always achievable. The EnerGent energy cooperative wanted to collaborate with DSO, Fluvius, because their grid management practices were a major barrier for the cooperative, but DSO was not keen to collaborate. Because of this, the case turned to using small-scale individual batteries to mimic a collective virtual neighbourhood battery and achieve energy management as a result (van Summeren et al., 2021).

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Scale is a critical parameter for achieving energy system change. Both examples illustrate the issue of needing scale to participate in the energy market. This means that a high number of DER should be involved, or one large cooperative entity must be responsible for operating the ICT or participating on behalf of multiple communities or actors. The growing involvement of citizens in smart grids, as co-investors and co-owners of ICT, may improve their transformative agency. The same is true for the availability of open-source software. Close ties and trust are important issues too (not so much for achieving scale but as key aspects of ENCI irrespective of their usefulness for system change).

From a critical-societal perspective, one might ask *who* do these ICT tools ultimately serve, and what may be the unintended, or hidden side-effects of their widespread adoption? For instance, in promoting smart meters, appliances and grids, is the EU Clean Energy Package (2019) concerned primarily with flexibility in the electricity market, or the economic well-being of citizens? It is clear from the case studies that a smart grid algorithm can serve both ends, however, there could be an unintended consequence of increasing disassociation of individuals from the energy system itself. This is evident from increasing passivity of dwellers when smart grid technology can manage their household's energy use 'in the background', based on the electricity availability in the grid. In Deliverable 1.1, explicit attention is given to the delegation of agency to technology (as a passive form of ENCI). It may be worth asking how the convenience introduced by ICT reconciles with the more active, community-building nature of energy cooperatives and other community-based ENCI forms (Laes & Bombaerts, 2021).

However, from the analysis within this deliverable, such a contrast was not described by ENCI actors. Any lack of prominence of ICT within ENCI cases, like energy cooperatives, appears not to be due to a lack of desire on their part to introduce these tools. The cases which are more advanced in applying ICT tools appear to be those who had previous technical expertise in the community (e.g., Weert Energy working group, and Loenen Energy's collaboration with scientist). Hence, it appears that energy literacy (which includes technical expertise of different sorts) may be a significant precondition for the role of ICT in ENCI. This deliverable also unveiled the importance of financing for the use of ICT. The small number of advanced ENCI cases involving technology all benefited from generous funding made available for innovative pilot experiments with novel technologies. However, this kind of ad-hoc, experimental funding is not realistic for scaling the use of ICT tools to most communities.

The pilot ICT-based projects involving sophisticated technology are very special projects, which owed a lot to special circumstances: generous funding, collaboration with knowledgeable actors on a non-commercial basis (in innovation projects) and the presence of exceptionally active and knowledgeable participants. ENCI does not always require IT. For the majority of the ENCI cases this was very important – just to put the ICT-based projects in perspective. Especially projects that do not involve energy trading, ICT (especially IT) is less important.

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4.1 Smart metering deployment in the EU

The EU is taking measures to enhance the deployment of smart metering and smart grids in member states.[24] There has been some opposition to this government-initiated smart grid movement, for example a court ruling in the Netherlands ('stop smart metering') concluded that people cannot be forced to accept smart meters. This shows that smart metering is eliciting a range of attitudes in response to its deployment in the EU.

This deliverable has also pointed to the discrepancies that may exist in terms of the characters of citizens who tend to be engaging with smart metering in the EU. Specifically, smart meters appear to be most appealing to those that are well educated, high-income earners, and living high convenience lifestyles. On the other hand, access to ICT tools like smart meters is less possible for individuals struggling with energy poverty and income inequality. While equal accessibility to technology is an important topic, smart meter deployment may not be fully necessary for all, from the perspective of meeting the climate targets within the EU. This suggests that there may be an overemphasis on smart meter deployment in the EU at the expense of more impactful and larger-scale measures targeting energy use reduction.

4.2 Simplification of technological tools and acceptance of their limits

Engagement with the electricity grid by citizens requires a certain level of expertise. Many of the initiatives have obtained relevant expertise. In addition, schemes and businesses are emerging to make the adoption of domestic technological renewable energy infrastructure (e.g., solar panels, home-batteries etc) simpler for the average citizen. In the case of Ameland, striking results were achieved in terms of encouraging citizens to invest in home insultation measures, heat pumps, and the use of large-scale solar power generation which is co-funded by citizens and linked to a smart grid involving energy system management using batteries, hydrogen and biogas digesters. The broad deliberation process and the actions of an active energy cooperation (AEC) and Ameland municipality helped to create support for the energy transition process, which, as a result of this, became more democratic and fair. For energy trading, ICT is an important enabler but for achieving justice and democracy it is not always necessary. ICT may lead people into passivity or money-driven behaviour (in smart grid configurations). An important issue for (further) investigation is the evolution of NCI projects and ENCI more generally.

24 Source: https://energy.ec.europa.eu/topics/markets-and-consumers/smart-grids-and-meters_en accessed 16.05.2023.

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Appendix 1

Do (did) specific types of ICT[25] help/enable the ENCI case to achieve its goals and how? What type of ICT technologies are (would) be required so that the case actors can achieve their goals and how?[26]

Types of ICT used Please select the ones that are relevant.	**Details about the ICT technologies used** Regarding the specifications / algorithms / architecture, conception and functioning, etc.	**How did these ICT technologies help/helped the case achieve its goals?**
☐ Community self-consumption		
☐ Peer-to-Peer energy trading within communities		
☐ ICT platform (Energy Management System – EMS)		
☐ Demand-response		
☐ Decentralising trading platform e.g. Blockchain		
☐ Aggregator of flexibility		
☐ Smart grid		
☐ Digital smart meters		
☐ Virtual Power Plant		
☐ Other, please specify:		

25 Some ICT case examples: community self-consumption platforms, peer-to-peer energy trading within the community, ICT - Energy Management System, decentralising trading platform - blockchain, digital smart metering, aggregator of flexibility.

26 Examples of how an ICT technology can help cases achieve their goals can be: 1) Through dedicated algorithms on a fair allocation of value; 2) Dedicated support networks to incorporate ENCI in (new) ICT technologies; 3) Through transparent and fair rules on designing ICT technologies together with citizens and their needs; 4) Making ICT platforms user and citizen centred; 5) Increasing scale of the ICT technology by working together with citizens (or energy communities); 6) Apply real time energy prices; 7) New ways for enabling neighbourhood batteries; 8) Simplify collective-citizen energy storage systems that are not located 'behind the meter' of households.

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Appendix 2

List of other ICT technologies mentioned

- Demand-response: La Borda's automated greenhouse roof technology (opens or closes based on weather conditions)
- Decentralising trading platform - GoiEner is investigating the potential for blockchain technology
- Aggregator of flexibility - Loenen Energy: Wattflex pilot
- Smart grid
- Intelligent system for monitoring energy consumption (La Borda case)
- The network operator's smart grid (Liander) benefits Loenen Energy indirectly
- VPP:
  - Loenen Energy cVPP
  - ECTC is investigating the potential for a VPP
- Other category:
  - Media/social network channels
  - Communication technology
  - Collaboration/participation platforms
  - 'Domotica systems'
  - Billing/consumption/purchasing platform for energy users
  - Neighbourhood battery technology
  - Carbon calculation technology
  - Investment platforms
  - Internal management platforms / systems for data management
  - Drone – for capturing footage
  - Hydrological measurement technology

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