Prescient building Operation utilizing Real Time data for Energy Dynamic Optimization

WP8 – HOLISTIC SUSTAINABILITY STRATEGY

D8.1 – New business landscape definition

Version 2.0

Issue date: 30/05/2023. Version 2.0: 04/10/2023 (after RP2 review)

Author(s): Jussi Valta (TAU), Kimmo Lummi (TAU), Tuukka Huosianmaa (TAU), Juha Koskela (TAU), Pertti Järventausta (TAU), Rasmus Suojansalo (TAU)

Editor: Jussi Valta (TAU)

Lead Beneficiary: Partner 2 – TAU – TAMPEREEN KORKEAKOULUSAATIO SR

Dissemination level: Public

Type: Report

Reviewers: Dimitris Makris (EUROCORE), Ana Fort (INCOTEC)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 958345

PRELUDE KEY FACTS

Project Title	**Prescient building Operation utilizing Real Time data for Energy Dynamic Optimization**
Starting date	01/12/2020
Duration in months	42
Call (part) identifier	H2020-NMBP-ST-IND-2020-singlestage
Topic	LC-EEB-07-2020 Smart Operation of Proactive Residential Buildings (IA)
Fixed EC Keywords	-
Free Keywords	Free running, model based predicted control, dynamic building simulation, demand side flexibility, proactive buildings, predictive maintenance, occupancy models, smartness assessment
Consortium	21 organisations

PRELUDE CONSORTIUM PARTNERS

	Participant organisation name	Country
1	AALBORG UNIVERSITET	DK
2	TAMPEREEN KORKEAKOULUSAATIO SR	FI
3	ASOCIACIÓN DE INVESTIGACIÓN METALÚRGICA DEL NOROESTE	ES
4	POLITECNICO DI TORINO	IT
5	FORSCHUNG BURGENLAND GMBH	AT
6	UNISMART - FONDAZIONE UNIVERSITÀ DEGLI STUDI DI PADOVA	IT
7	BRUNEL UNIVERSITY LONDON	UK
8	EMTECH DIASTIMIKI MONOPROSOPI IDIOTIKI ETAIREIA	EL
10	ESTIA SA	CH
11	EUROCORE CONSULTING	BE
12	IREN SMART SOLUTIONS SPA	IT
13	LIBRA AI TECHNOLOGIES PRIVATE IDIOTIKI KEFALAIOUCHIKI ETAIREIA	EL
14	STAM SRL	IT
15	LA SIA SRL	IT
16	TREE TECHNOLOGY SA	ES
17	1A INGENIEROS S.L.P	ES
18	DIMOS ATHINAION EPICHEIRISI MICHANOGRAFISIS	EL
19	BLOK ARCHITEKCI SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA	PL
20	CAISSE DE PREVOYANCE DE L'ETAT DE GENEVE	CH
21	INNOVACION Y CONSULTING TECNOLOGICOSL	ES
22	CORE INNOVATION CENTER NPO	GR

EXECUTIVE SUMMARY

This Deliverable of the PRELUDE project studies the business landscape for the PRELUDE solution. The technological development of wind and solar power, heat pumps, electric vehicles, sensors, and telecommunications systems has been rapid, and the prices are expected to decline even more in the future.

Relevant EU regulation is rapidly developing with new proposals to accelerate climate targets and reductions to the use of Russian fossil fuels are supporting the PRELUDE solution. The EU packages (Fit-for-55, Renovation Wave) that were aimed at COVID-19 recovery have led the way to the REPowerEU package. Also, the energy crisis during the winter of 2022 led many customers to increase their energy-saving efforts.

However, countries have different energy and climate policies, and existing infrastructures differ remarkably, for example, regarding the deployment of smart meters. Smart meters play an important part in creating demand response capable ecosystems with retailers providing dynamic tariffs and service providers creating solutions for the end-users. The diffusion of dynamic tariffs is supported by directives and regulators, meaning that the full benefits from these meters will appear more clearly when controllable loads like electric vehicles are diffused.

Home energy management systems (HEMS) providers are emerging with business models based on a subscription contract, by which HEMS is provided as a service to the customer. Optimizable issues in the business model design are the scope of the ecosystem and who builds the ecosystem. Either the ecosystem is built by the customer or the HEMS solution provider, and either the ecosystem is very large or very focused. With lead users, it is possible to offer a very limited service, such as a control signal, from which the users can develop their own solutions, yet mass markets work differently. The lead users are typically technically oriented people who own their houses or summer cottages and have controllable loads like electric vehicle chargers. A related optimizable decision is on positioning in hardware/software. There are also licensing costs related to data access from electricity markets.

On the district level, the business landscape is unclear, but the role of public actors is emphasised due to the connection with urban planning policies and other municipal processes. In addition, European directives support district-level solutions by pushing member states to establish different energy community legislations, reviewed in chapter 3.4. These energy communities need to optimise between different value streams, ranging from collectively owned energy production to flexibility services to the grid. In general, the business opportunities in district-level solutions shift towards offers that can bridge distributed and centralised energy solutions. Policy options, reviewed in Chapter 2, influence these business models, but they need to balance between policies supporting flexibility and self-consumption. The case studies conducted in Finland show that the identity of district-level energy communities is based on sectoral integration and data-based solutions, however, more grassroots-based projects can have more social and environmental identities. Distributed solutions may destroy some value from centralised solutions, and finding the best use of both resources would lead to the best outcomes.

Overall, the PRELUDE business landscape can be defined in three principles:

- PRELUDE is realised by multiple stakeholders who are shifting positions in the value chain.
- Data management can add significant value but must be managed efficiently.
- Regulation is evolving towards incentives for smart energy utilisation also outside one property.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

BUC	Business Use Case
CEC	Citizen Energy Community
D	Deliverable
DR	Demand Response
DSO	Distribution System Operator
EC	Energy Community
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certification
ESCO	Energy Services Company
ETS	Emission Trading System
EV	Electric Vehicle
GA	Grant Agreement
Haas	HEMS as a service
HEMS	Home Energy Management System
HVAC	Heating, Ventilation, and Air Conditioning
JARC	Jointly Acting Renewable Self-Consumers
NECP	National Energy and Climate Plans
PV	Photovoltaic
RE	Renewable Energy
REC	Renewable Energy Community
RES	Renewable Energy Sources
RET	Renewable Energy Technologies
TSO	Transmission system operator
V2H	Vehicle-to-home
V2L	Vehicle-to-load
VPP	Virtual Power Plant
VRE	Variable Renewable Energy
WP	Work Package

1. INTRODUCTION

This deliverable explores PRELUDE's business landscape. PRELUDE creates a data-driven service for building energy optimisation with low-cost technologies. This includes a set of optimised functions in buildings: indoor quality, renewable energy (RE) self-consumption, HVAC system optimisation, big data analysis, and free running strategies in passive solutions. PRELUDE's Business Use Cases (BUCs) are divided into four: real-time energy monitoring, predictive maintenance, facilitation of aggregation business in buildings, and renovation roadmaps.

This report has a dual structure: on the one hand, it studies the macro-level development of regulatory frameworks and recent market trends. On the other hand, it studies local-level dynamics in the business environment. Business models are an overarching theme with the division to value proposition, value delivery and value capture elements. At the building-level, chapter 3.3. introduces the perspective of the HEMS (Home energy management system) service provider, and 3.2. introduces the BUCs being developed in the PRELUDE project through the case study in Geneva.

Energy communities (ECs) are a central development related to PRELUDE, and these case studies help to positioning it in the evolving business landscape. Economic analysis is performed on EC models, with different loads and regulations. To make sense of the evolving field and relations between building-level solutions, there is a review and analysis of the different value streams in upcoming EC models. There are also case studies on the district-level solutions being developed in Finland which are using strategic niche management and ecosystem legitimation approaches.

These deliverable covers: theoretical exploration of business landscape topics; secondary research on relevant standards, politics, and regulation; case studies on emerging service providers in the HEMS business sector, Prelude demo sites, and case studies in other projects; and economic evaluations, based on simulations done in Matlab.

2. MACRO-LEVEL BUSINESS ENVIRONMENT

2.1. Recent developments in the PRELUDE business environment

Currently, the changes in the energy market are significant and fast. The adoption of electric vehicles, heat pumps, and distributed solar PV are rapidly changing the customer role, but also the system requirements on who they are integrated into the system. The heat pump market grew globally by 11% in 2022; in Europe, the growth was 40%, hitting 3 million units (Monschauer et al., 2023). Heat pump diffusion is set to be accelerated by including heating fuels in the Emission trading system in 2027 and national targets for phasing out fossil fuel-based heating. The electric vehicle (EV) market in Europe grew to 34% in 2022; approximately half consists of battery-EVs and the other half of plug-in-EVs (Euronews 2022). The solar PV market also experienced a 45% increase in 2022 (SolarPower Europe, 2022).

In addition to these small-scale investments from the grid edge, centralised renewable energy is rapidly gaining a market share in Europe: the solar PV market is soaring with 47% growth in 2022 (SolarPower Europe, 2022). Also, the battery storage market is rapidly increasing, especially in markets like Germany, where the annual battery storage installations increased by 71% in 2022, of which 1614 MWh were residential (Rystad Energy Battery Solutions, 2023).

As the end-users adopt more and more distributed energy resources (DERs), the role of incumbent utilities and other stakeholders is challenged, and the need for further collaboration between these actors becomes more pronounced. As a result, new business models arise, such as IT platforms and utility-as-a-service business models. Simultaneously with the adoption of DERs, new markets for stacking value from them are opening up. (Loock, 2020) These options will be reviewed in more detail in chapter 3.4.

The increasing demand from end-users to invest in DERs and integrate them into the energy system opens doors for new service providers at the customer's end. These actors include aggregators, energy service companies (ESCOs) and EC/platform operators. Aggregators collect, coordinate, and make contracts with prosumers and their flexibility resources, and then operate in different flexibility markets with them (Kubli & Canzi, 2021). ESCOs offer energy as a turnkey service. They often make guarantees of energy savings, so from the customer's perspective the energy efficiency measures pay for themselves (Reis et al., 2021). EC operators help communities in governing and operating the local energy supply. This includes activities like managing community-owned assets, possibly with a market platform, providing supplementary energy to end-customers, stakeholder management with internal and external parties, and possibly aggregating flexibility resources (Schwidtal et al., 2022).

2.2. Applied standards in demo cases

The PRELUDE project is implemented and used by various stakeholders who follow different standards. Whereas some standards are general to many fields, some are very specific. These fields range from ventilation and air conditioning systems to Personal Data and Energy efficiency.

EUROCORE has summarised the different standards into a web page available here. This web page was created by receiving feedback from project members: TAU, AIMEN, POLITO, FB, EMTECH, ESTIA, LIBRA, STAM, TREE, BLOK. Note that this site is still a work-in-progress and might not include all relevant standards.

2.3. Recent development of the EU-level policies

The palette of EU policies regarding the PRELUDE solutions is wide and there has been an acceleration of policies since the COVID-19 crisis and the Russian attack on Ukraine. As a basis for all policy initiatives, there is the EU Green Deal (European Commission, 2019), initiated in December 2019, which states ambitions for climate neutrality in the EU by 2050. It has three main pillars (which are aligned with the PRELUDE solution):

- Power system security and adequacy,
- Digitalization for energy transition, and
- Consumer-centric sustainable transition.

Also, the transition is aimed at contributing to social cohesion, long-term growth and sustainability.

This initiative was influenced by the Covid-pandemic, and the package was accompanied by new proposals in a legislative package Fit-for-55 in 2021. In this package, the reduction of greenhouse gas emissions was set to 55% instead of 40%, which was previously set (compared to 1990 levels) (Maris & Flouros, 2021).

Furthermore, the EU launched the Renovation Wave Strategy in October 2020, which plans to improve buildings' energy efficiency and adoption of smart technologies while stimulating the construction sector and broader economy. It considers the importance of deep renovations, which happen only at 0,2% yearly fashion currently (European Commission, 2020). Also, staged renovation is mentioned and supported by tools like Digital Building Logbooks, Building Renovation Passports, Smart Readiness Indicators and EPCs (Energy Performance Certificate). This was accompanied by new financing streams, such as the Recovery and Resilience Facility. The public sector needs to approach 3% annual renovation rates (European Commission, 2020).

The Renovation Wave strategy is heavily interlinked with the Energy Performance of Buildings Directive (EPBD). This directive is currently being updated by the EU. The new proposal introduces a new policy tool: Minimum energy performance standard. The aim of the directive would be to improve the energy efficiency of the worst-performing building stock (Sunderland, 2023).

In 2022, the EU launched yet another plan, REPowerEU (European Commission, 2022b), in response to the Russian invasion, aiming to rapidly reduce the usage of Russian fossil fuels by 2027. For making heating and cooling sectors more renewable, negotiations between EU institutions have concluded that an average of 1,9% annual increase is needed (IEA, 2023).

2.4. Comparison of national policies related to PRELUDE

2.4.1. National energy and climate plans and renovation strategies

To implement the targets in the Green Deal, the European Union demands member states to declare their energy strategies and climate targets. Their task is to construct 10-year integrated plans, called National Energy and Climate Plans (NECP). These plans are wide and include plans for emission reductions, energy efficiency, interconnections, and R&D (Maris & Flouros, 2021).

Table 1. National renovation strategies and incentives (summarised from European Commission, 2021)

	Targets and financing needs
Italy	• Decarbonisation: By 2030: 32.7 Mton CO2 emissions (residential) 10.9 Mton CO2 emissions (non-residential); by 2050: 0.6 Mton CO2 emissions • Renovation rate: by 2030: 2% and 2.8 % (2020-2030) - non-residential; by 2040 and 2050: 2.6%. • By 2050 66% of the existing buildings renovated; 80% of the current non-residential buildings renovated. • Energy savings: By 2030: 0.33 Mtoe/year (1.14 Mtoe/y) savings – residential and 0.24 Mtoe/y savings non-residential; By 2050: 13 Mtoe final energy consumption (residential),11 Mtoe final energy consumption (non-residential) • By 2030: EUR 5-8.8 billion (2020-2024) available for municipalities to make buildings seismic safer/securer and more energy efficient • By 2050: Investment needs (2020-2050) for the residential sector: EUR 9-12 billion/year, investment needs (2020-2050) for offices: EUR 0.7 billion/year investment needs (2020-2050) for offices: EUR 0.5 billion/year.
Greece	• Upgrade 12-15% of buildings by 2030. • Renovation rate by 2050: 1.6% (doubling the 2015 one) • 45-49% of building envelopes in residential and 19-20% in non-residential buildings by 2050. • 28-40% Final energy demand reduction (vs 2015) by 2050. • By 2030: about EUR 10 billion per year • By 2050: up to EUR 20 billion per year
Poland	• Complete discontinuation of the use of coal for heating purposes (by 2030 in cities, 2040 in all residential buildings) • Phasing out the use of other fossil fuels, in particular natural gas for heating by 2050 (as key energy carrier by 2030) • 2 400 000 energy renovations during 2021-2022 • Stopping support for coal-fired heat sources in 2022 • Maintaining tax allowances for renovations and heat source changes. • Thermo-modernisation and Renovation Fund
Switzerland	• Most cantons provide subsidies of around 10 to 15 percent for energy-efficient renovations and the replacement of old heating systems (UBS Insights, 2022)
Denmark	• Reduction of heating needs by 35% by 2050. • A 100% fossil-free energy supply by 2050. • Energy consumption of existing building stock reduced by 50% • Investment needs are estimated at DKK 40.6-76.2 billion until 2050 (=EUR 5.3-9.9 billion) • Indicative milestones for the efficiency of the building stock • Saving an additional 1.4 TWh requires almost double the investment (DKK 76.2 billion vs 40.6 DKK) or 0.28 DKK/kWh vs 0.43 DKK/kWh saved
Finland	• The goal is for all buildings (residential and non-residential) to have an energy class of C or above by 2050. • Removing all vacant buildings from the building stock (by 2050, only 70% of the Finnish building stock will remain). • CO2 emissions reduced by 90% by 2050. • Implementing the strategy will cost EUR 24 billion over the course of 30 years, or EUR 800 million per year

Even though the criteria and methodologies of NECP are defined by the European Commission, making comparisons from the country profiles is rather difficult. For instance, renovation rate targets are in different ways. From the case countries, Maris & Flouros (2021) evaluate that Italy and Denmark have the most ambitious and clearly addressed NECPs. Greece and Finland are "fence-sitters", and Poland is seen as a "foot-dragger".

In addition to NECPs, the case countries have lately set out policy measures for protecting consumers and accelerating the energy transition from fossil fuels. These measures emphasise increasing the use of heat pumps and replacing gas heating systems.

Table 2. Long-term energy crisis subsidies (Sgaravatti et al., 2022).

	Long-term energy crisis subsidies
Italy	• €600 mn fund to help big cities implement Recovery and Resilience Facility objectives.
Poland	• MyHEAT programme (€130 mn) on heat pumps in new homes. Subsidies account for 30%-45%.
Denmark	• €33.6 million fund for replacing gas heating systems • Payment delays of energy bills over 5 next years
Finland	• Additional increase (26mm) in household tax deductions on heating system renovations

2.4.2. Energy communities

European directives on ECs were initially released in 2019, and member states are currently in the process of transposing them into their national legislation. Although the deadline for implementation was set for 2021, the sector is still undergoing development, and there are ongoing changes in the legal framework. The REPowerEU initiative has also played a significant role in accelerating the development of ECs. For example, the EU Solar Strategy sets a target of having at least one EC in every town with a population exceeding 25,000 people (European Commission, 2022a). These legislative measures originate from directives governing Citizen Energy Communities (CECs), Renewable Energy Communities (RECs), and Jointly Acting Renewables Self-Consumers (JARCs). The level of importance assigned to ECs as part of the energy system varies considerably among member states (Frieden et al., 2020). Table 3 provides an overview of the regulatory aspects and associated economic models of ECs in the countries under consideration.

Table 3. Energy community regulation and incentives in case countries (data collected from Frieden et al., 2020)

	Regulation for ECs	Economic benefits for ECs.
Italy	• REC perimeter limits are in medium voltage sub-stations. Max 1 MW capacity. • Collective self-consumption within condominium/building.	• Incentives for self-consumption: feed-in premium 0.11 €/kWh. 40% investment grants from the Italian Recovery and Resilience Plan (Krug et al., 2023).
Greece	• ”Virtual net metering “ • Law 4513/2018 on EC. Requirements on locality, openness, effective control etc. • Separation of for- and non-profit ECs due to hijacking by investors. • Separation of for- and non-profit ECs due to hijacking by investors. • Up to 3MW	• Savings from the taxes and network tariffs from electricity self-consumed behind the meter.
Poland	• “Energy clusters” as a civil law agreement • CECs limited to distribution networks with a rated voltage level of no more than 110 kV.	• Removal of consumption-based surcharges
Switzerland	• EC model in regulatory planning. (A private grid model “ZEV” exists)	• ZEV model’s pricing is regulated and cannot be higher than from the local energy provider. Larger apartment buildings get access to liberalised electricity markets.
Denmark	• Collective Self-consumption possible within a building.	• Savings from grid fees and taxes
Finland	• Collective self-consumption within boundaries of single property.	• Savings from grid fees and taxes

From the case countries, it can be seen that Finland and Denmark have chosen the pathway of promoting ECs within property boundaries with exemptions on network tariffs and taxes. Of course, Denmark has also long traditions in cooperative structures related to district heating and wind power. Greece was one of the frontrunners in the EC space with the virtual net metering law. Poland’s legislation is still under development, but there are plans for “energy clusters” which could benefit from district-level energy self-consumption. Switzerland has a rather special form of EC in their legislation. The ZEV model enables district-level ECs with private grids if all the buildings are behind the same meter.

2.4.3. Aggregation and demand response

Demand response (DR) can be divided into implicit and explicit DR (Saviuc et al., 2022). The implicit DR is based on customers’ reactions to variable prices, whereas explicit DR is facilitated by an aggregator who manages energy assets and operates them on different DR markets. Customers get payments from the aggregator if they act upon the aggregator’s request, yet these systems are typically highly automated. Independent aggregators are supported by the IEMD directive (EU, 2019).

For PRELUDE, aggregation possibilities are important for the BUC3, which requires that the markets are open for residential and commercial loads. PRELUDE's ability to combine diverse resources is important since aggregators need a sufficient and diverse portfolio of assets to be able to participate in DR markets. There is an interesting interlinkage between ECs and aggregators because ECs bundle many end-users, typically for self-consumption. However, using the same resources (especially batteries and automation systems), it could be possible to participate also in DR markets and in that way extend the EC's value proposition (Claeys, 2021; Di Silvestre et al., 2021). Summarising DR and aggregation regulation is a rather complex task because of the variety of potential markets and related rules concerning them. However, one way of evaluating the development on a landscape-level is to look at previous analyses on DR markets and how they have been summarised. Table 4 shows results from two different studies that compared DR markets in Europe (Lucinda Murley & Mazzaferro, 2022; Saviuc et al., 2022).

Table 4. Aggregation policies in the case countries

	ExDR possibility (Saviuc et al., 2022)	**Independent aggregator legislation** (Saviuc et al., 2022)	**Existence of Independent aggregators** (Saviuc et al., 2022)	**Regulatory progress in demand side flexibility** (Murley & Mazzaferro, 2023)
Italy	Yes	No	No	3/5
Greece	No	No	No	3/5
Poland	Yes	No	No	1/5
Switzerland	N/A	N/A	N/A	4/5
Denmark	Yes	Yes	Yes	4/5
Finland	Yes	Yes	Yes	4/5

The results of the DR legislation comparison show that Poland is lacking in the legislative progress. Italy and Greece, have made strong regulatory progress during last. Finland and with recent developments also Switzerland and Denmark seem to be frontrunners in the DR markets. However, the report from the DR industry platform SmartEn (Murley & Mazzaferro, 2023) also shows that the potential market sizes and regulatory development of the Polish, Italian and Greek markets are significant.

2.4.4. Smart meters

Smart meters are an essential feature for smart buildings because they enable granular data measurement, enable customers to better follow their energy consumption, ease the billing process, and allow them to purchase dynamic contracts. They also help the network operator to get more visibility to the grid and, therefore, decrease the risk and length of blackouts.

The EU target stated in the Electricity directive (2009/72/EC) was that 80% of customers would have smart meters in 2020. According to the data from ACER & CEER (2022), the progress varies a lot between countries also within the case country sample. The directives set guidelines for smart meter functionalities, customer entitlement, and interoperability requirements, data management and access (EU, 2019). However, these differ between countries. One of the main reasons for different adoption rates is data security and privacy (de Wildt et al., 2019). Italy and Finland are currently installing the second-generation smart meters (see Table 5).

More recently, the discussion around smart meter usage has shifted towards creation of different services by using historical data or using smart meters in demand-side flexibility (Reif & Meeus, 2022). Furthermore, there are different standards used between HEMS and smart meters, most notably ZigBee and Z-Wave (Van De Kaa et al., 2021). This, arguably, slows down the diffusion of HEMS as some companies may want to wait and see which standard wins the battle. Besides electricity meters, smart meters are being rolled out for gas and water.

Table 5. Smart meters in the case countries (Eurelectric, 2020; Tounquet & Alaton, 2020)

	Share of smart meters (%)	Total metering points
Italy	98.5	36,789,000
Greece	2.6	7,500,000
Poland	8.3	17,719,000
Switzerland	16.8	5,100,000
Denmark	99.1	2,324,439
Finland	97.3	3,558,000

Some EU member states (Nordic countries, Estonia, the Netherlands) are also creating centralised Datahubs for improving data exchange and fostering innovation in the field. Instead of every DSO (distribution system operator) managing the data, these data hubs are often operated nationally by the transmission system operator (TSO). These platforms are used by customers, DSOs, regulators, TSOs, and retailers. Access to researchers and service providers is also relevant as the platforms aim to enable creation of new business models (Küfeoğlu et al., 2022).

2.4.5. Electricity prices

The price of electricity consists of four components, (1) the price of electricity purchased from a supplier, (2) distribution tariff, (3) taxes and other tax-like payments and (4) value added tax (VAT). These components' roles as a part of the whole price varies across European countries. The price spikes during the winter 2022-2023 increased the wholesale electricity prices to very high levels, for which governments answered with different subsidy packages. Changes in electricity prices were therefore different, for instance, between the third and fourth quarter of 2022: Italy: 36 → 61 c€/kWh, Greece: 19 →17 c€/kWh, Poland 15 → 14 c€/kWh, Switzerland 21→ 27 ct/kWh, Denmark: 55 → 62 c€/kWh, Finland: 22 →25 c€/kWh (DG Energy, 2023a, 2023b; ElCom, 2022).

There are also significant differences in how well customers have options in having a dynamic electricity contract. EU has stated that all suppliers with more than 200,000 customers must offer dynamically priced contracts. All countries should ensure that at least one supplier offers a dynamic tariff. Table 6 summarises the current situation with dynamic price contracts in the energy and network tariff elements.

Table 6. Use of dynamic electricity tariffs in case countries (SmartEn, 2022)

	Dynamic price contracts	Network tariff TOU contracts
Italy	• Every supplier is free to offer dynamic prices. • Time-of-use tariffs as "default service"	• N/A
Greece	• N/A	• N/A
Poland	• The draft law introducing the mandatory offering of dynamic prices by sellers with more than 200,000 recipients is in the consultation phase	• Customer can choose double tariff (daytime and night-time) or in some cases a triple tariff. • Time definitions depend on the DSO.
Switzerland	• No (Lucinda Murley & Mazzaferro, 2022)	• Customer can in some cases choose a TOU tariff. • In some cases TOU tariffs are applied directly and cannot be chosen by customer. • Time definitions depend on the DSO.
Denmark	• Available	• All customers have a winter daytime and other time tariff. • This will be updated to a TOU tariff with five different times in 2023.
Finland	• Available • ~9 % had real-time contracts in 2021 (https://yle.fi/a/3-12655819)	• Customers can choose daytime and night-time tariff or winter daytime and other time tariff. • Almost all DSOs use time definition recommended by law 66/2009

Distribution tariffs, taxes and levies

DSOs can have different tariffs depending on the regulatory framework of the country. In the NRA model, the regulator sets the tariffs, and it does not matter in which DSO area you are located. In the mixed model, the NRA sets the regulation for the tariff, but the prices are set by the DSO. Italy and Greece have the NRA model, whereas Poland, Switzerland and Finland have the mixed model (AF-Mercados et al., 2015).

Table 7. Number of DSOs and tariff modes in the case countries

	Number of DSOs (Eurelectric, 2020)	**Tariff model**
Italy	130	NRA model
Greece	1	NRA model
Poland	189	mixed model
Switzerland	630	mixed model
Denmark	40	mixed model
Finland	77	mixed model

Taxes and levies have different structures and levels across countries. Consumption-based surcharges are roughly on the same level, yet the value-added-tax (VAT) levels are very different (Eurostat, 2023). The different distribution tariff and tax structures in the case countries are illustrated in Appendix A.

In summary, electricity price levels differ across countries. In addition, the price formation is different and dynamic pricing is in different roles. One of the reasons behind these differences is missing smart metering infrastructure. From PRELUDE's perspective, the effect of the electricity price is mixed. High electricity prices in Denmark pose incentives for energy efficiency and self-consumption, but the role of electrification is more uncertain. Relatively low prices in Poland, for instance, incentivise electrification; however, there are less incentives for energy efficiency than in Denmark. Fluctuating prices incentivise investments for DR, but a more granular approach is needed to understand the aggregate structure of all price components, which can lead to peak shaving, feeding power to the grid or shifting demand.

2.4.6. Summary of the regulatory differences in case countries

Table 8 provides a rough estimation of the case countries' regulatory profiles from the PRELUDE service perspective. The scale is from one to three stars, with one star meaning weak implementation, two stars an intermediate implementation, and three stars meaning good implementation of the policy.

The NECP evaluation comes from the work by Maris & Flouros (2021). The ECs are evaluated based on how well different ECs are presented in the regulation (also ones using the public grid). In DR, the emphasis is on existing regulation, not market potential or future regulation. On electricity prices, the evaluation is done based on the availability of dynamic tariffs instead of price levels. This is due to the two-sided incentive of high and low prices. Also, comparisons with alternative heating sources, such as gas boilers would be beneficial (RAP, 2022).

Table 8. Summary of the regulatory comparison in case countries

	NECPs	**Energy communities**	**Explicit Demand response**	**Smart meters**	**Electricity prices**
Italy	***	***	**	***	***
Greece	**	**	**	*	*
Poland	*	*	*	*	*
Switzerland	n/a	**	***	*	*
Denmark	***	**	***	***	***
Finland	**	**	***	***	***

This rough comparison between the case countries indicates that Italy, Denmark, and Finland would suit the PRELUDE solution more than Greece, Poland, and Switzerland.

However, the compared elements are only some of the relevant ones, and a more granular approach is needed when evaluating the true market potential in the case countries and beyond. Also, many regional differences exist among support schemes, rules and prices, which means that there are differences also within the case countries.

3. LOCAL-LEVEL BUSINESS ENVIRONMENT

3.1. Theoretical background on business models and the context of smart buildings

As an overarching theme and approach, this deliverable takes the business model perspective. As a simple definition, a business model "defines how the enterprise creates and delivers value to customers, and then converts payments received to profits" (Teece, 2010) Business models are conceptual in nature rather than providing financial models of the business. A simple way of analysing business models is a categorisation of three elements: value delivery, value proposition and value capture.

Value capture

Value capture means the manner of making profit from the value creation. It generally refers to the cost structure and revenue streams in the business model canvas (Osterwalder & Pigneur, 2010). These include both Capex and Opex expenditures. In a multi-stakeholder context, value capture needs to be appropriated among partners so that everybody is motivated to work together (Reypens et al., 2016). There are different payment options in data-driven business models: one-time sales, time basis, project/commissioning, usage basis or some hybrid models (Passlick et al., 2021). In the case of a strong patent, mechanisms like licensing or sale of intellectual property can work as value capture. One differentiating factor in the ECs' and smart cities' contexts is the ability to attract private capital versus financing through public money (Bencsik et al., 2023; Vernay, Sebi, et al., 2023).

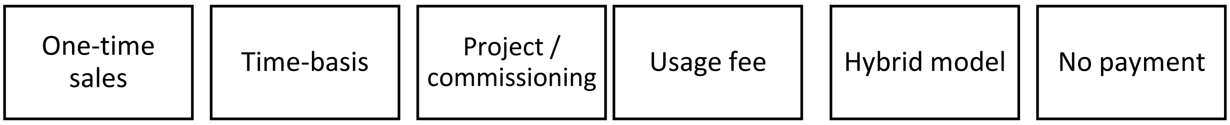


Figure 1. Value capture mechanisms from digital business models (Bencsik et al., 2023)

Value capture is also conceptualised as value appropriation because the method of sharing costs and benefits often happens within an ecosystem. In principle, the more an actor creates value in the ecosystem, the more it has a bargaining power to capture value for itself (Zott & Amit, 2010). However, all ecosystem members should gain value so that they are kept motivated to act as members. Ecosystem actors may create a new entity for ecosystem value capture.

Value proposition

The creation of value refers to the value proposition made for the customer: "What value is proposed through the product or service offering?" (Teece, 2010, p. 10) Osterwalder & Pigneur (2010) emphasise that value is created through a bundle of services that the specific customer segment values.

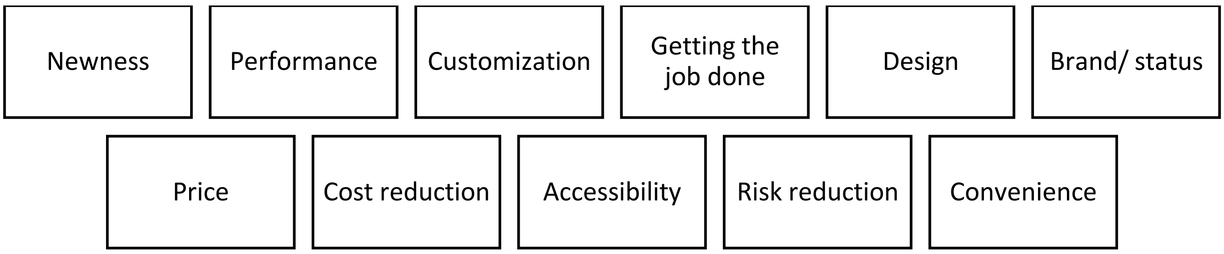


Figure 2. Non-exhaustive list of possible value propositions (Osterwalder & Pigneur, 2010)

However, the traditional business model canvas approach concentrates merely on the customer and not all stakeholders involved. Instead, literature on sustainable value proposition considers economic, social, and environmental value across multiple stakeholders (Bocken et al., 2014). New value creation opportunities can be found by capturing missed value from under-utilised assets and resources or waste streams or from solving the "destroyed value" that the current business models do (Bocken et al., 2013).

This is a similar approach to the ecosystem context, where defining value proposition has particular challenges because it is negotiated between different parties that are co-developing the value proposition together but are still operating independently and upon their own interests. Ecosystems, therefore, require a "multilateral alignment structure" for it to be realised (Adner, 2017). In that way, value realisation happens throughout the ecosystem, and all members are motivated to stay in the ecosystem (Thomas & Ritala, 2021).

Value delivery

Value delivery includes the key activities, resources, channels, partners and technologies used to deliver the customer value proposition (Osterwalder & Pigneur, 2010). In the smart city environment, partners can be divided into public and private organisations.

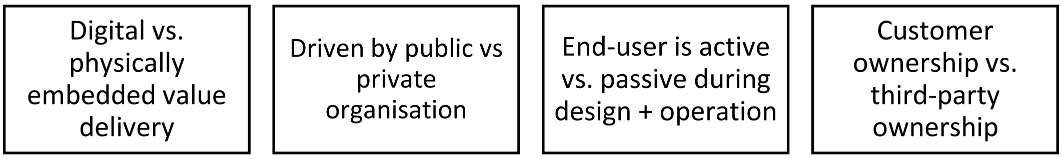


Figure 3. Value delivery choices in smart cities and energy communities (Bencsik et al., 2023; Reis et al., 2021)

From the ecosystem perspective, value delivery is a question of how well the partners are aligned and how well they co-specialise for delivering a coherent value proposition. In such environments, value delivery is intertwined with other ecosystem members offerings and services. Because an ecosystem is dependent on various complementors, promoting the whole ecosystem's technologies and solutions, co-development and promotion of standards can be seen as value creation (Ritala et al., 2013).

Business models can also be seen as networks. Here, value creation can be analysed in different elements, such as complementarities (bundling offerings), efficiency (reduction of transaction costs), novelty (new governance types, structures, activities), and lock-ins (how third parties and customers are retained) (Zott & Amit, 2010).

Digitalisation enables the creation of so-called "integrative business models", which utilise demand side mechanisms (instead of supply side) like customer complementarities to make a portfolio of business models (Aversa et al., 2021). Amazon, for example, has created several integrated business models that also create synergies between them, opportunities for customisation, and lock-in: Prime, Fulfilment, Web Services, Mechanical Turk and the physical stores.

3.2. Introduction of PRELUDE Business Use Cases through Geneva pilot project

The PRELUDE project has identified four different BUCs for its data platform. These use cases have been developed throughout the project in several workshops and the work is ongoing. In this chapter, we will briefly discuss these BUCs in relation to business models in the smart grid context more generally but also using experiences from one of the demo sites, the CPEG's multi-apartment building in Geneva. These findings are based on interviews with the main stakeholders related to the demo project.

BUC1 – Real-time monitoring solution

The real-time monitoring solution is a monitoring system targeted at both building occupants and building managers. It can be applied in high and low-tech buildings. The monitoring solution provides clear and relevant information about the building's operational energy consumption. This should help the users to understand and optimise their energy usage and help maintain comfort and air quality. As a principle, the service should be modular so that different devices are easily connected to it, and there are no dependencies on third parties. In addition, the graphical interface needs to be clear and user-friendly, and the amount of data that the user sees needs to be easily digestible, even though there may be a lot of data behind it.

In the Geneva case, real-time monitoring is provided for the tenants by CPEG and numerous data sources are also used by the service providers in the project. For the building owner, the increased visibility to conditions helps to evaluate the functioning and interplay of the renovations, new heat pump, insulation and solar PV. However, there are several challenges in data monitoring management and usage. Getting consent has been tricky, as it has been in other projects (Heuninckx et al., 2023). Many data collectors do not work, and there needs to be verification of their functioning. The amount of data is not essential but the simplification of data output is. At the same time, data anonymisation and data processing require resources. Customers' willingness to pay only for data is a question mark since there are no clear foreseen benefits that can be promised. The pilot project work has gathered lessons and experiences on these issues so that, as a result, the BUC can be developed into a focused, simple and scalable solution that can be applied in multiple buildings.

BUC2 - Building equipment predictive maintenance

The second BUC handles building equipment's predictive maintenance. It is a service meant primarily for building managers, but it also offers value for building occupants. It assesses the conditions of the building's technologies and gives a signal when there are some abnormalities. In this way, it helps to prevent disruptions of, for example, the HVAC system, which saves money for the building owner. Also, it improves safety as the possible equipment disruptions can be proactively fixed.

In the Geneva case, this BUC is under discussion but not currently being tested for several reasons. The data-related questions are linked to the data quality, and especially the missing data that needs to be fixed in the data sets. A more significant issue is related to the business model with the third-party technology and solution providers. They have existing contracts in the buildings that cover the warranties, service levels, pricing, and other factors. Aside from the building managers, their business model and operational processes may need to be aligned with the value that predictive maintenance from PRELUDE can offer. For creating a customer-centric value proposal, the business model of predictive maintenance should be planned accordingly. This would include elements like payment models (one-time sales, usage- or time-based pricing or some hybrid model.), value promise (all-in-one, condition monitoring, connectivity…), and deployment channel (physical, www, cloud…) (Ibarra et al., 2018; Passlick, Dreyer, et al., 2021). Also, when multiple companies are involved in data management, the regulation regarding, for example, anonymisation and other data ownership rules become very important to solve (Heuninckx et al., 2023).

BUC3 - Facilitate control of building energy systems to aggregators

The third identified BUC is facilitating control of building systems to aggregators. It allows responsive control and improves the building's readiness to use flexible loads, such as heating and cooling, electric vehicle chargers and storage systems, and in that way, participate in DR markets. This BUC was discussed in Copenhagen's workshop but not in detail. The value of this BUC comes via it's prediction and forecasting capabilities, and optimization of a building's functions. The aggregation business requires an ecosystem of actors who act together: building owner, aggregator, HVAC system operator, tenants, possible battery provider, and others. Liabilities, cyber security, operational complexity, system verification, data management and regulatory compliance require significant effort from all parties.

In the Geneva case, this BUC was not directly applied as aggregation is perhaps a later step in CPEG's portfolio. However, the issues on data management, maintenance of different systems (especially software), customer consent, customer satisfaction with changes in room temperatures, affect this BUC, too. A lack of data affects not only the planning and modelling, but also the operational level. Also, aggregation requires a certain level of economies-of-scale to be profitable. Therefore, dividing value fairly and sharing responsibilities between partners, acceptable contracts and tariffs for end-users, and the ability to optimise the building systems are important. As there are actors already doing collective self-consumption, and related billing and metering, adding aggregation to their activities would be a natural option. Finding these complementarities by bundling activities efficiently and avoiding extra transaction costs in each step (Zott & Amit, 2010) are the main challenges of this BUC.

BUC4 - Residential building renovation roadmap

The fourth BUC is a standalone service for a building renovation roadmap. It is a decision support system for mainly residential buildings with a special focus on energy. It gives recommendations on different levels, such as refurbishment actions and user tips to improve the energy performance of buildings. It has a potentially wide range of customers as it helps architects who offer renovation services, constructors and installers, engineering offices providing EPCs, and ESCOs. The software offers a list of recommended refurbishments, their costs, and tips for energy savings.

In the Geneva case, the renovations were done based on offers by engineering offices with different sets of technologies. An important goal of the project, and CPEG in general, is overcoming the performance gap. This gap refers to the difference between the expected savings that refurbishment investments are thought to bring, and the actual operational results. Geneva is also a special case due to local regulation, which demands improving energy efficiency regularly. The value proposition is therefore based on the trustworthiness of the renovation roadmap service. ESTIA is also continuing to analyse the results of the case study, with non-trivial costs in measuring, anonymisation, filling the missing data and data analysis. Besides this long-term partnership model, different business models for different service levels can be thought of, such as a pay-per-use model or a subscription model. Also, service can be based on a commission. A "freemium" (free and premium) model would include providing the basic elements of the service for free but offering that customer base more advanced services (Teece, 2010).

3.3. The Home Energy Management service provider perspective

This chapter presents the implications of a study which was conducted to identify and describe the home energy management solutions available commercially in Finland. The focus is on the concept of a home energy management system (HEMS), and how it can be provided as a service. The aggregator business model is also briefly discussed as well as other complementary providers who can support home energy management processes.

Methodology

The data for the study was collected with semi-structured interviews. Interviews were used to collect experiences in the words of the participants. These interviews provided in-depth data, allowed the participants to explain and interpret the situation much better than via just a surveys. The semi-structured nature added flexibility by offering the interviewees the chance to explain their experiences in their own words while the researcher also has the chance to make further questions and go into more detail on interesting and surprising aspects (Saunders et al., 2019, p. 444). The main disadvantage of semi-structured interviews is that they take a lot of time and effort, and the interviewed group size is smaller than for example with surveys. However, semi-structured interviews provide more in-depth exploration and getting to know the interviewees' individual thoughts (Adams, 2015). This suited the purpose of this research and the types of interviewees.

In Table 9, there is a summary of all the solution providers interviewed. There was not a big number of household solution providers in Finland. Nineteen providers were first identified, and from those the most interesting ones were contacted until there seemed to be enough interviewees considering the time limits and expected saturation of answers. This resulted in twelve providers being contacted. One person was selected, typically the founder especially in smaller companies. Seven providers accepted the invitation and five did not respond. The interviewees were clearly interested in the research. The process began in January and the first solution provider interview was held on the 2nd of February. The last solution provider interview was held on the 23rd of February.

Table 9. Summary of solution providers interviewed.

Index	Date	Offering	Age (years)	Employees	Duration
CI1	2.2.2023	Consumption optimization	0–2	1–10	49 min
CI2	8.2.2023	Consumption optimization	0–2	1–10	59 min
CI3	9.2.2023	Consumption optimization	6–10	1–10	76 min
CI4	10.2.2023	Consumption optimization	3–5	1–10	48 min
CI5	13.2.2023	Consumption metering	6–10	11–30	33 min
CI6	16.2.2023	Consumption optimization	6–10	1–10	54 min
CI7	23.2.2023	Electrical contracting	6–10	11–30	45 min

All the interviews except for CI6 were held online via Microsoft Teams with one interviewer and one interviewee participating. Online interviews allowed flexibility, long-distance interviews, and comfortable places for both participants. The recording and transcription tools of Teams were used to create transcriptions in real-time. The businesses represented were rather new, on average they had been working for five years, and many consumption optimization solutions had been founded within the last year. These providers also had smaller numbers of employees. In the case of CI4 and CI6 the company itself was in an older age group but the solution was in "0–2"-year age group. The average duration of an interview was 52 minutes.

Interview results

On value proposition

A business model can be defined as a design by which a business creates, delivers, and captures value (Teece, 2010). Value creation refers to processes that should generate increased value which is realized in the final product or service as perceived by the customer. The increased value can be communicated to customers as a value proposition. In this section the descriptions of elements in the interviewees' value propositions are presented.

In Table 10 the business model of interviewees, the devices that they currently optimize, and their future plans are listed. HEMS as a service (HaaS) was clearly the most common business model among interviewees. CI5 does not offer any consumption optimization yet. The results listed in the table are based on interviewees' own descriptions.

Table 10. Business models of interviewees

Index	Business Model	Optimized consumption	Future plans
CI1	HaaS / Aggregator	EV	Become an aggregator, optimize heat pump, thermostats, photovoltaics
CI2	HaaS	Shelly (appliances, heating, power supplies)	Grow the customer base
CI3	HaaS	Heating, water, EV, other big loads, photovoltaics	Grow the customer base
CI4	HaaS	Shelly (appliances, heating, power supplies)	Optimize boilers, EV, enable Tuya
CI5	Metering device retail	-	Add control functionality
CI6	HaaS	EV, boilers, heat pump, any big load device	Grow the customer base
CI7	HaaS / Electricity Contracting	Ventilation, heating, lighting	Grow the customer base

A home energy management system can be understood as a system that controls the energy consumption of a household to optimize it based on for example pricing signals. All the connections of a HEMS within a household are visually presented in Figure 4. The interviewees were not necessarily thinking of their offering in terms of HEMS but when the concept was explained through that figure, they recognized it well. After seeing the figure, CI4 made the following comment on their business model:

> *"What's essential is that, in principle, we do it as a service on cloud which means that the HEMS center [...] is not within the house but it's specifically on the outside. We do that on the outside and understand the risks related to that and so on." (CI4)*

In addition to providing energy management as a service, there is another role with big business potential, and that is the aggregator. Aggregators can combine consumption of households to create flexibility that can be traded. Only one of the interviewees had plans to become an aggregator, and that was CI1. The principals of their business model were otherwise like the other interviewees. Working as an aggregator adds more income sources but brings more relationships that need to be managed as the following comment shows:

"Then we also work with different electricity companies to get our product working with them, so they are practically our customers as well on the B2B side and then in the future we'll be participating in the reserve markets and therefore would interact together with the TSO as well." (CI1)

All the solution providers were targeting the same large customer group. The large amount of potential customers was viewed as a positive aspect, and they share the same needs that can be met with the value creation methods.

On value capture

Value capture refers to "the processes of securing profits from value creation and the distribution of those profits among participating actors such as providers, customers, and partners" (Sjödin et al., 2020). This section focuses on what kinds of value capture methods the interviewed providers had established. Value can be captured fairly with different pricing models that ensure that the provider secures profits while also leaving value to the customer. The pricing methods of interviewed providers are listed in Table 11. This table also includes the relationships of these providers. From these relationships it can be seen to whom the profits need to be distributed.

Table 11. Interviewees' value capture methods and relationships to other actors

Index	Business Model	Pricing methods	Relationships
CI1	HaaS / Aggregator	Not established: consumers pay for optimization monthly, electricity companies pay for flexibility	Work with DSO's and TSO for aggregator purposes, retailers (electricity companies)
CI2	HaaS	Monthly subscription	Potential collaboration with retailers
CI3	HaaS	Starting + service fee (monthly)	Collab with retail
CI4	HaaS	Monthly subscription	Collab with retail, electricians
CI5	Metering device retail	Pay once per device, subscribe to cloud	Open source - users
CI6	HaaS	Starting + service fee (monthly)	Collab with retail
CI7	HaaS / Electricity Contracting	Starting + service fee (monthly)	Apartment brokers, constructors

The ways of providing HEMS seemed to divide in two. It could operate from within the house, eliminating the need for outside connections and making privacy security management easier, or it could be operated from outside on a cloud. Operating from the outside and offering that as a service is like the model of software as a service (SaaS). HEMS as a service also follows similar pricing methods as all the providers had established or planned to use a monthly subscription method. In monthly subscription the customer pays on average a fee of €6 to €10 monthly to enable the optimization based on the spot price of electricity. The vision of HEMS as a service providers seems to be along the lines of

"a comprehensive solution which the households can control. So that the electric load is as smart as possible and all this would happen automatically through our app service including boilers, direct electric heating […], maximized utilization of solar power, electric vehicle charging, heat pumps, everything." (CI1)

Consumers get the most value out of optimizing big consumption sources and comprehensive solution which are viewed as more attractive. The cost savings are the biggest motivation for customers to acquire an energy management service. A comprehensive solution is most likely to satisfy financial and comfort needs, and interviewee CI3 points out that comprehensiveness may also be necessary due to more complex consumption:

> *"How this must be done [...] is that we look at it from the point of view of the property because it's the whole system that needs to be optimized [...] and the more this energy transition advances with customer's own production, electric vehicles etc., the more we need that control capability in the property and the most logical solution is to control the whole system." (CI3)*

In capturing the value of a solution, the providers must take the costs into account. Production development costs are among the highest of costs to solution providers. CI1 estimated that 60-70% of their resources goes to product development. There are little material or facilities when developing mostly software solutions. When the solution includes some physical components like is the case for CI6 those costs start to matter and CI6 said that designing a physical product does add its own challenges. Another significant cost is the licenses to use day-ahead price data from Nord Pool. All these costs have to be covered in the price in order for the solution providers to capture the value delivered.

Value delivery

There seems to be two different routes that service providers use to produce an attractive solution. First, there is the option to start by providing optimization for a single device or part of consumption, and then expanding horizontally to different devices. The second option is to provide a comprehensive package right from the beginning. Both models have their own challenges. As said, a single controllable element is not as attractive as controlling the whole system. On the other hand, developing a comprehensive solution usually requires more time and resources. Interviewees CI1, CI2, and CI4 chose to start by offering optimization to a single consumption source. Choosing to offer only one element may result in a need for the customer to have more knowledge about electricity consumption and technology as the quote from CI2 shows:

> *"We offer the control signal based on the weather forecast and electricity spot price and then different compensations that can be freely selected such as how sunny or windy it is [...] and that's sort of our part and then the user should decide according to their own consideration how to integrate the control signal to their real loads." (CI2)*

Providing a more limited solution is done by relying more on third party devices and software which makes those parties responsible for maintenance and operation. It is also common to use third party relays or smart plugs that the user has to get installed themselves. This is much cheaper than developing your own device. Interviewees CI3, CI6, and CI7 have developed their own systems and provide comprehensive services. CI3's view on responsibility is the following:

> *"A significant aspect is that when we deliver it as a turnkey solution, we also know that everything will work. We sort of wanted to make it easy and practical for the customer. [...] And quite many even big actors in the field have fallen in these things because when someone delivers components, some other installs, and no one is responsible if it doesn't work at the customer, so we want to make sure that it works." (CI3)*

CI7 does the turnkey delivery a little different than the rest since they are an electrical contractor whose customers are the property owners and developers. They provide smart consumption management to entire apartment buildings. The user and consumer getting the benefits of the savings is still the resident. CI7 highlights the importance of energy wise behavior:

"You see, the resident is in the middle of everything so sure enough that energy wise behavior has been our entire baseline with this system." (CI7)

The solution providers must communicate the value of these solutions clearly in order to gain attraction. In the next chapter is the part of results that handled the role of solution providers in virtual communities dealing also with knowledge sharing.

Discussion

What HEMS as a service provider were actually providing is visualized in Figure 4. This figure is based on Zhou et al. (2016) concept of a home energy management system which can smartly manage all electricity consumption within a household. The main functions of a HEMS include monitoring, logging, control, management, and alarms. Monitoring, watches the condition of operation and displays statuses for predictive maintenance. Logging is useful for active users who want to see the electricity prices and consumption data. Control functions control the consumption sources and can be operated from separate handheld devices. Management integrates all aspects of HEMS and enables the optimization. Alarm functions can notify the user if something goes wrong. Controllable devices and consumption sources include schedulable appliances and non-schedulable appliances, and electric vehicles. The HEMS should also take care of any production, connections to smart meters, and possibly to other users.

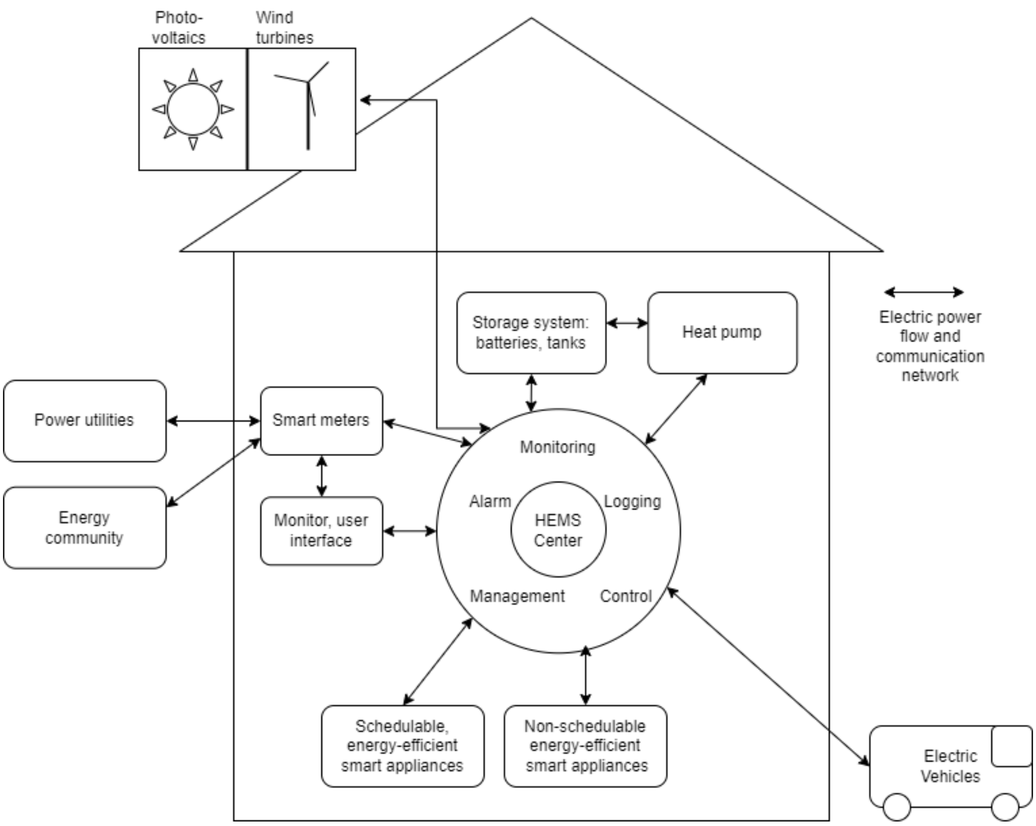


Figure 4. Architecture of an optimized household electricity network (adapted from Zhou et al. 2016)

The interview results revealed that HEMS can be provided comprehensively to cover all aspects of household energy consumption or with a specific focus on a single aspect. All the interviewees provided a service along the physical system to manage consumption. With a monthly subscription the consumers gain access to the electricity pricing data which is used to optimize consumption. The value that the consumers gain and are looking for is mostly monetary as seen in their bill savings. Based on the interviews this is the most valuable benefit for consumers. Comfort benefits were not noticeable, and at the very least, a HEMS should not reduce the comfort level of a household. Consumers can also gain benefits by increasing their knowledge of their own consumption levels.

The role of an aggregator is an emerging one, but that has much potential in the future. Since many players are currently building HEMS solutions it would make sense for these actors to add aggregator activities into their business model, as CI1 planned to do. Golmohamadi et al. (2019) suggested in their comprehensive study of multi-agent based optimization of aggregators that the responsive residential consumers should have HEMS which also allows the communication of data between actors. HEMS as a service provider are already have the system so they could also collect consumption data and use it to provide combined flexibility to the grid. Sending the data or allowing for some control over consumption would require more trust between the customers and solution providers.

3.4. Energy community types and value streams

The aim of this chapter is to introduce and explain the increasingly important concept of ECs, how they position in the Prelude business landscape and how they may affect the development of the field. Regulation on EC features in the Renewable Energy Directive and Citizen energy communities and self-consumption are covered in the IEMD directive (EU, 2018, 2019). This chapter is a summary of a conference article to be published in IEEE European Energy Markets 2023 (Valta et al., 2023).

ECs can occur within multi-apartment buildings, or they can consist of several buildings in a neighbourhood, region, or even country. We use the typology following the decision tree in Figure 5. The main difference between the EC types in this typology comes from the usage of the public grid and the role of the DSO. Next, we introduce the different EC types.

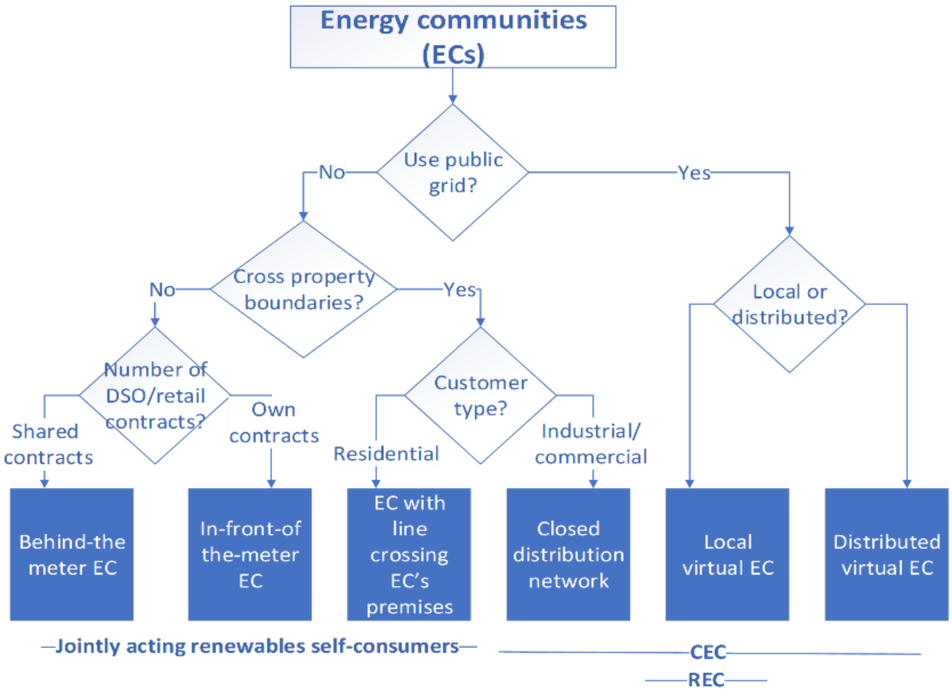


Figure 5. Energy community typology (Valta et al., 2021)

A) Behind-the-meter EC within one property

An EC can be set up within a single property area, like a housing complex, shopping centre, university campus, or hospital. In a behind-the-meter EC, the whole community shares one electricity meter provided by the DSO. This arrangement helps save money on network tariffs for everyone in the community. However, to make it work, all the members of the EC need to agree on using the same electricity retailer. They also need to handle the individual metering and billing either by themselves or through a separate service provider.

B) In-front-of-the-meter EC within one property

In-front-of-the-meter ECs within one property typically connect to the grid through a single point where their electricity is exchanged with the utility company. Each member of the EC has their own electricity retailer, and the DSO installs individual smart meters for them. In the past, in-front-of-the-meter ECs could only consume the electricity used by shared facilities like elevators, corridors, and common areas. However, recent changes in many countries' laws have expanded this, allowing EC members to offset the energy consumption of their individual apartments as well. Moreover, in certain countries, EC types A and B are also permitted to have a power generation unit located on a nearby plot. These developments are supported by directives on Direct lines.

Own grid

Certain exceptions within the European directives allow for ECs to have ownership of the grid in specific instances, also known as microgrids or "private wires" (Brown et al., 2019). Article 16 of the IEMD directive (EU, 2019) mentions that Member States can establish regulations enabling ECs to own, establish, purchase, or lease distribution networks and autonomously manage them. They may also grant CECs the right to manage distribution networks in their operational areas and establish the necessary procedures. However, ECs must adhere to the same regulations as DSOs, which can be challenging for smaller ECs. An example of such cases is found in industrial or commercial areas with Closed Distribution Networks. France and Italy have local integrated utilities that resemble ECs with their own grids, but this model is not intended for establishing new ECs (Eurelectric, 2019; Vernay, Sebi, et al., 2023). In these cases, the ECs manage the grid, metering, billing, and have a single point of connection with the distribution system operator's grid. Taxes for electricity consumption are paid in the usual manner.

Local virtual EC

A local virtual EC is a geographically confined EC comprising various property owners who utilize the public grid to transfer electricity using virtual metering. Typically, there is a substation or another point where the EC connects to the grid, and this connection has technical implications for the DSO. In these local ECs, members have their own electricity retailers, and the metering is provided by the DSO. However, some local virtual communities are defined based on non-technical factors like postal codes or specific boundaries (Frieden et al., 2020).

Distributed virtual EC

The distributed virtual EC can encompass members situated in different areas served by various DSOs. These non-location-dependent ECs consist of entities such as virtual power plants (VPPs) and cooperatives engaged in energy production, sales, and supply.

3.4.1. Value streams in different energy community types

Collective electricity purchasing and guarantees of origin

Collective electricity purchasing boosts individual members' negotiation power by enabling them to secure larger quantities under a single agreement. This benefits both members and retailers, who gain a larger customer base and increased revenue through a consolidated contract. Different EC types can form groups and negotiate collective electricity contracts facilitated by third-parties (Department of Energy & Climate Change, 2013). Cooperatives may also purchase shares in RE plants, receiving certificates of origin at a dedicated tariff (Reis et al., 2021). Sharing a retail contract becomes advantageous when EC members are part of the same property, enabling savings on network tariffs by having a single DSO contract and metering point. EC types A and C are particularly suited for this value stream.

Selling collectively owned production

ECs have the option to invest in their own electricity production, which can be sold on the electricity market. In production-based ECs, the entire production is typically sold to a retailer, usually through a feed-in tariff or other forms of compensation. In ECs focused on self-consumption, the surplus production, not used locally, is sold instead. The compensation for the surplus production can take the form of wholesale prices, feed-in tariffs, or may involve tax reductions and other surcharges (Reis et al., 2021).

Distributed virtual self-consumption

In virtual self-consumption, the electricity production from a remote location is measured and allocated to the respective members of the EC. For example, leasing a solar PV panel in a nearby location allows individuals to participate in the energy transition when their own conditions are unsuitable. In some cases, wind developers offer local residents a special tariff for the energy produced to enhance local project acceptance (Hampton et al., 2022; Vernay, Sebi, et al., 2023). Certain countries have implemented or considered virtual net metering programs, enabling surplus generation credits to be transferred to other consumption points owned by the same entity (Moura & Brito, 2019; Pahkala et al., 2018). Additionally, there are peer-to-peer schemes like Sonnen Community and matching services like Vandebron that happen in-front-of-the-meter (Iazzolino et al., 2022).

Price arbitrage

Price arbitrage involves optimizing electricity consumption and storage based on wholesale prices. During expensive hours, EC operators minimize consumption from the grid and maximize self-consumption, and during cheaper hours, they maximise usage of grid power and energy storage. EC platform operators can perform price arbitrage using their energy storage, taking advantage of price differences between the wholesale market and the EC's local market (Schwidtal et al., 2022). Incentives can exist for EC members with time-of-use or dynamic rates, but it becomes more complex when members have individual electricity contracts. Price arbitrage applies to all EC types, particularly in EC types A and C where customers share the same retailer and retail contract behind-the-meter and a common tariff or alternative incentive is put in place for engaging end-users.

Local self-consumption

Local self-consumption offsets reliance on the public grid and external retailers. Within property boundaries, self-consumption reduces taxes and network tariffs. Regulations in certain countries allow RECs to operate also within the same public low voltage distribution grid, but then certain level of grid tariffs are paid (Frieden et al., 2020; Iazzolino et al., 2022). Managing flexible loads, like water heaters and electric vehicle charging, can increase self-consumption. Incentives and value-sharing mechanisms foster self-consumption (Kulmala et al., 2021). Different EC types engage in local self-consumption, except for distributed virtual ECs that have distinct characteristics such as cross-DSO cooperation.

Balancing, reserve and ancillary services

The EC operator can aggregate resources for DR markets. This involves controlling, e.g., heating or cooling systems, while considering their normal functions and user comfort. These value streams are available to all EC types, but larger ECs are better suited due to relatively high market entry requirements.

Peak shaving and reductions in power charges

Avoiding peak power charges is valuable for ECs by managing loads to prevent capacity limits and reduce grid reinforcement investments. This benefits all EC types except virtual distributed ECs. However, dividing the benefits in local virtual ECs may lack clear methods or processes.

Avoiding outages

ECs can help to ensure supply security during outages using energy storage, V2H, or aggregators controlling the demand, and this can reduce the DSO's fees for disruptions when there is a collaboration deal made possible. ECs can also participate in capacity markets, requiring sufficient energy storage solutions (Claeys, 2021). In single properties, battery costs and rapidly developing V2L/V2H functions are changing the business landscape, particularly for EC type A. In general, private grids (type C) and local virtual ECs (type E) have more resources and incentives for energy storage investment and operation, which makes this value stream more probable for them.

Grid flexibility

ECs could provide grid flexibility services locally to solve grid congestions, for instance via local flexibility markets. This could postpone or reduce the DSO's grid reinforcement investments. This value stream happens locationally and is most typical for the local virtual EC as it uses the local public grid. The overall relations between the EC types and value streams is shown in Table 12 (Valta et al., 2023).

Table 12. Energy community value streams and how they are related to each energy community type ("X"= typical value stream, "(X)"= possible value stream, "-"= untypical value stream)

Type	Front-of-the-meter EC within one property	Behind-the-meter EC within one property	Own grid	Local virtual EC	Distributed virtual EC
Directive	JARC	JARC	CEC	REC, CEC	CEC
A. Collective electricity purchasing	(X)	X	X	(X)	(X)
B. Selling collectively owned production	(X)	(X)	(X)	(X)	X
C. Distributed self-consumption	(X)	(X)	(X)	(X)	X
D. Price arbitrage	(X)	X	X	(X)	(X)
E. Local self-consumption	X	X	X	X	(X)
F. Balancing, reserve, and ancillary services	(X)	(X)	X	X	X
G. Peak shaving and reductions in power charges	(X)	X	X	(X)	-
H. Avoiding outages	-	(X)	X	X	-
I. Grid flexibility	-	(X)	X	X	-

3.4.2. Implications on the business model development

Energy community member

ECs vary from simple models based on sole RE purchasing to very sophisticated ones combining different value streams. The level of complexity affects the whole customer journey. A grassroots movement consisting of ordinary citizens will probably not going to engage in complex flexibility services, but rather more simple value propositions, such as increased self-consumption or energy efficiency. For more complex models, there is a need for an operator or facilitator who connects different actors together and enables the EC service development.

Multiple stakeholders can be seen as EC members as the value can be shared among different actors, and they have different interests in the EC creation. Generally, the end-users are interested in economic and environmental benefits, system operators on the effects on the grid, and service providers on the scalability and profitability of the project. Financiers aim at lowering the economic risks. Local governments may also aim at creating a living lab environment (Kubli & Puranik, 2023). Creating a common value proposition for the end-user needs to be developed with these differences in mind.

Energy community operator

Value proposition

The EC operator needs to consider the different interests and value propositions by positioning in a certain location in the energy value chain. The traditional electricity value chain could be divided into generation, distribution, and retail, but aside from these, there are new elements in the chain: aggregator, digital platform provider, trading, flexibility options provider, consumption and contracting (Lowitzsch et al., 2023). Different EC types have different activities shared among the partners delivering the value. Servitization requires collaboration from the EC providers and stakeholders.

A commercialized customer-facing solution needs models where all stakeholders know their roles and processes. In EC type A and C, there is more clearly a service provider who is responsible for the whole EC, whereas in EC type B, D and E, the DSO, different retailers and the EC service provider are involved. One research (Barnes et al., 2022) found that ECs behind-the-meter were better able to differentiate themselves by offering services rather than kWhs as they had more control over the EC infrastructure and technologies. As there are limits and challenges to how big behind-the-meter systems can be, this remarks on the importance of collaboration in the EC design phase. One way to identify new value from ECs is to point out the dilemmas and destroyed value from some actor's perspective (Bocken et al., 2013).

As the end customers are increasingly investing in smart thermostats, electric vehicles and heat pumps, the existing assets are providing a more interesting opportunity to leverage more value (N. Bocken et al., 2013). The underutilized capacity of these already existing assets produces an option for their owners, the financing companies of these asset providers, and related companies, such as installers and engineering companies.

Value capture

The value capture mechanisms, i.e., the structure of costs and revenues from various EC types, differ remarkably. Typically, the costs are mostly up-front costs that consist of powerplant investments and related technologies. In behind-the-meter solutions, the EC also invests in smart meters and possibly the grid infrastructure. In virtual communities, the up-front investments can be smaller in relation to the customer basis. Yet, even if they use existing power production assets, they also include transaction and coordination costs in putting the EC in place and building the relevant data management platforms. The operational costs follow a similar logic, as all EC types include transaction costs, but in models behind-the-meter, the role of costs for maintenance and financing of physical assets is more important than in virtual ECs. Payments for using the public grid apply to all EC types, yet behind-the-meter models can have savings from them, relative to other models.

The revenue from the energy markets happens via the different value streams (introduced above): savings in energy bills by either offsetting buying from a retailer or by saving in network tariffs (volumetric or capacity costs), earnings from selling energy or from ancillary and flexibility markets through acting as an aggregator.

The operator has different options for revenue streams, ranging from asset sales to leasing agreements and subscription and brokerage fees (Burger & Luke, 2017). These mechanisms may vary between the flexibility and production-based value streams. In the energy service company (ESCo) model, the operator earns by the brokerage fee, namely the difference between the investment's financing costs and its energy selling price. A subscription fee can be combined also with operating peer-to-peer-markets or self-consumption schemes.

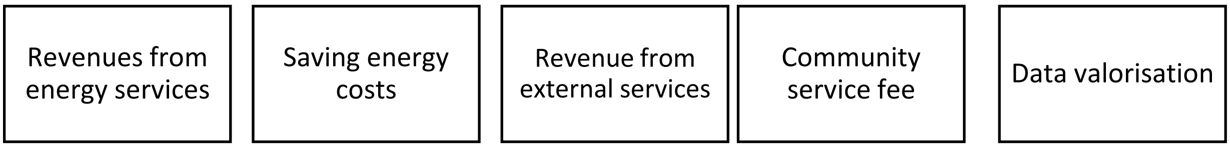


Figure 6. Value capture mechanisms from energy communities (Kubli & Puranik, 2023)

One question regarding the value capture is related to the value-sharing mechanisms and how they allocate the costs and benefits of EC's value delivery. A transition from the current model to an EC should treat customers equally and fairly. Overall, the EC pricing mechanisms are crucial for their success. The energy crisis of 2022 forced many retailers to provide only spot price-contracts. An EC operator could work as a risk manager locally to protect EC members against price spikes. Even though there are many elements to pricing, it needs to be simple enough for the customer to understand it well.

Value delivery

Data management and access require special attention from the EC operator. They are important in different steps of the EC lifecycle: feasibility studies and planning, operation, value sharing and allocation, optimization, and expanding the EC. The complexity of data management is caused by data quality, data security, complex regulations and a large number of stakeholders (Babilon et al., 2022). Different actors have different needs for data: aggregators need to know the availability of flexible loads and their impact on comfort levels, end-users want the energy consumption data visualized, and service providers managing the district-scale energy sharing want data on several buildings (Tuerk et al., 2021). Operators using machine learning require large data sets for training the models. Furthermore, smart meters need to be in place, and interoperability between different automation systems needs to be ensured. Depending on the proximity of EC members, these data systems may include the neighborhood, building or home area networks (Gjorgievski et al., 2021). Hoicka et al. (2021) also argue for a new kind of openness and participatory processes in energy system planning.

Scalability and network effects

Scalability of ECs is needed for EC operator business, yet it is not a straightforward process due to the socio-technical context of ECs (Vernay, Olsthoorn, et al., 2023). Network effects are familiar from mobile phone apps, such as Uber, LinkedIn or Airbnb: the more users there are, the greater the number of interested service or content providers, which again adds value to the users, and so a self-reinforcing circle is born. Markets where network effects create the core value for customers, are so-called winner-takes-all-markets. In a market close to ECs, the EV market, an important network effect has been related to the number of charging stations. Choosing a charging service with the widest presence offers the best value, however, shifting between charging stations has also become possible. In the context of ECs, scaling can happen on different levels: locally:

- EC spreads locally from one building to several buildings,
- EC adopts new resources, such as complementary technologies like EV chargers or smart thermostats.

Outside one location:

- Same technology is used in more sites,
- Same EC organization attracts new members and investments elsewhere. This would be the case in EC type E.
- ECs become institutionally recognized and same model diffuses elsewhere (vertical up-scaling).

Value streams based on investments to non-place-based production (type E) enable crowdfunding schemes and large participation volumes rapidly through an EC operator or platform (Kubli & Puranik, 2023). Local self-consumption-based value streams require more configurational work (Barnes et al., 2022) as they are coupled with on-site installations and the complexity of collective demand patterns. Yet, some elements also within these value streams, such as the digital tools (e.g., the value-sharing platforms) are scalable also for these value streams.

One reverse network effect that relates to self-consumption-based ECs is the idea that these models increase prices for non-EC members and therefore creates a self-reinforcing loop in which the incentive to join or create an EC increases with each new project (Abada et al., 2020).

The flexibility-based digital business models may scale relatively easily when customers already have flexible loads in their homes, although the assessments of the effects on user comfort and operational integration require extra effort. Interoperability and efficient data management become crucial for scaling these business models. Yet, complementing investments, such as home batteries require heavy up-front investments and reconfiguring work (Barnes et al., 2022). Business model innovations such as leasing can help to overcome these adoption barriers (Kubli & Canzi, 2021).

A social dilemma that arises from the scalability of different value streams and EC types comes from the value they can bring. Whereas scaling is based on efficiency and economies-of-scale, ECs also have a normative value to bring through the engagement of citizens and energy democracy, which, again, are relatively slow and local processes. This dilemma can be framed as different institutional logics, i.e. interests and priorities, of different stakeholders (Wittmayer et al., 2021). At the same time, this dilemma is related to the targeted value streams, which have different complexities from the layperson's perspective. Energy system-related value, like flexibility provision, can be more abstract than RE production and usage. Another social dilemma comes from scaling an EC internally. As the EC grows and attracts new members and investments, its operations become more hierarchical and professional, which can also decrease the democratic nature of the EC as a smaller-scale activity (Bauwens et al., 2022; Vernay, Olsthoorn, et al., 2023).

Institutions

Existing community structures facilitate the creation and decision-making of ECs, especially for housing associations and housing companies (EC types A and B). The existing institutions supporting them can serve ECs as intermediaries, conflict resolution mechanisms, transferring knowledge, and providing access to resources and networks. If only EC types A and B are supported for the self-consumption value stream, this can incentivize the creation of large property boundaries to avoid using the public grid. This can also influence urban planning and real estate development, especially when the DSO is privately owned. Different EC types rely on local institutions, facilitators, or virtual platforms. Sector coupling is easier in local ECs with integrated energy flows. The diverse transposition of the EC directive across EU member states is expected due to varying energy policies, market structures, infrastructure, and RE incentives. Numerous regulations impact ECs, including network tariffs and demand response markets.

EC types C and D are typically reliant on local institutions, but they often emerge through a combination of top-down and bottom-up approaches facilitated by entities like municipalities. On the other hand, EC type E represents a non-place-based community-of-interest that can spread independently of local institutions, often through online platforms. Another important factor is the integration of different energy sectors, known as sector coupling, which is more feasible in local ECs where energy flows are physically closely interconnected (Hoicka et al., 2021). The diverse implementation of the EC directive across EU member states is not surprising, considering the variations in energy policies, systems, infrastructure, and incentives for RE within each country.

3.5. Energy communities' economic evaluation in different contexts

The different EC types affect electricity costs and metering arrangements. The most noticeable difference is in whether the EC self-consumption saves on all network tariffs and taxes or not. In many cases, this means whether it is using the public grid (type B, D, or E) or happens behind one meter (type A). Also, some countries are allowing collective self-consumption to have both savings.

Figure 7 shows the difference the optimal sizing of the PV plant in an apartment building can have, and Figure 8 shows how much the annual savings on electricity bills are with the optimal PV plant sizing. The blue bar shows a case where self-consumption happens only in shared rooms, like elevators. The orange bar shows the case where self-consumption happens also in people's apartments. On average, the optimal PV plant size increases by 46% when self-consumption gets the full benefit.

Further benefits and optimal PV sizes are gained from adding flexible loads, such as electric vehicles, and batteries (BESS), to the EC. Many ECs may not currently have all the possible flexible load options, but it is expected that in the case of electric vehicles this will change since they are being adopted by many people. Allowing the EC to benefit more from self-consumption leads to incentives to have complementary assets that take part in the EC operation. These assets, again, have synergies with other value streams, such as price arbitrage and DR services, presented in the previous chapter. Adding features step-by-step in the EC is therefore an important element to keep in mind, and the interoperability of different technologies should be designed early in the process. These results and the background assumptions are more thoroughly explained in Deliverable 5.2.

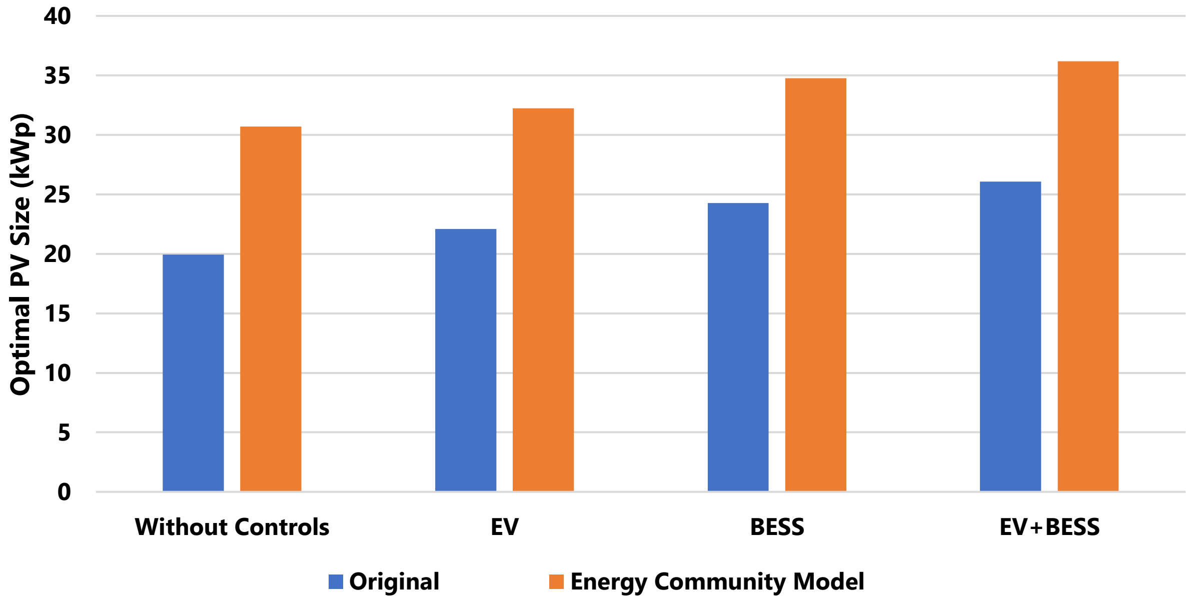


Figure 7. Impact of forming energy community to PV sizing

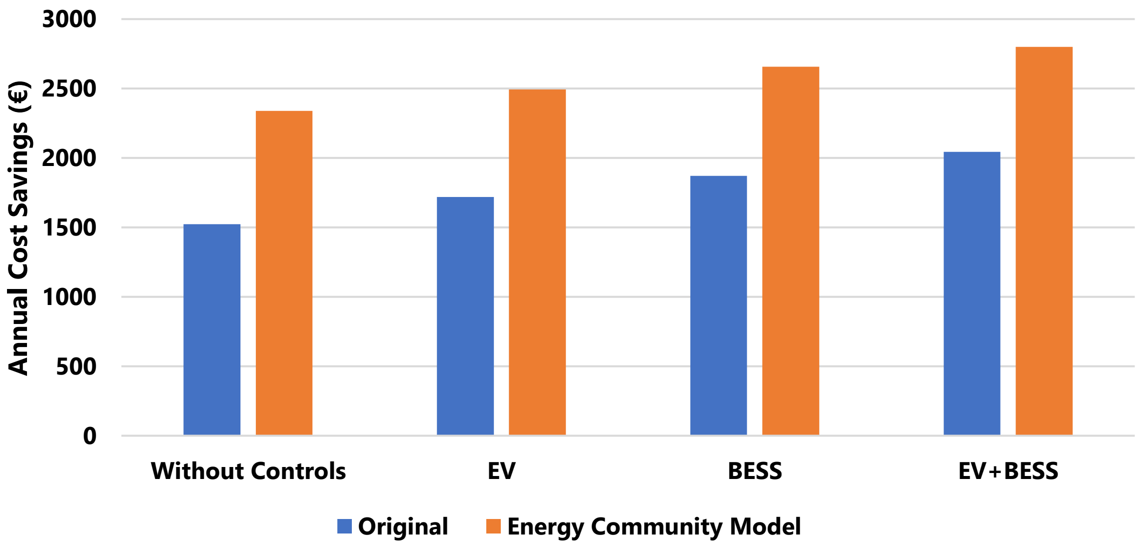


Figure 8. Impact of forming energy community to annual cost savings with optimal PV size

The other element that heavily influences the profitability of EC in the self-consumption value stream is the level of demand charges. In principle, the more the network tariffs are based on fixed charges (€/month) or demand charges (€/kW), the less incentives there are for mere self-consumption, whereas volumetric tariffs (€/kWh) incentivise to maximise the PV plant size. Furthermore, time-of-use tariffs can incentivise customers to self-consume during peak hours, such as mornings and evenings. Capacity-based tariffs, on the other hand, incentivise peak shaving mechanisms, which are included in smart charging systems, for example. However, they can disincentivise DR value streams, load shifting and price arbitrage, because the lower capacity does not enable large fluctuations in power demand. Deliverable 5.2 explains these dynamics more explicitly. In these simulations, all the buildings were connected to a district heating system. Buildings that rely on heat pumps and electric heating have even more demand for self-consumption.

3.6. Energy community formation at the district-level

3.6.1. Case 1: Legitimation of emerging energy community ecosystems

Background and case descriptions

One angle for studying the district-level solutions is the concept of legitimacy. This concept is particularly relevant due to the large number of stakeholders and the interplay between public and private actors that is needed. We conducted a multiple case study on four different EC cases, all situated in Finland. The data consisted of thirty interviews and available secondary data. Two of the cases were located in new residential areas, and two were located on new industrial sites. In all cases (described in Table 13), the municipality had a significant role in either initiating or supporting the project. Mostly, the projects are still in an early phase, except for case A, which is already in operational mode.

Table 13. Case descriptions and data used

Case and focal entity	**Case A – industrial EC. Focal actor: municipal utility**	**Case B – residential EC Focal actor: landowners**	**Case C – industrial EC Focal actor: wind energy developer**	**Case D residential EC Focal actor: city-owned regional developer**
Data	18 interviews, 1 project planning meeting, 2 seminars, 1 guided tour in the area, 26 news articles, 13 strategy papers/meeting notes, 27 stakeholder websites and reports	5 interviews, 1 workshop with 25 participants, 1 seminar, 10 news articles, 7 strategy papers, stakeholder websites and reports	3 interviews, 17 news articles, 9 strategy papers/meeting notes, stakeholder websites and reports	4 interviews, 2 workshops, 7 news articles, 24 stakeholder websites, announcements and reports, 7 academic publications
Energy-related goals	Energy self-sufficient industrial district	Smart own energy network, carbon-neutrality	Carbon-neutral industrial district	Carbon-negative residential area.
DSO ownership	Private	Private	Private	Municipality
Main technologies and infra	Solar PV, battery storage, fuel cells, gas motors.	Solar PV, seawater heat pumps, small-scale bio-CHP	Wind, Solar PV, battery storage, DH system, biogas	Solar PV, bi-directional DH and cooling system (use of excess heat with CHC heat pumps. Sources of energy: ground, air, lake), biogas and energy storage
Investor	Municipal utility	One possible option: energy community / cooperative with public and private investors	Private energy producers	Open options: utility, EC operator, and/or individual real estate developers
Development phase	Mobilization	Ideation	Ideation	Ideation

Theoretical framework

The theory used in this study was ecosystem legitimation, formulated by (Thomas & Ritala, 2021). In their theoretical framework, ecosystem legitimation is divided into two main processes: Discursive legitimation, and Performance-based legitimation.

The discursive legitimation includes several activities. Firstly, ecosystem legitimation requires framing, which directs attention towards the necessary and important features of the ecosystem. This includes visioning while identifying issues, demonstrating the ecosystem's benefits and motivating, often done by categorising the ecosystem to familiar offerings or processes. Also, the public interest is emphasised in framing. The second activity is sensemaking, by which the ecosystem members begin to comprehend the ecosystem's value proposition. This includes developing and sharing insights of the various components of the ecosystem value proposition and forming shared views. The third activity is the positioning of the ecosystem. By that the ecosystem members aim to answer, what is distinctive and valuable on the value proposition and how does it differ from the ordinary models? A successful positioning should also help in arguing the benefits the ecosystem brings to different stakeholders. The fourth discursive legitimation activity is recognizing, which is done by external stakeholders like media, regulators, analysts, and others.

The performative legitimation includes showing the superiority in performance compared to other solutions. Compared to discursive legitimation, it represents the more tangible and concrete actions of the ecosystem members. The activities related to it signal increasing commitment to the emerging ecosystem via different kinds of investments. These include strategic actions like, ecosystem-specific investments in resources and technologies, or organisational changes or new governance changes that devote resources to the development of the ecosystem. The governance mechanisms include pricing, membership rules, standardisation activities, and controlling the entrance (Thomas & Ritala, 2021). Typical dilemmas in ecosystem governance include balancing standardisation vs. variety of complementor outputs, process control vs. autonomy, and creating individual vs. collective incentives (Wareham & Fox, 2014).

The second activity class in performative legitimacy is value realisation. That refers to comparative success from the whole ecosystem's perspective, in delivering the ecosystem value proposal to the customer. That means that the ecosystem members are aligned profitably, effectively and fairly in the ecosystem value blueprint, which is used to describe the role of different ecosystem members in delivering it (Adner, 2017; Jacobides et al., 2018).

The third activity for performative legitimation is its adoption by users and complementors. Complementors play a significant role in ecosystem development through resource and skill deployment, and especially high-status complementors help in legitimating the ecosystem. Similarly, high-status customers help in proving the viability of the ecosystem offering. In ecosystem value propositions supporting network effects, customer adoption has its own specific legitimating impact related to the increasing value of having a larger customer base.

The fourth activity is intervention in the ecosystem by external actors. These include actions by financiers, governments, regulators and incumbents that prove the viability of the ecosystem. In the framework by Thomas & Ritala (2021), these two main legitimation processes lead to a strengthened ecosystem identity, which is defined as the "central, enduring and distinctive characteristics of the ecosystem".

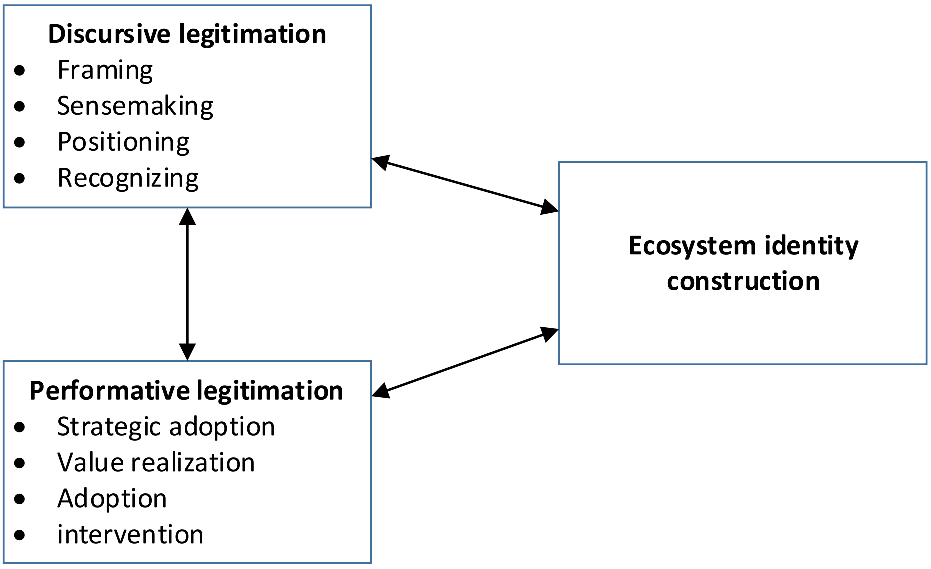


Figure 9. Process model of ecosystem legitimation (Thomas & Ritala, 2021)

Results

- **Framing**

The initial issues that triggered the project varied a lot. Case A emerged through the local utility's challenges to respond to tax increases for natural gas. This led to the ideation of alternative solutions utilising the existing infrastructure. Case B emerged from the initiative of local landowners, who faced regional plans for the urbanisation of their land. Their mission was to protect the local environment and social values from "traditional" urban planning. Case C was initiated by a wind power developer who wanted to find new ways for maintaining the acceptance of wind power in areas where there is high diffusion of wind power. In the words of the initiator:

> *"We should leave as many euros to the locals so they would be more supportive of wind power"* (Source: the wind power developer).

Case D is a large new urban district with high sustainability targets, and ECs have been seen as one solution to achieve them.

> *"Back then the municipal council had this setting that the city set a lot higher sustainability ambitions to the area that what is the business-as-usual"* (Source: public developer company representative).

Aside from the triggering issues, the project had several common issues to solve from an energy system and public interest perspective. All cases had a strong emphasis on supporting the sustainability targets locally and nationally. These included the national targets for RE and self-sufficiency, but also municipal targets were used in framing the projects. Case A, for instance, was positioned to solve the problem of "what to do when the sun doesn't shine, or the wind doesn't blow". The EC was seen as a response to decreasing shares and profitability of CHP plants in Finland, which have provided important base load also during cold winter days.

Also, the flexibility needs that increase due to the increased share of variable RE in the electricity system. In case A, also the security of supply and the quality of electricity provision was emphasised. All cases included a notion of the project acting as a test bed for future solutions and offering a springboard for commercialising new technological solutions. The project leader was also concerned about designing energy systems solely focused from a building-oriented perspective and lacking a more holistic system-level coordination, especially relating to the use of existing district heating and gas infrastructures.

- **Sensemaking**

There are multiple different components that different actors used for making sense of their EC ecosystems. As ECs posed a rather new but vague concept, it was compared to existing concepts in different ways. In the industrial EC, the concept was compared to old paper mill areas, where the mill owner acted as a coordinator of energy flows within the factory area. In the other industrial EC, the EC aimed at increasing regional self-sufficiency and the EC area was compared to tax-free trading areas. The discussion on the residential area EC in case D was compared to Superblocks in Barcelona and elsewhere. The self-consumption model was also compared to the Mankala-model, which is used to finance Finnish nuclear plants and provide the energy to their owners at the cost price.

Sensemaking has been done in different forums: workshops, Facebook-groups, public hearings and community meetings. However, as the future users are unknown, co-creation has its limitation. One possible suggested mechanism is group construction, in which interested families are involved in the planning process. Overall, sensemaking was done on many areas: organisational forms, financing arrangements and tariffs, service boundaries, and data management. Also, the EC-related regulation was often discussed, and related to this, there were some discussions on whether the property boundaries should be set large for the creation of their own decentralised energy system, connected but independently operating from the public grids and heat networks.

- **Positioning**

Unlike many ECs, the case studies aimed to position themselves in other ways than RE producers and consumers. Importantly, all cases included the features of flexibility and creating smart and holistic energy solutions that focus on efficiencies within the whole neighbourhood and not only a single building. The inclusion of open district heating systems and using excess heat within the area played an important role in this positioning. For example, in Case A, there are logistics centres in the area, who can provide excess heat from their operations, but making them useful for others requires knowledge sharing and understanding about the logistics centre operations. Ideally, a collaborative EC operator would design and optimise and coordinate different energy flows between EC members. Another aspect that was widely shared between the projects was power self-sufficiency and "not relying on markets", which include the trend of decreasing the number of dispatchable CHP plants and increasing the share of variable RE.

This centralized model was also thought of as being complex to manage, and case C was turning towards a distributed model with different responsible actors for electric grid operation, heating network operation, and energy production. The same applies to various other services, such as shared cars, rooms and waste disposal systems, as discussed in case B. The DSO, which operates electricity grids as their main competence, views such differentiation pragmatically, since managing also local grids requires many tasks and regulated obligations related to security, operations and reporting.

> *"It [the grid] does not do the maintenance by itself, it requires managing"* (Source: DSO representative.)

Also, the regulation leans towards such distributed models as the Finnish Electricity Act requires the unbundling of energy production and network management. However, there was a shared view of a need for closer collaboration between actors in the planning of energy systems.

- **Recognizing**

The European directives on ECs that were proposed in 2016 and finally in force in 2019, opened a window of opportunity, since they provided regulatory legitimacy for frontrunner projects to explore new solutions. In the words of the project initiator in case B:

> *"There have been exceptions in getting electricity across property boundaries [...] so we know the direction is changing".*

In case C, European directives offered a leeway for a solution that would distribute more of wind power's benefits to locals. The wind developer said:

> *"...I suggested to the municipality that this electricity could be transferred as a direct industrial network, according to the new EU directive. Then they realised how big of a potential there is."*

Moreover, case B aimed at receiving the "swan" certificate for the neighbourhood. This certificate is given to products and services that fulfil high sustainability standards. Case D is seeking the BREEAM Communities certificate, which is given to sustainable regional projects. The projects were often handled in local news media as significant regional projects. However, the focus in these articles was often quite technology-centred, leaving the social and organisational aspects to a smaller focus.

- **Strategic actions**

In the residential area cases, there are currently developer organisations who run the EC development forwards as a part of the larger housing and infrastructure development. In case D, this entity now owns the lands and later sells them to real estate developers, sets the rules for plot planning, but most importantly, can operate outside municipal budgeting rules and properly invest in developing a new and highly sustainable district. A manager in the developer company in case D said this was due to budgeting processes, which are hard to change:

> *"...for the municipality it is really hard to invest big in-front and gain income later."*

Here, the developer organisation has also invested a lot in designing and putting in place the rules for plot transfer conditions and related urban planning.

In case A, the now-built industrial EC, the municipality founded a new organisation alongside the municipal utility for operating the EC. It invested significantly to the EC area and provided the "backbone" for further development. In a way, it has acted as a risk taker for future investments.

On the technological side, the target is to be able to use modular solutions, which would not require tough co-development between the EC and technology providers. The bidirectional district heating systems, which has been at least planned in all the projects are large up-front investments that differ from business-as-usual solutions.

- **Value realization**

The case projects and their planning included different structures for asset ownership. In case A, both production and network energy assets are mainly owned centrally by the operator, whereas in case C, the energy production ownership is mainly divided among different energy producers. In case D, there are different proposed models presented for the ownership of energy assets, including a cooperative, service company and the utility. Also, the real estate developers have a lot of freedom in making decisions on energy investments in the buildings. These differences affect the way in which value is shared among users and complementors and how risk is shared. The same centralised vs. decentralised structural question is related to flexibility resources and energy storage. How the loads controlled in buildings and how individuals are incentivised to participate in demand response.

There are investments done on two levels: buildings and the energy system, and sharing the value and responsibilities between them is a crucial part for the nature of the EC. Whereas a decentralised approach could benefit building owners more than a centralised model, it also brings challenges to the coordination of the EC. The DH network is a good example of this: if some real estate developers decide not to join the DH network, the whole system loses the benefits from economies-of-scale.

For the DSO, the value of ECs depends on whether they use the public grid or not. If the ECs form independent networks, from the DSOs' perspective, value is being destroyed rather than created. For the construction companies, investing enough to reach the sustainability standards set by the EC, can become a challenge.

- **Adoption**

The initiators of the EC cases do not have all the capabilities and resources to operate the EC, for which getting good complementors is crucial. In some EC projects, the operator could become the focal actor because it holds access to data and controls the financial and energy flows. In case A, there is a large multinational company who has specialised in providing the operator platform, yet the utility remains the operator. In other cases, it is unclear who the operator could be. The capabilities of acting as an operator are currently scattered to different actors: utility, DSO, energy producers, automation providers, building managers and HVAC and DER providers. Activities such as customer engagement, financing, and warranties add to the complexity of the task.

- **Intervention**

The interventions from external actors provided proof that the projects were aligned with the broader social environment. The projects received different levels of funding ranging from funding for feasibility studies to investment grants for energy demonstration projects. Moreover, all the projects were attached to university collaboration as well as meetings and promotion by governmental agencies thriving for export business and sustainability. The introduction of relevant regulation on the national level is still unclear, however the case project pronounced the need for regulatory sandboxes in the energy field, and this has been developed on the ministry-level.

3.6.2. Case 2: Stakeholder expectations for new business models

A case study was conducted in Hiedanranta, a new urban area in Tampere, Finland. The area consists of approximately 50 apartment buildings and is planned for 25000 residents when finished. As a research method, this research collected 20 interviews and surveys. This research can be found in more detail in conference paper (Vanhanen et al., 2023) We divided the analysis into five categories, following the Strategic Niche Management theory and the related literature (Geels, 2004; Kallio et al., 2020; Kemp et al., 1998; Schot & Geels, 2008): actor networks; expectations and priorities; supporting rules; technical solutions; and business models and conflicts. These were further divided into three phases of energy value stream: production, distribution and consumption.

Actors and their expectations

The main stakeholders and their interests in the Hiedanranta residential area include different sectors:

- Construction: (real estate developers, construction companies)
- Energy and technology providers: District heating system operator (DHSO), DSO, ground-source heat pump providers, energy storage developers. The DSO is in monopoly position, whereas the

district heating company operates in competed sector. It is up to real estate developers to decide what kind of heating source the buildings will have. Therefore, it is important for the DHSO to stay competitive and attractive, both economically and ecologically. The DSO is willing to develop new demand-side solutions and tariffs, yet they do not see the immediate need for them in such an urban context.

- Developer company owned by the municipality, which also manages service companies for centralised parking lots and commercial properties in the area. It also sets the rules for real estate developers and data management.
- Industrial-scale customers locating in the area. For example, data centres are consumers that are important in energy system planning.

Also, investors are interested in the area since it is considered as a springboard for innovation. Also, the ministry expects the area to help in commercialising different energy solutions, especially for export markets. According to the surveys done, citizen, the EU, and citizen advocacy groups are the least important actors in developing the area.

Traditionally, there has been a network between the real estate developer and construction companies and the district heating utility. Behind this has been the fact that district heating provides a relatively easy, low-Capex and efficient way of heat provision to buildings. This has supported the low-margins and relatively short-term business logic of the construction sector. In the end, their main target is to stay competitive in the real estate market. Ground-source heat pumps and demand-side management solutions have higher Capex and some uncertainties in their functioning.

Supporting rules

There are multiple regulations that actors highlight and which steer the implementation of the EC . The DHSO says that the Emission Trading System (ETS) is enough for the shift from fossil fuels and no additional fiscal measures are needed. Their emphasis is on large power plants on the production side. As the DHSO is using a significant amount of biomass, its taxation is crucial for the profitability. Permitting the installation of new power lines in time is important in the dense area, especially for electric boilers and industrial-scale heat pumps.

For property developers, the introduction of small-scale generation surplus compensation, answers problems for implementing ECs within property boundaries. Solutions for the whole block or combining centralised parking lots with other buildings are not established. The EPC measures are a crucial policy to follow. Distribution tariffs should be rethought for distributed energy technologies.

The municipal energy experts and the development company have somewhat differing opinions on the impact of city planning on energy system development. The main dilemma is that the municipality cannot force property developers to join the DH in Finland, nor can they force them to buy green electricity. On the contrary, the city can mandate data interoperability measures and energy efficiency targets in the buildings.

Technical solutions

The technical solutions that have been planned include: solar PV on buildings, excess heat sources, open data, bioenergy carbon capture and storage, and DSM. The main challenge is to bridge the building-level energy optimisation, storage and flexibility with city-level operations. Avoiding double investments for system optimisation is not reasonable. The bidirectional low temperature DH network that is surely built in the area will facilitate transactions, yet the focus of the DHSO on this kind of collaboration is on larger actors like data centres.

Business models and conflicts

Overall, combining decentralised and centralised solutions poses some conflicts and dilemmas in the creation of district-level ECs. The DHSO is not very interested in open data-based solutions, because they have invested and have expertise in optimising the city-scale system. DSM solutions would also decrease DHSO's revenue in current business models. On the other hand, ground-source heat pumps are used to avoid joining the DH system, which also decreases DH networks viability.

One proposed solution to act as the middleman is an EC operator, who would take care of financing, technological investments, and optimise locally the energy usage. The boundaries of such an actor remain unsolved, since an EC operator can carry out services all the way to the building's indoor conditions and offer VPP business models, if it wanted. This would, however, require a wide set of capabilities, which are not currently held by existing actors.

3.6.3. Conclusions of the case studies

These two case studies have shown that there are different drivers towards district-level ECs. The case projects were linked to public authorities and urban planning, which also highlights the importance of designing the EC from very early on in the project lifecycle. As cities are adopting ambitious climate plans (initiatives like ICLEI, C40, Global Covenant of Mayors for Climate and Energy, etc.), the large role of the public actors will continue to be the case.

Overall, the EC models are new and require legitimation, which from the ecosystem perspective, needs positioning and collective value realisation. Different collaboration modes and public-private partnerships will become important to manage. The central utility does not always see distributed solutions as beneficial, especially if they have invested heavily in centralised power plants.

The case studies were done in Finland, which has its limitations but also benefits. The context there highlights the role of district heating, and the digitalisation is some steps ahead from many countries. This shifts the identity of the EC towards sector coupling through heat and electricity. In many parts of Europe, gas acts in a bigger role. Also, the unregulated nature of district heating and situation of Finnish legislation on EC should be noticed when compared with cases in other countries.

4. CONCLUSIONS

This deliverable has studied the PRELUDE business landscape from different perspectives and levels: regulatory barriers, enabling business models, economic evaluations and EC creation processes.

The barriers for such an ecosystem to emerge are multiple. On the technological side, there are battles over standards and missing infrastructure (e.g. smart meters), management of data collection and sensors. On the regulatory level, there are differences in how smart buildings and ECs are being regulated. These challenges are pronounced in the district-level projects, which are connected to urban planning processes and existing utility operating models. On the inter-organisational level, there are path dependencies on how contracts and responsibilities have been divided in the past. Changing or integrating new services on top of existing ones requires shared interests from different parties. Especially the regulatory decisions have an impact on the economic attractiveness of different ECs and the related value streams.

In an ideal world, PRELUDE would act as a part of an ecosystem for demand response and energy efficiency. This ecosystem would include different collaborating actors, IT companies specialising in data analytics, aggregators and other service providers for demand response, electricity retailers on smart tariffs, etc. (Carmichael et al., 2021). There is, however, a lot of work ahead to clear the bottlenecks (e.g. lacking infrastructure, interoperability issues, lacking customer trust and knowledge, data quality issues) ahead of the ecosystem (see also Loock, 2020). The development through the demos in PRELUDE and other projects can be seen as an ambidextrous process between exploration and exploitation modes (see Figure 10). The projects are opportunities to test new things and, for example, collect data from multiple data sources that would not be used in conventional cases.

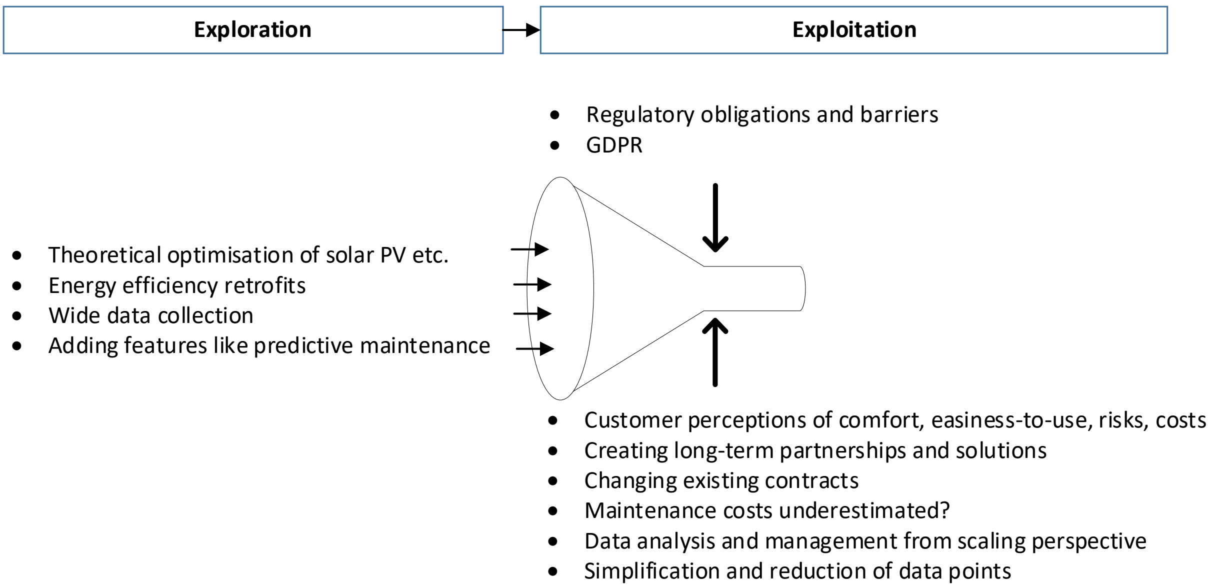


Figure 10. Shifting between exploration and exploitation modes in Geneva demo case (adapted from Nielsen et al., 2019).

To maximize the benefits derived from the demo cases and achieve the effective implementation of scalable solutions, prioritization and simplification of solutions are necessary. At the same time, the exploration mode should continue, so that the PRELUDE solution recognises the right channels to the rapidly evolving market of smart buildings.

Finally, how should the Prelude business landscape be defined? The following elements arise from the analysis of this Deliverable:

- *Prelude is realised by multiple stakeholders who have shifting positions in the value chain.*

As a baseline, customers are adopting controllable loads like heat pumps and electric vehicles and smart homes. Accommodating these distributed assets in a previously centralised energy system requires a) business models that redistribute value among actors, b) trust for long-term collaboration, c) new kinds of contracts, also between public and private actors, and d) appreciation of local communities, whose motivations, assets, and infrastructures differ.

- *Data management can add significant value but must be managed efficiently.*

GDPR, data collection, data ownership questions in a multi-stakeholder environment, and data analysis set requirements and costs that need to add value to the end-customer or otherwise, they won't be paid.

- *Regulation is evolving towards incentives for smart energy utilisation also outside one property.*

Dynamic tariffs and smart metering are becoming more common. Decarbonisation policies are multi-level in their nature. Cities are especially interesting because they are close to the implementation of the transition. Electrification sets new demands for local-level coordination, for which ECs are one solution.

REFERENCES

Abada, I., Ehrenmann, A., & Lambin, X. (2020). Unintended consequences: The snowball effect of energy communities. *Energy Policy*, *143*, 111597. https://doi.org/10.1016/j.enpol.2020.111597

ACER, & CEER. (2022). *Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2021* (p. 97).

Adams, W. (2015). *Conducting Semi-Structured Interviews*. https://doi.org/10.1002/9781119171386.ch19

Adner, R. (2017). Ecosystem as Structure: An Actionable Construct for Strategy. *Journal of Management*, *43*(1), 39–58. https://doi.org/10.1177/0149206316678451

AF-Mercados, REF-E, & Indra. (2015). *Study on tariff design for distribution systems*. 652.

Aversa, P., Haefliger, S., Hueller, F., & Reza, D. G. (2021). Customer complementarity in the digital space: Exploring Amazon's business model diversification. *Long Range Planning*, *54*(5), 101985. https://doi.org/10.1016/j.lrp.2020.101985

Babilon, L., Battaglia, M., Robers, M., Degel, M., & Ludwig, K. (2022). *Energy communities: Accelerators of the decentralised energy transition*. Deutsche Energie-Agentur.

Barnes, J., Hansen, P., Kamin, T., Golob, U., Musolino, M., & Nicita, A. (2022). Energy communities as demand-side innovators? Assessing the potential of European cases to reduce demand and foster flexibility. *Energy Research & Social Science*, *93*, 102848. https://doi.org/10.1016/j.erss.2022.102848

Bauwens, T., Vaskelainen, T., & Frenken, K. (2022). Conceptualising institutional complexity in the upscaling of community enterprises: Lessons from renewable energy and carsharing. *Environmental Innovation and Societal Transitions*, *42*, 138–151. https://doi.org/10.1016/j.eist.2021.12.007

Bencsik, B., Palmié, M., Parida, V., Wincent, J., & Gassmann, O. (2023). Business models for digital sustainability: Framework, microfoundations of value capture, and empirical evidence from 130 smart city services. *Journal of Business Research*, *160*, 113757. https://doi.org/10.1016/j.jbusres.2023.113757

Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S. (2014). *A literature and practice review to develop sustainable business model archetypes*. *65*, 42–56. https://doi.org/10.1016/j.jclepro.2013.11.039

Bocken, N., Short, S., Rana, P., & Evans, S. (2013). A value mapping tool for sustainable business modelling. *Corporate Governance: The International Journal of Business in Society*, *13*(5), 482–497. https://doi.org/10.1108/CG-06-2013-0078

Brown, D., Hall, S., & Davis, M. E. (2019). Prosumers in the post subsidy era: An exploration of new prosumer business models in the UK. *Energy Policy*, *135*, 110984. https://doi.org/10.1016/j.enpol.2019.110984

Burger, S. P., & Luke, M. (2017). Business models for distributed energy resources: A review and empirical analysis. *Energy Policy*, *109*(July), 230–248. https://doi.org/10.1016/j.enpol.2017.07.007

Carmichael, R., Gross, R., Hanna, R., Rhodes, A., & Green, T. (2021). The Demand Response Technology Cluster: Accelerating UK residential consumer engagement with time-of-use tariffs, electric vehicles and smart meters via digital comparison tools. *Renewable and Sustainable Energy Reviews*, *139*, 110701. https://doi.org/10.1016/j.rser.2020.110701

Claeys, B. (2021). *Energy communities with grid benefits* (pp. 1–16). Regulatory Assistance Project. https://www.raponline.org/knowledge-center/energy-communities-with-grid-benefits-a-quest-for-a-blueprint/

de Wildt, T. E., Chappin, E. J. L., van de Kaa, G., Herder, P. M., &, & van de Poel, I. R. (2019). Conflicting values in the smart electricity grid a comprehensive overview. *Renewable and Sustainable Energy Reviews*, *111*, 194–196.

Department of Energy & Climate Change. (2013). *Collective Purchasing and Switching: What consumers need to know*. https://www.gov.uk/guidance/collective-switching-and-purchasing

DG Energy. (2023a). *Quarterly Report on European Electricity markets Q3 2022*.

DG Energy. (2023b). *Quarterly Report on European Electricity Markets Q4 2022*.

Di Silvestre, M. L., Ippolito, M. G., Sanseverino, E. R., Sciumè, G., & Vasile, A. (2021). Energy self-consumers and renewable energy communities in Italy: New actors of the electric power systems. *Renewable and Sustainable Energy Reviews*, *151*, 111565. https://doi.org/10.1016/j.rser.2021.111565

ElCom. (2022). *Forte augmentation des prix de l'électricité 2023*. Https://Www.Admin.Ch/Gov/Fr/Accueil/Documentation/Communiques.Msg-Id-90237.Html. https://www.admin.ch/gov/fr/accueil/documentation/communiques.msg-id-90237.html

EU. (2018). Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources. *Official Journal of the European Union*, 82–209.

EU. (2019). Directive 2019/944 on Common rules for the internal market for electricity. *Official Journal of the European Union*.

Eurelectric. (2019). *Citizens Energy Communities: Recommendations for a successful contribution to decarbonisation*.

Eurelectric. (2020). *Distribution Grids in Europe Facts and Figures 2020*.

European Commission. (2020). *A Renovation Wave for Europe—Greening our buildings, creating jobs, improving lives*.

European Commission. (2021). *Analysis of the national long-term renovation strategies*.

European Commission. (2022a). *EU Solar Energy Strategy*.

European Commission. (2022b). *REPowerEU: Joint European Action for more affordable, secure and sustainable energy*.

European Commission. (2019). *A European Green Deal*. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

Eurostat. (2023). *Electricity price statistics*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics#Electricity_prices_for_household_consumers

Frieden, D., Tuerk, A., Neumann, C., D'Herbemont, S., & Roberts, J. (2020). *Collective self-consumption and energy communities: Trends and challenges in the transposition of the EU framework* (Issue December).

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6–7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Gjorgievski, V. Z., Cundeva, S., & Georghiou, G. E. (2021). Social arrangements, technical designs and impacts of energy communities: A review. *Renewable Energy*, *169*, 1138–1156. https://doi.org/10.1016/j.renene.2021.01.078

Golmohamadi, H., Keypour, R., Bak-Jensen, B., & Pillai, J. R. (2019). A multi-agent based optimization of residential and industrial demand response aggregators. *International Journal of Electrical Power & Energy Systems*, *107*, 472–485. https://doi.org/10.1016/j.ijepes.2018.12.020

Hampton, H., Foley, A., Del Rio, D. F., Smyth, B., Laverty, D., & Caulfield, B. (2022). Customer engagement strategies in retail electricity markets: A comprehensive and comparative review. *Energy Research & Social Science*, *90*, 102611. https://doi.org/10.1016/j.erss.2022.102611

Hoicka, C. E., Lowitzsch, J., Brisbois, M. C., Kumar, A., & Ramirez Camargo, L. (2021). Implementing a just renewable energy transition: Policy advice for transposing the new European rules for renewable energy communities. *Energy Policy*, *156*. https://doi.org/10.1016/j.enpol.2021.112435

Iazzolino, G., Sorrentino, N., Menniti, D., Pinnarelli, A., De Carolis, M., & Mendicino, L. (2022). Energy communities and key features emerged from business models review. *Energy Policy*, *165*, 112929. https://doi.org/10.1016/j.enpol.2022.112929

IEA. (2023). *Renewables 2022 Analysis and forecast to 2027*.

Jacobides, M. G., Cennamo, C., & Gawer, A. (2018). Towards a theory of ecosystems. *Strategic Management Journal*, *39*(8), 2255–2276. https://doi.org/10.1002/smj.2904

Kallio, L., Heiskanen, E., Apajalahti, E.-L., & Matschoss, K. (2020). Farm power: How a new business model impacts the energy transition in Finland. *Energy Research & Social Science*, *65*, 101484. https://doi.org/10.1016/j.erss.2020.101484

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management*, *10*(2), 175–198.

Krug, M., Di Nucci, M. R., Schwarz, L., Alonso, I., Azevedo, I., Bastiani, M., Dyląg, A., Laes, E., Hinsch, A., Klāvs, G., Kudreņickis, I., Maleki, P., Massa, G., Meynaerts, E., Pappa, S., & Standal, K. (2023). Implementing European Union Provisions and Enabling Frameworks for Renewable Energy Communities in Nine Countries: Progress, Delays, and Gaps. *Sustainability*, *15*(11), 8861. https://doi.org/10.3390/su15118861

Kubli, M., & Canzi, P. (2021). Business strategies for flexibility aggregators to steer clear of being "too small to bid." *Renewable and Sustainable Energy Reviews*, *143*, 110908. https://doi.org/10.1016/j.rser.2021.110908

Kubli, M., & Puranik, S. (2023). A typology of business models for energy communities: Current and emerging design options. *Renewable and Sustainable Energy Reviews*, *176*, 113165. https://doi.org/10.1016/j.rser.2023.113165

Küfeoğlu, S., Açıkgöz, E., Taşcı, Y. E., Arslan, T. Y., Priesmann, J., & Praktiknjo, A. (2022). Designing the Business Ecosystem of a Decentralised Energy Datahub. *Energies*, *15*(2), 650. https://doi.org/10.3390/en15020650

Loock, M. (2020). Unlocking the value of digitalization for the European energy transition: A typology of innovative business models. *Energy Research and Social Science*, *69*(June). https://doi.org/10.1016/j.erss.2020.101740

Lowitzsch, J., Kreutzer, K., George, J., Croonenbroeck, C., & Breitschopf, B. (2023). Development prospects for energy communities in the EU identifying best practice and future opportunities using a morphological approach. *Energy Policy*, *174*, 113414. https://doi.org/10.1016/j.enpol.2022.113414

Lucinda Murley, & Mazzaferro, C. A. (2022). *European Market Monitor for Demand Side Flexibility 2021*. Delta-EE; SmarEn.

Maris, G., & Flouros, F. (2021). The Green Deal, National Energy and Climate Plans in Europe: Member States' Compliance and Strategies. *Administrative Sciences*, *11*(3), 75. https://doi.org/10.3390/admsci11030075

Monschauer, Y., Delmastro, C., & Martinez-Gordon, R. (2023, March 31). *Global heat pump sales continue double-digit growth*. https://www.iea.org/commentaries/global-heat-pump-sales-continue-double-digit-growth

Moura, R., & Brito, M. C. (2019). Prosumer aggregation policies, country experience and business models. *Energy Policy*, *132*, 820–830. https://doi.org/10.1016/j.enpol.2019.06.053

Murley, L., & Mazzaferro, C. A. (2023). *2022 Market Monitor for Demand Side Flexibility*.

Nielsen, B. F., Baer, D., & Lindkvist, C. (2019). Identifying and supporting exploratory and exploitative models of innovation in municipal urban planning; key challenges from seven Norwegian energy ambitious neighborhood pilots. *Technological Forecasting and Social Change*, *142*, 142–153. https://doi.org/10.1016/j.techfore.2018.11.007

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation*.

Pahkala, T., Uimonen, H., & Väre, V. (2018). *Flexible and customer-centred electricity system—Final report of the Smart Grid Working Group* (p. 46). Publications of the Ministry of Economic Affairs and Employment.

Passlick, J., Dreyer, S., Olivotti, D., Grützner, L., Eilers, D., & Breitner, M. H. (2021). Predictive maintenance as an internet of things enabled business model: A taxonomy. *Electronic Markets*, *31*(1), 67–87. https://doi.org/10.1007/s12525-020-00440-5

RAP. (2022). *Levelling the playing field: Aligning heating energy taxes and levies in Europe with climate goals*.

Reif, V., & Meeus, L. (2022). Smart metering interoperability issues and solutions: Taking inspiration from other ecosystems and sectors. *Utilities Policy*, *76*, 101360. https://doi.org/10.1016/j.jup.2022.101360

Reis, I. F. G., Gonçalves, I., Lopes, M. A. R., & Henggeler Antunes, C. (2021). Business models for energy communities: A review of key issues and trends. *Renewable and Sustainable Energy Reviews*, *144*, 111013. https://doi.org/10.1016/j.rser.2021.111013

Reypens, C., Lievens, A., & Blazevic, V. (2016). Leveraging value in multi-stakeholder innovation networks: A process framework for value co-creation and capture. *Industrial Marketing Management*, *56*, 40–50. https://doi.org/10.1016/j.indmarman.2016.03.005

Ritala, P., Agouridas, V., Assimakopoulos, D., & Gies, O. (2013). Value creation and capture mechanisms in innovation ecosystems: A comparative case study. *International Journal of Technology Management*, *63*, 244–267.

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (Eighth Edition). Pearson.

Saviuc, I., Zabala López, C., Puskás-Tompos, A., Rollert, K., & Bertoldi, P. (2022). *Explicit demand response for small end-users and independent aggregators: Status, context, enablers and barriers.* Publications Office. https://data.europa.eu/doi/10.2760/625919

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, *20*(5), 537–554. https://doi.org/10.1080/09537320802292651

Schwidtal, J. M., Piccini, P., Troncia, M., Chitchyan, R., Montakhabi, M., Francis, C., Gorbatcheva, A., Capper, T., Mustafa, M. A., Andoni, M., Robu, V., Bahloul, M., & Kiesling, L. (2022). *Emerging Business Models in Local Energy Markets: A Systematic Review of Peer-To-Peer, Community Self-Consumption, and Transactive Energy Models* (p. 98). http://dx.doi.org/10.2139/ssrn.4032760

Sgaravatti, G., Tagliapietra, S., & Zachmann, G. (2022). *National policies to shield consumers from rising energy prices*. Bruegel. https://www.bruegel.org/dataset/national-policies-shield-consumers-rising-energy-prices

Sjödin, D., Parida, V., Jovanovic, M., & Visnjic, I. (2020). Value Creation and Value Capture Alignment in Business Model Innovation: A Process View on Outcome-Based Business Models. *Journal of Product Innovation Management*, *37*(2), 158–183. https://doi.org/10.1111/jpim.12516

SmartEn. (2022). The implementation of the electricity market design to drive demand-side flexibility. In *Smarten monitoring report* (Issue March, pp. 1–30).

SolarPower Europe. (2022). *EU market outlook for solar power 2022-2026*.

Sunderland, L. (2023). *A European framework for minimum energy performance standards*. RAP.

Teece, D. J. (2010). Business Models , Business Strategy and Innovation. *Long Range Planning*, *43*(2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003

Thomas, L. D. W., & Ritala, P. (2021). Ecosystem Legitimacy Emergence: A Collective Action View. *Journal of Management*, *January*. https://doi.org/10.1177/0149206320986617

Tounquet, F., & Alaton, C. (2020). Benchmarking Smart Metering Deployment in EU-28. In *European Commission* (Issue December). https://op.europa.eu/en/publication-detail/-/publication/b397ef73-698f-11ea-b735-01aa75ed71a1/language-en

Tuerk, A., Frieden, D., Neumann, C., Latanis, K., Tsitsanis, A., Kousouris, S., Llorente, J., Heimonen, I., Reda, F., Ala-Juusela, M., Allaerts, K., Caerts, C., Schwarzl, T., Ulbrich, M., Stosch, A., & Ramschak, T. (2021). Integrating Plus Energy Buildings and Districts with the EU Energy Community Framework: Regulatory Opportunities, Barriers and Technological Solutions. *Buildings*, *11*(10), 468. https://doi.org/10.3390/buildings11100468

Valta, J., Kulmala, A., Järventausta, P., Kirjavainen, J., Mäkinen, S., Björkqvist, T., Uusitalo, S., Systä, K., & Repo, S. (2021). *Towards practical typology of energy communities: Main differentiating elements and examples of promising implementations*. CIRED 2021.

Valta, J., Lummi, K., Vanhanen, T., & Järventausta, P. (2023). *Value streams in different energy community types – Review and Implications*. European Energy Markets 2023.

Van De Kaa, G., Stoccuto, S., & Calderón, C. V. (2021). A battle over smart standards: Compatibility, governance, and innovation in home energy management systems and smart meters in the Netherlands. *Energy Research & Social Science*, *82*, 102302. https://doi.org/10.1016/j.erss.2021.102302

Vanhanen, T., Valta, J., & Valkokari, K. (2023). *Setting the Stage for a Future Positive Energy District – expectations on Energy System Operators in Case Hiedanranta*. EEM 2023, Lappeenranta.

Vernay, A.-L., Olsthoorn, M., Sebi, C., & Gauthier, C. (2023). The identity trap of community renewable energy in France. *Energy Policy*, *177*, 113562. https://doi.org/10.1016/j.enpol.2023.113562

Vernay, A.-L., Sebi, C., & Arroyo, F. (2023). Energy community business models and their impact on the energy transition: Lessons learnt from France. *Energy Policy*, *175*, 113473. https://doi.org/10.1016/j.enpol.2023.113473

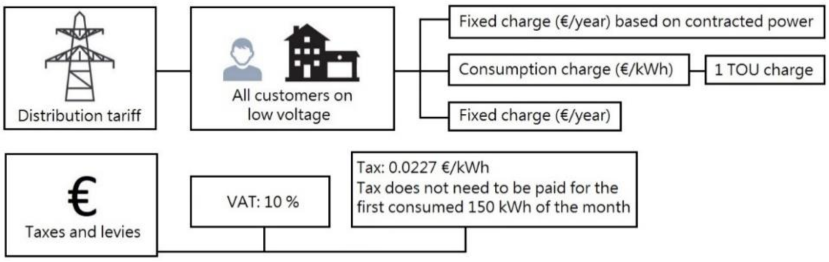
Wareham, J., & Fox, P. B. (2014). *Technology Ecosystem Governance*. *May 2019*.

Wittmayer, J. M., Avelino, F., Pel, B., & Campos, I. (2021). Contributing to sustainable and just energy systems? The mainstreaming of renewable energy prosumerism within and across institutional logics. *Energy Policy*, *149*. https://doi.org/10.1016/j.enpol.2020.112053

Zhou, B., Li, W., Chan, K. W., Cao, Y., Kuang, Y., Liu, X., & Wang, X. (2016). Smart home energy management systems: Concept, configurations, and scheduling strategies. *Renewable and Sustainable Energy Reviews*, *61*, 30–40. https://doi.org/10.1016/j.rser.2016.03.047

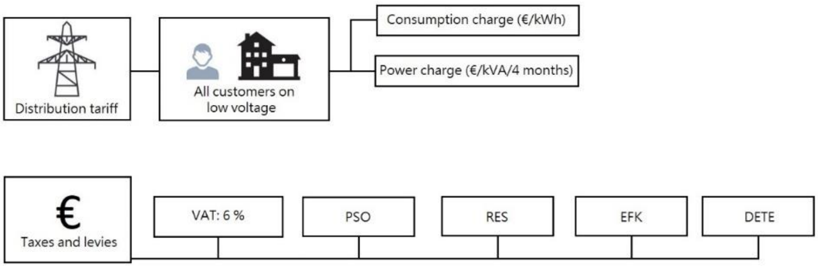
Zott, C., & Amit, R. (2010). Business model design: An activity system perspective. *Long Range Planning*, *43*(2–3), 216–226. https://doi.org/10.1016/j.lrp.2009.07.004

APPENDIX A



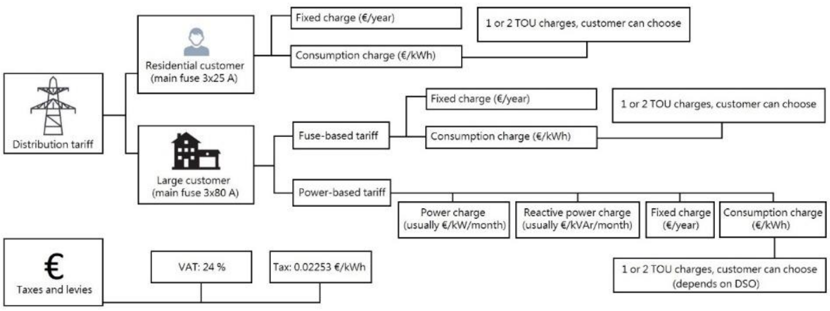
a)

A1. Figure 11. Distribution tariff, taxes and levies in Italy.



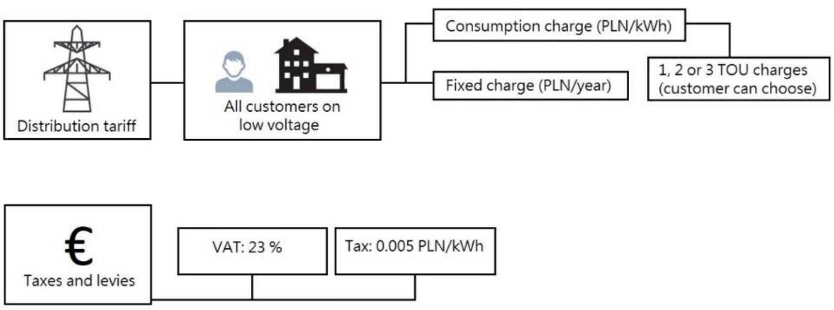
b)

A2. Figure 12. Distribution tariff, taxes and levies in Greece.



c)

A3. Figure 13. Distribution tariff, taxes and levies in Finland.



d)

A4. Figure 14. Distribution tariff, taxes and levies in Poland.