Report on improved market design, business models and financing models for sector coupling

(Tasks 1.2, 1.3, 1.4 and 1.5)

D1.2

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About ReInvent

In 2030 and beyond, multiple energy vectors (electricity, gas, heat, green molecules) will play a role in an interconnected energy system. Increased electrification will support sector integration between end user segments. To benefit maximally from the advantages of sector coupling, a fundamental rethinking of market design, business models and financing models is needed. ReInvent will define a roadmap for sector coupling in Belgium. The ReInvent approach is based on 4 pillars and is a combination of 1) conceptual analysis, 2) sound modelling, 3) proofing of concepts by relevant test cases, and 3) an ambitious impact assessment and replication strategy.

The **first pillar** will analyse the role of different energy vectors (gas, power, heat, and green molecules) in the Belgian energy mix. This includes the impact on infrastructure, market design and business models for different energy end user groups. Based on discussions with project partners and relevant stakeholders, different concepts for both supply-side and demand-side sector integration will be proposed. In addition to the operational implications of sector integration, the financial implications in terms of risk, return, and uncertainty will be analysed.

The **second pillar** will develop the ReInvent modelling and simulation. This multi-sectoral simulation environment will capture the different dynamics of different vectors in multiple timeframes, for multiple scenarios, for multiple market design options, for multiple services, including different end-use sectors and different layers of the physical networks and their interconnection. Innovations modelled in ReInvent aim at the overarching goal of augmenting and realizing the potential of sector coupling in providing key flexibility, balancing, and adequacy services to the multi-energy system and the electric grid.

The **third pillar** will look at a selection of reference test cases that represent main use cases of sector coupling/integration. These applications will provide real data that allow proofing of the developed models in the second pillar. In addition, the models of the second pillar will provide necessary insights to the test cases about the impact of the ReInvent solutions on the operational and financial stability of the presented solution. The ReInvent test cases address different vectors, end user segments and applications and are selected based on the technologies and applications that will play a central role in a future integrated system but still face barriers today that hinder their expected breakthrough.

The **fourth pillar** will define a roadmap for improved sector coupling and sector integration for Belgium. This includes an impact assessment of a wide roll-out of the solutions for the Belgian energy system, in particular the implications for security of supply and system balancing.

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List of Abbreviations and Acronyms

Acronym	*Meaning*
5GDHC	5th Generation District Heating and Cooling
ACER	Agency for the Cooperation of Energy Regulators
aFRR	Automatic Frequency Restoration Reserve
AMR	Automated Meter Reading
API	Application Programming Interface
ASBL	Association Sans But Lucratif (Non-Profit Association)
BESS	Battery Energy Storage System
BeLux	Belgian-Luxembourg Gas Market Area
BRP	Balance Responsible Party
BUC	Business Use Case
CACM	Capacity Allocation and Congestion Management
CAPEX	Capital Expenditure
CEC	Citizen Energy Community (Communauté d'Énergie Citoyenne)
CET	Central European Time
CFADS	Cash Flow Available for Debt Service
CfD	Contract for Difference
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CREG	Commission for Electricity and Gas Regulation (Belgium)
CV	Cooperative Company (Coöperatieve Vennootschap)
CWaPE	Walloon Energy Regulator
DA	Day-Ahead
DER	Distributed Energy Resource
DHC	District Heating and Cooling
DSCR	Debt Service Coverage Ratio
DSO	Distribution System Operator
EC	Energy Community
EEX	European Energy Exchange
EGB	Energiegemeenschap van Burgers (Citizen Energy Community)
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSO-G	European Network of Transmission System Operators for Gas
EU	European Union
EV	Electric Vehicle
FCR	Frequency Containment Reserve
GFPP	Gas-Fired Power Plant
GOT	Gate Opening Time

GCT	Gate Closure Time
HEG	Hernieuwbare Energiegemeenschap (Renewable Energy Community)
HNO	Hydrogen Network Operator
HVDC	High Voltage Direct Current
ICT	Information and Communication Technology
ID	Intraday
IoT	Internet of Things
KPI	Key Performance Indicator
LLCR	Loan Life Coverage Ratio
mFRR	Manual Frequency Restoration Reserve
OTC	Over-the-Counter
OCGT	Open Cycle Gas Turbine
OPEX	Operational Expenditure
P2P	Peer-to-Peer
POG	Product Oversight and Governance
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PV	Photovoltaic
REC	Renewable Energy Community
RES	Renewable Energy Source
SME	Small and Medium-sized Enterprise
SPV	Special Purpose Vehicle
TSO	Transmission System Operator
V2G	Vehicle-to-Grid
WP	Work Package
ZTP	Zeebrugge Trading Point

Executive Summary

This deliverable, together with ReInvent Deliverable D1.1 [1], presents the final results of Work Package 1 of the ReInvent project and completes the first pillar of the project. The objective of this pillar is to analyse the role of different energy vectors, including electricity, gas, heat, and green molecules, in the future Belgian energy system and to assess their implications for infrastructure development, market organisation, business models, and investment decisions. Building on the analysis presented in D1.1, this deliverable focuses on the practical implementation of sector integration by investigating the market, business, financial, and digital conditions required to enable both supply-side and demand-side integration across energy carriers.

Improved market design considering sector integration

The deliverable analyses the current organisation of Belgian electricity, gas, hydrogen, and heat markets and examines the interactions created by multi-carrier technologies such as gas-fired generation, combined heat and power units, power-to-heat installations, electrolysers, and industrial cogeneration systems. Although these technologies create physical and economic interdependencies between energy carriers, the associated markets remain largely organised and operated independently.

The analysis identifies several barriers that can limit the efficient operation of sector-coupling technologies. These include differences in product durations, different operating days between energy carriers, sequential market closures resulting in incomplete information, regulatory fragmentation, administrative complexity, and unequal levels of market maturity and liquidity across energy carriers.

To explore potential improvements, three alternative market-design concepts are assessed: isolated markets, coordinated markets, and fully integrated markets. The comparison highlights the trade-offs between efficiency gains and implementation complexity. The evaluation indicates that coordinated markets, characterised by greater alignment of market timelines and procedures across carriers while preserving separate market structures, may provide significant benefits for sector-coupling technologies without requiring a complete redesign of existing energy markets.

Business Models for improved sector coupling

The business-model analysis investigates how sector-coupling concepts can create value for different stakeholder groups and under which conditions these concepts can be successfully deployed and scaled. Recognising that different actors face different constraints and opportunities, the analysis adopts an archetype-based approach for three target groups: industrial actors, energy communities, and residential users.

For industrial actors, several archetypes are identified, ranging from cautiously optimistic adopters to large integrated industrial actors. The assessment links these archetypes to business models such as long-term contractual arrangements, industrial hubs, flexibility services, and innovation-oriented platforms. Industrial

deployment of sector coupling is shown to depend strongly on risk management, infrastructure availability, long-term revenue certainty, and investment readiness.

For energy communities, the analysis reviews the evolving European and Belgian regulatory frameworks and identifies a range of archetypes, including institutional anchors, innovative pioneers, citizen-led initiatives, business clusters, and public entities. The assessment demonstrates that community-scale sector coupling can create value through shared generation, storage, flexibility services, energy sharing, and cooperative ownership structures. The viability of such models is influenced by governance arrangements, access to data, regulatory conditions, and the availability of suitable digital tools.

For residential actors, the study highlights the diversity of household profiles and identifies archetypes with differing attitudes towards technology adoption, flexibility provision, and energy services. The analysis shows that sector-coupling business models must balance affordability, simplicity, trust, and perceived control while addressing structural barriers such as split incentives for tenants. Business models such as Energy-as-a-Service, smart home optimisation, collective purchasing schemes, shared energy services, and community-based initiatives may each play a role for different user groups.

Across all target groups, the study identifies five categories of enabling conditions: technical conditions, economic and commercial conditions, regulatory and market-design conditions, organisational and governance conditions, and behavioural and acceptance conditions. These conditions influence both implementation and scalability of sector-coupling business models.

Financing Decisions for multi-energy projects

The financing analysis examines how different financing structures can support the development of multi-energy projects. Multi-energy projects vary considerably in scale, ownership structure, revenue model, and technological complexity, which affects both risk profiles and financing requirements.

The deliverable reviews several financing mechanisms, including investment loans, leasing, equity financing, project finance, and crowdfunding. For each financing type, typical application areas, eligibility conditions, advantages, and limitations are discussed. Particular attention is given to the distinction between conventional financing approaches for proven technologies and specialised financing structures required for larger, more complex, or innovative projects.

Beyond financing structures, the deliverable explores the concept of project bankability. The analysis identifies key bankability factors, including technical maturity, revenue certainty, financial viability, regulatory compliance, ownership structure, project documentation, and stakeholder support. To support financing decisions, an assessment framework is proposed that links project characteristics and risk factors to financing suitability and financing outcomes.

The findings show that access to financing depends not only on technology performance but also on the availability of predictable revenues, adequate risk allocation, sufficient equity contributions, robust documentation, and compliance with regulatory and technical requirements.

Automated transactions in distributed multi-energy systems

The final technical chapter investigates digital solutions that can support automated transactions in distributed and sector-coupled energy systems. The increasing complexity of energy communities, distributed flexibility, shared mobility, local energy sharing, and multi-energy interactions creates a need for trusted and efficient transaction mechanisms.

Several categories of digital solutions are reviewed, including blockchain-enabled settlement mechanisms, peer-to-peer energy trading platforms, local flexibility markets, multi-energy tokenisation approaches, certificate-tracking systems, and balance-settlement ledgers. The analysis discusses the characteristics, strengths, and limitations of each solution family and evaluates their suitability for distributed energy applications.

Particular attention is given to the ReInvent Business Use Case in the Otterbeek social-housing energy community, where blockchain is used selectively for token settlement and incentive management while metering, optimisation, and allocation functions remain off-chain. This example illustrates how digital solutions can support local self-consumption, electric mobility, and coordinated energy management while addressing privacy and governance considerations.

The assessment demonstrates that no single digital architecture is universally applicable. Instead, different levels of functionality and complexity can be combined through modular approaches that integrate metering, optimisation, settlement, and governance components according to specific project requirements.

1 Introduction

The transition towards a climate-neutral energy system increasingly requires the integration of multiple energy carriers, end-use sectors, and market actors. Sector coupling, which links electricity, gas, hydrogen, heat, and flexible demand, is widely recognized as a key enabler for improving system efficiency, facilitating renewable energy integration, and enhancing overall energy-system flexibility. However, unlocking the full potential of sector coupling requires not only technological innovation, but also appropriate market designs, viable business models, suitable financing mechanisms, and effective transaction frameworks.

1.1 Objectives of the Work Reported in this Deliverable

This deliverable, together with ReInvent Deliverable D1.1 [1], presents the final results of Work Package 1 of the ReInvent project and completes the first pillar of the project. The objective of this pillar is to analyse the role of different energy vectors, including electricity, gas, heat, and green molecules, in the future Belgian energy system and to assess their implications for infrastructure development, market organisation, business models, and investment decisions. Building on the analysis presented in D1.1, this deliverable focuses on the practical implementation of sector integration by investigating the market, business, financial, and digital conditions required to enable both supply-side and demand-side integration across energy carriers.

To this end, the deliverable investigates sector coupling from four complementary perspectives, corresponding to four different tasks. First, Task 1.2 analyses current market arrangements and explores **alternative market-design concepts** that can improve coordination between electricity, gas, hydrogen, and heat markets. Second, Task 1.3 examines **business model opportunities** for different stakeholder groups and assesses how sector coupling can create and capture value. Third, Task 1.4 investigates **financing approaches, key bankability factors, and investment decision-making processes** associated with multi-energy projects. Finally, Task 1.5 reviews **digital solutions for automated transactions** in distributed multi-energy environments and assesses their potential role in supporting future sector-coupled energy systems.

Together, these four tasks provide a comprehensive assessment of the market, economic, financial, and digital conditions required to accelerate the deployment of sector-coupling solutions in Belgium.

1.2 Outline of the Deliverable

This deliverable is organised into seven chapters. Following this introduction, Chapters 2 to 5 present the results of Tasks 1.2 to 1.5, covering respectively improved market design for sector integration, business models for sector coupling, financing decisions for multi-energy projects, and digital solutions for automated transactions in distributed multi-energy systems. Chapter 6 synthesises the key findings across the four tasks.

2 Improved market design considering sector integration

This chapter reviews the main characteristics of the electricity, gas, hydrogen and heat markets and examines how differences in their design can affect the coordination of multi-carrier energy systems. The analysis focuses on the interaction between markets, identifying potential barriers arising from differences in product granularity, market timelines, operating-day definitions and balancing arrangements. Based on these barriers, a set of potential market-design adaptations is discussed, with particular attention to measures that could improve temporal coordination between energy carriers, such as shorter product durations and better alignment of market operating periods.

The findings of this chapter provide input to subsequent work of the project. In following tasks, selected market-design changes identified here are quantitatively assessed using a market optimization framework to determine their impact on the profitability and balancing-market participation of different sector-coupling technologies. Together, these activities complement the qualitative market-design assessment presented in this chapter with a quantitative evaluation of selected changes and their broader implications for improved coordination across the markets.

2.1 Current market status

2.1.1. Electricity market

In the pre-liberalization period, the electricity sector in Europe was vertically integrated, with state-owned companies performing most of the activities within the electricity supply chain (i.e., generation, transmission, and distribution). A set of liberalization reforms was adopted in Europe starting in 1996 to introduce competition into the electricity market [2]. These reforms transformed the sector, for example, by creating a competitive wholesale electricity market, unbundling vertically integrated activities, and opening national markets to cross-border trading.

The current European electricity market design is built upon market-based price formation and cross-border integration. Generation and supply activities are competitive, while transmission and distribution remain regulated natural monopolies subject to strict unbundling rules. At the wholesale level, electricity prices are determined through competitive bidding processes organised in sequential markets. Market integration across Member States is achieved through harmonised EU network codes and coordinated operational mechanisms. For example, the Capacity Allocation and Congestion Management Regulation [3] establishes a guideline on cross-border capacity allocation in day-ahead (DA) and intraday (ID) markets, while the Electricity Balancing Guideline [4] harmonises balancing market design.

Within this framework, Belgium forms a single bidding zone fully integrated into the coupled European electricity market. The Belgian transmission system operator (TSO), Elia, operates the high-voltage transmission

grid, ensures system security, allocates cross-border capacity through market coupling mechanisms, procures balancing reserves, and performs imbalance settlement [5]. Regulatory oversight is exercised by the national regulatory authority, the Commissie voor de Regulering van de Elektriciteit en het Gas (CREG), acting in coordination with the Agency for the Cooperation of Energy Regulators (ACER) at European level. In parallel, ENTSO-E coordinates cooperation among European TSOs, supports capacity calculation and market integration processes, and contributes to maintaining the secure and efficient functioning of the interconnected electricity system [6], [7]. The functioning of the electricity market can be understood through the following key mechanisms:

Wholesale trading stages: Electricity can be traded through bilateral contracts or the wholesale market. The European wholesale electricity market comprises multiple temporal stages, including the forward, day-ahead, intraday, and balancing markets. The electricity day is defined from 00:00 to 24:00, with trading products and delivery schedules generally referenced to this period. Figure 2-1 illustrates the typical temporal organization of European electricity markets. Years to two days before delivery, the forward market allows market participants to hedge the risk against future short-term price fluctuations [8]. In the short-term, electricity is traded one day before delivery in the day-ahead market. It operates as a uniform-price auction cleared at noon (12:00 CET) on the day preceding delivery. Market participants submit, in the simplest cases, price-quantity bids for each Market Time Unit (15 minutes). Following day-ahead market clearing, participants can modify their day-ahead commitments in the intraday market. In Belgium, the intraday market includes continuous trading, which remains open until shortly before real time, and complementary auctions held at predefined times [9].

Balancing and Imbalance Settlement: The TSO procures balancing capacity and energy to correct any imbalances between supply and demand. Depending on market regulations, reserve capacity is procured from years or hours in advance. In fact, European markets have largely moved towards day-ahead capacity procurement for balancing reserves with the establishment of European balancing market platforms [10]. Right before delivery time, the balancing energy market takes place, where the TSO activates energy reserves for different balancing products (e.g., frequency containment reserve (FCR), automatic frequency restoration reserve (aFRR), and manual frequency restoration reserve (mFRR). After electricity delivery, the imbalances caused by Balance Responsible Parties (BRPs), which are responsible for the balance at each access point to the grid, are remunerated or penalized depending on their individual imbalance and their imbalance position compared to the system imbalance. Figure 2-2 illustrates the operation timing of the day-ahead, intraday and balancing markets, including gate open times (GOT), gate closure times (GCT), and the results publication.

Transmission capacity allocation: Different from gas markets, in the electricity market, transmission capacity is allocated implicitly together with energy in the market clearing process. In the day-ahead market, a common European algorithm (EUPHEMIA) simultaneously determines electricity prices and cross-border exchanges while respecting network limits. Belgium participates in the Core region, where a flow-based market coupling methodology is applied. This approach takes into account how commercial exchanges affect physical flows on

critical transmission lines, allowing a more efficient use of interconnection capacity [11]. In the intraday timeframe, cross-border capacity continues to be allocated implicitly through continuous trading up to shortly before delivery. Within Belgium itself, the situation is different. As stated above, Belgium forms a single bidding zone, meaning that there is one wholesale electricity price for the entire country. Internal grid constraints within the Belgian transmission network are therefore not directly reflected in different market prices. Instead, if internal congestion occurs after the market has cleared, Elia manages it through operational measures such as redispatching generation units or activating flexibility. The costs of these actions are recovered through regulated mechanisms rather than through zonal price differences.

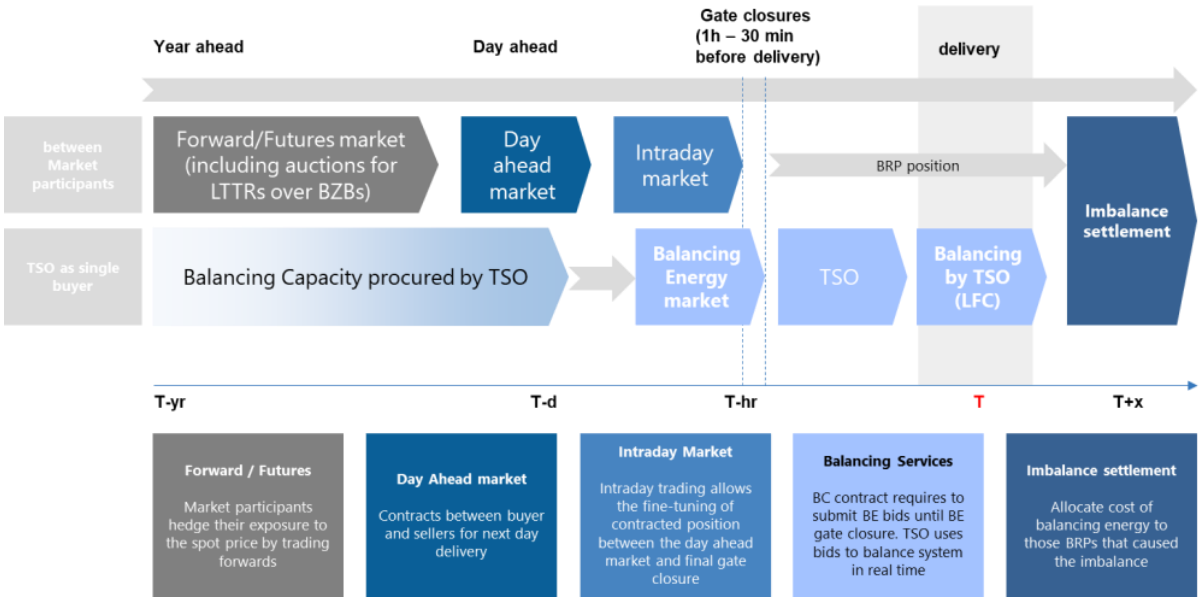


Figure 2-1 Temporal stages of European electricity markets [9]

2.1.2. Gas market

Starting in the late 1990s, the European Union initiated a series of liberalization reforms to introduce competition into the gas market. These reforms aimed to unbundle vertically integrated companies, create competitive wholesale markets, and facilitate cross-border trading [12]. Most EU countries now use an entry-exit model, where shippers book capacity rights independently at entry and exit points, decoupling gas trading from network congestion management. This approach has increased market flexibility and supports the development of liquid wholesale trading hubs. The European gas market operates under a regulatory framework designed to ensure security of supply, competition, and market integration. Regulatory oversight is provided by the Agency for the Cooperation of Energy Regulators (ACER) together with national regulatory authorities. In parallel, the European Network of Transmission System Operators for Gas (ENTSO-G) facilitates cross-border cooperation among transmission system operators (TSOs) and supports the secure and efficient operation of the interconnected European gas network [13].

Belgium forms an integrated gas market together with Luxembourg through the Belgian-Luxembourg (BeLux) market area. This integration has resulted in a harmonised balancing regime and enhanced market liquidity. In Belgium, the transmission system operator (TSO), Fluxys Belgium, operates the gas transmission network, manages capacity allocation, facilitates cross-border gas flows, and supports the balancing framework of the BeLux market [14]. The gas day in the BeLux market starts at 06:00. The functioning of the BeLux gas market can be understood through the following key mechanisms:

Gas trading: Gas ownership is transferred through trading hubs, which can be either physical or virtual. A physical hub corresponds to a specific location on the transmission network where gas is physically delivered and received. In contrast, a virtual hub allows ownership transfers within an entire balancing zone without requiring physical delivery at a specific point.

The virtual trading point of the integrated Belgian-Luxembourg market is the Zeebrugge Trading Point (ZTP). ZTP products can be traded on exchanges such as the European Energy Exchange (EEX) [15].

Trading can occur either through exchanges or over-the-counter (OTC) markets. Exchange trading involves anonymous transactions of standardized products cleared through a central counterparty, while OTC trading consists of bilateral agreements between known counterparties and allows greater contractual flexibility.

Market participants can trade different products depending on their needs:

- Spot contracts: These involve the immediate purchase or sale of natural gas for delivery, typically within 30 days, allowing buyers and sellers to respond quickly to changing conditions or unexpected needs. Spot prices are influenced by current supply and demand conditions.
- A within-day product in gas markets refers to contracts for the purchase or sale of natural gas that are traded and delivered within the same day.
- A daily product in gas markets refers to contracts for the purchase or sale of natural gas that are traded and delivered within a single day.
- A monthly product in gas markets refers to contracts for the purchase or sale of natural gas that are traded and delivered over a month-long period.

Standard exchange-traded spot products are delivered at a constant hourly rate over their delivery period. For a daily product, the traded volume is delivered uniformly throughout all hours of the gas day. For a within-day product, the traded volume is delivered uniformly over the remaining hours of the gas day after the trade is concluded. In contrast, OTC transactions may involve profile deliveries, where gas quantities vary between hours according to an agreed delivery profile. Figure 2-3 illustrates the operation timing of the daily and within-day markets in Belgium.

Balancing and imbalance settlement: The balancing of the BeLux market is managed by Balansys (the Balancing Operator) and follows a commercial balancing model [16]. An imbalance in the gas market occurs when there is a discrepancy between the amount of natural gas delivery and offtake. The Grid User Balancing Position refers to the hourly value of the imbalance of the grid user within a specific zone. This value indicates whether a grid user has a surplus or deficit of gas at any given hour, based on their actual usage. The Market Balancing Position is the aggregate of all grid user balancing positions within a specific zone. It represents the overall imbalance of the market for that zone, showing whether the market has a surplus or deficit of gas.

Shippers are primarily responsible for maintaining balance in their portfolios. As long as the market balancing position remains within predefined thresholds, Balansys does not intervene. When the market imbalance exceeds these thresholds, Balansys undertakes residual balancing actions through the market to address the shortfall or surplus, and the costs are allocated to the parties contributing to the imbalance. Unlike electricity markets, the BeLux gas market does not have a dedicated balancing market. Instead, balancing actions are performed through the within-day market. Balansys communicates its intention to buy or sell gas on the exchange. Market participants can then trade with Balansys, enabling the balancing operator to procure the gas volumes required to restore the market balance. At the end of each gas day, residual imbalances are settled financially, and all shippers start the following gas day with a zero balancing position.

Allocation of network capacity: The BeLux market follows the entry-exit model, which allows market participants to book entry and exit capacities independently. Gas entering the market area can subsequently be traded without being linked to a predefined transport route, creating a transport system based on a market zone rather than contractual paths.

Capacity allocation rules are established by Commission Regulation (EU) 2017/459 establishing a network code on capacity allocation mechanisms in gas transmission systems [17]. In Belgium, network capacities are traded via the PRISMA platform, a leading European gas capacity trading platform, that facilitates the sale and purchase of gas transport and storage capacity [18].

Nomination: Nominations are used to communicate planned gas flows to the TSOs. Shippers submit nominations to operators such as Fluxys Belgium and Creos Luxembourg, specifying the quantities of gas to be transported. These nominations enable TSOs to monitor gas flows and support the balancing of the transmission system. The nomination process follows the Full Hour + 2 rule, under which nominations must be submitted at least two hours before the start of the corresponding gas flow period.

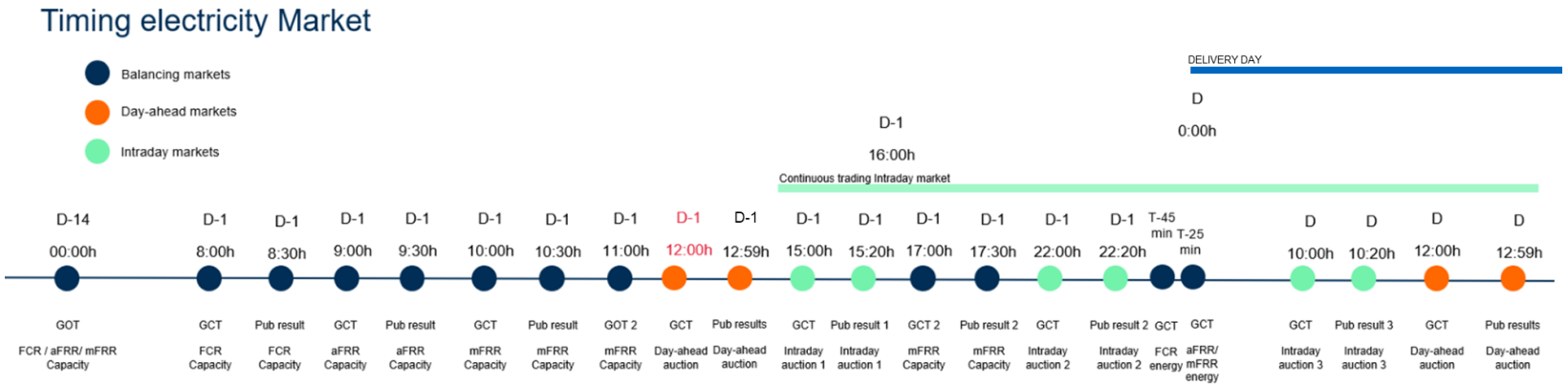


Figure 2-2 Market timings in the Belgian electricity market: day-ahead, intraday, and balancing markets

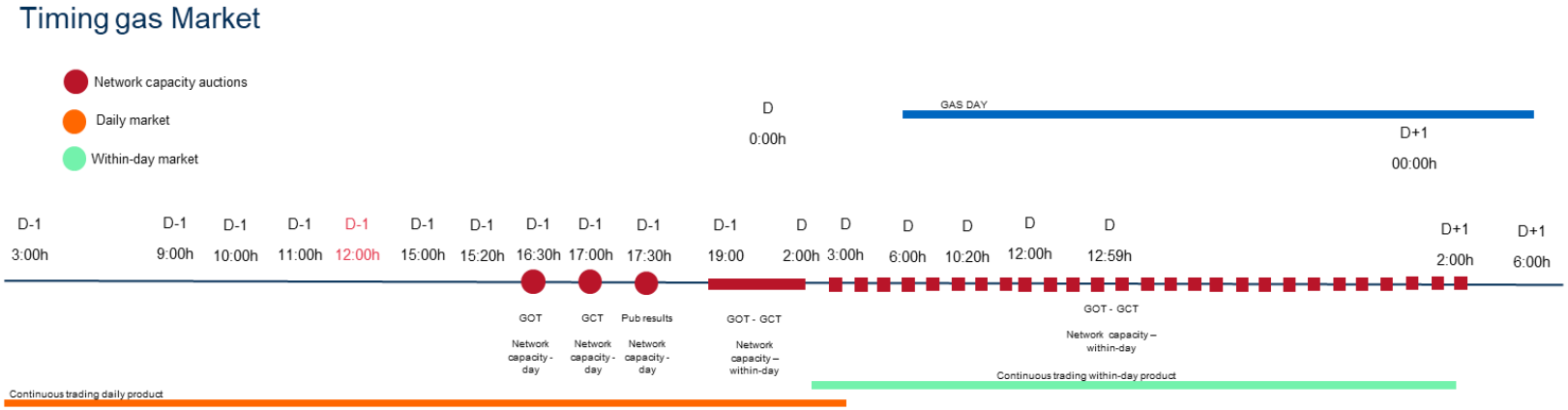


Figure 2-3 Market timings in the Belgian gas market: daily, within-day and network capacity markets

2.1.3. Hydrogen market

The hydrogen market in Europe is still in its very initial stage, but it is rapidly evolving with significant policy support [19]. Currently, hydrogen trading is limited and primarily occurs through bilateral agreements. However, as part of the transformation of the energy sector, the European Commission has established a common framework to support the creation of hydrogen markets in the EU. More specifically, Directive (2024/1788) lays out a set of rules aimed at facilitating the emergence of markets for hydrogen, commodity-based hydrogen trading and liquid trading hubs [20]. This directive is aligned with the EU Hydrogen Strategy [19], which advocates for a unified and competitive internal hydrogen market, where cross-border trade flows freely. This strategy is expected to enhance competition, lower costs, and bolster energy security across the EU. Additionally, the strategy highlights the importance of developing a liquid market characterized by commodity-based hydrogen trading, which would not only facilitate the entrance of new producers but also promote closer integration with other energy sectors. In this regard, as the market matures, it is expected that trading mechanisms will evolve to include exchanges and standardized contracts, with efforts already underway by, for example, the European Energy Exchange [21].

In Belgium, Fluxys Hydrogen has been designated as the Hydrogen Network Operator (HNO). Its role is to support the development of the Belgian hydrogen market through a non-discriminatory third-party access regime based on transparent and regulated methodologies [22]. The proposed market design is inspired by the principles applied in the natural gas market and is currently under development. Subject to regulatory approval, the model is expected to be presented to market participants by the end of 2026. The proposed hydrogen market model includes the following key elements:

Network Topology: The Belgian open-access hydrogen transport network would be designed to connect production and import locations with consumption regions organized into balancing zones. These balancing zones are interconnected with neighbouring countries and, where relevant, with each other. Figure 2-4 illustrates the conceptual representation of the network of the proposed hydrogen transport system, including balancing zones, trading points (i.e., virtual/notional point within a balancing zone where network users can transfer ownership of hydrogen), and the associated entry and exit capacities.

The network topology aims to facilitate the efficient transport of hydrogen between production, consumption, import, and export locations while supporting the progressive development of the hydrogen market and accommodating anticipated future demand.

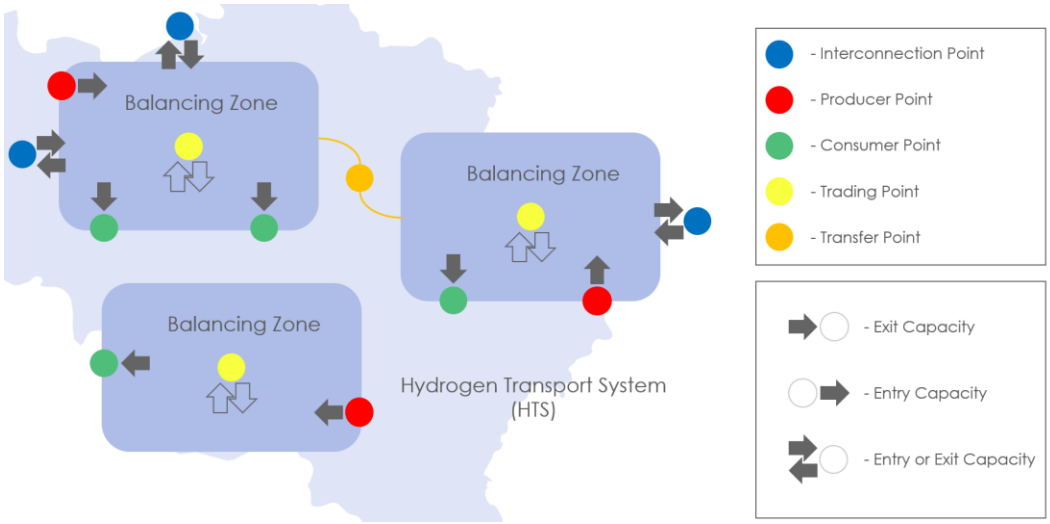


Figure 2-4 Conceptual representation of proposed hydrogen network topology and commercial points.

Commercial Model: The proposed commercial model is based on an entry-exit system combined with balancing rules within balancing zones. Transport services are offered at commercial points where hydrogen can enter or leave the network. These commercial points can be either physical or virtual.

Physical points include connected customer installations (producers and consumers), interconnection points with neighbouring countries, import terminals, storage facilities, and transfer points between balancing zones. Virtual points include trading points where ownership of hydrogen can be exchanged between market participants.

Transmission services: Entry and exit transmission services can be subscribed at both physical and virtual commercial points. An entry service enables a network user to inject hydrogen into the transport network, whereas an exit service enables hydrogen withdrawal from the network.

As in the natural gas market, the entry-exit system allows network users to book entry and exit capacities independently, providing greater flexibility and reducing the complexity associated with predefined point-to-point transport routes. Transmission services are offered on a ship-or-pay basis, meaning that network users pay for the subscribed capacity regardless of its actual utilisation.

Balancing Model and Rules: Transmission services are utilised through nominations submitted within the subscribed capacity rights at the relevant commercial points. The balancing model requires network users to maintain a balance between their hydrogen injections and withdrawals within each balancing zone over a specified period. Once validated and matched, nominations determine the commercial flows that are subject to balancing.

The physical flows used for allocation purposes should reflect the corresponding commercial flows, ensuring that hydrogen injections and withdrawals remain balanced and preventing the accumulation of imbalances within the hydrogen transport system.

2.1.4. Heat market

Contrary to the electricity and gas markets, the market for heat is less homogeneous and has not been liberalized, since there are too few producers to have an actual heating market with competition [23]. Heat trading, which takes place through district heating networks, is predominantly local, with considerable differences across European countries. In countries like Denmark and Sweden, district heating systems are well-developed and play a vital role in meeting heating demands . However, in countries like Belgium, less than 1% of the residential demand is met through district heating networks [25], [26].

In countries with highly developed district heating networks, where predominant models of ownership are cooperative ownership in rural areas and municipal ownership in urban areas [27], prices are highly regulated, and regional authorities choose suppliers based on socio-economic benefits [28]. In most cases, heat trading takes place through long-term contracts between heat producers and consumers where supply volumes, prices, and quality standards are defined. However, in cities like Copenhagen, the transmission companies optimize and operate the heat production plan from various providers (e.g., Combined heat and power (CHP) plants, waste incinerators, peak boilers, etc.) to meet the heating demand with a day-ahead dispatch plan for the subsequent two days and an intraday plan [28]. The cost of heat depends on fuel prices, capacity and efficiency of the plants, operational expenditure (OPEX), energy and CO2 taxes, income from the power market, and production subsidies.

The regulation of heat markets is largely diverse across the continent, with limited overarching EU-level directives. National regulations defined by national and regional authorities regulate the operation of the district heating network by focusing, for example, on tariff setting, consumer protection, and promoting the use of renewable energy sources in heating [24].

2.2 Interactions between different markets

While the Belgian wholesale markets for electricity, gas, hydrogen (under development), and heat (district heating networks) are institutionally organised as separate systems, they are interconnected through technologies that convert one energy carrier into another. These multi-carrier conversion technologies act as physical and economic interfaces between markets, transmitting price signals and operational decisions across carriers. The resulting interactions can be grouped according to the type of carrier coupling involved.

1.1.1 Gas–Electricity Coupling:



The most structurally significant interaction in Belgium occurs between the gas and electricity wholesale markets through gas-fired generation assets. Gas-fired power plants (GFPPs), including both combined-cycle and open-cycle gas turbines (OCGTs), procure natural gas, for instance, in the BeLux gas market and convert it into electricity sold in the day-ahead, intraday, and balancing markets. Their operational decisions depend on the relationship between electricity prices and gas prices, adjusted for efficiency and carbon costs. Variations in gas prices therefore directly influence electricity supply offers, while electricity demand affects gas consumption volumes. In this way, demand in the electricity market influences gas demand, and gas market conditions affect electricity market outcomes.

2.2.1. Gas–Electricity–Heat Coupling:



Combined heat and power units create a three-way linkage between gas, electricity, and heat systems. CHP installations consume natural gas (and potentially hydrogen in the future) and simultaneously produce electricity and heat. Electricity is typically sold in wholesale markets, whereas heat is supplied to district heating networks or industrial consumers. The dispatch of CHP units is therefore determined by the joint value of electricity and heat outputs relative to fuel costs. When electricity prices are favourable, CHP operators may increase power generation, provided that sufficient heat offtake exists. Conversely, heat demand conditions influence the level of electricity generation that can be economically sustained. Through CHPs, heat system conditions indirectly influence electricity market supply, while gas prices shape both heat and power production costs.

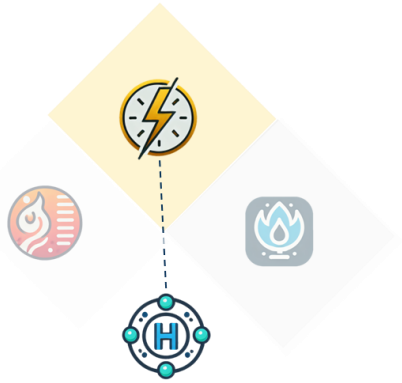
Waste-to-energy plants and industrial cogeneration units operate according to similar principles when they simultaneously participate in electricity markets and supply heat to district heating networks or industrial users. As a result, these installations further strengthen the interaction between gas, electricity, and heat systems.

2.2.2. Electricity–Heat Coupling:



Electricity and heat markets are also linked through power-to-heat technologies deployed within district heating networks. Large-scale electric boilers and industrial heat pumps consume electricity purchased from wholesale markets and convert it into usable heat. Their operation depends on electricity price levels relative to alternative heat production costs, such as gas-fired boilers. During periods of low electricity prices (often associated with high renewable generation) electric heat production may increase, raising electricity demand from the heat sector. Conversely, higher electricity prices may shift heat production toward gas-fired units. Although heat itself is not traded on a wholesale exchange, district heating systems respond to electricity price signals through their internal dispatch optimisation, thereby creating indirect feedback effects on the electricity market.

2.2.3. Electricity–Hydrogen Coupling:

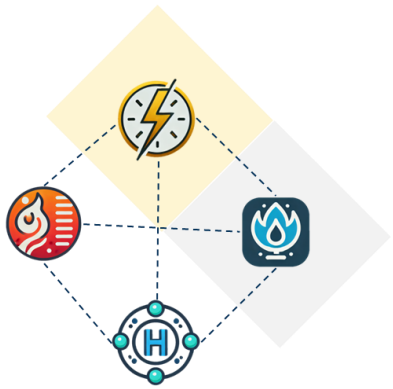


Electrolysers introduce a growing linkage between electricity and hydrogen systems. By consuming electricity to produce hydrogen, electrolysers translate wholesale electricity price signals into hydrogen production volumes. Although a hydrogen wholesale market is not yet established in Belgium, future hydrogen market design is expected to resemble the entry–exit structure of gas markets. In such a framework, electricity prices will directly influence hydrogen supply costs and injection volumes into hydrogen networks. Conversely, hydrogen demand conditions will affect electrolyser operating profiles and therefore electricity demand patterns, particularly in the day-ahead and intraday markets.

Looking forward, hydrogen-to-power technologies, such as hydrogen-fired turbines or fuel cells, could further strengthen this bidirectional coupling by converting hydrogen back into electricity, thereby linking hydrogen market conditions to electricity supply

2.2.4. Industrial Multi-Carrier Systems:

Beyond utility-scale assets, industrial sites (particularly in clusters such as the Port of Antwerp) operate integrated energy systems that combine gas consumption, steam production, electricity generation, and heat supply. Steam turbines and cogeneration units in these facilities may export electricity to the wholesale market while simultaneously supplying process heat. Their operational strategies depend on relative fuel costs, electricity prices, and internal heat demand, thereby linking wholesale electricity and gas markets to industrial energy systems.



2.2.5. Summary of cross-carrier interactions:

Taken together, these technologies establish multiple channels of interaction between Belgian wholesale markets. Gas-fired generation links gas and electricity price formation; CHP and industrial cogeneration connect gas, electricity, and heat systems; power-to-heat technologies couple electricity and heat; and electrolysers link electricity with emerging hydrogen markets. Although each carrier is traded and balanced under distinct regulatory frameworks, multi-carrier technologies ensure that developments in one market propagate to others through economic dispatch decisions and energy conversion processes. These structural interdependencies form the basis for multi-carrier optimisation and system-wide flexibility in the Belgian energy landscape.

Table 2-1 provides an overview of the principal multi-carrier technologies operating in the Belgian context and summarises the carriers they convert, the wholesale markets in which they participate, and the type of cross-market interaction they create. These technologies constitute the structural interface between electricity, gas, hydrogen, and heat systems.

Table 2-1: Principal multi-carrier technology linkages and associated market interactions.

Technology	Input Carrier(s)	Output Carrier(s)	Relevant Belgian Wholesale Markets	Nature of Market Interaction
Gas-Fired Power Plant (GFPP)	Natural gas	Electricity	Gas (within-day, daily), Electricity (DA, ID, balancing)	Gas price influences electricity supply bids; electricity demand drives gas demand
Combined Heat and Power (CHP)	Natural gas (future: hydrogen)	Electricity + Heat	Gas (within-day, daily), Electricity (DA, ID, balancing), Heat (district heating contracts)	Electricity and heat outputs are jointly optimised in response to fuel costs, electricity prices, and heat demand
Electric Boiler (Power-to-Heat)	Electricity	Heat	Electricity (DA, ID, balancing), Heat (district heating dispatch)	Electricity prices influence the economic dispatch of heat production
Large Heat Pump	Electricity	Heat	Electricity (DA, ID, balancing), Heat (district heating dispatch)	Electricity prices determine the competitiveness of electric heat production relative to alternative heat sources
Electrolyser	Electricity	Hydrogen	Electricity (DA, ID, flexibility), Future hydrogen markets	Electricity prices determine hydrogen production volumes
Hydrogen-Fired Turbine (future)	Hydrogen	Electricity	Hydrogen market, Electricity (DA, ID, balancing)	Hydrogen prices influence electricity supply bids
Industrial Steam Turbine / Cogeneration	Gas / Hydrogen / Waste Heat	Electricity + Process Heat	Gas (within-day, daily), Electricity (DA, ID)	Industrial heat demand influences electricity bids

2.3 Multi-carrier markets for sector coupling

2.3.1. Existing barriers

The previous section demonstrated that electricity, gas, hydrogen, and heat systems are physically interconnected through multi-carrier conversion technologies. Assets such as gas-fired power plants, CHP units, electrolysers, power-to-heat installations, and industrial cogeneration facilities convert energy between carriers and therefore operate across multiple markets simultaneously. However, despite this physical and economic interdependence, electricity, gas, hydrogen, and heat markets remain organised largely in isolation from one another. Each carrier follows its own product definitions, trading timelines, balancing arrangements, settlement periods, and gate closure sequences, resulting in market optimisation processes that are performed separately for each carrier.

This fragmented market organisation creates challenges for operators of multi-carrier technologies. The economic value of these assets depends on price relationships and operational conditions across several energy carriers, yet their market participation is governed by independent and often misaligned market frameworks. Consequently, operators may face constraints and opportunity costs when attempting to optimise asset dispatch across markets [29]. As sector coupling becomes increasingly important through electrification, hydrogen deployment, and the integration of heat networks, these challenges become more pronounced. The barriers presented in the following subsections were identified through a combination of literature review and semi-structured interviews conducted with key stakeholders, including transmission system operators and owners of multi-carrier technologies from both the utility and industrial sectors.

Different Product Durations Across Carriers: The Belgian electricity market operates at high temporal resolution, with 15-minute products in the day-ahead, intraday, balancing, and imbalance settlement stages. This creates strong short-term price signals and enables flexible technologies to respond rapidly to changing system conditions. Differences in product duration across energy carriers partly reflect their underlying physical characteristics and balancing requirements. Electricity requires supply and demand to be balanced at high temporal resolution, due to the limited inherent flexibility of the electricity system. By contrast, gas trading is primarily organised through daily and within-day products, whose delivery is spread uniformly over a gas day or the remaining hours of the day. As a result, gas market participants operate at a substantially lower temporal granularity than in electricity markets. Hydrogen markets, as currently envisioned under EU hydrogen market design proposals, are expected to follow a similar structure. Heat systems in Belgium are even less granular, as district heating networks typically operate under seasonal demand patterns and medium- to long-term contractual arrangements rather than short-term tradable products.

For multi-carrier technologies, these differences in temporal granularity constrain optimisation. A CHP unit may face a short-term electricity price spike while fuel procurement takes place through gas products organised

primarily on daily and within-day horizons and heat delivery remains subject to relatively fixed obligations. Similarly, an electrolyser reacting to short-term electricity price changes may operate within hydrogen supply or offtake arrangements structured on longer time horizons. The asymmetry in temporal granularity across carriers reduces the ability of conversion technologies to exploit short-term price signals in a coordinated manner.

Different Operating Days: Electricity markets in Belgium operate on a calendar-day basis (00:00–24:00). In contrast, the gas market operates on a gas day running from 06:00 to 06:00. Hydrogen market design proposals similarly foresee daily operational periods aligned with gas market operation. Unlike electricity, gas, and hydrogen, heat is generally not traded through a wholesale market and therefore does not follow a standardised market operating day.

For assets that simultaneously participate in electricity, gas, and (future) hydrogen markets, such as gas-fired power plants, CHP units, or future hydrogen-fired generators, these misaligned operating days complicate portfolio management. A single electricity trading day overlaps with two gas-day periods and, potentially, two hydrogen operating days. As a result, operators must coordinate trading, nominations, and settlement processes across multiple temporal frameworks. This increases operational complexity and can make the optimisation of multi-carrier assets more challenging.

Sequential Market Closures and Incomplete Information: Wholesale markets across energy carriers operate according to different trading timelines and gate closure schedules. As a result, decisions in one market often need to be taken before complete information is available regarding conditions in other carriers. For example, electricity market positions may need to be established before final gas procurement decisions have been made or before updated information becomes available regarding heat demand or future hydrogen requirements.

For operators of multi-carrier technologies, this sequencing introduces uncertainty into bidding and dispatch decisions. A CHP operator participating in the electricity day-ahead market must estimate future fuel costs and heat requirements when determining its electricity market position. Similarly, an electrolyser may commit to electricity consumption before future hydrogen demand conditions are fully known. These uncertainties complicate cross-carrier optimisation and may lead operators to adopt more conservative bidding strategies, thereby limiting the utilisation of available flexibility.

Regulatory Fragmentation and Administrative Complexity: Electricity, gas, hydrogen, and heat systems are governed by distinct regulatory and institutional frameworks. Electricity and gas markets, for example, are managed by separate transmission system operators and market operators, each with their own contractual arrangements, communication procedures, and regulatory requirements. Hydrogen market frameworks are currently being developed under new European regulatory packages, while heat systems are primarily governed through regional regulation and contractual arrangements rather than harmonised wholesale market rules.

For operators of multi-carrier technologies, this regulatory fragmentation results in multiple administrative and compliance requirements. Market participants must navigate different nomination procedures, reporting

obligations, contractual arrangements, and settlement frameworks across carriers. These differences increase operational complexity and transaction costs, particularly for smaller actors and new entrants seeking to deploy sector-coupling technologies. As a result, the administrative burden associated with participating in multiple energy markets may limit the adoption and efficient operation of multi-carrier assets.

Uneven Market Maturity and Liquidity: Electricity and gas wholesale markets in Belgium are relatively mature and liquid, offering a broad range of trading products and risk-management instruments, including forward contracts. However, while the gas market is currently well developed, its longer-term role is subject to uncertainty as decarbonisation reduces and reshapes gas demand. Declining or changing traded volumes could eventually affect market liquidity, market depth, and the availability of risk-management instruments. In contrast, hydrogen markets are still at an early stage of development, and market liquidity is expected to emerge gradually as production, consumption, and trading volumes increase. Heat systems generally lack wholesale markets altogether, with heat exchanges typically governed through bilateral agreements and long-term contractual arrangements.

These differences in market maturity create unequal opportunities for risk management and commercial optimisation. For example, electricity and gas price exposures can be managed through established trading and hedging instruments, whereas comparable mechanisms remain limited or unavailable for hydrogen and heat. The absence of liquid markets and transparent price signals can increase uncertainty regarding future revenues and operating conditions. Consequently, differences in liquidity, market depth, and risk-management opportunities influence both investment decisions and the operational strategies of multi-carrier technologies.

Taken together, these barriers demonstrate that Belgian wholesale markets, although individually well-functioning, are not fully aligned with the operational characteristics of sector coupling technologies. Differences in product structures, operating days, market closures, price dynamics, regulatory frameworks, network allocation mechanisms, and market maturity limit the efficient coordination of cross-carrier flexibility. As electrification intensifies, hydrogen markets mature, and district heating networks expand, the cost of these misalignments may increase. Enhancing coordination across carriers is therefore essential for enabling efficient multi-carrier optimisation and supporting the long-term decarbonisation of the Belgian energy system. Table 2-2 summarizes the identified barriers affecting efficient participation of multi-carrier technologies in Belgian wholesale markets and highlights their operational and system-level implications.

Table 2-2 Key barriers to efficient participation of multi-carrier technologies

Barrier	*Core Structural Difference*	*Impact on Multi-Carrier Technologies*	*System-Level Implication*
Different Product Durations	Electricity markets operate with 15-minute products, whereas gas markets (and future hydrogen markets) rely primarily on daily and within-day products. Heat systems are governed by longer-term contractual arrangements.	Limits the ability of technologies to respond simultaneously to price signals across carriers, reducing opportunities for coordinated optimisation.	Reduces the efficient utilisation of cross-carrier flexibility and may limit system-wide optimisation.
Different Operating Days	Electricity markets operate on a calendar day (00:00–24:00), whereas gas markets (and future hydrogen markets) operate on a gas day (06:00–06:00). Heat systems do not follow a standardised market operating day.	Increases operational complexity by requiring market participants to coordinate activities across multiple temporal frameworks.	Reduces the efficient utilisation of cross-carrier flexibility and may limit system-wide optimisation.
Sequential Market Closures and Incomplete Information	Electricity, gas, hydrogen, and heat-related decisions are taken according to different trading timelines and gate closure schedules. Market commitments in one carrier may therefore be made before complete information is available regarding conditions in another carrier.	Introduces uncertainty into bidding and dispatch decisions, potentially leading to more conservative market participation and reduced utilisation of flexibility.	May result in suboptimal dispatch decisions and reduced system efficiency.
Regulatory Fragmentation and Administrative Complexity	Electricity, gas, hydrogen, and heat systems are governed by distinct regulatory and institutional frameworks, each with its own procedures, obligations, and settlement arrangements.	Increases administrative burden, transaction costs, and operational complexity, particularly for smaller actors and new entrants.	May slow the deployment and market participation of sector-coupling technologies.
Uneven Market Maturity and Liquidity	Electricity and gas markets are mature and liquid, whereas hydrogen markets remain under development and heat systems generally rely on bilateral contractual arrangements.	Creates unequal opportunities for risk management and commercial optimisation, influencing investment and operational decisions.	May hinder investment in emerging sector-coupling technologies and slow market development.

2.3.2. Market concepts for sector coupling

The barriers identified in the previous section highlight that current energy markets are not fully aligned with the operational characteristics of multi-carrier technologies. In particular, differences in product durations, operating days, market closure schedules, regulatory frameworks, and market maturity complicate the participation of technologies that simultaneously interact with electricity, gas, hydrogen, and heat systems. As sector coupling becomes increasingly important for achieving decarbonisation objectives, there is growing interest in market designs that facilitate more efficient coordination across energy carriers.

To explore how the identified barriers could be addressed, this work considers three alternative market design concepts representing increasing levels of coordination between energy carriers: isolated markets, coordinated markets, and fully integrated markets. These concepts differ in the degree to which market structures, timelines, and optimisation processes are aligned across carriers, thereby providing a framework for evaluating the potential benefits of deeper cross-sector integration.

- **Isolated Markets:** The isolated markets configuration represents the current market setting in which electricity, gas, hydrogen, and heat systems operate largely independently. Each energy carrier is traded in its own market with distinct products, operating days, gate closure schedules, balancing arrangements, and regulatory frameworks. Market clearing occurs separately for each carrier, and coordination between sectors arises only indirectly through the operational decisions of market participants operating multi-carrier technologies.

  In this setting, operators of multi-carrier technologies must individually interpret price signals, manage market risks, and optimise asset dispatch across several independent markets. Information exchange between carriers occurs only through the actions of market participants rather than through coordinated market mechanisms. Consequently, the barriers identified in the previous section remain fully present. Differences in product durations, operating days, market closures, regulatory frameworks, and market maturity continue to constrain the efficient utilisation of cross-carrier flexibility. This configuration reflects the historical development of energy markets and preserves the institutional independence of each sector. However, it places the full responsibility for cross-carrier coordination on market participants, requiring them to independently manage the interactions between multiple energy carriers.

- **Coordinated Markets:** The coordinated markets configuration introduces targeted harmonisation between energy carriers while preserving separate market structures and clearing mechanisms. Rather than merging electricity, gas, hydrogen, and heat markets into a single market, selected design elements are aligned to reduce the identified barriers. Coordination primarily focuses on temporal aspects of market operation. Examples include the alignment of product durations, operating days, and market gate closures across carriers. Such measures reduce the complexity

faced by operators of multi-carrier technologies and improve the consistency of information available when market decisions are made. For instance, synchronising electricity and gas operating days would simplify the portfolio management of gas-fired power plants and CHP units. Similarly, introducing shorter-duration gas and hydrogen products could improve the ability of flexible technologies to respond to short-term electricity price signals. Aligning market closure times would further reduce uncertainty by allowing participants to make decisions based on more complete and consistent information across carriers.

Beyond temporal alignment, coordination may also involve harmonizing for example nomination procedures. Although electricity, gas, hydrogen, and heat markets continue to be cleared independently, market participants benefit from more consistent operational structures and improved visibility of conditions in other carriers. Under this concept, multi-carrier technologies remain responsible for optimising their own operation across markets. However, improved coordination reduces operational complexity, transaction costs, and uncertainty, thereby facilitating more efficient participation in multiple markets. The coordinated markets configuration therefore represents an intermediate approach that seeks to improve system efficiency while preserving the institutional independence of existing market structures.

- **Fully Integrated Markets:** The fully integrated markets configuration represents a theoretical benchmark in which electricity, gas, hydrogen, and heat are jointly optimised within a unified market framework. Rather than clearing each carrier separately, a central market operator performs a single optimisation that simultaneously determines the allocation of resources across all energy carriers. In this configuration, multi-carrier technologies are explicitly represented within the market-clearing process through conversion relationships linking the different carriers. Technologies such as gas-fired power plants, CHP units, electrolysers, power-to-heat installations, and hydrogen-fired generators are therefore no longer required to optimise their participation across multiple independent markets. Instead, their operational flexibility is directly incorporated into a system-wide optimisation framework.

  This market design removes many of the identified barriers. Product durations, operating days, and market closure schedules are inherently aligned. Information is shared through a common optimisation process rather than through sequential market interactions, and market participants interact with a unified market framework rather than multiple regulatory and administrative systems. Within such a framework, prices across carriers emerge simultaneously from a coordinated allocation of resources, allowing the value of sector-coupling technologies to be fully reflected in market outcomes. By explicitly considering the interactions between electricity, gas, hydrogen, and heat systems, the market-clearing mechanism can identify the economically optimal use of flexibility across all carriers.

A fully integrated market design should not be interpreted as a realistic implementation pathway, as it would require the harmonisation of market rules, regulatory frameworks, governance structures, and market-clearing processes across fundamentally different energy carriers. Rather, it serves as a theoretical benchmark against which the performance of more practical coordination approaches can be compared.

Figure 2-5 summarises the main characteristics of the three market design concepts and illustrates the increasing degree of coordination between energy carriers.

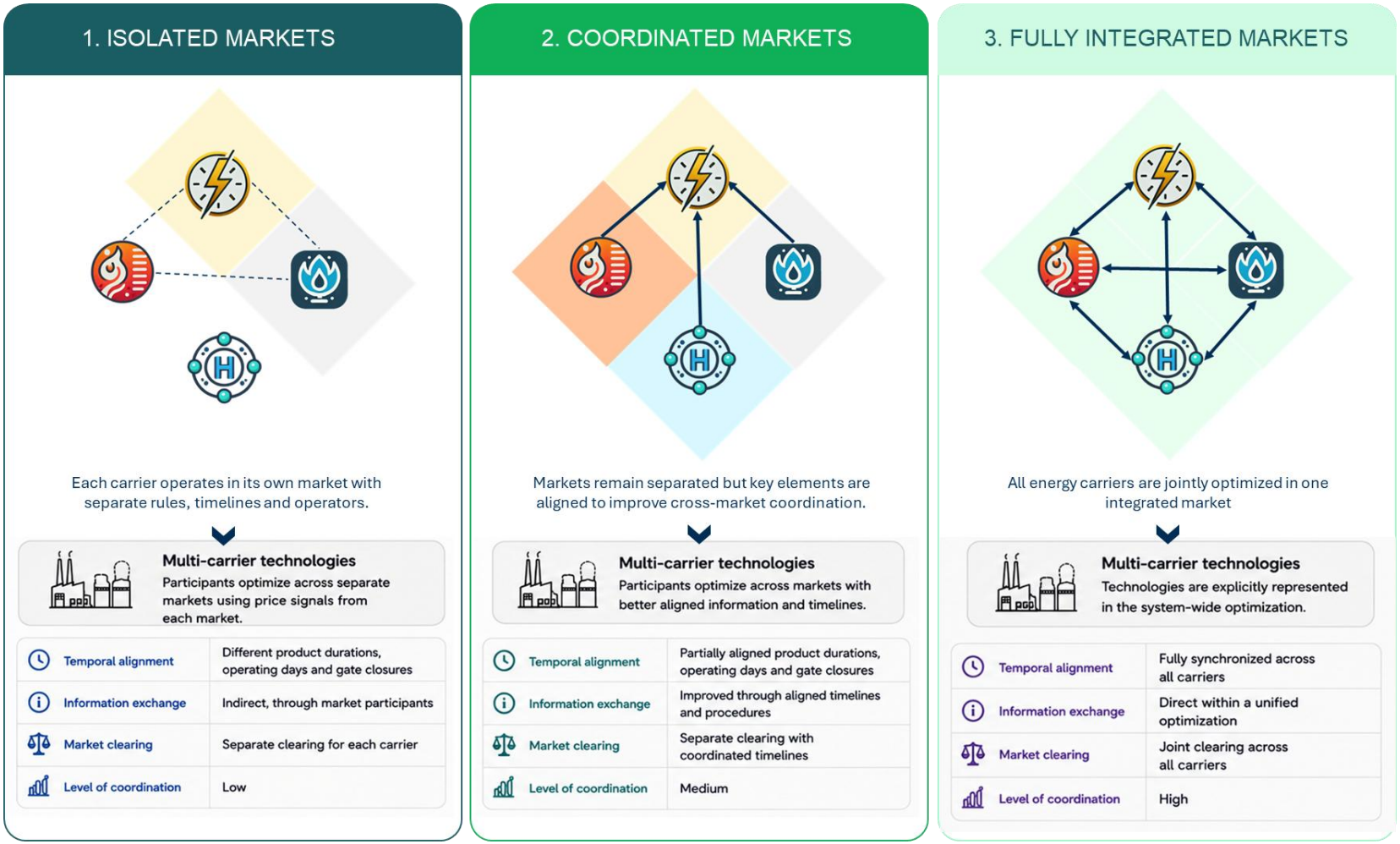


Figure 2-5 Representation of isolated, coordinated, and fully integrated market designs

2.4 Qualitative analysis

The three market design concepts introduced in the previous section are evaluated using a qualitative set of Key Performance Indicators (KPIs). KPI-based approaches are widely used to assess complex energy systems across dimensions such as efficiency, reliability, and cost. In electricity market design, evaluations commonly focus on dispatch efficiency and the quality of price signals guiding operational decisions. Building on these principles, seven KPIs are defined covering three broad dimensions: (i) system performance (resource allocation efficiency, utilisation of sector-coupling flexibility, and price signal consistency across carriers), (ii) market participant conditions (operational complexity for market participants and information availability at the bidding stage), and (iii) market design feasibility (complexity of market clearing and implementation complexity).

The assessment is qualitative and is based on the characteristics of the market design concepts described in the previous sections, complemented by insights obtained through the literature review and stakeholder interviews. The ratings are intended to compare the relative strengths and weaknesses of the different concepts rather than provide a quantitative measure of performance. Table 2-3 summarises the results.

Table 2-3 Qualitative assessment of market design concepts.

Key Performance Indicator	***Isolated markets***	***Coordinated markets***	***Fully integrated markets***
Resource allocation efficiency	Medium	High	Very high
Utilisation of sector-coupling flexibility	Medium	High	Very high
Price signal consistency across carriers	Low–medium	Medium–high	High
Operational complexity for market participants	High	Medium	Low
Complexity of market clearing	Low	Low–medium	High
Information availability at bidding stage	Low	Medium	High
Implementation complexity	Low	Medium	Very high

The comparison highlights clear differences between the three concepts. In the **isolated markets** configuration, interactions between energy carriers occur only indirectly through the actions of market participants. While this preserves the independence of individual markets and requires limited institutional change, differences in product durations, operating days, market closure schedules, and regulatory frameworks create challenges for operators of multi-carrier technologies. As a result, sector-coupling flexibility may not be fully utilised and market participants face relatively high operational complexity when coordinating activities across multiple carriers.

The **coordinated markets** concept improves performance by aligning selected market design elements while maintaining separate market-clearing processes. Harmonisation of product durations, operating days, and market gate closures reduces uncertainty and improves the consistency of information available when bidding decisions are made. In addition, greater alignment of market procedures facilitates the participation of multi-carrier technologies and enhances the utilisation of cross-carrier flexibility. Consequently, coordinated markets achieve higher resource allocation efficiency and better price signal consistency than isolated markets, while maintaining a relatively moderate level of implementation complexity.

The **fully integrated markets** concept represents a theoretical benchmark in which all energy carriers are jointly optimised through a unified market-clearing process. By explicitly incorporating multi-carrier technologies into a single optimisation framework, this concept achieves the highest levels of resource allocation efficiency, flexibility utilisation, information availability, and price signal consistency. However, these benefits come at the cost of significantly increased market-clearing complexity and extremely high implementation complexity. A fully integrated market design should therefore not be interpreted as a realistic implementation option, as it would require the harmonisation of market rules, regulatory frameworks, governance structures, and market-clearing processes across fundamentally different energy carriers.

Overall, the assessment suggests that coordinated markets provide the most balanced solution. While the fully integrated concept achieves the highest performance across most KPIs, it primarily serves as a theoretical benchmark against which more realistic approaches can be evaluated. The coordinated markets concept captures a substantial share of the potential benefits associated with cross-carrier coordination while remaining broadly compatible with existing market structures and institutional arrangements. It therefore represents a pragmatic pathway towards improving the integration of electricity, gas, hydrogen, and heat systems in Belgium.

3 Business models for improved sector coupling

3.1 Rationale for archetype-specific business models

Sector coupling requires more than the technical integration of electricity, heat, gas, hydrogen, storage and mobility. It also requires business models that fit the actors expected to adopt, operate, finance or benefit from these solutions. The EU Strategy for Energy System Integration explicitly frames sector integration as a process involving not only technologies and infrastructure, but also digitalisation, smart grids, flexibility markets and new business models [29]. Similarly, recent work on demand-side flexibility stresses that flexibility only becomes valuable when it is properly integrated into market, planning and regulatory frameworks [31].

Previous ReInvent work (ReInvent Deliverable D1.1) [1] identified a broad portfolio of business models relevant to sector coupling, including Energy-as-a-Service, hydrogen services, storage-as-a-service, peer-to-peer trading, virtual power plants, Heat-as-a-Service, collective self-consumption and community energy models. It also identified general drivers and barriers, such as regulatory uncertainty, high upfront costs, technological complexity, collaboration needs and customer acceptance. This section builds on that earlier work but does not repeat the general business model landscape. Instead, it asks more specific questions: **which business models fit which types of actors, and under which conditions can they support sector coupling in practice?**

This distinction is necessary because target groups are not homogeneous. Industrial firms, energy communities and households differ in investment readiness, risk tolerance, technical capacity, access to finance, trust in institutions and providers, willingness to share data or assets, ability to engage with complex regulation, and preferred level of control. A one-size-fits-all business model risks misalignment with these differences. For example, a large industrial actor considering hydrogen offtake may require long-term contractual certainty, while an experimental community energy initiative may need a sandbox environment, and a tenant may require a split-incentive solution that aligns landlord investment with occupant benefits.

Archetypes are therefore used here as practical design profiles rather than fixed or exhaustive actor categories. They **help translate actor heterogeneity into business model design choices.** For each target group, the archetypes indicate what actors need, which business model logic is most appropriate, which enabling conditions must be in place, and how ReInvent Business Use Cases can be positioned for uptake, scalability and replicability.

This approach is consistent with recent evidence that clean energy transitions depend not only on technology availability, but also on consumer participation, institutional capacity, flexibility valuation, and tailored policy design. **Energy communities**, for example, are recognised by the European Commission as a mechanism through which citizens, companies and local actors can collectively invest in, produce, consume, and share renewable energy [31]. At the same time, **household** energy choices are shaped by behavioural, financial and contextual

factors, meaning that adoption cannot be assumed from technical potential alone [32]. In **industry**, large-scale sector coupling depends on stable investment frameworks, infrastructure coordination and bankable revenue models, particularly for capital-intensive options such as hydrogen, electrification and multi-vector hubs [33].

The purpose of this section is therefore to connect target groups, archetypes, suitable business models, enabling conditions and ReInvent Business Use Cases as defined in ReInvent D3.1 [34].

The analytical sequence is as follows:

- the main actor archetypes are described for industry, energy communities and residential actors, and then linked to suitable business model logics (section 3.3)
- the enabling conditions for successful sector coupling are identified (section 3.4)
- selected ReInvent BUCs are assessed through this archetype-based lens (section 3.5)

3.2 Methodological approach

The analysis followed seven linked steps combining empirical segmentation, documentary analysis, business model design, and application to the ReInvent Business Use Cases as shown in the figure below.



Figure 3-1: Methodological approach business model identification

First, the business model concepts, drivers and barriers identified in ReInvent Deliverable D1.1 [1] were consolidated with selected **policy and scientific literature** on energy system integration, demand-side flexibility, industrial decarbonisation, energy communities and household energy adoption. This established the initial portfolio of business model mechanisms and the technical, commercial, regulatory, organisational and behavioural conditions against which they could be assessed.

Second, separate evidence was collected for industry, energy communities, and residential actors. **Qualitative interviews** were used to inform three target-group-specific surveys, which were subsequently analysed separately using latent class analysis. The analysis focused on recurring differences in factors such as investment readiness, perceived barriers and benefits, technology preferences, trust, willingness to collaborate, and capacity to act. The resulting classes were interpreted through their defining indicators and triangulated with the qualitative material and relevant literature.

The statistically derived classes were supplemented, where necessary, by structural actor profiles. These **additional profiles** represent positions that create distinct business model constraints because of asset ownership, legal status or decision-making authority. For example, tenants are not treated as a psycho-behavioural segment equivalent to a latent class; rather, they are considered an actor category defined by limited control over building-level investments. The same distinction applies to public entities or other organisational profiles that were added through qualitative or institutional analysis rather than estimated directly from the survey data.

Third, **each archetype was mapped to a common set of business model design dimensions**: the target actor and value proposition; ownership and governance; service and operational arrangements; revenue streams and cost allocation; financing and risk allocation; data and digital requirements; and regulatory or market-access conditions. The matching was based primarily on behavioural, organisational and decision-related characteristics rather than on socio-demographic variables.

Fourth, **the 17 BUCs defined in D3.1 were screened for their relevance to business model development**. Reinvent Deliverable D3.1 [34]is used consistently as the source for BUC numbering, naming and scope. Where an “a” and “b” variant concern the same underlying case, the variants are discussed together, while retaining the distinction between the baseline configuration and the flexibility-enhanced configuration. Detailed assessment focuses on BUCs with a direct value-creation, actor, ownership, governance, financing or market-access dimension. BUCs concerned primarily with whole-system modelling, technology potential or billing are included only where their results materially affect the business model analysis.

Fifth, **the archetype–business model–BUC mappings were compared across the three target groups to identify recurring enabling and scalability conditions**. These conditions were grouped into five categories: technical; economic and commercial; regulatory and market-design; organisational and governance; and behavioural and acceptance conditions. BUC-specific modelling results and expert interviews were used as supplementary evidence where available. Quantitative results are attributed to the relevant ReInvent deliverable [35], while expert interviews are treated as contextual qualitative evidence and not as representative evidence of a wider population.

To ensure comparability, the subsections for industry, energy communities and residential actors follow the same structure: target-group scope and evidence base; archetype description; archetype-to-business-model mapping; application to relevant BUCs; and enabling and scalability conditions. Business model concepts that may be unfamiliar to non-specialist readers are defined at first use.

The resulting mappings should be interpreted as evidence-informed design propositions rather than as causal impact estimates. They identify plausible matches between actor profiles and business model configurations, but do not by themselves demonstrate that a particular model will cause adoption, profitability

or successful replication. Those outcomes require further validation through BUC-specific modelling, implementation evidence and stakeholder testing.

3.3 Target groups and archetypes

The previous section established the rationale and methodology for tailoring sector-coupling business models to different actor profiles. This section applies that approach to three target groups: industry, energy communities and residential actors. Consistent with ReInvent Deliverable D3.1, which assigns Task 1.3 the development of archetypes for different end-use segments and the translation of these archetypes and associated business model features into tailored business models [1], the purpose is to **define practical design profiles** rather than rigid or mutually exclusive classifications. This archetype-based approach builds on the observation that participation in sector coupling depends on more than technical potential. **Industrial actors** differ in investment capacity, risk exposure, energy intensity and strategic readiness. **Energy communities** differ in maturity, governance capacity, experimentation appetite and ability to manage shared assets. **Residential actors** differ in trust, perceived control, ownership status, technical confidence and exposure to upfront costs. Recent work on household energy choices confirms that adoption of low-emission technologies such as solar panels and heat pumps is shaped by household-level behavioural, financial and contextual factors, rather than by technology availability alone[35]. Similarly, demand response participation depends on programme design, price signals and incentives, while energy communities require collective governance arrangements that allow citizens, companies and local actors to invest in, produce, sell and consume renewable energy [31].

To facilitate comparison, the three target-group subsections follow the same structure. Each table presents the archetype, its defining profile, principal needs, best-fit business model logic, the rationale for the proposed match and its relevance for sector coupling. The explanatory text following each table clarifies the principal business model concepts and the conditions under which the proposed match is likely to be viable. The mappings should therefore be read as evidence-informed design propositions rather than deterministic predictions: an actor may correspond to more than one archetype, and its profile may evolve as its experience, capabilities and operating context change.

3.3.1. Industry archetypes

Table 3-1: Mapping of industry archetypes to suitable sector-coupling business model approaches.

Archetype	*Who they are*	*Main needs*	*Best-fit business model(s)*	*Why this model fits*	*Sector-coupling relevance*
Cautiously Optimistic Implementers	Companies of different sizes that are open to sector coupling but are not yet fully ready to implement it. They may show interest in electrification, renewable energy, flexibility or hydrogen, but remain cautious about cost, disruption and risk.	Step-by-step support; trusted technical partners; public subsidies; reduced investment risk; evidence from pilots; clear implementation pathways.	Public-backed pilot; municipal/EU demonstration project; risk-shielded partnership; managed service model.	These companies are not opposed to sector coupling, but they need confidence before committing. Public support, trusted facilitation and staged implementation reduce perceived and actual risk.	Relevant for early deployment of 5GDHC, BESS, hydrogen pilots, industrial heat pumps, electrification measures and local flexibility schemes.
Strategic Market Actors	Larger or more mature companies that already have a decarbonisation or sector-coupling strategy. They are ready to invest if the regulatory and commercial framework is stable.	Long-term certainty; predictable revenues; clear market rules; bankable contracts; infrastructure planning; regulatory stability.	Power Purchase Agreements (PPAs); hydrogen offtake agreements; Contracts for Difference (CfDs); capacity contracts; long-term flexibility contracts; long-term heat/cooling service contracts.	These actors can invest, but only if revenue, demand and regulation are predictable. Long-term contracts reduce exposure to price and demand uncertainty.	Relevant for green hydrogen, renewable PPAs, large-scale electrification, hydrogen infrastructure, flexibility markets and industrial energy hubs.
Selective Innovators	Startups, technology firms, niche industrial actors or experimental companies willing to test new sector-coupling solutions under flexible conditions.	Freedom to experiment; regulatory flexibility; fast setup; data access; innovation support; platform access; low administrative burden.	Innovation sandbox; digital platform model; API-enabled flexibility ecosystem; shadow-operation pilot; automated transaction pilot.	These actors are open to experimentation but may be constrained by rigid regulation or conventional contracting models. Sandboxes and platforms allow rapid testing of new technologies, services and market roles.	Relevant for thermal flexibility platforms, BESS optimisation, EV charging flexibility, automated transactions, peer-to-peer trading, hydrogen/electric mobility comparisons and multi-utility flexibility platforms.
Industrial Giants / Integrated Industrial Actors	Large industrial or infrastructure actors with complex, multi-vector energy needs and internal capacity to manage large capital expenditure (CAPEX) and system complexity. Examples may include chemical clusters, ports, large industrial sites, infrastructure operators or major hydrogen actors.	Deep decarbonisation pathways; integrated infrastructure; long-term investment certainty; strategic partnerships; regulatory engagement; cluster-level planning; multi-vector optimisation.	Integrated industrial hub model; hydrogen hub model; multi-utility flexibility platform; infrastructure backbone model; cluster optimisation model.	These actors have the scale and technical capacity to benefit from integrated systems rather than isolated technologies. They can manage complex investments and coordinate multiple energy vectors over long time horizons.	Relevant for hydrogen backbones, industrial heat and steam networks, port clusters, multi-carrier flexibility, CO_2 and hydrogen infrastructure, and large-scale sector-coupling hubs.

The industry archetypes show that industrial sector-coupling business models must be differentiated by readiness, risk tolerance and scale. Cautiously Optimistic Implementers need low-risk pilots and trusted support before adopting technologies such as 5th-generation district heating and cooling (5GDHC), battery energy storage system (BESS) or hydrogen. Strategic Market Actors can support larger investments but require stable regulation and bankable long-term contracts. Selective Innovators are suited to sandboxes, digital platforms and experimental flexibility models. Industrial Giants or Integrated Industrial Actors are best placed for large-scale hub models involving multiple energy vectors, infrastructure coordination and long-term decarbonisation pathways.

3.3.2. Energy community archetypes

Energy communities still are relatively new market actors in the energy transition. The initial EU-legislation goes back to 2018. The EU Commission introduced two related concepts, what already can create confusion. The transposition of the EU-definitions in the Member States also is quite different across Europe, what makes it more difficult to analyse which business models for energy communities are applicable in the different Member States. In Belgium the situation is even more difficult, due to the separate policy framework for energy communities in the three regions Flanders, Wallonia and Brussels. So before we can draw conclusions on business models for energy communities, we first must better understand the framework in the three regions.

3.3.2.1 Energy communities in Europe

Energy communities received an explicit legal basis at EU level through the Clean Energy for all Europeans legislative package. Two related concepts were introduced: Renewable Energy Communities (RECs) under Directive (EU) 2018/2001 on the promotion of energy from renewable sources, and Citizen Energy Communities (CECs) under Directive (EU) 2019/944 on common rules for the internal market for electricity [35][36]. Although the two concepts differ in their scope, membership and governance requirements, both aim to enable citizens and other local actors to participate more actively in the energy system rather than acting solely as final consumers.

Under the EU framework, energy communities can engage in activities such as producing, consuming, storing, sharing and selling energy, while providing environmental, economic or social benefits to their members or the areas in which they operate. Energy communities can therefore support several forms of sector coupling, including collective renewable generation, shared storage, electric mobility, heating and cooling, and demand-side flexibility. Their relevance for ReInvent lies particularly in their capacity to coordinate multiple actors and assets within collective business models.

Member States were required to transpose the relevant provisions of the two Directives into national legislation and to establish regulatory frameworks for energy communities. Implementation nevertheless differs

substantially across Europe. National frameworks vary in areas such as eligible participants, governance requirements, geographical limitations, energy-sharing arrangements, network charges, registration procedures and access to energy markets. REScoop.eu monitors these differences through its transposition tracker for RECs and CECs [38]. Consequently, the viability and scalability of a particular energy-community business model cannot be assessed independently of the national and regional regulatory context in which it operates.

3.3.2.2 Energy communities in Belgium: evolution

The development of energy communities in Belgium can be understood as the convergence of two related evolutions.

First, citizen energy cooperatives were already active in Belgium in the start of the twenty-first century, long before energy communities were formally introduced into EU legislation. In both Flanders and Wallonia, citizens organised collectively to invest in renewable energy projects such as wind, solar, hydropower and biomass. These cooperatives developed models based on citizen ownership and democratic participation and, in some cases, also contributed to the supply of renewable electricity to their members. They can therefore be considered important precursors to the energy-community models that were subsequently formalised at European level in 2018. Citizen energy cooperatives are represented regionally through the federations REScoop.Vlaanderen and REScoop Wallonie, which support cooperation between their members, knowledge exchange and representation in energy-policy discussions [39], [40].

Second, the introduction of Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs) through European legislation in 2018 created a formal regulatory framework for a broader range of collective energy initiatives. In addition to citizen cooperatives, these frameworks enable citizens, local authorities, SMEs and other eligible actors to cooperate in activities such as renewable-energy production, consumption, storage, energy sharing and other energy services, subject to the specific conditions applicable to RECs and CECs [36], [37]. Energy communities must have a legal personality in accordance with the applicable regional framework; cooperatives and non-profit associations are among the legal forms used in practice.

In **Belgium**, assessing energy communities and their sector-coupling potential is more complex than in many other EU Member States because of the country's multi-level energy governance structure. Responsibility for energy policy is divided between the federal level and the three Regions—Flanders, Wallonia and the Brussels-Capital Region—and each Region has developed its own legislation and implementation framework for energy communities. This has resulted in a fragmented and evolving regulatory landscape, with differences in terminology, eligible actors, geographical scope, energy-sharing arrangements, registration or authorisation procedures and other operational conditions. These **regional differences** are particularly relevant for business model development because they influence which collective activities can be implemented, which actors may participate and under what conditions value can be created and shared.

The following subsection therefore compares the principal collective-energy concepts and regulatory arrangements in Flanders, Wallonia and the Brussels-Capital Region before examining the ReInvent energy-community archetypes.

3.3.2.3 Energy Communities in Belgium: collective concepts and registration

The three Belgian Regions have implemented different frameworks for energy communities and collective energy sharing. The differences concern not only the administrative procedure for establishing an energy community, but also the types of collective arrangements available, who may participate or exercise control, the geographical scope of the community and the conditions under which energy can be shared. Table 3-2 summarises the main differences that are relevant for the business model analysis.

Table 3-2: Characteristics of Energy-community concepts in the three Belgian Regions

Region	*Energy-community concepts in the regulation*	*Main distinguishing characteristics*	*Administrative procedure*	*Other collective energy-sharing concepts*
Flanders	Energiegemeenschap van Burgers (EGB; Citizen Energy Community) and Hernieuwbare-Energiegemeenschap (HEG; Renewable Energy Community)	An HEG is limited to renewable energy, has a proximity requirement and restricts participation to citizens, local authorities and SMEs. An EGB allows broader participation, including larger companies, although effective control is restricted to citizens, local authorities and small enterprises.	EGBs and HEGs must notify the Vlaamse Nutsregulator within 30 days after establishment.	Energy sharing within an apartment or multifunctional building; sharing between a participant's own locations; person-to-person energy transactions
Wallonia	Communauté d'Énergie Citoyenne (CEC) and Communauté d'Énergie Renouvelable (CER)	A CER is based on renewable energy, is subject to proximity requirements and restricts participation to natural persons, local authorities and SMEs. A CEC has a broader geographical scope and may include a wider group of members, although effective control is restricted. Energy sharing within one building can take place without creating an energy community.	Creation of an energy community must be notified to CWaPE. Energy sharing within an energy community requires separate prior authorisation.	Collective renewable-electricity sharing between active customers within the same building
Brussels-Capital	Citizen Energy Community, Renewable Energy Community and Local Energy Community	Brussels recognises an additional Local Energy Community. Renewable and Local Energy Communities use renewable electricity and apply proximity-related conditions. The different community types also differ in eligible membership, effective control and ownership of production installations.	Prior authorisation from BRUGEL is required to operate an energy community. The authorisation is valid for 10 years and can be renewed.	Energy sharing within the same building and peer-to-peer energy trading

The applicable regional concept determines which actors can participate, who can exercise control, which production assets can be included, how geographically dispersed participants can be and whether collective energy sharing requires the creation of a formal energy community.

The registration procedures also differ substantially: Flanders relies mainly on notification, Wallonia combines notification of the community with separate authorisation of energy-sharing activities, while Brussels applies an ex-ante licensing procedure.

Registration of energy communities in Flanders

Flanders recognises two forms of energy community: the **Energiegemeenschap van Burgers (EGB)** and the **Hernieuwbare-Energiegemeenschap (HEG)** [41]. Both must have legal personality and may engage in activities such as energy production, consumption, storage, energy services and EV charging. However, there are important differences. An HEG operates exclusively with renewable energy, participation is limited to citizens, local authorities and SMEs, and its activities are subject to technical or geographical proximity requirements. The HEG must also own the installations used for its activities. An EGB can include a broader range of participants, including larger enterprises, and is not subject to the same proximity requirement, although effective control is restricted to citizens, local authorities and qualifying small enterprises .

Both EGBs and HEGs are subject to a **notification obligation** to the Vlaamse Nutsregulator. Notification has been mandatory since 1 January 2022 and must take place within 30 days after establishment. This is not equivalent to prior authorisation: through the notification, the organisation declares that it meets the conditions for an energy community. The Vlaamse Nutsregulator maintains a public register of notified communities, which was most recently updated in June 2026. Its 2025 monitoring report identified approximately 80 unique organisations registered as EGBs, HEGs or both [42].

Importantly, collective energy sharing in Flanders does not always require an energy community. Energy can also be shared within an apartment or multifunctional building, between different locations belonging to the same participant, or through person-to-person arrangements . These alternatives may offer a simpler business model where the objective is primarily electricity sharing rather than the broader collective activities and governance associated with an energy community.

Registration of energy communities in Wallonia

Wallonia distinguishes between a **Communauté d'Énergie Renouvelable (CER)** and a **Communauté d'Énergie Citoyenne (CEC)** [43]. A CER is restricted to natural persons, local authorities and SMEs, must use renewable energy and is subject to a proximity requirement. A CEC is limited to the electricity sector and may have a broader membership and geographical scope, although effective control is restricted to natural persons, local authorities and qualifying small enterprises . Both forms must have a legal personality and may perform activities including electricity production, storage, sharing, aggregation, flexibility and EV charging.

Wallonia also distinguishes an energy community from **collective energy sharing within the same building**. In the latter case, participating active customers and the production installation are located within or on the same building, and renewable electricity can be shared without establishing a CER or CEC[43]. This distinction is relevant because it allows certain collective self-consumption models to operate with a lighter governance structure than a formal energy community.

The creation of a CER or CEC must be **notified to CWaPE before it begins activities on the electricity market** [X4]. CWaPE verifies whether the notification file is complete, but acknowledgement of a complete notification does not itself constitute confirmation that the community complies with all legal requirements. Where the community intends to share electricity among its participants, that sharing activity requires a separate prior authorisation from CWaPE .

The current CWaPE register lists **nine energy communities with complete notification files** Each notified community must also provide annual reporting to CWaPE. Since June 2026, notification, modifications and annual reporting are carried out through online forms.

CWaPE has additionally published **guidelines on the conformity assessment of the statutes of energy communities** [43]. These guidelines explain how CWaPE assesses whether the statutes of CERs and CECs comply with the regulatory requirements and provide practical guidance for the notification and reporting procedures.

Registration of energy communities in Brussels region

The Brussels-Capital Region recognises **three types of energy community**: the Citizen Energy Community, Renewable Energy Community and **Local Energy Community**[44] . The categories differ according to the types of actors that may participate and exercise effective control, the activities they may undertake, the origin of the electricity and the ownership of production installations. In Renewable and Local Energy Communities, the electricity must originate from renewable sources, and effective control is linked to members located in proximity to the relevant projects. Citizen and Renewable Energy Communities may also provide aggregation, flexibility, energy and EV-charging services.

As in the other Regions, not every collective electricity-sharing arrangement requires the creation of an energy community. Brussels also provides for electricity sharing between participants within the same building and for peer-to-peer trading. The choice between these arrangements and a formal energy community therefore depends on the number and type of participants, the geographical scope and the wider activities that the initiative intends to undertake.

Unlike the notification-based approaches used for establishing energy communities in Flanders and Wallonia, operating an energy community in Brussels requires **prior authorisation from BRUGEL** . BRUGEL

must respond to a complete authorisation request within 60 days. Once granted, the authorisation is valid for 10 years and can subsequently be renewed [45].

BRUGEL maintains a public register of authorised energy communities. As of the most recent update in 2026, **34 energy communities** had received an authorisation, with the most recent entries approved in May 2026 [46]. The Brussels framework can therefore be characterised as a more explicit ex-ante authorisation model, whereas the Flemish and Walloon systems rely initially on notification, although Wallonia subsequently requires authorisation for energy-sharing activities.

3.3.2.4 Energy communities archetypes in REINVENT

Table 3-3: Mapping of energy community archetypes to suitable sector-coupling business models

Archetype	*Who they are*	*Main needs*	*Best-fit business model(s)*	*Why this model fits*	*Sector-coupling relevance*
Institutional Anchors	Large, mature and established energy cooperatives or community energy organisations with structured governance, existing assets and experience in renewable energy projects.	Policy clarity; regulatory simplification; access to larger projects; stable revenue models; professional financing tools; technical capacity.	PPA model; cooperative ownership; public-private partnership; collective self-consumption; shared storage model.	These organisations have the governance capacity to manage larger and more complex projects, but need clear rules, bankable revenue structures and access to finance.	Relevant for larger PV, wind, shared storage, cooperative BESS, district heating, flexibility aggregation and community-scale sector coupling.
Innovative Pioneers	Small or emerging energy communities experimenting with new models such as peer-to-peer trading, microgrids, local flexibility or digital platforms.	Regulatory sandboxes; technical assistance; innovation grants; low administrative burden; digital tools; freedom to test new models.	Peer-to-peer trading; digital energy trading platform; innovation sandbox; automated transactions; local flexibility pilot.	These groups are motivated by experimentation and autonomy but often lack scale and face regulatory uncertainty. Sandbox and platform models allow controlled testing.	Relevant for digital trading, local flexibility, EV charging coordination, automated settlement, microgrids and experimental energy-sharing mechanisms.
Citizen-Led Pragmatists	Active cooperatives or citizen groups that value fairness, affordability and local ownership, but prefer manageable and proven models over highly experimental ones.	Affordable systems; transparent governance; simple contracts; funding support; local ownership; trusted partners.	Cooperative self-consumption; co-owned generation; collective renewable projects; shared local assets.	These actors are willing to participate when the model is understandable, fair and locally beneficial. Cooperative models align with their trust and ownership preferences.	Relevant for shared PV, local wind, BESS, shared EVs, collective renovation, local flexibility and community-based heat solutions.
SME / Business Cluster	Groups of SMEs, local businesses or business-park actors collaborating on energy production, sharing, storage or flexibility.	Simplified contracts; shared assets; joint operations; cost-sharing mechanisms; clear allocation of benefits and risks; technical coordination.	Cluster self-consumption; business-cluster energy sharing; co-owned generation; shared BESS; local flexibility platform.	Individual SMEs may lack scale, capital or expertise. Cluster models allow them to pool resources, share risk and improve local energy matching.	Relevant for business parks, local renewable sharing, shared storage, BESS, heat/cooling networks, SME flexibility and local industrial energy communities.
Public Entities	Municipalities, intermunicipal agencies, public bodies or territorial development organisations acting as facilitators, conveners, infrastructure enablers or public-interest investors.	Legal mandate; funding access; procurement-compatible models; technical capacity; governance clarity; public legitimacy; coordination tools.	Public-private partnership; public-led infrastructure facilitation; municipal energy platform; public-backed pilot; hybrid ownership model.	Public actors can convene stakeholders, reduce risk, provide legitimacy, support infrastructure planning and unlock access to public assets or funding.	Relevant for district heating, business-cluster energy sharing, public buildings, local hydrogen infrastructure, EV charging, energy communities and public-interest flexibility projects.

Despite the regional differences explained in the previous section, we were able to identify five archetypes for Energy Communities that can be applied in all three Belgian regions.

Institutional anchors represent mature energy communities that have reached a degree of professionalism and that have a wide range of energy projects in their investment portfolio: a combination of larger PV, wind, district heating, flexibility aggregation. Because of this diversification they have the biggest potential in making advantage of community-scale sector coupling.

Innovative Pioneers are rather smaller or emerging energy communities that invest in innovative projects, like e.g. car sharing projects. They can take advantage of sector coupling when they manage to get grid access, but for a small community that is a challenge.

Citizen-Led Pragmatists invest in proven concepts where the business model is quite secure, like solar panels. But they prefer to invest in rather local and small scale projects, where local ownership and local involvement is key. Therefore for this archetype it is rather difficult to take advantage of sector coupling.

SME / Business Clusters operate on the scale of a local business park or a larger geographical area. The primary goal of this archetype is to lower their energy bill by energy sharing schemes within the business cluster, and maximising self-consumption within the EC via BESS investments. For this archetype sector coupling can lead to additional benefits for the Energy Community and the grid if they can get grid access.

Public Entities include municipalities, intermunicipal organisations and other public bodies that may establish or participate in an Energy Community to facilitate energy sharing across their public building stock, for example municipal offices, sports facilities, administrative buildings, schools and childcare facilities. This archetype is still at an early stage of development in Belgium but offers potentially significant opportunities for sector coupling. By coordinating electricity generation and consumption across multiple public buildings, public entities could combine local renewable generation with shared storage, EV charging, heat pumps and demand-side flexibility. The viability of such models depends on factors including the complementarity of building load profiles, access to suitable metering and energy-management systems, procurement and governance arrangements, and the applicable regional energy-sharing framework. Further analysis is therefore needed to determine under which conditions sector coupling can create economic and system-level benefits for public-sector energy communities.

3.3.3. Residential Archetypes

Table 3-4: Mapping of residential archetypes to suitable sector-coupling business model approaches.

Archetype	*Who they are*	*Main needs*	*Best-fit business model(s)*	*Why this model fits*	*Sector-coupling relevance*
Confident Pragmatists	Homeowners with existing or planned energy technologies such as PV, EVs, batteries or heat pumps. They are relatively confident, technically interested and motivated by both cost savings and environmental benefits.	Smart tools; financial optimisation; control over energy use; access to flexibility revenues; reliable technology bundles; clear return on investment.	Energy-as-a-Service bundle; smart home energy management; demand response contract; EV smart charging / V2G model; PV-battery-heat pump bundle.	These households have the confidence and assets needed to participate actively. They respond well to models that increase control, savings and environmental performance.	Relevant for distributed flexibility, smart charging, heat pump optimisation, self-consumption, household batteries, aggregation and demand response.
Regulation-Averse Sceptics	Homeowners with limited energy technology adoption, low interest and low trust in providers, regulation or policy incentives. They may perceive energy transition measures as complex, risky or imposed from outside.	Simplicity; trusted intermediaries; low hassle; strong guarantees; transparent pricing; minimal upfront effort; protection from technical and regulatory complexity.	Concierge-style offer; one-stop-shop service; managed renovation/energy service; performance-guaranteed contract; trusted local intermediary model.	These households are unlikely to engage with complex incentives or technical details. A managed service reduces cognitive burden and perceived risk.	Relevant for heat pump adoption, renovation, basic energy efficiency, simplified EV charging offers and gradual participation in flexibility or aggregation.
Cautious Idealists	Homeowners who care about sustainability but feel uncertain, under-informed or constrained by cost, complexity or lack of confidence. They are motivated but need support and collective reassurance.	Low-cost entry points; friendly guidance; peer examples; community support; grants; simple participation models; trusted advice.	Community energy project; shared solar; collective purchasing scheme; peer-led renovation support; neighbourhood energy programme.	These households are values-driven but need help turning motivation into action. Collective models reduce uncertainty and provide social proof.	Relevant for community solar, collective renovation, shared batteries, neighbourhood heat solutions, cooperative EV charging and local demand-response participation.
Tenants	Tenants in social housing or private rental dwellings, often living in apartments or homes with poor energy performance and high energy bills. They usually have limited control over major building investments.	Legal and financial frameworks that encourage owners to invest; protection from rent increases; lower energy bills; fair allocation of renovation benefits; accessible information.	Split-incentive model; landlord-tenant renovation agreement; social housing energy service model; on-bill or rent-linked repayment with safeguards; community/shared energy access model.	Tenants cannot usually invest directly in building-level technologies. Business models must align landlord investment incentives with tenant benefits and prevent unfair cost shifting.	Relevant for building renovation, heat pumps, collective heating, shared solar, social housing energy communities and inclusive access to low-carbon technologies.

Residential actors are central to sector coupling because many enabling assets are located at household or building level, including rooftop PV, heat pumps, electric vehicles, home batteries, smart meters and demand-

response-ready appliances. These assets can support electrification, local self-consumption and flexibility, but households differ strongly in their ability and willingness to adopt or operate them. The residential archetypes therefore refine the broader business model categories identified in earlier ReInvent work, i.e. ReInvent Deliverable D1.1 [1].

Confident Pragmatists are the most suitable early adopters for smart optimisation, EV smart charging, V2G, demand response and PV-battery-heat pump bundles, provided that the financial benefits, interoperability and user control are clear.

Regulation-Averse Sceptics require low-complexity offers, trusted intermediaries and guarantees, because technically sophisticated propositions are unlikely to scale if they increase perceived risk or administrative burden.

Cautious Idealists are motivated by sustainability but need support to move from intention to action. Collective purchasing, community energy projects, shared solar and peer-led renovation support can reduce uncertainty and provide social proof.

Tenants face a different constraint: they often lack control over building-level investments such as insulation, heating systems, rooftop PV, electrical upgrades or private charging infrastructure. For this group, business models must address split incentives, benefit pass-through, rent safeguards and access to shared or collectively organised energy services.

In **conclusion**, the key implication is that residential sector coupling cannot rely on a single household offer. Advanced flexibility models may scale first among confident and asset-owning households, while broader adoption requires simpler, trusted and more inclusive models. For tenants, scalability depends less on individual willingness and more on institutional arrangements that align the interests of occupants, landlords, housing providers and service operators.

3.4 Enabling conditions for sector coupling business models

The archetype-specific business models described above require a set of enabling conditions to become operational, scalable and replicable. These conditions are not independent from one another. A technically feasible model may still fail if market access is unclear, if revenues are not bankable, if participants do not trust the coordinator, or if costs and benefits are not allocated transparently.

For this reason, enabling conditions are grouped here into five categories: technical, economic and commercial, regulatory and market-design, organisational and governance, and behavioural and acceptance conditions.

3.4.1. Technical conditions

Technical compatibility is the first requirement for sector coupling business models. The relevant technologies must be available, interoperable and controllable. This includes physical assets such as heat pumps, electrolysers, batteries, EV chargers, thermal storage, district heating and cooling infrastructure, hydrogen storage, and grid connections, but also digital assets such as smart meters, monitoring systems, forecasting tools and optimisation platforms. The EU Strategy for Energy System Integration underlines the role of information and communication technology (ICT), digitalisation, smart grids, smart meters in enabling a more integrated energy system [47].

For heat and cooling models, the key technical conditions include building compatibility, sufficient heat or cold demand density, suitable local heat/cold balance, and access to thermal storage. In 5GDHC systems, for example, scalability depends not only on the network concept but also on the suitability of connected buildings, the availability of low-temperature sources, and the capacity to coordinate building-level heat pumps and chillers. For hydrogen models, the relevant conditions include electrolyser capacity, access to renewable electricity, compression and storage infrastructure, refuelling or transport infrastructure, and hydrogen certification systems. For flexibility models, controllable assets, reliable forecasting, baseline measurement, metering and a market interface are essential.

Digital infrastructure is particularly important because sector coupling often requires coordination across multiple assets and actors. Without reliable metering, data exchange, optimisation and settlement systems, business models such as flexibility aggregation, smart charging, peer-to-peer trading or multi-utility platforms cannot operate efficiently.

3.4.2. Economic and commercial conditions

Sector coupling business models must also offer a credible economic logic for all relevant actors. This requires bankable revenue streams, predictable demand or offtake, transparent tariff structures, fair allocation of costs and benefits, and a clear view of CAPEX, OPEX and payback periods. High-CAPEX models, such as hydrogen production, district heating and cooling networks, BESS projects and industrial hub infrastructure, are particularly dependent on long-term revenue certainty.

For strategic industrial actors, suitable instruments may include PPAs, hydrogen offtake agreements, capacity contracts, flexibility service contracts and long-term heat or cooling service contracts. The appropriate instrument depends on the underlying activity and the source of commercial risk. For example, an electrolyser operator may use a long-term renewable electricity PPA to secure a more predictable electricity supply and reduce exposure to wholesale electricity price volatility, while a hydrogen offtake agreement can provide greater certainty regarding future hydrogen demand and revenues. The 2024 EU Electricity Market Design reform strengthened the framework for long-term electricity contracts, including PPAs, and requires direct price-

support schemes for eligible new electricity-generation investments to take the form of two-way Contracts for Difference (CfDs) or equivalent schemes [48]. CfDs should therefore be understood primarily as a support mechanism for the electricity-generation assets supplying sector-coupling projects, rather than as a business model for hydrogen or flexibility itself. In the ReInvent context, these different contractual arrangements can contribute to bankability by providing greater certainty over key inputs, outputs or revenues, depending on the specific sector-coupling configuration.

For energy communities and business clusters, economic conditions differ somewhat. These actors may rely more on shared investment models, cooperative equity, grants, crowdfunding, simplified contracts and collective ownership. The commercial model must remain understandable and administratively manageable. If the allocation of savings, revenues or risks is too complex, participation may be limited even when the technical potential is strong. This is especially relevant for cluster self-consumption, shared storage, collective EV charging and community flexibility models.

3.4.3. Regulatory and market-design conditions

Regulatory clarity is a core enabling condition for sector coupling. Many business models depend on rules that determine whether actors can share energy, access flexibility markets, aggregate distributed assets, operate shared storage, trade locally, or connect to hydrogen, heat and electricity infrastructure. The revised EU electricity market framework explicitly recognises the need to assess flexibility needs and account for resources such as demand response, energy storage, interconnectors and flexible generation. ACER has also identified persistent barriers to demand response and distributed flexibility participation, including the need for stronger price signals, simplified market entry for aggregators and clearer rules for small and distributed resources [49].

For multi-carrier systems, regulatory fragmentation is a particular challenge. Electricity, gas, hydrogen and heat are governed by different rules, market timeframes, balancing arrangements and infrastructure access regimes. Business models that connect these carriers therefore require alignment between market rules, data exchange systems, settlement processes and network tariff structures. Hydrogen business models additionally require certification, third-party access rules, entry-exit or equivalent network models, balancing rules and infrastructure planning certainty. Heat and cooling models require clear heat network regulation, consumer protection rules and transparent tariff methodologies.

Regulatory sandboxes can play an important role for innovative models where existing rules are not yet fully adapted. This is relevant for peer-to-peer trading, automated transactions, local flexibility markets, dynamic tariffs, thermal flexibility, multi-utility platforms and new forms of aggregation. However, sandboxes should not become permanent exceptions. For scalability, lessons from pilots need to be translated into stable rules, standardised procedures and replicable market arrangements.

3.4.4. Organisational and governance conditions

Sector coupling business models often involve several actors with different roles: asset owners, users, operators, aggregators, suppliers, grid operators, public authorities, cooperatives, landlords and service providers. Successful implementation therefore requires clear actor roles, transparent governance, standardised contracts, data-sharing rules, liability allocation, dispute-resolution mechanisms, and clear procedures for joining and exiting the scheme.

A trusted coordinator or orchestrator is often necessary. In industrial hubs, this may be a port authority, infrastructure operator, aggregator, energy service provider or platform operator. In energy communities, it may be a cooperative, municipality, intermunicipal agency or community energy organisation. The coordinator's role is not only technical; it also includes managing trust, coordinating investment, allocating benefits, handling data and ensuring that participants understand their rights and obligations.

For industrial hubs and business clusters, governance conditions include secure data exchange, protection of commercially sensitive information, compensation mechanisms and cluster-level coordination. For energy communities, they include member engagement, democratic legitimacy, administrative capacity and technical support. For residential and tenant-oriented models, governance must also ensure consumer protection, affordability safeguards and fair treatment of households that have limited control over assets.

3.4.5. Behavioural and acceptance conditions

Finally, sector coupling business models must be acceptable to the actors expected to participate in them. Acceptance depends on trust in the operator or public authority, perceived fairness of tariffs and benefit allocation, perceived control over assets and decisions, confidence in technology reliability, willingness to share data, and clarity about risks and benefits. These conditions are especially important because many sector coupling models require actors to change behaviour, share information, accept new contractual arrangements or allow third-party control over flexible assets.

Different archetypes require different acceptance conditions. Cautiously Optimistic Implementers need pilots, guarantees and trusted technical support. Strategic Market Actors need regulatory certainty, credible counterparties and bankable commitments. Selective Innovators need autonomy, experimentation space and access to data. Energy communities need fairness, transparency and local value creation. Households require models that protect comfort, affordability and perceived control, while tenants require safeguards against unfair cost pass-through and mechanisms that ensure benefits reach occupants.

3.4.6. Conclusion

In summary, the enabling conditions for sector coupling are not limited to technology deployment. They concern the full socio-technical and commercial architecture of the business model: compatible assets, digital systems, stable regulation, bankable revenues, trusted coordination, fair benefit allocation and actor-specific acceptance. The relative importance of each condition differs by archetype, which is why business model design must be tailored rather than generic.

3.5 Application to Reinvent BUCs

3.5.1. Industry related BUCs

The industrial perspective is treated more briefly than the energy-community and residential perspectives because industry is not the main focus of the present archetype analysis. Nevertheless, several ReInvent BUCs provide relevant insights into industrial and business-sector applications of sector coupling.

The most directly relevant are **BUC6a/b**, which examine alternative business models for long-haul transport based on hydrogen and locally produced renewable electricity, and **BUC9**, which investigates whether flexible operation can improve the business case of a large-scale electrolyser. BUC9 is particularly relevant to industrial actors because it considers the interaction between hydrogen production, electricity procurement, hydrogen demand, infrastructure requirements and additional revenues from participation in electricity and balancing markets. Reinvent Deliverable D3.1[34] explicitly frames this BUC as covering both technical infrastructure requirements and improvements to the electrolyser business case.

Other BUCs provide adjacent insights without requiring a separate industrial case analysis. **BUC1a/b** addresses a collective heating and cooling business model in a business-park setting, while **BUC5a/b** examines Business Renewable Energy Communities and is therefore relevant to groups of SMEs and other business actors. **BUC7** provides broader system-level evidence on the conditions under which hydrogen may become beneficial for industrial and other applications, but it does not itself develop an actor-specific business model. These BUCs are therefore used as supporting evidence where relevant rather than analysed separately in detail.

Across these BUCs, the archetype framework suggests that industrial uptake depends principally on the actor's investment readiness, exposure to technical and market risk and capacity to manage complex energy assets. Strategic Market Actors require predictable input costs, credible offtake arrangements and sufficiently stable revenues; Selective Innovators may benefit from flexible contracts and opportunities to test new flexibility services; and Integrated Industrial Actors require coordinated infrastructure, long-term planning and clear allocation of costs and risks between multiple parties. The industrial BUCs therefore mainly illustrate how different contractual and coordination mechanisms can reduce uncertainty and improve the bankability of sector-coupling investments.

3.5.2. Energy communities related BUCs

In the REINVENT project four Energy Communities (EC) are involved as a Business Use Case (BUC)

Table 3-5: Overview of ReInvent energy community BUCs

BUC	*BUC owner in ReInvent*	*Region + geographical area of the EC*	*Juridical structure of the EC*	*Registered as EC*
BUC2: Collective, cross-sectoral business models for the integration of a BESS in a REC	Campina Energie	Flanders - Turnhout	CV	Yes
BUC3: Collective, cross-sectoral business models for car sharing in an Energy Community consisting of social housing	Klimaan	Flanders - Mechelen	CV	Yes
BUC4: Integration of collectively owned offshore wind energy production and the use of a largescale battery	SeaCoop	Belgium - Northsea	CV	Not yet
BUC5: Collective, cross-sectoral business models for Business Renewable Energy Communities	IDETA	Wallonia - Picardy region	ASBL (non-profit)	Not yet

3.5.2.1 Business Citizen Energy Community (BUC5)

Symco Energies (formerly Whapigreen) provides a relevant ReInvent example for the energy community archetype SME / Business Cluster. Unlike residential or neighbourhood energy communities, this BUC focuses on a business citizen energy community involving enterprises, public institutions and hospitals across Picardy Wallonia. The community is expected to combine wind, solar and Combined Heat and Power (CHP) resources, with approximately 60 consumption sites and 35 enterprises under study. Its main objective is to maximise local self-consumption by optimising both the sizing of local renewable generation and the operation of energy sharing mechanisms among members.

The most suitable business model logic for this BUC is therefore business-cluster energy sharing, combined with cluster self-consumption and, where relevant, shared flexibility. The community creates value by matching renewable production with the consumption profiles of different members. This is especially important because the economic attractiveness of the model depends on increasing the share of locally self-consumed renewable electricity and reducing the amount of electricity purchased from external suppliers. The integration of flexibility options, including load shifting in cooling systems, water pumping and EV charging, strengthens this model by allowing members to adapt demand to local renewable production.

The Symco Energies case also illustrates why energy community business models cannot be assessed only through the presence of renewable assets. Several boundary conditions directly affect scalability. First, the model depends on the availability of quarter-hourly consumption and production data. AMR (Automated Meter

Reading) or smart meters are necessary to simulate, allocate and settle collective self-consumption between members. Without adequate metering, both replication and operational optimisation become difficult.

Second, the community requires sufficient complementarity between members' load profiles. If production and consumption profiles are poorly aligned, the community may not achieve enough local self-consumption to make participation economically attractive. Battery storage can reduce this constraint by shifting surplus generation to periods of higher demand, but this requires interoperable energy management systems (EMS) that can operate at community level rather than only at single-site level.

Third, the case highlights the importance of governance and participation. Effective functioning of the community depends on members participating in statutory decision-making, but companies may prefer a lighter form of membership because of time and resource constraints. This creates a governance tension: the community needs active participation to remain legitimate and operational, while business members may prefer low administrative burden. In addition, current rules limiting effective control of energy communities to natural persons, local authorities and small businesses may discourage larger companies from participating if they represent a large share of consumption or production but cannot exercise corresponding decision-making influence. This directly affects the attractiveness of the model for larger business-cluster members.

Fourth, Symco Energies shows that supplier contracts and administrative fees can materially affect the business case. Members may need to renegotiate electricity purchase agreements to account for fluctuating community energy volumes, and suppliers may charge fixed annual fees for adapting contracts to energy sharing. These costs can weigh heavily on smaller participants or low-volume communities. The business model therefore needs simplified contractual arrangements, transparent allocation rules and sufficient shared-energy volumes to ensure that administrative costs do not outweigh electricity savings.

Finally, the BUC highlights an acceptance challenge. Energy communities introduce new concepts for many companies, including dynamic allocation rules, residual supply contracts, energy sharing, interaction with DSOs and uncertainty around renewable generation volumes. SMEs with limited internal energy expertise may perceive these arrangements as complex or risky. The scalability of Symco Energy therefore depends not only on technical and economic optimisation, but also on communication, advisory support, standardised tools and credible evidence from real operation.

Overall, the analysis confirms that the most relevant archetype is SME / Business Cluster, with Public Entities as an important enabling archetype where intermunicipal or territorial actors facilitate coordination. The strongest scalability conditions are smart metering, interoperable community-level EMS, complementary consumption and production profiles, simple supplier-contract arrangements, fair governance, and clear evidence that the model produces net benefits for members.

3.5.2.2 Social charging shared EVs (BUC3)

The business case of Klimaan BUC 3a/b is based on the coordination between a Renewable Energy Community and a Shared Mobility Operator. The energy community has excess rooftop PV production, while the shared EV fleet creates a flexible local electricity demand that can absorb part of this surplus. By coordinating charging with local PV availability and tariff conditions, the model can increase local self-consumption, reduce EV charging costs and improve the operating economics of shared electric mobility. The business case therefore does not rely only on selling renewable electricity, but on combining energy sharing, smart charging and shared mobility into one integrated service.

This creates a direct link with the residential archetypes. For Tenants, especially in social housing, the model addresses a structural barrier: residents may not own the roof, the PV system, the charger or the vehicle, but they can still benefit from locally produced renewable electricity and access to electric mobility through a shared service. For Cautious Idealists, the collective model lowers the threshold for participation by reducing individual investment risk and providing a community-based pathway into low-carbon mobility. The case is less directly targeted at Confident Pragmatists, who may be more suited to individual smart charging or V2G models, but it shows how similar flexibility principles can be adapted to households with lower ownership, capital and control.

3.5.2.3 Integration of a Battery Energy Storage System in a REC (BUC2)

Campina Energie has, throughout ReInvent, focused on a business use case that investigates the potential of collective, cross-sectoral business models for the integration of a Battery Energy Storage System (BESS) in a renewable energy community. Campina Energie itself, being an established energy community, can be classified under the Institutional Anchor archetype. The business use case as it currently exists already makes use of a PPA, which corresponds to one of the business models that were identified as best fitting for this archetype: The BUC of Campina Energie in ReInvent looks at one of their cases, where they own a solar installation on a school roof, sell energy to the school, which also has its own solar installation.

The requirement for the extension of the existing business use case derives from the contractual (PPA) relationship between Campina Energie and the school, which implies that negative injection prices either lead to financial losses for the school or to lost energy in the form of curtailment (and therefore financial losses to Campina Energie). To avoid these losses, the idea is to install a BESS for which the optimal business model logic needed to be researched, based on the technical possibilities.

The executed simulation study indicated that the business model logic that delivers most benefits is the one that optimises the energy management at the community level (i.e. taking into account both the two solar installations and the battery), rather than at the individual stakeholder level. This allows the installation of the BESS to achieve both lower net costs and less energy lost through curtailment. Translating this to the 'best fit business models' for energy communities with the Institutional Anchor archetype indicates that collective self-

consumption and a shared-storage model are indeed the preferable business approaches. An extension of the analysis also showed that this approach is future-proof: with injection prices expected to become negative more often, the savings of applying the community level business logic increase.

Note that this result is quite in line with what was found to be the optimal business logic for the Symco Energy business use case described before. Apart from the commitment to the cooperative model, established citizen energy communities can indeed often apply similar business logic as business-driven energy communities to optimise the benefit of local energy infrastructure for their members.

This clear indication towards collectively management of energy production and storage does give rise to some new questions, in particular concerning the **financial arrangements**: how are costs (for installing the required control components) and benefits (who benefits from the lower overall electricity cost) shared? A successful application of this business logic will therefore depend on good and fair agreements between the stakeholders, for example in the form of a tailored PPA.

From a **technical perspective**, some open questions remain when it comes to the data acquisition and control of the different installations. For example, if installations belonging to different stakeholders need to be controlled, who invests in the control itself and how are these control elements integrated. While certainly relevant, the answers to these questions are not expected to impact the business logic itself, since no technical assumptions of such nature were made during the study.

A crucial element in the Campina Energie case is the fact that all three installations are behind the same grid connection point. If this would not be the case, the fact that additional costs would have to be paid for the energy exchanged (according to Flemish legislation on energy sharing) will change the cost picture. In terms of replication, it is therefore key to ensure that the considered installations are all behind the same connection point. Alternatively, and perhaps more interestingly, replication would require legislative amendments to allow such business models under different connection arrangements. As is the case for the technical aspects, this business model becomes more challenging when different stakeholders owning their own assets are involved.

3.5.2.4 Collective Offshore Wind Integration through Battery Storage (BUC4)

SeaCoop is **a Renewable Energy Community (REC)**. It is a partnership established by more than thirty Belgian citizen cooperatives (affiliated with REScoop Flanders and REScoop Wallonia). The goal of this umbrella cooperative is to give citizens the opportunity to jointly invest in large-scale renewable energy projects, such as wind farms in the North Sea. Projects are realized through the legal entity behind SeaCoop (also known as the “Onze Energie” - Our Energy, initiative), allowing citizens to become co-owners of the produced wind energy. Citizens can participate through local energy cooperatives, ensuring that locally generated or purchased electricity reaches households via a short supply chain.

SeaCoop utilizes **Contracts for Difference (CfDs**) as a smart financial risk-sharing mechanism to guarantee stable energy prices for thousands of citizen-investors. In this two-sided system, the government sets a fixed "strike price". There are two options:

- If wholesale electricity rates falls below it, the government compensates the cooperative;
- if rates exceed it, profits are returned to the state.

This model enables the 34 Belgian cooperatives connected to SeaCoop to participate in major tenders like the Princess Elisabeth Zone offshore wind projects without exposing everyday citizens to extreme market risks.

Key features of this model include:

- **Price Stability:** It ensures reliable revenue streams for citizen-investors and stable, predictable electricity tariffs for consumers.
- **Citizen Participation**: It guarantees that citizens can hold co-ownership in offshore wind concessions, giving half a million Belgians direct control over their energy production.
- **Regulatory Backing:** The mechanism integrates with EU electricity Market Reforms that mandate two-way CfDs for low-carbon investments and aligns with the Belgian federal government's offshore tender rules.

The simulation results in WP3 indicate that integrating a large-scale battery at the renewable energy community level can reduce the combined profiling and imbalance settlement costs associated with offshore wind supply to residential demand.

The first and major hurdle that still has to be overcome is the realization of both **Ventilus and Boucle du Hainaut connections**. These two highly interconnected 380 kV high-voltage grid expansions are being developed by Elia, Belgium's TSO. Together, they form a crucial energy backbone designed to transport offshore wind power from the North Sea into the inland grid. Once these interconnections will be implemented (Ventilus by end 2030 and Boucle du Hainaut by end 2033)

3.5.3. Residential related BUCs

Residential sector coupling is strongly linked to the uptake and operation of distributed energy and mobility assets, including electric vehicles (EVs), smart chargers, rooftop PV, heat pumps, home batteries, smart meters and other controllable household loads. These assets can contribute to electrification, increase local use of renewable electricity and provide flexibility to the electricity system. However, their contribution depends not only on technical availability, but also on whether households have sufficient control over the relevant assets, understand the proposed service, trust the actors involved and perceive a clear economic or practical benefit.

Within ReInvent, residential actors are particularly relevant to the Business Use Cases addressing EV flexibility and charging. **BUC10, "Potential for flexibility provision with a portfolio of EVs,"** investigates the

extent to which a portfolio of electric vehicles can provide flexibility to the electricity system. **BUC11, "Smart billing solutions for EV charging (focus on a large fleet of EVs),"** and **BUC12, "Smart billing solutions for EV charging (focus on collective car sharing),"** examine the billing and transaction arrangements required to support increasingly distributed and flexible EV charging. **BUC3a/b**, which combines an energy community in social housing with shared electric mobility and flexibility, is also highly relevant to residential actors, as is explained in section 3.5.2.2.

The residential archetypes identified in this study differ in their capacity and willingness to participate in these business models. **Confident Pragmatists** are the most likely to engage with smart charging, dynamic tariffs, aggregation or, where technically available, vehicle-to-grid services, provided that the financial benefits are transparent and sufficient user control is retained. For this group, suitable business models include smart charging services, flexibility contracts and integrated energy-management offers that combine EV charging with other household assets such as PV, batteries or heat pumps.

Regulation-Averse Sceptics require a different proposition. Complex tariffs, unfamiliar market arrangements and requirements to actively manage flexibility may reinforce rather than reduce perceived risk. For these households, the most suitable approach is therefore a low-complexity managed service in which optimisation is largely automated and the contractual conditions, expected savings and consumer protections are clearly communicated. Trusted intermediaries, guarantees and simple billing arrangements are particularly important for this archetype.

Cautious Idealists may be motivated by environmental benefits but require additional support to translate positive attitudes into participation. Collective purchasing schemes, community-based energy services, shared charging solutions and neighbourhood-level initiatives can reduce the perceived complexity and financial risk of adoption. Peer examples, trusted advice and relatively low-cost entry points are therefore likely to be more important for this archetype than highly sophisticated market-based flexibility propositions.

Tenants face primarily structural rather than attitudinal constraints. They often have limited authority over rooftop PV, heating systems, electrical upgrades, parking facilities or private charging infrastructure. Residential business models targeting tenants therefore need to separate access from asset ownership and align the incentives of tenants, landlords, housing providers and service operators. Relevant approaches include shared charging, collective energy services, landlord–tenant agreements and other arrangements that ensure that investment costs and resulting benefits are allocated fairly. The Klimaan BUC3a/b illustrates this issue in a social-housing context and is discussed in detail under subsection 3.5.2.2.

Supplementary qualitative evidence was obtained through an expert interview with EV Belgium, the Belgian sector organisation for electric mobility. The interview was used to contextualise the residential analysis, particularly with regard to EV adoption, smart and bidirectional charging, charging behaviour, regulation, user

incentives and access to charging infrastructure. As this evidence is based on a single expert interview, it should be interpreted as exploratory and contextual rather than as representative evidence of household behaviour.

The interview indicated that several important barriers to EV-based sector coupling are organisational, regulatory and behavioural rather than purely technological. Smart charging and bidirectional charging were considered increasingly technically feasible, while practical uptake also depends on charging access, appropriate regulation, user awareness and sufficiently clear incentives. Uncoordinated charging may create additional electricity demand during existing peak periods when many users charge their vehicles after returning home. Automated smart charging can mitigate this effect by shifting charging to periods that are more favourable from the perspective of electricity prices, renewable generation or grid conditions.

The importance of a clear **user-level value proposition** was also emphasised. Households are unlikely to provide charging flexibility solely because it creates benefits for the wider energy system. Business models therefore need to translate system value into benefits that are visible to users, for example through lower charging costs, favourable dynamic tariffs, explicit remuneration for flexibility or bundled mobility-and-energy services. This is particularly relevant for **Confident Pragmatists**, who may be willing to optimise charging when the financial benefit is transparent and sufficient control over vehicle availability is retained.

For **Regulation-Averse Sceptics** and **Cautious Idealists**, the interview reinforces the importance of simplicity, trust and understandable information. Perceptions concerning EV purchase costs, charging availability, technology reliability and overall cost of ownership can influence uptake even where the underlying market conditions are improving. One-stop-shop services, trusted intermediaries, transparent total-cost-of-ownership information and straightforward charging arrangements may therefore be more appropriate than complex flexibility propositions for these groups.

For **Tenants**, the main constraints are more structural. Residential EV business models cannot assume access to a private parking space, a private charging point or decision-making authority over building-level electrical infrastructure. Suitable models therefore require shared or collectively organised charging access, transparent billing and arrangements that coordinate the interests of tenants, landlords, housing providers and charge point operators. Where an energy community is involved, collective energy sharing may provide an additional mechanism for connecting locally generated renewable electricity with shared mobility and charging services.

3.6 Scalability condition across target groups

The previous sections identified archetype-specific business model requirements and examined how these relate to the relevant ReInvent BUCs. This section synthesises those findings by identifying the main conditions that affect whether the proposed business model logics can move beyond individual pilots or cases and be replicated at a larger scale. It therefore does not introduce new archetypes or business models but summarises the recurring barriers and enabling conditions identified across the industry, energy-community and residential analyses.

Scalability depends on the extent to which a business model fits the target group's investment capacity, exposure to risk, technical and organisational readiness, governance capacity and ability to participate in the proposed arrangement. These conditions differ across target groups. Industrial actors are generally more strongly affected by capital intensity, infrastructure coordination and long-term commercial uncertainty; energy communities face additional governance, collective decision-making and region-specific regulatory constraints; and residential actors are more sensitive to affordability, trust, complexity and the degree of control they have over relevant assets

Table 3-6 summarises these differences by linking the main scalability barriers for each target group to the business model logics and enabling conditions identified in the preceding sections. The table should be read as a synthesis of the archetype and BUC analysis rather than as a separate classification.

Table 3-6: Overview of scalability barriers, enabling conditions and scalability implications

Target group	*Main scalability barrier*	*Suitable business model logic*	*Key enabling conditions*	*Scalability implication*
Industry	High CAPEX, operational risk, regulatory uncertainty, complex infrastructure	Long-term contracts, public-backed pilots, innovation platforms, industrial hubs	Stable regulation; bankable contracts; trusted orchestrators; infrastructure planning; market access; risk-sharing	Scales when commercial risk is reduced and infrastructure is coordinated across actors, sites and energy vectors
Energy communities	Regulatory complexity, limited professional capacity, governance burden, financing constraints	Cooperative self-consumption, digital trading, business-cluster sharing, public-private partnership (PPP)	Clear energy-sharing rules; simple contracts; technical assistance; fair benefit allocation; digital tools; access to finance	Scales when governance is simple, benefits are transparent and local actors can capture value collectively
Residential	Low trust, split incentives, upfront cost, complexity, limited control	Energy-as-a-Service, one-stop-shop, community energy, split-incentive models, smart home optimisation	Trusted intermediaries; low upfront costs; comfort and affordability protection; landlord-tenant alignment; clear savings	Scales when participation is simple, affordable, trustworthy and adapted to household agency

Actors need to understand the benefits they can expect, the costs they may incur and the risks they are expected to assume. Without a transparent and credible value proposition, even technically viable solutions are unlikely to attract sustained participation.

Scalability also depends on a **bankable revenue or savings logic**. Expected revenues, cost savings or other financial benefits must be sufficiently predictable to justify investment and continued participation. The precise mechanism will differ between target groups, but the underlying principle is the same: the economic value created by sector coupling must be identifiable and sufficiently reliable.

Regulatory clarity is equally important. Rules governing energy sharing, flexibility provision, hydrogen, heating and cooling, infrastructure access and related market activities need to be sufficiently clear and stable for actors to make investment and operational decisions. Regulatory uncertainty can increase perceived risk and undermine otherwise viable business models.

Finally, multi-actor sector-coupling models require **trusted coordination**. An operator, aggregator, cooperative, public body or digital platform may be needed to coordinate assets, contractual relationships, data exchanges and responsibilities between participants. The credibility and capacity of this coordinating actor can therefore become an important condition for both implementation and replication.

3.7 Conclusions

Sector coupling is more likely to scale when business models are tailored to differences in actors' capabilities, constraints and decision-making conditions. For **industrial actors**, this means reducing investment and operational risk, providing long-term commercial certainty and coordinating the infrastructure required for multi-vector energy systems. For **energy communities**, scalability depends on manageable governance arrangements, transparent and fair allocation of costs and benefits, and regulatory frameworks that enable collective activities such as energy sharing, storage and flexibility provision. For **residential actors**, successful models need to minimise complexity, build trust and provide affordable and accessible participation pathways.

Across these target groups, the common requirement is alignment between the technical solution, the actor's capacity and willingness to participate, and the commercial and governance arrangements through which value is created and distributed. Sector coupling should therefore not be approached as a purely technological integration challenge. Its scalability also depends on whether the associated business model provides a credible value proposition, allocates risks and benefits appropriately, and fits the practical circumstances of the actors expected to participate.

4 Financing decisions for multi-energy projects

Multi-energy projects combine multiple energy technologies and services, such as solar panels, batteries, wind turbines, heat pumps, electric vehicle charging infrastructure, and energy sharing mechanisms. These projects often differ significantly in scale, ownership structure, revenue model, technical complexity, and risk profile. As a result, selecting an appropriate financing structure is a key factor in determining project feasibility and bankability.

This chapter provides an overview of the financing solutions that can be considered for multi-energy projects. It explains the characteristics, advantages, and limitations of each financing type, including investment loans, leasing, equity financing, project finance, and crowdfunding. In addition, the chapter discusses the factors that influence the bankability of multi-energy projects and proposes an assessment framework that can support financing decisions.

4.1 Categorization of multi-energy projects

Multi-energy projects can be classified according to **four key dimensions**: **scale, ownership structure, revenue model, and technological complexity**. This categorization is important because it influences the project's risk profile, expected cash flows, access to guarantees or public support mechanisms, and ultimately the most appropriate financing approach.

Scale: From a financing perspective, different project categories present distinct challenges and opportunities. Small-scale residential projects typically rely on simplified financing mechanisms and are often assessed based on the creditworthiness of individual households. Larger projects, by contrast, can attract project finance or institutional investors due to their scale and more predictable revenue streams.

Ownership structure: Similarly, ownership arrangements influence financing options, as cooperatives and public-private partnerships may benefit from dedicated funding schemes or guarantees that are not available to privately owned projects.

Revenue model: The underlying revenue model is equally important. Projects that generate stable revenues through energy sales or long-term contracts are generally perceived as less risky than projects that depend heavily on market-based flexibility services or imbalance trading.

Technological complexity: Finally, the degree of technological integration affects both the investment needs and the risk profile. While single-technology projects are typically well understood by financiers, integrated multi-energy systems and innovative pilot projects may require tailored financing solutions, additional guarantees, or public support to address the higher uncertainty associated with their performance and revenue generation.

Table 4-1: Categorization of multi-energy projects for financing purposes

Category	*Options*
Scale	• Small-scale projects (e.g. residential or SME solar installations) • Medium-scale projects (e.g. energy communities, collective energy systems) • Large-scale projects (e.g. battery parks, solar farms, wind parks)
Ownership structure	• Private individual ownership • Corporate ownership • Cooperative ownership • Public-private partnerships
Revenue model	• Energy cost savings • Energy sales • Flexibility services • Imbalance market participation • Combined revenue streams
Technological complexity	• Single-technology projects • Multi-technology integrated projects • Innovative or pilot projects

4.2 Types of financing

Depending on the characteristics of the project, different financing structures may be appropriate. The following financing types are discussed in this section:

- An **investment loan** is a traditional credit facility in which a financial institution provides capital for the acquisition and installation of assets. The borrower repays the loan over a predefined period through periodic repayments consisting of capital and interest.
- **Leasing** is a financing arrangement in which the financier purchases an asset and grants the customer the right to use it in exchange for periodic lease payments. Depending on the leasing structure, ownership may remain with the lessor for part or all of the contract period.
- **Equity financing** refers to capital that is invested directly by project sponsors, shareholders, cooperative members, or other investors. Unlike debt financing, equity does not need to be repaid according to a fixed schedule but carries a higher risk for investors.
- **Project finance** is a specialized financing structure in which repayment depends primarily on the projected cashflows generated by the project itself. The structure is typically used for large-scale projects with predictable revenues and dedicated project entities.
- **Crowdfunding** enables a project developer to raise capital from a large number of individuals through specialized platforms. Funding may be provided as debt, equity, or donations and can complement traditional financing methods.

In the remainder of this section, the different types of financing are elaborated further, with a specific focus on when to choose certain financing types or when not.

4.2.1. Investment Loan

Investment loans are the most widely used financing solution for renewable energy projects. They provide long-term financing for the acquisition and installation of energy assets and offer flexibility in terms of repayment schedules, financing amounts, and collateral arrangements. As a conventional debt-financing instrument, they are particularly suited to technologies with a proven track record and predictable cash flows.

Investment loans are commonly used to finance solar panels, wind turbines (up to 300 kW), heat pumps, solar water heaters, and battery systems, including battery parks. They are especially appropriate for projects involving higher investment amounts, longer repayment periods, or complex ownership arrangements such as building rights or leaseholds. Repayment periods can typically extend up to 15 years, making them suitable for assets with long technical lifetimes and extended payback periods.

Debt tenor (i.e. the loan repayment period) must not exceed the conservatively assessed economic life of the financed asset and should remain within the period supported by warranties, maintenance arrangements, key revenue contracts and forecast cash-flow visibility. For batteries, the assessment must include degradation, cycle assumptions, augmentation or replacement requirements and end-of-life value.

Financing conditions can be tailored to the characteristics of the project, considering factors such as the level of own contribution, the availability of support from a solvent parent company or affiliated entity, the technical lifespan of the installation, and the existence of maintenance contracts or other legal agreements.

Where leasing is excluded under the applicable battery-financing policy, an investment loan is the standard debt solution for smaller and medium-sized projects. Larger ring-fenced projects may qualify for project finance, subject to project size, cash-flow predictability, sponsor support and the applicable approval framework.

For smaller projects with limited investment needs and short payback periods, leasing may offer a more efficient financing solution where it is available and permitted. Nevertheless, investment loans remain the preferred and most robust financing approach for the majority of renewable energy and multi-energy projects.

A summary of the application field and characteristics of investment loans is provided in Table 4-2.

Table 4-2: Overview of application field and characteristics of investments loans.

When to choose an investment Loan
Standard financing method Investment loans are the default option for financing: • Solar panels • Wind turbines (up to 300 kW) • Heat pumps • Solar water heaters • Batteries (including battery parks)
Required financing method Investments loans are required for imbalance market projects: • For battery projects that generate income from the imbalance market, leasing is not allowed. • In these cases, an investment loan is mandatory.
Suitable for larger and riskier projects Especially relevant for projects with: • Higher investment amounts • Longer repayment periods (up to 15 years) • Complex ownership structures (e.g. building rights, leaseholds)
Flexible structuring Can be tailored based on: • Own contribution (typically 40%) • Group support (solvent parent company or affiliated entity) • Technical lifespan of the installation • Maintenance contracts and legal agreements
When not to choose an investment loan
Alternative financing types preferred • If the project is small-scale, short-term, and eligible for leasing, leasing is the preferred solution as it may be a more efficient option.

4.2.2. Leasing

Leasing is an alternative financing solution whereby the financier acquires the asset and grants usage rights to the customer in exchange for periodic lease payments. This structure can be attractive when the financed asset retains residual value and can be transferred or relocated. In renewable energy projects, leasing can offer financing flexibility for specific technologies, particularly batteries that do not rely on flexibility revenues. The suitability of leasing depends on technical characteristics, ownership arrangements, and collateral requirements. Although leasing can be an efficient alternative to traditional lending, regulatory constraints and asset-classification risks must be carefully assessed before selecting this financing option.

Leasing may only be considered where imbalance-market revenues are ancillary and are not required to demonstrate the base-case repayment capacity. If the project's debt-service capacity depends materially on imbalance-market, aFRR, mFRR, FCR or other merchant flexibility revenues, the project must be assessed under the dedicated battery-financing policy and financed through an investment loan or another specifically approved structure.

Leasing can also serve as an alternative to an investment loan for clients who do not own the property where the asset is installed, such as tenants, usufruct holders, or holders of building rights. In general, leasing is recommended when the financed asset is easily transportable and retains a certain residual value.

For assets installed on property not owned by the lessee, leasing is only appropriate if legal due diligence confirms that the lessor retains enforceable ownership rights, accession or immovable-property risks are adequately mitigated, the site owner acknowledges the lessor's rights, and the asset can legally and technically be removed or transferred following default or contract termination.

However, leasing is not applicable in all situations. It is not allowed for battery projects that operate only on the imbalance market and depend on this income stream for their repayment capacity as explained before. If the required security package cannot be validly established, neither leasing nor an investment loan should be approved automatically. The file must be referred for a legal and credit assessment to determine whether alternative security, sponsor support, additional equity or another financing structure is acceptable. In addition, a risk may arise when there is a possibility that the financed asset could be classified as immovable property.

The table below summarizes the main applications and characteristics of leasing.

Table 4-3: Overview of application field and characteristics of leasing.

When to choose leasing
For battery financing (excluding imbalance market projects) • Leasing is allowed for batteries that do not only rely on the imbalance market for revenue. • If the battery project does depend on imbalance market income, leasing is not permitted and a separate policy framework applies.
Based on technical advice Leasing terms are determined by technical assessments, which may specify: • Required collateral or guarantees • Appropriate contract duration
As an alternative to investment loans Leasing may be suitable for clients who: • Do not own the property (e.g. tenants, usufruct holders, or holders of building rights) • Leasing is recommended when the asset is easily transportable and retains a certain residual value.
When not to choose leasing
Alternative financing types preferred • Leasing is not allowed for battery projects that operate on the imbalance market and depend on that income for repayment capacity. • If a pledge on company property is not allowed. • In such cases, only investment loans are considered. • A risk arises when an asset may potentially become classified as immovable property.

4.2.3. POG (Product Oversight & Governance)

Product Oversight & Governance (POG) is not a financing method in itself, but rather a framework used by financial institutions to assess the suitability, risks, and collateral requirements associated with a financing solution. In the context of renewable energy projects, POG supports credit decisions by evaluating project characteristics, identifying potential risks, and determining whether additional guarantees or security structures are required. As such, it functions as a risk management and collateral assessment instrument that complements the financing process rather than providing capital directly.

For smaller renewable energy projects, POG can serve as the primary guarantee mechanism. This is typically the case for credit files with a value of up to €400,000 and is commonly applied to technologies such as photovoltaic installations, wind turbines, heat pumps, and solar thermal systems. By establishing a security position before the renewable energy asset is installed, POG provides lenders with additional protection during the implementation phase of the project. This allows financial institutions to maintain a stronger negotiation position in the event of project-related issues and, where applicable, provides access to assets beyond the financed installation itself.

The framework is particularly relevant in situations where the financed equipment may have a limited resale or recovery value. In such cases, POG helps assess whether the available collateral is sufficient to cover the lender's risk exposure. When the recovery value of the asset is considered inadequate, the financing institution may require supplementary guarantees or other security arrangements. Similar considerations apply to battery energy storage projects, where technical evaluations are used to determine whether POG alone provides an appropriate level of protection or whether additional safeguards are necessary.

While POG can function as the primary collateral mechanism for smaller projects, its use becomes more limited as project size and complexity increase. For credit files exceeding €400,000, stricter collateral requirements generally apply and additional legal assessments may be required. These can include reviews of lease agreements, building rights arrangements, or other contractual structures that influence the lender's security position. Depending on the project risk profile, legal advice and supplementary security instruments may also be required. In battery storage projects participating in imbalance markets, POG is typically used in combination with 'second-tier' guarantees or other forms of additional collateral.

Additional security may include an enforceable parent-company guarantee, cash collateral, a pledge over accounts and receivables, assignment of material project contracts, additional asset security or another instrument accepted under the applicable credit policy. The required security must be determined case by case.

Overall, POG should be viewed as a governance and risk mitigation framework that supports financing decisions rather than as a financing instrument itself. Its primary value lies in providing lenders with confidence regarding project risks, strengthening their security position, and ensuring that appropriate collateral arrangements are in place throughout the lifecycle of the investment.

An overview of the main application areas of POG and additional conditions is given in the table below.

Table 4-4: Overview of application field and characteristics of POG.

When to choose POG
As a primary collateral for smaller loans • For credit files ≤ €400,000, POG is used as the main guarantee. • Especially relevant for installations like solar panels, wind turbines, heat pumps, and solar boilers.
To manage risk before installation POG is applied before the installation takes place, ensuring: • The bank has a negotiation position if issues arise. • Access to other assets beyond the renewable energy installation
In cases with limited recovery value • If the financed goods have low resale or recovery value, POG is supplemented with additional guarantees.
In battery financing (non-imbalance market) • Technical advice determines whether POG is sufficient or if extra guarantees are needed.
When not to choose POG
When POG is not sufficient For credit files > €400,000, stricter norms apply: • Additional legal checks (e.g. lease or building rights agreements) • Possibly legal advice and additional securities • In imbalance market battery projects, POG is used but must be complemented with second-tier guarantees.

4.2.4. Equity financing

Equity financing refers to capital that is invested directly by project sponsors, shareholders, cooperative members, or other investors to support the development of a renewable energy project. Unlike debt financing, equity does not need to be repaid according to a fixed schedule and therefore does not create recurring repayment obligations for the project. Instead, equity investors assume a greater share of the project risk and their return depends on the overall performance and profitability of the investment. As a result, equity constitutes risk-bearing capital that strengthens the financial structure of a project and can improve its ability to attract external financing.

In renewable energy projects, equity contributions are often required to demonstrate the commitment of the project sponsors and to reduce the financing risk borne by lenders. A higher level of own contribution provides an additional financial buffer and improves the resilience of the project in the event of lower-than-expected revenues or changing market conditions. This is particularly relevant in projects that are exposed to significant revenue uncertainty, such as battery storage projects operating in volatile electricity markets. By

ensuring that investors have a substantial financial stake in the project, equity financing aligns incentives and strengthens confidence in the long-term viability of the investment.

For battery-park investments, a 40% equity contribution is used as an indicative starting point, unless the applicable credit policy prescribes a mandatory minimum. The equity ratio should be calculated on an explicitly defined financing base, such as total eligible project cost excluding recoverable VAT and non-financed ancillary expenditure. Any deviation must be justified by the project's cash-flow resilience, sponsor strength, liquidity, collateral package and revenue certainty.

Costs excluded from the eligible energy-asset financing base must still be fully funded. The financing plan must show whether these costs are covered by additional sponsor equity, a separate credit facility, subsidies or another committed source of funds. Unfunded ancillary costs must be included in the completion-risk assessment.

The required level of equity may be reduced when the project benefits from support from a financially strong parent company or corporate group. In such cases, the group can compensate for a lower direct equity contribution by providing explicit guarantees, collateral, or other forms of financial backing. This additional support reduces the risk exposure of lenders and can facilitate access to financing under more favourable conditions. Similarly, projects that benefit from substantial equity input or strong group support may obtain financing with shorter repayment periods, reflecting the stronger financial position and lower overall risk profile of the investment.

Equity financing alone is not always sufficient to secure project financing. Where investors are unable to provide the required own contribution and no credible group support is available, the project may fail to meet the lender's financing requirements. Lower equity levels are therefore generally only acceptable when accompanied by strong guarantees, adequate liquidity reserves, or other mechanisms that mitigate the resulting increase in financial risk.

An overview of the main application areas of equity financing is given in the table below.

Table 4-5: Overview of application field and characteristics of equity financing.

When to choose Sponsor equity contribution
Standard requirement for battery projects • A 40% own contribution is typically required for battery park investments. • This applies to the renewable energy components only, not to additional costs (e.g. roof renovation, legal fees).
To reduce credit risk • A higher own contribution helps mitigate financial risk, especially in volatile markets like the imbalance market. • It ensures the investor has a stake in the project, increasing commitment and resilience.
When group support is available • If the project is backed by a solvent and profitable group, the required own contribution may be reduced. • In such cases, the group must provide concrete guarantees or collateral.
For short repayment periods • Projects with strong equity input can benefit from shorter loan durations (e.g. 5-7 years). • This is especially relevant for battery projects with fast payback potential.
When not to choose Own Contribution / Equity
When equity is not sufficient • If the investor cannot provide the required equity and lacks group support, the project may not be eligible for financing under this framework. • Lower equity contributions are only acceptable when compensated by strong group backing and liquidity buffers.

4.2.5. Project finance

Project finance is a specialized financing structure in which the repayment of debt is based primarily on the future cash flows generated by a specific project rather than on the balance sheet strength of the project sponsors. As a result, the viability of the financing depends on the project's ability to generate stable and predictable revenues over its lifetime. This financing approach is commonly used for large infrastructure and renewable energy projects where the project can be treated as a standalone economic entity with clearly identifiable revenues and risks.

In the renewable energy sector, project finance is particularly suitable for large-scale investments such as battery parks, solar farms, and wind energy installations. Project finance is generally considered for larger transactions where the financing amount justifies the additional structuring, diligence, monitoring and legal costs. An indicative transaction-size threshold may be applied under internal policy, but project size alone does not determine eligibility.

A key characteristic of project finance is that debt repayment is linked directly to the future cash flows generated by the project. Long-term revenue arrangements, such as Power Purchase Agreements (PPAs) or other electricity off-take agreements, can provide the level of revenue certainty required to support this financing structure. By securing predictable income streams, such arrangements reduce uncertainty for lenders and improve the project's bankability.

The credit assessment must consider PPA tenor, pricing formula, volume obligations, curtailment provisions, imbalance allocation, termination rights, change-in-law provisions, counterparty credit quality and the share of production or capacity that remains exposed to merchant prices.

Project finance may be suitable for a dedicated project company with limited standalone balance-sheet strength, provided that the project has a robust contractual and cash-flow structure. Sponsor or parent support may be required during development, construction, ramp-up or for specifically retained risks, but its scope depends on whether the financing is non-recourse or limited-recourse.

Another advantage of project finance is the ability to tailor the financing structure to the specific characteristics of the project. This may include customised risk-sharing arrangements, extensive legal and technical due diligence, and the implementation of project-specific guarantees and security mechanisms. Such structuring allows risks to be allocated to the parties best able to manage them while providing lenders with an appropriate level of protection.

Due to its complexity, project finance is generally reserved for larger projects as mentioned above and specialised financing teams. It is typically used in a corporate banking context where dedicated expertise is available to assess project risks, undertake the necessary due diligence, and structure appropriate financing arrangements. For smaller renewable energy installations with limited capital requirements and straightforward business models, a conventional investment loan is usually a more efficient and appropriate financing solution. Project finance is also not suitable for projects that lack a clear and predictable cash flow generation mechanism. In such situations, alternative financing structures that depend more heavily on the financial strength of the sponsor may be more appropriate.

Table 4-6 provides an overview of the application areas of project financing.

Table 4-6: Overview of application field and characteristics of project financing.

When to choose project finance
For large-scale renewable energy projects Project Finance is ideal for high-investment projects such as: • Battery parks • Solar farms • Wind energy installations Especially when the investment exceeds €10,000,000 and has a standalone business model.
When repayment depends on project cash flows • Suitable when the loan repayment is based on future income generated by the project, not on the company's overall financials. • Often supported by Power Purchase Agreements (PPAs) or "Stroomafnameovereenkomsten" (SAOs).
For entities with limited balance sheet strength Useful for new companies (newcos) or energy cooperatives that: • Are part of a solvent group • Have a clear and predictable revenue model
When specialized structuring is needed Project Finance allows for: • Tailored risk-sharing • Legal and technical due diligence • Custom guarantees and securities
For Corporate Banking clients Within KBC, Project Finance is handled by Corporate Banking and may involve: • Delegation levels (e.g. SCA CC) • Collaboration with Small Project Finance teams
When not to choose project finance
When project finance is not suitable • For small-scale or simple installations, a standard investment loan is more appropriate. • If the project does not generate its own cash flow, Project Finance is not suitable.

4.2.6. Crowdfunding

Crowdfunding is a financing mechanism through which project developers raise capital from a large number of individual investors via dedicated online platforms. Depending on the structure of the campaign, contributors may provide funding in the form of loans, equity investments, or donations. As such, crowdfunding can support debt financing, equity financing, and grant-like funding arrangements. For energy communities, it represents an alternative channel to mobilise capital and can complement more traditional financing sources such as bank loans, public subsidies, or member contributions.

Crowdfunding is particularly suitable for small-scale, community-driven, or innovative projects that may face difficulties accessing conventional financing due to limited credit history, insufficient collateral, or a lack of proven track record. It can also be attractive for projects with a strong environmental or social dimension, as these characteristics often resonate with individual investors and local supporters. Beyond raising capital, crowdfunding can strengthen community engagement by allowing citizens, members, or stakeholders to participate directly in project development. In this way, supporters can become advocates or co-investors, helping to build local ownership and acceptance of renewable energy initiatives.

An additional advantage of crowdfunding is the relatively rapid and flexible access to funding that online platforms can provide. Campaigns can be tailored to specific project objectives and timeframes, allowing developers to test market interest while simultaneously raising capital. Successful crowdfunding campaigns may also demonstrate public demand and investor confidence, which can facilitate access to additional institutional or commercial funding sources.

Despite these advantages, crowdfunding is not suitable for all projects. Large-scale energy infrastructure developments often require substantially more capital than can realistically be obtained through crowdfunding campaigns. Furthermore, developers must consider platform fees, regulatory requirements, and the administrative effort associated with managing a large number of small investors. The success of crowdfunding also depends on the ability to attract sufficient public interest, and unsuccessful campaigns may negatively affect the credibility of the project and its prospects for securing future financing. Consequently, crowdfunding is generally most effective as a complementary financing mechanism for projects with a clear community focus, strong public appeal, or limited access to traditional funding sources.

Where crowdfunding is combined with bank debt, the financing structure must define ranking, subordination, repayment restrictions, security sharing, enforcement rights, information rights and intercreditor arrangements. Crowdfunded capital may only be treated as quasi-equity where its contractual terms provide sufficient subordination and loss-absorbing capacity.

Crowdfunding may provide an additional or alternative funding channel, but timing and execution certainty depend on platform onboarding, regulatory requirements, investor demand and campaign success. It should not be assumed to be faster than bank financing.

Table 4-7 summarises the main situations in which crowdfunding may be an appropriate financing option.

Table 4-7: Overview of application field and characteristics of Crowdfunding.

When to choose Crowdfunding
For Small-Scale or Community Projects • Crowdfunding may be suitable • for local, grassroots, or startup initiatives. • Especially useful when traditional financing is not accessible due to limited credit history or lack of collateral.
To Build Community Engagement • It helps connect with local supporters, turning them into advocates and co-investors. • This is valuable for schools, cooperatives, or social enterprises aiming to install solar panels or wind turbines.
When Seeking Flexible and Fast Funding • Campaigns can be launched rapidly and tailored to specific goals and timelines**.**
For Projects with Clear Public Appeal • Works well when the project has a strong environmental or social message. • Successful campaigns often serve as proof of market interest, which can attract further institutional funding.
When Traditional Financing Is Not an Option Crowdfunding is a good alternative when: • The developer is new or lacks financial history. • The project is innovative but not yet proven.
When not to choose crowdfunding
When Crowdfunding is not suitable • Large-scale utility projects often require more capital than crowdfunding can provide. • Regulatory hurdles and platform fees can complicate the process. • Managing many small investors can be resource intensive. • Failed campaigns may damage credibility and future funding chances.

4.3 Requirements for financing

The bankability of multi-energy projects depends on strict compliance with regulations and insurance requirements, robust technical validation, and thorough documentation. When applying for a loan, it is crucial to **comply with all relevant regulations**, **including local requirements**. For example, installing a wind turbine requires permits and approvals from various authorities. Credit analysis may begin before all permits are final, but approval, contracting or drawdown must be made conditional on receipt of the permits and approvals required under the applicable credit policy. No assumption should be made that outstanding permits will be obtained. Additionally, some cities and municipalities have specific regulations that must be met.

For energy solutions, the file must identify the required **grid-connection documents**, their status, any capacity or injection limitations, connection costs, technical conditions and the consequences of delay or curtailment for the financial model.

Furthermore, compliance with **insurance requirements** is essential. For instance, when installing batteries, fire safety regulations set by the fire department must be followed. Failure to comply can result in high insurance premiums or even denial of coverage, which can jeopardize the project's financing.

Every loan application for an energy project undergoes a **technical screening**. If the technology is well-known, the bank will benchmark the proposal against existing solutions. If the requested loan amount is substantially higher than the benchmark, the client will be informed and must decide whether to proceed. For new or innovative technologies, the bank may seek advice from a knowledge institution or technical expert. In the case of large-scale projects, an external partner is always involved to provide an independent assessment and, where necessary, ongoing monitoring. This ensures that the technical risks are properly evaluated and managed throughout the project's lifecycle.

Finally, **additional supporting documentation** may need to be considered, including the following:

- **Environmental Impact Assessments**: Some projects may require environmental studies or impact assessments before financing can be approved.
- **Project Documentation**: Comprehensive documentation, including business plans, technical drawings, and contracts, is often required to support the credit application.
- **Stakeholder Engagement**: For community-based or cooperative projects, evidence of stakeholder support and participation can enhance bankability.
- **Financial Viability**: The project's expected cash flows, payback period, and sensitivity to market changes are key factors in the credit decision.

4.4 Overview of applicable financing mechanisms

The selection of appropriate financing types depends on factors such as project scale, technology maturity, risk allocation, ownership structure, and revenue certainty. Table 4-8 inks the financing options introduced in section 4.2 to their typical application areas and the key requirements that support their use.

Table 4-8: Linking financing types to type of projects and requirements

Financing Type	*Best Suited For*	*Typical Requirements*
Investment Loan	Proven technologies and projects with identifiable sponsors	Creditworthy borrower, permits, technical review, collateral package
Leasing	Moveable assets with residual value	Clear ownership structure, low immovable-property risk, transferable assets
Equity Financing	High-risk or innovative projects	Sponsor commitment, risk-bearing capital, liquidity support
Project Finance	Large-scale ring-fenced projects	Dedicated Special Purpose Vehicle (SPV), predictable cash flows, stressed Debt Service Coverage Ratio (DSCR) compliance, legal due diligence, long-term revenue arrangements
Crowdfunding	Community and cooperative projects	Strong local support, public engagement, transparent governance

4.5 Financial assessment framework multi-energy projects

Access to financing is a critical success factor for the development and deployment of multi-energy projects. Financial institutions, investors, and other funding providers evaluate projects not only on their technical and environmental merits, but also on their ability to generate predictable revenues, manage risks, and comply with regulatory and financial requirements. Given the complexity of multi-energy systems, which often combine multiple technologies, stakeholders, and revenue streams, a structured assessment of project bankability is essential.

This section presents a financial assessment framework for multi-energy projects. It first identifies the principal factors influencing bankability and proposes a practical assessment framework that can be used to evaluate financing readiness and support investment decisions.

4.5.1. Factors influencing bankability

Bankability is a combination of several factors such as desirability (e.g. is it a sustainable solution), economic and technical feasibility, associated risks and the viability of the proposed solution. The bankability of a multi-energy project thus depends on a combination of factors. Financial institutions assess these elements collectively to determine whether a project can generate sufficient and predictable returns while maintaining an acceptable risk profile. Addressing these factors early in the process increases the likelihood of successful financing and long-term project viability.

The following factors can be distinguished:

- **Technical maturity:** Proven technologies generally present lower risks than innovative or experimental solutions. Technologies with a demonstrated track record are easier to finance because performance and maintenance requirements are well understood.
- **Revenue certainty:** Projects supported by stable revenue streams, such as long-term energy contracts, power purchase agreements, or regulated income mechanisms, are typically considered more bankable.
- **Financial viability:** The financial performance of a project is evaluated through expected cashflows, debt service capability, payback periods, and sensitivity analyses. Projects must demonstrate sufficient resilience under different market conditions.
- **Regulatory compliance:** Permits, environmental approvals, insurance coverage, and compliance with local legislation are essential prerequisites for financing.
- **Ownership and governance:** The financial strength and experience of the project owners significantly influence financing decisions. Clearly defined governance structures and responsibilities increase confidence among lenders and investors.
- **Project documentation:** A comprehensive project dossier including technical studies, contracts, business plans, and risk assessments is necessary to support financing decisions.
- **Community and stakeholder support:** For energy communities and cooperative projects, stakeholder commitment and community participation can positively influence financing feasibility.

4.5.2. Assessment framework

The assessment framework translates the bankability factors identified in the previous section into a structured financing review. Its purpose is to determine whether a multi-energy project is sufficiently mature, financially resilient and legally enforceable to proceed to credit approval, and to identify the conditions or risk mitigants required where weaknesses remain. The framework is intended as a screening and structuring tool. It does not replace the applicable credit policy, delegated approval authority, technical due diligence or legal review.

The assessment follows six consecutive steps. This sequence avoids treating individual indicators in isolation and ensures that fundamental weaknesses are addressed before an overall financing outcome is considered.

Step 1: Define the project and proposed financing structure

The review starts by defining:

- the project perimeter;
- the assets and services included;
- the ownership and contractual structure;
- the construction and operating model; and
- the proposed financing instrument.

The categorisation set out earlier in this chapter, namely scale, ownership structure, revenue model and technological complexity, should be used to determine the required depth of the assessment and the most appropriate financing route.

Step 2: Verify threshold requirements

Before assigning risk classifications, the assessor verifies whether the essential financing requirements have been met or can be made conditions precedent to approval, contracting or drawdown. These requirements include:

- the availability and status of material permits and regulatory approvals;
- the insurability of the project and its principal assets;
- the status and adequacy of the grid connection;
- a complete and committed funding plan;
- enforceable ownership and security rights; and
- adequate technical and contractual documentation.

A missing critical permit, an uninsurable design, an unfinanced cost item or an unenforceable security position cannot be offset by a strong assessment in another category. Such matters must be resolved, appropriately mitigated or explicitly addressed through the approval and documentation process.

Step 3: Assess the core credit factors

Each core credit factor is assigned a **Low**, **Medium** or **High** risk classification using consistent and verifiable evidence. The classification should reflect the project as financed, including its contractual protections, sponsor support, risk allocation and proposed security package, rather than assessing the technology in isolation. Table 4-9 explains the main assessment questions and supporting evidence for the different credit factors.

Table 4-9: Core credit-factor assessment

Credit factor	*Primary assessment question*	*Examples of supporting evidence*
Technology	Can the technology and integrated system perform as forecasted over the financing period?	Operating references, warranties, degradation assumptions, technical opinion, maintenance plan and acceptance tests
Revenue certainty	How predictable and enforceable are the revenues that support debt repayment?	PPA, tolling or offtake contracts, tariff arrangements, merchant exposure, volume obligations and termination provisions
Equity contribution	Is sufficient risk-bearing capital committed and available to absorb cost overruns and downside performance?	Sources-and-uses statement, evidence of committed equity, funding timetable and treatment of ancillary costs
DSCR	Does forecast CFADS (Cash Flow Available for Debt Service) provide adequate headroom above scheduled debt service in the base case and under stress?	Base-case and downside financial models, debt schedule, sensitivity analysis and covenant calculations
Sponsor strength	Can the sponsor provide the experience, liquidity and support required to deliver and operate the project?	Financial statements, track record, support undertakings, guarantees and liquidity evidence
Permits	Are the material permits and regulatory approvals complete, valid and aligned with the project schedule?	Permit register, approvals, outstanding conditions, legal review and implementation timetable
Grid connection	Is the required import and/or export capacity available on terms consistent with the business case?	Connection agreement, capacity allocation, curtailment conditions, connection costs and delivery schedule

Step 4: Test financial resilience and debt capacity

For cash-flow-based financing, the analysis should use a consistently defined **Cash Flow Available for Debt Service**, or CFADS. At a minimum, the financial assessment should consider:

- base-case and stressed Debt Service Coverage Ratio;
- debt tenor relative to the economic life of the assets;
- debt tenor relative to the duration of the principal revenue contracts;
- minimum cash requirements;
- debt-service reserve requirements, where applicable;
- distribution lock-up triggers;
- covenant headroom; and
- Loan Life Coverage Ratio, where relevant to the financing structure.

The assumptions used in the financial model must remain consistent with the conclusions of the technical, contractual and regulatory assessments. Material deviations from technical or cost benchmarks must be explained and reflected in:

- the eligible investment cost;
- the collateral or recovery value;
- contingency provisions;
- the funding requirement; and
- the project cash-flow model.

A negative or qualified technical opinion should lead to remediation, additional safeguards, reduced financing or escalation through the applicable approval process.

Step 5: Evaluate execution, counterparty and completion risks

The assessment should then test whether the project can be delivered on time, within budget and in accordance with the required technical and contractual performance standards. Relevant execution and completion considerations include:

- contractor experience and financial capacity;
- fixed-price and date-certain construction arrangements;
- performance guarantees;
- delay liquidated damages;
- contingency funding;
- interface risk between technologies and contractors;
- commissioning and acceptance testing; and
- sponsor support for cost overruns or delayed completion.

Counterparty analysis should cover the credit quality, contractual obligations, termination rights, replacement options and concentration risk associated with key offtakers, aggregators, energy suppliers, equipment suppliers, construction contractors, operators and service providers. The analysis should also determine whether the project remains viable if a key counterparty underperforms, terminates its contract or must be replaced.

Step 6: Determine the financing outcome and required mitigants

The individual risk classifications are considered together to determine an indicative financing outcome. The assessment is not a simple arithmetic score. A strong result in one category cannot automatically compensate for a fundamental weakness in repayment capacity, legal enforceability, permits, insurance, grid access, committed funding or completion support. Table 4-10 converts the principal credit factors into indicative risk

categories. The thresholds and descriptors support a consistent initial screening but should not be interpreted as automatic approval or rejection rules.

- The final classification must reflect:
- the complete project context;
- the interaction between the different risk factors;
- the quality and reliability of the supporting evidence;
- the proposed contractual and security protections;
- the results of the downside analysis; and
- the applicable credit policy.

Table 4-10: Indicative credit-risk classification by factor

Credit factor	*Low risk*	*Medium risk*	*High risk*
Technology	Proven	Limited track record	Innovative or pilot
Revenue certainty	Contracted, such as PPA or tolling	Mixed contracted and merchant revenues	Fully merchant
Equity contribution	More than 40%	20% to 40%	Less than 20%
DSCR, base case	More than 1.30x	1.15x to 1.30x	Less than 1.15x
Sponsor strength	Strong group support	Moderate support	Weak support
Permits	Fully obtained	Minor conditions outstanding	Major permits missing
Grid connection	Secured	Partially secured	Not secured
Indicative financing outcome	Standard approval process	Conditional approval or additional mitigants	Decline or restructure

The glossary below explains how each factor should be understood when applying Table 4-10. The definitions are deliberately project-focused and should be read together with the supporting evidence requirements in Table 4-9.

Table 4-11: Glossary of credit factors

Credit factor	*Explanation*
Technology	The maturity, operating record and performance predictability of the individual technologies and of the integrated multi-energy system. The assessment considers design complexity, warranties, expected degradation, maintenance requirements, interoperability, operational dependencies and reliance on unproven components or configurations. A project may use individually proven technologies but still present integration risk if those technologies have not previously operated together under comparable conditions.
Revenue certainty	The degree to which future project income is predictable, contractually supported and legally enforceable. Contracted revenues may include Power Purchase Agreements, tolling arrangements, offtake agreements, availability payments or regulated support mechanisms. Merchant revenues depend on future market prices, spreads, activation volumes or service demand and are therefore less certain. The assessment should also consider contract tenor, pricing formulas, volume commitments, termination rights, counterparty quality and the proportion of total revenues that remains exposed to market conditions.
Equity contribution	The share of the defined project financing base funded with risk-bearing capital rather than debt. Equity provides a financial buffer against construction overruns, delayed commissioning, slower-than-expected ramp-up and weaker operating performance. The calculation basis must be clearly defined and applied consistently. Costs outside the eligible financing base must also have a committed source of funding and should not remain as an unaddressed completion risk.
DSCR, base case	The Debt Service Coverage Ratio measures the project's capacity to pay scheduled interest and principal from Cash Flow Available for Debt Service. It is generally calculated as CFADS divided by total debt service for the relevant period. A ratio above 1.00x indicates that forecast cash flow exceeds scheduled debt service, while a higher ratio provides additional headroom against downside performance. The base-case DSCR should always be considered together with stressed DSCR results, covenant levels, cash reserves and the reliability of the underlying assumptions.
Sponsor strength	The sponsor's financial capacity, relevant experience, strategic commitment and ability to support the project through development, construction, ramp-up and operation. The assessment considers the sponsor's balance sheet, liquidity, profitability, track record, ownership commitment and capacity to provide additional equity, guarantees or completion support. Support should only be recognised where it is sufficiently explicit, legally enforceable and available for the period during which it may be required.
Permits	The status, validity and completeness of all material permits, licences, environmental approvals and regulatory authorisations required to construct, connect, operate and, where relevant, decommission the project. The assessment should distinguish between minor administrative conditions and approvals that are fundamental to project implementation. It should also consider permit expiry dates, appeal risks, conditions attached to approvals and alignment with the construction and financing timetable.
Grid connection	The degree to which the project has secured the electricity, gas, hydrogen or heat-network capacity required by its business case. The assessment covers import and export capacity, connection timing, technical conditions, connection costs, curtailment or congestion limitations, operational restrictions and any dependencies on network reinforcement. A connection should only be considered secured when the relevant rights and obligations are adequately documented and consistent with the financial model.
Indicative financing outcome	The preliminary conclusion derived from the combined assessment of the credit factors, threshold requirements and project-specific evidence. It indicates whether the project may proceed through the standard approval process, requires additional conditions or mitigants, or must be restructured before financing can be considered. It is not an approval decision in itself and remains subject to the applicable credit authority, due diligence, documentation and policy requirements.

The individual risk classifications are then considered together to determine an indicative financing outcome. Medium-risk factors normally require explicit conditions, additional evidence or risk mitigants. High-risk factors require restructuring, stronger support, additional equity or a different financing approach before approval can be considered, as explained in Table 4-12.

Table 4-12: From risk assessment to financing decision

Risk profile	***Assessment output***	***Typical response***
Low-risk profile	Core factors are predominantly low risk, and no critical threshold issue remains	Proceed through the standard approval process, subject to normal documentation and conditions
Mixed or medium-risk profile	One or more factors require additional protection, clarification or evidence	Define conditions precedent, covenants, reserves, guarantees, additional equity, contractual amendments or enhanced monitoring
High-risk or structurally incomplete profile	One or more critical factors are high risk, or a threshold requirement is not satisfied	Restructure the project or financing, obtain missing approvals or support, reduce debt, change the financing instrument, or decline if the weakness cannot be mitigated

5 Automated transactions in a multi-energy distributed context

5.1 Overview of solutions for automatic transactions

Automated transactions in a distributed multi-energy context refer to the automatic registration, validation, settlement, and execution of value exchanges among actors, assets, and services in local energy systems. In practice, these transactions are not limited to electricity; they increasingly involve flexibility, charging sessions, shared mobility, heat, renewable certificates, and community rewards. The core design challenge is therefore not only technical automation, but also trustworthy coordination across multiple actors that do not fully share the same data systems, incentives, or governance arrangements. In the remainder of this section, a non-exhaustive list of solution classes is presented, starting with the solution studies as part of one of the ReInvent BUCs.

One of the ReInvent BUCs, the "BUC12 Smart billing solutions for EV charging (focus on collective car sharing)", specifically looks at smart billing solutions in the context of shared EVs in a social housing district, i.e. the Otterbeek district, linked to the ReInvent test case of Klimaan [34]. Otterbeek is a social-housing energy community in Mechelen where rooftop solar has been installed on the district's homes, while shared electric vehicles and charging infrastructure create a controllable local demand. The central problem is temporal mismatch: the community generates substantial solar electricity during daytime, yet a large share of consumption occurs outside the solar production window, which means that surplus power is injected into the grid at relatively low value rather than being consumed locally. The proposed Otterbeek solution addresses this mismatch through a blockchain-enabled settlement and reward layer. Residents who help the community increase local self-consumption - especially by using shared electric vehicles and charging them during solar-rich periods - receive reward tokens that can later be redeemed within the community mobility ecosystem. Importantly, the architecture is deliberately restrained: raw metering data, consumption data, and reward calculations remain off chain, while blockchain is used only for the minting, transfer, and redemption of the reward token. This design reduces privacy exposure, limits transaction cost, and preserves an auditable settlement history without placing detailed behavioural data on a public ledger. This Otterbeek-type architecture can be described as an off-chain calculation plus on-chain settlement **model**. It allocates each task to the layer best suited to it: fine-grained measurement, forecasting, optimisation, and reward logic remain off chain, whereas the blockchain is reserved for final settlement and token lifecycle management. This design logic is increasingly visible in recent work (L2 ADI layer on Ethereum) on blockchain-enabled sector-coupled energy communities, where distributed ledgers are used selectively for automated remuneration and trusted coordination rather than as a full replacement for existing metering or optimisation infrastructures.

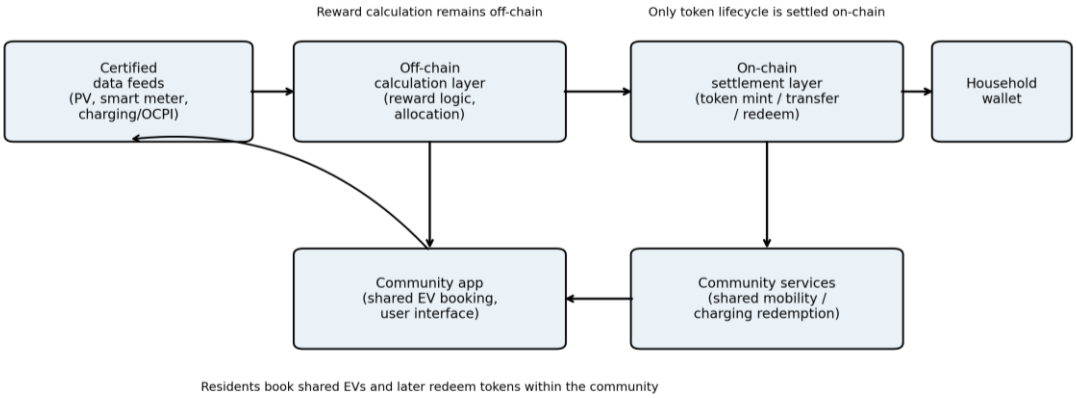


Figure 5-1: Simplified architecture of the automated transaction model of Otterbeek.

From a financing perspective, the architecture must be supplemented with the contractual and monetary flows, including the parties responsible for funding rewards, operating the platform, validating data, maintaining wallets, redeeming tokens and covering settlement shortfalls. Token issuance should not be considered a bankable revenue stream unless the underlying funding obligation is legally enforceable and supported by a creditworthy counterparty.

A second family of solutions consists of peer-to-peer (P2P) energy trading platforms. In these platforms, smart meter data are used to match local generation and consumption among participants, and the resulting exchanges are automatically recorded and settled at predefined intervals. Powerledger, for example, describes European and international cases in which blockchain-based accounting is used to validate demand and generation readings, record transfers, and support participant choice over energy source or generator provenance. The strength of this family lies in transparency and direct matching, but its practical adoption often depends on how well local market rules, tariff allocation, and supplier responsibilities are aligned with the platform.

A third category comprises local flexibility markets and transactive energy platforms. Here, automated transactions are not restricted to the exchange of kilowatt-hours; they also remunerate flexible response by batteries, electric vehicles, controllable loads, and thermal assets. The PARITY project, for instance, developed a blockchain- and IoT-enabled market environment for flexibility management, while the Electron TraDER initiative demonstrated that local energy markets can coordinate generation curtailment and flexible demand in real time, with direct physical impact on local network conditions. This makes flexibility-oriented solutions especially relevant in communities where the objective is not only local sharing, but also congestion management, curtailment reduction, or market access for distributed flexibility.

A fourth solution family is emerging specifically from sector coupling: multi-energy tokenisation and integrated settlement approaches that seek to represent electricity, heat, and flexibility in a common transaction framework. Research on multi-energy blockchain architectures shows that token standards can be used to represent both electrical and thermal flexibility in integrated building and community contexts, enabling settlement and exchange across more than one energy carrier. This direction is particularly relevant for future communities in which photovoltaic assets, batteries, heat pumps, electric vehicles, and thermal storage all interact, but its current deployment maturity remains lower than in electricity-only applications because tariff structures, market and balancing rules, and infrastructure governance remain strongly carrier-specific.

Two further categories are also relevant. Blockchain-based balance settlement ledgers focus on community accounting, reconciliation, and balance settlement within broader electricity market environments, rather than on direct user-facing incentives. Certificate and traceability layers, by contrast, focus on Guarantees of Origin, renewable claims, and auditable asset provenance. Energy Web's architecture is particularly illustrative here, as it explicitly positions decentralised infrastructures around traceability and the integration of distributed flexibility into energy systems. These categories do not directly solve the operational challenge of increasing local self-consumption, but they can become important complementary layers when communities scale, interact with external counterparties, or need more robust auditability for energy or sustainability claims.

Taken together, these examples show that there is **no single "best" solution for automated transactions in distributed multi-energy systems**. Rather, the solution space ranges from narrowly scoped reward-settlement mechanisms to more ambitious local markets, flexibility platforms, and multi-energy transaction layers. The most robust cases tend to be those in which blockchain is used as one modular component in a broader digital architecture, rather than as a stand-alone replacement for metering, optimisation, billing, and community governance.

5.2 Assessment of proposed solutions

The proposed solutions can be assessed against six criteria that are particularly relevant for distributed, sector-coupled energy communities: (i) suitability for multi-energy contexts, (ii) degree of settlement automation, (iii) cost and scalability, (iv) privacy and governance robustness, (v) interoperability with existing market and metering systems, and (vi) deployment maturity**.** These criteria are useful because they allow solution families with different purposes to be compared in a consistent way.

The Otterbeek-type hybrid model performs particularly well in terms of privacy, governance, and near-term deployability. Because only the final reward token lifecycle is settled on-chain, the on-chain footprint remains intentionally small, transaction costs can be bounded, and detailed behavioural or metering data remain outside the blockchain environment. This makes the model well suited to regulated community settings - and especially to social-housing contexts - where privacy, governance control, and low administrative burden are more

important than creating a fully liberalised local market from the outset. Its main limitation is that it does not, by itself, replace the broader retail settlement, balancing, and network charging arrangements of the electricity system.

P2P trading platforms score highly on transparency and direct traceability. They are especially strong when the strategic objective is to expose provenance, allow participants to choose their source of energy, or record interval-based exchanges among multiple actors. However, their fit with regulated community settings is more mixed. In many jurisdictions, the value proposition of direct P2P trading is constrained by the institutional roles of suppliers, the tariff treatment of local exchanges, and the allocation of balancing responsibility. As a result, these platforms can be powerful in digitally mature environments, but they often face higher regulatory friction than incentive-based community settlement models such as Otterbeek.

Flexibility marketplace solutions offer the highest potential system value among the assessed categories, because they link automated transactions to congestion management, curtailment reduction, and the activation of distributed flexibility. They are particularly relevant where communities have access to batteries, electric vehicles, smart charging, thermal flexibility, or power-to-heat assets. Yet this higher system value comes with greater integration complexity: interoperability with DSOs, aggregators, forecasting systems, market interfaces, and asset control layers becomes critical. For that reason, flexibility marketplaces are highly promising as a second or third step in a community's digital transition, but they are often too complex to serve as the first operational layer in early-stage pilots

Multi-energy tokenisation solutions are strategically important because they align conceptually with sector coupling. They provide a pathway toward representing electricity, heat, and flexibility within one common transaction logic, which is highly relevant for future integrated communities. However, their deployment maturity remains lower than that of incentive settlement or electricity-only P2P platforms. Most examples still remain at pilot, prototype, or research level, and existing regulatory frameworks continue to govern different carriers through different metering, balancing, and tariff rules. Consequently, multi-energy tokenisation is analytically powerful and future-oriented, but it is not yet the most straightforward entry point for implementation in present-day community settings [50], [51], [52].

Balance settlement ledgers and certificate/traceability layers play a more infrastructural role. Settlement ledgers can provide a robust accounting backbone once communities interact with wider supplier environments, flexibility markets, or inter-community exchanges. Certificate and traceability layers add value when auditable renewable claims, provenance, and structured ESG reporting become important. However, neither category directly addresses the behavioural question at the core of Otterbeek-like use cases: how to shift demand, charging, or mobility patterns so that self-consumption rises within the community. They should therefore be understood as complementary layers rather than stand-alone mechanisms for local behavioural optimisation [53], [54], [55].

The assessment therefore suggests that the most robust **near-term pathway** for sector-coupled energy communities is a **modular hybrid architecture**. In such a model, trusted measurement, optimisation, and allocation logic remain off chain, while blockchain is used selectively for immutable settlement, token lifecycle management, auditable value transfer, and controlled rights management. This design is already visible in the Otterbeek proposal and is consistent with the broader evolution of digital platforms for energy communities described in recent European literature and projects. Over time, richer flexibility functions, inter-community settlement, traceability, and more advanced multi-energy coordination can be added as additional layers once the business case, governance model, and regulatory fit have been validated.

5.3 Concluding implication for the ReInvent context

For the ReInvent context, and especially for community cases such as Otterbeek, the evidence points toward a **phased digital architecture**. In phase one, a constrained blockchain settlement and incentive layer can be used to reward behaviour that improves local self-consumption while preserving privacy and governance control. In phase two, the same architecture can be extended with smart charging orchestration and richer reward logic. In phase three, once operational evidence and economics are sufficiently robust, wider flexibility participation, inter-community settlement, and more explicit multi-energy coordination can be added. In this sense, blockchain should not be understood as a universal replacement for existing market institutions, but as a carefully delimited infrastructure component that supports trust, automation, and controlled value circulation in distributed multi-energy systems.

6 Conclusions

This deliverable has examined the key enabling conditions for sector integration in Belgium from market, business, financial, and digital perspectives. The analysis highlights that effective integration of electricity, gas, heat, and green molecules requires not only technological solutions, but also appropriate market arrangements, viable business models, access to financing, and interoperable digital infrastructures. Together, these elements form the foundation for scaling sector-coupled energy systems and unlocking the flexibility, efficiency, and decarbonisation benefits of an increasingly integrated energy system.

Improved market design considering sector integration

This deliverable analysed the interaction between electricity, gas, hydrogen, and heat systems in Belgium and showed that, although these carriers are increasingly interconnected through multi-carrier technologies, their associated markets remain largely organised and optimised in isolation. Technologies such as gas-fired power plants, CHP units, electrolysers, power-to-heat installations, and industrial cogeneration units create strong physical and economic links between carriers, yet current market designs do not fully reflect these interdependencies. As a result, operators of multi-carrier assets face challenges when attempting to optimise their participation across multiple markets.

Through a combination of literature review and stakeholder interviews, five principal barriers to efficient cross-carrier participation were identified: differences in product durations, different operating days, sequential market closures leading to incomplete information, regulatory fragmentation and administrative complexity, and uneven market maturity and liquidity. While these characteristics have emerged from the independent development of individual energy markets, they can constrain the efficient utilisation of cross-carrier flexibility and increase the operational complexity faced by market participants.

To address these challenges, three alternative market design concepts were evaluated: isolated markets, coordinated markets, and fully integrated markets. The qualitative assessment indicates that coordinated markets provide the most balanced solution. By aligning selected market design elements, such as product durations, operating days, and market closure schedules, coordinated markets can significantly improve the utilisation of multi-carrier flexibility while preserving the existing institutional structure of individual energy markets. Although fully integrated markets achieve the highest theoretical performance, they are unlikely to represent a realistic implementation pathway due to the extensive regulatory, institutional, and governance changes that would be required. Consequently, **coordinated markets appear to offer the most promising pathway for supporting sector coupling** and improving the integration of electricity, gas, hydrogen, and heat systems in Belgium.

Business models and actor-specific scalability

The business model analysis shows that improved sector coupling cannot rely on one single generic model. Viability depends on how well the technical solution, contractual arrangements and allocation of risks and benefits fit the capabilities and constraints of the actors involved. **Industrial actors, energy communities and residential actors differ substantially in investment capacity, organisational maturity, control over assets and tolerance of risk and complexity.** Archetype-based tailoring is therefore important for translating technically feasible solutions into implementable propositions.

Across the ReInvent BUCs, several recurring conclusions emerge. Industrial scalability depends mainly on reducing investment uncertainty through predictable costs, credible revenue or offtake arrangements and coordinated infrastructure planning. Energy communities require manageable governance, fair benefit allocation, access to data and suitable energy-management systems, while regional differences between Flanders, Wallonia and Brussels affect how community business models can be replicated. Residential participation depends strongly on simplicity, trust, affordability and control over assets; for tenants, collective or service-based models are particularly important. A further conclusion is that value increasingly arises from coordination across assets and actors, rather than from individual technologies in isolation. Community-level optimisation, coordinated EV charging, shared infrastructure and flexibility services can improve the business case when the resulting value is distributed transparently.

Looking ahead, replication will require standardised but adaptable business model templates that can accommodate different archetypes, regulatory contexts and levels of technical maturity. Further validation should combine BUC modelling results with implementation experience and stakeholder testing, with particular attention to contractual arrangements, governance, benefit sharing and the valorisation of flexibility.

Financing multi-energy projects

Financing multi-energy projects requires a financing approach that reflects the specific characteristics, risk profile, and revenue structure of the project. No single financing mechanism is suitable for all project types. Rather, the choice between investment loans, leasing, equity financing, project finance, crowdfunding, or combinations thereof depends on factors such as project scale, ownership structure, technological maturity, revenue certainty, and the availability of collateral or sponsor support.

Beyond the selection of an appropriate financing structure, project bankability remains a key determinant of financing feasibility. Bankability depends on a combination of technical maturity, predictable revenues, regulatory compliance, financial viability, governance arrangements, and the quality of project documentation. Projects that combine proven technologies with stable cash flows, adequate equity contributions, secured permits, and strong sponsor support are generally better positioned to attract financing. Conversely, innovative or highly merchant-exposed projects often require additional safeguards, risk-sharing mechanisms, public support, or higher equity contributions.

As multi-energy systems become increasingly important for achieving decarbonisation objectives, financing frameworks will need to accommodate more integrated and innovative business models. A structured assessment of financing suitability and project bankability can support consistent investment decisions while balancing risk and opportunity. Ultimately, access to finance will play a critical role in enabling the deployment and scale-up of multi-energy projects and in translating sector-coupling concepts into bankable and investable solutions.

Automated transactions in a multi-energy distributed context

The analysis of automated transaction solutions demonstrates that digital infrastructures will play an increasingly important role in enabling sector-coupled and distributed energy systems. As energy communities and other multi-actor energy arrangements become more complex, automated mechanisms for measuring, validating, settling, and rewarding energy-related transactions can help reduce administrative burdens, improve transparency, and support the coordination of distributed assets and participants.

The review of different solution families, including blockchain-enabled settlement mechanisms, peer-to-peer trading platforms, flexibility marketplaces, multi-energy tokenisation approaches, and certificate-based traceability systems, shows that each addresses different needs and levels of system maturity. No single solution emerges as universally optimal. Instead, the suitability of a digital architecture depends on the objectives of the application, the characteristics of the participating actors, regulatory requirements, and the desired level of market integration.

For the ReInvent context, the assessment suggests that a modular and phased approach provides the most practical pathway. In particular, architectures that combine trusted off-chain measurement, optimisation, and allocation processes with selective on-chain settlement and incentive mechanisms offer a good balance between automation, scalability, privacy, and governance requirements. Such architectures can initially support local self-consumption and behavioural incentives and can subsequently be extended with smart charging, flexibility services, inter-community exchanges, and broader multi-energy coordination functionalities.

References

[1] P. Valkering *et al.*, "ReInvent D1.1 Implication and opportunities for sector coupling in Belgium." 2024. [Online]. Available: https://reinvent-project.be/sites/reinventproject/files/ReInvent%20D1.1%20-%20Implication%20and%20Opportunities%20for%20Sector%20Coupling%20in%20Belgium.pdf

[2] C. Canestrini, "Liberalisation of the European electricity markets: a glass half full," *Florence School of Regulation*, Apr. 27, 2016. Accessed: Jun. 09, 2026. [Online]. Available: https://fsr.eui.eu/liberalisation-european-electricity-markets-glass-half-full/

[3] European Commission, *Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management*, vol. 197. 2015. Accessed: Jun. 09, 2026. [Online]. Available: http://data.europa.eu/eli/reg/2015/1222/oj

[4] *Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing*, vol. 312. 2017. Accessed: Jun. 09, 2026. [Online]. Available: http://data.europa.eu/eli/reg/2017/2195/oj

[5] Elia, "About Elia." Accessed: Jun. 09, 2026. [Online]. Available: https://www.elia.be/en/about-elia

[6] ACER, "About ACER." Accessed: Jun. 09, 2026. [Online]. Available: https://www.acer.europa.eu/the-agency/about-acer

[7] ENTSO-E, "ENTSO-E Mission Statement." Accessed: Jun. 09, 2026. [Online]. Available: https://www.entsoe.eu/about/inside-entsoe/mission-statement/

[8] ACER, "ACER policy paper on the further development of the EU electricity forward market." Accessed: Jun. 09, 2026. [Online]. Available: https://www.acer.europa.eu/acer-policy-paper-further-development-eu-electricity-forward-market

[9] ACER, "Market rules for different electricity market timeframes." Accessed: Jun. 09, 2026. [Online]. Available: https://www.acer.europa.eu/electricity/market-rules/market-rules-different-electricity-market-timeframes

[10] ACER, "Balancing Energy Platforms." Accessed: Jun. 09, 2026. [Online]. Available: https://www.acer.europa.eu/electricity/market-rules/electricity-balancing/balancing-energy-platforms

[11] ENTSO-E, "About Core CCR." Accessed: Jun. 09, 2026. [Online]. Available: https://www.entsoe.eu/bites/ccr-core/about/

[12] N. Hasse, "European gas market liberalisation: Are regulatory regimes moving towards convergence?," Oxford Institute for Energy Studies. Accessed: Jun. 09, 2026. [Online]. Available: https://www.oxfordenergy.org/publications/european-gas-market-liberalisation-are-regulatory-regimes-moving-towards-convergence/

[13] ENTSOG, "ENTSOG." Accessed: Jun. 10, 2026. [Online]. Available: https://www.entsog.eu/

[14] Fluxys, "Fluxys Belgium." Accessed: Jun. 10, 2026. [Online]. Available: https://www.fluxys.com/en/about-us/fluxys-belgium

[15] EEX, "Trading Natural Gas at EEX." Accessed: Jun. 10, 2026. [Online]. Available: https://www.eex.com/en/markets/natural-gas

[16] Balansys, "Balansys: Who we are," Balansys. Accessed: Jun. 10, 2026. [Online]. Available: https://www.balansys.eu/la-societe/

[17] European Commission, *Commission Regulation (EU) 2017/459 of 16 March 2017 establishing a network code on capacity allocation mechanisms in gas transmission systems and repealing Regulation (EU) No 984/2013*, vol. 072. 2017. Accessed: Jun. 10, 2026. [Online]. Available: http://data.europa.eu/eli/reg/2017/459/oj

[18] PRISMA, "Welcome to PRISMA." Accessed: Jun. 10, 2026. [Online]. Available: https://app.prisma-capacity.eu/

[19] European Commission, "Hydrogen strategy." Accessed: Jun. 10, 2026. [Online]. Available: https://energy.ec.europa.eu/topics/eus-energy-system/hydrogen_en

[20] European Parliament, *Directive (EU) 2024/1788 of the European Parliament and of the Council of 13 June 2024 on common rules for the internal markets for renewable gas, natural gas and hydrogen, amending Directive (EU) 2023/1791 and repealing Directive 2009/73/EC*. 2024. Accessed: Jun. 10, 2026. [Online]. Available: http://data.europa.eu/eli/dir/2024/1788/oj

[21] EEX, “EEX Hydrogen Market.” Accessed: Jun. 10, 2026. [Online]. Available: https://www.eex.com/en/markets/hydrogen#29222
[22] Fluxys, “Fluxys hydrogen.” Accessed: Jun. 11, 2026. [Online]. Available: https://www.fluxys.com/en/about-us/fluxys-hydrogen
[23] Varmelast, “Varmelastsamarbejdet.” Accessed: Jun. 11, 2026. [Online]. Available: https://www.varmelast.dk/om-varmelast/varmelastsamarbejdet
[24] Directorate-General for Energy (European Commission) *et al.*, *District heating and cooling in the European Union: overview of markets and regulatory frameworks under the revised Renewable Energy Directive*. Publications Office of the European Union, 2022. Accessed: Jun. 11, 2026. [Online]. Available: https://data.europa.eu/doi/10.2833/962525
[25] VEKA, “Warmte in Vlaanderen. Rapport 2020,” Vlaanderen.be. Accessed: Jun. 11, 2026. [Online]. Available: https://www.vlaanderen.be/publicaties/warmte-in-vlaanderen-rapport-2020
[26] VREG, “Over de activiteit warmtenetten bij de VREG in 2022-2023: RAPP-2023-12,” 2023. Accessed: Jun. 11, 2026. [Online]. Available: https://www.vlaamsenutsregulator.be/publicaties/rapp-2023-12
[27] K. Johansen and S. Werner, “Something is sustainable in the state of Denmark: A review of the Danish district heating sector,” *Renew. Sustain. Energy Rev.*, vol. 158, p. 112117, Apr. 2022, doi: 10.1016/j.rser.2022.112117.
[28] Eco-Business, “District Energy: Energy efficiency for urban areas,” Eco-Business. Accessed: Jun. 11, 2026. [Online]. Available: https://www.eco-business.com/research/district-energy-energy-efficiency-for-urban-areas/
[29] S. Shariat Torbaghan *et al.*, “Designing day-ahead multi-carrier markets for flexibility: Models and clearing algorithms,” *Appl. Energy*, vol. 285, p. 116390, Mar. 2021, doi: 10.1016/j.apenergy.2020.116390.
[30] European Commission, “Energy System Integration.” Accessed: Aug. 25, 2026. [Online]. Available: https://energy.ec.europa.eu/topics/eus-energy-system/energy-system-integration_en
[31] European Commission, “Energy Communities.” Accessed: Aug. 25, 2026. [Online]. Available: https://energy.ec.europa.eu/topics/markets-and-consumers/energy-consumers-and-prosumers/energy-communities_en
[32] S. Hall, J. Anable, J. Hardy, M. Workman, C. Mazur, and Y. Matthews, “Matching consumer segments to innovative utility business models,” *Nat. Energy*, vol. 6, no. 4, pp. 349–361, Mar. 2021, doi: 10.1038/s41560-021-00781-1.
[33] IEA, “Energy Technology Perspectives 2024,” Paris, 2024. [Online]. Available: https://www.iea.org/reports/energy-technology-perspectives-2024
[34] K. Kessels *et al.*, “ReInvent D3.1 Definition of use cases and KPIs.” ReInvent, Oct. 16, 2024. Accessed: Sep. 21, 2026. [Online]. Available: https://reinvent-project.be/sites/reinventproject/files/ReInvent%20D3.1%20-%20Definition%20of%20Use%20Cases%20and%20KPIs.pdf
[35] “Household energy choices: New empirical evidence and policy implications for sustainable behaviour,” OECD Environment Working Papers 247, Aug. 2024. doi: 10.1787/534a14fe-en.
[36] *Directive on the promotion of the use of energy from renewable sources*. 2018. [Online]. Available: https://eur-lex.europa.eu/eli/dir/2018/2001/oj/eng
[37] *Directive on common rules for the internal market for electricity*. 2019. [Online]. Available: https://eur-lex.europa.eu/eli/dir/2019/944/oj/eng
[38] REScoop.eu, “REScoop.eu Policy Tracker.” Accessed: Aug. 25, 2026. [Online]. Available: https://www.rescoop.eu/policy/policy-tracker
[39] “REScoop.Vlaanderen.” Accessed: Aug. 25, 2026. [Online]. Available: https://rescoopv.be
[40] “REScoop.Wallonie.” Accessed: Aug. 25, 2026. [Online]. Available: https://www.rescoop-wallonie.be
[41] “Energiegemeenschappen.” Accessed: Aug. 25, 2026. [Online]. Available: https://www.vlaamsenutsregulator.be/elektriciteit-en-aardgas/energieprijzen-en-facturen/energiegemeenschappen
[42] “Energiegemeenschappen.” Accessed: Aug. 28, 2026. [Online]. Available: https://www.vlaamsenutsregulator.be/elektriciteit-en-aardgas/energieprijzen-en-facturen/energiegemeenschappen

[43] CWaPE, “Guide relatif au contrôle de conformité des statuts d’une communauté d’énergie.” Mar. 05, 2026. [Online]. Available: https://www.cwape.be/sites/default/files/cwape-documents/2026.03.05-0064-Lignes%20directrices%20contr%C3%B4le%20de%20conformit%C3%A9%20statuts%20CE%20-%20M%C3%A0J.pdf
[44] “Brugel - Energiegemeenschappen.” Accessed: Aug. 28, 2026. [Online]. Available: https://energysharing.brugel.brussels/nl_BE/energysharing/energiegemeenschappen-406
[45] Brugel, “Interpretatiegids voor vergunningen van de energiegemeenschap.” Jun. 30, 2023. [Online]. Available: https://brugel.brussels/publication/document/brochures/2023/nl/Gids_Vergunningen_energiegemeenschappen.pdf
[46] “Brugel - Vergunde gemeenschappen.” Accessed: Aug. 28, 2026. [Online]. Available: https://energysharing.brugel.brussels/nl_BE/energysharing/vergunde-gemeenschappen-586
[47] “Energy system integration.” Accessed: Sep. 14, 2026. [Online]. Available: https://energy.ec.europa.eu/topics/eus-energy-system/energy-system-integration_en
[48] *Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 amending Regulations (EU) 2019/942 and (EU) 2019/943 as regards improving the Union’s electricity market design (Text with EEA relevance)*. 2024. Accessed: Aug. 28, 2026. [Online]. Available: http://data.europa.eu/eli/reg/2024/1747/oj
[49] ACER, “Flexibility.” Accessed: Aug. 26, 2026. [Online]. Available: https://www.acer.europa.eu/flexibility
[50] C. C. Damiano, C. Riccardo, B. Umberto, D. S. Eugenio, and M. P. Antonio, “Blockchain Applications for Building and Smart Grid System: Innovative Energy Framework from UE Case Studies,” in *Multiphysics and Multiscale Building Physics*, vol. 553, U. Berardi, Ed., Singapore: Springer Nature Singapore, 2025, pp. 607–614. doi: 10.1007/978-981-97-8309-0_82.
[51] O. Marin, T. Cioara, and I. Anghel, “Blockchain Solution for Buildings’ Multi-Energy Flexibility Trading Using Multi-Token Standards,” *Future Internet*, vol. 15, no. 5, p. 177, May 2023, doi: 10.3390/fi15050177.
[52] “Electron – flowing into flexible energy,” nesta. Accessed: Sep. 21, 2026. [Online]. Available: https://www.nesta.org.uk/project-updates/electron-flowing-into-flexible-energy/
[53] Mathias, “Building Trust in Vulnerable Communities: Insights from Otterbeek’s Energy Initiative,” Tandems. Accessed: Sep. 21, 2026. [Online]. Available: https://lifetandems.eu/building-trust-in-vulnerable-communities-insights-from-otterbeeks-energy-initiative/
[54] “EW-DOS: The Energy Web Decentralized Operating System.” energy web, Dec. 2019. [Online]. Available: https://www.securities.io/wp-content/uploads/2022/05/EnergyWeb.pdf
[55] “Automated Verification for Renewable Energy Offsets.” [Online]. Available: https://chainscorelabs.com/use-cases/carbon-credit-markets-and-offsets/carbon-credit-mrv-automation/automated-verification-for-renewable-energy-offsets