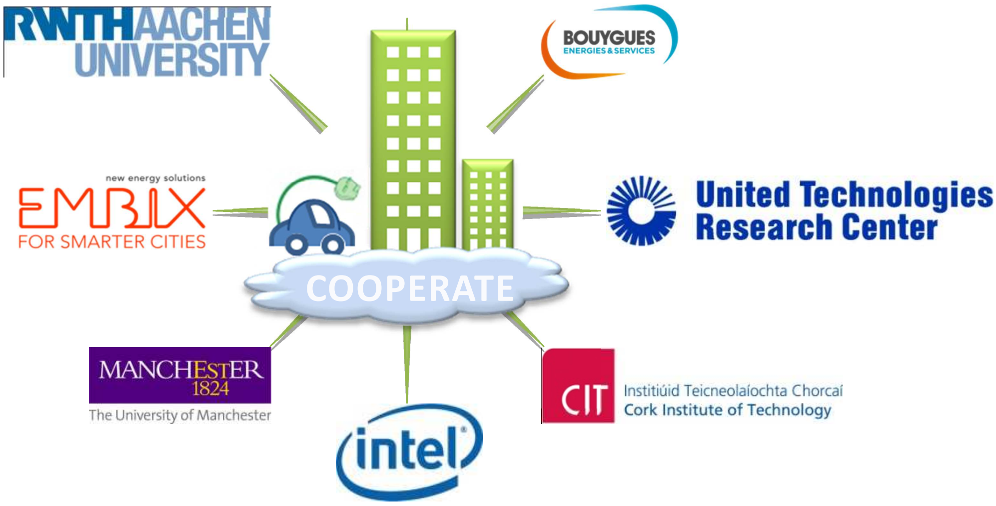
BUSINESS MODELS AND ENABLERS

COOPERaTE

Deliverable D6.1

Business Models and Cost Benefit Analysis for Energy Positive Neighbourhoods



Dissemination Level: Public

Project Number	:	600063
Project Title	:	COOPERaTE
Deliverable Dissemination Level	:	Public
Deliverable Number	:	D6.1

Title of Deliverable	:	Business Models and Cost Benefit Analysis for Energy Positive Neighbourhoods
Nature of Deliverable	:	Report
Internal Document Number	:	Deliverable_D6 1_Business Models and Cost Benefit Analysis for Energy Positive Neighbourhoods
Contractual Delivery Date	:	12
Actual Delivery Date	:	30 September, 2013
Work Package	:	WP6
Estimated Person Months	:	11.5
Author(s)	:	Eduardo Alejandro Martínez Ceseña, Nicholas Good, Sascha Junghanns and Pierluigi Mancarella
Contributors	:	Kostas Kouramas
Total number of pages (including cover)	:	70

Abstract This document defines the main actors, multi-commodity and information transactions, and market frameworks that will be explored as part of the cost benefit analysis of the COOPERaTE paradigm.

Keyword list Energy Positive Neighbourhood, Cost Benefit Analysis, Business models, Distributed Energy Resources, Smart Grid

Document History

Date	Revision	Comment	Author/Editor	Affiliation
12 Sep, 2013	1	Initial draft version	Eduardo Martínez and Sascha Junghanns	UNIMAN
13 Sep, 2013	2	Review structure	Nicholas Good	UNIMAN
14 Sep, 2013	3	Rewrite background	Eduardo Martínez	UNIMAN
15 Sep, 2013	4	Extend description of gas, heat and CO_2 markets and underlying actors	Nicholas Good	UNIMAN
16 Sep, 2013	5	Extend section 4	Eduardo Martínez	UNIMAN
17 Sep, 2013	6	Restructure/rewrite section 3	Nicholas Good	UNIMAN
18 Sep, 2013	7	Review section 1 and 2	Nicholas Good	UNIMAN
19 Sep, 2013	8	Review section 3	Eduardo Martínez	UNIMAN
20 Sep, 2013	9	Review section 4	Nicholas Good	UNIMAN
21 Sep, 2013	10	Restructure and edit document (Now I has 7 sections)	Eduardo Martínez and Nicholas Good	UNIMAN
22 Sep, 2013	11	Review/edit/proofread document	Eduardo Martínez	UNIMAN
23 Sep, 2013	12	Review/edit/proofread document	Nicholas Good	UNIMAN
24 Sep, 2013	13	Update background discussion	Eduardo Martínez	UNIMAN
25 Sep, 2013	14	Update mappings	Nicholas Good	UNIMAN
26 Sep, 2013	15	Update market discussion	Eduardo Martínez and Nicholas good	UNIMAN
27 Sep, 2013	16	Expand information on CO_2 and heat markets, directional pricing, interactions between the EPN and retailers and aggregators, and investment costs	Pierluigi Mancarella	UNIMAN
28 Sep, 2013	17	Updating sections 1, 2, 6 and 7	Eduardo Martínez	UNIMAN
29 Sep, 2013	18	Updating Sections 3, 4 and 5	Nicholas Good and Sascha Junghanns	UNIMAN
30 Sep, 2013	19	Proofreading	Eduardo Martínez, Nicholas Good and Pierluigi Mancarella	UNIMAN
01 Oct, 2013	20	Review/edit/proofread document	Kostas Kouramas	UTRCI
01 Oct, 2013	21	Final proofreading	Eduardo Martínez, Nicholas Good and Pierluigi Mancarella	UNIMAN

Executive Summary

The objective of COOPERaTE is to develop an open, scalable neighbourhood systems integration and management platform linking local monitoring and control functions with a cloud based service platform for the delivery of innovative energy management, security and other future services. The platform will enable the delivery of energy services, allow the management and trading of locally generated energy and grid based energy supplies, and links with other local and cloud based services such as security/safety and transportation in order to progress towards energy positive neighbourhoods.

This work package (work package six), namely “Business Models and Enablers” builds upon work package one (“Requirements, Use Case, Information Model and Architecture Specification”) and interacts with the other work packages and in particular work packages two (“Neighbourhood Power and Energy Management”) and four (“System Integration and Technology Validation”) in order to analyse the likely operation practices of EPNs and role of ICT, respectively. Work package six was formed to: (i) identify various possible services, markets and regulatory contexts, as well as the major actors (external and internal to the neighbourhood) involved in businesses related to energy positive neighbourhoods (EPNs); (ii) quantify the economic implications (costs and benefits) of an EPN within different commercial and regulatory contexts; (iii) assess the implications of various information and communications technology (ICT) and energy infrastructures and services provision business models; and (iv) identify the most suitable paradigms to maximise the techno-economic efficiency of the EPN taking into account all the actors involved in the multi-service value chain.

This document reports the outputs of the first task of the Business Models and Enablers work package, namely the baseline definition of a multi-criteria cost benefit analysis (CBA) for the assessment of business models for energy positive neighbourhoods.

Specifically, the main outcome of this deliverable is the formalization of the CBA in terms of (i) the main actors (internal and external) involved in the EPN business cases, (ii) value along the multi-commodity flow chain (e.g. cash, energy, emissions and information) and (iii) potential market frameworks internal and external to the EPNs that determine both the costs (i.e. investments needed for the installation and maintenance of EPN enabling, and the actors that are likely to incur the associated costs) and benefits (i.e. utility allocation among underlying actors) associated with the EPN. This information will be critical for the next stage of this work package, in which a multi-commodity CBA platform capable of simulating and optimising the behaviour of the involved actors and allocate costs and benefits within the various business models, commercial and regulatory frameworks will be developed.

Table of Contents

List of Figures

List of tables

Acronyms

BC	Business Case
CBA	Cost Benefit Analysis
CHP	Combined Heat and Power
DER	Distributed Energy Resource
DES	Distributed Energy Storage
DG	Distributed Generation
DNCM	Distribution Network Constraint Management (BC3)
DR	Demand Response
DSO	Distribution System Operator
DUoS	Distribution Use of System
EES	Electrical Energy Storage
EHP	Electric Heat Pump
EPN	Energy Positive Neighbourhood
ESCo	Energy Service Company
EV	Electric Vehicles
HP	Heat Pump
ICT	Information and Communications Technology
IRR	Internal Rate of Return
MIP	Minimisation of Imbalance Penalties (BC 2)
NEM	Neighbourhood Energy Manager
NPV	Net Present Value
OPWM	Optimal Purchase on the Wholesale Market (BC 1)
OR	Operating Reserve (BC4)
TES	Thermal Energy Storage
TSO	Transmission System Operator
TUoS	Transmission Use of System
UC	Use Case

1 Document Objectives and Content

The main aim of the “Business Models and Enablers” work package within COOPERaTE is the development of a general framework for the assessment of the economic and financial implications of different business models for different actors in an Energy Positive Neighbourhood (EPN). The framework will be based on a multi-criteria Cost Benefit Analysis (CBA) (e.g. considering multiple energy and CO_2 markets).

This deliverable sets the bases for the abovementioned CBA. In particular, this document:

- Identifies key actors involved in the EPN business by reviewing the characteristics of an EPN and the environment in which it operates: In **Section 2**, a general description of an EPN and the external commodity markets in which it could operate (i.e. electricity, gas, heat and CO_2) is provided. The discussion centres on the roles of key actors within and outside the neighbourhood in the economic and efficient operation of an EPN.

- Investigates plausible examples of business cases for the EPN based on use cases previously defined for the neighbourhood (the use cases were defined in [1]). In **Section 3**, four energy based business cases and a non-energy based business case are presented. Great emphasis is placed on the energy based business cases (e.g. businesses based on electricity/power system service trading) as their benefits are tangible and can be properly captured by commodity markets. Conversely, even though non-energy services may be attractive for end-users, benefits from the services (e.g. parking services) are often not tangible (e.g. increased utility from finding parking spaces faster) and cannot be captured by existing market structures. Thus, financing for non-energy services may have to come directly from end-users or (preferably) from profits from energy based services. In the light of this, It is argued that energy based services will play a key role in enabling the EPN concept and financing non-energy services.

- Present a methodology for the mapping of multi commodity flows associated with the business cases. In **Section 4**, a thorough description of the mapping approach used to capture multi-commodity flows within and outside the EPN is provided. This approach will allow us to capture all the (economic and environmental) values along the multi-commodity flow chain, including interactions with external networks and market entities, and to highlight potential conflicting objectives along the value chain. **Section 5** presents the different mappings developed for baseline scenarios and all business cases under consideration.

- Discusses different market frameworks. In **Section 6** the impacts of various internal and external market structures on the EPN business are discussed. Particular emphasis is placed on the impact of different market structures on the valuation (i.e. associated costs and benefits) of services from the EPN and other actors, as well as on the distribution of wealth and costs within the EPN. Whenever the market acknowledges and values a service provided by the EPN it may be placing less value on equivalents service provided by other actors. These trade-offs must be considered when assessing the market framework. The distribution of costs and wealth within the EPN will be greatly influenced by the ownership of EPN enabling infrastructure and the functions of the neighbourhood.

- Presents the fundamental formulation of the multi-criteria CBA. In **Section 7**, some of the more well-known and accepted techniques used for a multi-criteria CBA are presented. Finally, in **Section 8**, the main conclusions from this deliverable are summarised.

The output of this deliverable is the formalization of the CBA in terms of (i) key actors involved in the EPN business; (ii) functions that map the costs (e.g. investments in infrastructure, and operations and maintenance) and benefits accruing to the various actors though the relevant flows of multi commodities, and (iii) attributes that characterize the potential business model context (e.g. price reflectivity and ownership alternatives). In other words, the main objectives of this report are to address the following questions associated with a CBA of EPNs:

- Who are the main actors directly and indirectly involved in the business of EPNs (inside and outside the neighbourhood), and what are the potential roles taken by the actors and the EPN?

- How can the multi-commodity flows between the EPN and other actors be captured?

- What is the potential impact of different market frameworks on the business case of EPNs and other actors?

2 Background

The combined effects of increasing environmental concerns (e.g. CO_2 emissions) , technological advances (e.g. Information and Communications Technology, ICT), trends to electrification of transport (e.g. through the introduction of Electric Vehicles, EV), trends to greater interactions between heating and electricity (e.g. through development of Electric Heat Pump, EHP, and, Combined Heat and Power, CHP, markets) and ageing energy infrastructure (e.g. parts of the power system are approaching the end of their useful life) are directing attention to the potential of modernising energy systems to facilitate the economic and efficient use of energy resources and the active participation of the demand side (e.g. clients at the neighbourhood level) in the management of the energy system.

The COOPERaTE consortium proposes the development of "*scalable neighbourhood systems integration and management platform linking local monitoring and control functions with a cloud based service platform*" [1] as an alternative to not only maximise energy efficiency and economy, and improve demand side participation, but to enable non-energy services that can be attractive at the neighbourhood level (e.g. parking and security improvements). The platform would set the basis for the formation of EPNs.

This work package, namely "Business Models and Enablers" focuses on the economic enablers for EPNs and has as a main objective the identification of key factors needed to realise an EPN from a technical, commercial and social viewpoint. The answer will be investigated following a three stage process involving (i) the identification of key factors needed to perform a multi-criteria CBA of business models for EPNs, (ii) the evaluation of the business models, and (iii) ultimately the identification of EPN enablers. This report presents the main outputs from the first task, namely "*Business model definitions and multi-criteria cost benefit analysis*"

This section defines the CBA in terms of the main actors involved in the business cases of EPNs. For this purpose a clear understanding of the characteristics of the EPN and actors within the neighbourhood, as well as the interactions between EPNs and their external environment (e.g. power and gas markets and underlying actors) is required.

The following subsections provides a brief review of the EPN concept, first by analysing the settings and actors that form the neighbourhood and later focusing on the environment in which the EPN would operate.

2.1 Energy positive neighbourhoods

As defined within the context of COOPERaTE, an EPN is "*a neighbourhood which can maximise usage of local and renewable energy resources whilst positively contributing to the optimisation and security of the wider electricity grid*" [1]. By maximising the use of local energy sources, the EPN aims at reducing its net consumption to zero, that is producing as much energy (or more) than it consumes.

The EPN is mainly characterised by its expected functionalities, and the actors that facilitate those functionalities. In accordance, the main functionalities of the EPN or, using the COOPERaTE lexicon, the energy related and non-energy related use cases and their associated application services are reviewed in the following subsection. Afterwards, taking the use cases as a reference, the main actors (e.g. end-users and Distributed Energy Resources, DERs) needed to enable an EPN are identified and discussed.

2.1.1 Example functions

COOPERaTE work package 1, namely "*Requirements, Use Case, Information Model, and Architecture Specification*" identified the following examples of potential energy based and non-energy based use cases for EPNs [1][2].

2.1.1.1 Energy based use cases

- **Real-time monitoring of the consumption of a neighbourhood**: Real time measurements would allow the identification of the key contributors to energy consumption during times of peak prices; thus facilitating the reduction of overall energy consumption. This use case requires the availability of real-time energy measurements, real-time pricing information, and interfacing with smart meters.

- **Energy demand and power generation forecasting**: By collecting historical data from measurements (e.g. real time consumption), it would be possible to forecast the energy consumption and generation of the neighbourhood at different stages (e.g. hour ahead and day ahead). The forecasts would be used to assess future energy consumption needs and schedule generation accordingly, thus improving the efficiency and economy of the EPN. This use case requires the existence of an actor that performs the forecasts and can store their required historical energy information.

- **Optimisation of power imports, exports and usage**: Apart from energy demand and generation predictions, weather forecasts (e.g. solar radiation and temperature) and market price signals can be used to improve the management of the EPN, particularly to decide whether to import energy or generate it with local resources. For example, accurate renewable energy availability forecasts and energy consumption and generation would allow storage to have enough capacity available to store all surplus renewable generation (in case the EPN aims at maximising renewable energy usage). This service case has similar requirements to the previous cases, plus the need of a real-time optimisation engine.

- **Demand Response (DR)**: The neighbourhood could manage its energy consumption to provide DR (e.g. use local generation and storage to reduce its overall consumption) as a single entity. The EPN could participate in a DR programme and perceive the associated benefits. This use case requires means for communicating with actors that request the service, a platform to process the request and included as an input to be considered for the real-time EPN optimisation engine, and procedures to override automated decisions whenever needed.

2.1.1.2 Non-energy based use cases:

The availability of ICT infrastructure combined with the creation of mobile applications (apps) and installation of video surveillance (e.g. closed circuit television), sensors and other infrastructure would enable the EPN to provide non-energy services such as:

- **Parking Service**: The ICT infrastructure can be utilised to determine the location of available parking spaces (and EV charging points) within the neighbourhood. By combining this information with the desired destination and requirements of users (e.g. EPN inhabitants and visitors), the EPN can offer users information about parking place (and charging points) availability near their destination. This service would reduce commute time and energy consumption by vehicle, which can be deemed important benefits if the amount of vehicles and difficulty to find parking spaces in the neighbourhood are significant.

- **Security Service**: Access to different parts of the neighbourhood can be granted or restricted to different personnel. The rationally is to identify users via mobile access credential (e.g. as a smart phone application) that would be presented at a neighbourhood entry point. Afterwards, surveillance and automatic door access would be used to monitor the movement of the user and grant them access to permitted areas. This would increase customer comfort by allowing them to access specific areas without being forced to enter their credentials again.

- **Participatory sensing use-case & associated service**: Customer engagement in the management of the EPN (regarding aesthetic, security, planning and operation, and other actions) can be facilitated and monitored with mobile phone applications and interfaces. This service would motivate a positive response from customers, which is crucial for the success of EPNs.

It is important to note that a key factor for enabling non-energy based used cases is the fact that different EPN services can share ICT and other infrastructure. The benefits of the non-energy based use cases are generally not tangible and can be complex to assess (e.g. what is the value associated with finding parking space faster?), which complicates the justification of investments in enabling technologies. Nevertheless, if the enabling technologies are already in place (e.g. for the provision of other services), a non-energy based service can be provided without requiring significant additional investments (if any). Furthermore, if other services provided by the EPN are profitable, a share of the profits can be directed to the operation and maintenance of non-energy services[1].

2.1.2 EPN internal actors

Under the current vision of an EPN, its use cases and the associated application services, it can be concluded that the neighbourhood should be comprised of advanced ICT and automation infrastructure to monitor and optimise the performance of the EPN and provide services for the neighbourhood and external actors, end-users with flexible energy demand and DERs such as different forms of heat and electricity storage, small heat and power generation, and a Neighbourhood Energy Manager (NEM) that supervises the performance of the EPN, participates in the active management of the system when necessary (e.g. under emergency situations) and interacts with relevant actors (e.g. contracts new services and makes requests to policy makers). This is further elaborated below:

[1] The magnitude and allocation of profits and ownership of EPN infrastructure (i.e. actors that are likely to invest in underlying infrastructure) may vary under different market structures; thus it will not always be possible to use the profits to finance non-energy services. This will be further discussed in section 6.

- **ICT provider**: ICT will play a key role in the EPN by enabling communications between the EPN and relevant actors within and outside the neighbourhood, as well as to monitor signals (e.g. prices) required for the provision of energy and non-energy services. In this work, the interactions with the ICT provider are used to illustrate cases where investments in additional ICT infrastructure are needed for the provision of a system compared with the baseline scenario (See section 6.2.1).

- **Neighbourhood Energy Manager (NEM)**: The NEM is a proposed new role for an entity that manages energy and non-energy services for a single or for several neighbourhoods. While most of the neighbourhood control (e.g. energy consumption and generation) will be handled automatically via the COOPERaTE platform and associated services, the NEM takes a supervisory role as a human in the loop for handling unpredictable events and stakeholder management. The NEM may own and operate the platform, just operate it, or just take the role of a market operator within the EPN whereas ownership lies with (and related investments taken by) other actors (e.g. retailers, aggregators and existing neighbourhood actors) .

- **End-users**: The neighbourhood will comprise a wide variety of end-users including households, residential and commercial buildings and small businesses, among others. ICT will provide customers with information regarding their energy consumption and expenses, and signals from the NEM to encourage energy consumption changes (e.g. price signals, incentives or direct control). The flexibility of customers to modify their energy consumption and their response to different signals will vary based on their individual preferences, activities, socioeconomic level, and other factors. Thus, the NEM will require a portfolio of signals to maximise energy flexibility from the EPN while addressing each customer's circumstances.

- **Distributed energy storage (DES)**: Different energy storage technologies may be available within the neighbourhood, such as Electrical Energy Storage (EES) and Thermal Energy Storage (TES). EES from battery banks and other fixed infrastructure will be permanently within the EPN, whereas EES from mobile resources such as EV will only be available at certain times (e.g. at night). DES provides the options of storing surplus generation that can be used at times of generation shortages and/or store cheap energy that can be used or sell at times of high prices. The latter under the assumption that some form of time based price signal is available.

- **Distributed heat**: Heating, cooling and domestic hot water can be provided within the neighbourhood with Heat Pumps (HPs) that operate with either electricity or gas. Another popular technology is CHP, which produces both thermal (heat or cooling) and electrical energy in a single process. These technologies provide the option to meet heating requirements either by importing heat directly, importing gas or electricity for the HPs.

- **Distributed generation (DG)**: Small fuel based or renewable energy based DG can be installed throughout the neighbourhood. Gas based DG tends to be highly efficient and relatively environmentally friendly (i.e. low CO_2 emissions), and can be used by the EPN whenever the trade-off between electricity and gas prices is convenient. Renewable energy based DG (e.g. solar PV systems installed on rooftops) are not dependent on volatile prices but on an uncertain energy resource. The output of these resources has to be forecasted in order to facilitate the use of renewable energies in the management of the EPN (e.g. to ensure that surplus renewable energy can be exported or stored when needed).

The EPN will optimise its performance by coordinating proper actions from the aforementioned actors whenever technically and economically feasible. For example, during periods of high electricity prices, the EPN might decide to meet demand requirements by reducing energy consumption, using cheaper electricity from storage, generating power from DG, reducing HPs electricity consumption by using gas, or any other combinations. As a result, the EPN will have flexibility to meet internal energy requirements whereas following different criteria (e.g. costs and CO_2 minimisation and renewable energy use maximisation) and provide a wide range of services.

It is important to note that investments in underlying infrastructure would be required to establish an EPN. Key actors would have to incur the up-front costs (and related risks) of EPN enabling infrastructure. In exchange, these actors would likely retain ownership (and even control) of the infrastructure and/or require compensation from the neighbourhood platform (e.g. economic profits from the provision of services). Potential ownership and cost/benefit allocations under different market regulations will be further discussed in section 6.

2.2 External commodity markets

The framework of external market commodity markets is a key factor to enable the EPN concept. The market framework must properly acknowledge the benefits that EPNs can provide to the energy system (e.g. end-user cost reductions, CO_2 mitigation and services for other actors, among others) by offering tangible incentives (e.g. price signals and financial support) in exchange of relevant services[2].

Furthermore, as discussed previously, only after the EPN technology to enable tangible energy based services is in place, would non-energy services likely become economically viable. That is because it can be difficult for the NEM to justify investments in enabling infrastructure for services with non-tangible benefits such as parking space service, unless the investment is minimal. This might be the case when most underlying infrastructure has been placed previously for the provision of economically tractable services (e.g. energy based services).

This subsection reviews the generalities of markets in which the EPN, in its role as an energy source or service provider, might participate in.

2.2.1 The electricity power market

Traditionally, electricity trading has been conducted based on two premises. Firstly, electricity has to be produced and consumed in real time as large electricity storage is deemed economically unfeasible. Secondly, most electricity is generated far from zones of consumption and thus the power grid must transport large volumes of energy through long distances from the generation sites to the zones of consumption (transmission level) and distribute the energy throughout the zones (distribution level) (the EPN will be connected at this level).

[2] Services provided by EPNs must be more attractive than services facilitated by other means (e.g. less costly, and/or more reliable and environmentally friendly) for regulators to adjust the market framework to acknowledge the benefits of EPNs.

In accordance, in liberalised environments the power market has been designed for the trading of energy in advance (i.e. ensuring that enough energy is available when needed), availability of additional energy for contingency purposes (i.e. ensuring that any generation-consumption mismatch can be corrected), and ancillary services (providing energy related services such as voltage, capacity and frequency support and ensuring that all parts of the grid function as reliably, efficiently and economically as possible[3]).Additionally current markets have been designed to internalise costs of transmission and distribution (i.e. the price of electricity at the distribution level is higher than at the transmission level)[4] and "protect" end-users from price volatility (i.e. end-users perceive fixed price rates rather than real time prices). This market philosophy is optimum under traditional practices where all energy flows in one direction (i.e. from generation to consumption) and the demand side is not meant to participate in the management of the system. Both assumptions are not compatible with the EPN concept.

In practice, the electricity market comprises several markets for the trade of electrical energy and related service at different time periods. It would be impractical to describe all existing market structures as the specific characteristics of the markets vary in each country; nevertheless, a reasonable general description of key markets can be provided as presented below.

- **Wholesale market**: Traditionally, most energy is traded in advance in the wholesale market. Energy can be traded from several years in advance until gate closure (gate closure is 1 hour before delivery in the UK). This market is typically pool based, meaning that the market electricity price is set as a function of the prices and power offered by generation and retailers and it might consider network constraints at the transmission level (i.e. nodal prices). Alternatively, energy can be traded without regard for network constraints via unrestricted bilateral contracts as in the UK [4].

- **Balancing market**: The balancing market typically operates between gate closure and time of delivery and is managed by the system operator (the Transmission System Operator, TSO, takes this function in the UK). In this market, generators offer to increase or decrease their output and retailers offer to increase or decrease the consumption of their end-users if requested by the system operator for balancing the system.

- **Imbalance settlement:** Actors participating in the markets may not generate or consume the exact amount of power that they traded. These actors might be held responsible for introducing imbalances to the market (balancing responsible actors) and be penalised accordingly. Balancing penalties are calculated ex-post based on the position of the balancing responsible actors and the costs for balancing the market (these costs are taken from the balancing market). Settlement processes vary but often prices are designed such that actors are penalised for imbalances, providing an incentive to balance their position before delivery.

[3] It is important to note that not all ancillary services are market tender and some actors such as generators have the responsibility to provide certain services. For the case of the UK consult [3].

[4] Uses of system charges are applied for the use of the transmission network and the different levels of the distribution network, namely high, medium and low voltage. Thus, at any given time, an end-user connected to the low voltage distribution network will tend to pay more for energy than customers in the medium distribution network, and so on.

- **Ancillary service market**: This market is typically managed by the system operator, which is the single buyer, and it is used to trade ancillary services beyond the obligation of actors [3]. That is, actors that have fulfilled their ancillary service obligations with the system operator may trade additional services in the market.

- **Retail market**: This market exists whenever different retailers can supply customers in the same zone (e.g. single customers or aggregators). In this case, customers have the option to contract the supplier that best meet their needs (e.g. lower costs or renewable energies support[5]). As, retailers can make agreements directly with end-users, it is possible to have different retailers operating within the EPN.

In addition to the electricity markets, a conceptual **constraint management market** is considered in this work. This market would be managed by the distribution system operator (DSO) for the trading of energy services to meet constraints, increase reliability and relax reinforcement requirements at the distribution level, among other services. The introduction of this market is necessary to enable business cases in which the EPN sells services to the DSO.

2.2.2 The gas market

Gas, like electricity, is traded as a commodity in liberalised market environments. Like electricity it must be transmitted from the producer to the consumer through transmission and distribution networks. Also like electricity, security of service must be maintained by respecting certain constraints on the operation of the network. However, unlike the electricity sector, large scale storage is economically viable and the provision of balancing and ancillary services in the gas sector is not a critical issue in the short term.

Gas network pressure constraints, analogous to electricity network voltage constraints, are relatively relaxed. In fact, the ability to vary the network pressure (known as “linepack”) can be considered an inherent storage capability. As a result there is no need for balancing or ancillary services in the short term to ensure the security of the system (whereas an electricity system must be balanced on a timescale of seconds, gas networks are balanced on timescales ranging from one hour to one month [5]).

Similarly to the electricity market, the gas market comprises wholesale, balancing, ancillary and retail markets. Gas is traded in advance in a wholesale market to ensure it is available when needed. Unlike in the electricity market however there is no “gate closure” at which gas system users (known as shippers) must finalise their position. Instead shippers (who must balance their position or face penalties) continue to trade up until delivery to ensure a balanced position, competing with the gas system operator who is seeking to maintain system security. In the balancing market, shippers and the gas system operator can procure gas balancing services, in the form of buy/sell options. Often these services are procured bilaterally over the long-medium term, though there are some instances of shorter market based procurement [5]. The ancillary market is mainly used to trade a type of ancillary service from large industrial customers who accept interruptible contracts. These customers are curtailed at times of high stress if all balancing options have been

[5] When bilateral trading is possible, some retailers can make a compromise to secure a percentage of energy from renewable sources.

exhausted. The retail market allows customers to contract the retailer in their area that best meets their need.

In this report the gas markets are only addressed implicitly via interactions between the EPN and gas suppliers. This allows the deliverable to centre on the explicit interactions between the EPN and the different parts of the electricity market and underlying actors. There are three main reasons for this simplification. Firstly, EPNs are expected to actively trade (import and export) at the different levels of the electricity market, whereas mainly managing imports from the gas network. Exports for the gas network are deemed negligible. Secondly, the gas storage capacity of the EPN is low, meaning that the neighbourhood has little means to influence the gas balancing market. Finally, even in a case where there is a significant surplus of electricity that would enable the EPN to meet its full energy needs and there are the means to export gas back to the network, it would not make economic sense.

.

2.2.3 The heat market

Unlike electricity and gas, heat (in the form of hot water and sometimes steam) is not suited to transport over large networks due to the large losses experienced. Although such losses can be mitigated to enable city scale networks and heat sources several kilometres from their demand, most heat networks are much smaller. Currently there are more than 5000 district heating systems in Europe supplying more than 9% of total European heat demand [6], though penetration varies greatly by country. The localised nature of heat networks means that there are no common codes for organisation of heat markets (where markets exist, many heat networks operate as monopoly heat providers).

In principle, there can be a heat network supplying several EPNs. Thus, the rationale that EPNs can exploit trade-offs between heat and other energy vectors (e.g. gas and electricity) is considered from a conceptual perspective. This is further discussed in section 3.

2.2.4 Emissions and efficiency markets

Increasing concerns about environmental threats and energy demand growth have directed attention to the usage of energy, particularly to the associated efficiency and CO_2 footprint. Accordingly, several countries have developed emissions and efficiency markets or other mechanisms to incentivise energy efficiency improvements and/or CO_2 reductions. Emissions reductions and efficiency improvement mechanisms are closely related and may be mutually exclusive to avoid overlapping as energy efficiency improvements also result in CO_2 reductions. An example of this is the UK’s carbon reduction commitment energy efficiency scheme, which only targets efficiency improvements from actors that are not already covered by climate change agreements and the EU emissions trading system [7].

The use of markets for the trade of emission reductions or efficiency improvement (in the form of import energy reductions) certificates is meant to facilitate achieving the underlying objectives (e.g. binding targets at the national or European level) at the lowest cost. That is, actors that can reduce their CO_2 footprint and energy consumption at low costs are incentivised to obtain certificates that would be bought by actors who would otherwise incur significant costs to meet their mandatory targets. The CO_2/energy reduction targets, as well as the allocation of certificates are based on baselines set for each actor.

The baseline is a key factor for the success of the aforementioned markets, as it determines the magnitude of the emissions/energy savings achieved by each actor; thus the allocation of certificates. The baseline can be set static or dynamic. The estimation of the former is relatively simple as it can be based mainly on historical data, but the accuracy of such baseline can be low. Conversely, dynamic baselines are deemed to produce the best results but their estimation is complex, as the baseline has to be calculated periodically in consideration on factors that would affect underlying emissions/consumption (e.g. changes in environmental conditions, available technology and end-user behaviour, among others). In this regard, the information captured by the EPN platform should favour the use of dynamic baselines[6].

In Europe CO_2 is traded as a commodity by power stations and large industrial users in the EU emissions trading system. However, to reduce regulatory burden, installations with emissions less than 25000 tonnes CO_2 per year and (if combustion activities are taking place) a rated thermal input of 35 MW and hospitals are omitted from the scheme, given the implementation of equivalent measures [8]. Energy efficiency certificates can also be traded as commodities in some countries (e.g. Italy and France) by large actors such as Energy Service Companies (ESCos) and gas distributors [9].

Even though there are no emissions or efficiency markets for small applications, there are bespoke support schemes and obligations for small actors (e.g. at the household level) such as feed-in tariffs [10] and energy performance certificates [11]. These schemes incentivise or obliged small actors to invest in energy efficiency improvement mechanisms (e.g. insolation) or renewable generation systems (e.g. domestic PV systems). The use of these schemes instead of exposing the actors to the markets implies that small end-users are deemed unable or unwilling to handle price volatility from the markets (this is not the case for an EPN).

2.2.5 External actors

2.2.5.1 Existing external actors and associated roles

Based on the scope of this work, and the characteristics of the electricity, gas, heat, and emissions/efficiency markets, the external actors that will have a greater influence on the business of EPNs are:

- **Transmission System Operator**: The TSO is a regulated entity, who is responsible for the management and sometimes the development of the transmission grid and for the operation of most electricity markets (the TSO might own or only operate the network). TSOs provide physical access to the electricity market to different players (e.g. generators) according to non-discriminatory and transparent rules and might take the role of market operators. In addition, TSOs ensure the security of supply, safe operation and maintenance of the system and generation-consumption balance via services provided by different actors in accordance to the grid code or contracted in the balancing and ancillary markets [3]. The costs of buying balancing services are usually transferred to the parties who are unbalanced; whereas the costs of real-time balancing are typically transferred to end-users (the

[6] The subject of energy baselines is tackled specifically in work package 5

wholesale electricity price is increased by a Transmission Use of System, TUoS, charge).

- **Distribution System Operator**: The DSO is a regulated entity, who is responsible for the transport of the electrical power on the distribution networks (the distribution network is normally divided into high, medium and low voltage networks) between transmission and the end-users. Similarly to TSOs, DSOs provide physical access to the distribution network to end-users according to non-discriminatory and transparent rules. The DSOs are also in charge of the safe and economic operation of the network and for investments in new infrastructure. Distribution costs are externalised to end-users in the form of Distribution Use of System (DUoS) charges and connection charges. Although, depending on the characteristics of the end-users and regulation, the charges may be paid directly by end-users or by retailers (i.e. retailers represent small end-users).

- **Producers**: Bulk generation comprises traditional large generators connected to the transmission system, such as steam turbines, wind parks or big hydro plants. These generators can participate directly on the wholesale, balancing and ancillary markets. This type of generation tends to have an advantage in the wholesale market due to their economies of scale; although their fitness to participate on the balancing and ancillary markets depend on the generation technology (e.g. generation technologies with a slow and expensive response such as nuclear are not adequate to provide balancing or ancillary services).

- **Gas supplier**: The gas supplier is the only actor in the gas sector that is addressed in detail in this work. The main function of the gas supplier is to trade gas with end-users (e.g. the EPN). For this purpose the supplier has to either extract gas from the network or contract another actor that has the rights to extract gas from the network. Actors that can extract gas from the network (gas shippers) have to sign a contract with the gas system operator and are balancing responsible in the sense that they must ensure that the amount of gas they inject into or extract from the system balances with their contract.

- **ICT services provider**: ICT services providers deliver the communication infrastructure so that the EPN is able to communicate with, monitor and, if needed, control, DERs and DR. Depending on the terms of the contract between the NEM and active consumers, ICT services costs can all be borne by the aggregator or they can be shared between the aggregator and active consumers (ownership options will be reviewed in subsection 6.2.1).

- **Retailer**: The electricity retailer acts as an intermediate agent between the wholesale and balancing energy markets and end-users. The normal operation of the retailer involves buying energy from the wholesale market at a variable price and selling the energy to end-users at a fixed price (or through tariffs that change at different periods such as day and night), whilst being balancing responsible (i.e. getting penalised from consuming a different amount of power than contracted) and participating in the balancing market (i.e. changing consumption in response of balancing market requests).

Usually the retailer will sell energy to end-users on fixed rates, the retailers thus perceiving economic benefits from protecting customers from price variability.

- **Aggregator**: Aggregators act as intermediaries between small customers and other actors in the system who may wish to purchase the flexibility they offer. Their main function is to group large numbers of relatively small customers to create economies of scale in order that the flexibility available on the demand side can access relevant markets. The role of the aggregator is critical to enable the EPN concept; thus further discussion is provided below.

2.2.5.2 Alternative roles for aggregators, retailers and NEMs

Given the separation of roles from actors, it is possible for various actors to take the role of aggregators. This would have a significant impact on the business case of EPNs that would be commercially connected to aggregators.

If the role of an aggregator providing services to an EPN is to be fulfilled by an already existing actor, that actor would be one which already has a strong relationship with the EPN. That is, either the DSO (by virtue of its physical connection and likely role[7]) or the retailer (who already has a commercial relationship with the EPN) would take the role of aggregator. As the DSO, as a monopoly provider of access to the distribution network, is necessarily a regulated entity in liberalised power systems, it is unlikely to fulfil the role of aggregator[8]. The DSO would have to forego its current role to become an aggregator. Retailers on the other hand do not have impediments to take both a retailer and an aggregator role and indeed may be well placed to exploit the synergies available from providing energy from the centralised power system to the end-user whilst also providing flexibility services from the end-user to the power system.

Based on this, two base cases are defined for the aggregator role, namely retailer-aggregator and independent aggregator. The retailer-aggregator combines retail and aggregator roles. By doing so balance responsibility is held by the actor performing the aggregator role. The options for offering services are reduced here as the aggregator function of the retailer-aggregator will benefit the retailer function before offering services to other actors. The independent aggregator will sit apart from the electricity retailer. The EPN will have two interactions with the power system; the traditional purchasing of energy from the retailer and a new relationship with the independent aggregator through whom it sells flexibility. From this position it can exploit the resources of the EPN to partake in the various business cases defined, being free to offer services to any other actor. The combination of the aggregator role with some other role will be considered when appropriate but primary focus will be put on interactions in the commodity markets identified. It is critical to note that the independent aggregator may disturb the position of the retailer (i.e. introduce market imbalances) when it exploits the flexibility of the EPN. This effect will be captured and investigated.

It is important to note that the role of aggregator could also be fulfilled by new actors that are currently not active in the power system. This could include any actor with a strong relationship with EPNs (e.g. local government bodies, property developers, equipment manufacturers or facilities management companies) though there would be synergistic advantages for those actors which can exploit technical knowledge (equipment manufacturers) or existing ICT systems (facilities management

[7] The DSO might be in charge of the installation and operation of EPN enabling infrastructure such as smart meters.

[8] Regulated actors are forbidden to compete with non-regulated actors.

companies). Equally the aggregator role could be fulfilled by independent actors unrelated with the EPN. Such actors may focus on aggregation alone with responsibility stopping at the power system side of the meter, or they may exploit synergies that are enabled by additionally taking the role of an energy services provider. Such an actor may be termed an aggrESCo (concatenation of aggregator and Energy Services Company, ESCo) and could assume (through a contractual agreement) the responsibility for provision of certain energy services (e.g. heating), possibly through the assumption of an outsourced NEM role. Indeed if the NEM is willing to bear the costs (e.g. license and transaction costs) it could fulfil the aggregator role itself. Clearly there are many options for an aggregator that is not joined with some other energy system actor.

It is also important to note that an EPN may be achieved without central coordination of interaction with the power system (electricity purchasing and selling of flexibility). The NEM role may be reduced or eliminated if parties within the EPN retain/establish their own commercial relationships with retailers/aggregators. If there is demand for intra-EPN energy/flexibility markets the NEM may be the operator for such markets. Alternatively, if no intra-EPN markets are to exist, the NEM role may become peripheral with the concept of energy positivity being achieved through the direct interaction of parties within the EPN with various retailers and aggregators in the wider power system.

3 Business cases

Now that the characteristics of the EPN (e.g. use cases), its environment, and the main actors involved in the EPN business case have been defined, it is possible to define several potential business cases for the neighbourhood.

The business cases can be based on the EPN participation on a single or several commodity markets (detailed in section 2.2). Indeed, all these factors should be considered in order for the true economic value of the EPN to be discovered. The flexibility embedded in EPN makes it ideal to exploit trade-offs in different markets. This could either be through performing arbitrage between markets for the same commodity (e.g. shifting electricity usage from one period to another) or through switching the provision of some energy service (e.g. heating) from one energy vector to another (for example switching of heat provision from an electricity via an EHP to gas via a CHP unit or heat from a heat network).

The business cases detailed below are based on the primacy of economic criteria. However it is important to acknowledge that other criteria exist. For example it is possible to optimise the operation of an EPN with respect to CO_2 emission (minimisation of emissions), local resources utilisation (maximisation of their use) or utility (maximisation of the efficacy of energy services without regard for any other criteria). Indeed it is possible that operation may be optimised with respect to several criteria simultaneously through the allocation of weights to the competing objectives.[9]. However it is important to note that if value is placed on criteria other than economic criteria then it is generally true that the result will be sub-optimal economically.

In this work several business cases that are likely to be suited well to the features of an EPN have been identified. Given that most EPNs (and certainly the two test sites in the COOPERaTE project) are connected to electrical and gas networks and that opportunities for arbitrage and system service provision in the gas system are small (as discussed in section 2.2.2), the selected business cases focus on electrical power system. Nevertheless, it should be noted that no matter the primary focus of the business case, all markets must and shall be considered as the ability to switch interest from one energy market to another (i.e. electricity to gas) is a key factor (along with storage and service curtailment) which creates the flexibility of the EPN.

The business cases considered in this document are described in Table 1 below. In order that a comparison can be made between the value of energy and capacity service markets, two energy based services (i.e. BC1 and BC2, which relate to the optimisation use case, UC3) and two capacity based services (i.e. BC3 and BC4, which relate to the demand response use case, UC4) were identified. Additionally a mixed energy/information service business case (BC5, related to the parking use case, UC5) is described to illustrate the potential for synergies between energy and non-energy services.

[9] Although this work package offers some recommendations for the optimisation of the operation of EPNs, optimisation specifics and criteria will ultimately be determined in work package 2, namely "*Neighbourhood Power and Energy Management*".

Table 1: Overview of the investigated business cases

No.	Name	Short Description
BC1*	OPWM	Optimised Purchase of electricity on the Wholesale Market
BC2*	MIP	Minimise Imbalance Penalties
BC3*	DNCM	Distribution Network Constraint Management
BC4*	OR	Operating Reserve to the system operator
BC5*	Parking	Provision of an information based parking service

*BC: Business case.

3.1 Optimised Purchase on the Wholesale Market (OPWM) Business Case (BC1)

The principle of business case 1 is to *minimise the cost for the purchase of electricity for the EPN*. Purchase of energy for supply to end-users is by definition the responsibility of the retailer (or the actor taking this role). The retailer must try to purchase the electricity that its end-users (including the EPN) need in the wholesale market (e.g. through bilateral contracts often agreed years in advance, to day-ahead and intra-day markets) in order to avoid price volatility in the single-sided balancing mechanism and unfavourable prices in the imbalance settlement process.

If the retailer also takes the role of aggregator (i.e. retailer-aggregator), then *the retailer-aggregator may use the flexibility of the EPN in order to optimise the wholesale market purchase of electricity*. Conversely, if the retailer is not the aggregator, then the retailer may contract with the aggregator to provide such a service, or indeed an independent aggregator may seek profit by utilising EPN flexibility to play the market itself. Flexibility in such a case may be realised by using energy storage to shift electricity purchase from expensive to cheap periods, either by storing electricity in EES or using an EHP and TES to generate heat in advance of demand so that the EHP may avoid operation at times of high price. Also, it may be possible to switch heat provision from electrically driven plant to gas driven plant or to a heat network at times of high electricity price if the price difference makes this profitable.

It should be noted that demand for energy services, such as heating, which dictate the flexibility of the EPN are often not known ahead of time. Thus the effect of uncertainty can be substantial (especially if trading is on wholesale markets many months before delivery) and the *importance of adequate forecasting and optimisation methods become vital* for the viability of this business case.

3.2 Minimisation of Imbalance Penalties (MIP) Business Cases (BC2)

As already mentioned, all *balancing responsible parties (e.g. retailers and producers) are subject to unfavourable prices in the imbalance settlement process if consumption (or production) does not match their market position*. Whilst it is unlikely that a market could develop for the trading of energy to balance positions after gate closure (as this would undermine the balancing market and threaten the stability of the system) it is possible *that a retailer may use the flexibility of their customers (such as the EPN), or contract with an aggregator to utilise the flexibility of their customers, to avoid these unfavourable balancing prices*.

Although the MIP business case is conceptually very similar to BC1, both being essentially energy trading business cases, key differences exist. Firstly price variability is generally greater for imbalance prices. As the period of delivery is approached, the options for dealing with unexpected imbalances decrease as the amount of resources that can react at the required time scale dwindle. This presents an advantage to those balancing responsible parties which can call on flexible resources at short notice (e.g. EPNs). Secondly, whereas for BC1 the primary challenge laid in forecasting, the primary challenge for BC2 lies in control. This is because the uncertainty around physical consumption/production reduces as the time of delivery is approached and hence the shorter the lead time between the control action being instigated and realised, the greater the value.

3.3 Distribution Network Constraint Management (DNCM) Business Case (BC3)

The DNCM business case assesses the *use of flexibility to provide services to the DSO for management of the distribution network*. Such a service does not currently exist but could be considered analogous to services that TSOs procure for management of transmission constraints[10]. *BC3 is likely to become necessary as greater penetration of (potentially) flexible and responsive large loads (e.g. EHP and EV) and DG (e.g. CHP and PV) are likely to increase the net load and (given the lack of diversity in many of the resources for such technologies such as sunlight for PV and temperature for EHP) decrease the diversity of the resources*. These phenomena are likely to increase the need for active distribution network management (effectively transforming the DSO from simply a provider and maintainer of grid infrastructure to something more akin to a small TSO) that can be an economically attractive solution to distribution network voltage and capacity issues that may rise, for example, from high power injection into the network at times of high solar irradiation and low demand, and high power demand from the network brought about by the likely correlation of EV charging, EHP operation and residual electricity demand on deep winter early evenings.

The DNCM service is a capacity based service (rather than energy service) as it is meant to modify the capacity requirements of the distribution network by reducing the net load on network in the case of thermal limit constraints being reached (through an increase in DG or a reduction in electricity demand) or increase the net load in the case of voltage limits being reached (through a decrease in DG or an increase in electricity demand).

Typically, the provision of capacity services requires an availability payment to ensure the contracted level of power reduction/increase and a call payment. Capacity payments may be for any period during which the DSO deems the network susceptible to capacity related problems. These payments generally form the majority of the cash flow for the aggregator as the service is unlikely to be called often as it is linked to network extremes. The call of service will result in a net increase/decrease of energy and this is settled through a payment (to the aggregator or by the aggregator as appropriate) for the energy transaction.

The price in such a market will be set by the alternatives available to the DSO. Given that the service will be necessary to maintain the security of the distribution network, the price should be related to the value of lost load (which will occur if no action is

[10] EPNs could also provide a constraint management service to the TSO. The distribution network constraint management has been considered given the lack of competition on distribution networks for such a service and greater potential number of markets for such a service

taken) or the value of infrastructure upgrades (which must occur to avoid lost load if no DR is enacted). Both of these options are expected to be expensive in comparison to DNCM, thus BC3 is expected to be valuable, if indeed operational limits are threatened on the distribution network in question.

3.4 Operating Reserve (OR) Business Case (BC4)

The OR business case investigates the procurement of operating reserve by the system operator. Such a service is required by system operators so that they are able to correct drops in system frequency and thus maintain system stability. It is an established service and as such the market is mature.

The exact definition of OR varies by system (see [12]) but, generally speaking, it is a service that is available to system operators at timescales of seconds to minutes.

The OR service supplies additional real power from an increase in energy production or a decrease in demand on instruction from the system operator within specified timescales. Similarly to BC3, the system operator will pay an availability fee to ensure the contracted amount of power is available only for part of the day (at times of high demand when the likelihood of a service call increases and the cost of alternative action, through the balancing market, can be very costly). Again the availability fee is expected to be the main source of income for the service provider as the service is unlikely to be called often (around 50 times per year for the average provider in the UK), and an energy payment would also be made whenever the service is called.

3.5 Parking Business Case (BC5)

This business case is directly taken from the parking service use case (view section 2.1.1.2 for a description of the use case). *BC5 differs from the other business cases in the sense that its associated benefits are not tangible in existing markets.* Accordingly the parking business case would likely have to be financed directly by end-users or from profits associated to other business cases. In that regard, BC5 can be seen more as a non-tangible service that relies on direct financing or on other business cases than as a proper business case. Regardless, as the provision of non-energy services is deemed one of the key functionalities of EPNs, *BC5 is considered as a means to demonstrate how the mapping methodology can be applicable to non-energy based services.*

The parking service was selected particularly because the EV parking service most intuitively demonstrates the synergies between energy and information. For the mapping of the service, it is assumed that there are a number of parking spaces, some with EV charging capability. It is considered that a smart phone app is used for the communication and a database to store real-time parking space occupancy data. Based on the parking situation, a parking recommendation for a user is communicated under constraints such as user's intended destination, preferences regarding parking cost, EV charging capability or walking distance.

4 Mapping methodology

Now that the main actors involved in the business of EPNs have been identified and several business cases have been selected, the next target of this deliverable is to find a solution for the second question concerning the development of a CBA for EPNs, namely how can the multi-commodity flows between the EPN and other actors be captured?

Based on this work, the solution for the abovementioned question is the development of a flow mapping methodology which underpins the business case development for the identified use cases. This chapter outlines such a flow mapping methodology.

As shown in Figure 1, the strategic flow mapping is central to understanding how the value flows between actors (both within an EPN and in the wider power system) when various business cases are implemented. Firstly, these flows must be identified for base cases (external and internal to the EPN) for given inputs regarding the DERs available in the EPN and the nature of the power system. The base cases build the baseline for the strategic flow mapping onto which distinct business cases (marked in red) are applied. Secondly, the strategic flow mapping of the business cases is used to identify all relevant flows (particularly those different from the base case) and to later summarise them in an Interaction Matrix. The Interaction Matrix is a key feature of the business case modelling. It uses the exchanges identified in the value flow mappings to show in matrix form the exchanges between actors enabling quantification of the effect of business cases on the cash and commodity flows of all actors. This will be a most powerful tool in the investigation of the PN business cases as it enables full understanding of the effect of business cases on all actors in the highly networked environment of the power system.

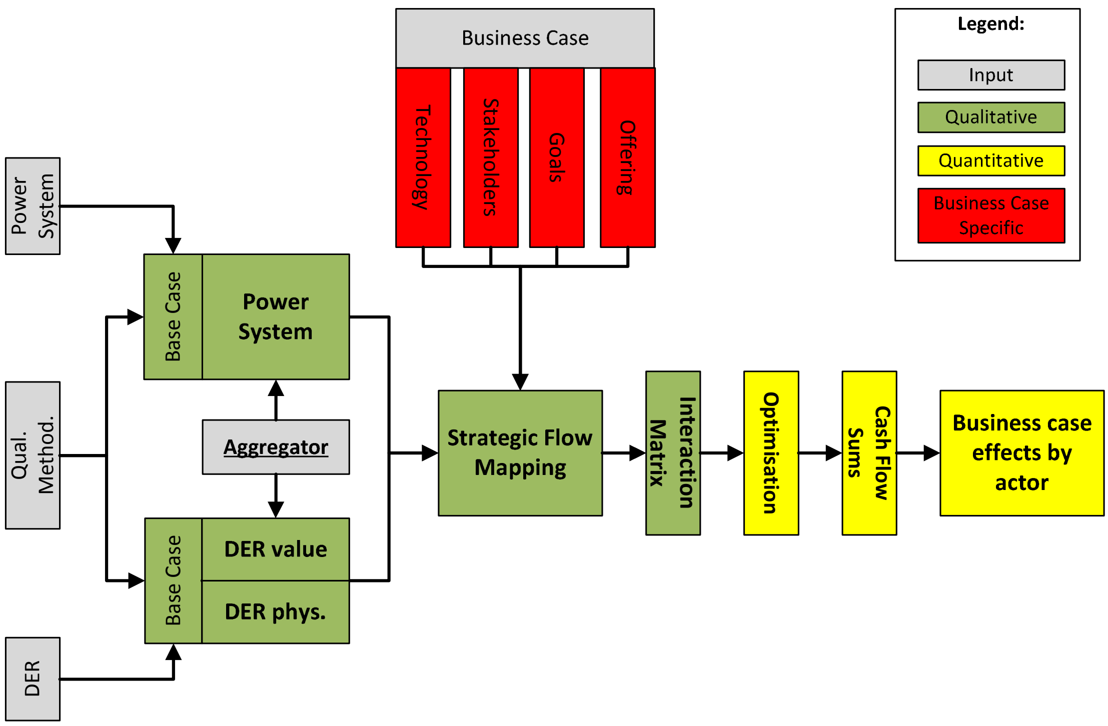


Figure 1: Overview of the strategic framework of the assessment

The stages presented in the rest of the strategic framework shown in the figure above (i.e. optimisation, cash flow sums and business case effects by actor) are beyond the scope of this deliverable. These stages will be addressed in the next deliverable (D6.2) and will involve a close collaboration with work package 2, which is the main work package responsible for defining the EPN optimisation specifications.

In the following subsections a thorough description of the value flow mapping methodology is given. As discussed in section 2, a distinction is made between internal and external EPN conditions. Afterwards, the formulation of the interaction matrix is described.

4.1 Value mapping

The foundation for the mapping methodology is the e3 value methodology. The e3 value methodology is an interdisciplinary methodology for the evaluation of business cases in highly networked environments with the objective of understanding the effects on all actors and to assess the business case profitability with respect to those actors [13]. A key aspect of the e3 methodology is the mapping of commodity and cash flows as exchanges; every commodity flow must have an associated remuneration.

The methodology describes business cases to a high level of detail utilising complex sets of ports, agents and triggering actions (stimuli). However, the level of detail may be considered excessive for strategic, practical assessment as the one presented in this report. Therefore, a simplified version of the value mappings is utilised in this work.

As in the e3 methodology, actors and their relevant roles are specified and the interactions between the actors are represented by the relevant exchanges of commodities and cash, see Figure 2. It is key to note that whilst the e3 methodology focused on exchanges related to the power system, here exchanges of all energy related commodities are mapped, which is an innovative development.

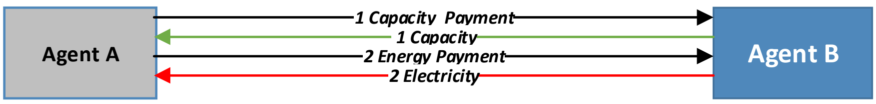


Figure 2: Generic value exchange mapping for flexibility business cases

This mapping framework has been developed for multi-commodity exchanges both outside (external EPN) and within (internal EPN) the neighbourhood.

4.2 External EPN environment mapping

4.2.1 External EPN environment actors/roles

The actors in the external EPN environment, namely external actors (view section 2.2) may take several roles simultaneously in related markets external to the EPN, which have to be clearly defined when creating the mappings. An example of this is the TSO, which can normally fulfil three different roles (see Figure 3).

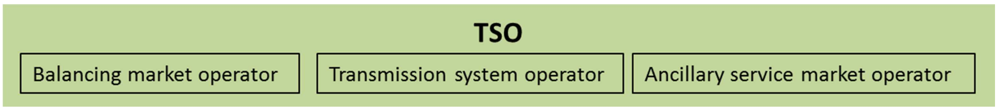


Figure 3: The TSO actor and its roles

For the sake of simplicity, a colour code is adopted for the representation of roles taken by relevant actors. As shown in Figure 4, roles are broken down into four groups. The EPN, represented by the NEM (orange), takes the role of the end-user. The aggregator (turquoise) manages the EPNs interactions. The role of other power system actors, who may be relevant (but not central) to the business cases of the EPN, are represented with the colour green. The role of the last actor, namely the generic ICT provider is presented with the colour pink.

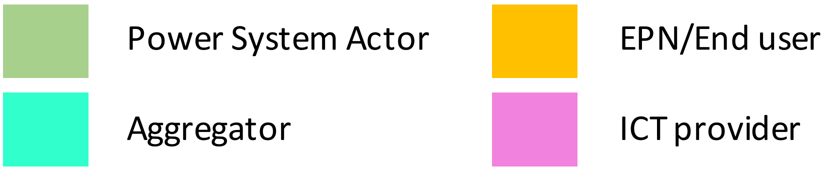


Figure 4: Representation of actors in the external EPN mapping

4.2.2 External EPN flows

The various flows between the external actors are represented with arrows of different colours as shown in Figure 5.

Figure 5: Representation of flow types in the external EPN mapping

In this list electricity and gas are tangible flows as the commodities are directly measurable from existing markets and the attendant cash flow can be simply calculated by applying a per unit cost. The remaining commodity flows are intangible. The flow could be guaranteeing access to a network to allow physical delivery of another commodity (grid access), guaranteeing the ability of that network to operate so that that commodity could be delivered (e.g. reliability) or be an option to enact the exchange of a commodity (flexibility option), among others. Within the intangible flows, a generic ICT flow is described. This flow could represent exchange of hardware or software and is necessary to provide the communications and information to enable the other exchanges.

4.3 Internal EPN mapping

Within the EPN the situation with regards to value mapping is more complex. Whereas outside the EPN value is traded through markets that are (generally) already established, the market frameworks which may underpin exchange of commodities within the EPN are not currently established. Hence the form of internal EPN value flow mapping will vary depending on frameworks investigated (see section 6.2 for discussion on possible frameworks). Below, in the next two subsections, two mapping methods for the EPN are described. The first is based upon the premise that all EPN resources trade as separate economic agents (thus the mapping is similar to the external EPN environment cases described above). The second focuses on the flow of commodities and may be a basis for distributing value between agents if the NEM implements the EPN concept through direct resource control rather than through a market approach. Both methods described assume trading of commodities is handled by the NEM. In practice each actor within the EPN may conduct its own trading with external actors. For simplicity the mapping methodology in this document shows only trading through the NEM, though all possibilities will be investigated in the relevant deliverables.

4.3.1 Internal EPN value flow mapping

Within the EPN, DERs are split into three sub categories: Demand, DG and DES (i.e. TES and EES). DES can be associated with a demand or generation unit or stand alone.

Assuming the DERs are economically independent actors then a value mapping methodology is needed to understand the flow of value around the system. An example is provided to illustrate the application of value flow mapping on a simple EPN (view Figure 6) under the premise that all trading within the EPN is conducted through markets (pool based) operated by the NEM. In this example, a CHP unit actor and a demand actor are shown. The different multi-commodity exchanges between the NEM and the actors are numbered from one to seven. The CHP unit must purchase primary energy (gas, exchange 1) from the NEM in order to produce heat and electricity which it sells back to the NEM (exchange 2 and 5). The flexibility available from the CHP (enhanced through the use of the associated TES), which can be sold to the NEM, is represented by exchange 4. The demand unit purchases electricity and heat through the NEM (exchanges 6 and 7). The demand unit also has the capability to sell flexibility to the NEM both through shifting/curtailing demand for electricity and heat and through exploiting flexibility in the associated TES.

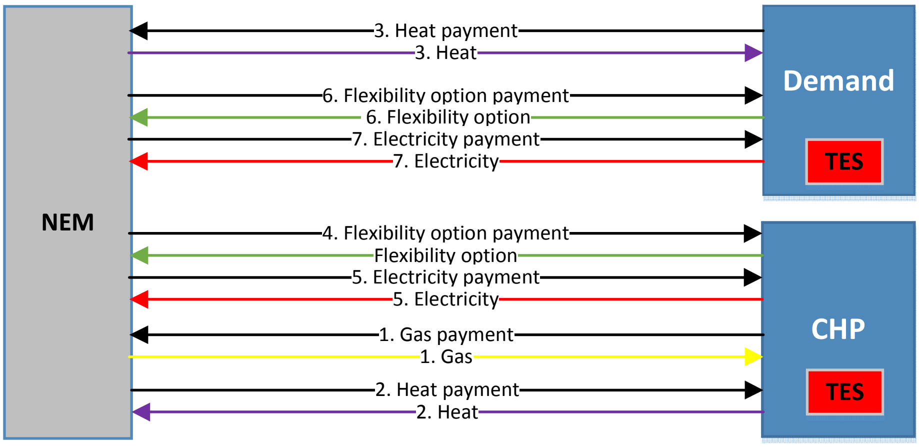


Figure 6: Example of value flow mapping of the EPN System

4.3.2 Internal EPN physical mapping

The physical mapping of the EPN allows visualisation of commodity flows around the EPN. Besides being useful for information, it is also necessary for the determination of methods by which any benefits/costs may be returned to the proper actors within the EPN or to the NEM in case the NEM manages the EPN via direct control and is responsible for distribution wealth and costs within the neighbourhood.

Here explanation of the physical mapping is given through consideration of the three types of actors within the EPN, namely: the NEM, central DERs (which are un-associated with any demand) and end-users (demand, with varying degrees of flexibility). Under the assumption that the NEM is responsible for all commodity flows entering the EPN (though other arrangements are possible) Figure 7 shows the NEM actor. The commodities being considered will vary case by case but in general these will include electricity (flow 2), gas (flow 3), flexibility (flow 4), CO_2 (flow 5) and heat (flow 6). Cash flow, associated with the exchange of various commodities, is also shown (flow 1).

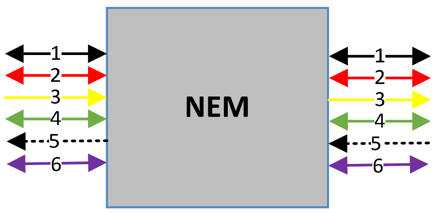


Figure 7: NEM physical mapping

Regarding central DERs (DG or storage), the inputs and outputs associated to each technology are mapped. For example, an element with single inputs and outputs, such as an individual DG are described as simple black boxes with inputs and outputs, whereas an element with multiple inputs and outputs, such as a CHP with heat, electricity gas and CO_2 is presented with more complex flows as shown in Figure 8.

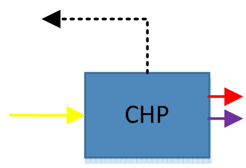


Figure 8: CHP physical mapping

For the end-users' energy consumption (Figure 9), demand is differentiated by electricity (W) (such as for electrical appliances), heat (Q) (such as for hot water) and combined demand (W+Q) (such as for a washing machine). The type of flexibility of different loads can be modelled using flexibility classes (n) where a zero denotes a non-flexible load and higher index values (e.g. 1) denote increasingly flexible classes of loads. For example, computer equipment may be considered non-flexible, lighting may be considered to have limited flexibility (it may be acceptable to reduce it for a period of time) and an EHP may be considered to be very flexible.

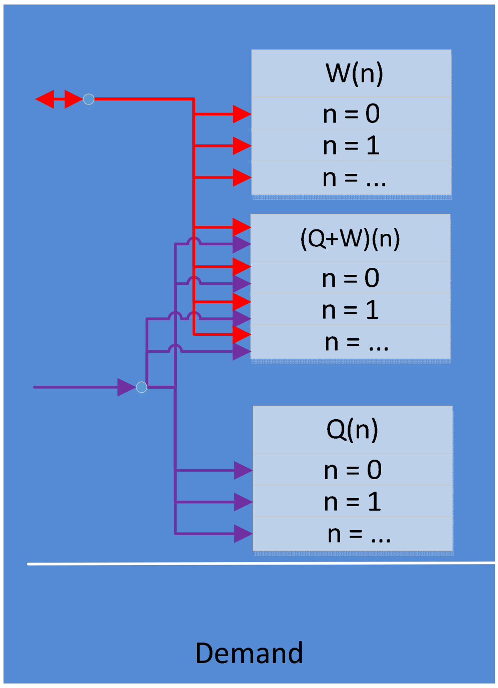


Figure 9: Demand physical mapping

4.4 Interaction matrix

Although flow mapping is a comprehensive visual approach, limitations exist on the direct extraction of information and communication of the results, owing to the large amount of interconnections. For each business case the interactions between actors can be mapped using a matrix informed by the flow mapping (interaction matrix).

In the interaction matrix, the type of commodity being exchanged (from actor A on the left to actor B along the top) is denoted. Such a matrix is shown in Table 2. The presence of exchanges is shown by a blacked out square, but in practice the value of the exchange or the amount of exchange (for tangible commodities) would be shown instead.

Table 2: Interaction matrix

Sum of cash		Actor 2	Payment						
		Retailer - Aggregator					TSO	EPN	
Actor 1	Good/Service	BSUoS fee	DUoS fee	Payment for electricity	TUoS fee	Payment for gas	Payment for electricity	Payment for electricity	Payment for gas
DSO	Distribution network operation and maintenance								
Producer	Electricity (BM market)								
	Electricity (wholesale market)								
	Electricity (imbalance market)								
Retailer-Aggregator	Electricity (BM market)								
	Electricity (retail market)								
	Electricity (imbalance market)								
	Gas								
TSO	Balanced system								
	Transmission network operation and maintenance								
Gas supplier	Gas								

5 Results

5.1 Base cases mapping

As previously discussed, in order to measure the effect of a business case, the flows associated with the business case must be contrasted to those associated with a base case. The base cases have been defined for both external and internal EPN conditions.

5.1.1 External EPN base case

The external EPN base case is used as a reference scenario to which the various business cases can be compared to. The base case shows the arrangement of the actors that are related to the provision of electrical energy and gas to end-users (heat is excluded at this stage given the lack of standard trading arrangements, where heat networks exist). The map showing these actors and their interaction is given in Figure 10.

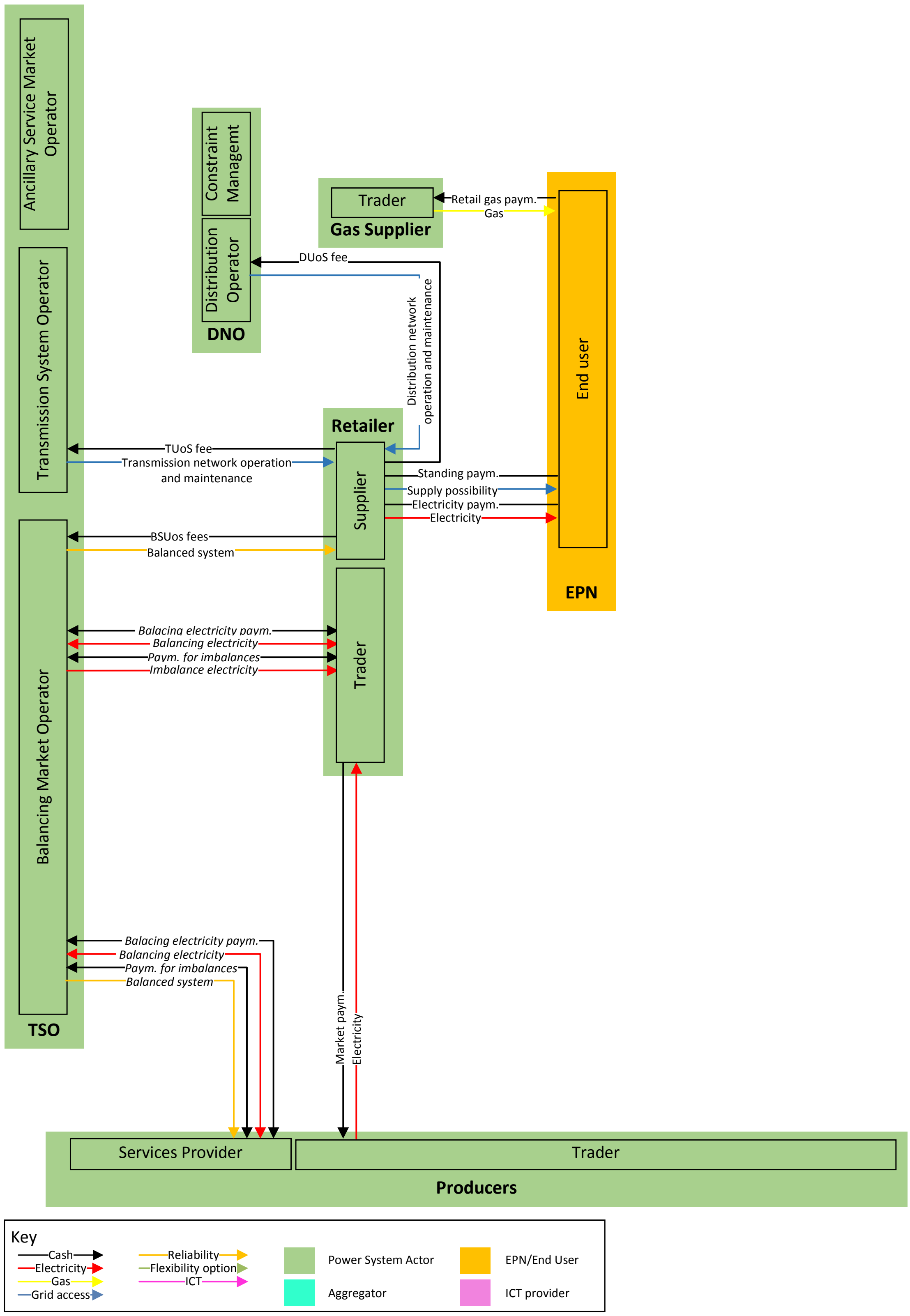


Figure 10: Current market case.

5.1.2 Internal EPN Base Case

Two internal EPN base cases are described (one for value flows and a second one for physical flows).

5.1.2.1 Mapping of the Value Flow Base Case for the EPN

Three types of actors are considered for the value flow mapping of the internal EPN case, namely end-users (including flexible and non-flexible demand), DG and storage actors. In addition, both end-users and DG may incorporate DES, as shown in Figure 11.

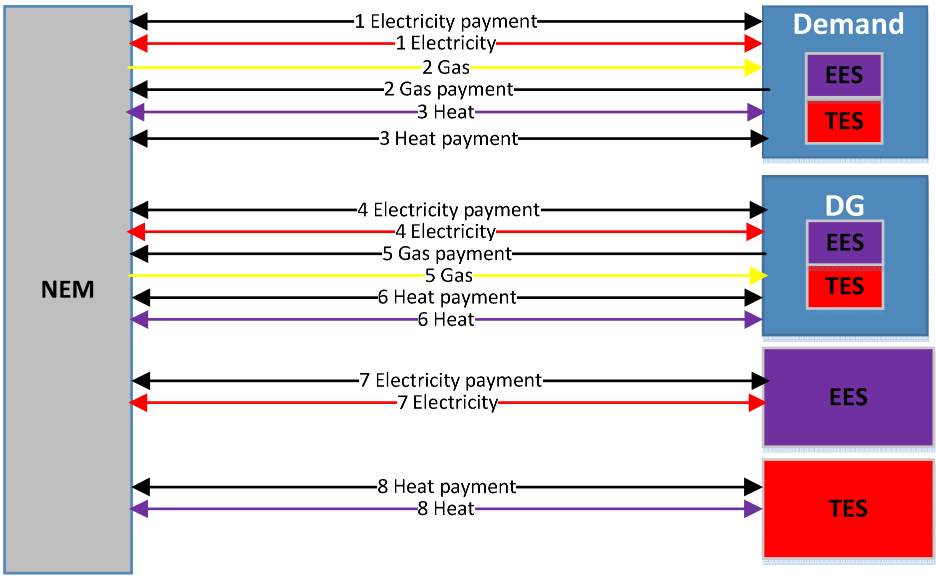


Figure 11: Value flow mapping of the EPN System

Given that management responsibility in the EPN is assumed to be delegated to the NEM, a pool based system is used with all flows passing to or from the NEM.

5.1.2.2 Mapping of the Physical Base Case for the EPN

The physical base case attempts to demonstrate the various types of physical actors that may lie in the EPN and the physical commodity flows that may occur between them. Also shown are the information flows around the EPN which are required to facilitate intelligent operation.

In contrast to the more generic value flow mapping, the physical base case considers the main energy and information flows for the EPN (Figure 12). It is a graphical approach to show the different types of DERs and their interactions that can be found within the system. Through the mapping, the source of flexibility which constitutes the resource is located. The energy flows that contribute to the provision of the flexibility can be identified. Distinction is made between DERs that are attached to some end-user and central DERs due to the differing behaviour of such actors if they primarily exist to serve one end-user.

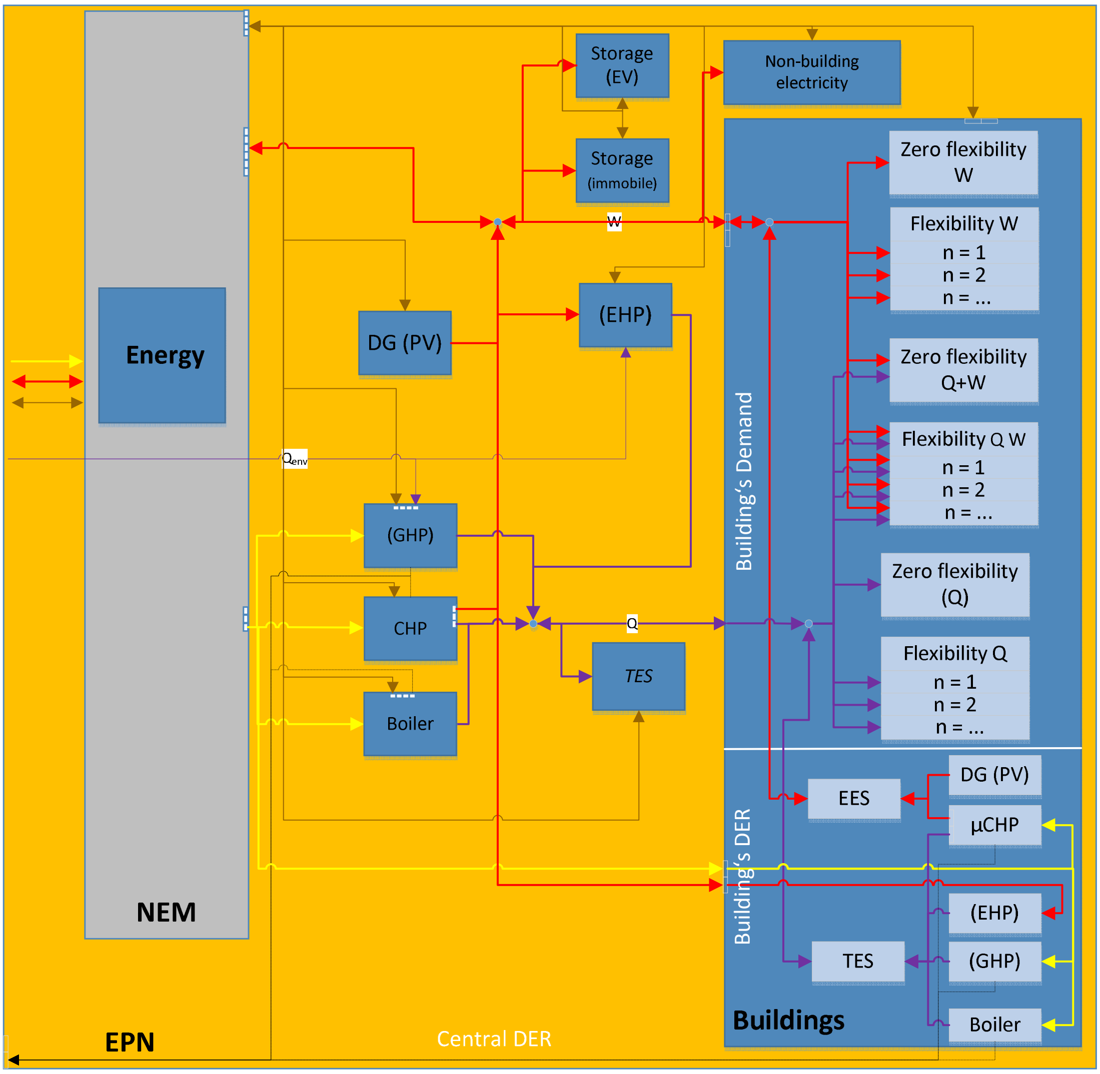


Figure 12: Example physical base case flow mapping of EPN

5.2 Business cases mapping

Now that the base cases have been determined, the different business cases can be mapped, as shown in the following subsections. For each business case the value flow mapping is defined for a retailer-aggregator case, in which one actor supplies energy and access to markets in which the flexibility can be exploited, and an independent aggregator case, in which separate actors supply energy (the retailer) and flexibility market access (the aggregator). In the evaluation of these business cases interaction matrices (see section 4.4) will be used to map the quantities (of cash and commodities) that flow between actors. The interaction matrices are not included at this stage, as their efficacy is currently limited because the quantification of the business cases is not included in this deliverable (i.e. the matrices rely on the quantification of the business case to provide relevant values).

Moreover, the ICT provider actor and associated flows are shown in all business case mappings. Additional ICT flows indicate that power system actors need to adopt extra ICT software/hardware.

5.2.1 Optimised Purchase on the Wholesale Market (BC1)

Below Figure 13 shows the mapping for the OPWM business case for the independent aggregator case. Flows that appear in addition to the base case are shown in bold. The basis of this business case is that the aggregator trades energy with the power system actors which take part in the wholesale market (e.g. retailers and producers) by utilising the flexibility in the EPN. The trading may not disturb the profile of energy bought by the EPN from the retailer if that condition is required. If the profile is disturbed however, any detriment may be compensated through the exchange between the aggregator and retailer.

Figure 14 shows the business case for the retailer-aggregator case. The combination of the retailer and aggregator roles means that there are two exchanges of electricity between the retailer-aggregator and the EPN. This may appear odd but is necessary to maintain separation between the supply of electricity and the trading of flexibility. The combination of the retailer and aggregator roles is also interesting as any imbalance caused to the retailer's position through trading of flexibility is now internal to that actor, rather than causing conflict between two separate actors.

Note also that there are two trading flows between the retailer aggregator actor and the producer actor. In practice the retailer aggregator would not conduct two exchanges but the exchanges remain separate here to illustrate the separate roles.

As with all the power system related business cases, it is important to acknowledge the indirect effects actions can have. For example if the aggregator purchases electricity differently in comparison to the base case, the value exchanges between the aggregator and the TSO and the DSO can be affected as well. This phenomenon is illustrated by the following example.

If the aggregator increases its electricity purchase in one settlement period to avoid the purchase of expensive electricity at peak times, the peak power consumption of the aggregator is likely to reduce. This can have an influence on the DUoS and TUoS fees as the methodologies for calculating these fees are usually based on peak demand.

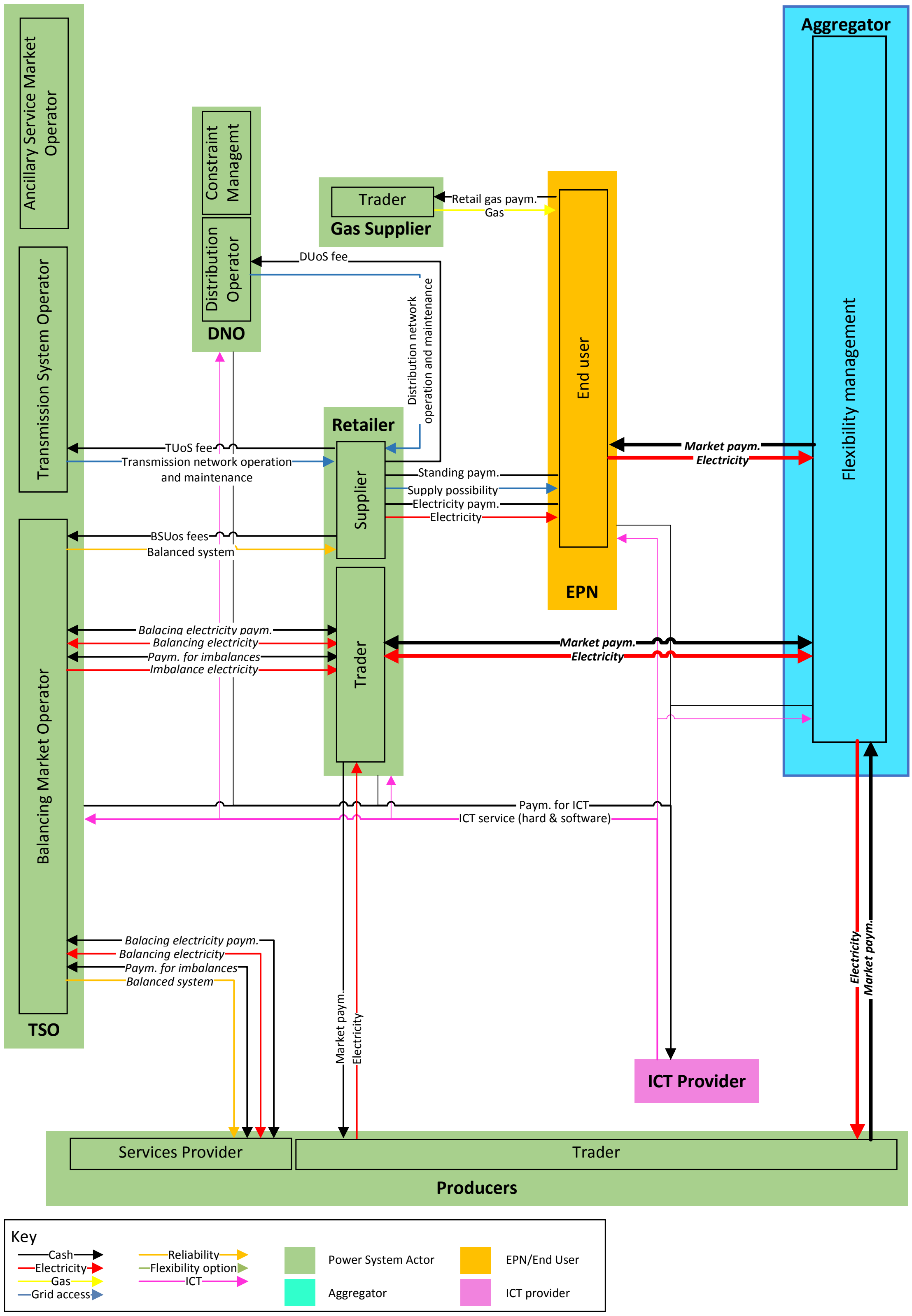


Figure 13: Independent aggregator case mapping for BC1

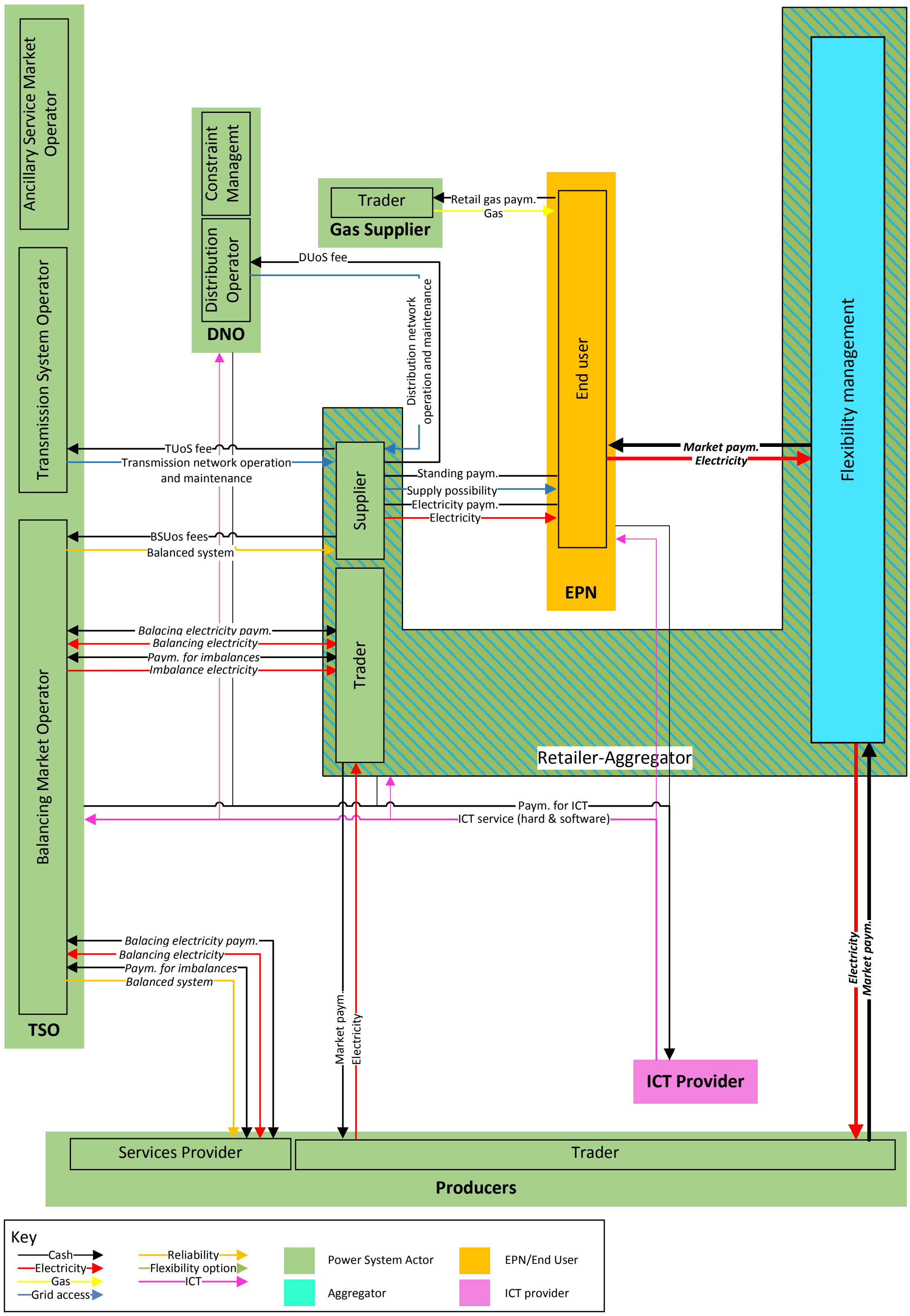


Figure 14: Independent aggregator case for BC1

5.2.2 Minimisation of Imbalance Penalties Business Cases (BC2)

Figure 15 shows BC2 for the independent aggregator case. It is assumed that the retailer could contract with a separate party (the aggregator) in order to balance its own position (as this business case is useful for balancing responsible parties). It may well be that an aggregator may have to have an exclusive relationship with a balancing responsible party in order that instability is not introduced into the balancing process. This will be investigated and all realistic scenarios considered.

Figure 16 shows BC2 for the retailer-aggregator case. Note that, as with BC1, there are duplicated flows between the retailer-aggregator actor and another actor (the TSO). In practice the net exchange would be of interest, though the two sets are shown here to illustrate fully the business case.

5.2.3 Distribution Network Constraint Management Business Case (BC3)

Below the value flow mapping for the independent aggregator case is shown in Figure 17. Figure 18 shows the value flow mapping for BC3 for the retailer-aggregator case with the primary exchange highlighted in bold lettering.

Indirect consequences of this business case that will be captured by the flow mapping are likely to be on wholesale energy and imbalance penalty payments. If the DNCM service is called before gate closure the indirect effect may be to reduce power purchase at the time of the service call (if the call is to reduce consumption). This may result in a net reduction in energy costs as the time of the service call is likely to coincide with periods of high energy prices. If the call is near real time the aggregator may be forced to buy/sell on the ex-post imbalance market. As trading in this market often carries penalties this is more likely to result in an increase in overall energy costs. Of course in both cases the indirect effect may in fact be that the NEM increases on-site power production. The decision will be dependent on the outcome of the optimisation and the objective of that optimisation (e.g. energy minimisation, cost minimisation, among others).

5.2.4 Operating Reserve Business Case (BC4)

Figure 19 shows the mapping for the independent aggregator case and Figure 20 shows the value flow mapping for the retailer-aggregator case.

Indirect consequences of this business case are again likely to relate to changes to wholesale energy purchases, imbalance penalty payments or self-production scheduling. It is uncertain whether the indirect effects are likely to be beneficial or not to the aggregator as calls for operating reserve are not tightly correlated with demand. Thus it is possible that energy payback (if that occurs) may occur at times of high price so that the aggregator suffers an indirect dis-benefit (insofar as energy costs are concerned), though of course this may be beneficial for other market actors.

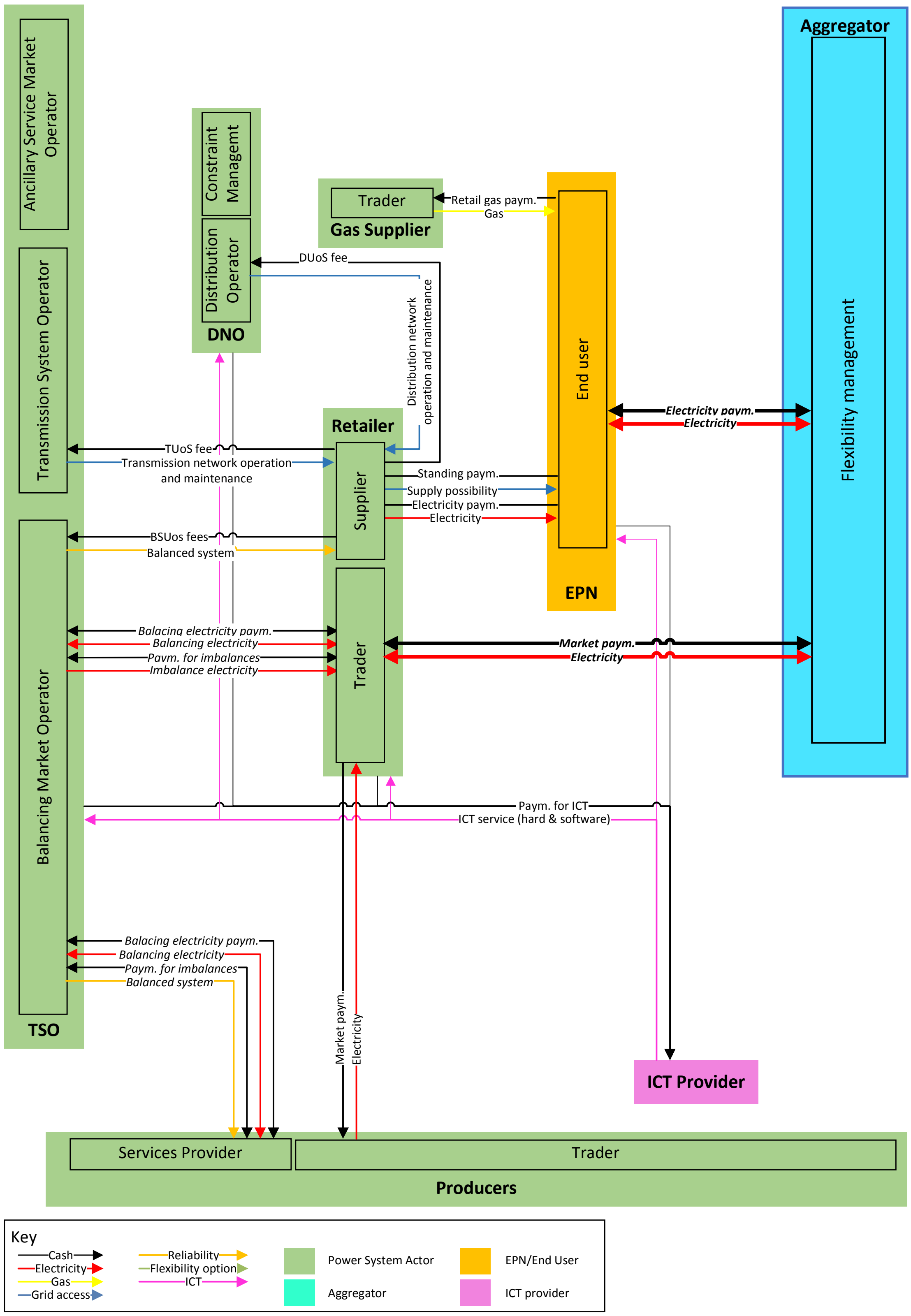


Figure 15: Independent-aggregator business case for BC2

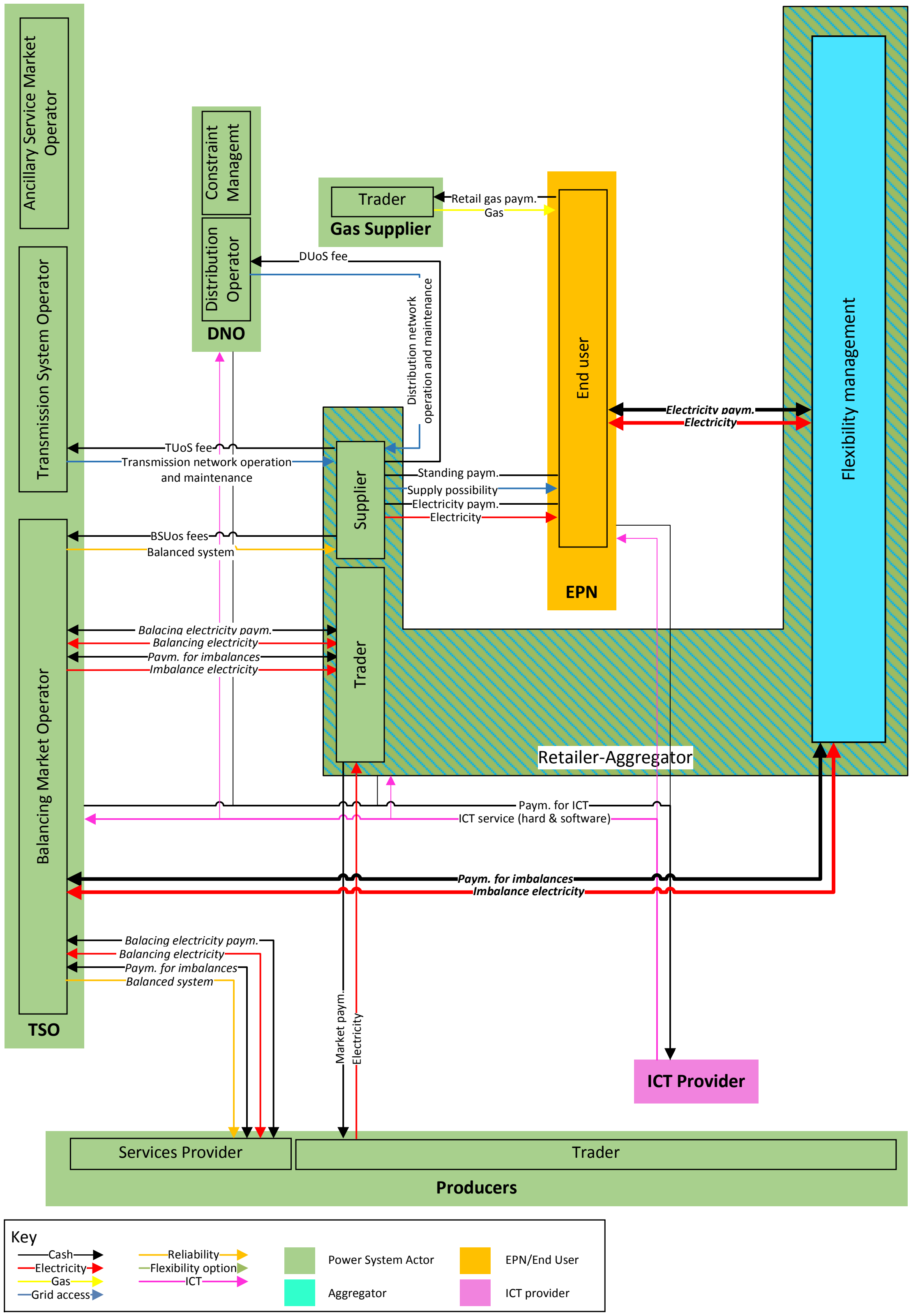


Figure 16: Retailer-aggregator business case for BC2

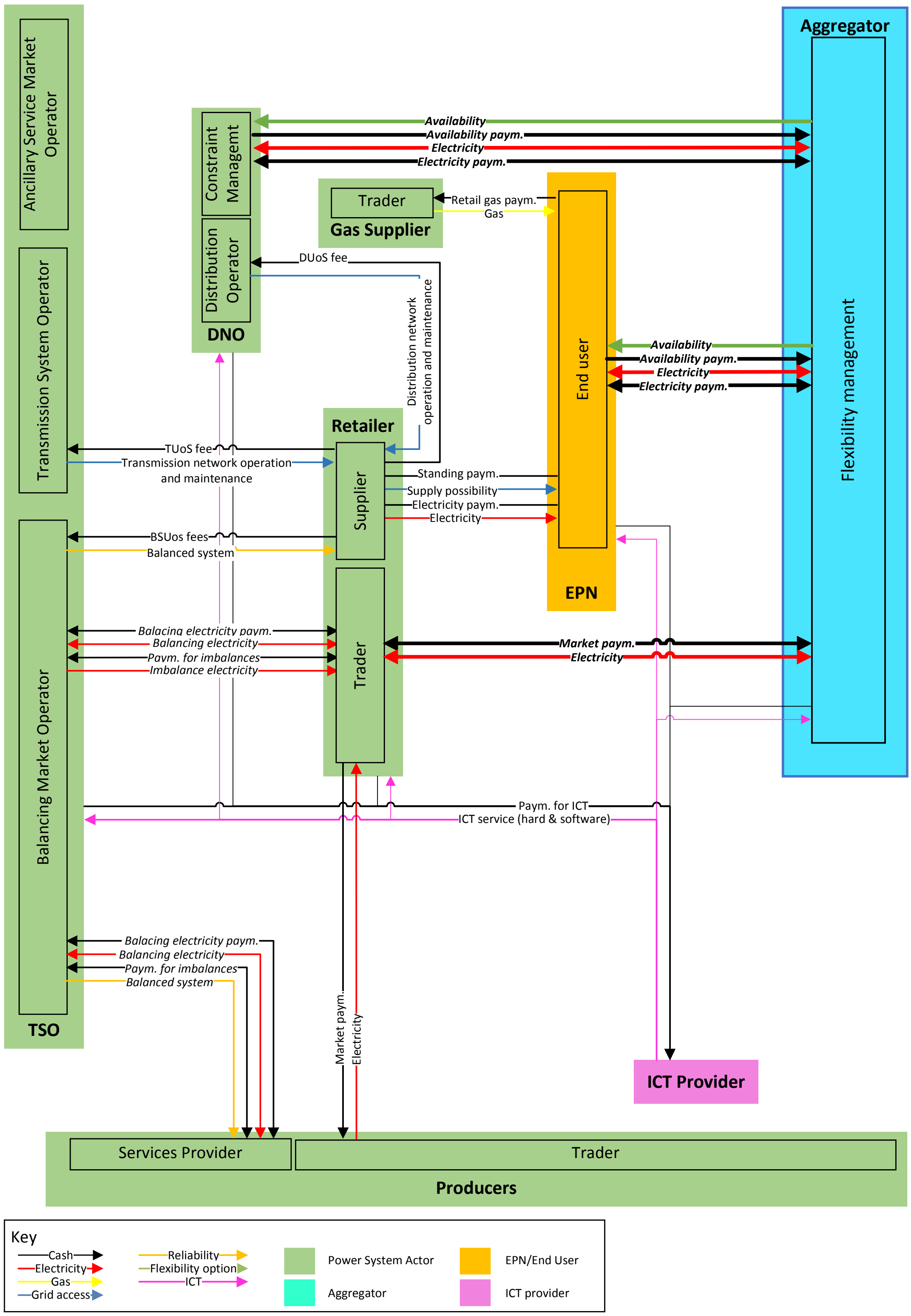


Figure 17: Independent aggregator case mapping for BC3

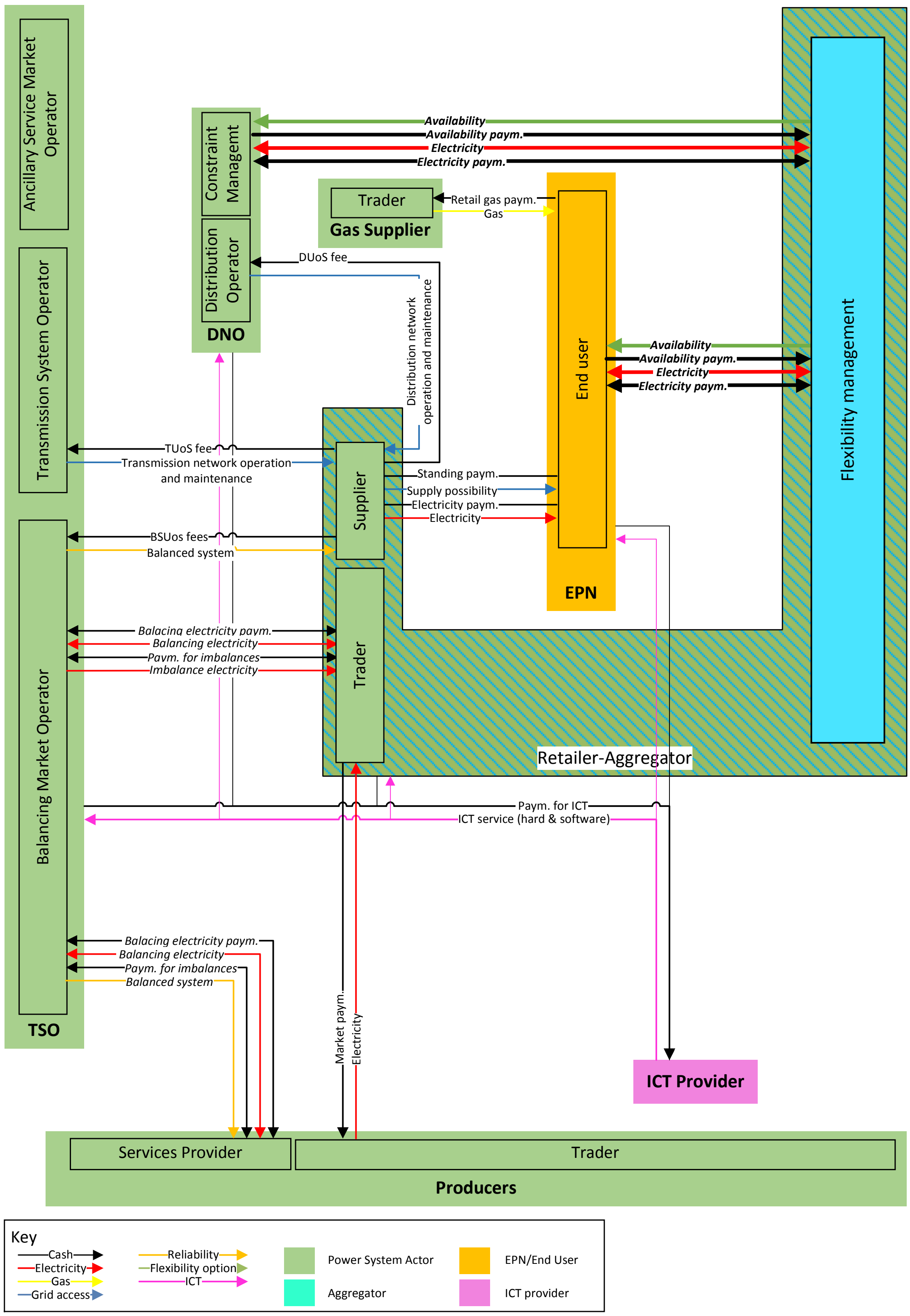


Figure 18: Retailer-aggregator case mapping for BC3

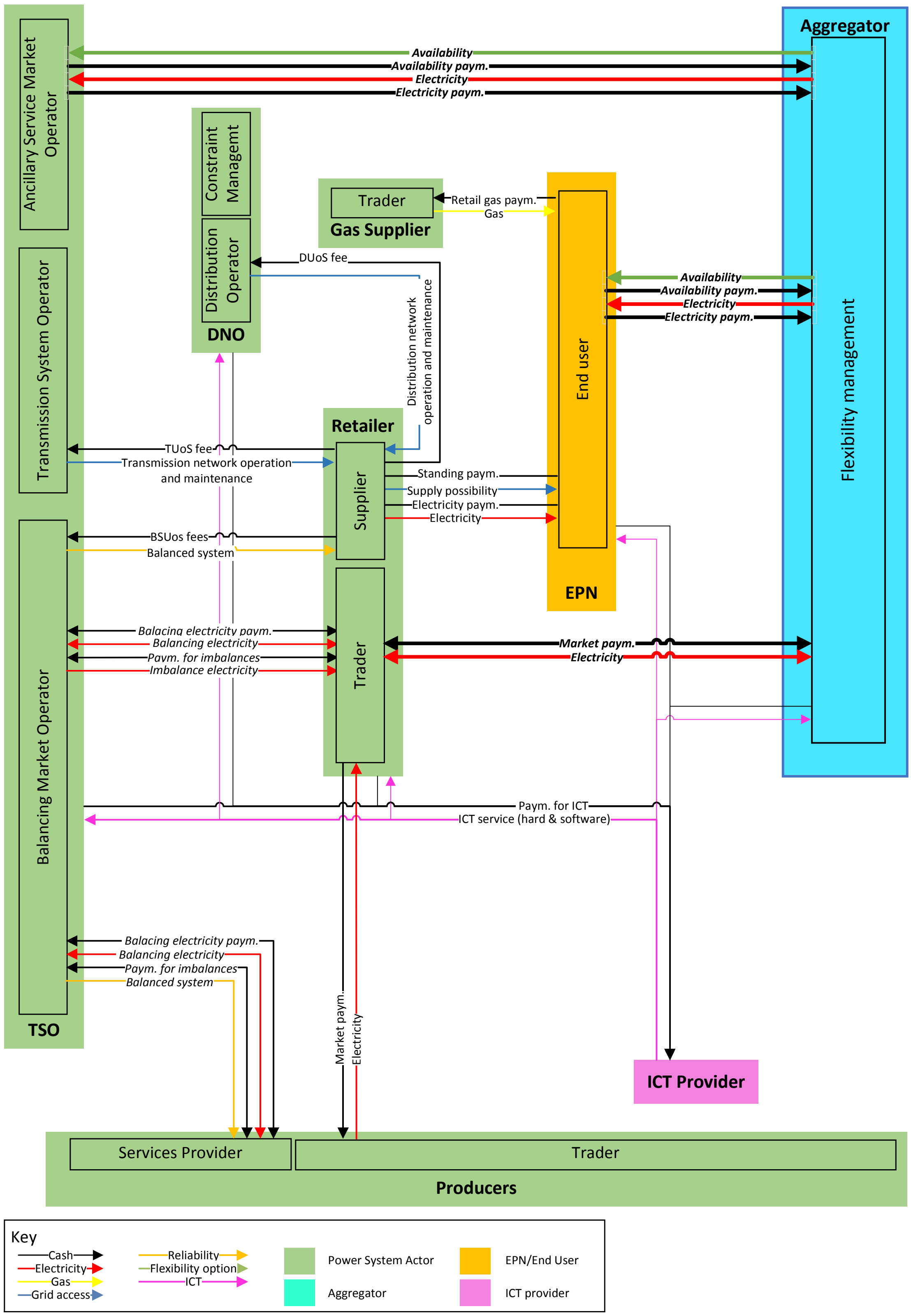


Figure 19: Independent aggregator case mapping for BC4

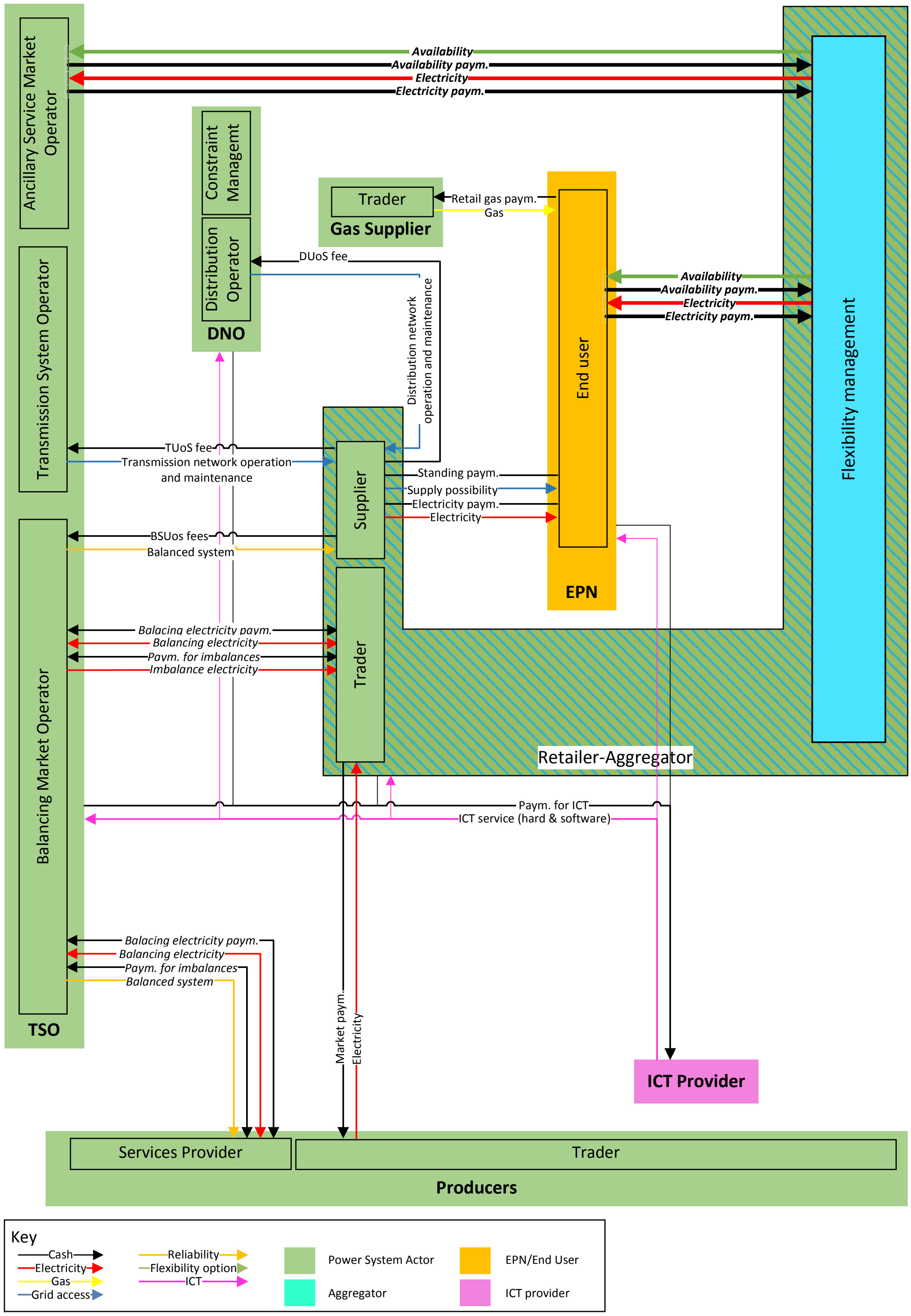


Figure 20: Retailer-aggregator case mapping for BC4

5.2.5 Parking Business Case (BC5)

In Figure 21 a possible mapping of the parking service is given. The brown arrows indicate flows of information and the red electricity. The green boxes relate to actors relevant to the parking use case, the blue to energy storage, the pink to ICT resources and the black box indicate the user interactions.

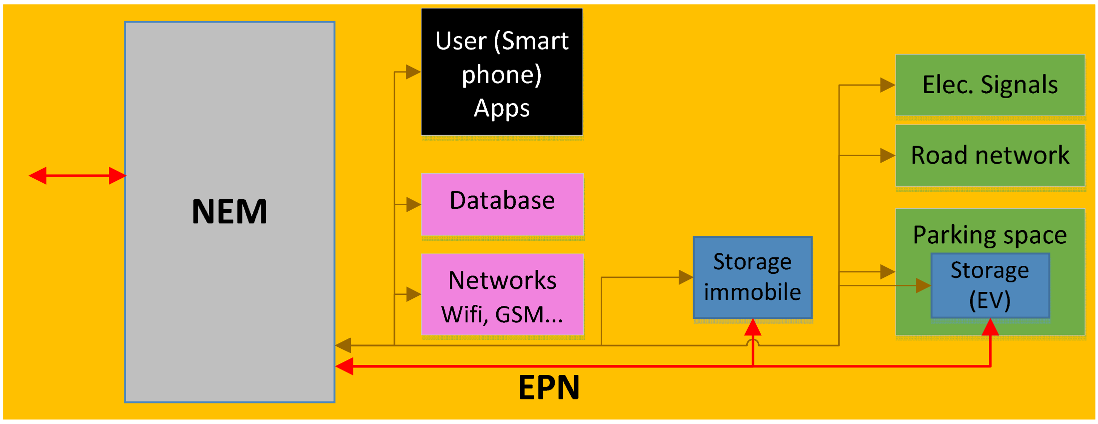


Figure 21: Mapping of parking service business

6 Market frameworks

Now that the CBA has been defined in terms of underlying actors and the proper methodology to capture relevant multi-commodity flows has been outlined, the next and final target of this deliverable is to find a solution for the third question posed in this work, namely what is the potential impact of different market frameworks on the business case of EPNs and other actors?

Accordingly, this section has as a main objective a discussion on the potential impact of different market frameworks on the business case of EPNs and other actors. The following subsections explore different potential market frameworks for both external and internal EPN market environments. That is, between external market structures that dictate the process by which value and costs are created by the EPN from the global welfare perspective (e.g. economic, technical and environmental), and internal market structures that determine which actors should invest in underlying infrastructure and the process by which the EPN allocates value among its internal actors. The implications associated with the market structures for the EPN as well as for other actors and the markets are discussed throughout this section.

6.1 External market frameworks

A market framework is the basis to incentivise actors into performing actions (or providing services) that are deemed beneficial and to discourage actions that are regarded as negative. The perception of beneficial and negative actions is typically based on the perspective of the market, the physical system (e.g. power grid), other actors and general welfare, among other perspectives (e.g. complexity to manage the services, society and the environment). Clearly, market frameworks would only be modified by policy makers and regulators to incentivise particular services from a given actor (e.g. an EPN) after it is proven that the underlying services are more attractive (e.g. economically efficient and/or environmentally acceptable) than equivalent services provided by other actors. Nevertheless, even if the benefits from EPN services are proven and EPNs are to be adopted on a large scale, identifying proper market frameworks to both incentivise the use of services from the neighbourhoods and to maintain the efficient operation of the multi-commodity markets is a daunting task. Different feasible market structures must be explored to identify the best transaction schemes for the EPN, other actors and the overall markets.

Different external market structure variations that may impact the business case for EPNs are reviewed. For such purpose, it is imperative to identify to understand the key features of an EPN (with regards to the services it might provide), how current market frameworks acknowledge or disregard these features, and how market structure changes would improve or deter the acknowledgement of these key features.

6.1.1 Key Features of an EPN

The primary features of an EPN are its small scale (i.e. compared to retailers, large customers and other external market actors), its location on the distribution network, and, given appropriate ICT, its flexibility and responsiveness (given intelligent utilisation of internal resources such as DR and DERs to manage trade-offs between different energy vectors and services in various markets).

The small scale of the EPN is an important feature as it places the EPN at a disadvantage in markets where it is in direct competition with bulk generation. For example the EPN would be at a disadvantage if it were to compete against other actors that benefit from economy of scale on the basis of energy costs alone during off-peak periods (e.g. if DG from the EPN is to be traded on the wholesale and balancing markets).

The location of EPNs on distribution networks mean that they are ideally located to trade services at the distribution level and to support the distribution network (and, to a lesser degree, support the transmission grids). On the other hand, the EPNs can have negative effects on the business of DSOs. EPNs can provide services to other actors connected at the distribution (and transmission) level. Services traded at the distribution level would avoid the use of the transmission network and parts of the distribution network (avoiding associated TUoS and DUoS charges), thus sparing the networks from additional burden. In addition, DR and DG can be utilised to relax network capacity constraints at both transmission and distribution levels (this was illustrated in the business cases discussed in section 3.3 and 3.4). However, EPNs can cause negative effects for DSOs, particularly in the absence of a market (or another scheme) in which the neighbourhood can sell services to the DSO. Due to its nature, the EPN will reduce use of the electricity grid (e.g. by improving energy efficiency and supplying energy needs with local resources, among others) and thus, reduced DUoS charges for the DSO. This drawback from the DSO's perspective could be overlooked if the EPN can trade services for the distribution grid that would reduce costs for the DSO. Nevertheless, in the absence of a market or proper regulation that incentivises the EPN to meet support the distribution network, the operation of the EPN could result in additional costs for the DSO. For example, the normal operation of the neighbourhood could result in the introduction of energy flows (e.g. excess DG at times of low demand) that could cause network issues (e.g. voltage problems) and lead to costly distribution network reinforcements.

The flexibility and responsiveness of the EPN brought about by automation and availability of different technologies (i.e. ICT and DERs) and energy sources (i.e. electricity, gas and heat) allows the neighbourhood to optimise its performance based on different criteria, particularly if the EPN is allowed a fair participation in the different markets. This would allow the EPN to support different objectives set by the market structure, such as (i) reduction of generation costs by storing power during periods of low cost and releasing it during peak time (this is particularly viable with large storage capabilities and if peak time in the neighbourhood does not coincide with market peaks), (ii) integration of renewables (by adjusting consumption and storage to capture renewable energy), (iii) minimisation of energy costs (by adjusting energy imports to coincide with cheaper sources of energy during periods of low costs), (iv) increasing network security by providing ancillary services to the electricity network, among others. Clearly, the EPN would benefit the most from a framework that relies on multiple criteria and thus allows the neighbourhood to use all its capabilities.

6.1.2 Value and costs recognised by current market frameworks

Current market structures (view section 2.2) mainly acknowledge benefits and costs from services provided by large actors (e.g. producers and retailers) as generally market rules and the markets themselves favour large actors. In addition, the market structure implicitly suggests that small actors are unable or unwilling to handle market price volatilities and balancing responsibilities, or that enabling services from such actors is too costly from an economic, technical and/or regulatory perspective.

The wholesale, balancing and ancillary markets are generally not accessible for small end-users such as the EPN (i.e. membership costs and capacity requirements are too high for small end-users). Furthermore, as discussed in the previous subsection, EPNs would be at a disadvantage in these markets as larger actors would be favoured by economies of scale (although the EPNs may still be competitive on terms of flexibility). EPNs could have an edge on services at the distribution level. Nevertheless, currently there are no markets for the trade of such services.

Small end-users are shielded from real-time market signals or balancing responsibilities as their participation in the CO_2 market is via incentive schemes, and all price fluctuations and balancing obligations associated with the gas and electricity markets are absorbed by gas suppliers and retailers, respectively. This is not ideal for EPNs that can handle real-time signals and balancing responsibilities, especially because the neighbourhood (particularly end-users) have to pay a fee (e.g. retailer fee) for receiving such services under this scheme.

Based on this, current market structures generally fail to acknowledge most of the key features of the EPN concept.

6.1.3 Alternative market structures

Changes in the market framework would alter the manner in which benefits and costs are acknowledged and thus result in a different allocation of value to EPNs and other market players. Three potential market framework alternatives are considered:

1. Small end-users such as the EPN are isolated from the market by actors (e.g. retailers or incentive policies in the case of the power market) who present them with fixed tariffs. The electricity tariff is directional (i.e. import prices marginally lower than the retail price and export tariffs marginally lower than a fixed equivalent to the wholesale market) to discourage exports and thus network usage and associated issues, whereas CO_2 and efficiency improvements are valued at a fixed rate.

2. Small end-users such as the EPN have an alternative to participate in the markets directly. The EPN perceives real-time prices (although the electricity prices are still directional) and becomes balancing responsible. This would imply that the capacity and costs (e.g. certification and membership) requirements for the participation in the different markets are adjusted to facilitate the participation of small end-users. In this scenario the baseline for CO_2 and efficiency improvements is assumed static.

3. The markets are adjusted to allow “fair” participation of small end-users such as the EPN and bespoke markets for the trade of services from small customers are created. Dynamic baselines are now considered for the CO_2 and efficiency markets.

It is important to highlight that these market scenarios might be negative for end-users without EPN capabilities (e.g. a household without smart appliances has the risk of incurring high costs if exposed to real time prices). Thus, it is assumed that small end-users that do not belong to an EPN, do not have sufficient levels of automation or simply are unwilling to change their current operation philosophy, are allowed to operate under the current market structure even though EPNs operate in the market structures under analysis.

6.1.3.1 Fixed pricing

In this scenario, the market structure still considers that small end-users should not handle price volatilities or balancing responsibilities (instead end-user pay a fee to other actors such as retailers to handle these responsibilities) and neglects their potential contribution to the grid (e.g. directional pricing is used to limit exports and thus potential issues for the network). This market structure is generally consistent with current regulations and provides modest benefits to EPNs by neglecting most of the services that could be provided by the neighbourhood.

Under this market structure investments will likely be needed in infrastructure for the EPN mainly for the installation and maintenance of DERs for local consumption and energy storage, as well as for the implementation of energy efficiency measures. Investments in ICT may be made, particularly if the EPN sells services to actors that participate in the different markets and are exposed to underlying price signals (e.g. the retailer). Discussion regarding the actors that would likely incur the costs associated to EPN enabling infrastructure is provided in section 6.2.

Incentives for the EPN to reduce CO_2 emissions and increase energy efficiency would likely take the form of feed-in tariffs for low carbon technologies (e.g. domestic PV systems) and mandatory energy efficiency standards for buildings (e.g. insulation standards). Electricity trading would likely be via directional pricing that would encourage use of local generation and discourage energy exports (i.e. to avoid potential issues in the distribution network). A single tariff may be used for gas trading as the EPN is unlikely to export gas.

The EPNs may mainly profit from increased energy efficiency, reduced energy imports and energy storage (particularly in the form of heat). Efficiency improvements would be mainly encouraged by the mandatory standards; although, additional improvements could be attractive if energy prices are high. Electricity imports would be reduced via the installation of DG, some of which would likely be based on renewable energy sources due to the feed-in tariffs. Although additions of DG capacity may be limited due to the low price for exports offered by the directional tariff. In this regard, the flexibility of the EPN to store surplus electricity will play a key role as, instead of exporting energy, it may be converted to heat for its immediate use or storage (e.g. via the use of EHPs and TES) or stored directly by EES.

In this scenario there might be investments in additional infrastructure for the provision of non-energy based services (e.g. parking services), especially if there is some ICT within the EPN and profits from other services are significant. Ultimately, the decision of enabling the services will lie on the actors within the EPN, particularly on their preferences (criteria).

6.1.3.2 Real time pricing

This market structure acknowledges the contribution of some small customers to the different markets and assumes that small end-users can compete on equal grounds with other actors (i.e. market participation costs and capacity requirements would be lowered). Although, the potential benefits that the grid can accrue from small end-users are still ignored. This scheme would allow EPNs to use more of their potential resources compared to the previous case, thus securing higher benefits that would otherwise go to the generation side.

This structure would encourage the EPN to use most of its resources to become competitive in existing markets. That is, use forecasts, ICT and DERs to meet local energy requirements whereas exploiting all trade-offs between CO_2, efficiency, gas, heat and electricity prices. However, economies of scale and DUoS and TUoS may pose an issue.

The EPN would now have the flexibility to choose which means to use to achieve CO_2 and efficiency targets based on static baselines, although the use of static baselines may result in over or under estimation of the EPN emissions and/or efficiency, which is undesirable[11]. The EPN would become balancing responsible in the gas market and would have to dedicate some of its flexibility to balance its position in the market; in exchange it would perceive lower gas prices as retail charges would be averted. Gas price volatility is unlikely to be an issue for the EPN as, compared to electricity prices that vary on a half an hour basis, gas prices tend to vary on a daily basis.

The EPN would now be able to participate in the electricity wholesale market (using forecasts to determine potential imports and exports), in the balancing market, and in the imbalance settlement process (using DERs, particularly storage to provide balancing services and avoid imbalance penalties[12]). This would allow the EPN to not only manage trade-offs between prices of different energy vectors, but also between the value of electricity at different times (i.e. in the whole sale and balancing market). On the one hand, the flexibility of the EPNs might give them an edge to provide ancillary services and participate in the balancing market. On the other hand, participation of the EPN in the markets could be limited by "unfair" DUoS and TUoS charges that are considered for energy trades. That is, as the system charges are considered, the EPNs would not be able to take an advantage of trading energy with adjacent actors to avoid the use of part of the network, as the DUoS and TUoS would still be charged (this will be further discussed in the next subsection). This may imply that even though the EPN could profit from interactions with the markets, the main benefits would come from the use of own resources and services (this would need to be further explored).

In this case, significant investments would be needed in most EPN enabling infrastructure and services (e.g. ICT, DERs, forecasting and so forth). Additionally, the EPN may incur extra costs associated to market participation (e.g. membership and automation and administrative costs associated to trading) and balancing (e.g. imbalance charges). The market operators are also likely to incur additional costs related to managing transactions of a large number of EPNs and other small actors.

Regardless of the significant costs incurred by the EPN, under this market structure the neighbourhoods may perceive more profits than in the previous case (potentially enough to offset costs and produce substantial profits), as the EPNs are given more freedom to use their resources. Energy efficiency improvements and CO_2 abatement may now be more profit driven, DG might still be mostly used for local consumption but sufficient DES would be needed to manage to variable energy prices and provide balancing services (i.e. EHPs and TES would still play a major role, but EES may become more attractive), and forecasts and additional ICT would be needed for the management of the neighbourhood considering available resources and prices

[11] On the one hand, underestimating the performance of the EPN would reduce the benefits it perceives. On the other hand, overestimating it will ultimately affect the market and all participants. An example of this would be to the issue of certificate above the requirements of binding targets, which would drastically reduce the price of the certificates.

[12] It will be critical to analyse/quantify how, by providing different services, the EPN may imbalance its position in the market and require balancing actions to avoid exposure to imbalance penalties.

variations. This EPN configuration would provide part of the required infrastructure and, thus a strong business case for non-energy services.

6.1.3.3 Bespoke markets

Under this market structure, all potential benefits from EPNs in the different markets would be acknowledged. This would imply that EPN based solutions are deemed as valuable as or more valuable than solutions offered from other actors and thus, a significant percentage of benefits previously directed to other sources would be available for EPNs.

In this scenario, part of the ICT infrastructure will be used to monitor the efficiency and the carbon footprint of the neighbourhood for the formulation of dynamic baselines that would improve the process by which certificates are issued for the neighbourhood. The wholesale, balancing and ancillary markets would be adjusted to account for externalities[13], and for the location of each actor and their use of the transmission and distribution networks to provide a service. Externalities would be traded directly in the balancing market or via a bespoke mechanism[14]. The location of each actor could be incorporated into the market by adjusting market offers based on the associated use of the networks and TUoS and DUoS. In other words, if a load at the distribution level is to be supplied, bulk generation with associated TUoS and DUoS charges would compete with EPN generation with lower associated DUoS, increasing the competitiveness of EPNs for local trading. In addition new markets (e.g. constraint management market) would be introduced for EPNs to trade bespoke services such as services for DSOs (e.g. view section 5.2.3).

Similarly to the previous case, significant costs will be incurred to place and maintain the different EPN enabling infrastructure and to facilitate participation of a significant amount of small actors in the different markets. These investments would likely be higher than in previous cases as more flexibility (and thus infrastructure) is required from EPNs and new markets may have to be created. Nevertheless, this scenario may allow the EPNs to realise their full potential (e.g. maximise economic benefits or other criteria and enable non-energy services) by enabling them to use all their flexibility to exploit multi-commodity and inter-temporal trade-offs (e.g. trade-offs between the value of gas, heat and electricity during different periods). In addition, the EPN may be actively involved in the efficient operation of the distribution network via the proposed constraints management market. It is important to note that the operation of the EPN can be detrimental for the network without the existence of a market (or other mechanism) that incentivises the EPN to take the network into consideration. An alternative to the constraint management market that could be explored is simply a set of mandatory network services imposed by the grid code, such as current ancillary service obligations faced by generators [3].

It is important to note that a market framework that provides strong incentives for EPNs may have negative impacts on other actors (e.g. DSOs and large generators). These effects must ultimately be considered in the CBA that will be developed in this work package.

[13] Externalities represent value or costs indirectly created by the normal operation of an actor. For example, by providing a balancing service to the retailer, the EPN might be creating value for generation in the form of losses reductions or for the DSO in the form of network congestion reduction.
[14] For example, a fixed periodic payment can be offered to the EPN in exchange for constantly managing the voltage level in a specific zone of the distribution grid.

6.2 Internal market frameworks

Once the external market structure has been determined and the expected value of the EPN can be characterised (e.g. from economic, technical and/or environmental perspectives), the next task is to determine which actors would likely be responsible for investing in EPN enabling infrastructure and the process by which the EPN allocates value internally, namely internal market structure.

As a reference, inside the EPN value may be allocated via two markets, namely local retail and ancillary services. The retail market would provide means for minimising dependence on imports, thus averting TUoS and some DUoS (e.g. high voltage DUoS), by promoting internal energy trading (e.g. exchanges within the EPN at the corresponding buying and selling prices). This could be an attractive alternative for the EPN to retail or wholesale market price signals that include implicitly both DUoS and TUoS costs (view Figure 22). The existence of such market may be of interest to the end-users aggregators, retailers and/or independent entities that may take the role of NEM.

Local ancillary markets would provide small scale network services (e.g. voltage control) within the EPN or in neighbouring sections of the grid. This could be particularly attractive for DSOs who would normally have to take some corrective actions or even reinforce the network to fix these issues. Thus, the DSO may be the main buyer in the ancillary market.

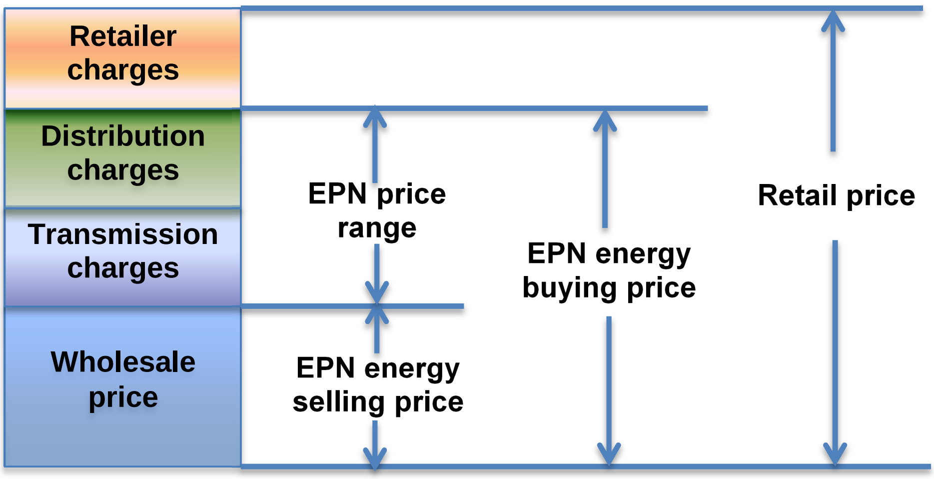


Figure 22: Example of a potential tariff structure within the EPN

Considering that the internal market structure of the EPN may direct benefits to different actors, it is reasonable to assume that the market structure would be closely related to the actor(s) that invest in the EPN enabling technologies (i.e. EPN ownership) and their objectives.

6.2.1 Internal market ownership solutions

The introduction of the local markets into the EPN will depend on the ownership of the underlying infrastructure (e.g. ICT, DG, DES, and so forth). In other words, if the DSO owns the infrastructure (DSO monopoly), it would be mainly used to enable a local ancillary market that would benefit the DSO itself, whereas if end-users alone (end-user consortium) or the DSO, end-users and other actors (free market) own the infrastructure, it would be used to enable the retail market (i.e. end-users get most benefits) or both markets (i.e. benefits are shared), respectively.

6.2.1.1 DSO Monopoly

DSOs can be motivated to invest in EPN enabling technologies (as long as regulators allow it) in networks that are technically challenged (e.g. voltage issues) and/or approaching capacity limits whenever this alternative is economically more attractive than traditional solutions such as costly distribution network reinforcements. In such a case, the DSO might invest mainly in the underlying EPN infrastructure needed to provide ancillary services to the network. Although, there would not be a real retail market as the NEM would be obliged to provide most (if not all) services requested by the DSO. As the DSO is a regulated entity, it is unlikely to take the role of NEM because it would not be allowed to use the EPN to compete with non-regulated actors.

As the DSO would mainly monopolise the neighbourhood, most services would go towards supporting the distribution grid, leaving little benefits for end-users. The DSO is likely to invest primarily on infrastructure to support energy services, thus this type of EPN might not have the infrastructure needed to engender non-energy services for customers within the neighbourhood.

As a concluding remark, in this ownership scheme the DSO would invest in EPN enabling infrastructure to support the distribution network if it is deemed more economically efficient than traditional solutions (e.g. network reinforcement), and the NEM would offer most of the services of the EPN to the DSO. It is important to note that this scenario is analysed under the premise that only the DSO invests in the EPN enabling infrastructure and thus the EPN operates based on the objectives of the system operator. In practice, different actors may invest in EPN enabling infrastructure, thus enabling the provision of several services. This will be discussed in the free market subsection.

6.2.1.2 End-user consortium

Small customers do not typically make large investments in electricity infrastructure unless they expect significant benefits. Accordingly, end-users would not invest in EPN infrastructure unless retail prices are significantly high and/or strong financial incentives for ICT and other enabling infrastructure are in place (e.g. feed-in tariff and energy efficiency regulations). In addition, strong social incentives may be needed to encourage investments in additional infrastructure and periodic costs to enable and maintain non-energy services (e.g. cases where the location of parking spaces by traditional means has become an outstanding issue). Although, end-users would be more keen on the service if the EPN produces sufficient profits to finance it than if end-users themselves have to pay to enable the non-energy services.

Under this framework, there would not be a real retail market as both the loads and electricity and heat sources would be owned by the same actors (i.e. end-users). This type of EPN would focus on capturing benefits for end-users based on underlying criteria (e.g. economic gain and attitude towards environmental concerns). The EPN may thus focus on trading energy and services (flexibility) with other actors in underlying markets[15]. This may facilitate the participation of the EPN in the emissions and efficiency markets, particularly if it is deemed profitable and end-users have a strong interest in environmental wellbeing.

[15] As previously discussed DSOs could also benefit from this structure if a mechanism to trade with the EPN (e.g. network constraints market) is in place.

As a summary, this ownership scenario can be caused by strong expected benefits (and social benefits) perceived from the EPN concept and regulatory support in the form of financing, economic incentives, and so forth. This scheme may be beneficial for all underlying internal and external actors, particularly if proper market structures are in place.

6.2.1.3 Free market

A free market can be introduced to the neighbourhood when different actors (including retailers, end-users and regulators, among others) perceive business opportunities from the EPN concept and are willing to make the required investments. This might include different retailers interested in balancing services, DSOs seeking network support, independent actors keen on profiting from financing building insulation upgrades and/or providing non-energy based services, and so forth. This variety of objectives within the neighbourhood may lead to investments in a wide range of ICT, automation, DERs, and other technologies and thus, increase the flexibility and potential services that the EPNs can provide. As a result, this ownership scheme (particularly if coupled with the bespoke external markets vision) is highly consistent with the EPN defined in the COOPERaTE vision [1][2].

The business opportunities needed to create the free market can be originated from a traditional business platform or a multi-sided platform [14]. The traditional platform relies on the idea that an actor would invest in ICT and other technology required to enable the service and would afterwards profit from providing the service. Ergo, many different actors would have to identify business potential and be willing to invest in order to enable the free market. The multi-sided platform on the other hand provides services to groups of actors that might need each other (e.g. sellers and customers) and can interact through the platform. In this scheme, the more actors from one side join the platform (e.g. end-users) the more attractive the platform becomes for the other group of actors (e.g. external actors). Accordingly, an actor such as the NEM or the ICT provider could invest in ICT infrastructure for end-users (who may be interested if the infrastructure is facilitated at low costs or is free) and would charge other actors (e.g. retailers and aggregators, among others) for the use of the platform. Under this scheme, the owner of the platform would incur the costs and associated risks[16], but may perceive substantial benefits if the platform is successful[17], end-users would be encouraged to join due to the low cost (if any) of the platform, and other actors would be incentivised to participate as membership and associated investment costs may be negligible compared to costs required otherwise.

The free market ownership model may enable significant flexibility from EPNs brought about by investments on a wide variety of technologies. However, a proper market structure must be created to manage the internal free market (e.g. the NEM could take the role of a market operator) and facilitate an efficient and economic (i.e. fair) operation of the EPN (e.g. managing conflicting objectives and avoiding market power).

In conclusion, this ownership scheme is viable if different actors perceive business opportunities in the EPN concept (e.g. due to a traditional or multi-sided platform), and it may produce significant benefits for the neighbourhood as long as the free market is properly regulated.

[16] The platform might consist purely on ICT infrastructure, leaving investments on other technologies to other actors.

[17] If policy makers and regulators acknowledge the benefits of EPNs, regulations and/or incentives may be placed to encourage investments in multi-sided platforms for EPNs.

6.2.2 Internal market management

The operation of local retail and ancillary markets within the EPN would clearly be affected by the level of automation within the neighbourhood and control philosophy and criteria taken by the NEM.

6.2.2.1 ICT and automation levels

The availability of ICT and automation would be key factors for the creation of local markets. As the NEM is envisioned having access to most actors within the neighbourhood via the EPN platform, it is reasonable to assume that local pool based markets in which the NEM acts as the market operator can be formed. In this case, several markets managed by the NEM can be defined for the trade of different services (e.g. electricity, heat and flexibility options). The NEM would collect all offers (e.g. in the form of price and/or quantity bids) and determine both the services that would be provided and their associated prices.

An alternative market structure would be via bilateral trading. This would allow actors to trade services with their preferred actors at a price that they both agree without intervention of the NEM. Nevertheless, the existence of such a market structure within an EPN is arguable, as (i) it would require significantly more ICT and automation infrastructure (and software) than the pool based market as communications would have to be enabled between all (or most) actors and most biddings would have to be handled automatically in real time, (ii) it could lead to undesired market power (i.e. actors manipulating prices on their favour) exercised by some actors due to the relatively small size of the market, and (iii) it would increase the complexity of the EPN as actors might override requests from the NEM.

Indeed, these factors may be worth exploring. Nevertheless, this would require complex and time consuming analyses, and it is not clear at this stage if the results would provide sufficient valuable information compared to the analysis of the pool based structure. Based on this, only the pool market structure has been considered in this deliverable (view section 5.1.2).

6.2.2.2 Local criteria

Local criteria considered by the NEM or underlying actors within the EPN would also have a great impact on the operation of internal markets, particularly when local objectives (e.g. zero net consumption) conflict with external objectives associated with the market structure (e.g. maximisation of profits). Such conflicts may result in the NEM overriding external requests and incurring the related costs (e.g. loss of business or penalisation).

Internal market criteria would also play a key role in enabling non-energy services, as small end-users, especially at the household level, may not follow purely economic objectives and may be interested in environmental, social or other types of benefits. In this case, interest in non-energy services can be engendered via advertisements or other social factors.

The criteria will play a key role in the definition of a CBA, as both benefits (e.g. economic and environmental) and costs (e.g. investments, and operation and maintenance costs) are determined by the criteria. Particular focus should be placed on how criteria changes affect the business model of the EPN and underlying actors. As an example, consider that end-users in a neighbourhood with costly energy bills invest in DG for self-use (is it a convenient investment?). Afterwards, new retailers emerge in the area offering the end-users lower electricity tariffs; rendering benefits from DG for self-use low (e.g. increasing payback time from 5 years to 20 years) (what options does the EPN offer under these circumstances?). Consider that in this case, the business of DG could shift from self-use to the provision of other services such as balancing for retailers. How would this affect the business model of the EPN? What would happen if the retailer requires the EPN to increase consumption to balance its position but the market price is high and it may be profitable to export generation? The multi criteria CBA developed in this work package aims at providing insights regarding these questions.

7 Cost Benefit Analysis

Once the different costs and benefits for the different actors within and outside the EPN have been mapped (e.g. using the methodology presented in section 4 of this deliverable) under given market frameworks (e.g. the internal and external frameworks considered in section 6), it is possible to perform multi-criteria CBAs from the perspective of the different underlying actors.

A CBA consists of comparing costs and benefit flows associated with a given investment project from the perspective of a given actor (the selected actor is not necessarily the actor that makes the investment), with the objective of identifying whether or not the benefits from the underlying investment offset the corresponding cost. Thus, the CBA provides an indicator of whether or not a given investment project is beneficial or not for a given actor. In the context of this project, several CBAs would be performed from the perspective of different actors (e.g. end-users, DSOs, retailers, and so forth) under different market frameworks and considering different attributes for the EPNs (e.g. infrastructure and associated services) with the objective of identifying the conditions that engender or deter attractive business cases for EPNs.

The CBA can be performed based on a variety of well-known and widely used criteria based on the time-value of money such as net present value (NPV), internal rate of return (IRR), payback time, among other criteria based on other premises (e.g. carbon footprint). A brief description of the time-value of money principle, the aforementioned criteria and multi-criteria analysis is provided below.

7.1 Time-value of money

The time value of money principle argues that money has a greater value in the present than in the future. That is, a rational investor (and most people) prefers to receive money in the present than to be promised the same amount of money in the future. Similarly, a rational investor would rather pay money in the future than pay the same amount immediately.

One reason for this perception of time-value of money is that capital secured in the present can be saved or invested to produce revenues in the future. Another reason is that capital devaluates with time due to inflation. Moreover, if a given amount of money is promised in the future, there is always some risk that the right amount cannot be delivered (e.g. less or no money might be received). Accordingly, in order for rational investors to sacrifice money (invest) in the present; the expected returns must include a premium that compensates for the time-value of money effect. The premium required to compensate for the time-value of money effect is usually expressed as a factor, namely discount rate (d).

Based on the time-value of money consideration, it is possible to quantify series of cash flows (i.e. costs and/or benefits) that occur in different periods (e.g. all cash flows within the same year) by referencing them to the same year (usually the present) based on the discount rate. This procedure is called discounting.

The time-value of money and related discounting procedure may be better explained with an example. Assume that the time-value of money is considered to be 10% (i.e. d=10%, thus a 10% premium per year is required from future money). That is, an investor would be indifferent between receiving 100€ today, 110€ in a year (i.e. 100€ x (100% + 10%), 121€ in two years (i.e. 100€ / $(100\% + 10\%)^2$), and so forth. Accordingly, an investment that offers to provide 110€ in a year plus 121€ in two years has a discounted value referenced to the present (or present value) of 200€

(i.e. 110€/(100% + 10%) + 121/(100% + 10%)^2). In general terms the present value of a cash flow can be expressed as follows:

$$Present\ value = \sum_{t}^{T} \frac{Cash\ flow_t}{(1+d)^t} \quad (1)$$

where *t* represents the different time periods (in this case years) during which the cash flows occur and *T* represents the last time period under consideration (usually the end of the operational lifetime of the investment project).

7.1.1 Net present value

The NPV criterion consists on comparing the costs and benefits associated to an investment project (during the expected operational lifetime of the project) in terms of their present value. The NPV can be expressed as follows:

$$NPV = \sum_{t}^{T} \frac{Benefits_t - Costs_t}{(1+d)^t} \quad (2)$$

This criterion produces a straight forward assessment of the project in the sense that the investment project is deemed beneficial as long as the NPV is positive (the project is considered inconvenient otherwise). This occurs because a positive NPV implies that the expected benefits not only exceed costs but also provide a premium that surpasses the discount rate. That is, the actor is better off investing in the project (or incurring the costs associated to the project) than placing the same amount of money elsewhere (e.g. the bank) even when receiving a premium equivalent to the discount rate for the money (10% in the example).

Even though the NPV criterion is clear, it does not provide much information about the investment. For example, it does not specify the amount of years that the actor has to wait before the benefit from the project offset the costs (e.g. payback time), nor the real premium than the project is providing[18]. Additional information can be obtained from other metrics (e.g. payback time and IRR).

7.1.2 Payback time

The payback time criterion is the period (normally years, but it can be expressed in weeks, months or other time periods) that is required for the project to become profitable (i.e. the minimum time needed to render the NPV equal to zero). Thus, the payback period can be calculated as the minimum value of the time period *T* that satisfies the following equation:

[18] A positive NPV indicates that the premium is higher than the discount rate (10% in the example), but it does not indicates the exact value of the premium.

$$0 \geq \sum_{t}^{T} \frac{Benefits_t - Costs_t}{(1+d)^t} \tag{3}$$

This tends to be an important metric as most actors are not only interested in highly profitable investment projects, but on profitable projects that payback in the short term.

7.1.3 Internal rate of return

The IRR is an indication of the exact premium that an investment project is offering in exchange for all costs incurred. The IRR can be estimated as the discount rate (d) that renders the present value of both benefits and costs the same. That is, the discount rate that satisfies the following equation:

$$\sum_{t}^{T} \frac{Benefits_t}{(1+d)^t} = \sum_{t}^{T} \frac{Costs_t}{(1+d)^t} \tag{4}$$

Conversely to the NPV criterion that centres on absolute profits, the IRR criterion shows the efficiency of an investment in regard of the premium that it produces compared to the costs. That is, whereas the NPV criterion favours investments with high profits regardless of the costs, the IRR criterion favours projects that produce more benefits in comparison to costs.

7.2 Multi-criteria analysis

A multi-criteria analysis can be defined as an analysis by which several investment projects are assessed on the basis of different criteria. For this purpose several techniques are available, such as the direct analysis, linear additive model, and hierarchy methods, among others. The outcome of a multi-criteria analysis is the identification of an investment project that is deemed to performed better than the rest with regard to all criteria (a ranking of the projects may also be possible). The development of a multi-criteria CBA is particularly relevant for this work, as special focus will be placed on the impact of EPNs on the business case of different actors that are likely to follow different criteria. This section briefly overviews classical multi-criteria analysis techniques that may be used for the assessment of the EPN concept. For such purpose, a small illustrative example is presented.

A multi-criteria CBA is meant to compare different investment project alternatives based on relevant criteria. In the context of this work, the investment projects may represent a vision of the EPN (e.g. investment in particular infrastructure and provision of a specific portfolio of services) from the perspective of an actor (e.g. end-users, retailers, and so forth) under a given market framework (e.g. external bespoke and internal free markets or any other combination). For this purpose, it is convenient to present the performance of the investment projects according to different criteria in the form of a matrix (performance matrix) as shown in Table 3. The performance of each investment option has, for illustration purposes, been set arbitrarily and, for the sake of simplicity, each criterion is expressed as either attractive or unattractive. In practice, the particular criteria would be expressed as a numerical value.

Table 3: Example of a multi-criteria performance matrix

Investment project	NPV	Payback time	IRR	CO_2 emissions
Option A	Attractive	Attractive	Attractive	Attractive
Option B	Unattractive	Attractive	Attractive	Attractive
Option C	Attractive	Attractive	Unattractive	Unattractive

The basic technique (and thus first step) to perform the multi-criteria analysis is the direct analysis. The direct analysis consists on inspecting if any of the options performs as well or better than all the other options according to each criterion. In this example, this would be option A, which is attractive according to all criteria under consideration. That is, this option offers high benefits (high NPV) on the short term (low payback times), high premium for the capital invested (high IRR) and low environmental impact (low CO_2 emissions), all of which are attractive for the corresponding criteria. In practice, there might not be an option that meets the direct analysis requirements, thus other multi-criteria techniques have to be used.

If it can be reasonably assumed that all criteria are independent from each other (e.g. the perception of the NPV will not change regardless of the payback time) and can be assigned a weight, the linear additive model may be applicable for the analysis. This technique consists on assigning a weight to each criterion and multiplying the score of each project by the weight. This would produce a single criterion for each project based on which the best investment option can be determined. In order to illustrate this, assume that each option is credited one point per criterion if its performance is attractive. Accordingly, Option B is worth three points (for its performance according to the Payback time, IRR and CO_2 criteria) and is deemed a better alternative than option C, which would only be credited two points (for its performance according to the NPV and payback time criteria), whilst Option A would be deemed the best option given its 4 points (for its performance according to all criteria). Clearly the weight assigned to each criterion is a key parameter, as it has significant impact on the outcome of this technique.

Now, if it is not reasonable to assume that all criteria are independent from each other (e.g. a high NPV is desired but short payback times are preferred) an analytical hierarchy process could be used. In this case a pairwise comparison approach (based on a particular analysis or judgement) is used to determine the proper weights for the different criteria and investment options. In order to illustrate this process, consider the pairwise weights shown in Table 4. The table shows how a given criteria (row) is valued with respect to other criteria (column) (e.g. the NPV criterion is deemed twice as valuable as the IRR criterion and three times more valuable than the CO_2 emissions criterion).

Table 4: Example pairwise weight for the different criteria

	NPV	Payback time	IRR	CO_2 emissions
NPV	1	0.5	2	3
Payback time	2	1	1	2
IRR	0.5	1	1	2
CO_2 emissions	0.333	0.5	0.5	1

The weights for each criterion associated to the example pairwise comparison are presented in Table 5. As it can be seen, the payback time is deemed the most valuable criterion, followed by the NPV, IRR and CO_2 emissions. An explanation of the mathematics required to process this matrix to obtain the weight for each criterion is beyond the scope of this deliverable. It will only be mentioned that the weights can be determined as the eigenvector associated with the maximum eigenvalue of the matrix (for more information view [15]).

Table 5: Criteria weights according to an analytical hierarchy process

Criterion	Weight
NPV	0.31
Payback time	0.34
IRR	0.23
CO_2 emissions	0.12

A similar procedure is performed for the investment options. For the sake of simplicity an illustration, Option A is not presented (as it would be deemed the best in this analysis due to its attractive performance according to all criteria) and an investment option is deemed twice as valuable as another if its performance under a given criterion is better according to Table 3. The results of such a pairwise comparison and the associated weights are shown in Table 6 and Table 7, respectively.

Table 6: Pairwise comparison of investment options

Options	NPV		Payback time		IRR		CO_2 emissions	
	B	C	B	C	B	C	B	C
B	1	0.5	1	1	1	2	1	2
C	2	1	1	1	0.5	1	0.5	1

Table 7: Example investment option weights according to an analytical hierarchy process

	NPV	Payback time	IRR	CO_2 emissions
Option B	0.33	0.5	0.67	0.67
Option C	0.67	0.5	0.33	0.33

Finally, the weights for both criteria and investment options are combined (i.e. the sum of the weight of the option multiplied by the weight of the corresponding criterion). The results show that option B is marginally a better option than option C under the selected criteria and weights.

Table 8: Results for the example according to an analytical hierarchy process

	NPV: 0.31	Payback: 0.34	IRR:0.23	CO_2 : 0.12	**Ranking**
Option B	0.33	0.5	0.67	0.67	**0.51**
Option C	0.67	0.5	0.33	0.33	**0.49**

8 Concluding remarks

This deliverable aims at formalizing a CBA framework for the assessment of business models for EPNs in terms of value chain actors, multi-commodity flows between actors and attributes of the business model context. In particular, this work was set to answer the following questions:

8.1 Who are the main actors involved in the EPN's business case?

Actors involved in the business case of EPNs can be categorized as internal actors within the EPNs and external actors that interact with the EPNs in multi-commodity markets (e.g. electricity, gas and CO_2).

Internal EPN actors comprise (i) the NEM who may own and/or operate the EPN, or just take the role of market operator within the neighbourhood, (ii) ICT providers who facilitate the communications infrastructure that connects the EPN with all relevant actors, (iii) end-users (e.g. households and commercial buildings) who might provide flexibility and own DERs, (iv) DES to store electricity and heat, and (v) distributed heat and DG that provide a source of thermal and electrical energy within the EPN.

Some typical external actors are: (i) the TSO which can take the role of market operator, (ii) DSOs who are responsible for the distribution network in which the EPN is connected, (iii) electricity producers who provide the main source of energy for the electricity markets, (iv) gas suppliers who provide gas to the EPN, (v) retailers that buy energy from the markets and sell it to aggregators and/or end-users, and (vi) aggregators who act as intermediaries between the EPN and other actors.

8.2 How can the multi-commodity flows between the EPN and other actors be captured?

The multi commodity flows between the EPN and other actors within and/or outside the neighbourhood can be assessed with a mapping framework.

The framework was utilised to map four energy based business cases and one non-energy based business case for EPNs, namely (i) optimised purchase on the wholesale market, (ii) minimisation of imbalance penalties, (iii) distribution network constraint management, (iv) operating reserve, and parking business cases. The energy based business cases were mapped based on the separation, with regards to the EPN, of energy retailing and flexibility trading roles. Energy was assumed to be provided to the EPN by a retailer whilst flexibility from the EPN was assumed to be traded by an aggregator. This clear separation formed the basis of one mapping approach, employed for each business case, whilst, given the likelihood of one actor fulfilling both these roles (given the synergies available), the combination of these roles (by a retailer-aggregator) formed the basis of a second mapping approach for each business case.

It was concluded that there are tangible business cases for energy based business models, as most benefits and costs and flows can be clearly defined in a market. However, this is not the case for non-energy based services that offer intangible benefits (e.g. additional comfort from finding parking spaces faster). Non-energy based cases must therefore be financed directly by end-users or by profits associated with energy based business cases.

8.3 What is the impact of different market frameworks on the business case of EPNs?

The business case of EPNs can be influenced by market frameworks both inside and outside the neighbourhood. External market frameworks, mainly affect the value (i.e. costs and benefits) that EPNs are expected to perceive, whereas internal market frameworks influence the allocation of benefits among internal EPN actors and provides insights on the actors that are likely to invest in the underlying infrastructure.

Current external market frameworks do not acknowledge most of the potential benefits from EPNs associated to their location at the distribution level, and flexibility and price responsiveness. Variations to the market frameworks may change this, but will undoubtedly affect other actors and the overall commodity market. Three potential changes to the market structure were analysed, namely introduction of fixed pricing, real time prices and bespoke markets. The introduction of fixed pricing may incentivise energy efficiency measures, and investments in DG (some of which may be based on renewable sources) for local consumption and energy storage (especially thermal) to enable consumption of energy surplus. Real time pricing, would allow the EPN to use most of its resources (e.g. forecasts, DERs and ICT) to manage price volatility and trade-offs between different energy vectors and markets at different time periods; thus increasing expected profits. Nevertheless, the participation of the EPN in the electricity markets may still be limited by “unfair” DUoS and TUoS charges. The introduction of bespoke markets would allow EPNs to realise their full potential by allowing the EPNs to use all their resources and trade with all actors in markets that fully capture the value of services from the distribution level. The bespoke markets may include constraint management markets in which the EPN can trade services to support the distribution network. This scenario has potential to engender investments in a wide variety of EPN enabling infrastructure from different actors. The CBA must assess the benefits and costs associated to each market structure from both the perspective of the EPN and other actors.

The functionality of internal market frameworks can be significantly affected by the ownership of EPN infrastructure and the operation philosophy and criteria used by the NEM. Clearly, the actors that own most EPN infrastructure would likely benefits the most from the EPN’s business case. This is the general conclusion after analysing potential EPN ownership models in which investments in the underlying infrastructure were made mainly by a DSO, end-users or different actors. Among these ownership models, the latter in which different actors own the EPN enabling infrastructure, namely free market, is deemed the most attractive for EPNs as it would result in investments in a wide variety of technologies that would engender flexibility within the neighbourhood. It is discussed that free markets can be enabled by traditional platforms in which different actors must make investments to enable part of the EPN’s business, or via multi sided platforms in which a single entity invests in the EPN platform and charges some actors for their use. The multi-sided platform may be a more attractive and feasible scheme to enable free markets within the EPN.

The internal operation philosophy that is deemed more reasonable for the EPN is based on pool markets managed by the NEM, as most infrastructure needed is expected to be available. Finally, criteria used by the EPN will play a key role in the definition of a CBA, as both benefits (e.g. economic and environmental) and costs (e.g. investments, and operation and maintenance costs) are determined by the criteria. Particular focus should be placed on addressing investment needs, changes in the business models, and other factors brought about by different criteria and changes in the criteria.

The outputs of this deliverable set the base for the business models definitions and multi-criteria CBA in terms of value chain actors, attributes that characterise the business model context, and functions that map the costs/benefits accruing to the various actors through the relevant multi-commodity flows, and the potentials of operating in different market frameworks. This information will be used for the next stage of this work package, which involves the development of a multi-commodity CBA platform capable of simulating and optimising the behaviour of the involved actors and allocate costs and benefits within the various business models, commercial and regulatory frameworks.

References

[1] D. Pesch, K. Ellis, K. Kouramas and Y. Assef, “Deliverable D1.1: Report on requirement and use-cases specifications,” COOPERaTE, 2013.

[2] L. Markus and G. Timo, “Deliverable D1.2: Report detailing neighbourhood information model semantics, “COOPERaTE, 2013.

[3] National Grid, “Services,” 2013. [Online]. Available: http://www.nationalgrid.com/uk/Electricity/Balancing/services/ , 2013

[4] H. Roger, “The electricity trading arrangements: A beginner’s guide,” ELEXON, 2012. [Online]. Available: http://www.elexon.co.uk/wp-content/uploads/2012/12/electricity_trading_arrangements_beginners_guide_v3.0.pdf

[5] N. Keyaerts, “Gas balancing and line pack flexibility concepts and methodologies for organizing and regulating gas balancing in liberalized and integrated EU gas markets,” 2012. [Online]. Available: http://www.mech.kuleuven.be/en/tme/research/energy_environment/Pdf/wpen2012-11.pdf

[6] KEMA, “Study on methodologies for gas transmission network tariffs and gas balancing fees in Europe - Annex - Submitted to : The European commission , directorate-general energy and transport,” 2009. [Online]. Available: http://ec.europa.eu/energy/gas_electricity/studies/doc/gas/2009_12_gas_transmission_and_balancing_annex_fact_sheets.pdf

[7] Department of Energy & Climate Change and Environment Agency, “ CRC Energy Efficiency Scheme,” 2013. [Online]. Available: https://www.gov.uk/crc-energy-efficiency-scheme

[8] DHC+ Technology Platform, “District heating & cooling: A vision towards 2020-2030-2050,” 2009. [Online]. Available: http://heating.danfoss.com/PCMNews/2860/Vision_DHC.pdf

[9] Gestore Servizi Energetici, “White certificates,” 2013. [Online]. Available: http://www.gse.it/en/White%20Certificates/Pages/default.aspx

[10] DECC, “Feed-in tariffs scheme consultation on comprehensive review phase 2A: solar PV control,”2012. [Online]. Available: http://www.fitariffs.co.uk/library/regulation/120209Consultation2A.pdf

[11] Department of Energy and Climate Change, “What measures does the Green Deal cover?,” 2011. [Online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48088/1734-what-measures-does-the-green-deal-cover.pdf

[12] Y. G. Rebours, D. S. Kirschen, M. Trotignon, and S. Rossignol, “A survey of frequency and voltage control ancillary services - Part II: Economic features,” *IEEE Transactions on Power Systems*, vol. 22, no. 1, pp. 358 –366, 2007.

[13] J.Gordijin and H. Akkermans, ”Business models for distributed generation in a Liberalized market environment,” *Electricity Power Systems Research*, vol. 77, no. 9, pp 1178 –1188, 2007.

[14] V. Giordiano and G. Fulli, “ A business case for Smart Grid technologies: A systemic perspective,” Energy Policy, vol. 40, pp. 252 –259, 2012.

[15] E. W. Weisstein,"Eigenvector," *MathWorld a Wolfram Web Resource*, 2013. [Online]. Available: http://mathworld.wolfram.com/Eigenvector.html