BUSINESS MODELS AND ENABLERS

COOPERaTE

WP6: Barriers and Enablers of the EPN concept

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Abstract - Within Work Package 6 (WP6) "Business Models and Enablers", this deliverable report explores the barriers and enablers to the EPN concept. Drawing on the literature on barriers and enablers to energy efficiency and demand response, and also drawing on insights from the COOPERaTE project, this report specifies classes of barriers/enablers, and also details the individual, relevant barriers/enablers. Barriers are grouped into political/regulatory, economic, social and technological. Above existing literature in the area, this work details barriers related to: the operational time-scale nature of EPN business cases (relates, as they are, to demand response and near-real time flexibility); the heavy reliance of EPN business cases on markets; and the heavy reliance of the EPN concept on technology (e.g., for sensing, communication, and actuation). Further, discussion on the barriers to the EPN concept is able to draw on insights from work undertaken on EPN business cases in previous deliverables. Subsequently, possible enablers for the detailed barriers are explored, again following the political/regulatory, economic, social and technological framework. The general requirement for enablers to be subject to CBA, to ensure that their benefits are greater than the cost of implementation is highlighted. Also highlighted is the general requirement for greater awareness of the potential value of EPNs, and similar distributed, demand-side resources, and the development of methodologies and models to assess their business cases.

Keyword list – energy positivity, demand response, flexibility, business cases, business models, barriers, enablers

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Executive Summary

The objective of COOPERaTE is to develop concepts and architectures for open, scalable neighbourhood systems integration and management platforms 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 concept will enable the delivery of energy services, allow the management and trading of locally generated energy and grid based energy supplies, and potentially link 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 6 – WP6), namely “Business Models and Enablers” relates to WP1 (“Requirements, Use Case, Information Model and Architecture Specification”) and interacts with the other work packages, in particular WP2 (“Neighbourhood Power and Energy Management”) and WP4 (“System Integration and Technology Validation”) in order to analyse the likely operation practices of EPNs and role of Information and Communications Technology (ICT), respectively.

WP6 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 ICT and energy infrastructures and services on different 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 deliverable is a qualitative assessment of the barriers and enablers of the EPN concept. Existing literature on barriers and enablers for energy efficiency and demand response are reviewed, to define relevant barriers and enablers. Barriers and enablers are classified as political/regulatory, economic, social and technological. Political/regulatory barriers are largely related to the persistence of the traditional energy-system paradigm, which does not appreciate the potential contribution of distributed, demand-side resources. Economic barriers can be classified as market failures and market barriers; these may be significant given the reliance of EPN business cases on energy markets. Social barriers can relate to organisational or behavioural barriers. Behavioural barriers in particular can be quite intractable, given the complex relationship between behaviour and institutions. Technological barriers relate to various aspects of data acquisition, exchange and management, as well as to the more general areas of standardisation and system complexity. Also under the technological classification are the physical network constraints that may arise. Enablers are matched to the described barriers, to attempt to present possible solutions. In the conclusion, particular areas of possible interest to regulators, to help enable flexibility (such as dynamic network pricing to counter network constraints), are highlighted.

The produced classification of barriers can be used to facilitate effective implementation of the EPN concept, by informing the **sensing** and **understanding** phases of the EPN development framework, as detailed in deliverable 1.8 “Report on Refined Process for Energy Positive Neighbourhoods”. The classification of enablers can be used to inform the **deciding** and **acting** phases of the framework.

Further, this deliverable draws on insights from the work conducted in WP6 (i.e. from the studies conducted on the two test beds) to demonstrate some of the barriers to, and enablers of, the EPN concept.

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Acronyms

BMS	Building Management System
CBA	Cost Benefit Analysis
DNCM	Distribution Network Constraint Management
DNO	Distribution Network Operator
DR	Demand Response
EE	Energy Efficiency
EPN	Energy Positive Neighbourhood
FM	Facilities Manager
FMS	Facilities Management System
GRDDL	Gleaning Resource Descriptions from Dialects of Languages
HTML	Hyper-Text Mark-up Language
ICT	Information and Communications Technology
IoT	Internet of Things
NEM	Neighbourhood Energy Manager
NIM	Neighbourhood Information Model
PCR	Platform Configuration Registers
PEST	Political, Economic, Social, Technological
PLC	Programmable Logic Controllers
POWDER	Protocol for Web Description Resources
OR	Operating Reserve
OT	Operating Technology

R2RML	RDB to RDF Mapping Language
RDF	Resource Description Framework
RIF	Rule Interchange Format
RIIO	Revenue+Inputs+Innovation+Outputs
SPARQL	SPARQL Protocol and RDF Query Language
SoS	System-of-Systems
TPM	Trusted Platform Module
W3C	World Wide Web Consortium
XML	eXtensible Mark-up Language

1 Document objectives and content

The first deliverable in this work package (D6.1 "Business models and CBA for Energy Positive Neighbourhoods") introduced local and energy system actors relevant for an Energy Positive Neighbourhood (EPN) and different markets in which an EPN may participate. This information was used to identify and discuss several potential business cases which an EPN may be able to pursue with the aim of minimising energy costs and even accruing profits. Subsequently, a value mapping methodology, which forms part of the Cost Benefit Analysis (CBA) process, was thoroughly detailed. The effect of various market frameworks on the EPN concept were then explored, before the principles of CBA were outlined.

This was followed by the second deliverable (D6.2 "Evaluation of Business Model Contexts"), which elucidated the value of the EPN concept, contrasting "classic" [1] and "enhanced" [2] definitions of energy positivity. Factors which can affect the inherent EPN concept value, namely the design of commercial and regulatory structures and transaction costs, were then explored. Subsequently, the CBA process employed in the COOPERaTE project was detailed, before several case studies were explored, to illustrate the effect of EPN objective(s), resources, regulation and business cases selection.

The third deliverable (D6.3 "Evaluation of Business Cases") then built on the methods and ideas detailed in D6.1 and D6.2 to explore the value of various business cases, for the specific tests sites. To do so the nature and prices of the relevant markets and charging regimes were detailed. This information is processed, informing a stochastic optimisation engine. This engine assessed the annual value, in terms of operational costs, of the various business cases. Besides consideration of various price signals, the effect of aggregation on value was explored. Sensitivity tests on the amount of energy storage and variability in energy prices explored future possible value. To demonstrate the impact of the regulatory context (as discussed in D6.2), business cases under various regulations were examined. Subsequently, the relevance of how benefits are shared is explored, before an economic analysis of the business cases is conducted.

This deliverable is the final deliverable for work package 6. It seeks to draw conclusions on (i) the barriers/gaps which restrict (or may restrict) the application of the EPN concept, (ii) the enablers which may overcome such barriers/gaps and (iii) the benefits that may result from implementation of the EPN concept. This will be done with reference to the previous work conducted in this work package, from the COOPERaTE project, and from other academic and industrial literature. The classifications of barriers and enablers may feed into the EPN development framework detailed in D1.8. The classification of barriers can contribute by informing the sensing and understanding phases, whilst the classification of enablers can inform the deciding and acting phases.

Section 2 explores the literature on barriers to the EPN concept, and related smart grid/energy concepts. In order to break down this complex, multi-faceted topic, the section is split in subsections, with *political/regulatory, economic, social* and *technical* (PEST), barriers presented separately. Building on **Section 2**, **Section 3** considers the enablers that might overcome the previously defined barriers. Again, the section

[1] "Classic" definition: An EPN is a neighbourhood that generates more electricity than it consumes.

[2] "Enhanced" definition: An EPN is a neighbourhood which can maximise usage of local and renewable energy sources whilst positively contributing to the optimisation and security of the wider electricity grid.

is broken down into *political/regulatory, economic, social* and *technical* classifications. Finally, **Section 4** concludes the report.

2 Barriers

2.1 Overview

The EPN concept clearly involves significant participation of the 'demand-side' in electricity (and other energy) markets and systems. This is a clear departure from the existing energy system paradigm, where electricity is centrally generated, transported through networks designed for one-way flow of energy, to passive consumers. Given the fundamental nature of the changes the EPN concept brings, there are multiple barriers to its implementation. As the EPN concept is defined for the first time in the COOPERaTE project, there is no academic or industrial literature which explicitly explores the barriers to the implementation of the EPN concept. However, there are several concepts in the field of smart grids/energy which bear similarities to the concept of the EPN (e.g., demand response and efficiency). By including study of the literature on barriers to these concepts, an accurate description of the barriers to the EPN concept can be formed.

Given the multiple factors included in the EPN definition[3] (maximisation of local and renewable energy, optimisation and security of the grid), and their time varying nature, **the EPN concept clearly bears similarity to the idea of *Demand Response* (DR) in energy systems** (i.e. the ability of demand to dynamically respond to changes in the energy system). Equivalent terms include electricity load shift, demand management and demand side response. The need for demand response in energy systems is expected to increase substantially in the near future [1]. Demand response involves users of energy responding to market or direct signals to alter patterns of consumption. **As outlined in D6.2, flexibility through demand response can be realised through *shifting* demand in time (using storage), *substituting* one energy vector for another, or *trading* end-user *utility* (i.e. forgoing some energy service by curtailing energy consumption)**. Below, an overview of the literature on demand response is given. Subsequently, an overview of the literature on *Energy Efficiency* (EE, or similar terms, e.g., energy conservation, demand reduction) is presented. Although less similar to the EPN concept (given the focus on one-off, rather than dynamic, on-going decisions), study of the barriers to energy efficiency (i.e., measures to reduce the amount of energy used to provide a product or service) is still useful, given the amount of work conducted in the area.

2.1.1 Demand response

Referring to the literature on this area, there is some relevant work. In [2], three broad types of barriers are detailed: market-related, behaviour-related and information-related. Here, the key barrier is defined as the 'chicken and egg' situation where actors require evidence of value, which cannot be demonstrated due to the reticence of actors to pursue DR business cases. This barrier is also highlighted as significant in [3]. Reference [4] regards barriers mostly as products of the required but unrealised changes to relevant institutions. For example, focus is put on the current definition of ancillary service products, which are suited to the capabilities of generators rather than demand. Similarly, conditions on minimum unit size or telemetry may be unnecessarily restrictive (particularly for small end-users with DR capabilities), given capabilities conferred by advancements in aggregator functions [5] and communication infrastructure [6]. Uncertainty on business models, required

[3] An EPN is defined in D1.1 as "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"

enabling infrastructure and restrictions due to retail-related regulation are also cited as barriers. Focusing on applications for industrial load shifting, [7] also explores barriers to DR, through surveys of end-users. This work defined seven types of barriers: technological, information, regulatory, economic, behavioural, organisational and competences. Further, these barriers are classified as internal or external to the load-shifting organisation, or both. The various identified barriers were then ranked to provide a rich (if subjective) description of the barriers.

Besides the academic literature, there is also interest in the barriers to DR from regulatory bodies. The UK's energy regulator (Ofgem) has demonstrated interest in the area [8]. As in [2], Ofgem notes the necessity of demonstrating to relevant parties the potential value of DR. The other defined key requirements are the necessity of signalling value (from relevant markets) to consumers, and the necessity of consumers having access to the necessary information (on value and on their capabilities). The current failure to meet these pre-conditions constitutes a barrier to DR.

2.1.2 Energy efficiency barriers

As acknowledged in [7], there are some similarities in the barriers to EE and the barriers to demand response. In particular, the taxonomies employed in the wide range of literature on the subject may be transferred, at least in part, to the study of barriers to DR. However, the quite different nature of DR (particularly in that it is a variable resource, with focus on operational cash flows, rather than investment) means that the relevance and significance of individual barriers may be quite different. In particular, the much greater relevance of markets to DR (given the greater frequency of interaction of DR with markets, or market-like institutions), means that the relative significance of various barriers to DR, compared to EE, can be quite different. Nevertheless, review of the literature on EE is useful. Compared to the literature on DR, the literature on EE (or energy demand reduction), and the barriers to it, are more developed. As the literature is extensive, we will focus on a key selection. For a complete review of the literature on EE barriers, [9] and [10] are useful references. An early work in the area [11] studied the 'paradox' of gradual diffusion of apparently cost-effective energy efficiency technologies. This work made the important observation, derived from the field of classical economics, that 'barriers' could be fundamentally categorised as market failures or non-market failures. In the first case the barrier is due to a failure of a market to operate properly. Thus the barrier can be removed by improving the functioning of the market. In the second, the barrier is due to non-(classical) economic reasons. As observed in [11], viewing EE through an economic lens highlights that policy should aim to encourage economic efficiency, rather than narrowly focusing on EE. This observation can be similarly applied to the EPN concept, under certain conditions, namely: liberalisation of energy system markets or absence of significant market failures (such as non-incorporation of externalities related to CO_2 emission).

Reference [12] builds on this separation of barriers into market and non-market failures, by defining barriers as: (i) economic; (ii) behavioural; and (iii) organisational. Here (i) is equivalent to the market failure definition, with (ii) and (iii) mapping to the non-market failures of [11]. As highlighted by [12], this typology is not exclusive, and barriers may have multiple aspects as well as be multiple and overlapping. Each of these three classifications has multiple examples, and can be informed by various fields, as shown in Table 2-1 (derived from [12]).

Table 2-1: Perspectives on energy efficiency barriers

Perspective	Examples	Theory

Economic	Imperfect information, asymmetric information, hidden costs, risk	Neo-classical economics
Behavioural	Inability to process information, form of information, trust, inertia	Transaction cost economics, psychology, decision theory
Organisational	Energy manager lacks power and influence, organisational culture leads to neglect of energy/environmental issues	Organisational theory

Several further studies draw on the seminal work in [12] and produce slightly different classifications due to differing perspectives and emphasis. Reference [9] refers to work on socio-technical change [13], which argues that social and technological change is complex and interrelated. Here, the authors focus on the interaction of people and technology, dividing barriers into technical (relating directly to technologies), technological (related to human interaction with technologies), and socio-technical (related to largely human factors). In [14] a stakeholder consultation leads to a classification which is related to that described in Table 2-1, but with a clearly more practical emphasis. The classifications proposed in [14] are: management, knowledge/information, financing, and policy. This practical classification is useful, for DR as well as EE, as it highlights the financing (difficulty in obtaining financing for a project) and policy (weak legislation, limited or perverse incentives) non-market failures, which cannot be derived from the classification in Table 2-1. A final study on EE worth mentioning is [15], which is an evolution of [12]. Although not explicitly a study on barriers, it is a useful summary of the issues around reduction in energy demand, which has connotations for DR. In particular, the identification of several apparently separate issues (technology lock-in, emergence, user behaviour, user preferences, and institutional design), which may, in fact, be regarded as characteristics/factors of complex systems [16] and signals a potentially important future direction for the study of barriers to EE and DR.

As demonstrated above, drawing on the literature of DR and EE, there are many and various classifications of barriers to the EPN concept that can be employed. As also shown, no matter which classification is adopted, barriers may span classes, and are frequently interrelated. In this context the ‘correct’ classification system is open to debate. In this report barriers shall be split into four classes:

- Political/regulatory,
- Economic,
- Social, and
- Technological.

Given the importance of markets to the EPN concept, and the clear definition of classical economic barriers (market failures), it is clearly instructive to define a class of economic barriers. Although [12] defines behavioural and organisational barriers separately, their common root in microeconomic theory motivates their common grouping. In this work they are covered by the ‘social barriers’ class. Given the importance of technology in the EPN concept a technical class is also defined. Finally, although closely related to economic barriers, a separate political/regulatory class is defined to better detail the role of political decisions in forming and eroding barriers to the EPN concept. In the remainder of this section the barriers are further explored, within the framework of the above defined classification. It should, however, be recognised that barriers may span classes, and should be viewed solely within the context of the assigned class.

2.2 Political/regulatory

Political/regulatory barriers are defined here as those barriers which exist as a result of government policies, usually enacted through regulation. In the literature **the distortionary effects (on markets) of government policies are sometimes regarded as a market failure** [17]. Such policies can result in barriers for a number of reasons. Firstly, markets can be distorted by the applicable tax code, which may treat various expenditures differently. Discrepancy in the treatment of operational/capital costs, or between substitutable goods (such as electricity and gas, or types of heaters) can cause distortion. Another tax-related barrier can arise from the installation of electricity storage in an EPN. When such storage lies behind a meter, tax will be charged on electricity used for charging the battery (as this cannot be separated from actual consumption). This will create a barrier to the efficient use of the storage [18].

Regulation may also cause distortion in markets if goods that are practicably substitutable (i.e., generation and consumption based Operating Reserve (OR)) are precluded from competing with each other. As highlighted in [18] this is part of a wider issue of the dominant paradigm in energy systems. Historically, electricity systems have built on the assumption that electricity flows from large scale central generators to passive, distributed users. Accordingly, the regulation of the system has been tailored to this paradigm. This can place barriers for the EPN concept when characteristics (such as minimum bid size, gate closure times and product definitions) are suitable for central generators, but not for EPNs wishing to partake in markets. A particular point is the separation, in some systems, of generation from demand into different parties responsible for balancing, which will preclude the use of flexible demand (such as in an EPN), for balancing generators.

A more fundamental barrier for EPNs, or the demand-side in general, is regulation which prevents market price signals from reaching ultimate consumers. As detailed in [18], and demonstrated in D6.3, such regulation not only damages business cases for EPNs or similar demand-side parties, but also inhibits the efficiency of markets. In cases where transaction costs are thought to outweigh the benefits of full price-pass-through, or where net-metering, as an incentive for small-scale generation [18] is appropriate, it may be justified to retain regulation of consumer prices. Striking a balance between these motivations, so as to minimise overall barriers to the EPN concept is difficult.

A further political barrier may result from uncertainty derived from unclear policy[4]. Survey based literature has highlighted this as a particular barrier to smart grid development [19], which can be extended to the EPN concept.

Finally, given the heavily regulated nature of energy network operators, the barriers to the EPN concept posed by the regulation of network operators must be mentioned [20]. These include: the focus on historical performance, rather than future requirements; short regulatory periods; focus on the network operator, rather than system-wide effects; and the lack of recognition of the value of research and development. In particular, the issue of different treatment of operational and capital cash flows is particularly relevant. Short regulatory periods, and the lack of uncertainty on the benefits of capital investment can encourage capital expenditure heavy grid expansion over operational expenditure heavy DR, leading to generally sub-optimal outcomes [21]. With reference to the business cases pursued in the

[4] This may be considered a special case of the uncertainty market barrier, see 2.3.2.

COOPERaTE project, such bias could result in a failure to consider the benefits of the Distribution Network Constraint Management (DNCM) business cases, or of the improvement to reliability if the EPN is able to act as a microgrid as discussed in D6.3.

2.3 Economic

Partly due to the existence of a convenient framework for their analysis (i.e. classical economic theory) there is a large body of work on economic barriers to EPN-related concepts (largely EE). **This work generally involves study of market failures (i.e. flaws in the way a market operates) and market barriers (i.e. other obstacles to the given objective)** [9]–[11], [17], [22], [23]. **Given the substantial role of markets in the EPN concept, this approach is appropriate for the study of EPN economic barriers.**

2.3.1 Market failures

The above cited works contain several classifications of market failures, mostly in relation to EE. Drawing particularly on [9], [10], [17], [23] Table 2-2 describes the general classes of market failures relevant to the EPN concept, which ae expanded upon below.

Table 2-2: Classification of market failures

Market failure	Description
Imperfect information	Classical economics assumes that all parties have access to free and perfect information. In reality this may not occur, which constitutes a failure.
Incomplete markets	Markets in which property rights are not well defined can be termed incomplete. This is a failure as it can result in a discrepancy between private and social costs and benefits [23].
Imperfect competition	Uncompetitive markets, where one or more parties have, and exercise, market power.

Imperfect information can occur for a number of reasons. In reality there are (cash and time) costs associated with collecting and processing information [17]. These search costs form part of the transaction costs of partaking in a market (see D6.2). The existence of these costs means that it may be infeasible for parties to collect all the relevant information, resulting in an 'Adverse selection' market failure [9], [23]. This is likely since, as described in D6.1, an EPN exists within energy systems that are very complex, which will increase search costs. Imperfect information may also arise if markets are so immature that the demand for certain types of information is not sufficient to motivate its collection and distribution by market participants [9].

A special type of information-related failure is that of asymmetric information, producing split incentives [9], [17], [23]. If one party has access to information which it cannot effectively communicate to another party (e.g. due to large transaction costs), then the parties have split incentives (which cannot be reconciled through a contract, because they are not defined). In the case of an EPN who has contracted with an aggregator (e.g. a retailer or a third party), this could arise if the aggregator cannot fully understand the flexibility of the EPN, as it cannot understand the user preferences which dictate (at least some of) the flexibility. If such user preferences were fully understood, there would be no failure, as the terms for flexibility exploitation could be defined in a contract. This can give rise to the 'principal-agent problem' [9], [23]. In this case the 'principal' does not have the necessary information to define a contractual obligation on the 'agent' (e.g., in the context of an EPN, the 'principal' EPN does not have information on the various markets to fully define how the 'agent' aggregator must act). This can lead to opportunistic behaviour on the part of the agent (aggregator), which is not in the interest of the principal (EPN).

Reference [10] details several further information-related failures, relating to lack of various knowledge or skills. However, these can be considered special cases of the 'Adverse selection' failure, as the result of such lack of skills/knowledge is a higher degree of adverse selection.

As detailed in [23], *incomplete markets* may arise when property rights are not well defined (i.e. comprehensively assigned, exclusive, transferable, and secure). For example, the costs of unregulated CO_2 emission are not exclusive; they accrue to many (through increased atmospheric warming, and associated implications). The existence of this 'externality' constitutes a market failure. As demonstrated in D6.3 this failure can lead to increased levels of CO_2 emission (with the associated increased cost to society), under certain business cases (e.g. those Irish business cases not involving wholesale electricity price signals). Another example of an incomplete market is where benefits of an asset are not excludable, as can be the case with DR [3], [24]. This can result in some parties free-riding, which is a clear market failure. An example is demonstrated in D6.3, where retail price signals are such that peak grid import is reduced compared to the base, load-following case. This benefits the Distribution Network Operator (DNO), by reducing peak load, without cost to the DNO. A further example may be where cost socialisation results in a lack of signals to market participants to adjust their behaviour in an appropriate way. An example can be the heuristic imbalance penalties applied in many imbalance settlement processes (see D6.3) [25].

A clear market failure occurs when a party/parties have such a large market share that they are able to exert market power, creating *imperfect competition*. In this scenario, parties can charge prices in excess of their marginal costs, resulting in an inefficient market.

2.3.2 Market barriers

As with the classes of market failures, there are many classes of (economic) market barriers detailed in the literature. An extensive list is given in [10]. Many of those classes, however, relate to information or behaviour, and are thus covered by the 'imperfect information' market failure, or by behaviour-related barriers (see 2.4.2). The remaining market barriers are summarised in Table 2-3.

Table 2-3: Classification of market barriers

Market barrier	Description
Access to capital	Some EPN-related activities may require additional capital investment. For some parties, with little reserves and/or poor credit rating, accessing capital may be problematic
Uncertainty	Uncertainty on future revenue/costs can pose a barrier
Hidden costs	Hidden costs related to market participation i.e. negotiation and enforcement costs associated with transactions (see D6.2) may be a barrier
Value	It is possible that flexibility is simply not valued in a system, as there is

	no requirement for it. This can be a barrier to the EPN concept

The degree to which *access to capital* is a barrier to the EPN concept will vary depending on the degree of investment required (which may be small, if the flexible infrastructure is largely already present, see D6.2), and the party making the investment. As demonstrated in D6.2, a retailer may be able to access capital at a cheaper rate than the constituents of the EPN itself, which will result in a retailer-led EPN being more economically attractive than an EPN-led version.

Inclusion of *uncertainty* as a separate market barrier is debatable. As highlighted in [9], it may be considered a barrier if parties are not able to reduce the implication of uncertainty to a calculated risk. However, this could be considered a result of *bounded rationality*, a behavioural barrier. Further, some parties may be particularly risk-averse, meaning that, even if risk can be estimated, uncertainty may prove a barrier. However, risk-averseness should be considered a preference resulting from the party's values. Hence, again, this may be considered a behavioural barrier. However, given the clear possibility of measures to address uncertainty (see 3.2), it shall be considered a separate market barrier here.

Hidden costs relate to the costs associated with participation in markets. These include negotiation and enforcement transaction costs (see D6.2), but not search transaction costs, which relate to the imperfect information market failure. If these hidden costs are excessive, they could represent a barrier to the EPN concept. As discussed in D6.2, such costs can been 'outsourced' to organised markets, who will charge fees to cover them. Such fees should be taken into account, as they may pose a barrier, particularly to small parties.

Value is not considered a barrier in the literature on EE, as the value of reducing energy consumption is assumed to be logical. However, for the EPN concept this is not so, as the value of flexibility is not given. Although all systems are likely to have some value for flexibility (as demand is always uncertain, and generator tripping is always possible) some systems will have more value than others. For example, flexibility may be more valuable in systems with highly variable and unreliable generation than in systems with a predictable and reliable generation.

2.4 Social

Social barriers may, in the first instance, be usefully classified following the example in [23], as organisational and behavioural. Organisational barriers may be relevant to commercial parties within an EPN, as such barriers relate to the social systems of such structured organisations. Arguably of greater importance are behavioural barriers. **Given the large number of decisions involved in utilising energy (particularly in an EPN where a higher level of engagement is required of users), behavioural barriers may be very significant.**

2.4.1 Organisational barriers

Reference [23] identifies two organisational barriers: power and culture. Power (or lack of it) may be a barrier where it relates to the power of the person within an organisation who has a responsibility for implementing the EPN concept. In the context of the COOPERaTE project, this person is the Neighbourhood Energy Manager (NEM) if the EPN is one organisation, or is likely to be a building's Facilities Manager (FM) if the EPN is made up of several parties. If the NEM/FM does not wield enough power within their organisation (e.g., to install necessary enabling technology, to instruct (to the degree possible) behaviour change, or to invest in increased flexibility), then the EPN concept may not be viable. Power, as a barrier, is closely linked to the less precise barrier of organisational culture. Indeed insufficient power for the NEM/FM is likely, in some part, to be due to the prevailing culture of the organisation. Specifically, if energy, environmental and even economic concerns (outside of the core business) are not generally regarded as important within the organisation, then this will form a general “soft” barrier to the EPN concept.

2.4.2 Behavioural barriers

Behavioural barriers may be described as those factors which explain why the behaviour of any individual deviates from that of the ideal, fully rational (in the classical economic sense) agent [26]. For a firm, rational means profit-maximising, whilst for an individual it means utility-maximising. This latter definition is more complex, as an individual must consider factors such as convenience and comfort, as well as cash. This can lead to barriers that are often considered to be behavioural (e.g. the requirement of veto over third party control of devices and general aversion due to perceived inconvenience [27]), to instead be classified as (micro)economic. Given that the definition of rational behaviour is open (e.g. is inertia, in fact, rational, as it economises on cognitive exertion [28]), such barriers shall be considered as behavioural here.

A useful definition of behavioural barriers can be drawn from work on barriers to EE [9], as shown in Table 2-4.

Table 2-4: Behavioural barriers

Barrier	Description
Form of information	Information is not regarded as intended by the sender, which means that the corresponding behaviour of the recipient is not as expected by the sender. An example can be the design of the user interface; a poor design can result in unexpected behaviour [27].
Credibility and trust	How the recipient of information regards the sender will dictate how such information is used. For example, do they trust the sender? Do they perceive them as reliable? Do they identify with them (i.e. do they think the sender has the same values)? The issue of trust is identified as important in EPN type concepts in [27].
Values	Besides cash cost minimisation, EPN consumers may be influenced by their values (e.g. environmental values, energy conservation values). If these values do not align well with the objective of the EPN, this may form a barrier.
Inertia	The entrenchment of (non-EPN aligned) behaviour may be a barrier, as such behaviour can take time to change, even if there is clear benefit to doing so.
Bounded rationality	Another reason that behaviour may not change, despite evidence of the benefit of doing so, is the existence of bounded rationality. As the cognitive capacity of an individual is constrained, it can be expected that, even with the necessary information, they may not reach the optimal decision, as they cannot successfully process the given information.

Of particular note is the impact of values on preferences for valuing an energy service. If an energy service is too highly valued by the user, they will not be willing to trade it to produce flexibility. This lack of flexibility can itself be considered a barrier [27].

Particular issues related to behaviour, which are often presented as barriers are user acceptance and privacy.

2.4.2.1 User acceptance

Particular issues on user acceptance that have been highlighted relate to perceived inconvenience of interventions. In this vein, [29] highlights the necessity that interventions "fit" with current lives. In this view a user may reject the EPN concept if they feel that its implementation requires excessive change to their current habits [27]. With reference to Table 2-4 this barrier may be classified as a 'values' and/or 'inertia' related barrier, as either user preferences (derived from their values) or inertia leads them to reject the change required as either undesirable or too radical. Another user acceptance barrier highlighted in the literature is the reticence to allow third party control of devices. As discussed in 2.4.2.2, this may be due to concerns on privacy, but it may also be related to a user's preferences with regard to concepts such as autonomy, ownership, power and control [30]. The identity of the third-party will be a material factor here, as some organisations elicit more recognition and trust than others (e.g. awareness of electricity retailers is generally higher than of DNOs).

It should be noted, however, that such user acceptance barriers may decline in relevance over time, as institutions (e.g., 'hard' institutions, such as markets and laws, and 'soft' institutions, such as social norms, change over time [26].

2.4.2.2 Privacy

Privacy barriers, related to users' unwillingness to share data are closely related to 'trust' barriers, as detailed in Table 2-4. As described in [30] the willingness of users to share data, is significantly related to the degree to which they trust the party they are sharing with. However, the amount of benefit the user can expect from sharing the data is also relevant. In particular, users may be concerned about the ability to derive non-energy related information (e.g. building occupancy and activity patterns) from such energy data [31].

2.5 Technological

Unlike for EE, technological related barriers are directly relevant to the EPN concept. These barriers may be classified under several interrelated themes which largely echo the central role of information outlined in section 2.3 and 2.4. These themes are summarised in Table 2-5, before being explored in more detail, below.

Table 2-5: Technological barriers

Barrier	Description
Technology development and implementation	Inadequate requirement elicitation, actual/perceived technology readiness, lack of clarity/uncertainty of technology capability.
Data acquisition and actuation	Lack of appropriate metering technology, cross-sectorial status of operating technology (OT).
Data benchmarking	Lack of suitable baselining methodology.
Data security and privacy	Lack of data security/confidence in data security.
Data Interoperability & Standardisation	Interoperability of technology standards, too much/little standardisation of products in markets.
System complexity	Increased system complexity, in particular due to increased variety.

Network constraints	Electricity distribution networks may be unable to deal with new peaks in demand.

2.5.1 Technology development and implementation

The EPN concept relies on state of the art Information and Communication Technology (ICT), or what is often described as Internet of Things (IoT) technology, which leverages both cloud and embedded computation. There may be barriers associated with misalignment between the design / development of such technology and its required application and deployment. Such issues can often be the result of a poor or hampered requirement elicitation process. There may be genuine and/or perceived technology readiness issues, or there may be misconceptions and/or uncertainty as to what the technology can deliver.

An example of this relates to ‘Big Data’ solutions. At times the customer can assume that the technology will identify new value opportunities for their business. The technology can be used to do exactly that, but it cannot independently deliver this. Big data technologies can deal with voluminous, heterogeneous, real-time and static data, and can identify new patterns within that data. However, content experts, with the capacity to interpret such data and identify what is of value relevant to the business context, are also required. Even with customers that understand this, a level of trust, or risk assessment, in making the investment is needed. This is because the decision is essentially based on the premise that by traversing more information, one should be able to make better decisions in controlling ones environment (see 2.5.6 on system complexity). This can be a significant barrier to technology development and implementation because the outcomes are not deterministic (i.e., there is uncertainty, see 2.3.2).

2.5.2 Data acquisition and actuation

Data acquisition and actuation pertain to the connection between the ICT cyber-world and that of the physical mechanical/electrical world, i.e., the things to be monitored and controlled within the EPN. This largely relies on existing Operating Technology (OT) within the EPN, such as Building Management Systems (BMS), Facility Management Systems (FMS), electrical meters, gas meters, Programmable Logic Controllers (PLCs), etc. Barriers to the EPN concept may exist where such existing infrastructure is inadequate. This can be the case for metering infrastructure, which may not be sufficiently disaggregated (temporally and/or spatially). This may be relevant as typically, energy markets trade in 15 minutes to 1 hour periods. Therefore, to partake in these markets, metering at this level is required. Further, depending on particular commercial arrangements, there may be a requirement for extensive sub-metering within the EPN. This may be required if it is deemed necessary to separate flexible and non-flexible resources, for example. It is also possible that, for some markets (e.g. for “fast” OR products, such as primary and secondary OR, in the Irish context, see D6.3) that even finer metering may be required, down to the scale of minutes or less.

More broadly, barriers may exist due to the traditional classification of OT as ‘built environment’ rather than ‘energy’ infrastructure. In essence the EPN is a cross-sectorial multi-ownership concept which adds to complexity (see 2.5.6) and this has implications for benchmarking (see 2.5.3), security and privacy (see 2.5.4), and standardisation (see 2.5.5).

2.5.3 Data benchmarking

Many of the business cases, which require action against a suitable ‘baseline’ profile, will require a suitable baseline methodology. To provide a baseline for measuring the delivery of certain products (such as OR or DNCM, see D6.3), adequate metering is a necessity, but not a sufficient condition. Whilst high resolution metering data can describe the consumption/generation for the given resource, it cannot tell, in the event of a product call (e.g., for OR or DNCM), what the profile would have been without the call. Indeed, there is no way of knowing what would have happened. But, to determine compliance with respect to the relevant contract, it is necessary that some baseline can be agreed between the buyer and seller. Indeed, as discussed in [2], establishing a baseline may be a barrier to deployment of an EPN as it can impede proper valuation of a product. Indeed, a complete analysis of the issues around baselining can be found in [2].

More generally, the lack of suitably detailed measurement can be a barrier, as it prevents the EPN from being properly managed. Also, further to the operational baseline barrier discussed above, the lack of appropriate and agreed assessment methodologies may be a barrier, e.g., for raising capital.

2.5.4 Data security and privacy

It's estimated some 50 billion things (i.e., machines) will be connected to the internet by 2020 [61]. Given user concerns on privacy (see 2.4.2.2), insufficient data security may be a barrier to widespread adoption. As per D1.6 'Report on Refined specification for Neighbourhood Management Architecture', there are several features of ICT systems supporting EPNs (akin to IoT systems) which are particularly relevant to security. Specifically, these related to the tendency of EPN/IoT systems to be:

- physically distributed
- a mixture of very small to very large devices
- dependent on closed & open or untrusted networks
- large scale deployments, which may extend to tens of thousands of components.

They also have complex attributes of other systems, such as:

- different parts of the system may be created by different vendors
- use and functionality changes over the duration of the system's lifecycle.

Table 2-6 outlines security aspects that need to be considered in any holistic approach to security. The top left column can be considered 'network' security, bottom left 'physical' security and right column 'other'. If such elements are not incorporated at the development stage it can be arduous in retrospect to implement them. If not addressed, security concerns can act as a considerable barrier to adoption, especially with cloud based technologies that require storage and processing of data off-premises. For more detail see section 6.2 of deliverable D1.6.

Table 2-6: A holistic approach to security

<table>
<tr><th colspan="2">Security considerations</th></tr>
<tr><td>- Firewall
- Virtual private networks
- Authentication</td><td rowspan="2">- Key management
- Device attestation
- Runtime controls
- Stack simplification
- Integrity measurement
- Data encryption</td></tr>
<tr><td>- Device-specific cert
- Trusted Platform Module (TPM) Platform Configuration Registers</td></tr>
</table>

(PCR) - **Secure boot** - **physical access**	- **Data authentication**

Separate to security is the issue of data privacy. As outlined in 2.4.2.2, unwillingness to share data due to fears of misuse or profiteering is a very real barrier to EPN concepts or more specifically to the adoption of the technology that underpins it. Developing ICT/IoT solutions that do not account for these concerns can impact the adoption/investment decision of any proposed offering.

Strategies for placing privacy control in the hands of end users was a specific focus of D3.3 ‘Report detailing dynamic cloud/edge workload exchange strategies’, while the neighbourhood information model in D1.5 incorporated ‘privacy by design’ concepts.

2.5.5 Data Interoperability and Standardisation

Lack of standardisation in enabling technologies is often cited as a barrier to EPN-type concepts. At the operational level standardisation in data exchange is required to ensure that all actors and devices that need to can communicate with each other, e.g. to send control signals or to submit bids and offers, and this echoes the link between market failure and imperfect information in 2.3.1.

Without the necessary standardisation here, the components of the EPN cannot talk to each other, and flexibility cannot be exploited [27]. Lack of standardisation on the interoperability of various components may also be a concern if it is thought that various devices may interfere with each other [29]. Further, lack of standardisation of EPN components may prove a barrier if there is concern on the part of those responsible for investing in equipment that they may become “locked-in” to a particular supplier. This may result in constraints on future decisions which lead to sub-optimal outcomes.

Assuming access to accurate data, one must deal with data formatting, transfer, transformation and semantics. If the latter could be agreed by all actors then the EPN concept could be delivered in rapid time. However, in reality interoperability has traditionally been, and continues to be, a very slow process taking many years due to competing approaches and alliances. Figure 2-1 gives a pertinent example illustrating the myriad of IoT alliances that traverse the various communication layers and potential domain verticals. Similar issues are relevant with respect to data acquisition (see 2.5.2), specifically for ‘smart’ metering.

Figure 2-1: IoT Alliances round-up Source http://postscapes.com March 2015

This shifting landscape of often competing approaches is a primary reason that the initial view of an overarching platform for the delivery of an EPN (see Figure 2-2) evolved within Cooperate to the System-of-Systems (SoS) approach of Figure 2-3.

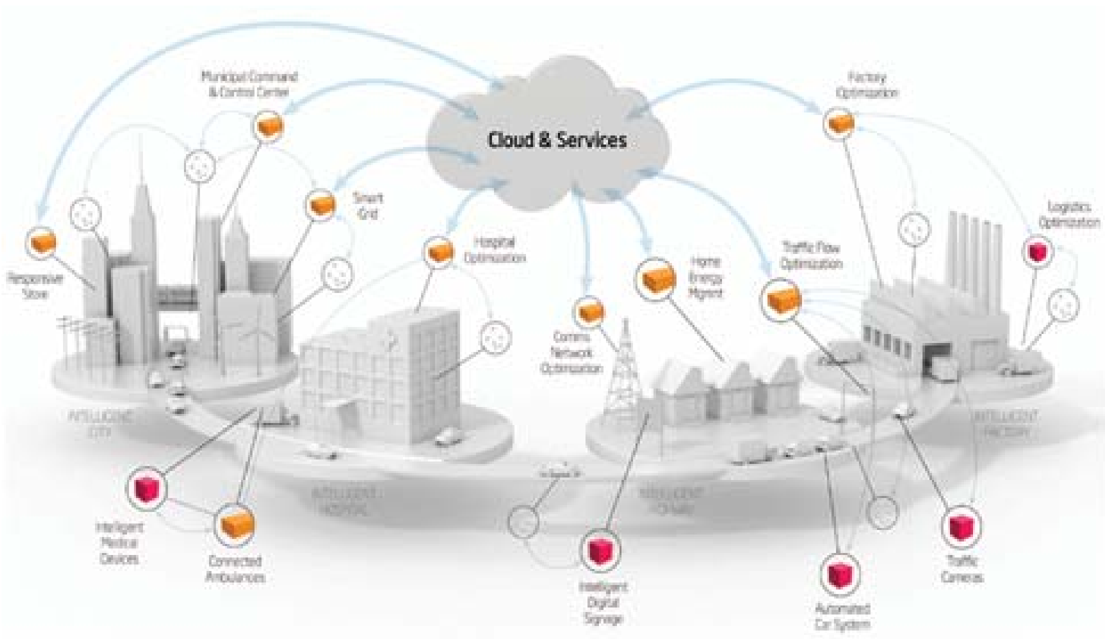

Figure 2-2: Original Cooperate platform based approach

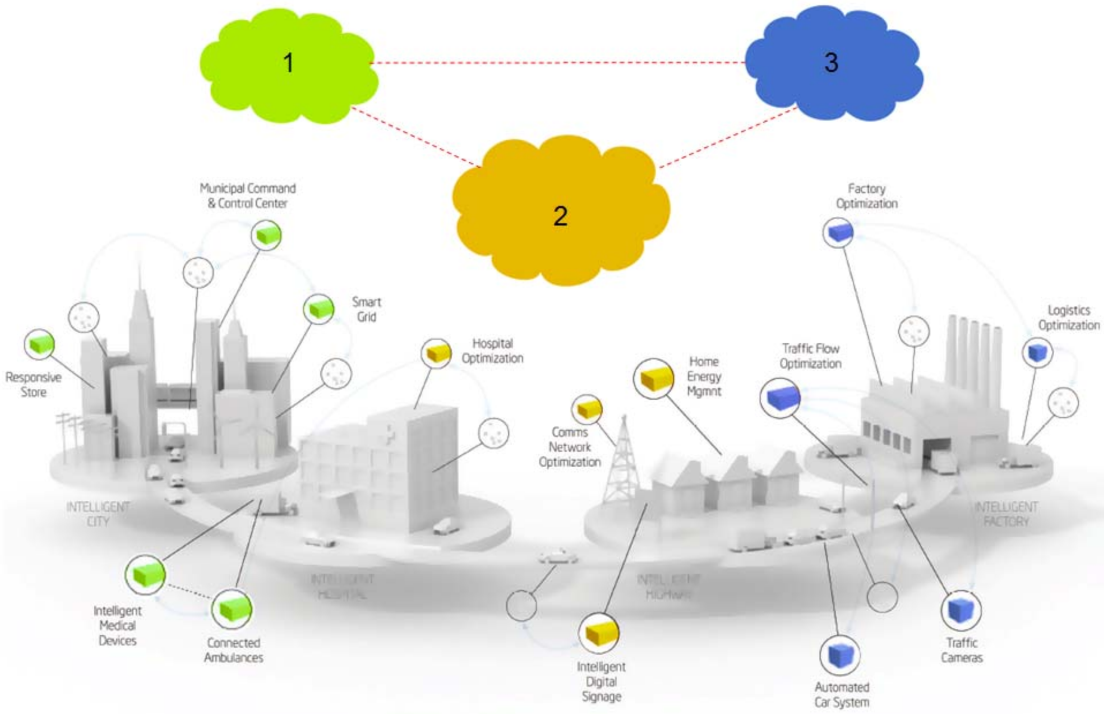

Figure 2-3: Proposed Cooperate SoS approach

As opposed to the barrier of too little standardisation described above, too much standardisation may also be a barrier. Although energy and capacity (the basic commodities which are being traded in all markets in which the EPN may partake) are continuous in nature, they ae typically traded as defined products. These products are standardised according to a number of attributes, e.g., amount (kW or kWh) or time of trade (week-ahead, day-ahead). For example, although OR could, in principle, be provided for any length of time, it is usually defined as a number of discrete products, each with its own features (i.e., response time, operating time). If the definitions of the standardised products are too restrictive, they may preclude provision by an EPN, or may mean that the full value of the EPN concept cannot be realised and hence result in sub-optimal system efficiency.

On the other hand however, standardisation of products generally reduces transaction costs, as the definition of a restricted number of products can reduce search and negotiation costs [32], see D6.2. Thus there may be tension between the motivation to reduce standardisation (to increase realised EPN value and system efficiency) and to increase standardisation (to reduce transaction costs).

2.5.6 System complexity

A specifically technological barrier to the EPN concept may lie in the complexity of the system, physical and economic, that EPN data services must negotiate [3]. In general, addressing data at the scale of the neighbourhood is subject to complexity as categorised by the ‘Four V’s’ of big data: Volume, Variety, Velocity and Veracity. In particular, variety on a number of aspects may increase complexity. For example, and as previously discussed, demand/generation must be disaggregated in time, to play in certain markets and to understand the power (capacity) implications of resources. Where there are network limitations within the EPN it may also be necessary to disaggregate in space also, and employ some kind of locational marginal pricing [33]. This can add substantially to the computational burden of any optimisation of the EPN. Further, as flexibility within an EPN can be best exploited by understanding the underlying energy services [34], additional complexity will result from understanding (and modelling) the EPN systems of energy conversion, storage and distribution, which link energy services to energy grids (see WP2).

The level of complexity in an EPN deriving from increased variety may be further increased by less technical considerations such as the ownership of the EPN and its constituents. For example, if, as with the Challenger campus test bed, the EPN is owned entirely by one party then complexity in the management and optimisation of the EPN is limited, as all necessary information is available. Even if there are multiple owners within the EPN, complexity may be limited if, through agreement, management and optimisation is undertaken by one party (such as the NEM). If, on the other hand, the various owners within the EPN do not wish to share information, and decentralised optimisation is required, complexity can increase substantially. This is due to the increased number of agents and increased amount of communication required in decentralised optimisation approaches, e.g., Lagrangian relaxation based methods [35], or game theory based intra-EPN markets [36].

Given the presence of these aspects of 'big data', and lack of agreed mechanisms for data exchange (see 2.5.5), the complexity of the EPN becomes a barrier. This is because, as the complexity of the system increases, so must the complexity infrastructure to control it. In cybernetics ('the science of communications and automatic control of systems in both machines and living things') [57], Ashby's law of requisite variety [58], [59] essentially states that 'only variety can destroy variety'. Thus any proposed ICT system for controlling an EPN must be equal to the variety or complexity of the EPN in order to control it. This may prove a barrier if the complexity of the system increases the computational burden of any optimisation to the extent that it cannot be practically executed in required time-scales. However, in practical terms any regulator of a system need only require a level of sophistication that can respond to the most likely stimuli. Nevertheless constructing an ICT system complex enough to reasonably control an EPN is an arduous task, primarily due to the variety introduced by a myriad of existing in-situ systems. This is why a SoS approach is posited within COOPERaTE.

2.5.7 Network constraints

The increasing levels of resources and flexible loads responding to dynamic price signal may result in technical issues on distribution networks, where those resources/loads are connected to the electricity networks. This is since controllers will shift large portions of power consumption towards the lowest price periods, which in turn may overload distribution network assets and lead to voltage rise/drop issues beyond the statutory voltage limits. Following the traditional planning approaches adopted by DNOs to maintain network constraints within limits, upgrading the distribution network assets is required. However, this may produce a technical barrier to the EPN concept, since network reinforcement is an expensive and time-consuming solution, resulting in a higher distribution network fee paid by EPNs.

2.6 Summary of barriers

Section 2 of this deliverable has identified and categorised barriers to the EPN concept, drawing on industrial and academic literature, particularly the literature on *flexibility*, *demand response* and *energy efficiency*. To summarise all the barriers, Table 2-7 presents barriers by class with a brief description.

Table 2-7: EPN barrier summary

Name	Description
Political/regulatory	

Tax	Tax codes may favour one form of expenditure over another.
System standards	Energy system markets and product standards may be unnecessarily restrictive.
Price pass-through	End-users may be unable to receive market price signals, which precludes market participation.
Unclear policy	General lack of clarity prevents commitment to new energy paradigm.
Network regulation	Out-dated network regulation may stunt interest in EPN services.
Economic	
Market failures	
Imperfect information	Incomplete or asymmetric information between parties will skew market outcomes.
Incomplete markets	Markets which do not account fully for all benefits and costs will skew market outcomes.
Imperfect competition	Excessive market power will inevitably lead to inefficiency in markets.
Market barriers	
Access to capital	EPN may be constrained by lack of access to capital for enabling investments.
Uncertainty	Uncertainty, or rather the inability to manage it, or preference to avoid it, may be a barrier for EPNs.
Hidden costs	Hidden transaction costs can hamper EPNs.
Value	Inherent lack of value for flexibility will fundamentally undermine the EPN concept
Social	
Organisational	
Power	Lack of power for decision maker within an organisation will hamper EPN concept.
Culture	More generally, lack of priority for energy/environmental factors within an organisation will prevent implementation of EPN concept.
Behavioural	
Form of information	The form of information presented to a user can result in undesired behaviour, if not optimal.
Credibility and trust	A lack of trust may result in undesirable responses to information sent.
Values	If user values do not align with EPN objectives, this may form a barrier.
Inertia	Entrenchment of non-EPN aligned behaviour may form a barrier to the EPN concept.
Bounded rationality	Cognitive limitations may prevent optimal behaviour.

User acceptance	Fit with current lives highlighted as a barrier to the EPN concept.
Privacy	Requirement for privacy (with regard to sharing information) may form a barrier to the EPN concept.
Technological	
ICT development & implementation	Tech readiness, misaligned expectations, poor elicitation processes, miss-use of technology.
Data acquisition & actuation	Myriad of physical interfaces, ownership and sectorial siloes. Data exchange & interoperability particularly problematic at the physical level.
Benchmarking	Lack of necessary metering and assessment methodology may form a barrier to understanding value, impacting investment & adoption.
Security & privacy	Another major barrier which creates much uncertainty due to concerns re malicious attacks and miss use of data and or profiteering without individual knowledge or reward.
Data Interoperability & Standardisation	Lack of standards may prevent implementation of enabling technologies. Data exchange / interoperability is a primary technological barrier, as data flows & data completeness underpin the overall EPN concept. Excessive standardisation of market products may prevent optimal exploitation of EPN flexibility provided through ICT adoption.
Complexity	Complexity may inhibit the assessment of EPN business cases, investment in & hence adoption of ICT solutions that underpin the overall concept.
Network constraints	Price responsive EPNs may increase coincidence of electricity demand, causing new peaks, which may violate electricity distribution network limits.

3 Enablers

Section 2 above details a comprehensive account of barriers to the EPN concept. Many of those barriers may be, at least to some degree, circumvented through implementation of various enablers. Below, relevant enablers are detailed, following the same PEST framework used in **Section 2**. The detailing of an enabler below does not necessarily constitute a recommendation for its adoption, as enablers typically have a cost associated with them. This cost may well exceed the associated benefit. Hence, adoption of any enabler should be subject to a cost-benefit analysis (see D6.3).

3.1 Political/regulatory

To counter the barrier caused by tax being charged on energy used for charging storage, separate metering of different types of resources may be implemented. This disaggregation of consumption, generation and storage can result in more efficient taxation (e.g., through avoidance of taxing charging of storage). A wider enabler is the more general review of energy system regulation to identify regulation which is a product of the legacy dominance of central electricity generation, and which unnecessarily inhibits distributed players, such as EPNs. This is clearly a significant task, and requires the support of all stakeholders, some of whom may have entrenched views of the substitutability of demand-side resources for generation resources in many areas.

A more specific enabler would be the ability to pass price signals (possibly through a third party) through to end-users, to promote efficiency in energy markets. Whilst there is demand amongst end-users for such capability (given the transfer of market risk to consumers that this would entail), regulators should offer the option. As with any new service/technology, adoption of the option may take time, but the growth of enabling technologies (e.g. smart meters, home automation, broadband internet) means that option may be increasingly attractive.

Further, cost-reflectivity in energy markets should be improved generally to improve market efficiency. For example, penalties for imbalance which do not fully reflect the costs of the imbalance (e.g. due to reserve provision, balancing mechanism operation) is a regulatory factor which inhibits efficient market operation. Measures should be taken, where cost effective, to make sure all markets are cost reflective. An example can be the measures being taken in the UK to reform imbalance pricing in the UK [37].

With regard to grid operator regulation, greater emphasis should be placed on innovation and new solutions (such as DNCM), such as that encouraged by the 'revenue+incentives+innovation+ouputs' (RIIO) framework in the UK [38].

In general, policy certainty is an enabler, to counter perceived uncertainty, which may inhibit commitment to the EPN concept.

3.2 Economic

Economic-related enablers will either relate to improvement in the functioning of markets (through fixing market failures), or intervention in market operation specifically to address some market barrier.

3.2.1 Market failures

A step to improving the functioning of markets, with particular regard to EPNs and other demand-side resources, can be the development of markets specifically for trading of demand-side flexibility, or for adjustment of existing markets [39], [40]. Such enablers could reduce search costs (which may be a significant proportion of potential profit) for EPNs, by bringing together buyers and sellers.

Enabling the EPN concept, through addressing the issue of ‘split incentives’, is particularly difficult. This is because user preferences (which the agent should take into account when acting on behalf of the EPN) are ill-defined, probably time variant, and probably not understood fully by the users themselves [41]. Here **efforts should focus on development of metrics of user preferences that might enable quantification and trading of flexibility (such as metrics on thermal comfort). Such metrics may then reduce the impact of split incentives by producing a means to effectively communicate information on user preferences.** A further enabler of the EPN concept may be development on the design of contracts, to better signal efficient behaviour to EPNs, thus increasing the available benefits. Reference [42] highlights the necessity of contracts to capture the preferences of consumers, which may require a wide variety of contracts.

To address the problem of incomplete markets (see 2.3.1), there is clearly a requirement to account for externalities, such as CO_2 emission. As suggested in D6.2 and explored in D6.3, this can be done (at the local level[5]) through development of a local CO_2 market. The issue of ‘free riding’, as multiple parties benefit from the exercising of DR, may be solved through concepts such as a ‘DR exchange’ [24], which can assign the costs of DR according to the received benefits. Similar solutions are being explored by industry parties [39], [43]. Alternatively a framework for remunerating service providers, which splits costs between beneficiaries, can be agreed [43].

To deal with barriers of imperfect competition, regulators must be able to monitor market power in EPN-related markets. This may especially be an issue in local markets, in which there are few participants (such as for DNCM).

3.2.2 Market barriers

The above detailed enablers relate to action to improve the functioning of markets. To address market barriers, it is necessary to intervene in markets to deal with features which are natural results of the market. Therefore, enablers to reduce barriers related to access to capital, uncertainty, hidden costs or value, generally require market intervention. However, if the enablers result in social benefit (as the EPN concept will) then such market intervention can be justified by governments.

Specifically, EPNs may be enabled by subsidies of various types. Loans may be offered at reduced rates, or guaranteed by government, to reduce barriers related to access to capital (such as with the UKs Green Deal [44]). If revenues are uncertain, tools such as contracts for difference can be offered to ensure a minimum payback [45]. Similarly, hidden costs, such as transaction costs, may be dealt with by subsidizing of a market which offers to handle negotiation and enforcement of contracts. It may be argued that the EPN concept can be enabled by similar intervention to deal with low value for flexibility. However, if there is an inherently low value for flexibility in a system, it is unlikely that any government will want to subsidise the participation of flexible parties, such as an EPN, in energy markets.

[5] Electricity generation in the EU is already subject to the EU emissions trading scheme

3.3 Social

Given the objectives of organisations to be profit-making, proliferation of information showing the cash benefit of the EPN concept should be a significant enabler to counter barriers of (lack of) power for the relevant decision maker, and culture within an organisation. However, as well documented, it may not be as simple as that since organisations do not always act perfectly rationally [46]. Nevertheless, an increase in status for the NEM or FM should help to enable the EPN concept. To counter any cultural barrier, a general education on the benefits of the EPN concept should be implemented.

Enabling individuals within the EPN to change their behaviour to promote the EPN concept may be more difficult. **Where behaviour to promote flexibility is constrained by bounded rationality (i.e. cognitive limits on the processing of information, which may relate to the time available, also), a significant enabler may be automation.** Automation, such as ‘Energy boxes’ [27], or smart thermostats, or building energy management systems, may enable the EPN concept by making operational decisions which the user is unable or unwilling to make. However, as such technology is unlikely to be able to fully capture user preferences, an important feature is the requirement for an ‘opt-out’ function [47]. This, however, will inevitably affect the value of EPN flexibility. Such technology may also be important in countering barriers of information presentation. Intuitive and clear information will enable the EPN concept by ensuring information is perceived as intended by the sender [48].

This leads on to discussion on user preferences, which derive from user values. The process of influencing user preferences to enable the EPN concept (e.g. attitudes to trading convenience or comfort for cash, or to allowing third party control of devices) is much less straightforward. As described in [26] the evolution of preferences is very complex, involving multiple feedbacks and, particularly, co-evolution with relevant institutions. There is no quick enabler here, though user values may be influenced by efforts to change institutions (e.g. changing social norms by influencing perceptions of energy use, or changing laws and regulation to communicate those changed norms). A related point is how to deal with the inertia barrier. Again, there is no quick fix, though ensuring information is transmitted correctly can ensure and can ameliorate inertia barriers, by making sure users ae fully aware of benefits.

Enabling the EPN concept through addressing concerns of trust may be more practical. Whilst trust in existing energy system actors may be low [27], **EPNs may be enabled through partnering with new third-parties (such as aggregators), circumventing issues of low levels of trust with existing actors. Increased trust between EPNs and aggregators may also assuage concerns on privacy, as end-users are more likely to be happy to share information (such as meter profiles) with parties who they trust.** Whatever the levels of trust, a principle that should be central to all EPN activities should be the ownership of consumer data by the consumer [27]. If this principle is clear, possibly enforced legally, consumers may have more confidence in the EPN concept. In addition, technical fixes, to ensure anonymization of data [49], may also enable the EPN concept, by giving confidence to end-users that their data cannot be exploited to obtain personal information.

3.4 Technological

3.4.1 Technology development and implementation

To ensure alignment between technology design/development and required application and deployment, the best known requirement engineering practises should be adopted. Good requirement elicitation practises will assist in ensuring correct identification of the desired service/use case, thus reducing technology misalignment and/or misuse. To this end, user led design, use-case development, and ethnography should be employed. **The importance of truly understanding what a customer/user is trying to achieve in purchasing and/or commissioning technology cannot be underestimated**, but is often poorly done. Incorporating user design principles and using ethnographic expertise in understanding the use-cases can save considerable frustration and cost further into the development and operation cycle.

To aid clarity on technology capability, succinct and clear documentation, specifications and user guides should be ensured. This removes uncertainty regarding technology fit, and ensures the technology is used as designed relative to the use-case. This builds on a good requirement elicitation process.

3.4.2 Data acquisition and actuation

If existing OT is inadequate, the EPN concept may be enabled through adoption of appropriate multi-protocol gateways and radio. These may play a key role in bridging the device network or OT world, and the internet. In addition, adoption of appropriate open agnostic technologies (e.g. OPC-UA, OpenHAB, OIC, etc.) and adapters, may be required. Such technology may be required as, in a world of multiple protocols, one needs the equivalent of translators to allow for common communication. Such agnostic technologies abstract and reduce complexity by acting as one-to-many adapters/translators.

Clearly, metering limitations can be countered by installation of high resolution ‘smart’ meters. Indeed such installation is being widely implemented [50], [51], at the dwelling/building level. However, further development may be needed on this front if EPN resources wish to partake in “fast” reserve markets, such as frequency regulation, which may require higher resolution metering. If storage within a property is to be metered separately (see 3.1), this may also require more investment.

To counter barriers relating to the EPN concept existing across both the built environment and energy sectors, plugin based architectures may be useful. Plugin based architectures promote modularity and extensibility, allowing parallel development and a clear path of development, thus aiding new feature/adapter development. This should promote cross-sector and third party development and hence adoption.

3.4.3 Data benchmarking

To enable EPN management, appropriate ‘smart’ metering is required as a high level of data visibility is central to the EPN concept. Beyond this, agreed assessment methodologies are required. Baseline methodologies and total cost of ownership methods can be used to assess return on investment. Such methodologies are also needed should one wish to leverage credits or incentives which are often required on sustainability focused investments. Additionally as our own EPN definition suggests, a more value focused and holistic assessment of the EPN needs to be taken. Assessing the impact of ICT investment as set apart from operational investment on sustainability goals can be difficult and efforts by the ITU [63] and GeSI [64] for example could prove useful in that context.

With regard to operational baselines, to enable markets which rely on “explicit” demand response (trading load) [52] to operate, a baselining method which is acceptable to all parties must be agreed. The nature of the baseline can be one of many. Several types have been set out in [53], as detailed in Table 3-1.

Table 3-1: Types of baseline method

Type	Description
Historic	This method uses historic load data taken from representative days to produce a baseline load profile, which is subtracted from metered data taken from the site. This baseline may be adjusted to take into account weather conditions during the DR event if these are deemed to influence demand. This methodology is most appropriate for DR programs which reduce (or increase) demand by a given volume.
Maximum base load	This method sets a static cap on the consumer's capacity, which is based on an estimate of the consumer's maximum load minus the capacity they have agreed to provide. This type of baseline is used for DR programs which are designed to reduce demand to a pre-defined level, such as critical peak rebate programs like the PJM Emergency Load Response Program [54].
Meter Before/ Meter After	This method uses metered data immediately before a DR event to set the baseline. Metered data during a DR event is then compared against this baseline to calculate the DR profile. This baseline methodology is most commonly used for ancillary services, where the reaction time and response duration are relatively short. A weakness of this methodology is that it only provides an accurate measure of DR volumes if the baseline load profile is flat during the DR event. If the baseline profile is falling then DR volumes are overestimated, whilst if it is rising DR volumes are underestimated.

3.4.4 Data security and privacy

Incorporation of security and privacy into EPN enabling infrastructure at the design phase is a necessary action to counter such barriers. The COOPERaTE project's Neighbourhood Information Model (NIM) is an example whereby data privacy was included as part of the data model development. Further, the general modular/cellular design of the smart grid in which an EPN will operate may actually increase security or rather reduce the impact of a successful attack.

Ownership of data is another general area where enablers can be found. The ability of users to tag their data, and to manage the life cycle of that data, may be an enabler by building the confidence of users. Further, enabling user choice on where data is archived (on the premises or in the cloud) may be an enabler by placing decisions on data storage in the user's hands. Successful anonymization of data may also enable the EPN concept as users feel their data cannot be abused.

3.4.5 Standardisation

Although the barrier of standardisation (w.r.t. technologies), is technological, the enabler is clearly more political. Various standards exist (e.g., for data formats, transfer mechanisms, transformation and semantics), but there simply needs to be agreement on which to follow. For data acquisition/actuation there could be benefit from leveraging established standards in the built environment. Overall, greatest priority should be on semantics, as establishing a common understanding is a necessary pre-cursor to more technical standardisation.

To progress standardisation of any form of technology, partnership, formation of alliances and cross-sectorial collaboration is required. Regulation may be required to narrow/hone focus around key standards. LinkedData and OpenData initiatives are a powerful means of addressing EPN goals. The very goal of such initiatives is to promote interoperability through the development in part of the semantic web [62]. 'To achieve and create Linked Data, technologies should be available for a common format (Resource Description Framework RDF), to enable either conversion or on-the-fly access to existing databases (relational, eXtensible Mark-up Language (XML), Hyper-Text Mark-up Language (HTML), etc.). It is also important to be able to setup query endpoints to access that data more conveniently. The World Wide Web Consortium (W3C) provides a palette of technologies to get access to the data:

- RDF,
- Gleaning Resource Descriptions from Dialects of Languages (GRDDL),
- Protocol for Web Description Resources (POWDER),
- RDFa,
- the upcoming RDB to RDF Mapping Language (R2RML),
- Rule Interchange Format (RIF), and
- Protocol and RDF Query Language (SPARQL).

More generally, the SoS approach can be viewed as an enabler. While the SoS concept is not new, it is newly gaining acceptance in the context of EPN realisation. There is also a growing realisation that there are few customers for complete end-to-end ICT solutions due to legacy/brownfield considerations. Thus the ability for ones offering to fit into the fabric of a wider system is becoming increasingly important for adoption.

With respect to standardisation in markets, to better realise the potential of an EPN to take part in relevant markets, it may be necessary to review the standard definition of products. However, there is no clear policy here, as, in all cases, the benefits from any relaxation in standards must be weighed against the associated rise in transaction costs.

3.4.6 System complexity

With regard to the barrier of complexity, there is, again, no easy answer. Complexity may be ameliorated by avoidance, if possible, of complex arrangements, such as situations involving decentralised ownership and optimisation. Whichever arrangement is required, and whatever the physical make-up of the EPN and nature of the markets, complexity may be further improved by the simplification of any optimisation. Time-steps may be lengthened, resources may be aggregated, and the number of scenarios (in a stochastic optimisation) may be limited. **The question, which may often not be definitively answered, is: what is the appropriate trade-off between reduced complexity, and increased accuracy?** The answer may change as computational power becomes cheaper and more available. In particular, development of big data technologies, when used in combination with domain heuristics can deliver real insights in coping with complexity. Machine-learning techniques are specifically useful in that regard.

More generally, adoption of a SoS approach, such as posited within this project, is one means of coping with complexity, by allowing individual systems to continue in the role, while providing recommender functionality at the district scale linking such systems.

3.4.7 Network constraints

An alternative to network reinforcement, which can enable the EPN concept, is the management of distribution networks in real time, by using the flexibility offered by the EPNs. To do so, **adequate real-time pricing mechanisms should be in place to encourage EPNs to change their power scheduling so that network constraints can be managed effectively below their limits**. The real-time price should ensure a lower energy payment for EPNs than the one that could be paid by only responding to the original dynamic price signal. A decision-making algorithm is needed to determine the required maximum power consumption/injection from EPNs to distribution networks at the time of network issue. The corresponding maximum power cap depends on the locations of the EPNs in the distribution networks [55]. To further encouraging EPNs to participate in the management of distribution network constraints, a percentage of the reduction in distribution network investments can be used as incentive for EPNs.

3.5 Summary of enablers

Section 3 of this deliverable has explored enablers which address the barriers described in **Section 2**. For an easy summary of enablers, associated with the relevant barriers, see Table 3-2.

Table 3-2: EPN enabler summary

Barrier	**Enabler**
Political/regulatory	
Tax	Disaggregate EPN resources.
System standards	Review of generation focused energy system paradigm.
Price pass-through	Give EPNs the choice to receive price signals, through third parties if necessary.
Unclear policy	Increased commitment to active demand from policy makers.
Network regulation	Appreciation of innovation in regulation, see [38].
Economic	
Market failures	
Imperfect information	Develop specific demand-side focused markets, or adapt existing markets to better suit the demand-side. Develop metrics to aid communication of preferences between principals and agents.
Incomplete markets	Local emission markets, to deal with CO_2 externalities. Development of DR exchanges, or a shared services framework, to split the cost of services between beneficiaries.
Imperfect competition	Strong regulator, to counter abuse of market power.
Market barriers	
Access to capital	Subsidy to reduce borrowing costs.
Uncertainty	Contracts-for-difference, to give certainty to cash flows.
Hidden costs	Subsidised markets, to facilitate trading for small-scale parties.
Value	N/A
Social	
Organisational	

Power	Increase status of energy manager.
Culture	Corporate education.
Behavioural	
Form of information	Optimise design of user interfaces
Credibility and trust	New, third parties may be able to build trust.
Values	Influence relevant institutions.
Inertia	Clear communication of benefits.
Bounded rationality	Automation.
User acceptance	Provision of 'opt-out' to retain control.
Privacy	Clarity on legal ownership of data, data anonymization.
Technological	
ICT development & implementation	Best known requirement elicitation and engineering practises.
Data acquisition & actuation	Appropriate metering, plug-in architectures.
Benchmarking	Agreed baselining method.
Security & privacy	Modular/cellular design, clarity on data ownership, data anonymization.
Standardisation	Political agreement on standards, general SoS approach.
System complexity	Avoidance of complex commercial arrangements, machine-learning techniques, optimal trade-off between complexity and accuracy in modelling, SoS approach.
Network constraints	Price incentives to motivate EPNs to reduce peak demand over network limits.

Above many enablers are identified. However, before any party attempts to implement any enabler, the cost of implementation should be considered. Particularly when the benefits from an enabler may accrue to many parties, **proper consideration should be given to a cost-benefit analysis, to ensure the benefits, in terms of EPN barrier reduction, justify the cost**.

Beyond the specific enablers detailed above, **a more general enabler of the EPN concept would be a general appreciation of the challenge of enabling EPNs**, and other, similar, distributed, demand-side energy resources. This can greatly contribute to the achievement of energy positivity for specific neighbourhoods, and economic efficiency, security and sustainability in modern energy systems. This, and **the achievement of energy positivity, would be greatly aided by development of the required methodologies and models**, such as this project has contributed towards.

4 Conclusion

This deliverable draws on experience gained in the COOPERaTE project, particularly in work package 6 (Business Models and Enablers), and further review of industrial and academic literature, to identify and categorise the barriers to the EPN concept. Subsequently, the enablers which may be able to counter the identified barriers are identified.

Firstly, the literature on concepts similar to the EPN concept (namely, DR and EE) is reviewed to identify transferable barriers and barrier classifications. Subsequently, broad groupings of barriers are identified, namely: political/regulatory, economic, social and technological. Political/regulatory barriers relate to barriers that exist to government policies, usually realised through regulation. Economic barriers are split into market failures (i.e. flaws in the way a market operates) and market barriers (other economic barriers). Social barriers are split into organisational and behavioural barriers. Technological barriers relate to specific technology functions, or to more general technical features (e.g., system complexity and standardisation).

Barriers of particular relevance to the COOPERaTE test beds are illustrated in D6.2 ("Evaluation of Business Model Contexts") and D6.3 ("Evaluation of Business Cases"):

- Regulation which prevents end-users seeing, and hence responding, to market signals
- Regulation which exempts parties from balance responsibility (such as in the Irish context), which reduce cost reflectivity in prices
- Electricity network regulation which values established solutions (grid expansion), to services that may be delivered by an EPN (DNCM or microgrid enabled reliability enhancement), or to other innovative methods of encouraging demand response (dynamic network pricing)
- Transaction costs for trading EPN flexibility (which may be a particular barrier for small scale parties, such as an EPN)
- Failure to account for environmental (CO_2) externalities, through a local emission trading scheme, which may result in undervaluation of EPN flexibility value
- Failure to properly allocate the costs of DR, so that some parties share the benefit of EPN flexibility, without cost. An example is the DNO in D6.3, which benefits from lower peak loads from EPN response to energy price signals

Subsequently, various enablers, relating to the specified barriers, are detailed along with many possible enablers. **However, a key point is that enablers themselves should be subject to a CBA, as some may prove to be more expensive to implement than the value that they unlock. More generally, the requirement for appropriate methodologies and models, to understand the potentially significant value of EPN-related business cases, is highlighted**.

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