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Deliverable D3.2.4: The virtual power plant concept from an economic perspective: updated final report

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Abstract
This report - issued in the framework of the EU-sponsored FENIX project - sets out to define the roles, functions, relationships and responsibilities of FENIX VPP concepts in overall system operation from an economic perspective. It is a precursor to the cost-benefit analyses of FENIX VPP concepts that will be undertaken as a separate activity. A VPP has the capability to flexibly aggregate attributes from a multitude of distributed energy resources (DER) by use of FENIX remote control intelligence. DER comprises renewable power plants, CHP plants, flexible loads and electricity storage devices, connected to distribution networks. DER attributes may encompass commercial inputs, products and/or services or relevant information for network management. DER inputs, products and services may relate to wholesale markets for energy commodities, ancillary network services and, when applicable, valuable market stimulation benefits and electricity generation attributes. The control centre functionalities are defined of an entity aggregating DER-associated products and services for creation of additional commercial value, using intelligence for remote control of flexible DER. The report presents a methodology to assess the economic viability of the FENIX VPPs. Based on a baseline and FENIX scenario regarding the future European power industry, business models are developed explaining for each of selected key actors that are to realize FENIX concepts, the business relationships with other economic actors.

CONTENTS

ABBREVIATIONS

CCL	climate change levy
CHP	combined heat and power
CVPP	commercial virtual power plant
DD	delegate dispatch
DG	distributed generation
DEMS	distribution energy management system
DER	distributed energy resources
DN	distribution network
DSM	demand-side management
DSO	distribution system operator
EMS	energy management system
ESCO	energy service company
FIP	feed-in premium
FIT	feed-in tariff
GO	guarantee of origin
HHI	Herfindahl-Hirschmann index
LEC	levy exemption certificate
MS	EU member state(s)
NETA	new electricity trading arrangements
OPF	optimal power flow (analysis)
OTC	over-the-counter
PPA	power purchasing agreement
REGO	renewable electricity guarantees of origin
RES-E	electricity from renewable sources
ROC	renewable obligation certificate
RPS	renewable portfolio standard
SCADA	supervisory control and data acquisition
SO	system operator
TN	transmission network
TSO	transmission system operator
TTF	title transfer facility
TVPP	technical virtual power plant
VPP	virtual power plant

Executive Summary

Objective and scope

This report seeks to characterise *from an economic perspective* key FENIX concepts of "smart" aggregation of commercial and technical DER functionalities. It identifies potential business opportunities for providers of smart aggregation services capitalising on the operational flexibility of distributed energy resources and shows how this aggregation may shape up. The report focuses on the roles, functions, relationships and responsibilities of FENIX VPP concepts in overall system operation from an economic perspective.

For the formulation of long-term business models a vision on the future development of governance structures in the electricity sector is needed. The report explains that both in a baseline and in a FENIX policy scenario the TSO will remain the last resort system co-ordinator. Yet, compared to the baseline scenario, in the FENIX scenario for the DSOs a much more pronounced role in overall system management is in the offing. In the FENIX scenario, distribution networks are poised to command, on aggregate, an appreciably higher share in overall system network capacity and in the provision of ancillary services respectively.

The report presents qualitative long-term business models of four central stakeholders in the DER aggregation business. For each of them, one model relates to a long-term future with a continuation of current policy trends towards network operators and the stimulation of market DER deployment (the baseline policy scenario) and one with a broad-based focus to make the electricity delivery system smarter (the FENIX policy scenario).

FENIX virtual power plant

The key research aspect of the FENIX project as a whole is the innovative remote operational control over a set of DER assets. Flexible deployment of aggregated DER by remote operational control is envisaged to improve the efficiency of network management functions from both a technical and (socio-)economic perspective. This report focuses on the economic perspective. In principle, DER owners have both legal and economic ownership of their DER assets. They may opt for commercial reasons to delegate the economic ownership of their asset to an operator of a commercial virtual power plant (CVPP). A FENIX CVPP will be commercially operated by either an incumbent supplier or an independent aggregator.

The grid code puts limitations to the exercise of economic ownership of grid-connected DER assets. Grid operators can make use of their rights to use the DER asset as a distribution network asset as authorised by the prevailing grid code. This report stresses the point that interventions by network operators should be governed by market-based principles to the maximum extent feasible, considering adequate integrity of network functioning. Operation of a technical virtual power plant (TVPP) by a DSO requires a continuous information flow on the scheduling of DER from all CVPPs and lone DER in the DSO operating region. Yet, over a given period it will affect actual scheduling of individual DER units normally for only a small fraction of time. Since nominated scheduling of the DER units accepted by the TSO after gate closure is supposed to be optimal, rescheduling of the DER units to meet TVPP objectives has to be financially compensated by the network operator concerned. Whenever possible, decisions of grid operators to limit the economic ownership of DER assets and to deploy them as network management assets should be economically optimal:

- DER owners should be given the possibility to make the commercial trade-off whether or not to relinquish the exercise of economic ownership for use as a network management asset by network operators which helps to yield the right price signals;
- The net social costs of alternative options open to grid operators to solve grid constraint issues without compromising adequate network integrity, should be higher;
- DER owners should get adequate compensation for the net benefits forgone of alternative power generation or power consumption: both network operators and DER owners should get a certain share in the net benefits of DER deployment for network management services.

Business models

For FENIX concepts to get adopted by the key stakeholders, for each one this should be economically advantageous. Hence, for each key stakeholder it has to be assessed how the business model

changes by adoption of the FENIX concept concerned. Based on economic considerations of the VPP concept as outlined above, this report presents business models with adoption of FENIX intelligence, elaborating qualitatively from an economic perspective the roles, functions, relationships and responsibilities of FENIX VPP concepts in qualitative business models.

The four central stakeholders and the relevant FENIX VPP notions adopted in the FENIX policy scenario are:

- The Transmission System Operator (TSO) who is responsible for governance of system-wide network services and who nominates energy contracts that need to be backed up by transport services to be provided by his network. The TSO can act, among others, as single-buyer counterpart of balancing and ancillary system services provided by flexible DER whose deployment is remotely controlled so as to shape up a value-optimising CVPP.
- The Distribution System Operator (DSO), adopting Technical Virtual Power Plant intelligence to remotely control DER for cost-effective integration in active management of his distribution network and for providing the TSO aggregated profiles of local network constraints. The TSO uses this information to nominate commercial aggregation of DER to levels transcending the distribution network.
- The commercial DER aggregator, adopting Commercial Virtual Power Plant (CVPP) intelligence to remotely control the flexible deployment of DER for the creation of additional value from a range of DER value drivers. CVPP aggregators can be incumbent supplier with bothtransmission-network connected and distributed generation assets under his operational control but also independent aggregators.
- The operator of DER assets, by whom it should be perceived as profitable for himself to have the operations of his assets surrendered to entities using FENIX-intelligence-guided remote control. FENIX concepts are deployed by advanced aggregators to capitalise on the operational flexibility of aggregated DER assets under their management.

Economic assessment

This report describes the cost-benefit analysis (CBA) methodology by which a variety of FENIX value propositions will be assessed. Point of departure will be the applications of FENIX concepts (use cases) that are tested in the concrete hands-on Southern Scenario demonstration programme (Alava network in northern Spain) and the Northern Scenario demonstration programme (Woking Borough Council in southern England) of FENIX Work Package 4. Each of the use cases will provide the setting of a CBA case study.

Relationship with other activities in FENIX Work Package 3

The cases for which CBA case studies will be conducted as well as the underlying baseline and alternative FENIX policy scenarios are defined by Task 3.1. The distinctive features of the baseline and FENIX policy scenarios determine cost and benefit streams of the CBA case studies. Sub-tasks 3.2.2 and 3.2.3 elaborate, for the Southern Scenario and Northern Scenario respectively, concrete conditions that are assumed to obtain around year 2020 regarding:

- the regulatory frameworks (S3.2.2): in deliverable D3.2.5.
- contractual arrangements (S3.2.3): in deliverable D3.2.6.

The actual CBA work will be performed in Task 3.3 and reported upon in deliverables 3.3.1 (interim deliverable of Task 3.3) and 3.3.2 (final deliverable of Task 3.3).

1. INTRODUCTION

1.1. Report scope

This report, resulting from Task 3.2.1 of the FENIX project, seeks to explore and characterise the virtual power plant concept from an economic perspective. It investigates the business opportunities for aggregation services offered to renewable and distributed energy resources (DER)[1] and how this aggregation may shape up.

The report elaborates on a set of technical notions of the virtual power plant (VPP). Point of departure in this respect is the FENIX vision document (Pudjianto, Ramsay, Strbac, 2006). FENIX deliverable 1.4.0 defines a VPP as:
"*a flexible representation of a portfolio of DER. A VPP not only aggregates the capacity of many diverse DER, it also creates a single operating profile from a composite of the parameters characterising each DER and incorporates spatial (i.e. network) constraints into its description of the capabilities of the portfolio*".

In order to assess the roles, functions, relationships and responsibilities in overall system operation, a vision is needed on the governance structure of the (European) electricity system on (long-term) timescales considered by the FENIX project and the policy environment shaping it. Notably the role of the distribution system operator (DSO)[2] merits special attention. To that effect, two long-term policy scenarios will be presented. The baseline policy scenario assumes a broadly continued evolution of current policy trends. Current trends include a fast increase of distributed generation within a liberalising European electricity sector. At the same time, as explained hereafter current regulatory and institutional settings preclude the use of DER capabilities in achieving required network operations. In contrast, the FENIX policy scenario presumes a broad package of enabling policies for network operators to genuinely integrate DER in the provision of electricity network services in optimal ways.

Based on the two European policy framework scenarios for the long term future, future business models will be presented and analysed of key DER aggregating actors. These models provide a qualitative insight into the roles and responsibilities that these actors will assume. Another focal issue of consideration is the way they will co-operate with other actors to achieve their business goals. These two key issues provide clues to emerging business opportunities and constraints.

This sets the stage for the introduction of a methodology to assess the economic feasibility of FENIX concepts for a number of concrete applications. The latter are derived from the FENIX Southern and Northern Scenario demonstration programmes. The methodology proposes subsequent cost-benefit analyses:

- from the private perspective of four central stakeholders respectively.
- from a system's perspective under prevailing market prices through consolidation of the four CBA exercises under the previous bullet point and due up-scaling to the appropriate national or regional level.
- from a societal perspective by adjusting the CBA under the previous bullet point for environmental and other externalities and possibly considerations of intergenerational equity regarding discounting future value streams.

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[1] Renewable and distributed energy resources show a large overlap. Yet renewable energy resources feeding transmission grids, not covered by the distributed energy resources (DER) concept, such as offshore wind may well assume great significance in future power supply (Global Wind Energy Council and Greenpeace, 2006). DER also covers CHP plants feeding into high/medium/low distribution networks, power storage devices and flexible power demand. Also for flexible power demand, both separately and in combination with emerging power storage technology, is poised to play an increasingly prominent role in ensuring adequate future electricity supply.

[2] This report adheres to EU legislation where the managing entity of a power distribution system is referred to as a *distribution system operator*. This entity is not necessarily a self-owned business entity. EU legislation warrants legal unbundling, not necessarily ownership unbundling, of power network management entities from commercial power generation, wholesale and retail companies, while network operation entities are stipulated to be treated as regulated monopolies. To date, in most EU member states DSOs are owned by vertically integrated suppliers and/or regional public authorities.

1.2. Report outline

In Chapter 2 we recapitulate some proposed conceptual frameworks, identify DER value drivers and key stakeholders in DER aggregation. A set of general scenario assumptions for the baseline and FENIX policy scenarios are explained in Chapter 3. Chapter 4 presents and analyses a baseline business model and a FENIX business model for each central DER aggregating actor considered in this report. Concluding remarks are made in Chapter 5.

2. VIRTUAL POWER PLANT CONCEPTS AND POWER NETWORK SCENARIOS

For making an assessment of FENIX virtual power plant concepts from an economic perspective, scenario assumptions will be made on some key factors shaping the future business environment of stakeholders in network integration of DER. This background chapter presents distinct FENIX notions, defined by the FENIX vision paper (Pudjianto, Ramsay, Strbac, 2006), and places these in an integrated economic perspective of DER value drivers and enhancement of DER value through aggregation.

This chapter starts with a brief review of FENIX virtual power plant concepts (Section 2.1). This is complemented with further considerations on the possible future evolution of electricity networks (Section 2.2). Section 2.3 sketches key developments shaping the business environment for DER in Europe and resulting DER value drivers. In Section 2.4, the central stakeholders are introduced upon whom this report's business models are patterned.

2.1. FENIX vision on VPP conceptualisation

The FENIX vision paper (Pudjianto, Ramsay, Strbac, 2006) zooms in, from a technical perspective, on the technical and commercial aggregation to enable (relatively small scale) DER and controllable load to participate efficiently in the energy market and in the provision of ancillary network services. Two key barriers for small scale DER to access the electricity market can be distinguished, that is:

1. Only DER with considerably large capacity can trade directly in various electricity markets.[3]
2. DER is not able to directly access (ancillary) markets for the provision of flexibility and controllability services to system operators who are in charge of system security and system quality assurance.

For (small) DER to scale these major barriers, the FENIX vision paper envisions the emergence of DER aggregating agents, called virtual power plants (VPPs). These are envisaged to play a key role in the FENIX scenario of the future European electricity supply sector. The FENIX vision document defines a VPP as (Pudjianto, Ramsay, Strbac, 2006: 5):

"*a flexible representation of a portfolio of DER. A VPP not only aggregates the capacity of many diverse DER, it also creates a single operating profile from a composite of the parameters characterising each DER and incorporates spatial (i.e. network) constraints into its description of the capabilities of the portfolio*."

Hence, a VPP could encompass functionalities of an imaginary single physical generation plant, with each functionality being a weighted average of the composite individual DERs. In this sense, a large-scale virtual power plant would refer to a multi-layer architecture of composite VPPs and individual DERs, aggregated bottom-up in the distribution network (DN) voltage level hierarchy up to levels comparable to large physical power plants connected to the transmission network (TN). The FENIX vision document provides the following description of large VPPs that function as TN-connected single generation plants:

"*For participation in transmission system management and current market activities, the VPP represents a portfolio of DER under a single profile. This makes the DER visible to the transmission system operator and presents a resource that can be used in the same way as transmission connected plant.*"

[3] Small-scale DER is facing several market access hurdles including prohibitive transaction costs, information asymmetry and regulatory barriers. For example, any market party that wants to trade in the Dutch APX has to pay an entrance fee of € 12,500 and an annual fixed charge of € 25,000.

A large-scale VPP, exercising economic ownership over a multitude of DER assets on a voluntary, commercial basis, can use these assets to create value on wholesale power markets. Such markets may comprise:

- forward markets based on tailor-made bilateral trades.
- OTC (over-the-counter) standardised bilateral trades, typically enabled by electronic bulletin boards.
- day-ahead power exchanges (with the power exchange as the central counterparty for buyers and sellers).
- intra-day adjustment power exchanges.
- intra-day bilateral adjustment trades.

Broadly speaking, VPPs may create value by mitigating financial trade risks and through operational optimalisation of the aggregate value creation by the whole portfolio of DER assets under management.

In addition, VPPs may make available DER assets for deployment by the TSO on the real-time balancing market. The latter market is a one-sided uniform-price market with the TSO as central counterparty who may accept or cancel regulating-up and regulating-down bids for the provision of balancing power. The TSO may also exercise economic ownership over DER resources when he calls on aggregators of DER to deliver previously contracted (other) system services. Probably more importantly, DSOs may call on certain DER resources encompassed by a VPP or lone DER resources to contribute to the relief of distribution network constraints and to contribute (other) system services for active management of distribution networks.

In the FENIX project, the activities in the commercial wholesale market and system management services are described respectively as "commercial" and "technical" activities, which derive the corresponding roles of "Commercial VPP (CVPP)" and "Technical VPP (TVPP)".

The CVPP agent acts on behalf of a multitude of DER assets to generate optimal commercial value from the CVPP portfolio in the wholesale electricity markets (with the exception of ancillary service and balancing markets organised by transmission network operators). The CVPP is described in the FENIX vision paper as:

"… a representation of a portfolio of DER that can be used to participate in energy markets in the same manner as transmission connected generating plant. For DER in the portfolio this approach reduces imbalance risk associated with lone operation in the market and provides the benefits of diversity of resource and increased capacity achieved through aggregation. DER can experience economies of scale in market participation and benefit from intelligence on market participation to maximise revenue opportunities."

The TVPP has the function of characterising the operating parameters of DER in a particular network location; it aggregates local network and DER capabilities to provide a picture of the capabilities of the distribution network at its interface with transmission. This is described in more detail in the vision paper:

"The technical VPP aggregates and models the response characteristics of a system containing DER, controllable loads and networks within a single electric-geographical (grid) area, essentially a description of sub-system operation. A hierarchy of TVPP aggregation may be created to characterise systematically the operation of DER at low, medium and high voltage regions of a local network, but at distribution-transmission network interfaces the TVPP presents a single profile representing the whole local network. This technical characterisation is equivalent to the characterisation that the transmission system operator has of transmission connected generation and corresponding transmission network topology."

The FENIX vision paper also proposes the role of TVPP agent will be taken on by the Distribution System Operator. This is justified as follows (Pudjianto, Ramsay, Strbac, 2006: 8):

"*..to characterise correctly the VPP contribution at the point of distribution-transmission connection also requires detailed, dynamic knowledge of the local network and to characterise the contribution of an individual DER to transmission system balancing in the context of the network, also requires a perspective of the resource in the context of the whole local network. Clearly, the DSO is optimally placed to understand how network conditions and constraints will contribute to the TVPP characterisation and individual DER capabilities.*"

The TVPP output (a technical characterisation of all DER in a local network described as a single profile) can be offered to the Transmission System Operator for evaluation along with offers for ancillary services from transmission connected generation. The FENIX vision paper does not propose precisely how the TVPP output will be presented into the ancillary services markets for evaluation. This interaction requires the balancing of technical feasibility and optimal operation and management of the networks, along with economic aspects of competitive market operation and monopoly regulation; all of which will be a key area for discussion in future refinement of this deliverable.

2.2. Some further considerations on network governance

In a paper written by Charlotte Ramsay and Matthew Leach a quite useful stylisation of DER aggregation is presented (Ramsay and Leach, 2005). Aggregation can be achieved at many different levels that involve varying degrees of interconnection, feedback and control. Ramsay and Leach provide three main aggregation categories which, in a way, could also be taken to be three consecutive aggregation development stages, i.e. (i) *Consolidation*; (ii) *Virtual Utility*; and (iii) *Microgrid*.

A *Consolidator* essentially provides aggregation services to small generators, bundling their produce for sale in bilateral and over-the-counter (OTC) forward and futures power markets, power exchanges and their imbalance positions to reduce overall net payment to the Balancing Mechanism. He would have virtually no ICT interconnection with his generator clients and thus also have no control over their generation process.

A *Virtual Utility* would bundle both small (distributed) generators and (flexible) loads to create value added in forward and balancing power markets, based on interconnectivity with clients and resulting control over power injected into and withdrawn from the power system concerned. Ramsay and Leach quote the definition by Awerbuch and Preston:

"The Virtual Utility is a flexible collaboration of independent, market driven entities that provide efficient energy service demanded by customers without necessarily owning the corresponding assets. The Virtual Utility becomes a metaphor for lean, flexible energy production/delivery and flexible, customer oriented energy service provision."

Virtual Utility technology (including ICT technology) would enable *inter alia* the following business opportunities (Ramsay and Leach, 2005):

- fuel type optimisation,
- relief of localised demand pressure and network constraints,
- capability to contribute to meeting high return peak load demands in wholesale markets,
- curtailment programme operation, curtailing flexible loads at peak time,
- offering balancing and ancillary services (reserve, frequency response, reactive power, black start).

Ramsay and Leach (2005) explore the idea that *Microgrids* as aggregators could usher in the final aggregation phase. A Microgrid might be described as a fully aggregated, interactive, and physically interconnected, system of distributed generators and loads that only have a relatively weak, fully consolidated, link with the higher-level distribution and central transmission network. This link enables profitable exchanges with central forward and balancing markets and functions as well as an "import and export" facility, providing last resort security to the semi-autonomous Microgrids.

Ramsay and Leach conclude that if a vertically integrated power supplier were to operate the role of Virtual Utility then:

"it would become an institution and a set of technologies to manage effectively a collection of distributed generation units all owned by a single vertically integrated energy supplier. The Virtual Utility approach could be adopted to manage a portfolio of decentralised generators operating in the same locality, perhaps in instances where local demands are beginning to necessitate a different and more active approach to distribution network".

Furthermore, for the Microgrid concept to transform the market for decentralised generation, considerable large scale and fundamental changes are needed in the way the market and indeed the whole sector is currently operating. They consider the Virtual Utility concept to denote a useful, flexible paradigm, at least *ad interim*:

- It is more flexible than a Microgrid.
- It requires little immediate change in overall network operations.
- It has the potential to make DER aggregation more profitable than Consolidator actors could realise.
- It leads to greater integration and responsiveness of the demand side.
- It leads potentially to a low carbon, Microgrid-oriented future.

With reference to the foregoing, a medium-term FENIX scenario could be regarded as a transitional rather than a "final" situation of a macro-network system consisting of completely independent Microgrids loosely connected with a skeleton transmission grid. On the other hand, the following compelling reasons suggest that even on long time scales interconnected European transmission networks will keep on to be the backbone of the electricity transport system, warranting a last-resort co-ordinating role for TSOs:

- In broad measure, DER-based technology is undergoing rapid cost-saving technological change reducing cost gaps with conventional transmission-based generation technology. Yet it is foreseen that even in the most DER oriented scenarios long-term time frames up to say year 2050 distributed generation technology will fall short by far to meet total European electricity demand more cost-effectively than conventional transmission-based generation technology.[4]
- Even large-scale renewable technologies, such as large hydropower and offshore windpower are expected to assume significant roles in the European electricity supply sector by 2050. Especially intermittent large-scale windpower warrants a strong trans-European interconnected transmission network.
- This is also warranted from a perspective of improving market efficiency in the face of increasing levels of market concentration in national MS electricity markets. An improved interconnection infrastructure will facilitate competition from market players in neighbouring member states.
- Conversely, from a market functioning perspective the Microgrid alternative would pose great challenges. What are the options for the consumer's choice when they are each embedded in a particular Microgrid? Moreover, entry barriers for generators and DER aggregators increase significantly in a Microgrid scenario.

Therefore, it will be assumed that in a medium-term FENIX scenario the TSO will remain the last resort co-ordinator of network balancing services. On the other hand, in such scenario the role the "average" DSOs relative to the "average" TSO will assume much more importance in terms of network capacity and arrangement of ancillary services:

- Through active network management by DSOs DER will provide a substantially increased part of the ancillary services in the overall system, and even more so in distributions networks.
- Increasingly price-elastic demand and embedded generation at the customer's side of the meter will impact negatively on the relative role of electricity delivered through public distribution networks and - even more so - on the residual demand-supply imbalances that have to be straightened out by TSO arrangements.
- The relative share of TN-connected generators will have subsided against a substantial increase in the share of distributed generators in total system power generation. A trend towards fast penetration of DG is one major undercurrent. Another major factor is the much better integration of DER

4 See e.g. the final report of the WETO H2 project (European Commission, 2007).

assets as valuable network management components on both the supply and the demand side. By implication, a FENIX scenario is to result in less overall TN-connected generation capacity compared to a business-as-usual scenario.

2.3. DER value drivers

The FENIX project zooms in on innovative avenues resulting in large-scale deployment of DER for ancillary network services. Yet the economic (business) perspective enabling this FENIX vision requires an integrated picture of DER value drivers and the role of DER aggregating entities to value driver enhancement. From the business-economic perspective as well as the societal vantage point a range of DER value drivers need to be considered in an integrated way:

Energy benefit/cost impacts

1. Generation and sale of electric energy based on DER.
2. Provision of balancing services to network operators.
3. Reduction in aggregate fuel procurement costs by improved sourcing capabilities (lower procurement price); possible reduction in T&D losses and less fuel-intensive generation mix (lower aggregate fuel quantity).

Other benefit/cost impacts

4. Provision of ancillary services to network operators.
5. Network capacity replacement value.
6. Acquiring financial benefits from support mechanisms for market deployment of DER.
7. Creation and sale of certified RES-E and CHP generation attributes, including notably generation from distributed RES-E and CHP plants.
8. The direct cost/revenue impact of market-based policy instruments for emissions control.
9. Impacts on the supply (in)security as regards electricity and fossil fuels respectively.

The value of *DER value driver #1* clearly lies in the commodity value of electric energy. However, direct market access is generally not feasible for small generators. More importantly though the commodity value of electricity is closely related to *DER value driver #2*, notably the need for balancing services. The non-storable nature of electricity has triggered the development of markets with strong incentives for robust scheduling of supply and demand, so that imbalances are minimized by participants in electricity "commodity" markets. This incentive is harnessed through trade enforcement. This mechanism enables better identification of the causes of imbalances and a pricing structure that associated high costs with these imbalances. In general, therefore, producers active in the electricity market rely on advanced portfolio management techniques, including forecasting, secure and robust scheduling. Generally such management systems come at cost that cannot by justified with respect to small generation portfolios as typically encountered by independent owners of DER generators. In fact, individual operators including DER operators cannot avoid deviations from their notified power injections into the grid. Deviation charges should incentivise system users to limit their deviations from notified injections or extractions to the extent possible. In several national power markets in Europe, financial benefits relating to support mechanisms for DER fully insulate or over-compensate for the imbalance costs, occasioned by DER. If, however, DER support mechanisms will be redesigned smarter and/or DER generators will become a competitive alternative to centralized production, balancing costs also will become relevant to DER. Hence, balancing cost may well render even more incremental commercial value to aggregation of small DER portfolios into larger ones.

The pricing structure that will imply high costs to market parties that cause (potential) system imbalances, will at the same time generate significant revenues for parties that offer balancing services.[5] In many countries a balancing market has been institutionalised. The main reason is that the balancing market is transparent and offers accessibility, though a minimum volume is generally required. Fur-

[5] An increase in intermittent supply by generators harnessing ambient energy (wind, sun) implies a rise in demand for balancing services. In a typical electricity supply system to date, the marginal units whose short-term marginal cost determines wholesale prices are open-cycle gas turbines. Yet at high DER penetration rates, DER-based facilities may undercut open-cycle gas turbines in determining the price on wholesale electricity markets. This, in turn, will reduce revenue streams to DER from providing balancing services. At system level, this would imply cost reductions which could benefit the end-users, contingent on what the regulator imposes.

thermore, specific technical requirements regarding the ramping characteristics are required. Typically such requirements can be addressed through aggregation as well.

Financial aggregation of DER services can improve the market power of DER regarding fuel procurement. Moreover, operational aggregation of DER resources to meet local energy needs and to mitigate local congestion problems as well as deployment of low-carbon distributed generators may lead to lower fuel use and/or energy losses per MWh of final electricity use. All factors enumerated in this paragraph may work out to bring down fuel input (*value driver #3)*. It should be noted though that at high penetration levels of intermittent distributed generators (DG), further penetration will tend to reduce the share of electricity generated by DG that can be absorbed by local load centres. As a result, after some penetration threshold further penetration of less controllable DER such as wind power and PV will increase energy losses per MWh of final electricity use. Active network management may raise this threshold and mitigate losses. Even so, at odds with conventional wisdom at very high and concentrated DG penetration levels, positive contribution of DG to reduction in network losses cannot be taken for granted. The net contribution of DER to reduction of T&D energy losses depends on location-specific (network-topology-specific) factors.

Moreover, a variety of non-balancing ancillary services needed for the management of the transmission and distribution systems is commercially contracted. Often these services are contracted bilaterally by TSOs and DSOs and transparency and accessibility of these markets to DER and DER aggregators is limited. Regulatory changes may create new opportunities for DER (*value driver #4*).

Furthermore, when starting out from low levels of distributed generation (DG) the penetration of DG increases this may obviate, reduce or delay network reinforcements at higher voltage networks (higher capacity wires, transformers, etc.) as local generation can cover more of the local peak load. In the aforementioned situation DG carries with it a positive network replacement value (*value driver #5*). This situation may reverse at quite high levels of DG penetration, when local load may be progressively less capable of absorbing the energy from DG. Surplus generation from local DG needs then to be diverted more and more through the high-voltage network to more remote electricity users. (Jansen et al., 2007); (Joode et al., 2007)

Driver #6 concerns support mechanisms for DER market deployment. A substantial share of currently DER-generated power would not be justified from a business-economic perspective but for strong public and private interventions in the power market. This holds especially for power generated by distributed renewable sources. As power as such is a homogeneous good, the case in favour of DER-generated power needs to be justified by strong positive externalities associated with DER-based generating technology as against centralised power supply. Indeed, in Europe the social perception of positive externalities associated DER based technology is gathering increasingly strong momentum. In many MS with feed-in tariffs (FIT) systems, FIT-eligible generators are granted priority access to the grid. The most important question for the business model of DER operators in such countries is whether the applicable FIT ensures him at least an acceptable return. He does not need to worry about selling his produce as he will receive for any amount of electricity he feeds in his feed-in tariff. Nor does he need to worry about the possible negative grid impacts he engenders and consequential penalties, e.g. unbalance penalties: the system operator will ensure socialisation of the costs of such impacts as long as the DER operator complies with the grid code. However, when DER operators participate in support schemes without priority network access they have to worry about selling their MWhs. If they sell contractually to electricity supplier by way of a power purchase agreement (PPA), the supplier will assume the balancing risk. But for the supplier to accept the shift of balancing risk from his counterparty to him, he will require a price discount that is at the very least commensurate with the value of this risk. Moreover, the supplier may include further clauses in the contract on the way his counterparty operates the plant to further reduce the supplier's balancing risk. In turn, compliance restrictions of the PPA agreement to DER operators may also open potential opportunities for them to generate additional income from the provision of certain ancillary services.

What is essential to note is that the design of DER support schemes strongly affects the business appetite of DER operators to provide ancillary services and their desire to be included in third party aggregation services. For instance, "fat" support mechanisms that do not make any, let alone any smart, allowance for optimising the social costs of grid integration will reduce the appetite of distributed generators to provide ancillary services and the disposition of DSOs to smoothly accommodate the former.

As *value driver #7* for DER operators of potentially significant importance within a FENIX future time-scale we identify certified generation attributes. The RES-E (renewable electricity) Directive and the CHP Directive order the EU member states (MS) to put in place "Guarantee of Origin" (GO) systems. These systems should enable that at request of eligible generators GOs can be issued, that certify certain pre-defined generation attributes. The RES-E directive envisions two applications for RES-E GO: facilitating trade in renewable and co-generated electricity and "transparency for the consumer's choice" (disclosure), whilst the CHP GO anticipates one application for CHP GO: "transparency for the consumer's choice" (disclosure). In fact, many more quite useful applications are possible.[6] Moreover, the aforementioned directives do not provide clear guidance in the design of GO systems. As a result, so far MS GO systems are quite diverse and generally do not meet their stated objectives. Therefore, at present GO trade still is of little significance to the business case of DER operators.

However, the Renewable (RES) Directive proposal launched by the Commission on 23 January 2008 sets mandatory targets regarding the share in final energy consumption to be met by RES. Moreover, on longer term DER support schemes have to be gradually phased out. This will make the case for DER generators and suppliers of "green" electricity products more urgent to lobby in favour of genuinely reliable electricity origin disclosure and verification through fully compatible, comprehensive and - last but not least - reliable electronic GO tracking and verification systems. The perceived contemporary problems regarding the suboptimal efficiency of European electricity markets with perceived high entry barriers for suppliers specialising in green electricity products, makes their case even stronger. In a FENIX future, DER aggregators can enhance their business case by offering specialised services in the creation and trade of GO.

DER value driver #8 concerns market-based emissions control instruments, such as emissions trading and/or emissions taxes. For specific DER technology this driver assumes relevance. It concerns:

- Fossil-fuel based distributed CHP above a certain threshold (50 MW_{th}; 20 $MW_{el.}$) with regard to EU GHG emissions allowance units. It is noted, that GHG emissions trading - depending on the allowance unit price and the pass-through to electricity prices - may have a quite significant (positive) *indirect* impact on DER competitiveness. Secondly, *when specifically distributed CHP based on fossil fuels or biomass is considered*, the direct impact has to be considered in DER aggregator business models.

- Both fossil-fuel and biomass-based distributed generation technology with regard to emissions trading or taxation regarding local- and regional-impact emissions such as SO_2, NO_x, PM. So far, within the EU market-based instruments for control of local- and regional-impact emissions are only applied in the Netherlands and Sweden (for NO_x emissions). Due to its limited overall *direct* significance for the whole range of DER technologies, we will not further elaborate on this eighth DER value driver.

DER value driver #9 relates to the supply security impacts as regards electricity and fossil fuels respectively. Regarding security of electricity supply the penetration of distributed generation makes the network management tasks, especially ensuring adequate quantity and quality of supply, much more complex. On the other hand, adoption of new active network management philosophies opens new avenues towards harnessing DER to enhance power supply security.[7] Moreover, use of ambient energy flows and local biomass waste flows would reduce the potential impact of cascading black-outs of high-voltage networks and reduce reliance on fossil fuels supplied by market parties controlled by remote, political less stable countries that wield increasingly strong market power.

[6] See for a more detailed discussion of existing and possible future system frameworks for generation attribute certification and trade e.g. Jansen *et al* (2005: Chapter 4).

[7] When more controllable distributed generation and controllable demand gets to a distribution network the reliability of the distribution network concerned may increase as such. Should there be a failure at the HV network, controllable DER may even render possible islanded network operations for some time.

The focus in the FENIX project is on DER value drivers ## 1-4. Yet, in a cost-benefit framework all value drivers identified above need to be taken into consideration on their potential incremental impacts when advanced concepts featuring in the FENIX project will be applied.

2.4. VPP stakeholders

The following central (potentially) DER aggregating stakeholders will be discerned in this report:

1. *Transmission System Operators.* The Transmission System Operator (TSO) who is responsible for governance of system-wide network services and who nominates energy contracts that need to be backed up by transport services to be provided by his network. The TSO can act, among others, as single-buyer counterpart of balancing and ancillary system services. Given prevailing MS-specific regulations, the TSO may wish to only consider DER-offers on the basis of aggregated DER so that the minimum required bid size can be attained.

2. *Distribution System Operators*. DSOs are referred to in EU legislation as managing electricity distribution networks. They are key in providing enabling conditions for information provision to Commercial Virtual Power Plants, whilst being the key stakeholder for adopting the Technical Virtual Power Plant concept. Key is that DEMS and the FENIX ICT infrastructure enable the TVPP agent to enhance the local provision of ancillary services through remote control of DER in the DN area.

3. *Commercial aggregators of DER.* Commercial aggregators of DER aggregate certain attributes of DER for commercial reasons. They include *integrated (also referred to as incumbent) energy suppliers*. These are retail suppliers of electricity – often of gas and/or water as well - commanding a significant share, say at least 5%, of the national retail power market. They tend to be vertically backwards integrated with network ownership and operation (in jurisdictions without ownership unbundling) and with centralized generation. "Incumbents" are able to efficiently integrate generation by own DER assets and procurement contracts (Power Purchasing Agreements) efficiently into their energy procurement contracts. They can harness of the portfolio effect of unplanned variability in energy demand by their clients and energy supply by own generation assets and contracted external generators. A second group of commercial DER aggregators are so-called *independent aggregators of DER*. "Independents" have a quite different position than incumbents. Aggregation may help to reduce costs of trading expertise and intelligence, lower entry barriers to energy markets, may result in a favourable portfolio effect regarding the balancing mechanism and a better negotiation position with respect to other market participants. [8]

4. *DER operators*. These actors should perceive that there's something in it for them to lend their support to the implementation of FENIX concepts. This includes the surrender of operational control of their assets as and when remotely required so by way of FENIX ICT intelligence. The collaboration of DER operators is essential to realisation of FENIX.

[8] Small suppliers - often catering niche markets such as green electricity customers or a certain type of small business entrepreneurs - can be regarded as a sub-category of independent aggregators. In the ensuing, we will not give special attention to small electricity suppliers.

3. SCENARIOS FOR FUTURE ELECTRICITY NETWORKS

3.1. Future business environment scenarios

The policy-driven future business environment will significantly impact the behaviour of business actors in the electricity supply industry in general and electricity distribution networks in particular. For the purpose of an economic characterisation of FENIX concepts our point of departure will be two alternative European policy scenarios on a longer term timeframe, say some 30 years from now. It will be a baseline policy scenario and a FENIX policy scenario. We first explain some major policy (including regulatory) aspects that are assumed to be valid in both scenarios. We then explain the aspects defining the baseline and the alternative FENIX policy scenario.

3.1.1. Common scenario aspects

Competition policy

Overall competitiveness of the European economy is being promoted through liberalisation of the EU electricity and gas markets as well as by separation of energy production, transportation and distribution activities. The electricity transmission and distribution networks will be fully unbundled (through ownership unbundling) from commercial activities of the electricity industry including electricity generation, trade, and retail supply. Operating transmission and distribution networks will be regulated. In the FENIX project context, it is noteworthy that more competitive electricity and gas markets will provide independent DER, aided by commercial DER aggregators, with more opportunities to enter these markets and, consequently, to implement economically viable business models. Third party aggregators may offer DER value enhancing services in e.g. PPA contract negotiations, accessing power exchanges or forward power markets, or the provision of balancing and ancillary services. This even applies to the baseline scenario, although in this scenario more consolidator-like forms of aggregation are envisioned without remote control of DER operations.

Adoption of (national variants) of the Scandinavian market model by most EU member states

Policymakers and regulators at European and MS level will seek to improve economic efficiency of the electricity sector. The Scandinavian model for shaping the electricity sector is assumed to prevail in a multitude of national variants. The former British power pool model set the first example in Europe of institutional electricity sector design at the first onset of liberalisation. In this power-pool model a central agent - typically the TSO or an entity closely associated with the TSO - manages a power pool, a one-sided day-ahead auction for electricity fed into the pool each half hour. Generators are mandated to place offer schedules (paired sets of 'bid' prices and quantities) for half-hour time intervals aggregated by the central agent to clear his estimated half-hourly aggregated demand. The central agent commits generating units based on a uniform clearing price determined by the price of the marginal unit committed. Network constraints are relieved through re-dispatch arranged by the TSO. The cost of this operation are socialised by a mark-up, called uplift, in the pool selling price charged to electricity suppliers. In the former British power pool model the central agent by and large solves power dispatch and system balancing concurrently. Yet, as inferred by the UK regulator, this model proved to be less effective in bringing about market efficiency and was replaced in the UK in 2000 by NETA and later by BETTA, both in broad measure variants of the Scandinavian power sector model.

The Scandinavian model allows for (i) decentralised decision making by commercial actors to enter into commercial "commodity" trades and (ii) the introduction of at least a day-ahead power exchange for short-term standardised electricity trading.[9] Commercial trading contracts and planning of power injections into and withdrawals from the electricity network system need to be notified to the TSO before the gate closure of the TSO-managed balancing market. The TSO in close collaboration with the DSOs in his control area will ensure that commercial contracts are honoured physically and arrange – often invisible for trading parties - for ancillary services to address network constraints and line losses. Costs of these services will be socialised into the full tariffs electricity customers have to pay. This is a pure balancing responsibility variant. In order to allow for intra-regional supply-demand imbalances, consequential inter-regional transmission requirements and transmission constraints, zonal or nodal tariffs - whether or not time-varying - can be introduced. An alternative response option, limiting to some extent decentralised decision making, is that the TSO can reject at a specified point in time between gate closure and near real-time nominated commercial contracts because of network (TN and/or DN) constraints. The second response option has the economic advantage of reduced need or real-time balancing but limits the scope for decentralised decision making and, consequently, its associated market deepening and thus market efficiency benefits.

In the pure balancing responsibility variant generators and consumers have the full responsibility to minimise deviations from nominated (notified) planning. Smaller entities may transfer their balancing responsibility to larger parties willing to assume balancing responsibility, as long as each network connection can be associated with one particular balancing responsible party. Post (balancing market) gate closure deviations from planning translate into an automatic contract with the TSO for rebalancing and settlement. For this balancing arrangement the TSO arranges a single buyer balancing market. Network operators themselves will also assume balancing responsibility for their procurement contracts to cover expected line losses on their respective networks.

The balancing market works as follows. Right after "closing the gate" the TSO and pertinent DSOs will perform optimal load flow analysis to determine network constraints. In the pure balancing responsibility variant wholesale market electricity contracts are respected. On the other hand, higher or lower demand than covered by contracts or profiles will be adjusted by the TSO. To that effect regulating-up bids (to increase generation / reduce load) and regulating-down bids (to reduce generation / increase load) are submitted to the TSO, broken down by price and quantity. So far, participants in the balancing market as counterparties of the TSO acting as single buyer are mainly large TN-connected power plants. Aggregating agents may organise bids from DER and aggregate these into a single aggregated DER profile per DSO-TSO point of interconnection and offer these aggregated DER bids to the TSO. The TSO in close communication with pertinent DSOs may accept aggregated DER bids and offers in full or for a selection of locational components or, alternatively, may reject them completely. Subsequently, the TSO can compile bid ladders for the upcoming/current programme time unit and notify DSOs, and - if they are the DER aggregators concerned – CVPPs, on dispatch orders for successful bids. Upon settlement, balancing responsible parties with ex post deviations from their nominated net demand planning[10] will have to pay (will receive), for each programme time unit, the system imbalance price plus (minus) a possible balancing incentive charge over their positive (negative) net demand deviation.[11]

[9] This can be complemented with intra-day adjustment markets and futures markets. Most European power exchanges organize day ahead auctions for every hour of the next day. Power exchanges are, technically speaking, not strictly necessary but greatly facilitate a liberalised electricity sector. For reasons of risk management suppliers typically wish to cover the greater part of the anticipated demand by their customers – the part that is relatively certain - by long-term contracts. Where futures markets do not exist this will be bilateral long-term contracts. The closer to power exchange gate closure, the better suppliers can predict actual real-time demand of their customers. However, by then positive or negative differences between predicted hourly demand and demand already covered by bilateral contracts for day-ahead trading time intervals (for most exchanges: one-hour intervals) are difficult to iron out through bilateral contracts. Liquid power exchanges with day-ahead trading and intra-day adjustment markets can much better facilitate that function of short-term contract portfolio rebalancing at lower transaction costs.

[10] Nominated planning for net supply can be equated to nominated planning for negative net demand.

[11] When on aggregate actual demand (in a certain programme time unit) exceeds nominated and approved supply the imbalance price will be determined by the marginal regulating-up bid to cover excess ex ante demand. In the case of ex ante surplus supply the imbalance price will be determined by the marginal regulating-down bid. Several members-ate-specific variants occur to the design of the balancing market described here.

In the balancing market the supply-side actors participate on a commercial basis. For primary frequency response centrally controlled arrangements by the TSO are resorted to. Currently primary frequency response arrangements are usually mandatory for large generating plants without compensation. In principle this could also be arranged on an alternative, regulated commercial, basis.

An enduring, strong societal support for DER
The strong societal pressure to enhance the role of DER in the generating mix is assumed to endure. Three major policy drivers will keep the pressure on: (i) the climate change issue, (ii) the long-term energy supply issue, (iii) industrialisation policy in MS with strong representation of DER stakeholders. As a result, on average market support mechanisms remain slowly subsiding but quite significant value driver to DER.

Another outcome of strong societal pressure to enhance the role of DER is assumed to be the emergence of *reliable, fully compatible* national electricity origin certification systems for at least renewable and CHP-based electricity. Electricity origin certificates for renewable- and CHP based electricity, are called Guarantees of Origin (GO) in EU legislation. Validity of the assumption will imply a thriving GO market in the EU and, in turn, GO will be another significant DER value driver, further stimulating the penetration of DER and DER aggregation services. It requires, among others, integration of the GO tracking system with DER support mechanisms (Jansen et al., 2005). Hence it will be assumed that *DER operators claiming DER support benefits for the main support mechanism will have to surrender GO*. This applies both to member states with feed-in tariffs (or premiums) and the ones with a RPS as the main support mechanism.

Smart metering
Smart metering at the network user's point of common coupling with the network is of crucial importance to the technical feasibility of the FENIX policy scenario. For the business model analysis in the next chapter it is relevant how the institutional arrangement of smart metering will be organised. For distributed generators and large DN-connected consumers it is assumed that they themselves have to arrange for metering equipment and for certified meter reading companies that will have to provide the DSO with meter readings.

A special case is smart metering of retail customers. A host of considerations need to be made allowance for from the perspective of efficient market design. Some essential ones are listed below:
- For efficiency reasons it seems appropriate to grant one business entity with a franchise to arrange for meter procurement, installation, maintenance and replacement as well as meter reading in a larger area, say the DSO area.
- The entity granted with the franchise gets access to information that potentially has a quite high commercial value to a host of commercial parties inside and outside the electricity sector. To an electricity supplier, apart from required information for billing and settlement, it provides valuable information on the demand profile evolution of retail customers. This will help the supplier to design his retail marketing and retail tariff setting strategy more effectively than competitors without such metering information. To commercial entities outside the electricity sector it potentially provides detailed information of the life style of retail customers.
- For these reasons, it seems in order to stringently regulate the meter company granted with the metering franchise in several respects: (i) scope of data collection; (ii) scope of data transfer to third parties with requirement of explicit consent of retail customer; (iii) level-playing field third party access to dedicated information subject to customer consent; (iv) adequate customer privacy enforcement; (v) allowable tariffs for metering services (vi) quality of service.
- Quality of service regards the meter standard which should allow feeding intelligent meter interfaces with data enabling smart, time-differentiated billing and remote control for the provision of ancillary services, but also the treatment of supplier switches by retail customers in the franchise area and metering services rendered to third parties.

Given the competition-sensitive information metering services can provide to electricity suppliers, the economic perspective suggests that suppliers should not be entrusted with retail metering. It could be entrusted either to the - fully unbundled - DSO or to an external certified metering company. *In the* *ensuing, it will be assumed that the DSO will be in charge of retail metering.*[12] Moreover, in order to not unduly annoy retail customers with separate home visits and an overkill of electricity-supply-related bills *it will be assumed that the supplier will be charged with collecting metering surcharges on the electricity bill of retail customers.*

3.2. Diverging scenario aspects

The two alternative economic assessment scenarios in this report relate to the prevalence/absence of an emerging and enduring strong societal pressure to *genuinely integrate DER* into the operational management of regulated electricity networks *in a cost-efficient way*. Integration would be fostered by governments through network regulating agencies and DER support agencies using appropriate, wide-ranging packages of incentives and penalties. This condition is considered essential for overcoming the strong institutional inertia inhibiting genuine integration of DER in power network operations.

The *baseline policy scenario* presumes that all joint scenario assumptions that have been explained above, will be met but that no appropriate fine tuning of DSO and DER market support regulation will be implemented, necessary for bringing about genuine integration of DER in network management practices. The baseline scenario implies that current "fit and forget" practices prevailing in operational network management all over Europe, will endure. Under this operational philosophy the integrity and reliability of network services rely primarily on:

- a very robust way of planning network expansion,
- network reinforcement that can successfully face any plausible future demand for network services without pro-active reliance on network services from distributed energy resources.

In the baseline scenario distributed generation will penetrate fast but even so the prevailing *passive network operational philosophy* will not be changed. Network operators will meet increasing operational challenges because of penetration of DER. They will tend to address these challenges primarily by robust conventional network reinforcement meeting at least the (N-1) contingency rule, but also *gradual* replacement in MV and LV distribution networks of obsolete components by controllable components such as on-line tap changing transformers and installing more network monitoring sensors. Moreover, DSOs will keep on lobbying for more stringent grid codes and will, when possible, at time-stacitly obstruct grid access of distributed generators by erecting "red tape" barriers.

In the *FENIX policy scenario* network regulatory agencies and DER support agencies will implement dedicated government policies to foster integration of DER in network operational management. Government policies will stipulate fast implementation of smart metering programmes targeted at all network users including retail customers. This will enable not only trading operations (accounting records of e.g. power quantities at quarterly, half or full hour time intervals) but also near real-time remote control by network operators *and commercial third parties*. In the FENIX scenario the (genuinely) unbundled DSO will provide access for both DSO and (at a regulated fair charge) third parties to the meter interface at the customer's doorstep on a level-playing-field basis subject to protocols ensuring explicit customer consent and absence of privacy infringements. Network regulators will strongly stimulate through appropriate incentives and penalties introduction of smart network tariffs such as time- and location-differentiated use of system charging. This will proceed in an indirect way through *smart output-based incentives* promoting efficient DER integration.[13] Also formal DSO investment planning procedures will be mandated to explicitly *include DER flexibility into peak demand and system reliability risk assessment guidelines*.

[12] It is noted that under current conditions with less effective unbundling in most European countries, that a certified metering company without any ownership ties with electricity suppliers might be a better alternative option. It is assumed that on longer term unbundling will have been implemented effectively throughout Europe.

[13] For example, the regulator may set, for the upcoming regulatory period, network-specific annual standards for average load (in MW) to be facilitated by a DSO. Ex post the regulator may reward (penalise) the DSO for negative (positive) hourly peak load deviations from the load standard for each hour of the year. This way the DSO is encouraged to apply time-differentiated UoDS charges to network customers that may bring about a flatter load duration curve. This in turn will reduce power losses in the DSO network (high loads having a disproportionately negative impact on line losses on the order of the power two) and postpone the need for investment in expanding the load-carrying capacity of distribution lines.

Moreover, DER support mechanisms will not only minimise abnormal profits by DER plant owners. *DER support mechanisms will also be designed smart* to foster the disposition of DER to enhance the social value per unit of generation (avoided consumption) including the provision of ancillary services that enhance social value. For example, in the case of production subsidies (feed-in tariffs; feed-in premiums) such technology specific subsidies per MWh will be time-differentiated. This could for example be aligned to movements of the commodity price on the power exchange, as could be the number of GOs issued per eligible MWh generated in countries with a Renewable Portfolio Standard as main support mechanism[14].

On the one hand, smart network tariffs in tandem with smart DER market support policies as well as DER-integrative network management practices will strongly induce DER operators to liaise with commercial providers of specialist operational services including notably DER aggregation services. On the other hand, pushed by the regulator and by more responsive and reliable DER behaviour, network operators will gain more confidence in relying on active network management philosophy using TVPP agents. The key point to make in conclusion is that for a FENIX scenario to become reality, one measure will simply not be enough. *To create a FENIX business environment, concurrent, fine-tuned, smart public interventions are warranted on a broad front of the policy framework regarding electricity network regulation and DER market stimulation.*

[14] Along with a mechanism to re-align the total number of GO issued per period (e.g. month) to the total number of MWh generated. Note that in both policy scenarios national GO tracking system are assumed to be fully integrated with national support mechanisms.

4. THE ROLE OF FENIX INTELLIGENCE IN FUTURE STAKE-HOLDER BUSINESS MODELS

This chapter introduces a methodology to systematically describe the business model of a key actor in the electricity supply system. This is used to characterise the role for FENIX aggregation intelligence in the future business models of four central DER aggregating stakeholders under baseline and FENIX scenario assumptions. The four central stakeholders are: the TSO, the DSO, the commercial aggregator of certain functions of DER assets and the DER operator. With respect to the commercial aggregator, this role can be assumed by integrated suppliers as well as by independent service providers to DER operators/owners.

4.1. Framework for analysing the business consequences of alternative DER deployment options

In this section we focus on the analysis of alternative DER deployment options with a focus on distributed generators (DG). Distributed generators add value in the upstream area of the electricity supply chain, depicted as the second-left component in the schematic representation of this chain in Figure 4.1 below. Yet the penetration of DG, especially distributed generation on the basis of intermittent renewable sources, brings about incremental costs in transmission and distribution networks. Reasons are that these networks have to be able to absorb reversed energy flows from lower voltage to higher voltage levels, whilst network management at higher DG penetration levels becomes much more complex. These costs have to be absorbed by the network operators and/or their customers, contingent on prevailing regulation. As a result, all components of the supply chain are facing changes as a result of more DG penetration.

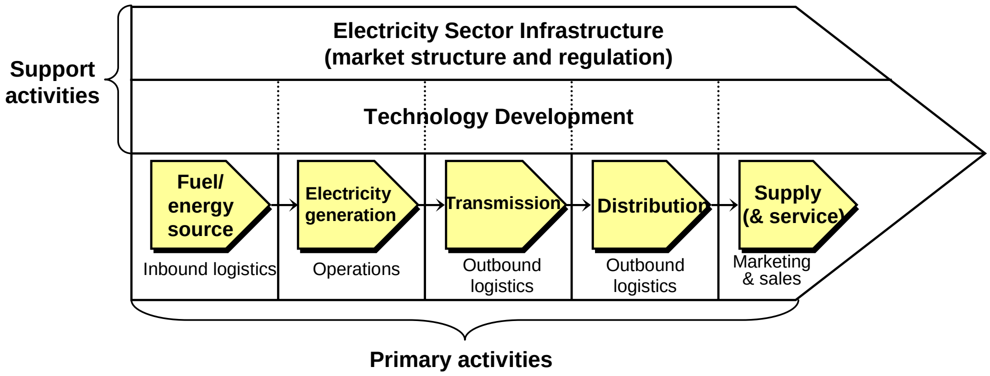
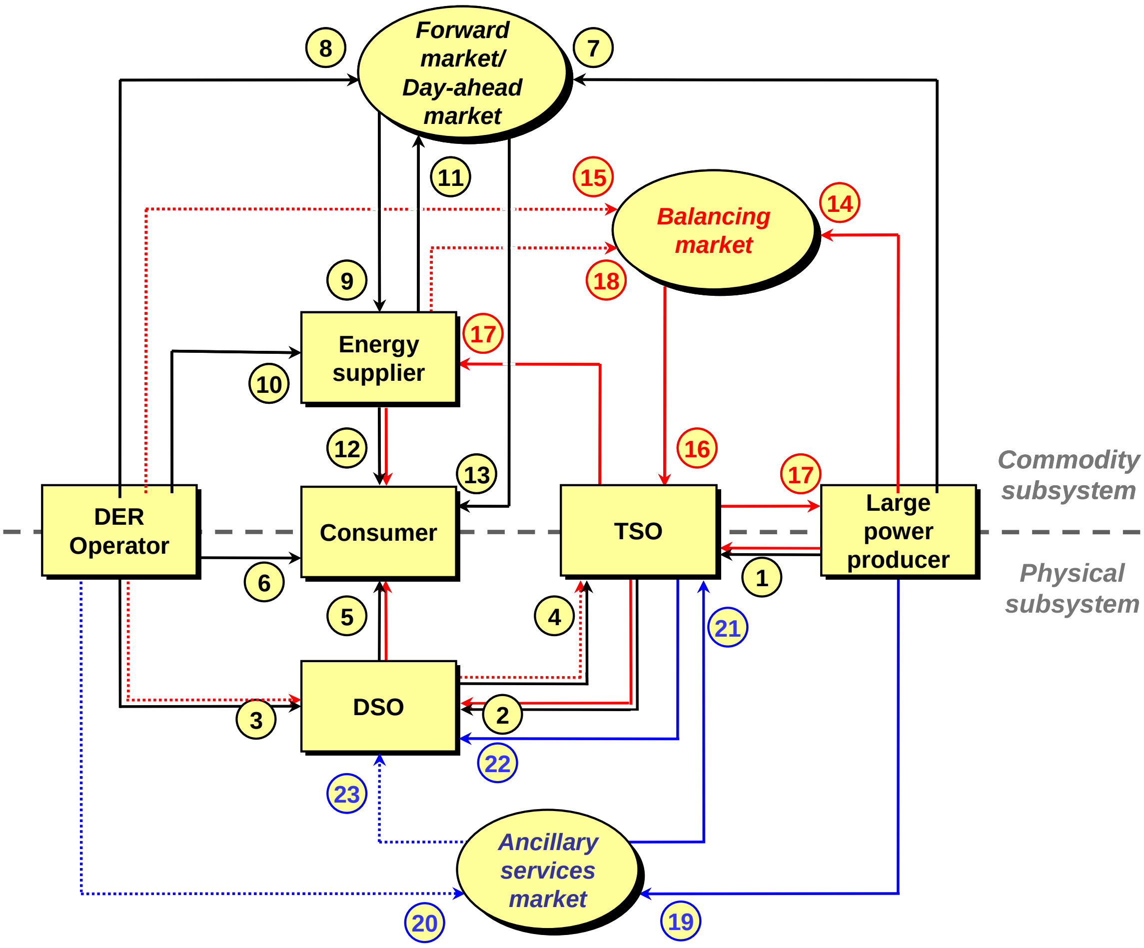


Figure 4.1 Schematic overview of the value chain of the electricity supply sector

To realise the conversion process yielding electricity and the uptake of the electricity produce by the market, a range of services need to be performed by other actors in the electricity system. In principle distributed generators can perform balancing and ancillary services to the benefit of other actors. For certain of these services, the application of FENIX concepts can be instrumental and might even be indispensable. Moreover, certain system services require input interactions between distinct parties that need to be commercially attractive at both ends: the input provider needs to earn at least enough to cover all incremental expenses, whilst the input receiver must be in a position to deploy the input profitably. Any adequate substitute to the input should have higher opportunity cost. The schematic overview above is too broad to gain insights into these kinds of business transactions within the electricity supply system. We explain a useful framework for this purpose in the remainder of this section.

In the EU-co-funded DISPOWER project an accounting framework has been developed to provide a detailed analysis of the intricate interrelationships between the various actor categories, broken down by service or product transaction. It starts out with a more or less complete overview of (essential) transactions for the whole market, with assignment of a number to each transaction. This scheme is generic: the national electricity markets of the 27 member states show - mostly small, sometimes large – variations to this generic scheme. Figure 4.2 presents a model of the electricity system and gives an overview of the economic transactions. The financial flows that result from the electricity trade are referred to as the 'commodity transactions', as distinct from transactions related to the physical electricity flows. The figure shows a theoretical view of the most important actors when they are completely unbundled. This means that all activities in the electricity market (production, transmission, distribution, and supply) are undertaken by different parties. This way, it is easier to identify the different costs and benefits of each activity. By contrast, in integrated companies revenue and cost streams between the different activity-based departments are not always explicitly known. Subsequently, details of each transaction are provided in a transaction table, shown in Figure 4.3 below. Before presenting this transaction table, we will explain the schematic overview of the electricity market (Figure 4.2) first.

Figure 4.2 includes all stakeholders at the distribution and transmission level: the DG operator, the DSO, a separate energy supplier, the large power producer connected to the transmission network, the transmission system operator (TSO), and the final consumer. The remainder of this section will elaborate on the (numbered) transactions in the figures.



Source: Werven and Scheepers (2005)

Figure 4.2 Overview of electricity market transactions and information exchange

Physical subsystem

The physical subsystem consists of the hardware that physically produces and transports electricity to customers, as well as the equipment that uses the electricity. The structure of the physical subsystem is determined by the nature of the components that make up the electricity supply system: the generators (large power producers and DG operators), the transmission network (TSO), the distribution networks (DSOs) and the loads (consumers). The physical subsystem is depicted in the lower part of Figure 4.2. The large power producers generate electricity that is fed into the transmission grid. Relation 1 represents the (regulated) agreement between the large power producer and the TSO. In exchange for a connection charge (and sometimes also a use of system charge) paid by the power producer, the TSO transports the produced electricity to the DSOs (2), who distribute it to the final consumer. Relation 5 represents the payment of the connection and use of system charges by the consumer to the DSO for the delivery of the electricity and system services. Figure 4.2 shows that electricity generated by DG operators is directly fed into the distribution network based on a (regulated) agreement between the DSO and the DG operators (3). The DG operator pays a connection charge and sometimes also a use of system charge to the DSO for electricity transport and for system services. Most of this electricity is then distributed to the consumer by the DSOs (5), but because of the growing amount of DG capacity, a local situation can occur in which supply exceeds demand. In that case the surplus of electricity is fed upwards into the transmission grid (4), after which the TSO transports it to other distribution networks (2). A last relevant physical stream concerns the auto-production of DG electricity (6). This is the direct consumption of electricity produced on-site by a consumer, skipping the commodity purchase and sale process through the energy supplier.

Commodity subsystem

In contrast with the physical power streams, the economic transactions related to the commodity flow are merely administrative and depicted in the upper part of Figure 4.2. Its goal is an efficient allocation of costs and benefits, within the constraints imposed by the physical system. The commodity subsystem is defined as the actors that are involved in the production, trade or consumption of electricity, in supporting activities or their regulation and their mutual relations. The commodity subsystem controls the physical subsystem, but is constrained by it at as well. Large power producers (7) and some very large DG operators (8) offer the commodity on the wholesale market, where the commodity is traded between different actors. Very large electricity consumers can buy the commodity directly on the wholesale market (13). Next to those consumers, energy suppliers buy commodity in the wholesale market (9) on the basis of wholesale contracts to serve smaller consumers. The trade on the wholesale market provides a payment for the produced electricity. Besides the wholesale market, the energy supplier extracts the commodity directly via (small) DG operators (10). The energy supplier subsequently delivers the commodity from the wholesale market and the DG operators to the consumers (12) who pay for it. Because energy suppliers are often 'long' (which means they have contracted more commodity than they plan to offer to consumers) there is a commodity stream backwards to the wholesale market (11).[15] Therefore, the energy supplier is a third party that offers commodity to the wholesale market.

In the situation that the energy supplier has accurately forecasted the actual amount of electricity that his consumers use, the received payment for the commodity (12) perfectly corresponds to the amount of delivered electricity (5). But deviations from forecasted use or planned generation often occur, and, due to the failing of the mechanism to balance supply and demand on the short-term, they create the need for an additional short-term balancing mechanism.

In some markets separate metering companies exist. In this analysis it is presumed that this activity is part of the DSO, the actor responsible for the physical power streams. The DSO provides metering data to the energy supplier.

Balancing market

A key concept of market liberalisation is the possibility for power producers on the one hand and suppliers as well as (large) power consumers on the other should have the freedom to enter into power delivery contracts. In many member states this lead to the introduction of balancing responsibility for market parties and a market-based balancing mechanism, hereafter called the balancing market. In this market the TSO acts as single buyer of (ramping up or down) balancing services from eligible providers offering the best price. Access to the supply side of the balancing market is mainly limited to the large power producers, but DG operators (in particular large CHP-units)

[15] To be sure to have enough commodity available for consumers, energy suppliers often contract more commodity beforehand than they think they will need at actual delivery. As from a day before actual delivery (when energy suppliers have a sound insight in the commodity demand for the next day), they offer their surplus commodity to the wholesale market.

and energy suppliers also have access.[16] Figure 4.2 shows the impact of the balancing market. The transactions that are less common in existing electricity market are shown with dotted lines. As soon as a situation of shortage arises, the TSO corrects this by buying the lowest priced commodity offer in the balancing market (16). Most offers come from the large power producers (14), but sometimes DG operators offer electricity as well (15, CHP units), just as energy suppliers (18). The TSO charges the energy supplier(s) that caused the imbalance (17) on basis of the (relatively high) price that it has paid on the balancing market. In case of a surplus of produced electricity, the TSO accepts and receives the highest bid in the balancing market for adjusting generating units downwards.[17] Also in this case the energy supplier(s) pay the TSO so-called imbalance charges. Handling these imbalance charges is arranged in the energy contracts between all market players, but mostly energy suppliers are responsible for the demand of their contracted consumers and contracted DG-operators. Therefore, the energy supplier has to pay the balancing costs in case there is a deviation of the forecasted use of its consumers or forecasted generation of its contracted DG operators.[18] In case a large power producer does not comply with its contracts, e.g. there is a malfunctioning of a generating facility, it has to pay for the balancing costs itself, as large power producers are responsible for their own energy program. As stated before, to stimulate market players to make their forecasts of electricity production and demand as accurate as possible and to act in accordance with these energy programs, the price for balancing power (imbalance charges) must be above the market price for electricity. Because balancing power is typically provided by units with high marginal costs, this is in practice always automatically the case.

The electricity system including the market for ancillary services
Next to the balancing mechanism (and the establishment of a separate balancing market), ancillary services are another relevant issue. Because these services have very different characteristics (as will be discussed later on in this section), it is not a matter of creating a separate ancillary services market. However, in Figure 4.2 the ancillary services are depicted as a separate market. It must not be taken too literal, but it is done to give a well-ordered idea of the place of these services within the electricity system.

According to the Electricity Directive (2003/54/EC), ancillary services are all services necessary for the operation of a transmission or distribution system. It comprises compensation for energy losses, frequency control (automated, local fast control and coordinated slow control), voltage and flow control (reactive power, active power, and regulation devices), and restoration of supply (black start, temporary island operation). These services are provided by generators and (other) distributed energy resources (19 and 20) as well as the system operators (21, 22 and 23). The latter are required to provide system reliability and power quality. As stated before, there is not one separate market for all ancillary services. An important distinction has to be made between distribution networks and the transmission network.

Transaction table, based on the electricity market scheme
Based on the transactions shown in the scheme of the electricity market system, depicted in Figure 4.2 above, a table of transactions in the electricity market can be made. See Table 4.1 below. As stated already, the precise configuration of the transaction scheme and transaction table is contingent on the design of a member-state-specific or region-specific electricity market and the associated regulatory framework.

[16] The offers of energy suppliers in the balancing market consist of demand response by their consumers (curtailment or shift of electricity use).
[17] Normally, producers have to pay the TSO (a relatively low price) for adjusting generating units downwards during a surplus in the total system. But it is possible that a negative price for electricity develops, in which case the producer receives money for producing less electricity (adjusting generating units downwards).
[18] An energy supplier takes over the 'energy program responsibility' of consumers. This means the responsibility of customers (who are not protected customers or licence holders) to draw up, or have drawn up, energy programs relating to the production, transmission and consumption of electricity, to announce them to the grid administrators and to act in accordance with these energy programs.

Table 4.1 Financial transactions and information exchange between energy market actors

	Actor	Offers	To	Expects in return
1	TSO	Connection to and use of transmission network	Large power producer	Connection charge + in some jurisdictions use of system charge
2	TSO	TN-DN power transmission services	DSO	Use of system charges on behalf of their customers
3	DSO	Connection to and use of distribution network	DG operator	Connection charge + in some jurisdictions use of system charge
4	TSO	DN-TN power transmission services	DSO	Use of system charges on behalf of their customers
5	DSO	Power distribution services	Consumer	System (TS+DS) charges
6	DG operator	Power (physical)	Consumer	Full cost coverage (auto-production)
7	Large power producers	Power (commodity)	Wholesale market	Contract price
8	DG operator (consolidator)	Power (commodity)	Wholesale market	Contract price
9	Wholesale market	Power (commodity)	Power supplier	Contract price
10	DG operator	Power (commodity)	Power supplier	Contract price (often based on PPA)
11	Energy supplier	Power (commodity)	Wholesale market	Contract price
12	Energy supplier	Power (commodity)	Consumer	Contract price
13	Wholesale market	Power (commodity)	Large consumer	Contract price
14	Large power producer	Balancing services (commodity)	Balancing market	Marginal bid price
15	DER operator	Balancing services (commodity)	Balancing market	Marginal bid price
16	Balancing market	Balancing services (commodity)	TSO	Marginal bid price (TSO is single buyer)
17	Large power producer	Balancing services (physical)	TSO	Marginal bid price (TSO is single buyer)
18	Balancing market	Settlement of imbalance (deviations from notified power transactions)	Energy supplier[1]	
19	Large power producer	Ancillary services	Ancillary serves market	Nothing/contracted remuneration (depends on regulation)
20	DER operator (consolidator)	Ancillary services	Ancillary services market	Nothing/contracted remuneration (depends on regulation)
21	Ancillary services market	Ancillary services	TSO	Nothing/contracted remuneration (depends on regulation)
22	TSO	Ancillary services	DSO	System charges
23	Ancillary services market	Ancillary services	TSO	Nothing/contracted remuneration (depends on regulation)

1) Suppliers (including integrated ones with generating assets) are presumed to asumed to assume all balancing responsibility towards the balancing market
Source: Based on Werven and Scheepers (2005)

The transaction scheme enables to zoom in on a specific actor and all his economic relations with other market actors, based on the business model this actor uses. A business model depicts the expenditure flows a certain entrepreneur incurs as payment for inputs and the revenue flows that he collects by transacting the outputs resulting from his business activity. A business model provides schematic overview of the value proposition of a certain business activity. A business model can be quantified using a transaction table that covers the business model concerned. In the remainder of this chapter we will show and describe the business models of the key actors in DER aggregation processes. For each central actor we will show the business model in the baseline scenario situation and the business model using advanced FENIX concepts to remotely control DER assets in a flexible way to optimise total value added created by the DER assets under management of the aggregator. The quantification of a selection of business models to assess their economic rationale will be conducted in Task 3.3 of the FENIX project.

4.2. Application for cost-benefit analysis of concrete FENIX concepts

The CBA case studies will be simulations of the business models for distinct FENIX actors and the consolidated business case for all actors considered over the 10-year period around year 2020. For the Southern Scenario case studies considered include the application of FENIX intelligence for:

- DER offering balancing services (MWh) to the TSO.
- DER offering reserves (MW) to the TSO.
- DER offering reactive power services (MVAr) to the DSO.

The Northern Scenario encompasses the following FENIX case studies:

- Improved DER access to wholesale (forward, day-ahead) energy markets.
- DER to provide services to TSO-organised intra-day and real-time balancing market.
- DER to provide intra-day balancing to balancing-responsible parties.
- DER to provide tertiary reserve services to TSO (availability and, when called, energy).

The case studies are patterned on the FENIX Southern and Northern Demonstration programmes respectively. The cases are described in more detail in the forthcoming Deliverable 3.1.2.

Per case study notably the following steps will be undertaken:

1. Case study definition including the rationale of the FENIX value creation proposition. The key question is: where is the added value of the proposed FENIX business case over and above the baseline without application of FENIX operational intelligence?
2. Definition of the baseline, simulating the business environment under present regulatory frameworks plus already adopted plans for future regulatory changes.
3. Definition of the FENIX regulatory framework, simulating the business environment that evaluates towards a FENIX compatible scenario.
4. Setting up the baseline and FENIX transaction scheme + a transactions table covering the distinct electricity market players.
5. Construction of separate baseline and FENIX business model and the associated two tables of financial transactions for each of the four distinct actors: DER operators; Commercial aggregator (VPP); DSO (Technical VPP); TSO.
6. The differential FENIX cash flows with respect to baseline cash flows can then be determined for each of the four actors. This requires annual FENIX and baseline cash flows of benefits and costs over the 2015-2024 period for each actor. The differential cash flows determine the Net Present Value as indicator of the financial attractiveness of the FENIX business case for the actor concerned.
7. CBA of the consolidated FENIX business case aggregating the cash flows for all four categories of distinct actors. This, in turn, will provide indications of the attractiveness of the Fenix concept considered for the electricity system as a whole: e.g. does Fenix create efficiency gains for the whole system?
8. To derive the societal impact of a FENIX business case. This requires in addition to attribute external effects and to scale up the FENIX application to national e.g. Spanish and UK level and, when possible, even EU-wide level. If social cost-benefit analyses yields robust positive net present values this will provide a strong case to adjust the current regulatory in FENIX-compatible ways.

4.3. Business models

In this report for each central stakeholder generic business models are presented: one pertaining to the baseline policy scenario and the other to the FENIX policy scenario. For keeping the analysis transparent the number of business models will be limited to two per central stakeholder considered, acknowledging that in practice a myriad of baseline business models and FENIX VPP variants to the archetypes presented below are possible. As mentioned in the previous section, in the cost-benefit analyses of Task 3.3 concrete specific business cases will be investigated in detail.

The diagrammatic representations of the business models show solid black arrows: financial flows between the central stakeholder concerned and third parties. Black-arrow labels summarise the nature of the product/service provided in reverse direction. With the exception of remuneration of production factors under direct management of the central stakeholder (salaries of own staff and return on capital invested), the diagrammatic representations of the financial flows visualise the stakeholder's major revenue in-flows and expenditure out-flows.

Note that for reasons of simplicity the representations only show flows that can be monitored by the central stakeholder in question; only these flows are relevant for his business model. *Hence, financial flows between other actors in the business model diagrams are not shown.* Per central stakeholder, the respective two diagrams highlight some key differences between FENIX and baseline business models of the central stakeholders considered. Furthermore, they exhibit how FENIX concepts fit into the FENIX business model of central stakeholders and explain the most important economic functions of DER aggregators which FENIX VPP concepts have to integrate.

4.3.1. TSO: baseline business model

The baseline TSO business model, presented in **Figure 4.3** assumes that the TSO will not enter into a direct contractual relationship with DER on the provision of system-wide non-balancing ancillary services. For the latter the TSO will keep on relying on large, TN-connected conventional generators. Regarding the provision of balancing services, the advanced variant of the baseline scenario includes the possibility that aggregated, controllable DER - notably DN-connected CHP plants - is contracted directly to provide secondary and tertiary reserve services.

The TSO baseline business model encompasses the following major components:

Revenues

- In most MS the TSO organizes a balancing market where the TSO collects unbalance charges from balancing responsible parties with deviations from their notified injections or extractions contributing to near real-time system imbalances which the TSO has to eliminate by calling in the services of providers of balancing services in an economic way. Balancing charges to balancing responsible parties can assume negative amounts. In some member states certain DER operators can opt to assume direct balancing responsibility. In most cases responsibility for unbalance on account of DER is transferred by contract to a party with balancing responsibility, often a large supplier.
- The TSO imposes regulator-approved use-of-transmission-system (UoTS) charges to the DSOs who pass on these charges to the end-users connected to their respective grids. In some member states TN-connected and distributed generators share part of the TN transport charges whilst in other states they might be excluded.
- In general, contingent on MS-specific regulation connection costs of generators to the network are passed on to the latter. On the other hand, the incremental network reinforcement costs might or might not be recovered through location-specific UoTS charges.[19]
- The TSO imposes regulator-approved charges to the DSOs for delivery of ancillary network services which the DSOs will pass on to final electricity users connected to their respective networks.

Expenditures on outsourced goods and services

[19] In many member states network operators are allowed to pass on (acceptable) network reinforcement costs to the final consumers. In the UK, though, DG may shoulder at least part of these costs indirectly through locational use-of-system charges. In the Netherlands, DG above 10 MW per facility has to pay location-specific connection charges.

- The TSO eliminates near real-time system imbalances by calling in the services of providers of balancing services in an economic way at a market-based compensation, whilst the TSO may transfer negative unbalance charges (if negative at all) from balancing responsible parties with deviations from their notified injections or extractions which offset near real-time system imbalances.
- The TSO contracts potential providers of balancing services and pays the corresponding fees. DER entities, whether or not aggregated by an independent aggregator, might be directly contracted by the TSO to deliver secondary and tertiary reserve services.
- The TSO contracts potential providers of system-wide ancillary services and pays the corresponding fees. DER entities, whether or not aggregated by an independent aggregator, are generally not directly contracted by the TSO in the baseline scenario.
- The TSO incurs expenditures for non-power material inputs including payments to network equipment vendors, outsourced maintenance and ICT providers, spare parts and consumables.

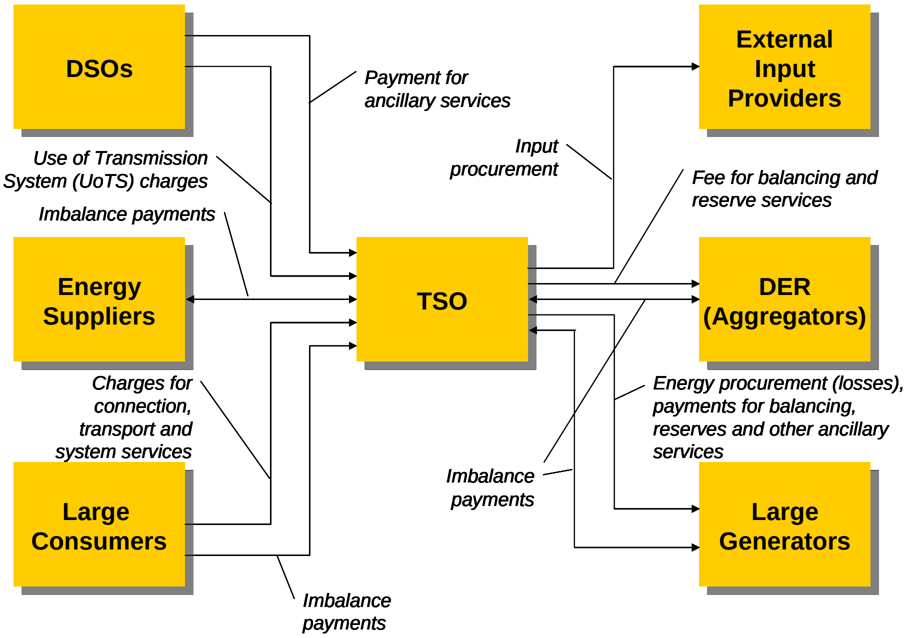


Figure 4.3 TSO baseline business model

4.3.2. TSO: FENIX business model

The TSO FENIX business model is broadly similar to the corresponding baseline model. Essential differences regard the expenditures side for services outsourced to DER operators or their independent aggregator with DER assets partly remotely controlled by the TSO and the eligibility of DER for global system (non-balancing) ancillary services. The expenditures side is shown hereafter.

Expenditures on outsourced goods and services

- The TSO eliminates near real-time system imbalances by calling in the services of providers of balancing services in an economic way at a market-based compensation, whilst the TSO may transfer negative unbalance charges (if negative at all) from balancing responsible parties with deviations from their notified injections or extractions which offset near real-time system imbalances.
- The TSO contracts potential providers of balancing services and pays the corresponding fees. DER entities, whether or not aggregated by an independent aggregator, might be directly contracted by the TSO to deliver secondary and tertiary reserve services. The providers of secondary reserve services are remotely controlled by the TSO.
- The TSO contracts potential providers of system-wide ancillary services and pays the corresponding fees. DER entities, whether or not aggregated by an independent aggregator, might be directly contracted by the TSO in the FENIX scenario and, by implication, be remotely controlled by the TSO to deliver the contracted services when required by the TSO.
- The TSO incurs expenditures for non-power material inputs including payments to network equipment vendors, outsourced maintenance and ICT providers, spare parts and consumables.

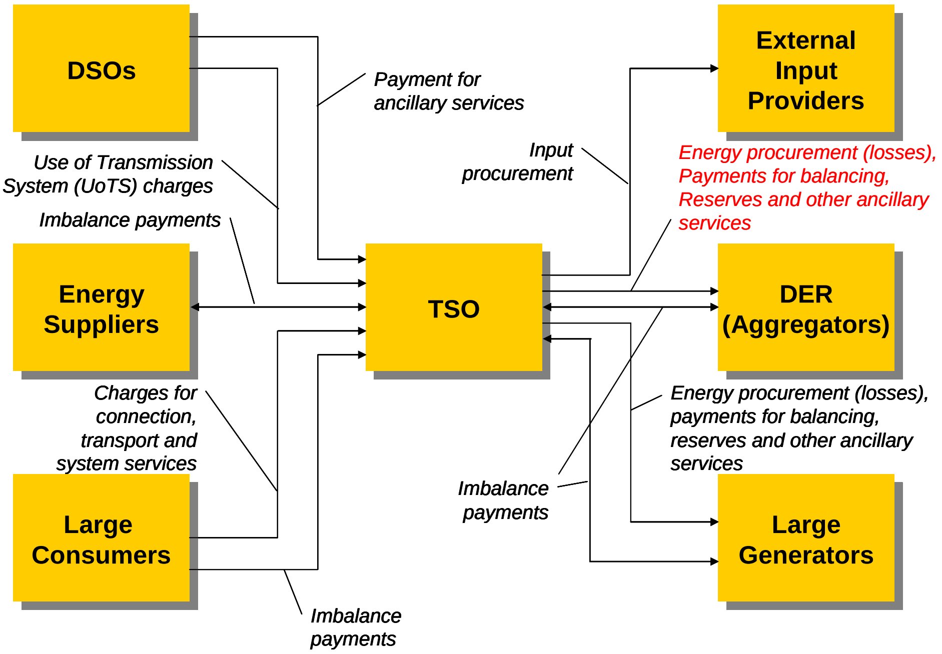


Figure 4.4 TSO FENIX business model

4.3.3. DSO: baseline business model

The baseline DSO business model assumes continuation of a fit-and-forget network management philosophy. In the baseline policy scenario the DSO is less able to address mounting network constraints as a result of high penetration of distributed generation in their networks, unless they undertake massive grid reinforcement programmes. The baseline scenario may imply higher Use of Distribution System (UoDS) tariffs and a less friendly treatment of DG customers. These likely implications and the slower implementation of smart metering and monitoring systems in the baseline policy scenario as compared to the FENIX scenario may attenuate the fast penetration of DER. Hence, although there will be appreciably more penetration of distributed generators than at present, DG penetration will be less in the baseline scenario than in the FENIX policy scenario. Commercial aggregators with DER customers in the DN area will only be of a consolidator type, i.e. they will provide financial DER aggregation services to create additional value for their DER customers but refrain from operational DER integration by wielding remote control over the plants of their DER customers. The diagrammatic presentation of the baseline DSO business model is shown in Figure 4.5.

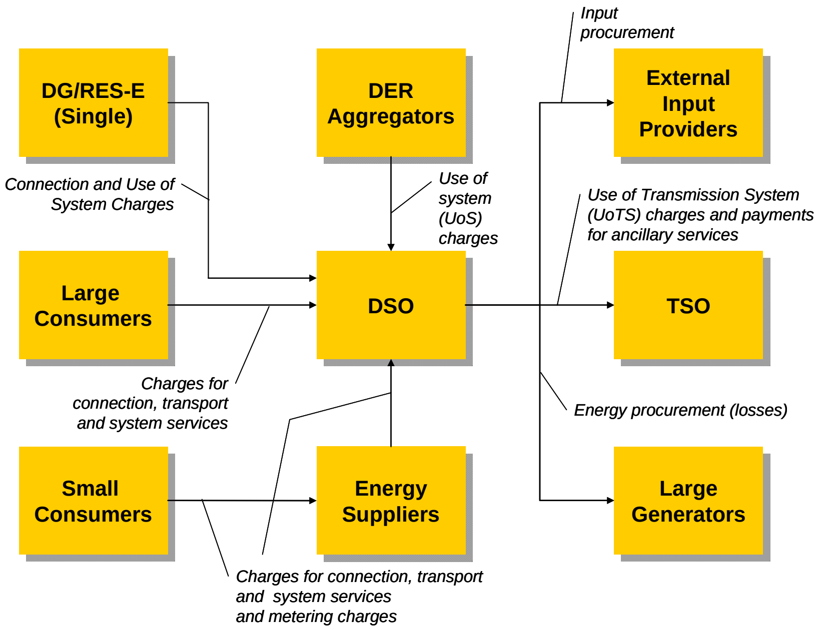


Figure 4.5 DSO baseline business model

The business model encompasses the following major components:

Revenues

- The DSO imposes regulator-approved connection (C) and use-of-distribution-system (UoDS) charges to distributed generators (DG). Some DER aggregators may act on their DER clients as a financial interface with the DSO as a service to reduce administration work for clients and to monitor correctness of DSO billing.
- The DSO imposes regulated connection, (cascaded) Use of System and services charges to DN-connected power consumers.
- Through intermediation of suppliers of retail consumers in the DSO area, the DSO receives regulated metering charges for the allowable cost to recover the up-front procurement cost of the meter at the retail consumer's doorstep and the allowable recurrent metering costs.[20]

Expenditures on outsourced goods and services

- The DSO passes on payments for approved transmission-system ancillary services charges (TAS) and use of transmission-system ancillary services (UoTS) charges from consumers to TSO.
- The DSO contracts large generators to deliver the energy needed to cover losses in the distribution system, either directly or indirectly through brokered trades or power markets.
- The DSO incurs expenditures for non-power material inputs including payments to network equipment vendors, outsourced maintenance and ICT providers, spare parts and consumables.

4.3.4. DSO: FENIX business model

The FENIX DSO business model is depicted in Figure 4.6 below. It contains the same type of revenue and expenditure flows as the corresponding baseline model. Yet in the FENIX policy scenario, as a result of active network management conducted by the DSO, a range of new financial flows appear. Also the role of conventional flows may change in significance as explained below. Changes compared to the baseline business model are highlighted in blue fonts.

[20] This is consistent with the scenario assumption that the (unbundled) DSO will be nominated to assume the role of regulated metering company in the DSO franchise area, both the baseline and the FENIX scenario. See Section 2.5. Note that it is assumed that the certified meter reading market for large consumers and distributed generators is free. *Small* distributed generators at household level "behind the meter", exporting to the grid might be considered as small consumers with negative demand in this respect.

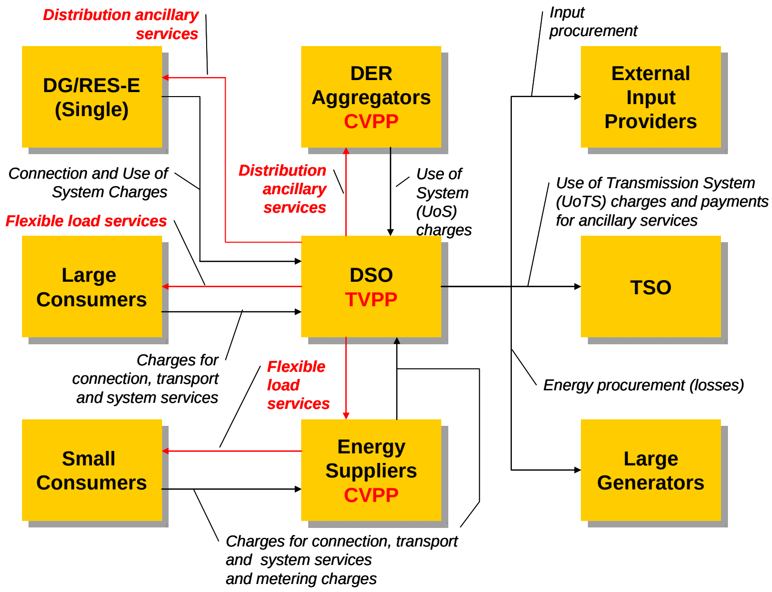


Figure 4.6 DSO FENIX business model

Revenues

- The DSO imposes regulated connection and use-of-distribution-system charges to distributed generators. These will also be charged to suppliers owning DG assets in the purview of the DSO. Connection charges for distributed generators will be shallow with partial socialization of concomitant reinforcement costs in UoDS, UoDS will be "smartened": time-variable UoDS charges with locational signals will be introduced, which will greatly improve cost-reflectivity of DN services rendered to distributed generators. As FENIX-type of incumbent DER aggregators will command a significant role, so will be the financial flows between FENIX-style DER aggregators and the DSO.

- The DSO imposes connection, (cascaded) Use of System charges, services charges and metering charges to DN-connected power consumers. Due to complexity of DN operational management, charges for DSO arranged ancillary services will be appreciably higher, whereas charges for TSO arranged services will be lower than in the baseline.

- Through intermediation of suppliers of retail consumers in the DSO area, the DSO receives metering charges for the allowable cost to recover the up-front procurement cost of the meter at the retail consumer's doorstep and the allowable recurrent metering costs. Allowable DSO revenues for metering services rendered will be higher than in the baseline due to appreciably higher demand for metering services by suppliers on behalf of their customers which contractually consented to delivery of load flexibility services.

Expenditures on outsourced goods and services

- The DSO passes on payments for TSO-arranged ancillary services charges and use of transmission-system ancillary services charges from consumers to TSO. In the FENIX policy scenario the importance of transmission-network facilitated generation and TSO-arranged ancillary services will be appreciably less compared to the baseline, and so will the related financial flows from DSO to TSO.

- The DSO contracts both DG and large generators to deliver the energy needed to cover losses in the distribution system. For large generators this will proceed either through direct bilateral contracts or indirectly through brokered trades and/or power markets. Research results from load flow analysis by Imperial College undertaken within the DG GRID project indicate that the impact of active network management on DN line losses are somewhat ambiguous.[21] In most cases line losses

[21] However, with very high and very concentrated DG penetration in relation to local load, active network management may negatively impact DN line losses. See www.dg-grid.org: project deliverables 8 and 10.

will be less. Smart regulation can help to reduce line losses under active network management. Moreover, in the FENIX policy scenario local DG will contribute to make up for local line losses. Hence, it can be safely assumed that, compared to the baseline, the need for the DSO to call upon large generators to compensate for line losses will be less and so will be the associated financial flow.

- The DSO incurs expenditures for non-power material inputs including payments to network equipment vendors, outsourced maintenance and ICT providers, spare parts and consumables. The composition of the financial flows concerned will be quite different from the baseline, while at this stage it cannot be assessed how the total amount concerned will compare in the FENIX policy scenario to the baseline. Investment in network reinforcement (including upgrading of switch gear and transformers and ICT infrastructure) in network sections where DG feeds in is poised to rise. On the other hand, investment in network expansion of higher voltage DN sections can be postponed.

Active network management will imply new expenditure flows:
- DSO-arranged ancillary services (DAS) provided by DG (including compensation for DN line losses), flexible loads (large consumers and willing retail consumers remotely controlled by their suppliers). Figure 4.6 shows that, in principle, FENIX-style independent commercial DER aggregators may play their part in arranging the provision of certain DAS and as intermediary in the financial settlement of DAS on behalf of their DER clients. It is noted that this is subject of further investigation within the FENIX project. The associated financial costs have to be recovered by the DSO through allowable network tariffs as explained above.

4.3.5. Commercial aggregators: baseline model

Commercial aggregators can be local actors active in just one DSO network area, but may as well service DER customers in several DSO areas. Large suppliers or independent aggregators, including large niche aggregators (e.g. aggregators of windpower operators or CHP plants in specific industrial branches) may reach sufficient size to apply for direct balancing responsible party status and to directly participate in electricity markets.

The commercial DER aggregator in the presentations that follow is a relatively large aggregator, aggregating DER in several DSO areas, capable of directly accessing markets of interest to DER operators. Most of his clients will be connected to the lower voltage level (MV/LV) networks, as these clients are not likely to have direct access to electricity markets and lack the commercial skills, trading infrastructure, and management time to achieve optimal trading performance themselves. In other words, DER aggregation for clients at lower voltage levels can create most value added. DER clients are especially interested in engaging the services of DER aggregators:
- to improve trading results netted of DER aggregator fees,
- to avoid or minimize investments in trading ICT and market entree and membership fees,
- to free up management time for core business activities:
  - to delegate "red tape" activities (such as obtaining eligible market support benefits),
  - to delegate market monitoring activities.

The presentations only show distributed generators as clients but distributed loads can be added without principally altering the business models to be presented hereafter.

Certain commercial aggregators, independent aggregators, may derive a non-trivial part of their business from DER support benefits and the green feature of the guarantees of origin (GO) that he trades with specialized trading knowledge on behalf of his clients. This applies most to aggregators with renewable electricity generators as clients. New environmental markets may offer new opportunities for aggregators such as markets in "white certificates" for aggregators of flexible loads. In fact, in some instances environmental markets can launch independent aggregators, which may subsequently start aggregating DER services targeted at electricity markets on the side.

The postulated commercial DER aggregator in the baseline scenario is a large consolidator. He brokers in aggregated tailor-made structured deals, e.g. non-standard block bids and offers on the power exchange and forward markets. He either deals directly on behalf of his DER clients or through a large intermediary with direct access to relevant markets. *For the sake of exposition, the baseline aggregator is postulated as a consolidator to show the differences with his counterpart using FENIX VPP concepts. Yet it is noted that in some member states already commercial aggregators are active that recently started to adopt some key features of FENIX CVPP agents.*

The postulated baseline aggregator does not absorb trading or balancing risk of for his clients nor does he apply remote control of his customers' generating facilities. If he deals directly, he will contractually transfer trading and balancing risks to his clients. If he deals indirectly, he also shifts trading risk to his DER customers by contract but shifts balancing risk to his large partner who directly trades – on the DER aggregator's behalf who in turn has to pay fees- on wholesale markets and is registered as balancing responsible party. Nonetheless, the aggregation process yields an interesting "free lunch" by virtue of the portfolio effect reducing balancing risk for his customers. Balancing risk occurs when (non profile) customers nominate their planned net load injections and deviate ex post from nominated planning. Each DER aggregator depicted in Figure 4.7 and Figure 4.8 respectively is assumed to be large enough to trade directly on electricity wholesale and balancing markets. The business model of the independent DER aggregator in the baseline scenario (Figure 4.7) looks as follows:

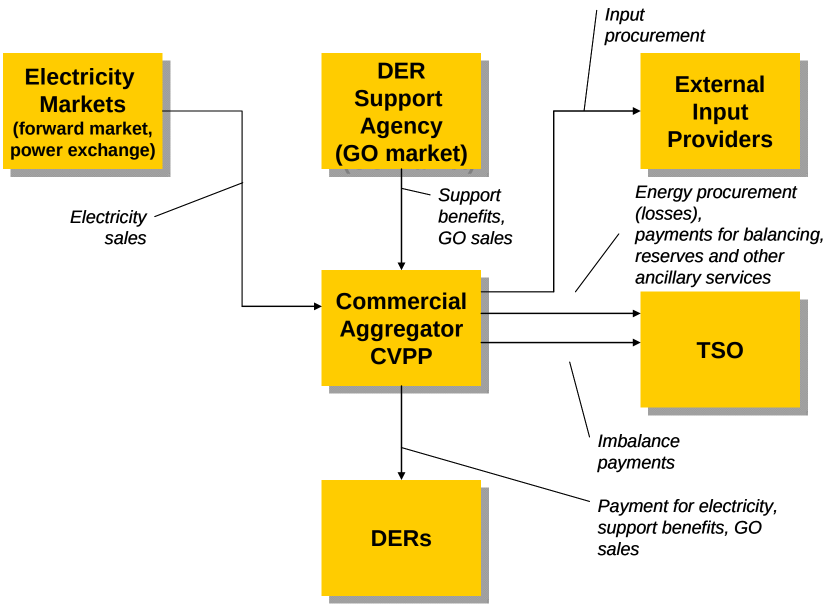


Figure 4.7 Commercial aggregator: baseline business model

Revenues
- Selling electricity to wholesale markets, directly or via large intermediary, on behalf of DER customers.
- Participation on the TSO-organised balancing market, directly or via large intermediary, on behalf of DER customers (revenues can at times be negative).
- Obtaining DER market support benefits on behalf of DER customers.
- Arranging issuance and selling GO certificates on the GO market on behalf of DER customers.
- Fees retained from DER proceeds to DER customers.

Expenditure on outsourced goods and services
- Transfers of DER proceeds for DER delivered goods and services, net of retained fees.
- Expenses on third party goods and services, such as procurement of ICT infrastructure for trading, payments for trading software licences and market membership payments.

Note that DER customers are connected with their respective DSOs and charged for network services by their DSOs. Unless DER and the (commercial) DER aggregator have a contract on the handling of network charges this is out side the purview of the DER aggregator.

4.3.6. CVPP: FENIX business model

The postulated commercial DER aggregator in the FENIX scenario uses a CVPP (commercial virtual power plant) agent for integrated operational optimisation of his DER portfolio to maximize aggregated commercial value added. He will typically absorb (or share) balancing and trading risk of (with) his clients for extra fee. The CVPP-equipped aggregator may even conclude a complete DER management contract with his DER-owning clients. The main components of the business model of this central actor are depicted in Figure 4.8 and are analysed below. Differences with the baseline independent DER aggregator above are indicated in blue fonts.

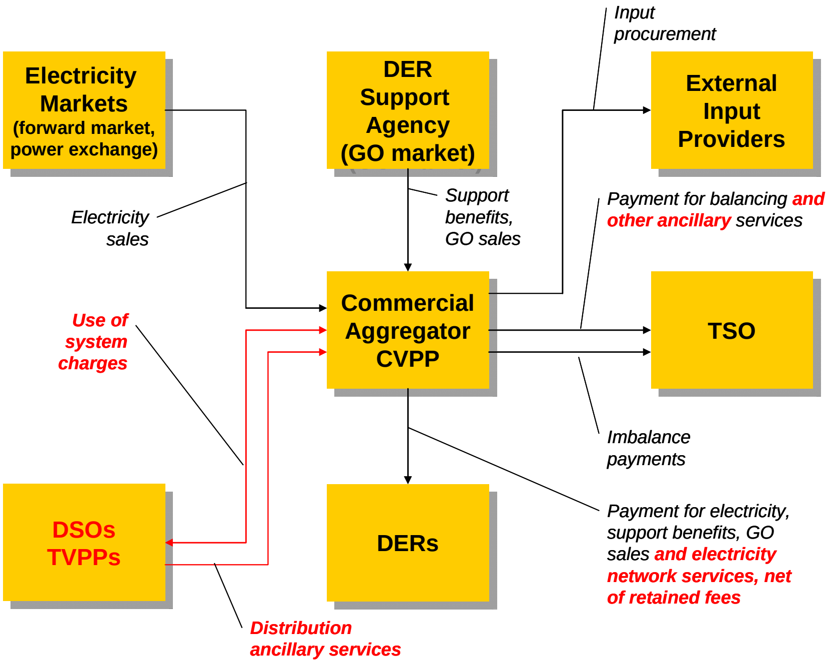


Figure 4.8 CVPP: FENIX business model

Revenues

- Selling electricity to wholesale markets, directly or via large intermediary, on behalf of DER customers.
- Participation on the TSO-organised balancing market, directly or via large intermediary, on behalf of DER customers (revenues can at times be negative).
- Provision of TSO-arranged non-balancing commercial ancillary services and DSO-arranged commercial ancillary services on behalf of DER customers. It is remarked that, in principle, FENIX-style independent commercial DER aggregators may play their part in arranging the provision of certain ancillary services and as intermediary in the financial settlement of ancillary services on behalf of their DER clients. However, this is subject of further investigation within the FENIX project.
- Obtaining DER market support benefits on behalf of DER customers.
- Arranging issuance and selling GO certificates on the GO market on behalf of DER customers.
- Fees retained from DER proceeds to DER customers. These might include a fee on proceeds from CVPP-arranged ancillary services delivery by DER.

Expenditure on outsourced goods and services

- Payments for DER delivered goods and services, net of retained fees. This may or may not encompass payments net of fee for CVPP-arranged ancillary services delivery by DER. Again we note that this is an issue for further research with the FENIX project.
- Expenses on third party goods and services, such as procurement of ICT infrastructure for trading and participation in commercial ancillary services markets, payments for trading software licences and market membership payments.

4.3.7. DER operators: baseline business model

To simplify the analysis we will concentrate on independent DG operators. In fact, the business models of providers of flexible demand services bear a great resemblance to corresponding ones of independent DG operators. Besides, DER assets under direct control of integrated suppliers are operated in a fashion quite similar to TN-connected generating assets under their control, provided the necessary ICT infrastructure for remote control is in place.

We will assume that direct entry of wholesale power markets is not feasible for isolated DG as a result of hurdles regarding financial scale and specialized market knowledge. The most basic baseline variant of an independent operator of a DG asset is to enter into a power purchase agreement (PPA) with an integrated supplier over a certain future period. The price might be linked to the price evolution of a certain futures contract or to the Day Ahead price on a certain public exchange. The integrated supplier will assume the balancing risk at a price, typically an undisclosed fee taking the form of a discount on the power purchase price. A somewhat more advanced baseline variant is the delivery of energy to an independent "consolidator" who bundles the energy deliveries of independent DER operators under his management into energy contracts with counterparts on electricity wholesale markets including the TSO regarding the provision of energy balancing services. The consolidator may either assume the consolidated balancing risk himself or enter into a contract with an integrated supplier to assume this risk at a (typically reduced but undisclosed) price. In the baseline situation, the independent DER aggregator is only a consolidator of financial contracts without exercise of operational control over the DER assets under management.

Revenues

- Selling electricity to either an integrated supplier or an independent consolidator.
- Participation on the TSO-organised balancing market, only if making use of the services of a consolidator.
- Obtaining DER market support benefits, either directly from the competent government agency or indirectly through using the services of a consolidator.
- Arranging issuance and selling GO certificates on the GO market, either directly or indirectly through using the services of a consolidator.

Expenditure on outsourced goods and services

- Fees for network services received from the DSO and TSO (DSO transfers fees for TN-services delivered to DG through the DSO concerned).
- Fees for outsourcing of balancing responsibility to an integrated supplier or an independent consolidator.
- Fees (either explicit or implicit) for intermediation in collection of revenue from support benefits and GO sales.

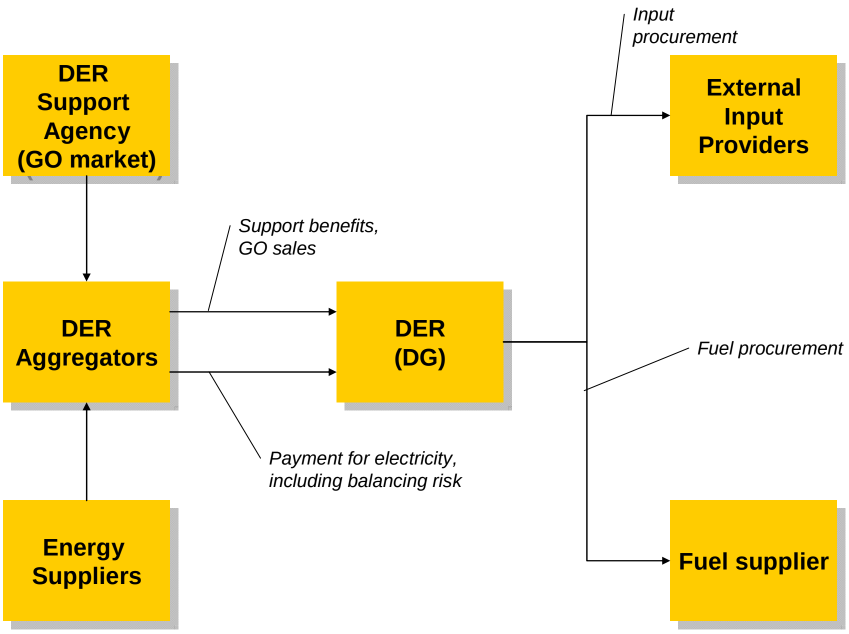


Figure 4.9 DER operator: baseline business model

4.3.8. DER operators: FENIX business model

DER operators enter into an operational management contract with surrender of remote control of the DER assets. Their counterpart is either an integrated supplier or an independent aggregator using advanced remote control ICT technology. The operations of the DER assets are co-optimised for delivery of energy to energy wholesale markets and/or ancillary services to the TSO and/or to DSOs concerned. To render the delivery of ancillary services attractive to DER operators, appropriate curtailment fees might be included as a compensation component when delivery of the ancillary service entails forgone generation of electricity and associated revenues.

Revenues

- Selling electricity to either an integrated supplier or an independent aggregator.
- Participation on the TSO-organised balancing market.
- Receipts of revenues from ancillary services provided, including curtailment fees.
- Obtaining DER market support benefits, either directly from the competent government agency or indirectly through using the services of the counterpart-aggregator.
- Arranging issuance and selling GO certificates on the GO market, either directly or indirectly through using the services of the counterpart-aggregator.

Expenditure on outsourced goods and services

- Fees for network services received from the DSO and TSO (DSO transfers fees for TN-services delivered to DG through the DSO concerned).
- Fees for outsourcing of balancing responsibility to an integrated supplier or an independent aggregator.
- Fees for arrangement of ancillary services to counterpart-aggregator.
- Fees (either explicit or implicit) for intermediation in collection of revenue from support benefits and GO sales.

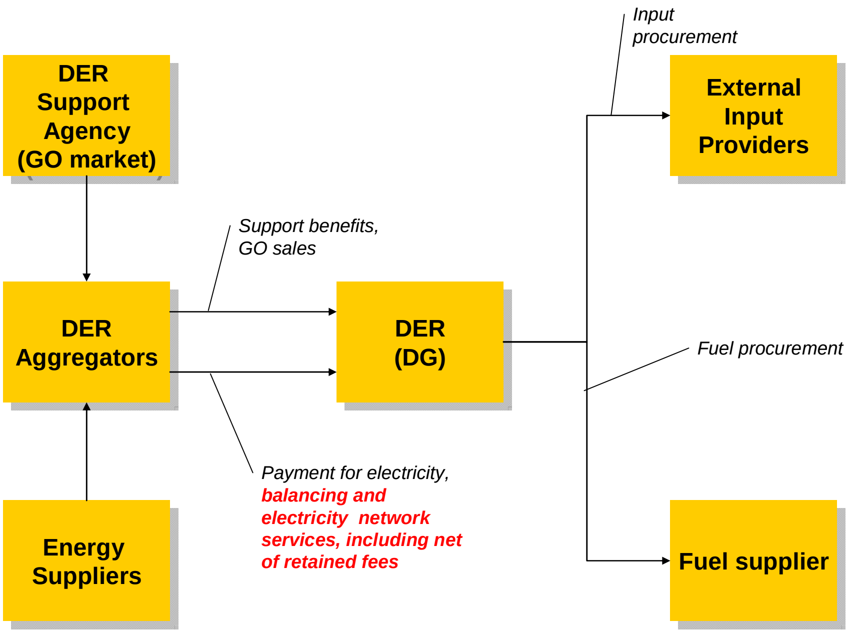


Figure 4.10 DER operator: FENIX business model

5. CONCLUDING REMARKS

In this report an approach has been introduced to systematically account for exchanges of goods and services between actors of the electricity system and the consequential business models for these actors under different system scenario frameworks. The analysis has focused on the role of DER and whether or not this role is effectuated through remote operational control by a third DER aggregating part or not. The latter is a key feature of FENIX applications. Task 3.3 will make an economic assessment of a selection of FENIX applications.

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