Future Industrial Structure of Distribution Sector

A report for the Customer-Led Distribution System Project

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1. Executive summary

1.1. Background

“Industry Structure” refers to the organization and interactions of the component parts of the electricity supply industry and its participants to meet the needs of customers and the government’s agenda for sustainability, security and affordability. Traditionally, the distribution network has a centralised system structure that takes electricity from grid supply points and distributes it to end customers. Energy customers, particularly those in the commercial and domestic sectors are generally passive and do not participate actively in resource optimisation or constraint management for two interlinked reasons, there being:

i) Limited capability to equip these customers to participate in markets, and

ii) Limited market features that incentivise flexibility.

The decarbonisation agenda has fundamentally changed the energy landscape for the distribution system and challenges the suitability of the extant centralised structure. There is a growing uptake of low carbon technologies such as distributed energy resources (DERs), and the prospect of electric vehicles in homes, businesses and communities. Digitalisation and decentralisation provide new opportunities and incentives for energy customers and third-party energy providers to engage actively in resource optimisation and system constraint management. Distribution system operators (DSO) could play a key part to turn DERs into highly valuable assets that could radically increase the utilisation of local renewable generation and distribution networks, with a consequent increase in operational efficiency.

Achieving this goal requires a fundamental change to the industrial structure at the distribution level, and to the roles and functions of the current distribution network operators (DNO) so as to proactively promote flexibility in electricity supply, and appropriately incentivise the growing number of market participants. There is a critical need to understand the changing roles, functions and interactions among existing and new players so as to allow the needs of customers and the objectives of government (such as decarbonisation and increase energy efficiency)to be met.

Much consideration is currently being given to the future structure of distribution systems and the changing roles and functions of the DSO. However, the current debate within the industry has two main limitations:

When contemplating different future industrial structures the alignment between various stakeholder objectives that result from changing roles and functions are not systematically analysed. This has the potential to create structures that will benefit one party to the detriment of others without a full awareness of the system consequences.

Focusing largely on the market prospects for network services could significantly limit the integration of DER into the energy system. Implementing a local energy market could deliver a much higher value for DERs as well as providing a prospect for reducing constraints on local distribution networks. A market environment that reflects both the surplus and shortage of energy and the degree of the local distribution network offers a prospect for facilitating a much higher volume of DER penetration [1] [2].

Our vision of a fit-for-purpose industrial structure for distribution systems is a customer focused energy system that delivers value for the energy customer, and also satisfies the government's agenda of ensuring the sustainability, security and affordability of electricity supplies. A key step towards this vision is to adapt the DNO's roles and functions to that of a DSO by opening up the energy market and the network market to a wider customer base. By introducing energy market, we explore the trade-offs between network efficiency and overall energy system efficiency. The overall system efficiency will be consists of both network efficiency and energy efficiency. Current industrial thinking focuses mainly on the idea that it is the DNO who will take up the role of DSO. However, there is the possibility that a DSO will become a new and separate stakeholder in the electricity supply system. Under this approach a DNO would retain its responsibility for planning and operating the distribution network, whilst a new DSO would be a market facilitator and coordinator all of the key stakeholders in the distribution system.

1.2. Options for the future industrial structure in the distribution system

In considering energy customers to be at the heart of the energy revolution, we propose three future Industry Structures for the distribution system. They range from one with highly centralised control to one with highly decentralised control. Each could be suitable for a future scenario with widely differing DER penetrations. These three structures conform well to National Grid's two future scenarios that meet the 2050 carbon reduction target. Our central-control dominated structure agrees well with the National Grid Two Degrees scenario, whilst our community-control dominated structure aligns with the National Grid Community Renewables scenario. In addition to these two scenarios we will consider a third scenario; the regional-control dominated structure which is a halfway house between the other two.

The role of a DSO in these futures may vary from one industrial structure to another. For each structure, we consider the DSO as having either a maximum role (which would encompass distribution network planning, network operation, and local market operation and coordination) or a minimal role (which would extend only to neutral market facilitator). The maximum role of a DSO for each structure is explained in each of the following structures.

Central-control dominated structure

- This structure is highly central-control dominated, and connects generation, demand, and storage at remote locations.
- Demand is predominantly met by centralised generation via the transmission grid and regional distribution networks. Approximately 80% of demand is supplied by centralised generation and the remaining 20% from distributed generation.
- The maximum DSO's role includes planning of the distribution network, and its operation. It would also manage a limited local network services market for the procurement of services needed to secure the distribution system.

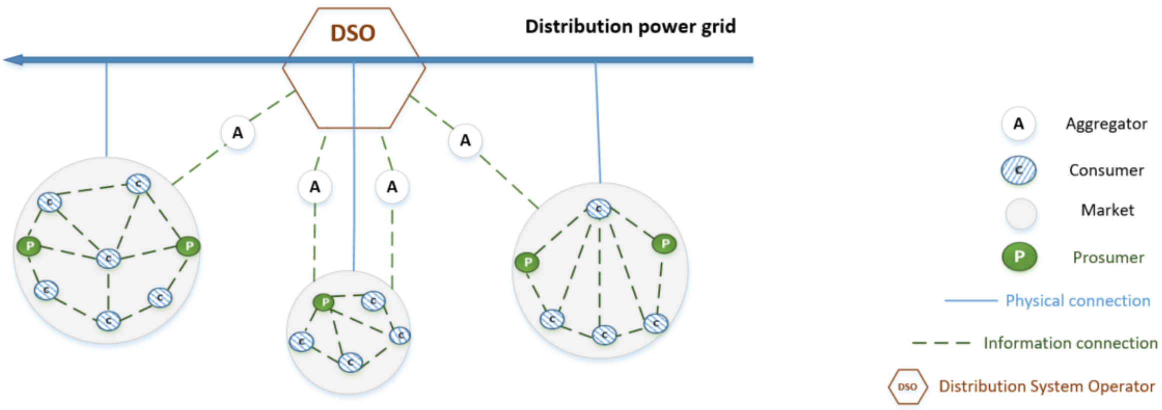


Fig. 1. Central-control dominated structure

Regional-control dominated structure

- This is a hybrid structure where distant and local distributed generation will both play a part in meeting customer demand.
- Demand is met by both centralised and local generation via the transmission grid and regional distribution networks. Approximately 50% of load is supplied by the centralised generation and the other 50% by distributed generation through a local energy market. The local energy markets could function at different voltage levels.
- The maximum DSO role covers planning and operating the distribution networks. The DSO would also operate and integrate a widespread network services market for network support services, as well as localised energy markets where these are appropriate.

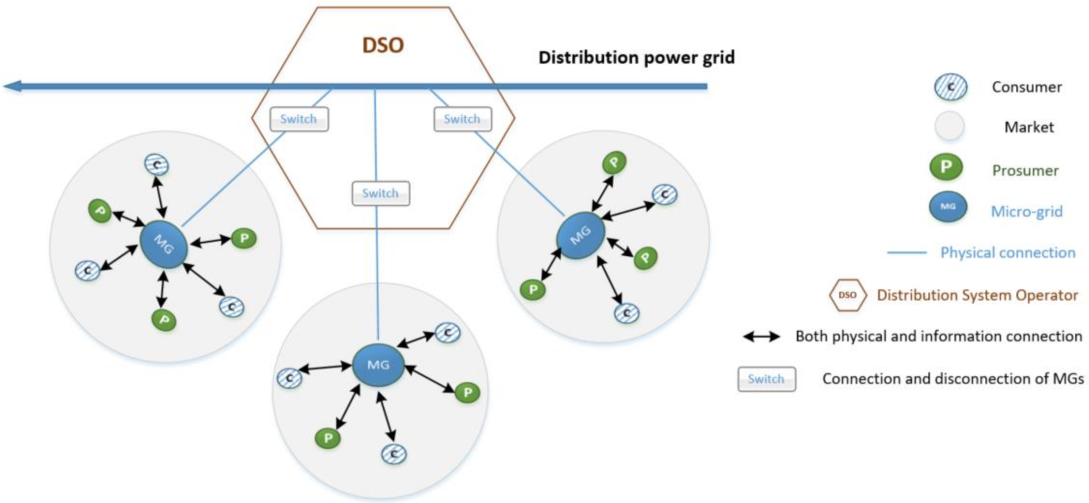


Fig. 2. Regional-control dominated structure

Community-control dominated structure

- This scenario has a highly distributed structure where generation, demand and storage are physically located within the same community.
- Demand is mainly supplied by distributed generation via local distribution networks. Approximately 80% of the demand is supplied by local generation through the local energy market, whilst the rest of the demand is supplied by centralised generation.
- The maximum DSO role includes the planning and operation of the distribution networks, operating the network services market, and operating local energy markets that would include their coordination with a national wholesale energy market.

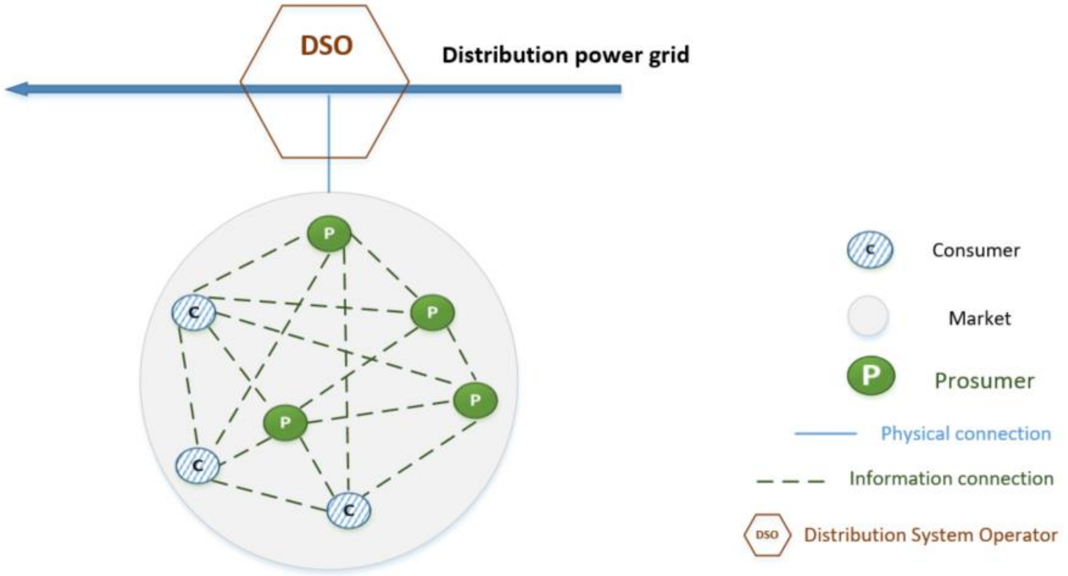


Fig. 3. Community-control dominated structure

Fig. 4 demonstrates a possible transition from a central-control dominated structure to a community-control dominated structure. The transition pathway indicates that as the DER penetration increases, the degree of decentralisation and of digitalisation also need to rise to deliver the full value of DERs. This in turn would facilitate and propel the growth of DERs.

Given increased DER intelligence, the third-party service providers will be provided with more opportunities on network services and energy services. The detailed opportunities will be explored in the future work. Consumers will also be provided with more opportunities that allow them to cope with the future uncertainties with DER intelligence rather network investment.

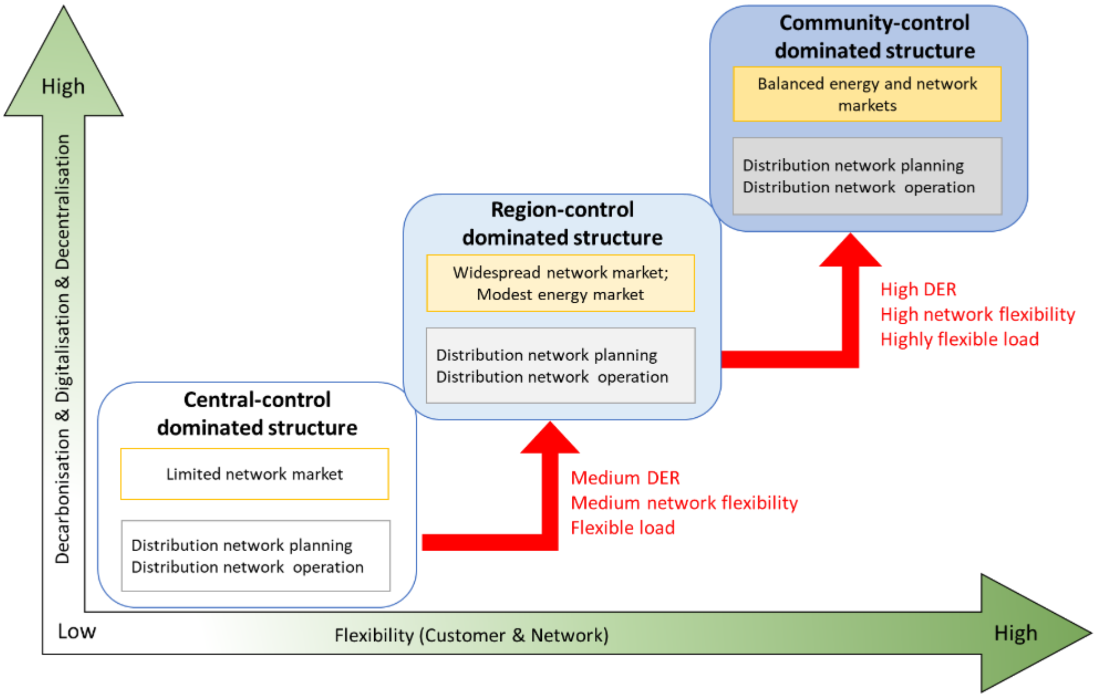


Fig. 4. The transition from Central-control dominated structure to Community-control dominated structure

1.3. Appraisal of possible future industrial structure

The relative merit of these three future industrial structures are assessed by way of a structured approach adapted from the Five Case Model [3] so as to arrive at a best possible decision that will be acceptable to all key stakeholders. This avoids each stakeholder acting independently and arriving at a decision that is best for them, but which could be detrimental to other key stakeholders. By providing a common approach and a common set of goals for all key stakeholders, it should be possible to arrive at a best possible structure that will deliver an optimal position for all key stakeholders, and thus substantially reduce the time taken to reach a consensus across the industry.

The work commissioned by Open Networks [4] is largely focused on the transitional changes and their impact on a DSO without systematically considering the consequences for other key stakeholders. It therefore displays an inherent weakness by failing to align the interests of multiple parties. This work extends the impact assessment of a transitional change to four further key stakeholders of the distribution system. It thus ensures a structure change that will be beneficial to all, including the DSO, distributed generation (DG), customers that are both active and passive, and in accordance with the public policies of government.

Adding key stakeholders to the assessment provides a holistic understanding for the industry and its regulation of moving to a different industrial structure. The impact on each key stakeholder and the overall system will assist the industry and the regulator to identify the most appropriate industrial structure that will deliver the best overall outcome. The initial impact assessment suggests that there is no unique structure that is able to benefit all simultaneously. Instead each of the structures considered will be preferable to a party depending on the future energy landscape that emerges.

2. Introduction

2.1. Background

“Industrial Structure” refers to the organisation and interactions of the component parts and participants of the electricity supply system [5, 6]. The industrial structure should reflect the increasing and changing needs of all the participants. Historically electricity has been generated by large, centralised power stations and then transmitted and distributed via the transmission and distribution networks to consumers. Generation and consumption are broadly matched in advance by way of centrally administered trading arrangements, and then fine-tuned in real time by the intervention of the System Operator, and automatically by equipment fitted by producers as a requirement in the Grid Code.

The decarbonisation agenda promoted by government calls for an increasing penetration of low carbon technologies (including DG) in homes and businesses, leading to a growing Distributed Energy Resources (DERs) at the periphery of the distribution system. A smart and flexible energy system facilitated by a DSO could transform these DERs into highly valuable assets that would both improve the utilisations of distributed energy production and the distribution networks. Ultimately this could enhance the operational efficiency of the local energy system. However, this would require a fundamental change to the “Industrial Structure” in order to deliver value to key stakeholders.

The distribution system is changing as the result of five drivers:

1) Decarbonisation [7, 8]: The UK government has set a decarbonisation target to increase distribution energy resources (DERs), such as distributed renewable generation and storage. According to National Grid’s “gone green” scenarios, intermittent renewables (including solar energy, wind energy, etc.) will account for 39% of the total electricity generation capacity by 2030 [9, 10].
2) Cost-effectiveness [11]: A large number of advanced devices, e.g. monitoring, communicating and controlling devices, will be needed to ensure the safe operation of an increasingly complex future distribution system. These devices are costly and require regular maintenance. It is important for the economic evolution of the system to minimise these costs for customers.
3) Security: A high level of DER penetration will result in voltage and/or thermal violations of the distribution network [12]. It will also increase the uncertainties and the associated difficulties for a DSO in planning the network.
4) Consumers changing to prosumers: A consequence of the DER development is that traditionally passive consumers will become increasingly active prosumers [13-19] who may wish to sell electricity generated by their own DERs. These prosumers will be inherently more flexible than consumers and will be willing to respond to price signals given by the DSO [20].
5) New business models: New technologies developed for a future distribution system enable companies to adopt new business models [17, 20]. With a wide range of advanced technologies available, passive customers will become increasingly active (either as consumers or prosumers) and the adoption of new business models will lead the distribution system to experience a substantial increase in its complexity.

2.2. The structure of this report

The objectives of this report are:

- To determine possible industrial structures for the future distribution system under different energy landscapes and the prospective roles of the DSO;
- To assess the relative merits of the proposed industrial structures. In particular it will analyse the impact of the industrial structures on key stakeholders and seek to identify structures that have the most merit across all stakeholders.

Chapter 3 reviews the literature concerning industrial structures from an academic state of the art viewpoint, and the current developments within the industry.

Chapter 4 develops three possible industrial structures for the future distribution system and describes three different scenarios for future energy landscapes.

Chapter 5 develops a systematic approach adapted from the Five Case Model for assessing the relative merits of each structure along four dimensions.

Chapter 6 summarises the key learnings and concludes the report.

3. Literature review of industrial structure

This chapter reviews the industrial structures from the perspectives of an academic-state-of-the-art, and from current thinking within the industry. Whilst the academic papers provide a higher level interaction between big and small players, the industry thinking outlines different models that can coordinate DERs at different levels, different scales and by different parties.

3.1. FPSA, SGAM and ON structural designs

3.1.1. Future Power System Architecture [5, 6]

The FPSA model proposes a vision for 2030 when the power system will be a sophisticated and intelligent infrastructure that allows a diverse range of novel technologies, active consumers and new business models to flourish. In this model the future power system is characterised by greater autonomy, efficient asset utilisation, and a resilient and secure power supply. This emerging complexity requires system stewardship that takes an entirely new, whole-system perspective in order to ensure effective and secure integration of multiple parties. The project has identified 35 new or significantly modified functions required to meet the 2030 power system objectives. These functions are grouped by seven major drivers. Each function corresponds to a specific business timeframe and is assessed in terms of both the prerequisites for implementation and the tipping point.

3.1.2. Smart Grid Architecture Model and the Open Networks project

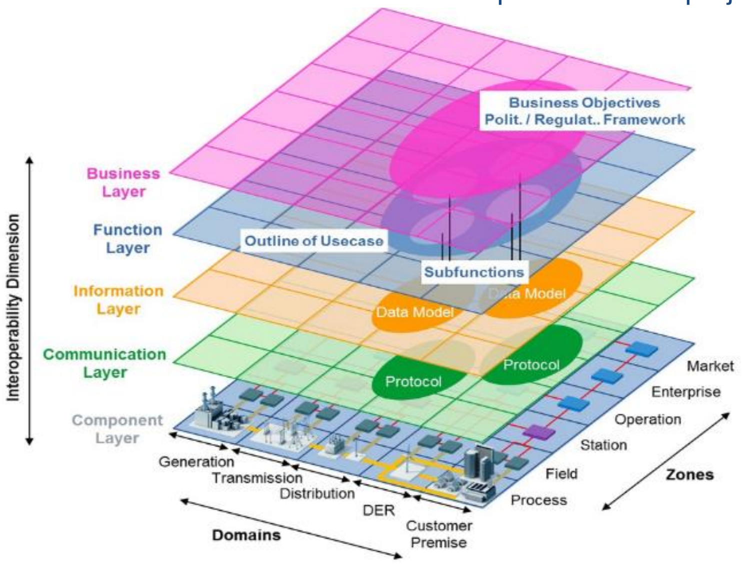


Fig. 5. Smart Grid Architecture Model [21]

The SGAM proposes a framework for the smart grid system. The above illustration provides a general idea of the industrial structure suggested (Fig. 5) [21]. It introduces a structure with five layers together with the interactions amongst them. The five layers (from top to bottom) are the business, function, information, communication and component layers. Each layer includes both domains and zones. Domains are the components of a complete electrical conversion chain and zones represent the different levels of power system management [21]. The SGAM approach has been adopted by the majority of the European leading projects, including those in the UK. [22-31].

The ON project follows the SGAM idea and proposes five worlds for the future power market that coordinate DERs at different levels and scales [32].

1) World A: DSO Coordinates – Here the DSO takes a central role as the neutral market facilitator for all DERs. The DSO also provides services on a locational basis to the Electricity System Operator (ESO).
2) World B: Coordinated DSO-ESO Procurement and Dispatch – In this world DSO and ESO work together to manage efficiently networks through coordinated procurement and control of flexibility resources
3) World C: Price-Driven Flexibility – Here changes are driven by Ofgem's reform of electricity network access and forward-looking charges. These changes lead to improved access arrangements and forward-looking price signals for customers.
4) World D: ESO Coordinates – In this world the ESO takes a central role in the procurement and control of flexibility services. The ESO acts as the neutral market facilitator for DERs, whilst the DSOs inform the ESO of their requirements
5) World E: Flexibility Coordinators – Here a national (or potentially regional) third party acts as the neutral market facilitator for DERs providing efficient services to the ESO and/or DSO as required.

3.2. Structures for the electricity market

Fig. 6 indicates four structures for the future electricity market design [17]. The dots are prosumer agents; dots with circles mean that the prosumers are grouped together to form a virtual power plant. The lines represent the transactions of prosumer services between agents.

In the first P2P model, all prosumers trade with each other directly and freely. This model is decentralised and inspired by the sharing economy concept [17]. The P2P market will include both long-term and short-term contracts based on the prosumer's requirements. Because of the complexity of the structure, specific regulations will be needed to ensure a safe and fair market environment.

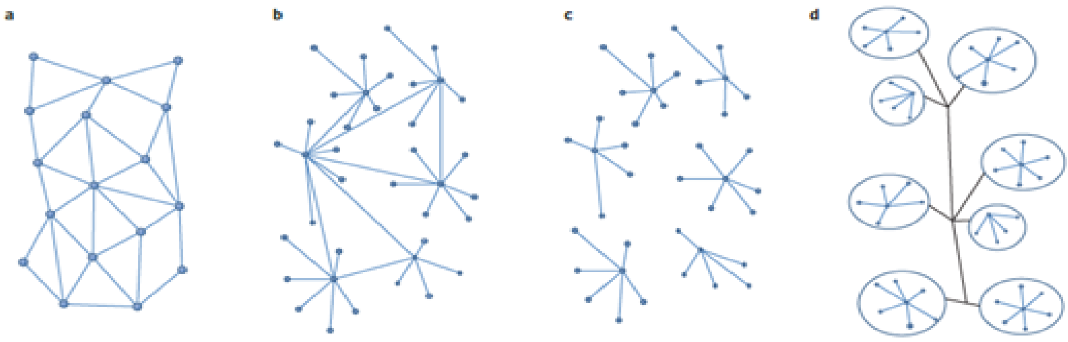


Fig. 6. a) Peer-to-peer model; b) Prosumer-to-interconnected MGs model; c) Prosumer-to-islanded MGs model; d) Organized prosumer group model taken from [17]

In Figure 6b), the prosumer-to-interconnected micro-grids model allows all prosumers to trade within a micro-grid that is connected to the main grid. Because of the connection to the main grid, prosumers are able to generate electricity as much as possible without any limitation. It therefore assumes that any excess energy can be absorbed by the main grid.

Similarly, the prosumer-to-islanded micro-grids model (Figure 6c) also allows prosumers to trade energy within the micro-grids. However, these micro-grids are isolated from each other, and excess energy can only be stored in local energy storage [17].

The organized prosumer group model introduces the idea of a virtual power plant, which would consist of several groups of prosumers. Each group is managed and operated by an aggregator and all groups are connected together to form a virtual power plant. This model provides opportunities for local energy management for local balancing, which is suitable for smart cities, smart buildings and smart homes [17].

Although the four models were originally created to focus on the electricity market, the idea can be extended to apply to the future distribution system. In the next section therefore we discuss the application of these four models to the industrial structure.

4. Options for future industrial structure

4.1. Future industrial structure design [33]

The distribution system is characterised by increasing decarbonisation, digitalisation and decentralisation. An increase in its complexity will pose a major challenge to its safe and efficient operation. To ensure the future distribution system delivers efficiency, security and can be operated sustainably [34], new industrial structures will be needed to keep up with the technological developments of energy customers, and the distribution system itself. In this section, we advance three possible conceptual structures for the future distribution system. We entitle these structures central-control dominated, regional-control dominated and community-control dominated. This is an initial stage in the conceptual design of these structures. We therefore aim to comment on emerging trends rather than detail the specific interactions and operations for each potential structure. The structures will be further improved and developed throughout the course of the project.

4.1.1. Central-control dominated structure

In the Central-control dominated structure, where generation demand and storage are physically remote from each other, load is mainly supplied by centralised generation by way of the transmission grid and local distribution networks. Approximately 80% of the demand is supplied by centralised generation with the remaining 20% supplied by local distributed generation. The DSO assumes the roles of planning the distribution network, operating both the distribution networks and the limited network market, and providing the coordination between the networks and the market. The scale of central-control dominated structure is similar to current DNO's licence areas.

As shown in Fig. 7, all customers (that is both consumers and prosumers) are connected to the main power grid, and all power transfers occur through the main grid. However, consumers are not restricted to buying energy from traditional retailers but can choose independent prosumers who can sell discounted clean energy. Local energy has a cheaper price, because if it is consumed locally, the cost of integrating distributed generation into the grid is reduced or removed. This cost can be very significant, spanning from distribution infrastructure upgrading and distribution system operation to transmission balancing, operating and investment cost. This price differential does not represent these network users avoiding network charges or taxes/levies at the expense of other customers.

Therefore, the central-control dominated structure supports the co-existence of the traditional retail market supplied from the wholesale market, and a new P2P energy market. Customers are free to participate in, or opt-out of any market.

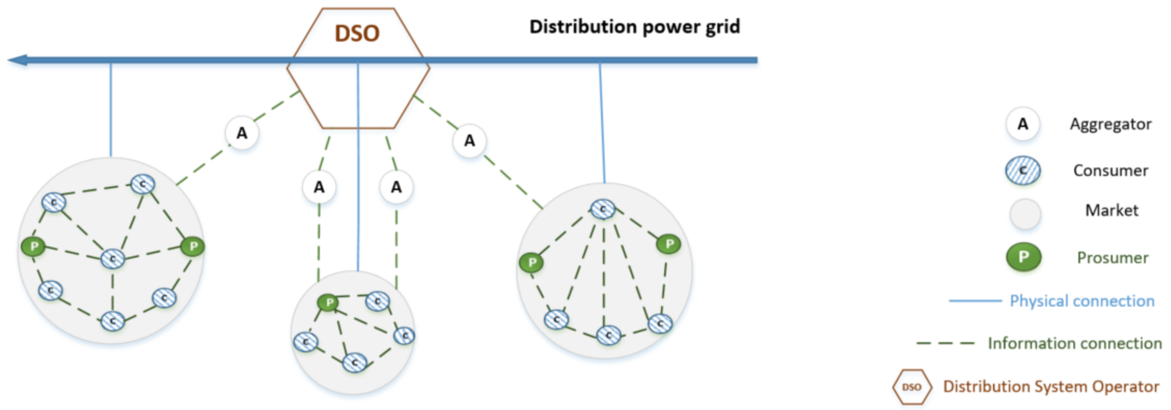


Fig. 7. Central-control dominated structure

Customers are grouped and organized by an aggregator into a single entity, which participate in both the local electricity markets and in the centralised wholesale market. It should be noted that aggregators are different from traditional retailers. They do not sell energy, but only provide communication services between customers and the DSO in order to assist the DSO to manage and operate the network [10]. Two possible forms of aggregators could be those with a geographically assigned franchise (monopoly), and those that compete with other aggregators in an area [2].

The DSO receives generation and demand information collected by the aggregators. The DSO then provides price signals that provide an incentive for customers to change their behaviour, and thus the pattern of their consumption or production. The net demand and system flow changes would help relieve network stress and maintain the secure operation of the distribution network. The active load changes will also contribute to local energy balancing that will reduce energy losses in transmission and distribution, and the need for ancillary services to stabilise the system.

The advantages of the central-control dominated structure are that:

- it requires minimal changes to the existing distribution network,
- it maintains the security of supply provided the centralised generation remains reliable.

The drawbacks of this model are that there could be:

- higher energy losses and maintenance costs for the whole supply system compared with other structures;
- the introduction of the aggregator as a new player into the distribution system would inevitably bring additional costs and privacy concerns for prosumers.

4.1.2. Regional-control dominated structure

Micro-grids are localised systems with grouped DERs and flexible loads. They can be connected to the grid or operated in an islanded mode [35]. Micro-grids improve the overall system efficiency, stability and reliability by utilising local generation to meet local demand [35]. The Regional-control dominated structure is a hybrid structure where demand is supplied by both centralised and local generation via the transmission grid and local distribution networks. Approximately 50% of the demand is supplied by centralised generation with the other 50% being supplied from distributed generation connected to micro-grids through the local energy market. The scale of regional-control dominated structure is potentially one of the DNO's licence areas.

In this structure the DSO assumes the roles of planning and operating the distribution networks as well as operating the flexibility market. It is illustrated in Fig. 8 where all customers are connected to a micro-grid. There can be two modes of operating the micro-grid. In the first mode micro-grids are connected to and exchange energy with the central grid. In the second mode micro-grids are operated as islands for the majority of the time and only connect to the main grid when a contingency arises. The first mode contributes to the optimal operation of the whole system but requires active control of the switched interface with the main grid. The second mode minimises the connection cost to the main power grid, but compromises the security of supply in the micro-grid.

The DSO plans and operates the network by controlling the switches between micro-grids and the main power grid. The connection of micro-grids allows optimal energy trading for both the local energy market and the wider network market. The DSO can also match demand with generation through wider network and local energy markets.

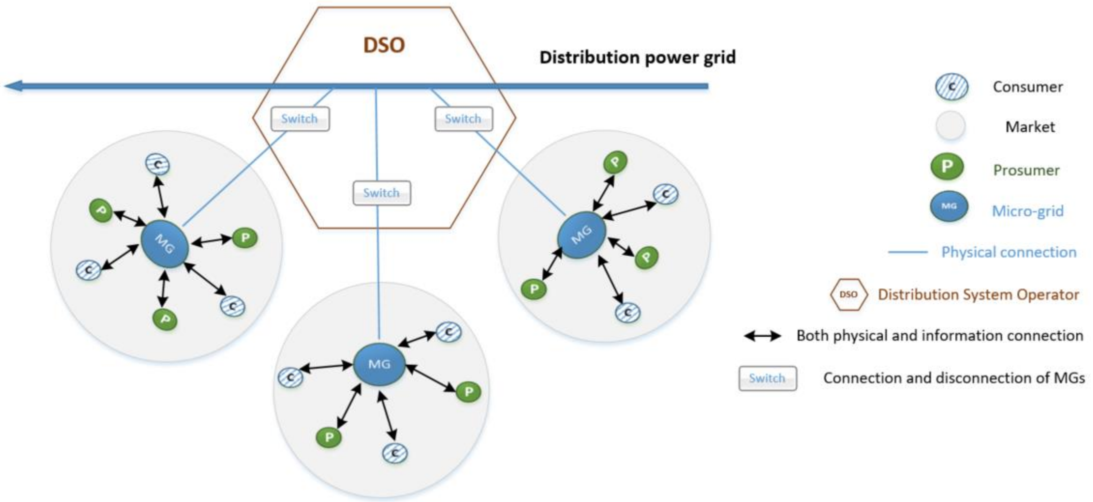


Fig. 8. Regional-control dominated structure

The regional-control dominated structure has the advantage that

- It is characterised by small-scale networks where significant problems can be addressed locally. Both the time and cost of solutions are minimised in providing customers with a safe, stable and cost-effective power supply.

It has the drawbacks of

- Reconfiguration of the current networks to suit the regional-control dominated structure would be costly and time-consuming;

- Switching between the main grid and micro-grids would need to be performed smoothly and would require the use of advanced and sophisticated technologies.

4.1.3. Community-control dominated structure

The community-control dominated structure is a distributed structure where generation, demand and storage are in close proximity. Demand is mainly supplied by local generation via local distribution networks. Approximately 80% of the demand is supplied by local generation through the local energy market whilst the remainder is supplied from centralised generation. The DSO roles include planning and operating the distribution networks, operating a balanced network market and energy market, and managing their coordination. The scale of community-control dominated structure varies from street levels to city levels.

Prosumers are the main players in the community-control dominated structure. Prosumers communicate and trade with each other directly through their local energy market.

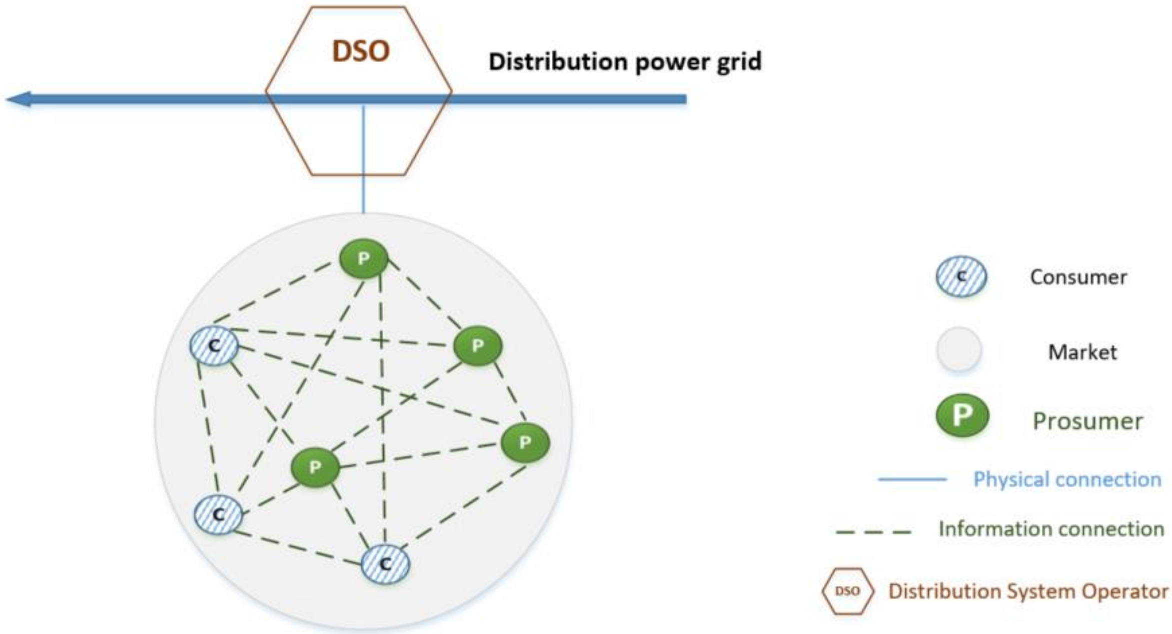


Fig. 9. Community-control dominated structure

The community-control dominated structure has the advantage that:

- The energy loss in transmission and distribution networks is minimised because local generation can supply local demand.

Its disadvantages are that:

- It is both time consuming and costly to build the community-control dominated structure which would require a large amount of ICT devices. Consequently, the cost allocation will be controversial because it will be unclear which party is responsible for these costs.
- It risks stranding network assets that previously had a significant value.

- It requires each customer, or group of customers, to be equipped with energy storage that can maintain a continuous power supply in the event of the absence of centralised generation.

4.2. High-level transition pathways

This sub-section describes possible transition pathways to a low carbon energy future that has high flexibility. The pathways depend on the degree of technological development, customer flexibility and decentralisation of the system as it evolves. Figure 10 is a simple illustration to show the potential impacts on the supply chain that result from a change in technology and market development. Technological development will impact how energy is produced, transmitted and consumed. Market development will influence how different parts of the supply chain interact. Depending on the pace and scale of the development, the combined impacts from markets and technologies would alter the future energy landscape, energy systems, and DSOs.

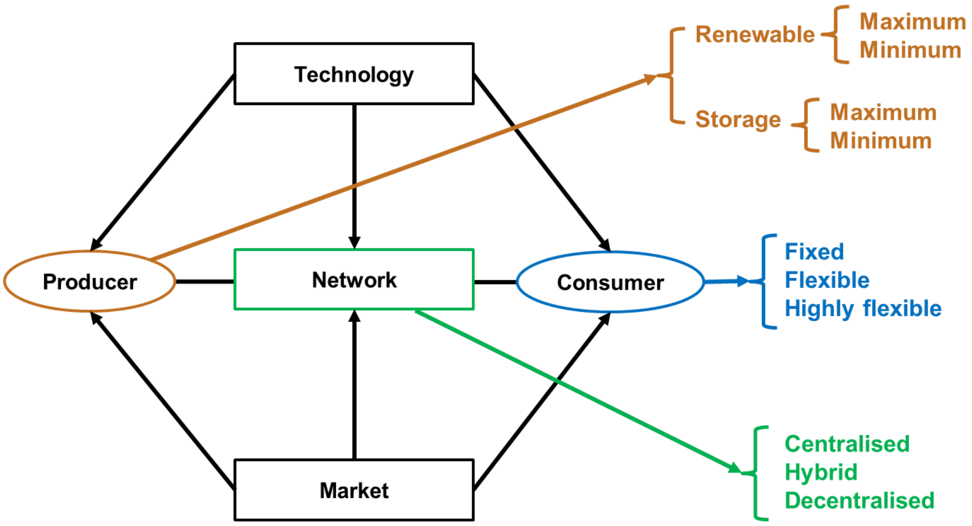


Fig. 10. The transition pathways

Based on our current understanding we have advanced high-level transition pathways for the evolution of the distribution system in three stages. These reflect the forecast technological, decarbonisation and digitalisation of the system.

Stage 1: This is the closest to the current energy system. The current system has a relatively low quantity of DERs and customers are mainly passive; as a result customer flexibility is low. The digitalisation across the distribution system is also relatively low, that is there are few ICT devices installed. The central-control dominated structure is suitable for this energy landscape. DSOs may plan the distribution system, and operate their networks and network services market; although there is only a limited local network services market in this centralised system[36].

Stage 2: In this stage penetration of DERs has grown to a higher level and more passive customers are becoming active. Now customer flexibility will be higher than that in Stage 1. The digitalisation is higher compared to the centralised system in that more ICT devices are installed. The regional-control dominated structure is suitable for this energy landscape. It is expected that network markets will emerge to support DER integration although the scope for local energy markets will still be very limited. DSOs may concentrate on their distribution operational businesses, operate the distribution network, and manage the network services market [36].

Stage 3: With a very high penetration level of DERs, active customers and distributed generation will assume a more prominent role. Customer flexibility will therefore be higher than that of Stages 1 and 2. Digitalisation is now very high in that there are a large number of ICT devices installed. The Community-control dominated structure is suitable for this energy landscape. The balancing energy market and network markets will be operated to optimise a large volume of distributed energy resources for this decentralised system. DSOs will work as coordinators, or neutral market facilitators, who administer the exchange of market information and administer market participation by participants from a technical perspective.

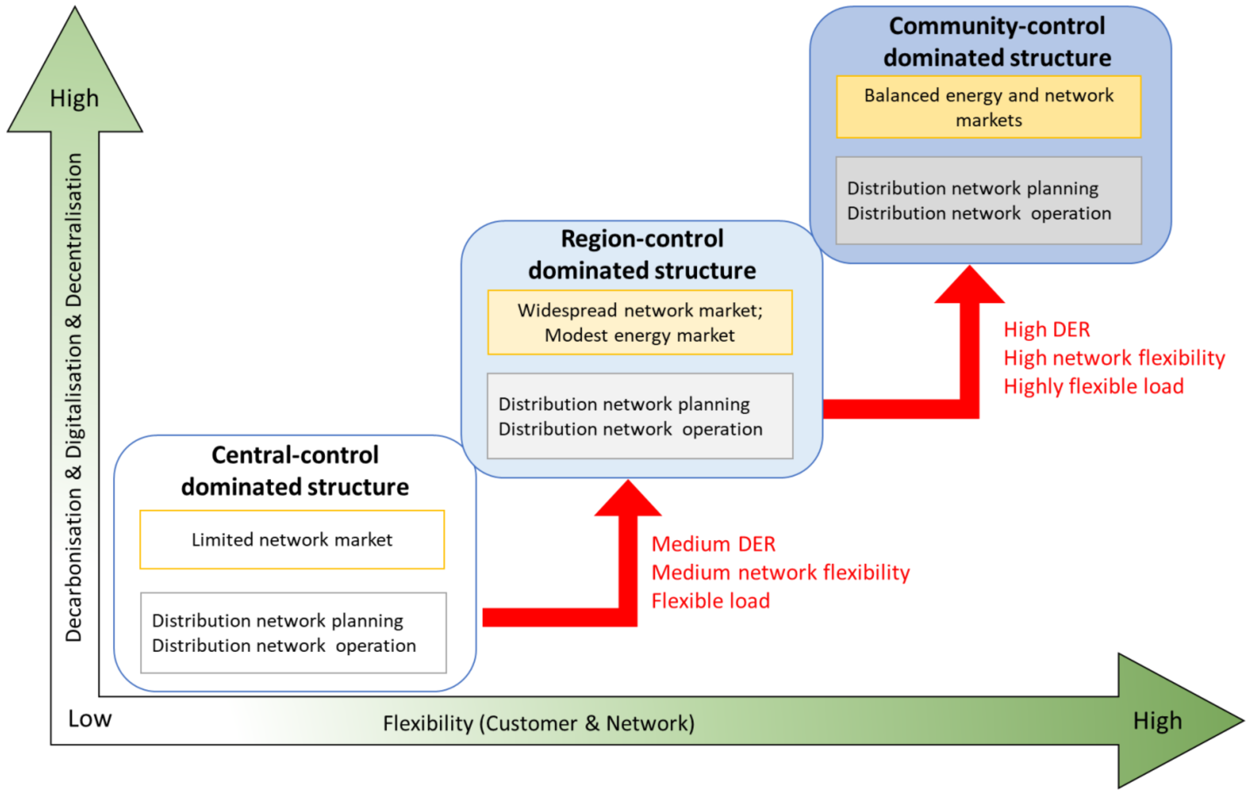


Fig. 11. The transition pathway for increasing decarbonisation, digitalisation and decentralisation

5. Appraisal of possible future industrial structure

An impact assessment of a future industrial structure is a highly complicated matter since not only does the energy system becomes more complex and uncertain but critically there are an increasing number of key stakeholders, each with its own objectives. An appraisal of possible future industrial structures would have to consider the changes to each of the key stakeholders and the whole system, and the alignment of interests across parties. This is so that structural changes that benefits some stakeholders receive, albeit to the detriment of others, can be identified. This section reviews the current practice for impact assessment. It proposes a systematic approach (adapted from the Five Case Model) for appraising future industrial structures that will enable the most beneficial situation for all key stakeholders to be identified.

5.1. Review of current methods to impact assessment

5.1.1. The assessment criteria for the electricity system operator framework [37]

Ofgem has published its assessment criteria for assessing the price control framework options that might be employed by the Electricity System Operator (ESO). The price control framework mainly considers the possible outcomes of evolving to an ESO. This package of options was assessed by Reckon using the assessment criteria as shown in Table I. The proposed approach for addressing the multiple assessment requirements in a coherent manner was to develop criteria within a hierarchical (or tiered) structure. This allows a relatively short set of high-level criteria/factors to be developed and presented in relatively general terms, which are then relevant across the broad range of options and questions to be assessed.

The rest of the assessment framework can then focus on identifying the different dimensions of those high-level factors that it may be relevant to consider (depending on the particular questions being addressed), and identifying some of the more specific factors and questions that are likely to be important in some types of assessment. Adopting this structure allows the high-level criteria to provide a range of practical assessment questions, without these resulting in what might otherwise be a relatively lengthy and complex list.

Table I sets out this framework of criteria. Reckon's approach in terms of the high-level (first tier) criteria is to include one broadly defined factor that will indicate likely success in the achievement of good outcomes by the ESO. The remaining high-level factors are then concerned with the "how?" questions, and in particular with whether or not an approach has characteristics that might make it more or less desirable for reasons other than those concerned directly with the achievement of good outcomes. Other first-tier factors concern implementation issues (such as implementation costs and ongoing regulatory costs and burdens), transparency and clarity, and the ability to be flexible and adaptable to future changes.

The second tier addresses dimensions that relate to each of the first tier criteria. Judging whether an approach would be expected to perform well in terms of achieving good outcomes raises a broad set of sub-questions, and we have proposed various dimensions that may be relevant. Presenting the assessment criteria in this fashion will ensure that the full range of relevant potential effects on customer outcomes is considered, without requiring a long and cumbersome list of high-level criteria.

In practice, considering a given dimension is likely to raise subsequent and more detailed questions or issues. These can be treated as forming a third level of assessment which would concern factors, features and risks of alternative options that affect the performance of these options against the first tier and second tier criteria. For example, in relation to the first tier criteria of achieving good outcomes from the ESO, more detailed questions relevant to supporting analysis could include the direct financial exposure of the ESO to the costs it incurs, competitive pressures and processes acting on the ESO, the robustness of its approach to uncertain future developments (e.g. ISO), and the risks of harm from regulatory micro-management.

This tier of supporting analysis is also relevant where a range of contextual factors can be identified and considered. For example the extent to which a given option can be expected to perform well in terms of whole system based responses may depend in part on the availability and degree of engagement of a diverse range of "voices" from those in a position to challenge current modes of operation in constructive and effective ways. The degree of engagement of such voices is likely to be influenced by the extent to which they have a stake in any system improvement. This in turn could affect both the charging arrangements and competitive conditions that influence the ability and incentives residing on different parties for them to promote a different mode of service provision.

Table I. The impact assessment criteria for ESO framework [37]

First tier (high-level) criteria	Second tier criteria – subsidiary dimensions and considerations
1. Capability to deliver good outcomes	a) Contribution to whole-system efficiency, coordination and transformation b) ESO service quality aligned with what customers want c) Aggregate ESO charges across GB customers to remunerate ESO d) Fair and cost-reflective ESO charges to customers e) Enabling the ESO to finance its activities
2. Implementation complexity and risk	a) Extent of move away from current regulatory arrangements b) Implementation challenges arising from complexity c) Uncertainty as to whether implementation is feasible at all
3. Regulatory effort and burden	a) Regulatory resource requirements for implementation b) Ongoing regulatory resource requirements c) Regulatory burden on ESO and other stakeholders
4. Transparency	a) Implications for engagement b) Implications for legitimacy
5. Adaptability to future changes	a) Impediments to future regulatory developments? b) How option-specific are implementation costs? c) Adaptability to technological change d) Adaptability to market developments

5.1.2. The Network Innovation Allowance of National Grid [38-40]

The National Grid Gas Transmission (NGGT) is transforming its business by delivering significant results from innovations in five strategic areas. These areas are those of safety, sustainability, financial performance, customer and stakeholder satisfaction, and service reliability and availability. Their measure of success from any innovation is assessed by analysing the change in performance criteria resulting from the change. This approach could also be applied to future structural changes in the distribution network.

1) **Safety:** Keeping people safe is the key priority. Innovation is driving greater safety across NGGT who explore new working practices by developing new tools, techniques and processes. There is also a focus on reducing the risk of damage by third parties working on or near their pipelines. This ensures the safest network for the workforce, customers and the general public.
2) **Sustainability:** Innovation has played a major role in NGGT's commitment to reducing emissions. NGGT is developing new technologies to reduce emissions both from vented gas and from its compressor fleet. Ultimately, this will reduce the impact NGGT's operations have on the environment.
3) **Strategic:** Cutting-edge technologies unlock the potential for smarter investment decisions on NGGT's network. NGGT is exploring these innovative techniques to deliver significant efficiencies in operations and exploit untapped sources of data.
4) **Customer and commercial:** NGGT aim to satisfy the needs of customers while preparing their network for the future demands from new sources of gas, and the impact it could have on the National Transmission System. This requires NGGT to challenge existing practices, and develop new methodologies and possible efficiencies in areas such as network constraint modelling.
5) **Reliability and operability:** Innovation is playing a vital role in identifying new opportunities to manage intelligently the network. A major focus has been on the inspection of its pipelines using more accurate and efficient methods. Techniques to optimise repairs and provide the best method of component recognition will help to build a more reliable network for the future.

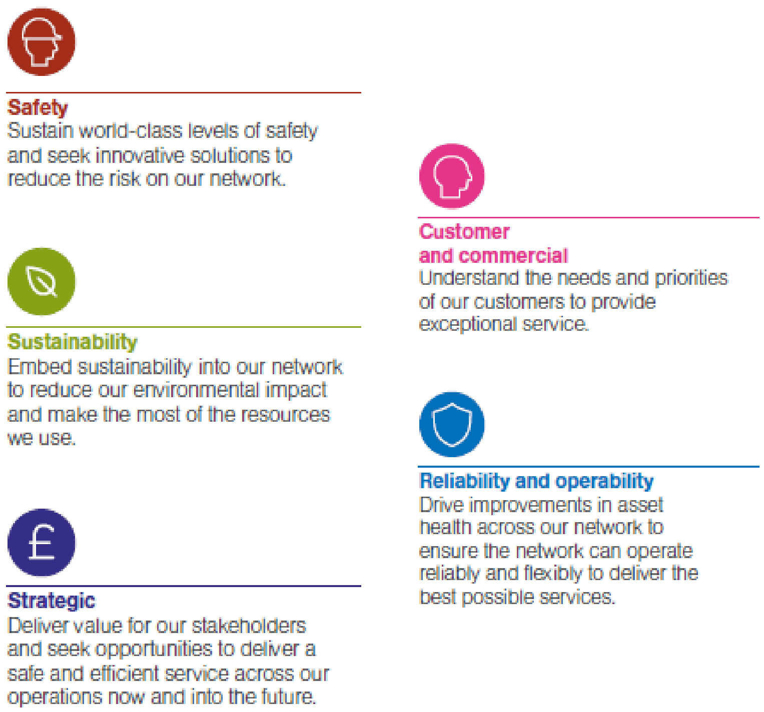


Fig. 12. Five key themes of NGGT's innovation portfolio

5.1.3. The Five Case Model [3, 41]

The Five Case Model [3] provides a discipline and structure designed to arrive at the best possible decision. The model was first developed around the early 2000s following poor quality and inconsistently structured business cases for IT developments that went to Treasury for approval and funding [3]. It has evolved over time and since the mid 2000s has been widely adopted across the public sector and the majority of government departments as the standard for making a business case [3].

The key feature of this model is the provision of a set of common goals and objectives for the purpose of assessing the impact of a change to all stakeholders. The five cases in the model identify common objectives across five dimensions so as to assess the impact on key stakeholders, as shown in Table II. These cases are strategic, economic, commercial, financial and management [41]. By providing a common approach and a common set of goals for all key stakeholders, the approach aims to arrive at a best possible structure that will deliver an optimal outcome across all key stakeholders. In electricity supply it would have the added benefit that it should then substantially reduce the time it would take to obtain a consensus across the industry.

1) **Strategic dimension**

   The strategic dimension sets out the rationale and objectives of the proposal (as outlined in Table II). It starts by describing the current arrangements, and how these might continue without any changes. This is known as Business As Usual (BAU). BAU provides the counterfactual against which alternative options are compared. The strategic dimension should also identify gaps in the evidence base. Bridging these gaps is the key rationale for intervention. The rationale and objectives should ideally be described in terms of outcomes, which will often be the changes experienced by people receiving a service; for example the improvements in health resulting from a change in the output of health services. The objectives should not bias the choice of options towards a particular pre-determined solution. The strategic dimension ensures the strategic fit of new proposals with the existing policies and wider public sector objectives. Constraints and dependencies should be understood, documented and explicitly taken into account.

2) Economic dimension

The economic dimension is the analytical heart of a business case where a detailed appraisal takes place. It considers the value of different options for the UK and where appropriate, the impact on different groups of people or parts of the UK. The measure of value to the UK as a whole is referred to here as the social value. Options appraisal in the economic dimension leads to the identification of a preferred option that is an optimum balance between costs, benefits and risks to society and the public sector, allowing for any unquantifiable factors which could affect a decision.

3) Commercial dimension

The commercial dimension covers procurement and commercial arrangements relating to the services and assets that would be required to implement a proposal. The procurement specification comes from the strategic and economic dimensions. The commercial dimension feeds information on costs, risk management, and timing back into the economic and financial dimensions as the procurement process proceeds. This is part of the iterative process necessary to develop an initial proposal into a mature business case.

4) Financial dimension

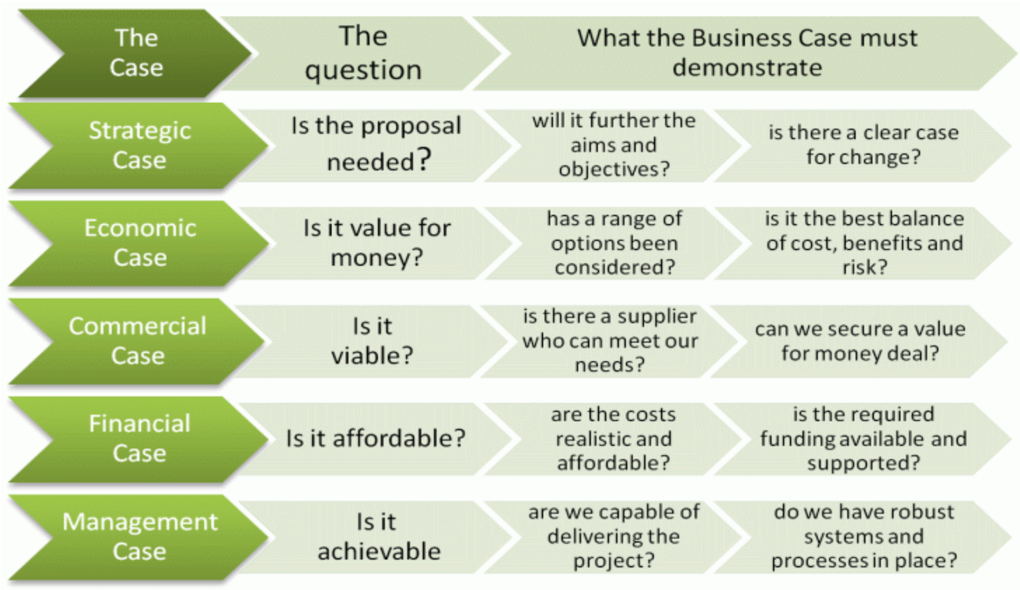
The financial dimension is concerned with the net cost to the public sector of the adoption of any proposal, taking into account all of the financial costs and benefits that would follow. It assesses affordability, whereas the economic dimension assesses whether the proposal delivers the best social value. The financial dimension is exclusively concerned with the financial impact on the public sector.

5) Management dimension

The management dimension is concerned with planning the practical arrangements for implementation. It demonstrates whether a preferred option can be delivered successfully. It includes the provision and management of the resources required for delivery of the proposal, and arrangements for managing budgets. It identifies the organisation responsible for implementation, when agreed milestones will be achieved, and when the proposal will be completed. The management dimension should also include:

- the risk register and plans for risk management;
- the benefit schedule, delivery monitoring (including factors to be monitored) and management arrangements;
- monitoring and evaluation arrangements during and after implementation, and any collection of data prior to implementation, as well as the provision of resources and who will be responsible.

Table II. The five case model



5.1.4. The impact assessment criteria of the Open Networks project [4]

An impact assessment method, adopting the Five Case Model, was proposed for the ON project [4]. It has 6 criteria and 29 sub-criteria in accordance with the cases in Table III (below). The ON's approach was to identify the key drivers of performance against each criterion and assess each Future World against those performance drivers. The qualitative assessment also looked at the risks, conflicts and potential for unintended consequences in the DSO transition, which could have a detrimental impact on consumers, and then sought to identify potential mitigations.

The assessment criterion for the ON project has the advantage of considering the enhancements to the customer experience for a future customer-led power system. The work commissioned by ON [4] is largely focused on the transitional changes and impacts on the DSO without considering its alignment to other key stakeholders when facing structural change. Our work thus extends the impact assessment from DSO to four additional key stakeholders in the distribution system. Overall it considers the impact on the DSO, DG, active customers, passive customers, and government.

Table III. The impact assessment criteria of ON [4]

The five cases	Criterion	Sub-criterion
Strategic case	Enhanced Customer experience	• Choice • Fairness • Affordability • Confidence and trust • Consumer benefits from Markets
	Greater environmental sustainability	• Facilitates greater energy efficiency • Facilitates decarbonisation of electricity generation • Facilitates decarbonisation of Heat/transport • More electricity consumed closer to point of generation i.e. lower losses
Economic case	Whole system optimisation	• Supports whole system optimization • Optimises locally • Brings more flexibility into the system • Manages conflicts • Avoids duplication • Exploits synergies
Commercial case	Market/ regulatory viability and available funding	• Market viability • Appropriate regulation:
Financial case		• Compatibility with regulatory funding • Funding available to support market participation
Management case	Industrial structure and organisation	• Levels of rules required • Delivers fair, neutral and transparent markets • Complexity of operating the Future World • Difficulty to implement • Future proof:
	Technical performance	• Degree of safety • Service reliability and availability • Physical cyber and security • Resilience and recovery • Clear dischargeable accountability

5.2. Proposed alternative impact assessment criteria

Building on these methodologies and analysis from the ON project, we propose a structured method for the purpose of arriving at the best possible decision that is acceptable to all key stakeholders. The method adapts the Five Case Model to establish common goals and objectives for key stakeholders across four dimensions [3]. The approach should avoid each stakeholder independently arriving at its own best decision, and which would then take time for these to be reconciled.

5.2.1. The four dimensions

The Five Case Model has been adapted to produce a common set of goals and objectives across four dimensions for assessing the impact on distribution system key stakeholders when moving to a different industrial structure. In this revision the financial and economic cases are merged to produce a single economic dimension in order to reduce the analysis. The four dimensions thus formed are shown in

Table **IV**. In this initial analyses, to demonstrate the concept, only 5 key stakeholders at the distribution system are considered.

Table IV. Our alternative set of Impact assessment criteria

Four dimensions / Key stakeholders		Strategic dimension	Economic dimension	Commercial dimension	Management dimension
		Sustainability and customer satisfaction	Cost-effectiveness	Market viability	Feasibility
Government					
DG					
DNO/DSO					
Customer	Passive customer				
	Active customer				

1) The strategic dimension – sustainability and customer satisfaction:

In accordance with the government's public policy objective for a sustainable future [34], a future distribution system should:

i) Facilitate de-carbonization of electricity generation, heat and transport

ii) Use flexible resources and increase energy efficiency

iii) Satisfy the changing needs of its various customers.

In other words, the future distribution system should facilitate an affordable, reliable, fair and transparent service for all customers.

2) The economic dimension – cost-effectiveness:

The economic dimension reflects the costs and benefits seen by different parties that result from the implementation and operation of changes dictated from the strategic dimension. It is highly likely that any change will benefit some stakeholders but be to the detriment of others. Because of the rapid evolution of the energy landscape, both in the economic behaviour of customers and the penetration of DERs, the distribution system will face significant changes in the future. To ensure a cost-effective system it will be necessary to identify changes that will be to the overall benefit of all stakeholders.

3) The commercial dimension – market viability:

The power market will become an important aspect for the distribution system as passive customers become active customers, and the penetration of DER increases. The future distribution system should be capable of facilitating a neutral, simple, fair and transparent market for all participants. The established power market is essentially a centralised energy market with ancillary services to ensure the quality and security of supplies. However, with the increase in DERs, the prospect of local energy markets has attracted much public interest. The operation and interaction of these markets will be complex and challenging. Ensuring a market environment that is stable and adaptable to future changes in the energy landscape is essential when contemplating future structures for the distribution system.

4) The management dimension – feasibility:

The management dimension addresses the feasibility of implementing a new structure for the distribution system. Adopting new technologies, new markets, new players, and new interactions, and the physical implementation of any new distribution structure is likely to be both complicated and costly. It may also pose significant challenges to the quality and security of supplies. This feasibility analysis will investigate if a change would decrease the complexity of implementation, as well as providing space for new developments, such as new business models and technological improvements.

5.2.2. The key stakeholders

Including key stakeholders in the assessment will assist the industry and its regulator in understanding the positive and negative impacts of a change in the industry structure on each party, and their consequential impact on the overall system. The results of the impact assessment will thus help in identifying the most appropriate structure for delivering optimality for all key stakeholders. In a future distribution system various types of stakeholders will exist. At this initial stage of the analysis we focus only on the distribution network and thus consider only a subset of stakeholders. Other stakeholders, such as suppliers, aggregators, the transmission owner and electricity system operator, can be added at a later stage to build a more complete picture. At this stage these are the key stakeholders we have included:

- Government: The government publishes policy guidelines for developing the energy system, and protects the interests and rights of customers.
- DG: The costs of distributed renewable technologies are decreasing and financial returns from investing in DERs are growing, particularly with emerging new business models and local markets. .
- DNO and future DSO: More local renewable resources, such as DG, electric vehicles (EVs) and energy storage (ES), are connecting to the distribution system. DNOs and future DSOs face the challenge of maintaining system reliability and safety whilst optimising the connected DER resources.
- Customers: Traditionally, the customer has been a passive consumer, only purchasing electricity from retailers, or central generators. With the increasing penetration of DERs more passive customers becomes active local prosumers who can shape the future development of the distribution system.

5.3. Assessment of the possible structures

The focus of this impact assessment has been the relative merit of possible future distribution system structures rather the absolute benefits they can deliver. This is an initial assessment using limited information. As we gather more feedback and inputs from the industry and a wider public the assessment can be improved and updated throughout the course of the project.

To carry out the analysis, a set of assessment criteria are used. These criteria will help industry and policymakers assess the impacts of a structural change on different stakeholders.

1) Strategic dimension:

- What are the required changes for each key stakeholder?
- What are the expected outcomes for each key stakeholder?
- How do these fit with wider government policies and objectives?

2) Economic dimension:

- What is the net value to the key stakeholders from introducing the new industrial structure compared to Business-As-Usual?
- What are the risks and their prospective costs, and how are they best managed?
- Which reflects the optimal net value to the society?

3) Commercial dimension:

- Can a realistic and credible commercial deal be struck?
- Who will manage which risks?

4) Management dimension:

- Are there realistic and robust delivery plans?
- How can the proposal be delivered?

The answers to these questions are the impacts on the key stakeholders that are brought about by a new industrial structure. The impacts vary from one stakeholder to another and can be positive or negative. To illustrate this, we use a red-amber-green (RAG) colour system as follows:

- Red indicates that the stakeholder receives a relatively low benefit from a change and, as a result, they are unwilling to make the change.
- Amber means that the change has a neutral influence on the stakeholder; that is the changes have both advantages and disadvantages at the same time.
- Green means that the stakeholder is willing to change given the benefits identified both currently and in the future.

Table V shows our initial assessment in a heat map format. Table **V** highlights under which dimensions each proposed structure performs best, and which stakeholders benefit most. We do not expect there will a single industrial structure capable of meeting the requirements of all stakeholders since only some stakeholders will be satisfied with the changes in any system structure. Instead, the methodology informs the advantages and disadvantages for each stakeholder under each dimension assessed against each possible structure. This will help the industry to identify the most appropriate structure that will benefit most stakeholders for a given energy landscape. The detailed assessment is included in an Appendix to this paper.

Table V. Impact assessment of the three industrial structures

Four dimensions	Strategic dimension			Economic dimension			Commercial dimension			Management dimension		
Government policies and objectives	• Facilitate de-carbonisation of electricity generation, heat and transport • Facilitate greater emphasis on using flexible resources and increasing energy efficiency • Facilitate affordable, reliable, fair and transparent services for customers			• Maximise benefits and minimise costs on implementation • Maximise benefits and minimise costs on operation • Potential benefits from future changes in energy landscape			• Facilitate neutral, simple, fair and transparent markets • Ensure a cost-effective and stable market environment • Adapt to future changes in energy landscape			• Improve safety and reliability • Decrease complexity on physical network implementation • Future proof: Provide space for new developments and has the ability to meet future requirements		
Assessment criteria	• What are the required changes for each key stakeholder? • What are the expected outcomes for each key stakeholder? • How do these fit with wider government policies and objectives?			• What is the net value to the key stakeholders from introducing the new industrial structure compared to Business-As-Usual? • What are the risks and their costs and how are they best managed? • Which reflects the optimal net value to the society?			• Can a realistic and credible commercial deal be struck? • Who will manage which the risks?			• Are there realistic and robust delivery plans? • How can the proposal be delivered?		
Key stakeholders	Central-control dominated structure	Regional-control dominated structure	Community-control dominated structure	Central-control dominated structure	Regional-control dominated structure	Community-control dominated structure	Central-control dominated structure	Regional-control dominated structure	Community-control dominated structure	Central-control dominated structure	Regional-control dominated structure	Community-control dominated structure
DSO												
Government												
DG												
Active customer												
Passive customer												

6. Key learnings and conclusions

The future distribution system is changing rapidly as a consequence of decarbonization, digitalisation and decentralisation. New industrial structures that keep up with these rapid developments are desirable so as to encourage greater optimisation and control of flexible resources, and enhance the overall optimality for key stakeholders.

The current review of industrial structures indicates two significant limitations when assessing differing future industrial structures:

1) Alignment between different stakeholder objectives from changing roles and functions are not systematically analysed. This has the potential to create structures that would benefit one party to the detriment of another;

2) The focus is largely on the network market or network services, which would severely limit the capability of DER integration to the energy systems. For the distribution system, introducing a local energy market, where active customers can trade energy with each other, could deliver a much higher value for DERs whilst reducing constraints and pressures for the reinforcement of extant networks. An appropriate combination of energy and network markets would assist in facilitating much higher volumes of DER penetration.

Three possible industrial structures are proposed in this report:

- The central-control dominated structure extracts the maximum value from the existing physical network. It has the highest reliability on the security of supply but shows the least flexibility of the three structures. The scale of central-control dominated structure is similar to current DNO's control areas.
- The regional-control dominated structure reconfigures part of the current distribution network to form smaller sized grids. It has the advantage of a high degree of local generation and offers the opportunity for load to balance with generation within the micro-grid. It can also assist in the balancing of the whole system by injecting or receiving energy from the main power grid. However, the cost of reconfiguring the network and its maintenance could be very high. The scale of regional-control dominated structure is potentially one of the DNO's control areas.
- The community-control dominated structure provides the most flexible environment to allow customers to trade on their own terms with minimum major network support. The reliability of the supply would be largely maintained by the community through its inherent high level of flexibility. The scale of community-control dominated structure varies from street levels to city levels.

The relative merits of these three future industrial structures are assessed by a systematic method derived from the Five Case Model. The key attribute of the Five Case Model is to provide a set of common goals and objectives when assessing the impact from moving to a different structure to all stakeholders. This avoids each stakeholder independently arriving at its best decisions, which may prove a detriment to other key stakeholders, and thus takes time to reconcile. By providing a common approach and a common set of goals for all key stakeholders, it should be possible to arrive at a best possible structure that will deliver an optimal position across all key stakeholders, and thus substantially reduce the time needed to reach a consensus across the industry.

The four dimensions of the approach are:

i. A strategic dimension which focuses on environmental sustainability and customer satisfaction;

ii. An economic dimension which analyse the cost-effectiveness of the changes;

iii. A commercial dimension which assesses the market viability of the new structure; and

iv. A management dimension which addresses whether the new structure is feasible to implement for the industry and its customers.

The criteria for each of these four dimensions are used to assess the impact on each of the key stakeholders named of moving to a different industrial structure. In this initial analysis the key stakeholders considered are the government, DG, DNO/DSO, and customers (active and passive). Other key stakeholders, such as retailers and aggregators, will be added in future analyses.

Using the proposed criteria, an impact assessment is carried out for three possible industry structures.

For the central-control dominated structure:

1) Government needs modest development in policies and regulations to support modest DERs penetration and their active management. Major energy production is from large generation and large renewable plant to achieve the low carbon target that would require backbone infrastructure to transmit to the load centre. The ability to adapt to different energy future is limited.
2) DNO/DSO needs relatively higher network investment and very modest changes in commercial arrangements for energy delivery, and for accommodating DERs. Modest network markets alone would deliver sufficient returns to limited DERs where they will support DNO/DSO to centrally manage congestions and balance energy. DNO/DSO's understanding of local intelligence may still be limited, thus cannot make the best use of highly dispersed DERs. The new network capacity is largely delivered by DNO/DSO.
3) DGs have very limited market options, its value is highly dependent on governmental subsidies and on services to the grid. The system value that they can tap is very limited. This limited value will further limit their future growth.
4) Active customer faces very modest returns in providing flexibility services to network. If active customers locate at areas with sufficient network capacity and limited network constraints, there is very value that flexibility can tap in. Again, due to limited market conditions, the future growth of flexibility is constrained.
5) Passive customer is more likely to face relatively high electricity price because of the high cost of integrating large renewables into the system, and the high cost of maintaining the security of supply. The value to move from passive to active customers is limited.

For the regional-control dominated structure:

1) Government needs advanced development in policies and regulations to support modest DERs penetration and their active management. Relatively less subsidies are required for renewable generation to achieve the low carbon target. The ability to adapt to different energy future is enhanced.
2) DNO/DSO needs lower network investment and more changes in commercial arrangements for energy delivery, and for accommodating DERs. Widespread network markets and modest energy market would deliver reasonable returns to increased DERs. DNO/DSO would have better understanding of local intelligence, thus make a better use of highly dispersed DERs. The new network capacity is delivered by both DNO/DSO and DERs.
3) DG has more market options, its value is less dependent on governmental subsidies. There is more system value that they can tap with the more market options. This value will facilitate their future growth.
4) Active customer would generate more returns in providing flexibility services to network and tap into cheap energy. Again, more market opportunities are provided so that their future growth is facilitated.
5) Passive customer is more likely to face lower electricity price because of renewables can integrate to both the grid and local flexibility. The value to move from passive to active customers is increased.

For the community-control dominated structure:

1) Government would need major development in policies and regulations to support very substantial DERs penetration and their active management. Market alone will drive renewable generation growth to achieve the low carbon target. The ability to adapt to different energy future is further enhanced.
2) DNO/DSO would have very limited need for network investment and major changes in commercial arrangements for energy delivery, and for accommodating DERs. Balanced network markets and energy market would deliver huge returns to increased DERs where they will support DNO/DSO to manage congestions and balance energy locally. DNO/DSO would have much better understanding of local intelligence, thus make the best use of highly dispersed DERs. The new network capacity is largely delivered by DERs.
3) DGs would have abundant market opportunities to direct trade their energy with local flexibility to substantially increase its value. This value will further drive their future growth.
4) Active customer would expect high returns in providing flexibility services to network and access cheap local energy. The value would attract more passive customers to become active.
5) Passive customer is more likely to face the lowest electricity price because of a lean central system, where abundant local flexibilities would mitigate both energy imbalancing and network requirements.

The assessment suggests that the central-control dominated structure would perform best for a system with a relatively low penetration of DERs (supplying 20% of demand) and a low level of digitalisation (limited ICT, particularly at HV/LV systems) and decentralisation (only limited network market), where centralised energy provision is still highly competitive. The regional-control dominated structure performs well for a system with modest penetration of DERs (supplying 50% of demand), and a modest level of digitalisation (modest ICT, high visibility of systems) and decentralisation (widespread of network markets and limited energy market). The community-control dominated structure performs best for a system with very high penetration of DERs (supplying 80% of demand), and a very high level of digitalisation (high level of visibility of the entire distribution system), and decentralisation (widespread of energy and network markets). The centralised supply only offers limited supply and acts as a back-up system.

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8. Appendix

8.1. Appendix-A Strategic dimension

Four dimensions	Strategic dimension		
Government policies and objectives	• Facilitate de-carbonisation of electricity generation, heat and transport • Facilitate greater emphasis on using flexible resources and increasing energy efficiency • Facilitate affordable, reliable, fair and transparent services for customers		
Assessment criteria	a) What are the required changes for each key stakeholder? b) What are the expected outcomes for each key stakeholder? c) How do these fit with wider government policies and objectives?		
Key stakeholders	Central-control dominated structure	Regional-control dominated structure	Community-control dominated structure
DNO/DSO	*a) 1. Investment planning:* · Relatively high network investment for adopting and accommodating DERs. · Very modest changes required in new commercial arrangements on connection and UoS charges to reflect the changing characteristics of network operation and customers behaviours. *a) 2. Network operation:* · Significant enhanced operation and management required to manage large penetration of DERs, limited understanding of local DER characteristics.	*a) 1. Investment planning:* · Relatively low network investment for adopting and accommodating DER. · More new commercial changes required on connection and UoS charges to reflect the changing characteristics of network operation and customer behaviours. *a) 2. Network operation:* · Enhanced operation and management are required to manage large penetration of DERs, the hybrid system has relative more understanding of local DER characteristics.	*a) 1. Investment planning:* · Lowest network investment for adopting DER. · More new commercial changes required on connection and UoS charges to reflect the changing characteristics of network operation and customer behaviours. *a) 2. Network operation:* · Very modest efforts on operation and management are required to manage large penetration of DERs, the decentralised system has the best understanding of local DER characteristics.

	a) 3. Network market operation:	*a) 3. Network market operation:*	*a) 3. Network market operation:*
	· Modest network markets to mobilise DERs to support DSO to centrally manage congestions and constraints.	**· Relatively larger scale of network markets to mobilise DERs to support DSO to manage congestions and constraints both centrally and locally.**	**· Modest network markets to support DSO to manage congestions and constraints both centrally and locally**
	a) 4. Energy market operation:	*a) 4. Energy market operation:*	*a) 4. Energy market operation:*
	· Very limited scale of energy market required to support energy balancing.	**· Relatively larger scale of energy markets required to mobilise DERs to absorb renewable energy.**	**· Widespread local energy markets to mobilise DERs to absorb renewable energy.**
	b) 1. Investment planning:	*b) 1. Investment planning:*	*b) 1. Investment planning:*
	· Large network investment to meet high penetration of DERs.	**· Relatively lower network investment to meet high penetration of DERs.**	**· Lowest network investment to meet high penetration of DERs.**
	b) 2. Network operation:	*b) 2. Network operation:*	*b) 2. Network operation:*
	· Poor performance to cope with future uncertainties because the centralised operation cannot make the best use of highly dispersed DERs, and innovations to take advantage of local intelligence and local resources are limited. **· Low local intelligence: most operational intelligence lies in the centralised distribution system operation.** **· Less efficient: The centralised, aggregated DER management approach would make it less efficient to respond to dynamics of localised DERs.**	**· Better performance to cope with future uncertainties because the hybrid structure makes better use of the highly dispersed DERs, and it has relatively more innovations to take advantage of local intelligence and local resources.** **· Relatively higher local intelligence, operational intelligence lies in both centralised and decentralised distribution system operation.** **· More efficient: The hybrid system would make it more efficient to respond to dynamics of localised DERs.**	**· Best performance to cope with future uncertainties because the decentralised structure makes the best use of the highly dispersed DERs, and it has relatively more innovations to take advantage of local intelligence and local resources.** **· Highest local intelligence, most operational intelligence lies in decentralised distribution system operation.** **· Most efficient: The decentralised, local DER management approach would make it the most efficient to respond to dynamics of localised DERs.**
	b) 3. Network market operation:	*b) 3. Network market operation:*	*b) 3. Network market operation:*
	· Innovation is largely limited to improving network market operational intelligence.	**· More innovations are encouraged to promote network market operational intelligence.**	**· More innovations are encouraged to promote network market operational intelligence.**

	b) 4. Energy market operation: · **Very limited energy market leads to low efficiency in absorbing renewable energy.**	*b) 4. Energy market operation:* · **Relatively larger scale of energy market leads to relatively higher efficiency in absorbing renewable energy.**	*b) 4. Energy market operation:* · **Widespread local energy markets leads to highest efficiency in absorbing renewable energy.**
	c) **• May take long time and/or expensive subsidies to meet the governmental policies and objectives. Security of supply is most likely to performing the best.**	*c)* **• More like to take shorter time and/or expensive subsidies to meet the governmental policies and objectives. Security of supply is most likely to performing the best.**	*c)* **• Most likely to meet the government policies and objectives very fast.**
Government	*a)* **• Very modest new policies and market regulations are required to adopt more DERs.** **• Very modest new policies and regulations on supporting innovation whilst ensuring good outcomes for consumers.**	*a)* **• More new policies and market regulations are required to adopt more DERs.** **• More new policies and regulations on supporting innovation whilst ensuring good outcomes for consumers.**	*a)* **• A lot more new policies and market regulations are required to adopt more DERs.** **• A lot more new policies and regulations on supporting innovation whilst ensuring good outcomes for consumers.**
	b) 1. Time input: · **Large amount of time is required to achieve the goals of adopting DER and increasing energy efficiency through central DER management.**	*b) 1. Time input:* · **Less time is required to achieve the goals of adopting DER and increasing energy efficiency through both central and local DER management.**	*b) 1. Time input:* · **Least time is required for new policies and market regulations through local DER management. The energy efficiency is more like to be very high because of low energy trading.**
	b) 2. Financial input: · **Expensive subsidies: Government drives the DER adoption which leads to expensive subsidies to meet the governmental policies and objectives.**	*b) 2. Financial input:* · **Relatively lower subsidies: Government and network market together to drive the DER adoption which leads to relatively lower subsidies to meet the governmental policies and objectives.**	*b) 2. Financial input:* · **Lowest subsidies: Energy market drives the DER adoption which leads to lowest subsidies to meet the governmental policies and objectives.**

	b) 3. Future uncertainty: · **Poor performance on coping with future uncertainties.**	*b) 3. Future uncertainty:* · **Better performance on coping with future uncertainties.**	*b) 3. Future uncertainty:* · **Best performance on coping with future uncertainties.**
	c) **• May take long time and expensive subsidies to meet the governmental policies and objectives; and not capable of allowing dynamic change.**	*c)* **• May take shorter time and less expensive subsidies to meet the governmental policies and objectives; and more capable of allowing dynamic change.**	*c)* **• May take shortest time and modest subsidies to meet the governmental policies and objectives; and very capable of allowing dynamic change.**
DG	*a) 1. Technical changes:* · **Least additional investment: very modest requirement for DG to provide flexible services.**	*a) 1. Technical changes:* · **More additional investment in new technologies to become more flexible and reliable, such as storages, forecasting tools, commercial instruments and new business models.**	*a) 1. Technical changes:* · **Most additional investment in new technologies to become more flexible and reliable, such as storages, forecasting tools, commercial instruments and new business models.**
	a) 2. Commercial changes: · **Very modest requirement for DG to join in new market and business models.**	*a) 2. Commercial changes:* · **More requirements for DG to join in new market and business models.**	*a) 2. Commercial changes:* · **Massive requirements for DG to join in new market and business models.**
	b) 1. Return of investment: · **Very limited:** **- DG survive on government's subsidies.** **- Electricity selling price is relative low.**	*b) 1. Return of investment:* · **Higher:** **- DG benefits from local energy trading.** **- Electricity selling price is relative higher.**	*b) 1. Return of investment:* · **Highest:** **- DG benefits the most from local energy trading.** **- Electricity selling price is the highest.**
	b) 2. Future outlook: · **Poor performance on coping with future uncertainties because the flexibility is very limited.**	*b) 2. Future outlook:* · **Better performance on coping with future uncertainties because the flexibility is higher.**	*b) 2. Future outlook:* · **Better performance on coping with future uncertainties because the flexibility is the highest.**
	c) **• May take long time and expensive cost to meet the governmental policies and objectives; and not capable of coping future uncertainties with limited flexibility.**	*c)* **• May take shorter time and less cost to meet the governmental policies and objectives; and more capable of coping future uncertainties with higher degree of flexibility.**	*c)* **• May take shortest time and modest subsidies to meet the governmental policies and objectives; and most likely to be very capable of coping future**

			uncertainties with the highest degree of flexibility.
Active customer	*a) 1. Technical changes:* · **Least additional investment: very modest requirement for active customers to provide flexible services.** *a) 2. Commercial changes:* · **Massive requirements for active customers to join in new market and business models.**	*a) 1. Technical changes:* · **More additional investment in new technologies to become more flexible and reliable, such as storages.** *a) 2. Commercial changes:* · **More requirements for active customers to join in new market and business models.**	*a) 1. Technical changes:* · **Most additional investment in new technologies to become more flexible and reliable, such as storages.** *a) 2. Commercial changes:* · **Very modest requirement for active customers to join in new market and business models.**
	b) 1. Return of investment: · **Very limited:** **- Electricity selling price is relative low.** *b) 2. Future outlook:* · **Poor performance on coping with future uncertainties because the flexibility is very limited.**	*b) 1. Return of investment:* · **Higher:** **- Electricity selling price is relative higher.** *b) 2. Future outlook:* · **Better performance on coping with future uncertainties because the flexibility is higher.**	*b) 1. Return of investment:* · **Highest:** **- Electricity selling price is the highest.** *b) 2. Future outlook:* · **Better performance on coping with future uncertainties because the flexibility is the highest.**
	c) **• May take long time and expensive cost to meet the governmental policies and objectives; and not capable of coping future uncertainties with limited flexibility.**	*c)* **• May take shorter time and less cost to meet the governmental policies and objectives; and more capable of coping future uncertainties with higher degree of flexibility.**	*c)* **• May take shortest time and modest subsidies to meet the governmental policies and objectives; and most likely to be very capable of coping future uncertainties with the highest degree of flexibility.**

Passive customer	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* · **Electricity price is the highest.** *b) 1. Return of investment:* **N/A** *b) 2. Future outlook:* · **Best performance on coping with future uncertainties because the required flexibility is very low.**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* · **Electricity price is lower.** *b) 1. Return of investment:* **N/A** *b) 2. Future outlook:* · **Better performance on coping with future uncertainties because the required flexibility is higher.**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* · **Electricity price is the lowest.** *b) 1. Return of investment:* **N/A** *b) 2. Future outlook:* · **Poor performance on coping with future uncertainties because the required flexibility is very high.**
	c) **• May take long time and expensive cost to meet the governmental policies and objectives; and not capable of coping future uncertainties with limited flexibility.**	*c)* **• May take shorter time and less cost to meet the governmental policies and objectives; and more c+B2:E65apable of coping future uncertainties with higher degree of flexibility.**	*c)* **• May take shortest time and modest subsidies to meet the governmental policies and objectives; and most likely to be very capable of coping future uncertainties with the highest degree of flexibility.**

8.2. Appendix-B Economic dimension

Four dimensions	Economic dimension		
Government policies and objectives	• Maximise benefits and minimise costs on implementation • Maximise benefits and minimise costs on operation • Potential benefits from future changes in energy landscape		
Assessment criteria	a) What is the net value to the key stakeholders from introducing the new industrial structure compared to Business-As-Usual? b) What are the risks and their costs and how are they best managed? c) Which reflects the optimal net value to the society?		
Key stakeholders	Central-control dominated structure	Regional-control dominated structure	Community-control dominated structure
DNO/DSO	*a) 1. Investment planning:* · Higher net value because DSO benefits from network investment with high penetration of DERs. · Higher net value because DSO benefits more from the commercial charges with high penetration of DERs. *a) 2. Network operation:* · Lowest net value because DSO has limited understanding of local DER characteristics. *a) 3. Network market operation:* · Low net value because modest network markets to mobilise DERs to support DSO to centrally manage congestions and constraints.	*a) 1. Investment planning:* · Lower net value because DSO benefits less from network investment with high penetration of DERs. · Lower net value because DSO benefits less from commercial charges with high penetration of DERs. *a) 2. Network operation:* · Lower net value because DSO has relative more understanding of local DER characteristics. *a) 3. Network market operation:* · Higher net value because relatively larger scale of network markets to mobilise DERs to support DSO to manage congestions and constraints both centrally and locally.	*a) 1. Investment planning:* · Lowest net value because DSO benefits least from network investment with high penetration of DERs. · Lowest net value because DSO benefits least from commercial charges with high penetration of DERs. *a) 2. Network operation:* · Higher net value because DSO has the best understanding of local DER characteristics. *a) 3. Network market operation:* · Low net value because modest network markets to support DSO to manage congestions and constraints both centrally and locally

	a) 4. Energy market operation:	*a) 4. Energy market operation:*	*a) 4. Energy market operation:*
	· Lowest net value because very limited scale of energy market required to support energy balancing.	**· Higher net value because relatively larger scale of energy markets required to mobilise DERs to absorb renewable energy.**	**· Higher net value because widespread local energy markets to mobilise DERs to absorb renewable energy.**
	b) 1. Investment planning:	*b) 1. Investment planning:*	*b) 1. Investment planning:*
	· Large cost on network investment to meet high penetration of DERs.	**· Relatively lower cost on network investment to meet high penetration of DERs.**	**· Lowest cost on network investment to meet high penetration of DERs.**
	b) 2. Network operation:	*b) 2. Network operation:*	*b) 2. Network operation:*
	· High risks because of poor performance to cope with future uncertainties.	**· Lower risks because of better performance to cope with future uncertainties.**	**· Lowest risks because of best performance to cope with future uncertainties.**
	· High risks because of low local intelligence	**· Lower risks because of higher local intelligence.**	**· Lowest risks because of highest local intelligence.**
	· Large cost because less efficient in responding to dynamics of localised DERs.	**· Lower cost because more efficient in responding to dynamics of localised DERs.**	**· Lowest cost because most efficient in responding to dynamics of localised DERs.**
	b) 3. Network market operation:	*b) 3. Network market operation:*	*b) 3. Network market operation:*
	· High risks because innovation is largely limited to improving network market operational intelligence.	**· Lower risks because more innovations are encouraged to promote network market operational intelligence.**	**· Lowest risks because more innovations are encouraged to promote network market operational intelligence.**
	b) 4. Energy market operation:	*b) 4. Energy market operation:*	*b) 4. Energy market operation:*
	· High cost because of low efficiency in absorbing renewable energy.	**· Lower cost because of relatively higher efficiency in absorbing renewable energy.**	**· Lowest cost because of highest efficiency in absorbing renewable energy.**

	c) • More likely to fail to reflect the optimal net value to society because of the high costs and risks.	c) • More like to reflect the optimal net value to society because of the lower costs and risks.	c) • Most likely to reflect the optimal net value to society because of the lowest costs and risks.
Government	**N/A**		
DG	a) 1. *Technical changes:* · High net value because of least additional investment. a) 2. *Commercial changes:* · Lowest net value because of limited opportunities for new market and business models.	a) 1. *Technical changes:* · Lower net value because of more additional investment in new technologies. a) 2. *Commercial changes:* · Higher net value because of more opportunities for new market and business models.	a) 1. *Technical changes:* · Lowest net value because of most additional investment in new technologies. a) 2. *Commercial changes:* · Highest net value because of massive opportunities for new market and business models.
	b) 1. *Return of investment:* · High risks of low return of investment. b) 2. *Future outlook:* · High risks because of poor performance to cope with future uncertainties.	b) 1. *Return of investment:* · Lower risks of low return of investment. b) 2. *Future outlook:* · Lower risks because of better performance to cope with future uncertainties.	b) 1. *Return of investment:* · Lowest risks of low return of investment. b) 2. *Future outlook:* · Lowest risks because of best performance to cope with future uncertainties.
	c) • Fail to reflect the optimal net value to society because of the high costs and risks.	c) • More like to reflect the optimal net value to society because of the lower costs and risks.	c) • Most likely to reflect the optimal net value to society because of the lowest costs and risks.

Active customer	*a) 1. Technical changes:* **· High net value because of least additional investment.** *a) 2. Commercial changes:* **· Lowest net value because of limited opportunities for new market and business models.**	*a) 1. Technical changes:* **· Lower net value because of more additional investment in new technologies.** *a) 2. Commercial changes:* **· Higher net value because of more opportunities for new market and business models.**	*a) 1. Technical changes:* **· Lowest net value because of most additional investment in new technologies.** *a) 2. Commercial changes:* **· Highest net value because of massive opportunities for new market and business models.**
	b) 1. Return of investment: **· High risks of low return of investment.** *b) 2. Future outlook:* **· High risks because of poor performance to cope with future uncertainties.**	*b) 1. Return of investment:* **· Lower risks of low return of investment.** *b) 2. Future outlook:* **· Lower risks because of better performance to cope with future uncertainties.**	*b) 1. Return of investment:* **· Lowest risks of low return of investment.** *b) 2. Future outlook:* **· Lowest risks because of best performance to cope with future uncertainties.**
	c) **• Fail to reflect the optimal net value to society because of the high costs and risks.**	*c)* **• More like to reflect the optimal net value to society because of the lower costs and risks.**	*c)* **• Most likely to reflect the optimal net value to society because of the lowest costs and risks..**
Passive customer	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Lowest net value because the electricity price is the highest.**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Lowest net value because the electricity price is lower.**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Lowest net value because the electricity price is the lowest.**
	b) 1. Return of investment: **N/A** *b) 2. Future outlook:* **· Minimised risks for passive customers because the system is mainly passive.**	*b) 1. Return of investment:* **N/A** *b) 2. Future outlook:* **· Higher risks for passive customers because the system is more active.**	*b) 1. Return of investment:* **N/A** *b) 2. Future outlook:* **· Highest risks for passive customers because the system is the most active..**
	c) **• More like to reflect the optimal net value to society because of the lower costs and risks.**	*c)* **• Most likely to reflect the optimal net value to society because of the lowest costs and risks.**	*c)* **• More like to reflect the optimal net value to society because of the lower costs and risks.**

8.3. Appendix-C Commercial dimension

Four dimensions	Commercial dimension		
Government policies and objectives	• Facilitate neutral, simple, fair and transparent markets • Ensure a cost-effective and stable market environment • Adapt to future changes in energy landscape		
Assessment criteria	a) Can a realistic and credible commercial deal be struck? b) Who will manage which the risks?		
Key stakeholders	Central-control dominated structure	Regional-control dominated structure	Community-control dominated structure
DNO/DSO	*a) 1. Investment planning:* **N/A** *a) 2. Network operation:* **N/A** *a) 3. Network market operation:* **· Lower chance of achievement because modest network markets to mobilise DERs to support DSO to centrally manage congestions and constraints.** *a) 4. Energy market operation:* **· Lower chance of achievement because very limited scale of energy market required to support energy balancing.**	*a) 1. Investment planning:* **N/A** *a) 2. Network operation:* **N/A** *a) 3. Network market operation:* **· Higher chance of achievement because relatively larger scale of network markets to mobilise DERs to support DSO to manage congestions and constraints both centrally and locally.** *a) 4. Energy market operation:* **· Higher chance of achievement because relatively larger scale of energy markets required to mobilise DERs to absorb renewable energy.**	*a) 1. Investment planning:* **N/A** *a) 2. Network operation:* **N/A** *a) 3. Network market operation:* **· Lower chance of achievement because modest network markets to support DSO to manage congestions and constraints both centrally and locally** *a) 4. Energy market operation:* **· Highest chance of achievement because widespread local energy markets to mobilise DERs to absorb renewable energy.**

	b) 1. Investment planning: **N/A** *b) 2. Network operation:* **N/A**	*b) 1. Investment planning:* **N/A** *b) 2. Network operation:* **N/A**	*b) 1. Investment planning:* **N/A** *b) 2. Network operation:* **N/A**
	b) 3. Network market operation: · **DSO will manage the risks.**	*b) 3. Network market operation:* · **DSO and third-party service providers will manage the risks.**	*b) 3. Network market operation:* · **DSO, third-party service providers and possible customer will manage the risks.**
	b) 4. Energy market operation: · **DSO will manage the risks.**	*b) 4. Energy market operation:* · **DSO and third-party service providers will manage the risks.**	*b) 4. Energy market operation:* · **DSO, third-party service providers and possible customer will manage the risks.**
Government	**N/A**		
DG	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* · **Lowest chance of achievement because very modest market opportunities are provided to DG.**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* · **Higher chance of achievement because more market opportunities are provided to DG.**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* · **Highest chance of achievement because massive market opportunities are provided to active customers.**
	b) 1. Return of investment: · **DG and government manage risks**	*b) 1. Return of investment:* · **DG and government manage risks**	*b) 1. Return of investment:* · **DG manage risks**
	b) 2. Future outlook: **N/A**	*b) 2. Future outlook:* **N/A**	*b) 2. Future outlook:* **N/A**

Active customer	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Lowest chance of achievement because very modest market opportunities are provided to active customers.**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Higher chance of achievement because more market opportunities are provided to active customers.**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Highest chance of achievement because massive market opportunities are provided to active customers.**
	b) 1. Return of investment: **· Active customers and government manage risks** *b) 2. Future outlook:* **N/A**	*b) 1. Return of investment:* **· Active customers and government manage risks** *b) 2. Future outlook:* **N/A**	*b) 1. Return of investment:* **· Active customers manage risks** *b) 2. Future outlook:* **N/A**
Passive customer	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Highest chance of achievement because the market mechanism is relatively simple for passive customers.**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Lower chance of achievement because the market mechanism is more complicated for passive customers.**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Lowest chance of achievement because the market mechanism is very complicated for passive customers.**
	b) 1. Return of investment: **N/A** *b) 2. Future outlook:* **N/A**	*b) 1. Return of investment:* **N/A** *b) 2. Future outlook:* **N/A**	*b) 1. Return of investment:* **N/A** *b) 2. Future outlook:* **N/A**

8.4. Appendix-D Management dimension

Four dimensions	Management dimension		
Government policies and objectives	• Improve safety and reliability • Decrease complexity on physical network implementation • Future proof: Provide space for new developments and has the ability to meet future requirements		
Assessment criteria	a) Are there realistic and robust delivery plans? b) How can the proposal be delivered?		
Key stakeholders	Central-control dominated structure	Regional-control dominated structure	Community-control dominated structure
DNO/DSO	*a) 1. Investment planning:* · Relatively less realistic to adopt and accommodate DERs through investment planning.	*a) 1. Investment planning:* · Relatively more realistic to adopt and accommodate DERs through investment planning.	*a) 1. Investment planning:* · Relatively not realistic to adopt and accommodate DERs through investment planning.
	a) 2. Network operation: · Significant enhanced operation and management required to build a robust system.	*a) 2. Network operation:* · Enhanced operation and management are required to build a robust system.	*a) 2. Network operation:* · Very modest efforts on operation and management are required to build a robust system.
	a) 3. Network market operation: · Relatively less realistic to mobilise DERs to support DSO to centrally manage congestions and constraints because of modest network markets.	*a) 3. Network market operation:* · Relatively more realistic to mobilise DERs to support DSO to manage congestions and constraints because of widespread network markets.	*a) 3. Network market operation:* · Relatively less realistic to mobilise DERs to support DSO to centrally manage congestions and constraints because of modest network markets.
	a) 4. Energy market operation: · Relatively less realistic because very limited scale of energy market is required to support energy balancing.	*a) 4. Energy market operation:* · Relatively less realistic because limited scale of energy markets required to mobilise DERs to absorb renewable energy.	*a) 4. Energy market operation:* · Relatively more realistic because of widespread local energy markets to mobilise DERs to absorb renewable energy.

	b) 1. Investment planning:	*b) 1. Investment planning:*	*b) 1. Investment planning:*
	· **Large network investment**	· **Relatively lower network investment**	· **Lowest network investment**
	b) 2. Network operation:	*b) 2. Network operation:*	*b) 2. Network operation:*
	· **More innovations to take advantage of local intelligence and local resources are limited.**	· **Less innovations to take advantage of local intelligence and local resources are limited.**	· **Least innovations to take advantage of local intelligence and local resources are limited.**
	· **Aggregate DERs to enhance network operation.**	· **Aggregate DERs to enhance network operation.**	
	b) 3. Network market operation:	*b) 3. Network market operation:*	*b) 3. Network market operation:*
	· **More innovations from DSO to improve network market operational intelligence.**	· **Less innovations from DSO to promote network market operational intelligence.**	· **Least innovations from DSO to promote network market operational intelligence.**
	b) 4. Energy market operation:	*b) 4. Energy market operation:*	*b) 4. Energy market operation:*
	· **Very limited actions required because limited scale of energy market.**	· **Relatively more actions required because larger scale of energy market.**	· **Most actions required because widespread energy market.**
Government	*a)* **• Very realistic because very modest efforts on new policies and market regulations are required**	*a)* **• Less realistic because more efforts on new policies and market regulations are required**	*a)* **• Least realistic because largest efforts on new policies and market regulations are required**
	b) 1. Time input:	*b) 1. Time input:*	*b) 1. Time input:*
	· **Large amount of time is required**	· **Less time is required**	· **Least time is required**
	b) 2. Financial input:	*b) 2. Financial input:*	*b) 2. Financial input:*
	· **Government input large subsidies**	· **Government input less subsidies**	· **Government input least subsidies**
	b) 3. Future uncertainty:	*b) 3. Future uncertainty:*	*b) 3. Future uncertainty:*
	· **More efforts on coping with future uncertainties.**	· **Less efforts on coping with future uncertainties.**	· **Least efforts on coping with future uncertainties.**

DG	*a) 1. Technical changes:* · **Very realistic because least additional investment: very modest requirement for DG to provide flexible services.**	*a) 1. Technical changes:* · **Less realistic because more additional investment in new technologies to become more flexible and reliable, such as storages, forecasting tools, commercial instruments and new business models.**	*a) 1. Technical changes:* · **Least realistic because most additional investment in new technologies to become more flexible and reliable, such as storages, forecasting tools, commercial instruments and new business models.**
	a) 2. Commercial changes: · **Very realistic because very modest requirement for DG to join in new market and business models.**	*a) 2. Commercial changes:* · **Less realistic because more requirements for DG to join in new market and business models.**	*a) 2. Commercial changes:* · **Least realistic because massive requirements for DG to join in new market and business models.**
	b) 1. Return of investment: · **Receive government's subsidies**	*b) 1. Return of investment:* · **Receive government's subsidies and join in energy trading**	*b) 1. Return of investment:* · **Join in energy trading actively**
	b) 2. Future outlook: · **Most actions required to cope with future uncertainties, because DG flexibility is low.**	*b) 2. Future outlook:* · **Less actions required on coping with future uncertainties because DG flexibility is higher.**	*b) 2. Future outlook:* · **Least actions required on coping with future uncertainties because DG flexibility is the highest.**
Active customer	*a) 1. Technical changes:* · **Small investment on energy storages to provide flexible and reliable services.**	*a) 1. Technical changes:* · **More investment on energy storages to provide flexible and reliable services.**	*a) 1. Technical changes:* · **Large investment on energy storages to provide flexible and reliable services.**
	a) 2. Commercial changes: · **Very difficult for active customers to join in new market and business models because of limited options.**	*a) 2. Commercial changes:* · **Easier for active customers to join in new market and business models with more options.**	*a) 2. Commercial changes:* · **Easiest for active customers to join in new market and business models with most options.**
	b) 1. Return of investment: · **Large efforts required to gain profits.**	*b) 1. Return of investment:* · **Less efforts required to gain profits.**	*b) 1. Return of investment:* · **Least efforts required to gain profits.**
	b) 2. Future outlook: **N/A**	*b) 2. Future outlook:* **N/A**	*b) 2. Future outlook:* **N/A**

Passive customer	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Very limited requirements for passive customers to join in electricity market.** *b) 1. Return of investment:* **N/A** *b) 2. Future outlook:* **N/A**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· More requirements for passive customers to join in electricity market.** *b) 1. Return of investment:* **N/A** *b) 2. Future outlook:* **N/A**	*a) 1. Technical changes:* **N/A** *a) 2. Commercial changes:* **· Much more requirements for passive customers to join in electricity market.** *b) 1. Return of investment:* **N/A** *b) 2. Future outlook:* **N/A**