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Demand response business model canvas: a tool for flexibility creation in the electricity markets

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Highlights

- Demand response and business model approaches are integrated.
- Business models for energy flexibility products remain relatively uncomprehended.
- A practical tool for demand response business model is presented.
- Nine business model elements introduced to address demand response complexity.
- Future directions in the demand response business field include conducting sustainability analyses, and developing new socio-technical configurations.

Key words: business model, demand response, demand-side management, electricity markets, energy transition

Abstract

Wind and solar power generation have been rapidly increasing on a global scale; this increase is limited by the capacities of the existing grids at maintaining balance between supply and demand to accommodate the fluctuations of these renewable energy resources. Therefore, grid flexibility has become a key factor in power systems. This study focuses on demand response business models (DRBMs), which have great potential for fostering energy flexibility in a cost-efficient and sustainable manner. Based on the literature review and empirical data from a case study, a business model analytical framework is proposed to explore the demand response potential based on value proposition, value creation and delivery, and value capture. This DRBM framework is characterised by nine elements: flexibility product, flexibility market segment, service attributes, demand response resources, resource availability, demand response mechanism, communication channels, cost structures, and revenue model. Based on this framework, a visualisation tool is proposed to help researchers and practitioners understand, integrate, and develop flexible electricity products. The application of this tool is then presented for electric vehicles as an example. The tool is valuable for evaluating the initial and untapped potentials of commercial demand response in electricity markets. This study thus contributes to the body of demand response literature via development of a holistic approach to assist recognition and creation of business models in emerging electricity markets.

1. Introduction

Climate change is a global phenomenon and has affected all regions around the world. In some regions, extreme weather conditions, such as extreme heat waves and droughts as well as irregular rainfall patterns, have become more common (McDonough et al., 2020). Thermal power generation technologies are known to have a major impact on global warming and health owing to the excessive use of fossil fuels (Strezov and Cho, 2020). Substituting these fossil fuels with renewable energy sources (RES) is recommended as one of the primary solutions for mitigating the environmental impact of present power generation practices. RES such as photovoltaic systems and wind turbines have recently emerged as clean and sustainable energy generation methods and are being increasingly accepted and utilised globally (Akella et al., 2009). In power systems where the contributions from the RES are high, the flexibility in power generation is low and cannot keep pace with the load patterns. RES have created new challenges for system operators, energy utilities and governments around the world, such as expansion of variable-output electricity generation, integrating the different RES to meet climate goals, addressing peak demand through meeting flexibility needs, difficulty in constructing new power lines, and increased dependence on electricity as the energy carrier (Ikäheimo et al., 2010). From the supply point of view, renewable energy generation challenges the balance of a transmission grid in a very short duration. At the distribution grid, reverse power flows can create congestion and voltage imbalances (Villar et al., 2018). From a usage perspective, consumers are more aware of global warming and are expected to play more active roles in achieving grid balancing, e.g. by utilizing the advantages of advancements in communication and metering technologies like smart meters. Consumers can modify their electricity demand, including reducing or shifting their consumption during critical periods.

This demand-side flexibility can be visualised as an opportunity to build a more cost-effective and sustainable power system instead of increasing generation capacity or grid strengthening (O'Connell et al., 2014). Demand-side flexibility has considerable influence on integration of the different RES and their optimal use (Hakimi et al., 2020; Jafari et al., 2020); it is expected to be a valuable tool even as the market penetration of RES increase (McPherson and Stoll, 2020). Globally, the demand-side flexibility expanded by 5% in 2019 but was still ten times lower than the level required for sustainable development. Currently, less than 2% of the global potential for demand-side flexibility is being utilised (IEA, 2020).

Demand-side management (DSM) is one of the most studied fields of electricity system flexibility and aims to optimise the flexibility on the consumer's side. DSM has two approaches: energy efficiency (EE) and demand response (DR). The latter, which is the focus of this study, is a mechanism based on consumer participation that encourages them to make temporary reductions in their energy demands. Thus, DR has the potential to balance supply and demand from a cleaner, more efficient, and more economical perspective.

DR is a broad concept and published research tend to address only particular issues, such as integration of different RES and impact on the distribution grid. Very minimal attention has been devoted to the holistic representation behind the DR concept and the relationships between its different constituent elements. Niesten and Alkemade (2016) discussed the methods by which value is created and captured in power systems and analysed the DR benefits for both power systems and participating customers. Behrangrad (2015) conducted an analysis of the existing and potential values of DR practices and described their main characteristics. Beyond technical aspects related to the power system, DR integrates socioeconomic elements, such as market signs and consumers' behaviours. Radenković et al. (2020) outlined consumers' behavioural aspects and their influence upon the power systems. Studying these elements and their relationships as well as focusing on the connections between the DR technical potential and realization of economic value constitute the core of the demand response business model (DRBM) analyses. Past research on the systemic analysis of DR practices are incomplete, yet there are no investigations in literature for the DR concept from the viewpoint of the business model (BM) theory.

This study attempts to narrow this gap by focusing on a BM canvas approach established on a framework comprising key elements that interact together within a system, which is the DRBM in this research. The objective of this work is to develop a conceptual framework of the DRBM and to propose a practical tool for researchers and DR practitioners. This framework expresses the business logic of DR practices and describes their value for different stakeholders by combining widely recognized BM components with specific DR aspects. This is a holistic approach that addresses the relationships between the BM components and explains how these components interact and affect each other. Based on this framework, a practical tool is proposed herein for researches to discuss the practices included under DR and to stimulate innovation by DR initiatives in electricity markets. This tool allows researchers to identify the main social, economic and technical parameters that influence future DR practices. Moreover, this tool can also be adapted to the needs of entrepreneurs who seek to discover and communicate potential innovations related to flexibility services in the electricity markets or existing energy actors (e.g. energy retailers) desiring to optimize power flexibility by reforming their current BMs. To illustrate and clarify the DRBM and its essential elements, this work relies on the detailed analysis of a single case study and five different examples chosen from the DR business field. The analysis of the DRBM elements can also be used as a guide by energy entrepreneurs and other industries wishing to examine the potential of the DRBM for themselves.

This research is a response to the call for new thinking about power systems and a more flexible grid to accommodate low-carbon technologies, such as renewable energy sources and electric vehicles (Shomali and Pinkse, 2016). This work contributes to business opportunities in the emerging electricity markets arising from DR (Cardoso and Torriti, 2018). The contributions in this work have drawn inspiration from Osterwalder et al. (Osterwalder et al., 2011), who emphasized the need for BM frameworks and visualisation tools that support researchers, entrepreneurs and organisations interested in studying and creating new BMs.

The remainder of this paper is organised as follows. Section 2 provides an overview of the BM concept and DR literature, and Section 3 outlines the research design and implementation methodologies explaining the analytical framework and presenting a case study and set of supportive examples. Section 4 presents some findings regarding the description of the BM framework for DR and the identification of its main elements; this section is further divided into three subsections, namely value proposition, value creation and delivery, and value capture. Section 5 draws upon the developed framework and BM visualisation perspectives to introduce the DRBM canvas, followed by an illustrative example as applied to electric vehicles. Section 6 discusses our main contributions and their implications. Section 7 presents some conclusions and discusses the scope for further research.

2. Theoretical background

2.1 Business model

A literature search for the term ‘business model’ returns results showing diverse use but a lack of consensus on its definition. The concept of a BM has gained acceptance among academic researchers and practitioners in the field. Research on BMs garnered attention during the dot-com bubble, when the internet enabled start-ups to create value via introducing novel and more efficient BMs (Amit and Zott, 2001).

A common agreement on the basic definition of the BM is its description of how a firm conducts business. Although it does not include all the aspects of the business as a complex social system, it defines the general logic behind the actual processes (Petrovic et al., 2001). The early understanding of the BM concept was as a logical tool that supported companies to make strategic decisions and manage new technologies (Chesbrough and Rosenbloom, 2002). The BM is seen as a systemic and conceptually rich construct that involves some key components. This view is in agreement with the widely noted BM canvas of Alex Osterwalder, which is a simplified design involving key decisions and activities structured under nine components (Osterwalder, 2004). Realistically, the BM can be considered as a system of interconnected and independent activities (Zott and Amit, 2010). A BM is a role model that detects the shared similarities between firms and the generic types of behaviours that can be outlined to simplify analysis (Baden-Fuller and Morgan, 2010). Therefore, a BM invites innovation through knowledge replication and model imitation (Enkel and Mezger, 2013). A BM can also be seen as an artefact, e.g. a visual template that supports collaboration, creativity, and innovation in teams, and shapes the process of developing new economic logic (Eppler and Hoffmann, 2013). Innovating a BM comprises reconfiguration of the model elements, including changes in content (e.g. product-service, resources, business activities), structure (linkages between involved parties and stakeholders), and governance (who performs the activities) (Zott and Amit, 2010). BMs have different uses and applications and assist in explaining the business, operations, and strategy development (Foss and Saebi, 2017). From a more abstract point of view, BM components are commonly aggregated into three types: value proposition, value creation and delivery, and value capture (Richardson, 2008). The value proposition component considers the value embedded in the product service, refers to the customer segments, and focuses on customer needs. Value creation and delivery covers the key stakeholder roles, such as suppliers and partners, and key activities, including distribution and resource utilization processes. Finally, the value capture component embraces the flow of expenses in terms of costs and corresponding incomes.

Recent research studies have also conceived BMs as the means of transformation to more sustainable economic systems (Wainstein and Bumpus, 2016) and to provide support for integrating sustainability aspects into organisations (Stubbs and Cocklin, 2008). The notion of a sustainable business model (SBM) reflects superior value to the customer and describes how firms can capture economic value while maintaining or generating natural social capital (Boons and Lüdeke-Freund, 2013). Today, the concept of SBM is seen as a method to recognise new business opportunities and create a competitive advantage (Yang et al., 2017). SBMs challenge the status-quo of a BM via development of a triple bottom-line BM, i.e. the integration of environmental, social, and business activities (Awan et al., 2018; Evans et al., 2017). SBMs go beyond delivering economic value and include a consideration of other forms of value for a broader range of stakeholders (Bocken et al., 2014).

The unbundling of energy utilities and liberalisation of energy markets have allowed the emergence of new BMs within the energy sector. Such social and political trends have enabled the study of many interesting research areas (Apajalahti et al., 2015; Richter, 2013). The concept of a BM has been outlined as an analysis framework for presenting a more sustainable energy utility (Helms, 2016; Richter, 2013), introducing new schemes to organise business activities around renewable energy technologies (Huijben and Verbong, 2013; Wainstein and Bumpus, 2016), and drawing comparisons between organisational configurations of renewables (Strupeit and Palm, 2016). Given that disruptive BMs are able to achieve larger system shifts (Bolton and Hannon, 2016; Johnson and Suskewicz, 2009), there is considerable interest in developing a clear and descriptive framework that can guide and support decision makers in innovating BMs, rather than products or processes (Osterwalder, 2004). The BM concept has been useful in describing the evolution of energy service companies (ESCOs) and in analysing the challenges of developing new and innovative EE services (Apajalahti et al., 2015).

These activities emphasise the BM theory as a method to understand the structures of innovative businesses. For many companies, DR is a powerful mechanism that can reduce energy costs; however, DR may not be suitable for all businesses. Businesses with low energy needs and small facilities have less capabilities to manipulate electricity loads and generate income. However, organisations that have already adopted EE measures are ideal candidates. Businesses with high electricity loads and smart meters are suitable for the initial DR requirements, since DR can achieve real impact with minimal disruption. This study uses the BM concept to create and build a BM canvas for DR to support the aforementioned kinds of companies and entrepreneurs in developing DR businesses.

2.2 Demand response service

EE has become a popular concept against climate change, but EE and DR have many common characteristics. Notably, they are energy management innovations, and there is consensus on their benefits for power systems. For businesses, both of them represent cost-efficient strategies to reduce energy-related expenses and are likely evaluated using the same criteria. However, EE and DR are fundamentally different; EE involves permanent or regular changes in the consumption, whereas DR requires temporary changes in the consumption patterns (i.e. of the order of minutes or seconds). The major difference between EE and DR is that DR is associated with factors beyond the purview of organisations, such as interactions with the markets, meteorological conditions, and other flexibility providers. Thus, a bi-directional communication infrastructure is often indispensable in the DR, and all the aforementioned factors render the DR implementation as a dynamic process and increase the uncertainties associated with its financial returns (Cardoso and Torriti, 2018). DR providers offer customers the chance to utilise their flexibility in the markets. Flexibility as an offered product is the power adjustment maintained at a particular moment for a specific duration from a certain location within the network (Villar et al., 2018). Within this scheme, DR is defined as the intentional modification of normal consumption patterns by end-user customers in response to incentives from the grid operators. The main aim here is to lower electricity usage at the time of high wholesale market prices or when system reliability is threatened. BMs that produce flexibility based on exercising DR have been enabled by the evolution of technology required for their implementation (Paterakis et al., 2017).

Some large industrial consumers are already reported to be exercising DR to reduce their energy costs (Samad and Kiliccote, 2012). Recently, different DRBMs have started to aggregate and connect medium-sized commercial and small-scale residential consumers to the power markets (Sisinni et al., 2017). These BMs offer flexibility by creating and capturing value from timing supply and demand over very short durations and even combine the timings of many supply and demand activities simultaneously (Helms et al., 2016). In contrast to industrial consumers, small- and medium-scale energy consumers face great barriers for participating in flexibility markets. Electricity markets often require the participants to have a minimum amount of power flexibility (e.g. 1 MW). Therefore, flexibility aggregation is indispensable.

Flexibility is necessary for achieving balance between the authorities, capacity and electricity markets, and electricity retailers. Transmission system operators (TSOs) are responsible for the operation of the transmission system and its stability, and distribution network operators (DSOs) are responsible for the operation of the distribution system and power delivery to the customers. By reducing the peak demand, TSOs and DSOs receive value in the form of low-cost services, increased network reliability, and avoided capital and congestion costs. Energy retailers are commercial entities that buy electrical energy from the market for their customers; retailers can benefit from the DR and lower their costs of purchasing electricity. DR has two approaches in terms of its applications (Albadi and El-Saadany, 2008): one is an explicit approach and the other is implicit. The former is incentive-based, in which customers receive direct payments from the TSO or a service provider upon the adjustment of their demand-side resources (generations or/and loads). In the DR field, aggregators' roles are important and mainly involve coordinating consumers' load flexibilities for trade in electricity markets in exchange for a percentage of the revenue. The latter is price-based and depends on customer reactions to dynamic markets or network pricing signals (Carreiro et al., 2017).

DR is not a new concept and has been used in various forms around the world for a long time. The most traditional forms of DR are interrupt services at critical times or differentiation between tariffs (e.g. night tariff vs. day tariff); however, more sophisticated forms have been implemented globally as more systems have been digitised and more connected devices have been deployed. To unlock the DR potential, new BMs need to be developed. An analysis of DR value propositions show a variety of products and services that can be created and delivered in electricity markets (Behrangrad, 2015). A major point of difference between traditional flexibility units' BMs (e.g. hydropower plants) and DRBM is the involvement of consumers in value creation and delivery (denoted as 'customers' henceforth). DR services depend on the customers' commitments, thereby developing more intimate relationships with the customers (Radenković et al., 2020). The former does not necessitate an intermediary actor between the service provider and electricity markets, whereas DRBMs are often developed by demand response providers (DRPs), such as an aggregator (Carreiro et al., 2017). DRP refers to an intermediary actor between the customers and purchasers, who sends notices asking the customers to modify their consumption patterns during demand peaks, to maintain grid stability and reliability in a cost-efficient manner. The primary difference between both approaches is that the former is based on fossil fuel consumption, whereas the latter is an environmentally friendly mode of flexibility.

Although the DR concept has been broadly researched in academic settings in the form of DR definition (Albadi and El-Saadany, 2008), classifications and programme types (Palensky and Dietrich, 2011), enabling technologies (Siano, 2014), growth potential in the electricity markets (Cappers et al., 2010; Dupuy and Linvill, 2019), products offered (Rahimi and Ipakchi, 2010), and market drivers and barriers (Cardoso and Torriti, 2018; Good et al., 2017), the DR concept from the BM perspective has not been investigated in depth, hence emphasizing a system-level holistic approach towards explaining how firms conduct business. This quest for further research is required to respond to social and market changes, namely increase in the competitiveness of the electricity markets (Apajalahti et al., 2015), uncertainty costs of DR implementation (Kim and Shcherbakova, 2011), and increase in customer awareness of renewable energies. In addition, although some types of DR resources are underused, newer innovative DR products and services continue to be introduced. For example, the wide use of smart communication technologies enable energy consumers to enrol in a variety of DR programs, thereby creating new market niches for entrepreneurs (Negnevitsky et al., 2010). Furthermore, traditional flexibility units depend on centralised medium-scale power plants, whereas DRBMs rely on distributed resources and are usually the results of accumulations of different and large numbers of customers with small-scale flexibilities. Thus, the captured value represents an increase in social welfare as the benefits are distributed among the participating customers (resource owners) and the system operator (product purchaser).

2.3 Sustainability challenges for DR

Literature on reducing the environmental impacts of different sectors often focus on the supply side, and less attention has been devoted to the fact that users are willing to be more active and that policy interventions can modify some behavioural aspects (Moberg et al., 2019). The potential of decarbonisation pathways on the demand side might be higher than that assumed in some studies (Creutzig et al., 2018). In the energy sector, demand-side approaches have focused EE aspects, which are often linked to technical innovations not only aimed at energy consumption reduction but also to policies that pursue behavioural changes (Mundaca et al., 2019).

It is assumed that energy consumption reduction is an important point of leverage for decreasing environmental impact; besides, DR activities can offer additional impacts when pursuing these goals.

Electricity consumption peaks increase carbon dioxide emissions as they often necessitate operation of fossil fuel power plants to balance the load and generation. The main DR programs are implemented to shift electricity loads to off-peak times to avoid excess carbon dioxide emissions (Srivastava et al., 2020).

DR can also be implemented to stabilize the distribution network. Avoiding distribution network congestion can bypass the use of diesel generators in overload zones (Aghaei et al., 2016). Moreover, from a material point of view, DSOs are not obliged to reinforce the network and electric components to last longer, thus saving on utilization of metals such as aluminium and copper (Siano, 2014).

However, the greatest influence of DR on sustainability aspects is regarding DR as an important point of leverage for the development of RES. The increased share of RES connected to the grid pose new technical and economic challenges to system operators. RES are intermittent resources, and their introduction indicates a shift from the traditional one-directional power flow to bidirectional flows. Integrating different RES into the grids add certain levels of uncertainties. Consequently, increased amounts of regulation, reserves, and load-following resources should be maintained. Generators incur significant costs from ramping, increased emissions, and increased wear and tear (Paterakis et al., 2017). DRBMs can mitigate such effects and increase demand during period in which excess renewables are available while reducing demand during low production periods (Saberi et al., 2019).

Lastly, DR can also be considered as an important method to leverage the development of electric vehicles and hence the decarbonisation of the mobility sector. DR has been advocated as one of the solutions to the overload problem due to electric vehicles, and reinforcing the distribution networks next to the charging stations have been necessitated (Shao et al., 2011).

3. Research design

DR is an approach that has been increasingly used for managing fluctuations in renewables. However, there is lack of knowledge regarding its potential opportunities, and the monetary benefits of flexibility achieved via DR seem unclear for both potential customers and entrepreneurs (Cardoso and Torriti, 2018; Good et al., 2017; O'Connell et al., 2014). DR is a specific business phenomenon, whereas BMs are largely used to describe business phenomena (Osterwalder et al., 2011), and have been heavily studied in the literature.

Therefore, it seems logical to search for a comprehensive conceptual framework of DR based on BMs. Such research could have two initial phases:

- starting from a literature review of DR, the BM elements are considered for the analytical framework; or
- a single case study is analysed from field work and compared with results of works available in literature to gather relevant information and justify the analysis.

The first research option, which involves a review of the DR literature, has major challenges. In particular, most academic publications in this domain are technology-oriented rather than businessoriented, and they tend to use the BM concept to describe new technical advancements. Another challenge concerns choosing the right level of abstraction for the BM framework (Massa and Tucci, 2013).

Among the diverse BM frameworks available, this study uses a widely cited framework as the theoretical basis to construct the scheme for analysing DRBMs (Figure 1). This framework is defined by three main elements, i.e. value proposition, value creation and delivery, and value capture (Richardson, 2008), and is a useful tool to analyse and represent general sustainable BM archetype (Bocken et al., 2014) fundamentals, BMs of shared economy (Ritter and Schanz, 2018), and influence of smart grids on BMs in the electricity sector (Shomali and Pinkse, 2016).

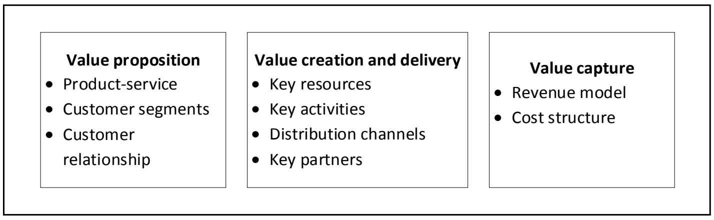

Figure 1 Three dimensions of the business model as analytical framework

The objective of the literature analysis was to explore, classify, evaluate, and compare different DRBM approaches as well as to investigate their key elements and relationships. The method consisted of the following phases: searching, data extraction, and thematic synthesis (Thomas and Harden, 2008). The Scopus search database was used to find targeted articles, and the search was limited to articles published between 2007 and the end of 2020 that included the following terms in the title: ‘Demand-side management’ OR ‘DR’ OR ‘electricity market’ OR ‘ancillary service’ OR ‘Frequency regulation’ OR ‘flexible electricity’ OR ‘energy storage’ OR ‘aggregator’ OR ‘Congestion management’ AND ‘DR’ in the keywords. The search yielded 1076 documents, from which 236 papers were selected after examination of the titles. From this group, 77 papers were selected after reading the abstracts. Ultimately, 42 papers were selected, including fourteen papers from a first-round paper’s references. The sample was summary based rather than exhaustive, as the objective was to not locate every available study, but rather to illustrate the range of concepts found in the studies. In the next phase, key concepts and relationships from the selected studies were abstracted. The synthesis took the form of three states: coding the findings of the primary studies according to their contributions to BM conceptualisation; organising these codes into related areas to construct themes; and developing analytical themes. The coding process included coding of the BM elements (value proposition, value creation and delivery, and value capture). Next, a search was conducted for similarities and differences between the codes to facilitate classification into a hierarchical tree structure. The findings of all the studies were gathered and placed in one list describing the different BM aspects of DR. Until this phase, the research did not go beyond the original studies' findings, and did not generate any additional concepts. In the next phase, descriptive themes were used, which emerged from an inductive analysis of the literature. This process was iterative and repeated until the new themes were sufficiently abstracted to potentially describe the DRBM.

A second source of data was based on a single case study approach. This work uses a case study method for in-depth investigations and insights (Yin, 1989). This single case represented a typical DRBM. The studied firm was the first independent aggregator in France and was considered an exemplary DR provider. A case study analysis was chosen as it can be fruitful when research is still at an early stage, and/or when existing theories and models appear insufficient. Specifically, an exploratory case study was performed, as the BMs for DR were an underexamined phenomenon, and there was inadequacy of empirical evidence regarding BMs (Yin et al., 1985).

Our selected case study is 'Energy Pool', a company that operates not just in France, but also in Europe, and in other countries such as Japan and Turkey. This company is well established and mature company and provides access to secondary data. The case provides information regarding the types of products, main customers, market conditions and competitiveness, key resources, and key activities.

Energy Pool was born from a call from an energy utility to its CEO in 2003, who at that time was the owner of an aluminium plant. The objective of the call was to negotiate the price of shutting down the plant, as they had an electricity shortfall from nuclear power plants caused by a hot summer and an inability to use river water to cool the plants.

Energy Pool was the first independent electricity aggregator in France. It was founded in 2009, and one year later, settled a strategic partnership with Schneider Electric. Energy Pool is an energy aggregator; it bundles industries' energy consumption and load flexibility in exchange for payments.

The empirical study was based on complementary sources: semi-structured interviews and archival data. Two in-depth interviews covering the entire set of BM aspects were conducted (3 hours, 17 minutes), and included questions related to BM elements such as key resources, capabilities, key partners, operational activities, incentives, economic models, customer segments, and market conditions. Extensive secondary data from the firm's internal sources was examined to obtain a comprehensive picture of the firm's BM dimensions. This included the firm website, social media pages, blogs, etc. Additionally, gaps were closed by including the firm's external resources, such as published articles, presentations, and news clips. The research analysis approach was based on a coding strategy. The data were coded for the different concepts and their relationships, focusing on their ties to the three BM elements (value proposition, value creation and delivery, and value capture).

Finally, five DR business cases were chosen, to cover the largest possible diversity in BMs. In Case 1, DR was used to protect parts of the distribution network (especially the feeders) from being overloaded (Ausnet, 2015), and this is an example of DR applied in the distribution grid. Case 2 was an automated DR program for a commercial logistic and warehouse company and was aimed at reducing energy cost. The program included site precooling before events, and shifting forklift battery charges to a locked mode to prevent charging during peak periods (Honeywell, 2012). This case shows the potential of DR in commercial firms. Case 3 was a hospital participating in an 'emergency resources service', using already existing on-site generation (EnerNOC, 2012), which illustrates the underused assists (on site-generation) to activate DR. Case 4 consisted of a dynamic DR pricing scheme based on a household thermostat for reducing the overall energy utility load capacity (Itron, 2018) and is an example of viability of small-scale consumers (household). Finally, Case 5 involved a paper plant that implemented an automated load response to provide primary reserve and sell frequency regulation in the energy market (Centrica, 2018). This case is an example of offering one of the most difficult flexibility products (see details in (Table 1**Error! Reference source not found.**).

Table 1 Internet cases of DR

Case	Customer	Main value proposition	Value creation	Value capture	Purchaser/ beneficiary
Case 1	Commercial and industrial regional site	Protecting parts of the distribution network from overload	Load reduction	DSO has of 22.5 MW of possible load reduction from 25 customers	DSO
Case 2	Commercial warehouse	Reduction bill cost based on dynamic pricing tariff	Load shifting of heating, ventilation, and air conditioning, forklift battery charge, etc.	Company's energy cost reduced by 30%	Energy utility
Case 3	Hospital	Providing 'emergency response service	Using on-site generation	Hospital earns $10,000 per year	TSO
Case 4	Households	Defer building additional generation units	Smart thermostat with software platform	Customers have 15% annual saving on electricity bill and utility has 46 MW reduction	Energy utility
Case 5	Paper manufacturing plant	Providing 'primary reserve'	Curtailment via the plant's automation system reacts in seconds with no human intervention required	Plant's revenue from DR participation	TSO

4. Findings

Based on the interview data, supportive examples, and literature review, nine interrelated elements of the DRBM were identified (flexibility product, market segments, service attributes, DR resources, resource availability, communication channels, DR mechanisms, cost structure, and revenue model). These elements are the bases of the DRBM framework (Figure 2).

These nine elements are analysed below, following the 'three values' structure: value proposition, value creation and delivery, and value capture (Bocken et al., 2013; Osterwalder et al., 2011; Richardson, 2008). The value proposition subsection includes the flexibility product, DR market segments, and service attributes. The value creation and delivery subsection includes DR resources, resource availability, DR mechanisms, and communication channels. The value capture subsection integrates the cost structures and revenue models.

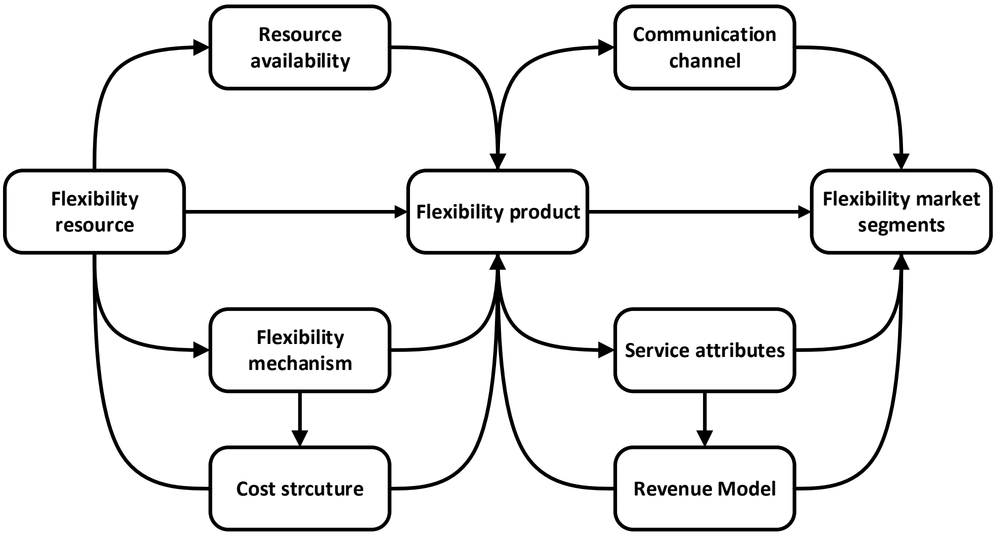

Figure 2 Demand response business model framework

4.1 Value proposition

DR value proposition is described through three main interrelated elements, namely flexibility product, service attributes, and market segment. Figure 3 outlines the main elements and the relationships among them.

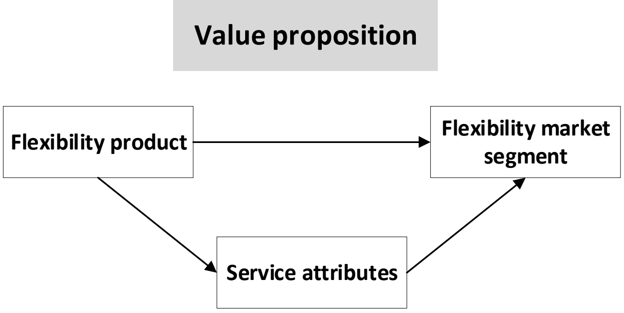

Figure 3 Demand response value proposition main elements

4.1.1 Flexibility product

The importance of DR stems from its contribution for maintaining a balance between supply and demand. The main stakeholders, e.g. TSOs, generation entities, DSOs, retailers, and consumers, seek to optimise their benefits with respect to the power system balance. Traditionally, flexibility products are created on the supply-side and are sold directly to TSOs. A common distinguishing characteristic of a DR value proposition is that it is created on the demand side, using load or distributed energy resources. Supply-side mechanisms are based on building new generation units and reinforcing the grid infrastructure, whereas demand-side mechanisms are mainly marked by modifications in the load or in distributed generation production. Accordingly, consumers and prosumers are now able to participate, and to obtain value from (i.e. valorise) their flexibility.

Flexibility comprises the possibility of modifying generation and/or consumption patterns in response to external signals (such as price or grid parameters), to mainly contribute to power system stability in a cost-efficient manner (Eid et al., 2016; Villar et al., 2018).

Flexibility products differ depending on the need that they are designed for. Flexibility in power systems is required by the TSOs to maintain system stability. When flexibility is used by market actors for optimising their revenue or their commitments, it represents a market flexibility. When flexibility is used by the TSO/ DSOs to handle critical local network situations such as avoiding, reducing, or postponing network expansions, it represents network flexibility (BDEW, 2015). Demand-side flexibility is considered as environmentally-driven approach, as it reduces our dependency on generation units (Aghaei et al., 2016).

The Energy Pool value proposition is to monetise the flexibility of large industrial plants in regards to reserve services and balancing markets. This includes two main beneficiaries: first, the industrial plants who have access to participate in the balancing market, and can therefore generate a new source of revenue; and second, the TSO, who profits from a product that increases system reliability with a lower cost. Moreover, TSOs can reduce costs via integration, and by allowing DR aggregators to participate in certain markets.

Seven major value propositions are addressed: capacity provision, system reliability, market efficiency, congestion management, load shaping, procurement improvement, and valorisation of customer flexibility (Bakr, 2019; Behrangrad, 2015). These value propositions are concerned with one or more power system actors (Figure 4), and under each value proposition, a more customised product can be produced based on the purchaser’s need.

Value proposition/ Power system actors	System operation	Generation	Transmission & distribution	retailer	Consumer
Capacity provision	Meeting the demand the future and current demand power capacity			Ensuing not go over the provided capacity and mitigating future capacity procurment	
System reliability	Maintaining power system balancing in short-term				
Market efficiency	Neutralize the exercise of market power and eliminates price spikes				
Congestion management			Reduction in infrastructure reinforcement and delay in network investment		
Procurment improvement				Avoiding purchasing from spot market during supply shortfall or forecast error	
Load shaping		Reducing imbalance cost espcailly for renewable energy resources		Increase load in some period and decrease it in another period to minimize procurment cost	
Valorising customer fleixbility					Having financial incentives from selling load flexbility to the TSO e.g. large industrial consumers

Figure 4 Value propositions of power system actors

4.1.1.1 Capacity provision

The system adequacy is the ability of the system power capacity to meet the total system load demand. As the capacity depends on demand peaks, during peak times, the DR can contribute to load reduction, reducing the required capacity and potentially displacing the need for generation capacity (Hegazy et al., 2003; Lynch et al., 2019; Zeng et al., 2017; Zhou et al., 2015). The capacity market is open to both supply-side and demand-side resources, e.g. successful participants receive a fixed revenue stream in exchange for an obligation to generate electricity or for an obligation to activate reductions during times of grid stress (Charles River Associates, 2017).

4.1.1.2 System reliability

Given the expected/unexpected changes in demand and supply, system reliability concerns the ability of DR to leverage flexibility and maintain system consistency from the demand side (Aghaei et al., 2016; Safdarian et al., 2014; Wang et al., 2017). This requires supplementary reserves (i.e. in addition to the generation units) that can be available during times of power system stress. These reserves are termed also ancillary services, and support very short variations in grid balance. In Europe, they are divided into three types: frequency containment reserves (FCR), frequency restoration reserves (FRR), and replacement reserves (RR). FCR (i.e. primary reserves) are used to stabilise frequency within a time frame of seconds, using automatic control and local activated reserves. FRR (secondary reserves) are used to restore system balance within an activation interval of seconds to 15 minutes, through automatic and central control. RR (tertiary reserves) are activated to restore the system balance and compensate for the FRRs, allowing the FRRs to be ready for the next short-term imbalance intervention. RR are controlled manually and are activated locally with a range of minutes to hours.

Another contractual service concerns interruptible load direct loads, and permits the TSO to curtail or reduce consumer load. This is usually a contractual agreement among some or all of the TSO, DR provider, retailer, and consumer, in which the provider directly controls the operation of the consumer's appliance (upwards or downwards) (Eid et al., 2016). This value proposition is suited for a short-term provision of flexibility and requires a very precise location of the activation.

4.1.1.3 Market efficiency

Market efficiency is the ability of the DR to reduce suppliers' market power and limit the ability of large producers to manipulate the prices of electricity (Paterakis et al., 2017; Siano, 2014). DR can neutralise the exercise of market power and eliminate price spikes (Rassenti et al., 2003).

4.1.1.4 Congestion management

Congestion management uses DR to reduce network overloading, and to reverse power flows from RESs in congested regions to avoid congestion in transmission and distribution networks (Amicarelli et al., 2017; Villar et al., 2018). The flexibility of the distribution network can contribute to load reduction in a less costly manner than a long-term network expansion; thus, the DSO benefits from avoiding network expansion (BDEW, 2015). For example, 'PowerMax' is a service for aggregating and controlling active power consumption, and for maintaining it below a current maximum value (Rahnama et al., 2017). In this manner, DSOs can ensure that network parts will never be loaded over a specific value, especially during the winter months of the year, when those equipment are exposed to higher overload risks.

4.1.1.5 Procurement improvement

Electricity retailers are exposed to market risks of financial losses when the wholesale price exceeds the fixed retail tariffs. This happens when retailers face a shortfall as a result of a load change or a load forecast error. Then, they must compensate by going to spot markets, where prices might be higher than their marginal cost. In this case, DR mechanisms such as load reduction or load shifting can limit or eliminate the electricity amount that must be bought from these risky markets (Ghazvini et al., 2015; Mahmoudi et al., 2014).

4.1.1.6 Load shaping

Load shaping is the capacity of the DR to achieve a desirable load, i.e. decreasing loads in peak times and increasing load in off-peak times. The result is a direct value proposition, as it decreases energy costs and increases profits for retailers, generation units, and consumers. Moreover, indirect value is also created, via increasing the power system balance for the TSO (Ioakimidis et al., 2018; Wang et al., 2019). Generation units, specifically renewables, can improve their market positions by reducing the uncertainty of production. Large renewables are exposed to additional costs from balancing of the forecasted production (market commitment) with real-time generation. Using storage facilities can improve the management of wind fluctuations and store otherwise curtailed wind energy. Storage can also provide an ancillary service by supporting the position of the wind farm in the reserve market (Rodrigues et al., 2016).

4.1.1.7 Valorisation of customer flexibility

DRPs provide access to the energy market by valorising load flexibility. The DRP provides a communication infrastructure and response plan; then, consumers obtain incentives for their participation (Ikäheimo et al., 2010). Large industrial plants mostly fit into this category. Herein, the DRP's roles are to help the plants activate their latent flexibility, and to allow them to participate via the aggregation of multiple plants. However, there are some issues related to industrial plants that might challenge the DRP. First, the process and equipment might have interdependencies between them, and any changes in the schedule of one process might influence the others. Second, electricity consumers have concerns regarding the protection of their usage data (Samad and Kiliccote, 2012). In the Cases 1, 2, and 4 shown below, customers are rewarded for responding to a critical peak pricing (CPP) scheme by occasionally shifting the timing of their operations to later in the evening. Explicit DR rewards are provided for customers in Case 1. In Cases 2 and 4, the DRP helps customers by providing a system that automatically responds to pricing changes. Table 2 indicates the flexibility products used in each case analysed in this study, as well as the market segment addressed by each actor.

Table 2 Internet cases of DR

Case	Flexibility product	Market segment
Energy Pool	System reliability	Reserves service
Case 1	Congestion management	Price responsive market & direct contract with the DSO
Case 2	Valorising customer flexibility	Price responsive market
Case 3	System reliability	Reserves services

Case 4	Valorising customer flexibility	Price responsive market
Case 5	System reliability	Reserves services: Primary reserve

4.1.2 Demand response markets

DR flexibility products can be traded with a purchaser directly through a contractual agreement, or indirectly through electricity markets, which can be categorised into four major types according to the time horizon: capacity planning, electricity wholesale market, ancillary services, and price-responsive market.

Capacity planning: Capacity markets are set up to ensure that there is sufficient supply when there is a major need.

Electricity wholesale market: In general, the wholesale electricity market comprises three blocks, according to the time horizon (Wang et al., 2015).

- The day-ahead (DA) market allows participants to bid, before each operating day, to ensure that their commitments are met.
- Intra-day markets are continuous markets for handling uncertainties (e.g. weather changes) after the close of the DA market. These markets enable market participants to correct their DA capacity bids. They are important in responding to changes in the renewable generation. In Europe, these are usually activated every hour.
- Real-time (balancing) markets send dispatch and price signals to market participants over short intervals (e.g. 5 min) to balance system loads, maintain system reserves, and resolve system congestion. The balancing market can be split into procurement and activation of reserves.

Ancillary service market: Reserve markets are markets that deal with short-term imbalances by dispatching resources within minutes or seconds. Ancillary markets comprise the three types of reserves (KU Leuven, 2015; Wang et al., 2015) mentioned above:

- FCR are used to stabilise the frequency within a time frame of a few seconds, using automatic control and locally activated reserves;
- FRR are used to restore the system balance within an activation interval of a few seconds to 15 min, via automatic and central control; and
- RR are used to restore the system balance and compensate for the FRRs, allowing them to be ready for the next short-term imbalance intervention. RR are controlled manually and activated locally, with a range of minutes to hours.

Energy Pool is mainly active in three markets: the capacity market, wholesale market, and reserve market. The reserve market includes the first, second, and tertiary reserves. In the first and second reserves, the firm provides frequency regulation in intervals between a few seconds and 15 min. In the tertiary reserves, the firm adjusts the loads in intervals greater than 15 min.

Price-responsive markets: This market segment allows DR customers to voluntarily respond to changes in electricity prices, and to limit their overall consumption when economically viable and attractive. In this regard, price-based DR programs are based on dynamic pricing mechanisms, in which the price fluctuates to reflect the real-time electricity cost. Typically, the price is increased during peak hours and is reduced during off-peak hours. This scheme has three general distinct mechanisms (Meyabadi and Deihimi, 2017). First, 'time-of-use,' in which the rates of electricity per unit consumption differ in different blocks of time (e.g. peak and off-peak blocks). Second, critical peak pricing, in which higher rates are imposed for critical periods. Consumers are informed of these price rises in advance, typically a day ahead. Finally, a real-time pricing mechanism charges consumers on an hourly basis, with pre-defined rates announced a day or an hour ahead.

4.1.3 Service attributes

While market segments address the needs of customers, service attributes refer to a set of factors influencing the flexibility products. If an available resource is used to provide a DR service, both the provider and producer should agree on five parameters (response speed, response duration, advance notice, utilisation rate, and load direction), as described below (Villar et al., 2018).

The *response speed* addresses the time interval between receiving the signal and activating the DR. For example, contingency reserves must be activated in few seconds or a few minutes.

The *response duration* defines the maximum and minimum activation durations. For example, in a replacement reserve, the load curtailment duration is long, e.g. up to multiple hours.

Advance notice indicates the time of the advanced notice prior to DR activation. For example, a replacement reserve has an advanced notice of 30 min.

The *utilisation rate* represents the frequency of the DR service exercised by the purchaser. For example, frequency regulation is a nearly continuous service; thus, it has a significantly high frequency rate.

Finally, the *load direction* indicates whether the customer must provide an asymmetric or symmetric service. The former indicates the ability of the resources to offer either a decrease or increase in the power output, whereas the latter concerns the provision of power output in both directions. For example, a frequency regulation service must run symmetrically, i.e. providing up-regulation as well as down-regulation.

4.2 Value creation and delivery

This subsection addresses the DR resources and their availability, DR mechanisms, and communication channels.

The DRBM core value creation is centred around ‘coupled services’ that link ‘timing’ with either a tangible resource (e.g. electric vehicles (EVs)) or an intangible resource (e.g. load) (Helms et al., 2016). Accordingly, the value creation consists of first identifying a resource that has potential to provide flexibility. Second, the timing of the supply and demand must be considered. While supply-side resources are often ready to provide a DR service, demand-side resources are often restricted and limited in their time and capacity; therefore, resource availability should be considered. The different types of resources and variations in purchasers’ needs and consumers’ constraints indicate that DR can employ different mechanisms to overcome these limitations. Finally, a communication channel is required to send and receive information concerning, e.g. electricity consumption, curtailment duration, advanced notice, and payment. The elements of value creation and delivery of DR are illustrated in Figure 5.

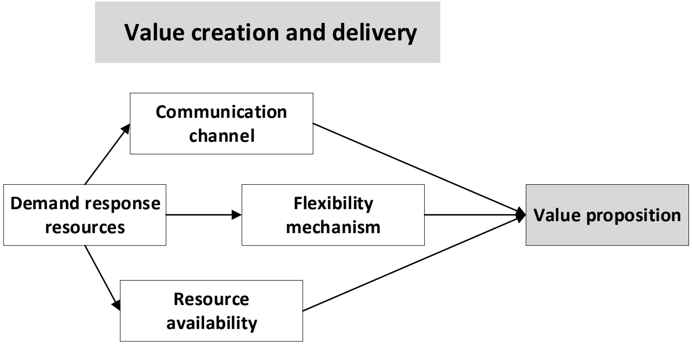

Figure 5 Elements of value creation and delivery of DR

4.2.1 Resources

Conventional DR resources, such as gas power plants, use fossil fuel as the main resource for generating flexibility. In contrast, a variety of resources can be found in innovative DRBMs. To meet the system flexibility needs, there exist power resources and energy resources. Power resources can provide the electricity system with a high-power value but cannot maintain this value for long durations. In contrast, energy resources can maintain a change in the power level for a longer duration (Eid et al., 2016).

Resources can be asset-based, such as in distributed generation and RES, or consumer-based (loads) (Helms et al., 2016). In this study, DR resources are classified into three types: demand-based, supply-based, and storage-based. Different types of customers can provide these valuable resources. The customers of demand-based resources are categorised into three main segments according to the average electricity consumption levels: residential, commercial, and industrial (Arias et al., 2018). Storage-based customers are actors that have invested in electric storage systems. These storage systems can be installed with flexibility as the main function, but can also serve as indirect storage-systems, where flexibility generation is a secondary function (e.g. EVs). A supply-based resource can be a renewable energy producer (e.g. a wind farm) or a prosumer (e.g. a household with a solar photovoltaic roof panel) (Ramos et al., 2020).

The above-mentioned resources are not independent of each other and are entirely available. For instance, residential customer consumption must obey the energy needs of a home; commercial customers depend on electrical energy for the sale and purchase of goods and services; and the usage of energy of industrial customers is tied to the conversion of commodities into commercial goods (Arias et al., 2018). Therefore, resources are influenced by their availability (see next subsection).

Energy Pool indicates that one of the most important BM inputs concerns the identification of the flexibility resources (e.g. industrial sites), and the setting up of an IT platform to enable operations on the flexibilities. The DR resources can be varied (see Table 3): 25 regional commercial and industrial sites in Case 1, a logistics and warehouse company with a monthly bill of $30,000 and a 500 KW load during the demand peak in Case 2, a hospital with a monthly bill of $70,000 in Case 3, 19,000 residential customers in Case 4, and a paper plant with an annual production of 5.7 million tons in Case 5. Notably, most of the employed resources are demand-based. However, in Case 2, the DRP took advantage of the building thermal capacity storage by precooling the site before a DR event during summer and preventing forklift batteries from being charged during peak hours. In Case 3, a rarely used on-site electric generator was used as a supply-based resource to enable the hospital to participate in DR.

Table 3 Demand response resources from studied cases

Case	Resource type	Resource
Energy Pool	Demand-based	Several national industrial plants
Case 1	Demand-based	Several regional industrial and commercial plants
Case 2	Demand-based and storage-	Logistic and warehouse company

	based	
Case 3	Demand-based and supply-based	Hospital
Case 4	Demand-based	Thousands of households
Case 5	Demand-based	Paper plant

4.2.2 Resource availability

In a business-as-usual flexibility system, customers are always available to provide the required demand, and are always interested in selling the maximum amount of energy. For example, in the case of fossil fuel plants, the resources are designed to be fully available, and are used for flexibility purposes during a few peak hours per day, making them inefficient. In innovative DRBMs, customers (consumers, prosumers, distributed energy resource owners) may not always be available to participate in DR operations, as they have other prioritised activities, or their commitment may be limited (Eid et al., 2016). The availability of EVs to participate in the DRBM can differ depending on the owner and period, and it is difficult to predict the availability of all the EVs in a fleet at a given time (Bhandari et al., 2018). Privately owned EVs are mainly available during evenings and weekends, i.e. approximately 50% of the weekly time. However, this share may rise to 90% if charging stations are available at the workplace. Furthermore, the option to switch off a residential refrigerator is limited, as excessive switching may damage or reduce the quality of food inside (Lakshmanan et al., 2017). Micro/combined heat and power units have an availability of 100%, as they are dedicated to producing heat and electricity. However, they are restricted by ecological and economic considerations, as they are fuelled by gas.

The availability of industrial resources is associated with the risk of having a negative impact on the customer’s core business. This risk can be outsourced by providing a strong assurance that customers will not be disrupted (Cardoso and Torriti, 2018), and developing smart intervention measures (Helms et al., 2016).

Availability relies on the ‘energy cost’ expenditure percentage of the total operation cost of the customer's business activities. Customers who have high energy costs, such as industrial plants, tend to have a higher economic motivation than customers with low energy costs, such as residential and commercial customers.

Demand-based resources rely on the behaviour of the consumer, which in turn depends on many different and time varying external factors, ranging from the weather to whether the consumer cooks dinner using an electric oven or a gas cooker (O’Connell et al., 2014).

Energy Pool demonstrates that new customers tend to not commit to an ‘availability contract’ because they are unsure whether they can curtail or reduce their consumption at any time, and they are unaware of the potential consequences of the production. In such cases, these customers prefer a ‘call contract’, in which they can accept or refuse a DR event. Thus, Energy Pool's role is to identify solutions that do not affect the production lines. Other customers, who are more confident regarding DR consequences, can commit to both types of contracts. In such cases, the roles of the DRPs in creating availability are extremely important, as they have the required experience. Within the industrial plant sector, Energy Pool distinguishes between three type of plant processes. First, in a ‘continuous process’, it is simply impossible to stop operations to fit with emergency situations. Second, a ‘complex process’ can be stopped with cautious operations, and its availability depends on the price. Finally, ‘side-processes’ have a large storage capacity and can be stopped almost daily.

4.2.3 Mechanisms

The literature review indicates that several mechanisms can be used in value creation processes. This subsection introduces the seven main mechanisms in value creation: aggregation, virtual power plants (VPPs), up-scale control, complementary resources, load shifting, load reduction, and standby DR.

The first key mechanism is ‘aggregation’, which offers the opportunity for small-scale energy customers to exploit their potential (Carreiro et al., 2017). Aggregation is a commercial function comprising pooling load flexibility and promoting small-scale energy customer access to electricity markets (Eurelectric, 2014; Villar et al., 2018). An aggregator is an intermediary between customers who provide flexibility and the procurers of this flexibility. Aggregation permits Energy Pool to have 600 MW of power available in the French electric grid, to provide power system reliability. Energy Pool uses aggregation for low-capacity industrial plants to increase its economies of scale, thus achieving a competitive advantage. Aggregation includes selecting the appropriate participants, as they differ in terms of their consumption patterns. Then, it examines their availability to participate, and finally affirms that the sum of MWhs fits the purchaser’s needs (see Figure 6). Aggregation is used within most of the cases. In Case 4, the dynamic pricing scheme of the energy utility permits the aggregation of 19,000 households and generates an energy reduction of 46 MW during peak hours. In Case 1, 25 commercial and residential sites participate in a regional DR program, generating 22.5 MW of load reduction.

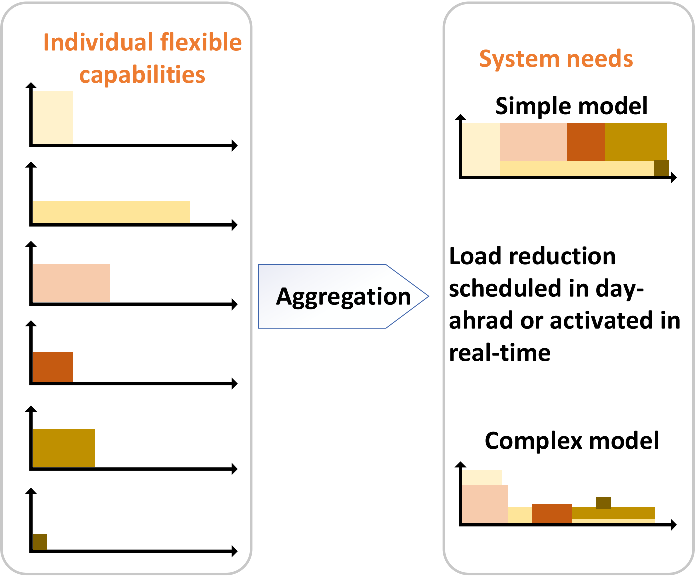

Figure 6 Aggregation process. Source: (Ichimua and Denis, 2016)

The VPP mechanism represents a distributed energy system that acts as an equivalent to a centralised power plant. This system uses a large number of generation units aggregated and interconnected in a centralised system, to achieve sufficient capacity as valorised on the wholesale market (Helms et al., 2016). A VPP can provide, for instance, centralised control over a fleet of EVs in times of parking, to subsequently trade their aggregated flexibility on the electricity market (Bhandari et al., 2018). This mechanism enables small-generation actors to participate in synchronisation activities and to gain a fee by offering their flexibility. The transaction cost for the DRP is high, as it entails managing a large number of small-scale producers.

'Up-scale control' refers to taking control over a large number of electrical assets to maintain their aggregated power consumption at a given upper limit (but lower than the typical value), without restricting the ability of the individual assets to function. An example of this mechanism is taking control (ON/OFF) over a number of residential refrigerators to maintain their aggregated power consumption at a given set-point value, without violating the temperature limits of the individual refrigerators. This can be achieved, as a refrigerator has the ability to store a temperature effect based on thermal inertia (Lakshmanan et al., 2017).

In some cases, considering only one type of resource hinders the exploitation of latent flexibility. 'Combining different and complementary resources' can increase the potential for generating a sufficient capacity, which would not be generated if each resource were to be considered alone (Rahnama et al., 2017). For example, a supermarket refrigeration system and chiller supported with ice storage can be used together in an experiment, to provide PowerMax service to a DSO. The two resources work alternatively. The sequences of actions can be described as follows. Before the service activation, the chiller makes ice during the off-peak hours and stores it in an isolated tank; this ice is used later for providing cooling while the chiller is off during service activation in on-peak hours. The refrigerators do not have the capability to store energy for a long duration; therefore, the process of reducing consumption is run by switching between the two consumption resources. When the chiller is off, the refrigerators can increase their consumption and store energy in the thermal form, in the form of refrigerated food. Afterwards, the chiller is turned on, and the refrigerators decrease their consumption to the minimum, thereby taking advantage of the saved energy (Rahnama et al., 2017).

Load shifting is a mechanism for enabling consumers/ prosumers to shift their load consumption to off-peak periods (Shaheen et al., 2016), or to periods with high renewable energy production (Yao et al., 2016). Scheduling the consumption of prosumers with rooftop photovoltaic systems and shifting their deferrable loads to hours with high solar power generation can lead to reductions in the energy expenses of users, and mitigate voltage rise problems in the distribution network (Yao et al., 2016). Load shifting is used in most of the studied cases (Table 4). In Case 1, the objective was to shift the consumption to the off-peak hours during the afternoons and evenings of hot summer days (above 35 degrees Celsius). In Case 2, the objective was to shift from a high-price time to a low-price time, as the company is exposed to up to 12 peak demand events each summer. Load adjustment refers to responding to a grid signal by adjusting the power of the resource (either up or down). The thermal storage of a heating, ventilation, and air conditioning system can be used to provide a frequency regulation service by adjusting a load up or down following a TSO signal (Zhao et al., 2013). Load adjustment is used in Case 5 as a primary reserve, requiring power adjustments up and down to provide frequency regulation services.

Load reduction indicates a reduction in the demand during peak times; in contrast to load shifting, the load is not activated outside of the peak periods.

Standby DR refers to specific means that provide another function but can also be used as DR mechanisms. For example, on-site generators are common for emergency uses across industrial and commercial facilities (Charles River Associates, 2017). This mechanism was used in Case 3, wherein there were underused generators with a 300 KW capacity.

Table 4 Demand response mechanisms of studied cases

Case	Mechanism
Energy Pool	Aggregation and load shift
Case 1	Aggregation, load shift, load reduction, and

	standby DR
Case 2	Load shift
Case 3	Aggregation and Standby DR
Case 4	Aggregation and load shift
Case 5	Aggregation and automated load adjustment

4.2.4 Communication channels

Energy Pool indicates that one of the most important BM inputs is the IT platform, i.e. the system facilitating operations regarding the flexibilities and connections between the involved parties.

The DRP, as a market intermediate, performs many activities: it registers participants and communicates with them, meters consumption, transfers the metered data, implements standards for metering and verification, ensures the security of data, and calculates participants' remunerations (Radenković et al., 2020). In a DRBM, the communication channel comprises the activities and technologies permitting the integration of DR, both technically and economically (Arias et al., 2018).

The basic requirement for a DRBM is a communication network enabling a bidirectional relationship and information exchange between customers and a DRP or system operator. The communication system can also include technologies for providing more predictable and efficient responses in a pre-set mode. These technologies are mainly used in EV charging/discharging, heating control systems, and ventilation and cooling systems. By coordinating the actors, optimisation technologies can maximise the economic benefits for participants, and minimise the risks of instability in the system.

4.3 Value capture

The main economic challenge in DR operations is in generating a sufficient income to cover the expenses of every firm creating and delivering DR value. In business-as-usual, the value is mainly captured by the provider; in DR, the captured value is shared by both the provider and customers. The DRP generates revenue, and customers receive remuneration for their participation. Customers are remunerated either by having their energy consumption altered according to price variations (price-based program) or by receiving direct income from modifying their load for a certain period following DRP or system operator signals. The key elements of value capture are described in Figure 7.

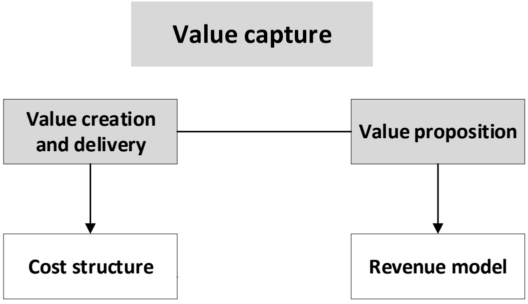

Figure 7 Elements of demand response value capture

As an example, on June 2nd, 2016, Energy Pool managed to curtail and sell 561 MW in France over 2 h, based on the participation of 46 industrial sites, equivalent to more than 2.200 million inhabitants (Energy Pool, 2016) (Figure 8). In Case 1, the DSO had a portfolio of 25.5 MW, which was adapted to meet the changing network requirements. In Case 2, a commercial company achieved a 30% reduction in its electricity bill. In Case 3, a hospital earned $10,000 annually by selling its availability to provide emergency DR services. Residential customers reduced their electricity bill by 15%, and an energy utility reduced its required capacity by 46 MW and 32 MW in winter and summer, respectively.

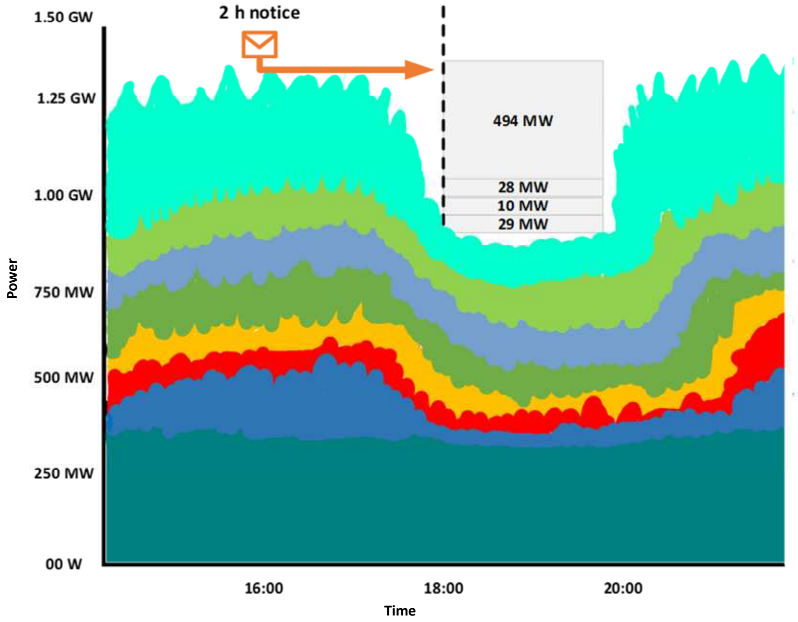

Figure 8 Energy pool curtailment on June 2nd 2016. Source: (Energy Pool, 2016)

In the case of controlling a set of residential refrigerators, the aggregator was able to reduce the value of the aggregated power by 27% for 2 h (Lakshmanan et al., 2017). This power reduction is a flexibility product, and can be traded on the electricity wholesale market or reserve market. The income is divided between the participating refrigerator's owner and the aggregator. The DRBM must be profitable for both the customers as well as the DRP. In the case of using a fleet of EVs to provide ancillary services in wholesale markets, the BM is profitable to the DRP, but the EVs may lose money;

this is mainly owing to the low prices in the electricity market and the high price of EV batteries (Bhandari et al., 2018).

Energy Pool offers customers two main contracts: ‘availability’ and ‘call’. In the former, the consumers put their availabilities at the disposal of Energy Pool, and stand by for a consumption shift. Often, they have a pre-determined capacity and price. However, the fee may be reduced by a penalty if the consumer is ultimately unavailable. In the latter, Energy pool calls the consumers and asks for a load shift by making an offer. In this case, the consumer is paid according to his/her performance. If the consumer is engaged in a program entailing availability payments and calls, he/she cannot refuse performance (or must face penalties).

The cost considered in the DRBM is mainly the initial participant cost. This comprises the activation cost, and includes the costs of investing in the enabling technology and establishing a response plan (Cardoso and Torriti, 2018). This main cost can be categorised into two types: transaction cost, and intervention cost (Helms et al., 2016).

The market transaction cost includes the costs of collecting information regarding products and customers, managing contracts, and procedures for external transactions. The DR transaction cost represents the costs of spending time identifying potential resources that can adjust their electricity consumption, understanding their electricity consumption patterns, assessing their suitability for participation, selecting the appropriate flexibility product, and evaluating the cost and benefits of each customer (i.e. the net return) (Cardoso and Torriti, 2018). The transaction cost is high when the DRP manages and aggregates a large number of customers.

The intervention cost is related to behavioural adaptation, and is based on the fact that consumers are traditionally unpredictable, and are not used to dynamically and temporally adapting their consumption processes (Helms et al., 2016). Supply-side resources have no intervention cost, as they can be managed easily.

5. Demand response business model canvas

5.1 Business model as a visualisation tool

Visualisation is a key approach for designing and analysing BMs (Osterwalder, 2004). Visualisation can support firms in better understanding and communicating their BMs, developing and generating new ideas, and overcoming organisational innovation barriers. They can stimulate collaborative innovation, reduce complexity, and enable improved knowledge sharing (Täuscher and Abdelkafi, 2017). Designing a visualisation tool for the management or engineering sciences poses several challenges, such as with regard to complexity, business-dominant logic, and knowledge (Eppler and Hoffmann, 2013).

Visualisation enables the communication of complex information. Aggregated DR has been described as a complex BM in the European electricity market (Koliou et al., 2015) that requires coordination between a large number of stakeholders (Sisinni et al., 2017). A DR project within an organisation requires the approval of multiple parties, i.e. not only the energy manager but also several decision makers, such as the financial and operational departments.

BM support is often employed during innovation processes by providing visualisation tools that challenge managers to change the status quo of the business, and to overcome the influence of the dominant logic. The goal of the intended canvas is to reinforce business flexibility on the demand side, rather than relying on the supply side. Additionally, it aims to support managers in considering latent load flexibility businesses. Accordingly, load flexibility can potentially be exploited in various industrial, commercial, and residential electrical activities, and each activity can contribute to the flexibility of the grid according to its capacity.

Visualisation tools, such as canvases, can also support knowledge elicitation and creation. According to Eppler and Hoffmann (2013), these tools generally stimulate thinking, foster shared thinking, and trigger memories. The intended canvas can trigger knowledge by disaggregating the DRBM and visualising its key elements. Furthermore, as they are interactive tools, visualisation tools can support managers in idea generation, decision making, planning, and knowledge sharing. These tools serve as devices between the managerial thinking and the economic activities (Martins et al., 2015) and business modelling as cognitive actions aimed at representing business activities in a simplified form that cognitively manipulate the BM to discover and evaluate alternative ways to be designed (Aversa et al., 2015).

Building on the conceptualisation of the DRBM, this study proposes the demand response business model canvas (DRBMC) as a practical tool for representing the main DR aspects required for creating economic value. The DRBMC was created to allow users to explore a more holistic BM. The canvas comprises nine elements: demand-side resource, resource availability, flexibility mechanism, communication channel, flexibility product, service attributes, flexibility market segment, revenue model, and cost structure (Figure 9).

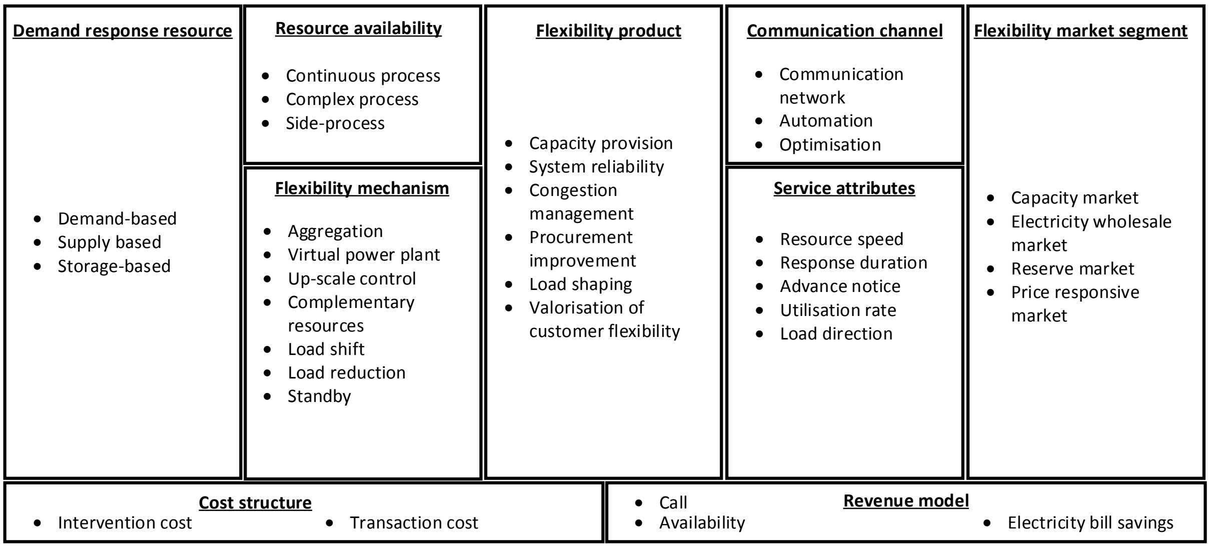

Figure 9 Demand response business model canvas

5.2 Application of the tool

Electric mobility is expanding at a rapid pace, and the sale of electric cars has recently doubled (IEA, 2019). New start-ups capture value by offering added values, such as Mobility as a Service. With the increasing challenges faced by power system reliability, DR services within the electric mobility field appear to have significant potential.

The tool's practicality is examined in this section by applying the canvas to a case of EVs providing DR service. The described BM is defined as a BM that generates economic value from coordinated and aggregated charging/discharging EVs by providing services in response to the grid requirement and needs of the system operator using intelligent communication infrastructure (Zheng et al., 2019). The main benefits of using this tool are to obtain a more profound understanding of the constituting elements of the proposed canvas, outline the its strengths and overcome its weaknesses, and to attempt to support the paper's main proposal. The data used in this application is obtained from the literature on EV DR. Given that the canvas comprises nine blocks, each one of them is discussed in detail. The detailed representation of the EV BM is illustrated in Figure 10.

5.2.1 Canvas of electric vehicle business model

Exercising DR on the charging of EVs can produce different ***flexibility products***, among which the most dominant one is frequency regulation. This service necessitates that the resource be able to charge and discharge (DeForest et al., 2018), which is consistent with the characteristics of EVs. The application of the DR load shaping mechanism on EVs can delay or avoid the upgrade of the distribution transformers in a particular region by preventing their overloading (Shao et al., 2011). EVs have the potential to advance the integration of wind power within the grid. EVs can absorb the access energy production that is otherwise wasted or curtailed, thereby improving the economics of wind energy generation (Richardson, 2013). Application of DR on a building with an EV parking lot shows that coordinating the charging/discharging contributes to the building's peak shaving, shifting the consumption to the off-peak hours (valley filling) (Ioakimidis et al., 2018).

The BM has clients in two major ***market segments***: price response and incentive based DR. An example of the former is 'time of use,' which indicates three different prices for the off-peak, mid peak, and on-peak periods, respectively. Herein, the objective is to maximise battery charging during low price periods. EVs, in incentive-based DR, can provide frequency regulation and reserve services. The latter is highly affected by the parking patterns, such as those in residential areas, and commercial and industrial areas (Nezamoddini and Wang, 2016).

EVs are a ***key resource*** for this BM. However, EVs can be coupled with other load or generation facilities, formulating an unlimited range of new resources. Herein, there are EVs of the residential sector, which refer to EVs owned by different individuals and an organisation or company EV fleet. DR resources are affected by the type and location of charging. Some EVs are charged at home during the night, some are charged near workplaces in the morning and afternoon, while others are charged in parks, with different charging timings (Sadeghianpourhamami et al., 2018).

On average, a private EV is parked for 95% of its lifetime, which indicates its greater ***availability*** among other resources. However, this BM may impose some constraints on the participating EVs. For example, in a symmetry regulation service, the optimal state of charge is 50% to reserve capacity for participating in both charging as well as discharging activities. This may influence the mobility of participants, thus reducing their comfort level. Moreover, this BM may result in generating additional costs for the building that the EVs are charging from, mainly due to exceeding the monthly power demand charges (DeForest et al., 2018). Resource availability is also associated with behavioural patterns of participating assets. Residential and industrial parking lots are suitable for DR services aiming at absorbing the surplus of renewable energy, as they tend to have capacity availability after midnight. In contrast, commercial parking lots tend to have capacity availability during the daytime; thus, they are suitable for load curtailment or discharging. However, the latter is less preferable owing to the frequent leaving and joining patterns (Nezamoddini and Wang, 2016)

The isolated contribution of an individual EV to the power system is negligible, and the effects of small-sized consumers in the electricity market are inefficient. Therefore, using a ***mechanism*** that increases the efficiency of the resources is a prerequisite. The coordination and management of the charging and discharging activities of a large number of participating EVs offer access to markets. An aggregator service between the system operator and vehicle owner enables a mutually beneficial coordination between the EV owners and the power system (Deng et al., 2020). This mechanism enables the management of aggregated battery loads from thousands of connected vehicles to achieve a sufficient tradable capacity (Weiller and Neely, 2014).

One of the major requirements for the implementation of this BM is a two-way ***communication infrastructure*** between the customer and the target market segment. For example, to protect the transformer in the distribution network from overloading, a load-monitoring device is needed to sense its loading level. The implementation of DR requires a direct communication between the vehicle, aggregator, and grid operator. This BM necessitates the remote and automatic control of vehicle charging and discharging. Studies on EVs demonstrate that the EVs' capability of quickly ramping up and down fits well with the ***service attributes*** of the secondary regulation service requirement (e.g. a reserve power that responds within 30 s).

Calculating the cost of resources and activities that are needed for the operation of a business is a decisive step. Therefore, a ***cost structure*** of the EV is considered, which represents the following. First, the cost of the participating EV in DR includes the additional electricity charge for load charging and the depreciation cost of the batteries. Second, the customer's remuneration is an essential aspect of the cost that is associated with the percentage paid to the customer and the price-based payment (varying vs. fixed retail) (Bhandari et al., 2018). Finally, the cost of infrastructure for maintaining communication and building response plans. There is a considerable cost associated with the aggregation and coordination of a large number of participants. However, automation can a play key role in reducing this cost.

The financial value derived from EVs can be represented as different ***economic models***. In the incentive-based DR, such as reserve services, the DRP receives the capacity payment and energy payment from the system operator. The capacity payment is determined by the maximum capacity that can be provided during the contract (KW), whereas energy payment is determined by the actual dispatched energy (KWh).

Non-commercial privately owned EVs used for energy trading in the spot market can create significant energy cost savings. However, this reduction in cost savings depends on technological characteristics as well as household size, office hours, and commute in terms of the distance covered. The participants have a higher financial return in the bidirectional service than in the unidirectional service (Meisel and Merfeld, 2020). Benefits of DR using peak shaving are the greatest for power plants in comparison with other participants, such as system operators and consumers (Li et al., 2020).

These are the range of options available to implement the DR service. The canvas shows the socio-economic elements of EVs applied to DRBM and reflects the currently existing and missing configuration within the BM. Considering this holistic approach, the canvas tends to support researchers in identifying new research gaps and EV start-ups to find new market niches and services.

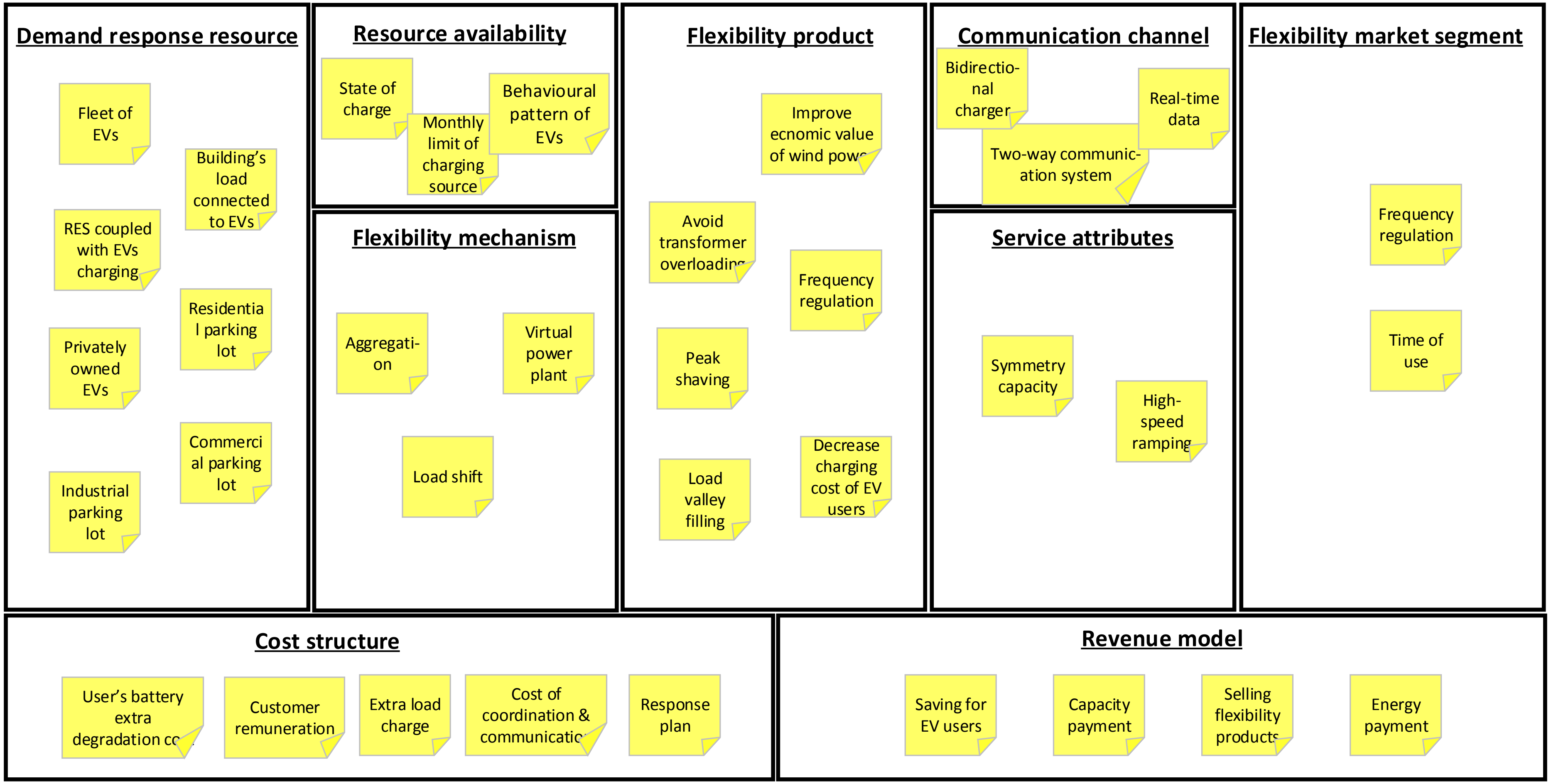

Figure 10 Electric vehicle demand response business model representation

6. Discussion

This paper presents a visualisation tool, through the conceptualisation of DRBM, for linking the BM theory to the research on power system flexibility. It focuses on researchers and practitioners working on the active engagement of demand-side loads and distributed energy resources in the context of low carbon power system transformation. The purpose is to assist in recognising and creating BMs in emerging electricity markets to reduce the environmental negative externalities of the electricity consumption and production. The DRBMC has the potential to outline uncaptured values from the DR domain and to reduce unfamiliarity and risks of its implementation.

DR implementation in the activities of firms is mainly determined by the cost of smart communication technologies and the emergence of new income sources. However, one key factor of success of DR is the ability to achieve temporal reconfiguration of the daily practices of a firm. Thus, DRBMC is designed to support researchers and decision-makers of firms in evaluating the potential of DR from technical, organisational, and business perspectives.

DRBMC identifies flexibility product categories, which are envisaged to provide assistance in assessing options and comparing their feasibilities, as well as reducing the electricity market complexity. DRBMC indicates the selected flexibility product and outlines the product's specific requirements, including duration, response speed, utilisation rate, notice period, and load direction. Selecting the right product is important, as the revenue model can differ considerably depending on the product. DRBMC can support firms housing additional equipment (e.g. metering system) that meet the DR service performance requirement, such as responding in a specific timeframe and interacting with firms' existing equipment. This entails a capital cost of equipment investment or upgrading. The canvas enables the comparison of different scenarios in terms of the required investment and return from electricity markets.

Offering new flexibility products poses a risk to the participating firms. In general, although flexibility products generate new revenue models, electricity flexibility is perceived as being not related to the firm's core business activities. Managers have concerns regarding the reduction in service level owning to DR service intervention and its impact on firm performance. This perception of DR may be because it is an unfamiliar concept. DRBMC captures this risk by referring to the availability level of the customer. DR can be more attractive once customers can commit and be available. This commitment can be optimised through the identification of an appropriate mechanism.

The emphasis on DRBM reflects its position and importance in increasing the sustainability of power systems. DRBMs can function as important catalysts in the transformation towards low carbon power systems. Considering the sustainable archetypes developed by Bocken et al. (2014) and the categories of BM innovations for sustainability, this research has gained some insights. First, DRBMs aim at reducing the consumption and production of electricity during peak periods by influencing consumption behaviour. This key aspect of reducing energy intensity supports the tendency of DRBM in encouraging sufficiency. Second, DRBMs are relatively considered to be based on the zero emission initiative in comparison with existing alternatives, i.e. they aim at avoiding building new generation units to meet the demand in peak hours. Third, congestion in transmission and distribution networks is a traditional issue that necessitates costly network upgrade and reinforcement. The reduction in local peaks enables the avoidance of network reinforcement for an assigned level of reliability. Thus, DRBMs aid in maximising the material productivity and in the efficient use of resources by limiting the power system expansion. Finally, demand flexibility has been addressed as a mechanism to facilitate higher penetrations of fluctuating RES, enabling a greater number of RES to be connected to the grid. Herein, DRBMs can aid in substituting with RES and accelerate their integration.

Although the DRBMC enables the realisation of these four leverages to reduce the environmental impact, it does not allow the quantification of the reduction in this impact. This study makes a significant contribution to the literature with regard to DR and BM theory by conceptualising the load flexibility value creation and capture and introducing a forethought approach in a BM to realise flexible demand in power systems. The study addresses the need for innovative DRBMs and difficulty in establishing a business case. While DRBMs contribute to the enhancement of social welfare, it is quite difficult to develop a viable BM. First, this welfare is distributed among a number of different parties. Second, DR for mall- and medium-scale energy consumers requires aggregation and coordination, which augments its complexity. Third, DR is a consumer-centred BM as it basically necessitates consumers' engagement and commitment. In this study, a conceptual framework for DRBM was developed to help overcome these challenges. The study proposes a tool as a methodological response to the lack of connection between the concept of DR and the BM theory. A detailed description of the BM components, their connectivity, and their impact on one another are highlighted. Research on analysing and designing DRBMs in the renewable and sustainable energy system can use the proposed framework. This study has some practical implications for both small- and medium-scale energy consumers as well as entrepreneurs in the energy industry. First, a firm with a considerable electricity load and several facilities can re-design its BM based on its deep knowledge of DR and its market opportunities. Firms that are not familiar with DR can actively innovate on their BMs through exploring the latent electricity flexibility and its market potential. Transforming from passive consumers towards an interactive BM design within the electricity market allows greater opportunities in reducing operational cost, brand differentiation, and achieving competitive advantages.

Energy entrepreneurs can explore the possibility of a radical BM innovation by manipulating the DRBMC and modifying one or more of its contents. For instance, a firm may introduce new value creation through a new load resource or create a portfolio of different complementary resources. Having a BM framework provides a reference language that fosters dialogue, creates a common understanding, and contributes to collective intelligence, which is significantly important in DR where several diverse stakeholders can be found. The DRBMC intends to facilitate the user's experience through a graphical representation that simplifies cognition and offers the possibility of virtual experimentation. In addition, it enables managers to articulate the value of their venture, and obtain support from external parties so as to gain legitimacy.

7. Conclusion

The decarbonisation of power systems and the integration of low-carbon technologies require additional demand-side flexibility, such as DR. In general, recognised as a cost-effective approach, DR has limited technological barriers; however, its deployment depends highly on energy entrepreneurs as well as small- and as small- and medium-scale energy consumers participation. Nevertheless, research on DRBM is limited. Based on a single case study and literature review, this study identified the key BM dimensions and proposed a DRBMC.

DR has been analysed from the theoretical perspective of the BM using an analysis framework that reflects the functions of BMs. DRBMC is defined as a conceptual tool that enables the holistic visualisation of the different elements that compose the production, delivery, and capture of the economic value of DR. DRBM flexibility products are based on modifying the normal demand patterns rather than augmenting the supply power capacity: an approach that stands in stark contrast to the traditional fossil fuel plant model of energy supply. In contrast, DRBM is strongly dependent on user acceptance and engagement. A key point is to increase the customer's awareness regarding the opportunities that exist for participation in DR and BM. Through the DRBMC, the user can analyse DR offers, and types of benefits that DR can generate for customers as well as entrepreneurs. Recognising a business opportunity requires the clear assessment of the market parties' needs and consideration of the existing flexibility products. The design of the flexibility products considers technical attributes (timeframe), commercial attributes (addressed purpose and impact on grid), and performance qualification (ability to deliver). By linking the flexibility products, flexibility resources, and energy markets, DRBMC can foster innovation by providing an overview of the possibilities and limitations in offering different services using the same resources.

The application of DRBMC provides scope for further research for better understanding the role of BM in encouraging a greater number of demand-side flexibility innovations. First, scholars may include more cases in the study, which may contribute to the evolution of the canvas. Second, DRBMC may include a detailed assessment of the benefits with respect to social aspects, such as society welfare gain and the relationship with behavioural patterns and actors' positions in different socio-technical configurations. Lastly, another area of research can focus on an extended version of the DRBMC incorporating advanced sustainability assessment tools that translate the electricity flexibility actions into quantitative sustainability indicators.

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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