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DELIVERABLE D2.2

Current and Future DR strategies Available and Enhanced DELTA DR Mechanisms Specification

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Executive Summary

The markets for Demand Response throughout the EU are in various stages of development and the landscape for DR is well described as an evolving one. Many market restrictions throughout Europe are likely to be lifted in coming years as the DR landscape evolves and policy and regulation adapts accordingly to utilise the potential of demand side assets in the development of electricity networks as more renewable energy sources are incorporated into generation capacity and the networks move further from centralised to distributed systems. This report offers an analysis of current and future DR strategies leading towards an enhanced specification of the DELTA mechanisms in the context of developed DR business models.

The routes to market for DR services in Europe are currently greatly dependent on which member state one is operating in. The UK, Belgium and the Nordic Countries are some of the most evolved for DR currently, although the picture is general is ever-changing.

DR Strategies are here clustered into 6 categories (implicit + 5 explicit) and detailed alongside differences in their implementation and examples of their enactment in EU members states. The 6 clustered DR Strategies used herein are:

- Direct Load Control
- Load Curtailment Requests
- Demand Reduction Bidding
- Ancillary Service Provision
- Emergency Response
- Implicit DR

As there is a move to standardisation of actor definitions and associated roles and terminologies for parties operating in the energy sector, the future role of DR is becoming clearer. An overview of DR programmes including actor involvement analysis is here presented to clarify the current situation including identifying the stakeholders and influential parties for various DR scenarios.

An analysis of state-of-the-art research programmes dealing with DR is presented to clarify future considerations for DR markets. Expected outcomes of these programmes are detailed and considered in the context of the developed business models and further detailing of the DELTA mechanisms.

The current market limitations and future developments pertaining to DR legislation in Cyprus and the UK are elaborated at the end of the report to frame the context of operations for the pilot sites.

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List of Acronyms and Abbreviations

Term	Description
aFRR	Automatically Activated Frequency Restoration Reserve
ACER	Agency for the Cooperation of Energy Regulators
ADE	Association for Decentralised Energy
AS	Ancillary Services
B2B	Business-to-business
BEIS	The Department for Business, Energy and Industrial Strategy (UK Government)
BRP	Balance Responsible Party
BM	Balancing Market
BMU	Balancing Mechanism Unit
BMC	Business Model Canvas
BMS	Building Management System
BEMS	Building Energy Management System
CHP	Combined Heat and Power
CM	Capacity Market
CPP	Critical Peak Pricing
DAM	Day-Ahead Market
DER	Distributed Energy Resources
DHW	Domestic Hot Water
Disco	Distribution Company
DR	Demand Response
DRMS	Demand Response Management System
DSBR	Demand Side Balancing Reserve
DSM	Demand Side Management
DSO	Distribution System Operators
DSF	Demand Side Flexibility
EC	European Commission

EDSR	Emergency Demand Side Response
EES	Energy Efficiency Service
EPRI	Electric Power Research Institute
ESCO	Energy Service Company
EU	European Union
EV	Electric Vehicle
FCDM	Frequency Control by Demand Management
FCR	Frequency Containment Reserves
FCR-N	Frequency Containment Reserves - Normal
FCR-D	Frequency Containment Reserves - Disturbance
FFR	Firm Frequency Response
FLESCO	Flexibility Service Company
FRR	Frequency Restoration Reserves
Genco	Generation Company
HIL	Hardware-in the-loop
ICT	Information Communication Technology
ISO	Independent System Operator
LEM	Local Energy Manager
LFC	Load Frequency Control
M&V	Measurement & Verification
MAS	Multi-agent System
mFRR	Manually Activated Frequency Restoration Reserve
MO	Market Operator
PU	Private Utility
PV	Photovoltaics
R1	Primary Frequency Control
R2	Secondary Frequency Control
R3	Tertiary Frequency Control

RES	Renewable Energy Sources
RR	Replacement Reserves
RTP	Real Time Pricing
SBR	Supplemental Balancing Reserve
SCR	Secondary Control Reserve
SO	System Operator
SR	Strategic Reserve
STOR	Short-Term Operating Reserve
ToU	Time of Use
Transco	Transmission Company
TSO	Transmission System Operator
UK	United Kingdom
US	United States (of America)
VPP	Virtual Power Plant
WM	Wholesale Market

1. Introduction

1.1 Scope and objectives of the deliverable

This deliverable, associated with Task 2.2 of the DELTA project, provides an analysis of every Demand Response strategy and mechanism currently employed in the energy markets over the globe while also providing a review of the state-of-the-art on research in Demand Response and thus mechanisms forthcoming in energy retail pertaining to Smart Grids. The involvement of actors is detailed and the key actors and interested parties thus identified. Various approaches to the deployment of Demand response strategies in the European markets are detailed by example and the regulatory limitations to participation detailed. Business cases for the DELTA solution are identified according the analyses above. Issues pertaining specifically to the pilot sites are elaborated.

1.2 Structure of the deliverable

In chapter 2, the strategies for demand response are clustered into 6 categories, with the specifics of each detailed and demonstrated by means of a sequence diagram. Differences in the implementation of these strategies are reported and examples of these strategies active in the markets are given.

Chapter 3 gives a detailed overview of the demand respond strategies operating today including an actor involvement analysis, detailing the roles of each actor and their interests in the clustered strategies as well as highlighting influential stakeholders and their place in the markets.

Chapter 4 provides a review of the state-of-the-art in Demand Response, highlighting research projects and associated business cases and relating these business cases to the business cases of DELTA.

Chapter 5 builds on the information of the previous chapters to demonstrate business cases and opportunities for DELTA while detailing key factors that will influence the demand response markets moving forward.

Chapters 6 and 7 review the particularities of the Demand Response markets at the pilot site locations (Cyprus and the UK, respectively) detailing the current situation and describing the opportunities and barriers to development moving forward.

1.3 Relation to Other Tasks and Deliverables

This report builds on the input of D2.1 in which there was an assessment of the energy markets in and regulatory guidelines in general. This report (D2.2), dealing more specifically with Demand Response strategies, will inform the development of business models due in its first iteration in the D2.3 report due at month 18 of the project.

1.4 Background

The European power system is profoundly changing. A paradigm-shift from centralised to distributed energy generation is well underway. New challenges are being generated by the increase of distributed energy resources (DERs) and these must be addressed in order to maintain reliability and security of energy supply.

Balancing power in the grid is a progressively challenging task, both for long-term and short-term balance. The ever-increasing contribution from renewable generation coupled with the associated variability, unpredictability and asynchronistic of supply; is expected to further complicate this task by increasing the number and scale of sharp fluctuations in demand/supply mismatch. The traditional mechanisms for managing these fluctuations by controllable, fossil-fuel-based power plants are becoming less effective as the proportion of such generation in the energy system is decreasing.

Demand Side Management (DSM) is a promising method for balancing supply and demand in power systems with a high share of variable renewable energy generation. The Electric Power Research Institute (EPRI) has defined DSM as follows:

‘DSM is the planning, implementation and monitoring of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape, i.e. time pattern and magnitude of a utility's load. Utility programs falling under the umbrella of DSM include load management, new uses, strategic conservation, electrification, customer generation and adjustments in market share’

Among the DSM solutions, Demand Response (DR) strategies are gaining more attention in power system operations lately, driven by growing interest in the smart grid concept. The so-called 'Winter Energy Package' defines 'Demand Response' as:

‘the change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including time-variable electricity prices or incentive payments, or in response to acceptance of the final customer's bid, alone or through aggregation, to sell demand reduction or increase at a price in organised markets as defined in Commission Implementing Regulation (EU) No 1348/2014 (Article 2(16) of the Proposal for a Directive of the European Parliament and of the Council on the internal market for electricity (recast) on common rules for the internal market in electricity (recast), 30.11.2016, COM(2016) 864 final 2016/0380 (COD))’

The Third Energy Package, from the European Commission, requires network operators to take the potential of DR and energy efficiency into account when planning system upgrades. Article 3.2 also states:

‘In relation to security of supply, energy efficiency/DSM and for the fulfilment of environmental goals and goals for energy from renewable sources, [...] Member States may introduce the implementation of long-term planning, taking into account the possibility of third parties seeking access to the system.’

Most consumers do not have the means to trade directly into the energy markets. Therefore, they require the services of an aggregator to participate. Aggregators pool loads of varying characteristics and offer backup for individual loads as part of the pooling activity, increasing the overall reliability and reducing risk for individual participants. The aggregated load is used to bid into the market, acting as a single resource. An aggregator’s success is entirely dependent upon the successful participation of the consumer in DR programmes.

The aim of this report is to provide an overview of the DR strategies and market mechanisms currently employed in the European energy markets, while also reviewing state-of-the-art research to provide insight into the future of DR. Furthermore, focusing on the DELTA demonstration activities, the current barriers to market participation for DR solutions are highlighted.

2. Clustering of DR Programmes and Strategies According to their Main Characteristics

To better understand the various routes to market in demand response demand response mechanisms are here clustered. At a high level, demand response can first be clustered into 2 super categories, namely: explicit and implicit demand response. Explicit demand response requires active participation of end users responding to requests from within an existing framework agreement. Implicit demand response is that that occurs naturally due to a tariff framework that encourages energy use at certain times and discourages energy use at others. There is a focus herein on the forms of explicit demand response as these are technically more difficult to achieve and can be addressed by the DELTA solution. Additionally, the position of European operators towards DR is set mainly by ancillary services and interruptible loads offers. A summary of the DR programs provided by the operators in several countries of Europe, based on the data showed in [1]–[4], is presented herein.

2.1 Direct Load Control

2.1.1 *Overview*

Typically for small commercial and residential consumers. Direct control of specific appliances is given to utilities, predominantly temperature regulation devices and occasionally lighting. The control mechanism is generally given as simple on/off commands. Notice of control events is given but the timeframe for notice is small (the order of minutes). The most common market approach for participation is fixed scheduled payments in the form of utility bill credits and additional participation payments.

The roles of actors involved in Direct Load Control mechanisms are demonstrated in Figure 1 by means of a sequence diagram.

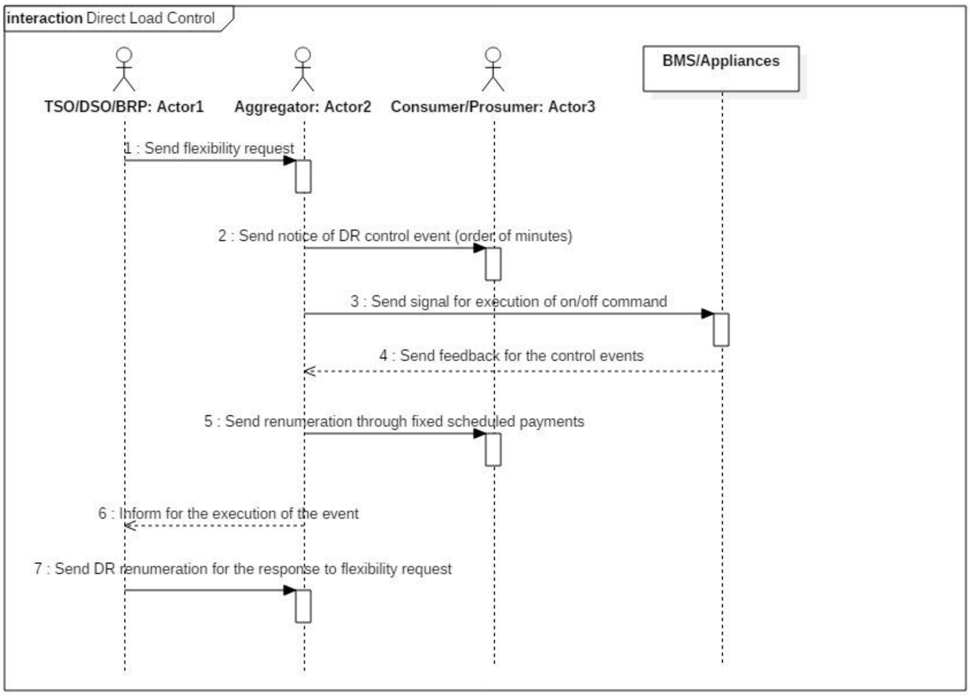

Figure 1: Direct Load Control Sequence Diagram

2.1.2 *Differences in Implementation*

Differences between the direct load control strategies are found in the following:

- Capacity commitment payment dependencies (some tiered schemes)
- Availability commitment dependencies (some tiered schemes)
- Event caps (number and length of time)

There are some tiered schemes on the market that offer payment rates in bands for varying amounts of capacity and/or availability committed, thus affecting optimum participation strategy dependent on the market in which one is operating.

Event caps also vary both in number per year and also length of time. There are often event caps reported in season and timeslot segments, highlighting known peak times as those where it most likely that Direct Load Control events will occur.

2.1.3 *Market Examples*

An overview of this strategy as it is employed in active markets is provided below to elaborate on specific differences in implementation and constraints to participation.

2.1.3.1 Czech Republic

In the Czech Republic, the ripple control system is being used as a DR measure. This scheme involves a one-way communication system whereby customers, by contracted authorization, allow specific agreed appliances to be externally controlled by the DSO. Control signals are superimposed on the 50 Hz supply in order to switch on or off high-power equipment, typically heating and water pumping equipment. This is considered a very effective load management mechanism. Approximately 46% of the overall household electricity consumption and 31% of the overall small-business electricity consumption in the Czech Republic is distributed under the ripple-controlled low tariff.

2.2 Load Curtailment Requests

2.2.1 *Overview*

Typically managed by aggregators. Load curtailment requests are similar to direct load control mechanisms although they typically involve greater user interaction for confirmation of participation and longer notice periods (the order of hours or day ahead). The curtailment options are integrated into retail tariffs that provide a rate discount or bill credit for agreeing to reduce load during system contingencies. Penalties maybe assessed for failure to curtail. The reward structures are widely varying; although, given the greater need for human interaction and the requirement for baselining submissions, payments are often focussed on participation with some capacity payment structures available for reliable users. Interruptible programs have traditionally been offered only to the largest industrial (or commercial) customers.

The roles of actors involved in Load Curtailment Requests mechanisms are demonstrated in Figure 2 by means of a sequence diagram.

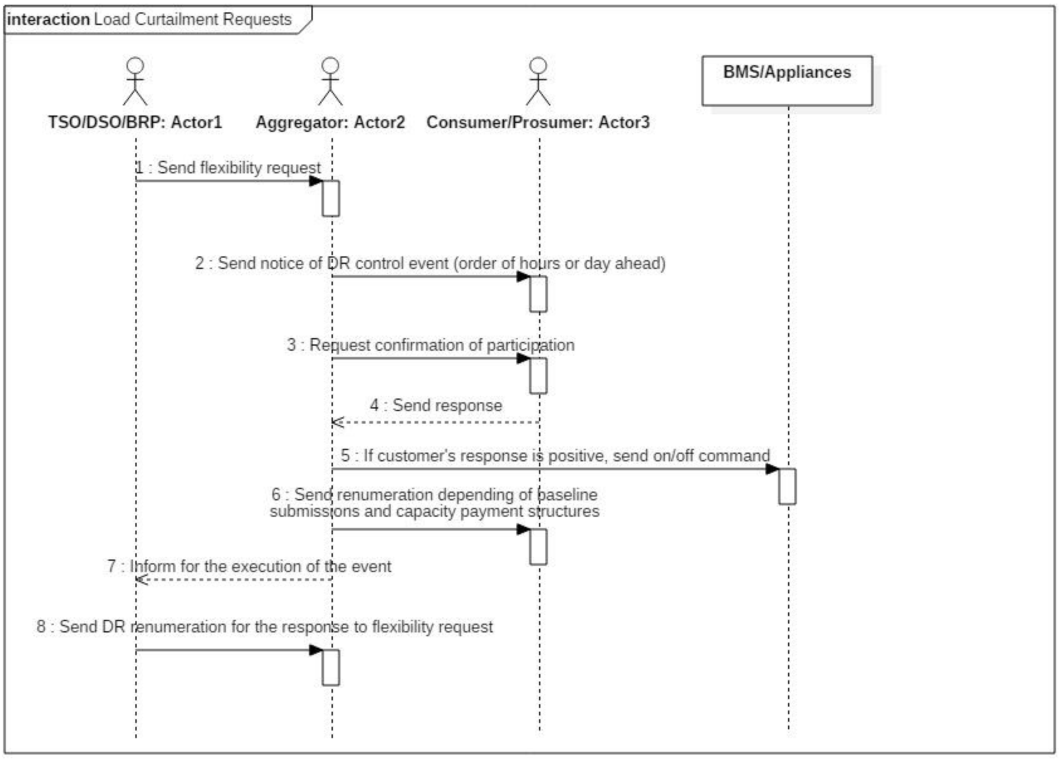

Figure 2: Load Curtailment Requests Sequence Diagram

2.2.2 *Differences in Implementation*

Differences between load curtailment request strategies are found in the following:

- Payments for capacity and/or availability with or without tiered rates for various notification periods
- Utility rate reductions
- Penalty schemes

Different markets offer different entrance points for minimum participation requirements. These can be location-dependent as well as market-specific. Load reduction requests are generally called for in blocks of power and payment for participation occurs on top of payment for availability and varies as factors of availability payments, typically starting at unity.

Another point for variation in payment schemes is notification time. In some markets load curtailment participation is tiered for notification periods with higher payments generally available for those who participate in markets that operate in shorter time-frames.

Some payments schemes include rate reduction for electricity payments so participating entities pay less for consumption whilst available for load curtailment.

Given that the typical framework for operation is to pay for availability as well as to provide additional payments for participation, penalties are dealt to entities that do not participate when called upon as this effectively breaks the availability agreement. Penalties vary in severity but must at least cover the cost of the availability and participation payment to alternative curtailment providers.

2.2.3 *Market Examples*

An overview of this strategy as it is employed in active markets is provided below to elaborate on specific differences in implementation and constraints to participation.

2.2.3.1 Spain

Aggregation is not currently allowed in Spain, yet individual loads can participate in interruptible load programs. There are differences in participation rules for geographically differentiated regions, namely the mainland and island regions [1]. The mainland interruptible load program allows base blocks of 5 MW and 90 MW for participation. Given that aggregation is not allowed in Spain, this is a barrier to participation of many consumers. The minimum block size for participation in the island regions is 800 kW. This entry point is low enough to significantly widen the scope of potential candidates for participation [2]. The capacity market in Spain is open to consumers, however, there is a lack of participation. Payments are given both for availability and utilization, and the penalty scheme for failure to participate when requested within availability period 120% of the availability price for the mainland regions and 100% for the island regions.

2.2.3.2 Germany

The minimum bid for interruptible loads in Germany is 50 MW and aggregators can only participate with a maximum of five loads. Two schemes are in place, namely: immediately interruptible and quickly interruptible. Power plants are contracted bilaterally by the TSO without auction or tendering processes. In general, the German market poses several barriers to participation. The technical requirements for primary control reserve are such that participation is almost exclusively undertaken by generators. Other markets embody risk due to time commitment requirements (Secondary Control Reserve specifies required availability for up to 12 hours) and effective penalties when consumption is above a flat, ‘normal’ baseline.

2.2.3.3 Greece

The Greek network operator procures 1.6 GW of interruptible capacity quarterly by means of a tendering process. An intractability scheme was introduced in Greece in 2014 and was active for 3 years, the scheme proved successful and was amended and prolonged in 2017 to widen the scope for participation and the cost to the consumer by reducing both the minimum bid size and the maximum payment. The required reaction time was also reduced to 5 minutes. Consumers are given fixed payments for participation.

2.3 Demand Reduction Bidding

2.3.1 *Overview*

A mechanism by which entities can sell load reduction, either directly as a large consumer or indirectly via an aggregator for smaller consumers. Typically, this occurs as a bidding process followed by the establishment of a merit order for dispatch to equilibrium. Demand Reduction Bidding is typically only offered to large (> 1 MW) customers.

In the case of bidding to capacity markets, customers offer load curtailments as system capacity to replace conventional generation or delivery resources. Customers typically receive day-ahead notice of events. Incentives usually consist of up-front reservation payments, and face penalties for failure to curtail when called upon to do so.

The roles of actors involved in Demand Reduction Bidding mechanisms are demonstrated in Figure 3 by means of a sequence diagram.

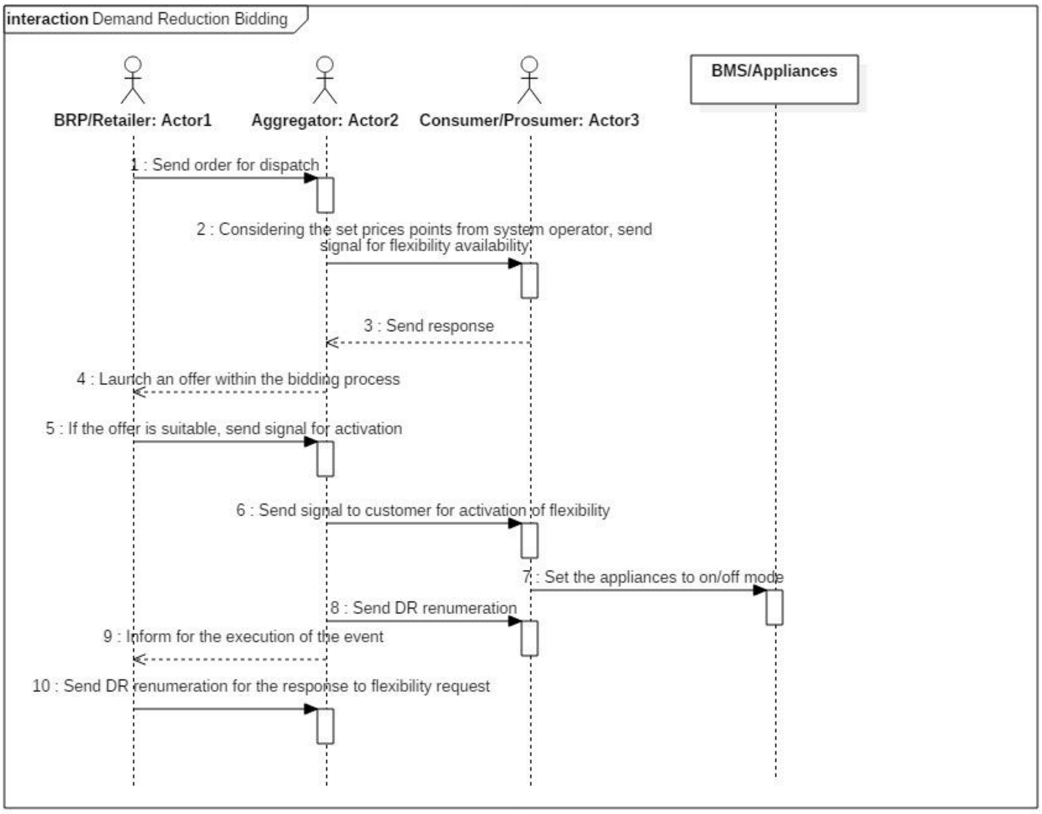

Figure 3: Demand Reduction Bidding Sequence Diagram

2.3.2 *Differences in Implementation*

Differences between the demand reduction bidding strategies are found in the following:

- Consumer defined price points
- System operator set price points - consumers bid in with capacity
- Contracting parties

The main differences in the implementation of demand reduction bidding strategies are found in the bidding framework. Essentially a merit order will be established at the end of a bidding process/multiple bidding processes that will define the dispatch for demand reduction. In some markets entities will bid in capacity and price and in others entities bid in capacity at price points set by the market operator. The number of bidding rounds, notifications to participations and timings of these differ across different markets.

Differences are also found in contracting parties that are responsible for the provision of demand reduction and in which agreements must be in place with whom.

2.3.3 *Market Examples*

An overview of this strategy as it is employed in active markets is provided below to elaborate on specific differences in implementation and constraints to participation.

2.3.3.1 Austria

The Austrian TSO allowed aggregation and Demand Response in the Balancing Market in 2013 and introduced amendments promoting aggregation and wider participation by reducing minimum technical unit size the following year. In the current framework, aggregators must contract with BRPs/retailers to activate flexibility in the balancing market. This step introduces added complexity and thus time and cost to market participation and uptake is far from the potential. There is no Demand Response in the spot market in Austria although theoretically Virtual Power Plants could participate in the day-ahead market.

2.3.3.2 Belgium

A Strategic Reserve program was introduced in Belgium in 2014 [5] in order to increase robustness and security of supply for the winter demand. Load flexibility is provided through the Interruptible Contracts programme, which is dedicated to Demand Response. The Wholesale and Balancing markets in Belgium are not open to Demand Response other than via Retailers' customer aggregation whereby consumers bid into the Belpox Spot power exchange. Aggregators must sign agreements with Retailers/BRPs to participate.

2.3.3.3 Nordic Countries

Despite having separate TSOs; Norway, Finland, Sweden and Denmark share a single electricity market and regulatory framework. Regulation in the Nordic countries allows for the participation prequalification of aggregated sources, rather than individual consumers in Demand Response. Aggregators can either participate as service providers for retailers by contractual agreement yet in order to participate as independent entities they must register as a BRP with an associated cost. Demand Response supply is contracted in the Nordic Spot Market and in the national Balancing Markets.

2.3.3.4 France

In France both the ancillary services and wholesale markets are open to Demand Response and independent aggregators. Retailers in France are required to buy capacity certificates up to the level of their portfolios' peak consumption. The market is open both to demand reduction and generation although DR participants can finalise offers closer to real-time, allowing for better portfolio assessment. Aggregators are allowed to bid in to the market prior to consumer contracting offering a well-defined pricing model.

2.3.3.5 Germany

Demand Response is active in Germany. Aggregators work as service providers to retailers, aggregating flexibility in the retailer's portfolio. Intraday markets are open for consumers working through retailers that offer the service, although it is not required for retailers to offer this service. There is no capacity market in Germany and capacity reserve is open for generation only. Virtual Power Plants have started to participate in the German accessible markets, but with very small amounts of Demand Response in their portfolio.

2.3.3.6 Italy

Italy has approved the introduction of a market-wide capacity mechanism that will operate for 10 years and will be reviewed for reform during its operation. Availability payments for capacity providers including conventional generators, renewable generators, storage operators and demand response operators; are provided. The capacity procurements take place by means of regular, competitive auctions. Imported electricity is included by attributing a given amount of capacity for which providers in neighboring EU Member States can compete.

2.3.3.7 Poland

Poland has plans to introduce a market-wide capacity mechanism where availability payments for capacity providers including conventional generators, renewable generators, storage operators and demand response operators; are provided. The capacity procurements take place by means of regular, competitive auctions. Electricity imports will be allowed for by offering some capacity to auction for providers in neighboring EU member states

The "Demand-Side Balancing Reserve" (DSBR), was introduced in winter 2015 with a contracted capacity of 318.7 MW and aggregated load accepted. DSBR targets large energy users who volunteer to reduce their demand during winter weekday evenings between 4 and 8 pm in return for a payment. The Supplemental Balancing Reserve (SBR) programme targets power stations that would otherwise close. One of the historical DR programmes, the Short-Term Operating Reserve (STOR), has been updated to provide better opportunities for aggregation via the STOR Premium Flexible and STOR Runway programmes.

2.3.3.8 UK

The UK has several aggregators active in the energy balancing market. Aggregators are not required to inform the suppliers prior to load curtailment; they have direct access to consumers; and may aggregate loads nationwide. A consumer participating in DR aggregation is contractually obliged to inform the supplier about the intended participation. Demand Response providers are eligible for 1-year capacity agreements and must only bid-in resources within their portfolio at the time of auction. Contrastingly, generators are eligible for 15-year capacity agreements and can bid-in with planned capacity. The mandatory provision of a credit cover for new (i.e., unproven) Demand Response poses a significant barrier to potential participants. A change to regulations, providing longer deadlines for credit cover submissions, is part of a current consultation process.

The new regulations within the Short-Term Operating Reserve (STOR) programme strongly devalued the market for consumers and approximately 9-10 aggregators have left. The requirements are challenging for consumers, as they require daily weekday participation, with a window of 11-13 hours per day, in order to be paid at a competitive level. It is possible to choose one-time window (morning/evening), but it involves an important devaluation of the resource, lowering revenues. Another significant barrier is the long period of time between contracting a site and obtaining first payments. Demand Response now represents a limited part of this reserve. A positive enabler is that prequalification takes place at the pooled assets level. However, signing a STOR framework agreement can take between 2 weeks and several months.

2.4 Ancillary Service Provision

2.4.1 *Overview*

For ancillary service provision, entities bid into markets ran by system or regional transmission operators. The ancillary services market is organised to negotiate energy loads to ensure reliability and energy quality through four key paths: system restarts, frequency control, voltage control, and stability control.

Frequency reserve and operating reserve services are the most common form of distributed ancillary service provision. Frequency response is a quick (order of minutes) load adjustment (either decrease or increase) triggered by real time signals to rebalance grid frequency to the operational set-point. Operating reserves are dispatchable power generators able to respond rapidly to signals in order to correct under generation conditions caused, for example, by generator failure or prediction errors. Payment schemes tend to be by capacity commitment.

Frequency control, which is the most commonly implemented ancillary service is divided into three types:

- Primary reserve – close to real-time actuation, it allows an automatic regulation of load to place frequency within bounds in a matter of seconds;
- Secondary reserve – after the primary reserve is successfully implemented and frequency is within bounds, the secondary automatic reserve is activated to place frequency at a target/standard value, as primary reserve returns to its previous level;
- Tertiary reserve – similar to what secondary reserve performs for primary reserve, this reserve implicates manual changes to the load that guarantee frequency stability and adequate value, as secondary reserve returns to its previous level as mentioned before for primary.

Further differences in frequency response strategies and terminologies are found in Frequency Containment Reserve (FCR) and Frequency Restoration Reserve (FRR). In the EU Internal Electricity Balancing Market refers to FCR as the operating reserves used for constant containment of frequency deviations (fluctuations) from nominal value in order to constantly maintain the power balance in the whole synchronously interconnected system. If the frequency deviates from the threshold values for longer than the acceptable time period (30 seconds), FCR is replaced by FRR, which according to Article 3(2)(7) of the Network Code on System Operation, refers to active power reserves available to restore system frequency to the nominal frequency and, for a synchronous area consisting of more than one Load-Frequency Control (LFC) area, to restore power balance to the scheduled value.

Further differentiation is made between automatically activated (aFRR) and manually activated (mFRR) services. aFRR is more deeply integrated with the TSO systems, while mFRR is activated manually in both a discrete and "close to" continuous manner by TSOs (Explanatory Document to all TSOs' proposal for the implementation framework for a European platform for the exchange of balancing energy from frequency restoration reserves with manual activation in accordance with Article 20 of Commission Regulation (EU) 2017/2195 establishing a guideline on electricity balancing, 15 May 2018, p. 5).

2.4.1.1 Notes on Virtual Power Plants

A Virtual Power Plant (VPP) is an integrated network of aggregated power stations and interruptible loads that acts as a large power plant by collective control of its distributed assets. VPPs are considered an important part of the energy transition, aggregating the output of wind plants, photovoltaic plants, biomass plants, and Combined Heat and Power (CHP) plants.

The most common of the ancillary and grid support services that can be provided by a VPP are:

- Load-Frequency Control;
- *Network Operators day ahead schedules include technical reserve, which can be provided by the VPP;*
- Voltage Regulation through Reactive Power Control;

- *The VPP can use its Distributed Generation units to local compensate reactive, contributing to Voltage Regulation;*
- Black Start;
- *Distribution Generation units with low (below one hour) start up times can aid the restoration of area outages, a service that can be provided by VPPs but not by conventional power plants;*
- Reduction of Power Losses on Distribution/Transmission Lines;
- *Localized generation can be provided by VPPs. Generation close to consumption mitigates the inefficiencies of the transmission system.*

The roles of actors involved in Ancillary Service Provision mechanisms are demonstrated in Figure 4 by means of a sequence diagram.

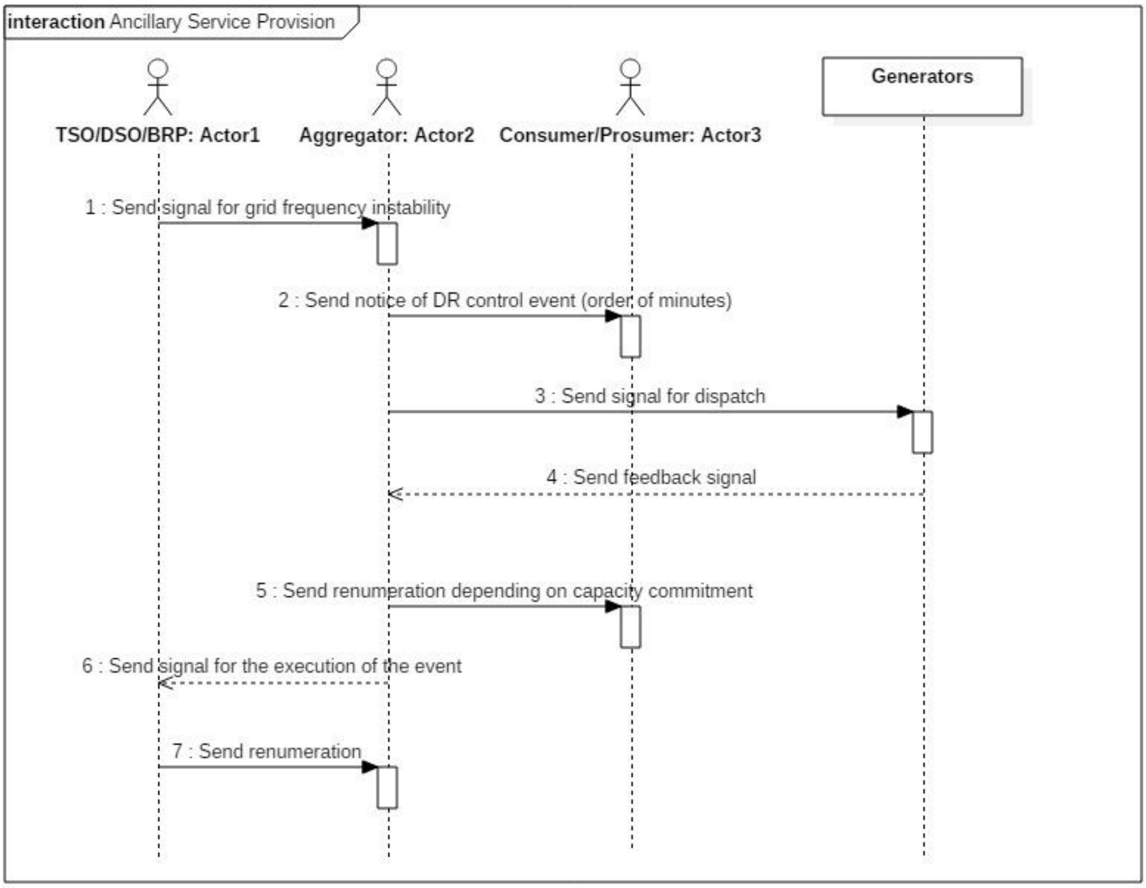

Figure 4: Ancillary Service Provision Sequence Diagram

2.4.2 *Difference in Implementation*

Differences between the ancillary services strategies are found in the following:

- Payment by availability/utilization
- Dependencies on threshold commitment levels for market entry/price points
- Price points for time to response

Payment is given for availability to accepted bids and entities are obliged to be on standby for operation. Further payment is given, typically at the spot market price, for participation if called upon to act for ancillary service provision.

As mentioned above, the frequency response service is separated into three categories, each requiring a different time to response. Typically, the fast response services are better paying due to the resulting increased grid stability and technological requirements for participation.

2.4.3 *Market Examples*

An overview of this strategy as it is employed in active markets is provided below to elaborate on specific differences in implementation and constraints to participation.

2.4.3.1 Austria

Primary control in Austria is tendered for weekly. There is a minimum entry size of 2 MW and temporally symmetric bids are required. Tertiary control is also tendered for on a weekly basis, with separate tenders for weekdays and weekends, both split into 6, 4-hour windows. In addition, a day-ahead auction for the same timeframes is held. However, this auction only offers payment for utilisation. The Secondary Control market is one of the few short term, auction-based markets open to demand side resources in Europe. The market is split into 3 products: 08:00-20:00 on weekdays, 20:00-08:00 on weeknights and weekends. The duration of each call is up to 4 hours, with a 10-hour rest period between calls (to allow consumers a guaranteed break in activations). Asymmetrical bids can be offered in this auction. Weekly bids are held which set the price for the customer’s availability and daily auctions are held for the energy component of the call. Payments are given for both availability and participation. The separation of positive and negative regulation supports demand-side participation as do the separated time windows.

2.4.3.2 Belgium

5 of 8 ancillary services programs in Belgium have been opened to aggregated demand. Demand Response services can participate in the Primary and Tertiary Reserves programmes, as well as in the Interruptible Contracts programme (classified under the Tertiary Reserve). However, the Secondary Reserve is not yet open to DR participation.

In FCR, there are 27 MW of load available to perform frequency control in upward regulation only. FRR is divided in two classes: interruptible and non-interruptible. The first has 261 MW and the latter 60 MW, both also with a possible aggregation participation. In RR, strategic reserve involves 97 MW. All programs are aimed at consumers with minimum capacity requirements of 1 MW, and actuation periods of 1 hour to a maximum of 12 hours.

Payments differ between programs. The FCR and non-interruptible FRR are only paid for capacity. The interruptible FRR pays both availability and utilization, while RR only pays by utilization. The penalties for the programs are 130% of the remuneration price, except for the interruptible FRR that where the penalty price is 120% of the remuneration price.

2.4.3.3 Finland

In Finland, FCR is divided in normal (FCR-N) and disturbance (FCR-D) operation with 500 kW active in normal and 230 MW in disturbance operation. There is currently 100-300 MW active in manual FRR and none in automatic operation. The majority of ancillary service programs have high minimum capacity requirements (5-10 MW) except for: FCR (100 kW in normal, and 1 MW in disturbance), in the intraday markets (Elbas - 100 kW), and in the day-ahead markets (Elspot – 100 kW). Only FCR-D on-off model and mFRR consider both availability and utilization payments, while FCR-N and FCR-D standard consider only availability payments. The remaining programs consider only utilization payments and these are often obtained from market places.

2.4.3.4 France

Significant changes to the market structure in France were introduced 2014. The volume for market entry in FCR and aFRR in France is 1 MW and both only allow symmetric bids. The minimum bid is set at 10 MW (still considered high and a market barrier to demand response although this was reduced from 50 MW) for mFRR and Replacement Reserves (RR). Demand Response participation (certificated consumption sites, industrial & aggregated load as participants) is limited to the transmission grid and is based on bilateral contracts with generators.

2.4.3.5 Germany

The control reserve programs in Germany all consider upward and downward regulation. In FRR, it is found two classes, normal and minute, both with a minimum of 5 MW, while in FCR, only 1 MW is required. In what concerns payments, FCR performs availability payment only, while FRR provides both availability and utilization. FCR firm frequency response and FRR are both divided in two classes, dynamic and non-dynamic, while RR short-term operating reserve is divided in committed and flexible. Very little consumer participation takes place in Primary Control Reserve as the technical modalities are still designed around generation. Consumers participating in Secondary Control Reserve (SCR), risk potential increases in grid tariffs for deviations from their normal (flat) energy consumption profile, which constitutes a significant financial disincentive for offering their flexibility in this market. On top of this, resources must be able to be dispatched for up to 12 hours.

2.4.3.6 UK

Firm Frequency Response (FFR) is open to Demand Response providers in UK, with a minimum capacity of 1 MW (since April 2017, before which date it was 10 MW), in both dynamic and non-dynamic profiles. Dynamic is where generation or consumption output will rise and fall automatically in line with the system frequency. Static is where an agreed amount of energy is delivered if the system frequency hits a certain trigger point e.g. 49.8 Hz.

The Frequency Control by Demand Management (FCDM) programme is used to manage large deviations in frequency, such as those caused by the sudden loss of a large generating unit. FCDM is triggered at a static set point of 49.7Hz and therefore there are few events per year. There were nine events in 2013 and nine in 2014, always with a maximum duration of 30 minutes. The service is a route to market for demand-side providers and is managed with bilateral contracts between providers and National Grid (TSO).

2.5 Emergency Response

2.5.1 *Overview*

Emergency Response programmes are agreements to limit consumption to a specified level when there is a grid level threat. There are typically predefined timeframes for required availability that reflect potential critical grid scenarios, primarily around peak load times. Participants are paid for availability and effectively join the merit order for dispatch, penalties are given if participants fail to produce when called upon.

The roles of actors involved in Ancillary Service Provision mechanisms are demonstrated in Figure 5 by means of a sequence diagram.

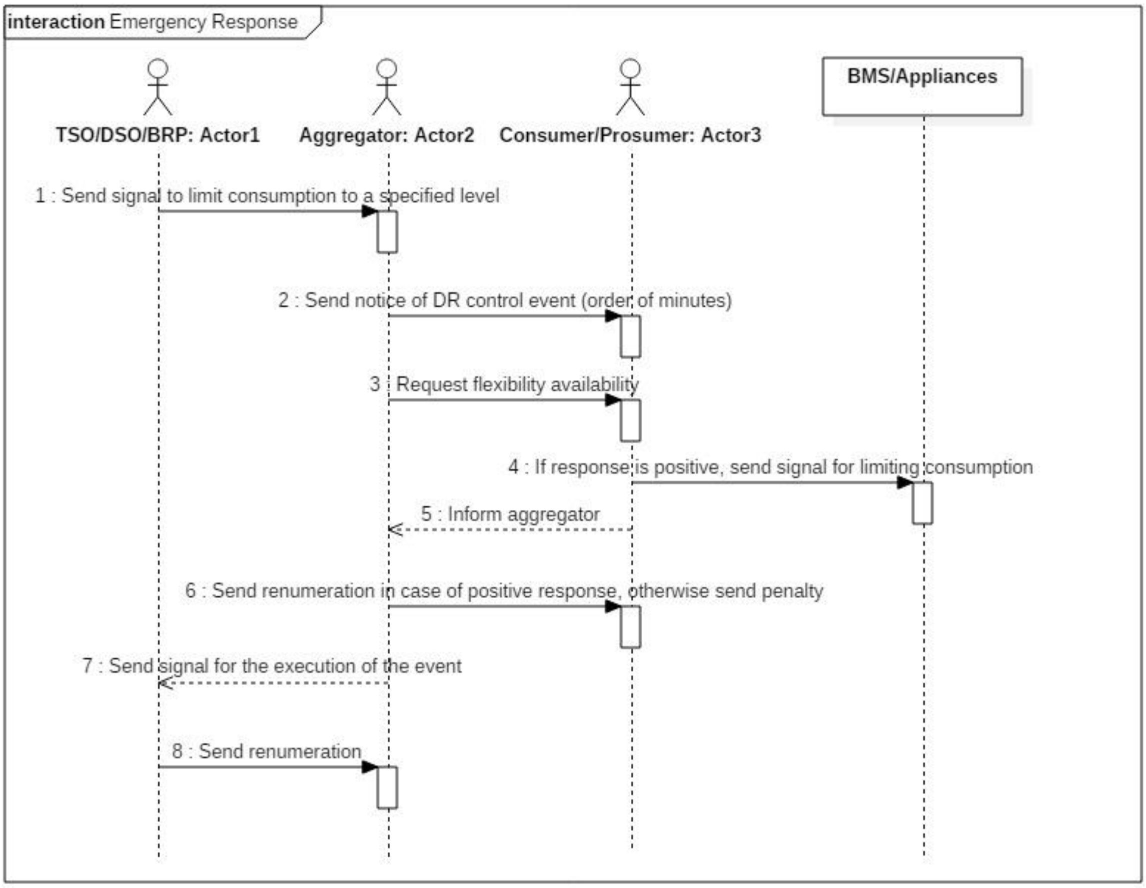

Figure 5: Emergency Response Sequence Diagram

2.5.2 *Differences in Implementation*

Differences between the emergency response strategies are found in the following:

- Timeframes for participation – these a situational depending on local and system wide issues
- After-the-fact payment schemes for provable voluntary actions

2.5.3 *Market Examples*

An overview of this strategy as it is employed in active markets is provided below to elaborate on specific differences in implementation and constraints to participation.

2.5.3.1 Poland

The Emergency Demand Side Response programme (EDSR) is currently the only route to market for DR in Poland. The EDSR market was activated in 2013 with seasonal provisions differing for winter and summer. The minimum bid is 10 MW and aggregation is allowed by the BRP. Agreements are in place for 2 years provision of a seasonal commitment with maxima for activations set to 1 per day, 3 per week and 15 per season. Load reduction calls can be for 2-4 (integer) hours. Units must be equipped with meters of at least hourly resolution.

2.6 Implicit DR

2.6.1 *Overview*

Implicit demand response is the application of tariffs in which the price of electricity is dependent on the time of use. There are many approaches to these tariffs, from a set two-point peak/off-peak tariff system to a real-time system responding to changes in the wholesale market and informing customers with little notice. A middle ground approach is found with critical peak pricing whereby a standard rate tariff is adjusted by pre-set amounts at peak times.

For these programmes to be offered the, metering device of the customer must be capable of providing verified meter readings with at least the same frequency/time segregation which is used for the tariff. The resolution of such meters tends to range from hourly to quarter-hourly, depending on the market. Retailers must also be allowed to adjust their settlement processes – so that they no longer purchase electricity according to averaged profiles but rather according to actual consumption.

Static forms of implicit demand response, such as Time of Use (ToU) tariffs are considered less valuable today as they can lead to negative profiling effects when coupled with intermittent renewables. Two examples of market-based implicit demand response are: Critical Peak Pricing (CPP), and Real Time Pricing (RTP).

- Critical Peak Pricing (CPP) is a programme usually developed for both residential and commercial consumers that involves raising prices or offering financial incentives to cut demand for a set number of hours on days when critical peaks in consumption are expected, often triggered by changes in weather conditions. Both the numbers of days on which a peak can be called and the number of hours are known beforehand and usually regulated at a regional or national level. By their nature, they occur at irregular intervals in either winter or summer and come under the heading of dynamic peak shifting.
- Real Time Pricing (RTP) is the programme most closely aligned with situations where supply as well as demand are variable or 'unbiddable', meaning that a significant portion of national capacity is sourced from intermittent renewable generation. RTP is a means by which retail prices follow wholesale prices from day to day, hour to hour or even minute by minute. Spot pricing can be linked with automation to lower demand whenever wholesale market prices go over a certain pre-set amount.

The roles of actors involved in Implicit DR mechanisms are demonstrated in Figure 6 by means of a sequence diagram.

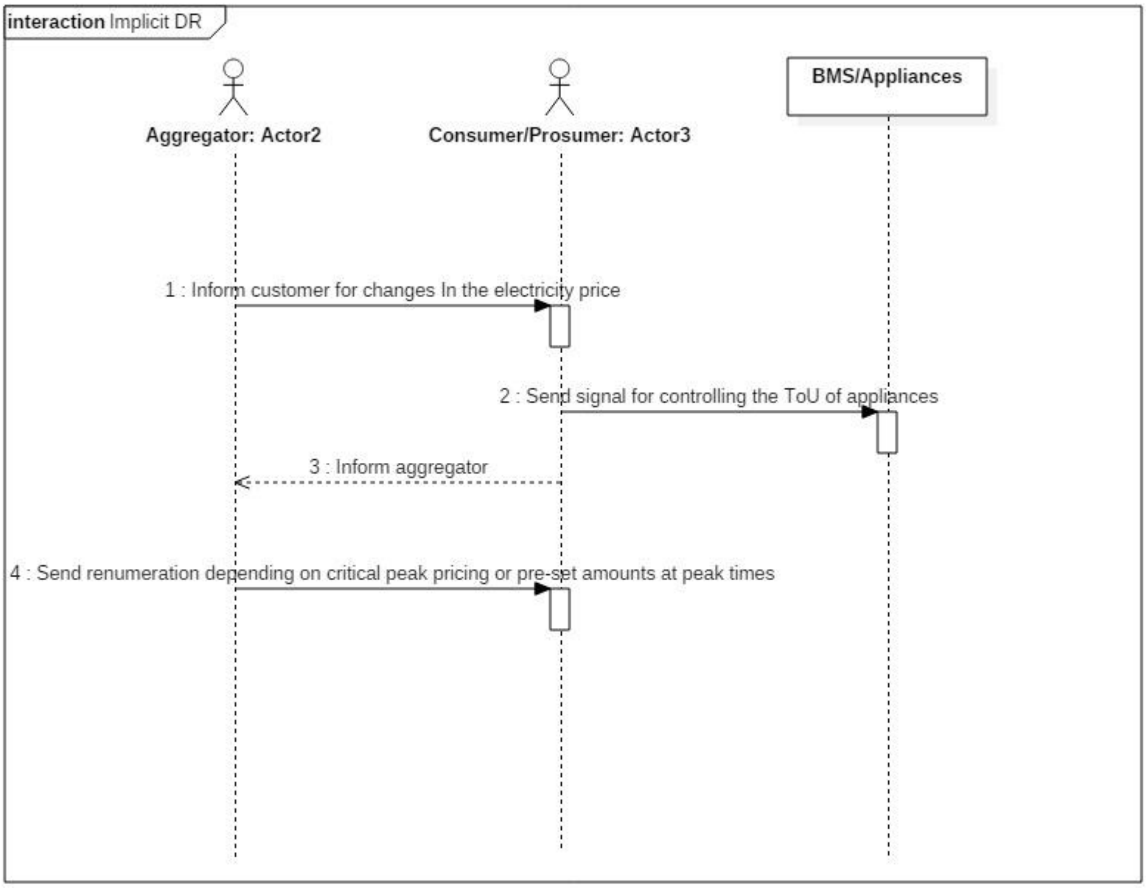

Figure 6: Implicit DR Sequence Diagram

2.6.2 *Differences in Implementation*

Differences between the implicit demand response strategies are found in the following:

- Timeframes and rate differences
- Critical event schemes and agreed limitations

There are a wide variety of varying time of use tariffs operating on different time frames and with different relative payments for each. Daily time varying tariffs are common to discourage use in peak events. Seasonal tariffs are utilised to mitigate against elevated usage mostly from weather related demand variation. Some markets operate with multiple tariffs and tariffs can be found as compounded tariffs over various time frames, such as daily and seasonal multiples.
Critical events where particularly high tariffs are imposed differ in the number of critical events that can/will be called, the length of time the event is active for and the notice periods associated with the event.

2.6.3 *Market Examples*

An overview of this strategy as it is employed in active markets is provided below to elaborate on specific differences in implementation and constraints to participation.

2.6.3.1 Nordic Countries

In the Nordic countries, implicit DR has been enabled through the rollout of smart meters and dynamic tariffs. These tariffs facilitate lowering the cost of energy to the consumer as, by accepting and engaging directly with the volatility of market prices, the customers are not paying for the risk that is otherwise born by the retailer. Furthermore, consumers are given the opportunity to reduce their energy costs by adapting their energy consumption patterns and shifting consumption towards cheaper periods. A criticism of the implementation of implicit demand response tariffs in the Nordic countries in the limited communication integration and thus flexibility.

2.6.3.2 France

Time of Use Tariffs (day/night) are implemented in France although consultation with stakeholders has raised the need for the introduction of critical peak pricing.

2.6.3.3 Germany

Most DSOs in the German electricity system offer two-day time tariffs and two-night time tariffs. There are essentially on- and off-peak tariffs for both day and night, with the main peak tariff occurring in the day and the main off-peak in the night associated with reduced network fees. This system is considered outdated in the context of high shares of renewables and distributed generation and the true on/off peak times cannot be covered by this tariff structure.

2.6.3.4 Spain

Implicit DR offerings in Spain are relatively evolved in comparison to neighboring EU member states. Companies are offered 3-period and 6-period tariffs with large deviations in peak and off-peak prices the fixed tariff (proportional to the hired power) and the variable tariff (related to the energy consumption) schemes. Shifting consumptions to period 6 (night, weekends and August) in the 6-period tariff allows significant economic savings for companies and many heavy energy use industries that require little human interaction do not run weekday daytime heavy energy operations a result.

In the residential retail market, domestic consumers can choose between free market and regulated market energy provision. The regulated market is determined by the Government and provided by a limited number of appointed traders to offer an hourly tariff with a fixed base amount that is charged per unit and an additional variable amount charged as a function of the electricity consumption. The fixed amount counts for approximately 60% of the energy cost and the fixed amount 40%. The variable component depends largely on the energy wholesale market price and is settled on the previous day. 1- and 2-period tariffs are offered. An example of daily price variations for consumers on the 1- and 2-period tariffs is given in Figure 7.

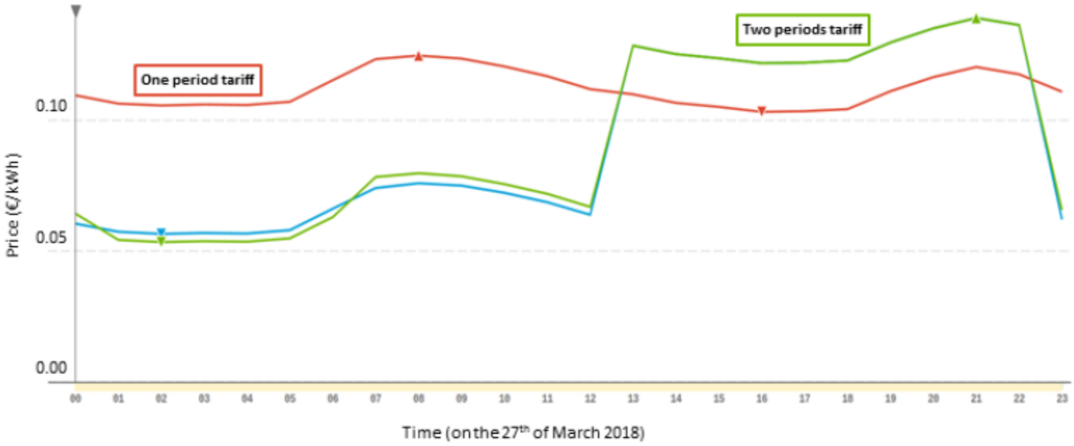

Figure 7: Example day for 1- and 2-period regulated tariff for domestic consumers in Spain. Hourly prices on 27/03/2018 [5]

In Figure 7, the red line shows the single period regulated tariff. On this example day, the difference between the cheapest (16:00) and the most expensive (08:00) prices is just 2.4 c€/kWh, the variation being approximately ±10% around the average price. This price difference is unlikely to impact consumer behaviour where effort is required to shift load. However, the 2-period tariff shows approximately ±40% variations around the average which is much more likely to incentivise behavioural change of the consumer.

3. Detailed Overview of DR Programs and Current DR Strategies Including Actor Involvement Analysis

In order to ensure that generation and demand are balanced at all times and in all locations, a range of measures (i.e. Flexibility Services) are employed across various time horizons. These services are secured under various procurement mechanisms (e.g. markets, bilateral agreements, competitive tendering, etc.) and can be broadly broken down as follows:

I. Capacity Market (CM): the aim is to deliver generation adequacy. The capacity contracts are assigned to providers through auctions envisioned to ensure a capacity requirement in order to match the reliability standard set by each national regulatory authority.
II. Wholesale Market (WM): this market allows generators to sell their electricity to suppliers from several years ahead up until Gate Closure (i.e. the time by which all notices must be provided).
III. Balancing Market (BM): its objective is to sustain demand and supply balance (energy) post Gate Closure as generators and suppliers will most probably generate or consume more or less than they have sold or bought in the WM. The system operator accepts offers and bids for electricity in order to balance the transmission system during the post Gate Closure period.
IV. Ancillary Services (AS): these are used by the system operator to make sure that supply matches demand at all times and that the system frequency stays within predetermined limits around the nominal level.

The integration of DR programs in the planning and operation of electricity systems from a time horizon point of view is demonstrated in Figure 8. An important demand side resource that can be considered independently, but not necessarily as disconnected from the above described DR programs is energy efficiency.

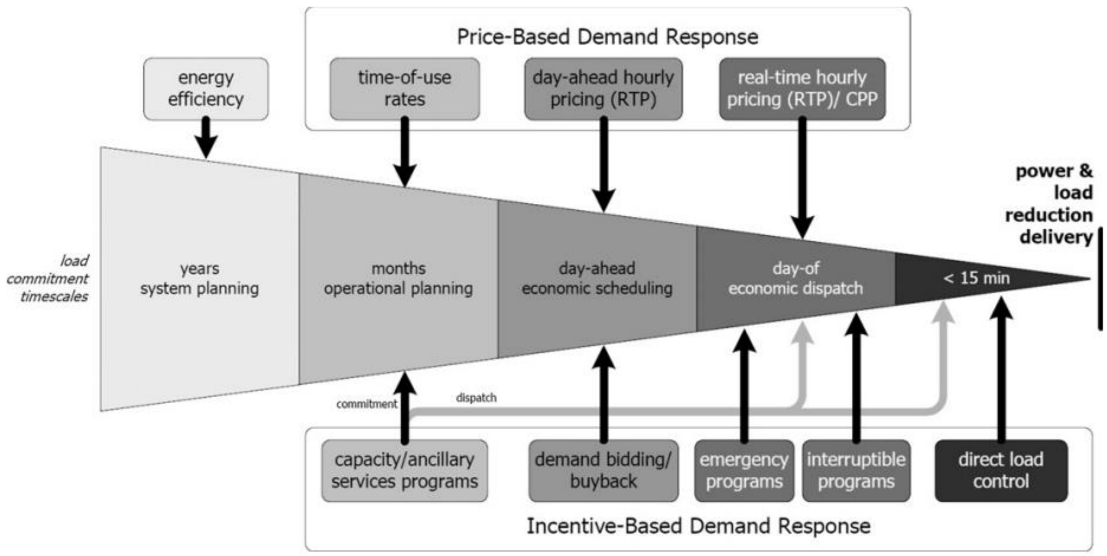

Figure 8: Demand response in electric system planning and operations [6]

3.1 Actor Definitions

The existing market participants have been described in the harmonized role model established by entso-e [7]. This Role Model has been developed in order to facilitate dialogue between the market participants from different countries through an agreed terminology and the designation of a single name for each role and domain that are prevalent within the electricity market. Establishing an agreed set of terminologies and role definitions is an ongoing process as the electricity system is evolving, thus the latest version (currently ENTSO-E, 2018) should be used at all times. In the following those roles relevant to the DELTA solution and the associated use cases are listed and supplemented by new roles such as the aggregator. To each role the potential use of flexibility is mentioned based on a functional perspective – not on existing business models.

3.1.1 *Independent System Operator (ISO)*

The ISO controls, coordinates and monitors the operation of the electric power system. The major responsibility is to ensure the security and reliability of the power system by providing supply of emergency reserves or reactive power from other entities. ISO must also ensure that the power system is operating operate in a fair way that doesn't benefit some market participants more than others.

3.1.2 *Transmission System Operator (TSO)*

Definition in the Harmonized role model, called System Operator: "A party that is responsible for a stable power system operation through a transmission grid in a geographical area. The System Operator will also determine and be responsible for cross border capacity and exchanges. If necessary, he may reduce allocated capacity to ensure operational stability". More specifically, TSOs must guarantee that adequate network transmission capacity is available for energy to flow freely between its producers and its end users, while maintaining system balance. Moreover, the TSO safeguards the system's long-term ability to meet electricity transmission demands while being responsible for maintaining the system's stability by deploying regulating capacity, reserve capacity, and incidental emergency capacity.

3.1.3 *Transmission Company (Transcos)*

The Transcos coordinate, control and monitor the transmission network. They own transmission assets (e.g. cables, lines, transformers and reactive compensation devices) and they operate according to the instructions of the independent system operator ISO. Their main responsibility is to transfer the electricity from the generators to the consumers. Furthermore, they are accountable for development the transmission system in order to ensure long-term ability of the system to meet demands for the transmission of electricity.

3.1.4 *Distribution System Operator (DSOs)*

According to Article 2(6) of the Directive 2009/72/EC, DSO is 'a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity.' This definition is left unchanged by the 'Winter Energy Package', 2016. Besides the regional distribution and supply task it is also the DSOs' responsibility to ensure the security of their networks with a high level of reliability and quality.

3.1.5 *Distribution Company (Discos)*

The Discos own and operate the local distribution network in an area. They can have monopolies, sell electrical energy to all customers connected to their network or they can be responsible only for operating maintaining as well as developing the distribution network and grid stability. Further responsibilities can be the integration of renewable energy sources at the distribution level and regional load balancing.

3.1.6 *Generating Company (Gencos)*

The generators produce and sell electrical energy. Gencos can own a single generating unit or a group of generating units, which then is referred to as Independent Power Producers (IPP). Generating companies can also sell services (regulation, voltage control and reserve capacity) to the system operator in cases where the quality and security of the electricity supply must be maintained.

3.1.7 *Market Operator (MO)*

The MO manages the market settlement system. Its objective is to match the bids and offers submitted from buyers and sellers and then determine the market price based on certain criteria according to the market structure. Additionally, the MO monitors the delivery of energy and forwards payments from buyers to sellers.

3.1.8 *Balance Responsible Party (BRP)*

The 'Winter Energy Package' defines a BRP as a market participant or its chosen representative responsible for its imbalances in the electricity market (EC, 2016). Given that the market participants have an implicit responsibility to balance the electricity system, the BRPs are financially responsible for keeping their own position balanced over a given timeframe (the Imbalance Settlement Period). The remaining short and long energy positions in real-time are described as the BRPs' negative and positive imbalances, respectively.

As described by entso-e in 2013, "In order to be balanced or help the system to be balanced according to the provision defined by the terms and conditions of each TSO, each BRP shall be entitled to change its Position in the Intraday timeframe until the Intraday Cross Zonal Gate Closure Time basing on rules and criteria defined by its Connecting TSO. In this case each BRP is obliged to respect specific rules and criteria as defined in terms and conditions of each TSO. Any modification of the Position declared by the BRP shall be submitted to the Connecting TSO if specified in accordance with the terms and conditions by each TSO. TSOs shall not be obliged to accept a change of Position by a BRP after the Intraday Cross Zonal Gate Closure Time. Some market designs rely on BRPs Positions being frozen prior to delivery; others allow for notifying intra-zonal trades after delivery which may help intermittent generation and Demand Side Response to participate in short time (bilateral) markets. TSOs that do not allow for ex-post notification are not obliged to do so and can continue current practice and those TSOs that do allow for ex-post notification are also allowed to continue current practice, even if it is not an obligation. A BRP is financially responsible for the residual imbalances of its perimeter (portfolio) after the process explained above concerning the modification of Position. TSOs are entitled to require BRPs to have a balanced Position after the day ahead process and this requirement would be included in the terms and conditions related to Balancing. This possibility is particular important for TSOs interacting with BRPs that only trade (i.e. have no portfolio of physical injections or withdrawals and hence no Allocated Volume). For those BRP's a balanced Position means that in their commercial trade schedules sales equal purchase. Without this requirement there would be volumes of energy unaccounted for in the system at this stage.”

3.1.9 *Retailer*

Retailers do not own any large physical assets of the power network. They buy electrical energy on the wholesale market and sell it to consumers who cannot participate in that market. Some retailers are subsidiaries of generation or distribution companies. The customers of each retailer can be connected to different Discos.

3.1.10 *Aggregator*

Aggregators can provide services to aggregate energy production from different sources, including local aggregation of power demand and power supply from consumers/prosumers.

3.1.11 *Prosumer*

A prosumer is a new entity that consumes but also can produce or store electricity. Prosumers are able to own and operate small or large parts of the power grid and obtain revenues according to their energy utilization.

3.1.12 *Customer*

A customer is an entity that consumes electricity. Small consumers are connected to the distribution system and they buy electricity from a retailer. Large consumers can, on the other hand, either buy electricity directly from the electricity market by bidding for purchase.

3.1.13 *Regulator*

The regulator is the governmental body assigned with the duty to ensure a fair and efficient operation of the electricity sector and participants. It defines the prices of the services and products offered by the entities having monopolies, while establishing rules for the energy market and examining cases in which market power may be misused.

3.2 Actor Involvement Overview

An overview of the involvement of the actors specified in section 3.1 in the DR strategies specified in section 2 is provided in Table 1.

Table 1: Actor Involvement in DR Strategies Overview

DR cluster Actors	Direct Load Control	Load curtailment requests	Demand reduction bidding	Ancillary Service provision	Emergency response	Implicit DR
Independent / Transmission System Operator	Not in the direct responsibilities of TSOs / limited usage	Directly interested but acting through the local DSO.	Not in the direct control of TSOs but aggregated result is useful to balance the system.	Directly interested since ancillary services are of prime importance in the day to day activities of TSOs	Directly interested since emergency procedures are in place to smoothly operate the system and avoid blackouts.	Not in the direct responsibilities of TSOs
Transmission Companies	Not directly involved or affected	Not directly involved since this is an operational need under emergencies.	Not in their direct interests.	Not in their direct interest	Not directly involved since this is an operational need under emergencies.	Interested to receive adequate use of system charge through the applied tariffs.
Distribution System Operator	High interest as the market facilitator and use of demand flexibilities for optimal use of infrastructure and security of supply.	Directly interested responding to local or system needs. In general, this action is highly automated.	Directly interested since DR will be used as an alternative to grid reinforcement and optimal use of resources.	Directly interested since ancillary services will be of prime importance in the day to day activities of DSOs	Directly interested responding to local or system needs. In general, this action is highly automated.	High interest as the market facilitator to use implicit DR effectively in optimal use of infrastructure and security of supply.
Distribution Companies	High interest in delivering optimal resource development.	Not directly involved since this is an operational need under emergencies.	Directly interested since DR will be used as an alternative to grid reinforcement and optimal use of resources.	Not in their direct interest	Not directly involved since this is an operational need under emergencies.	High interest in delivering optimal resource development.
Generating Companies	Not directly involved or affected.	Directly interested since load	Directly interested since their generation	Directly interested since ancillary	Directly interested since emergencies are	Not directly involved or affected.

		curtailment is a system need that results usually from generation shortage.	planning is dependent on the aggregated DR and the corresponding quoted prices.	services are a complementary source of income and they will surge maximising profits	a system need that results from active grid assets including generation.	
Market Operator	Directly involved since load management is directly related to the operation of the market.	Directly interested since load curtailment should be adequately covered in the market rules and the clearing out.	Directly interested since DR is a market activity driving optimal use of resources and responsive and fair rules are a must.	Directly interested since ancillary services are aimed to go through an open competitive process that should be supervised.	Directly interested since emergencies should be adequately covered in the market rules and the clearing out.	Directly involved since management of load through well selected tariffs creates a healthy market to operate.
Balance Responsible Party	Directly involved since load management is directly related to the balance of the grid.	Directly interested since load curtailment is the result of imbalance at a specific point in time.	Directly interested since DR usage affects hour to hour balance hence directly involved in the process.	Not in their direct interest.	Directly interested since emergencies need restoration of balanced conditions through automated actions and follow up activities.	Directly involved since load management is directly related to the balance of the grid.
Retailers	Directly involved since load management of their load portfolio can be managed directly by them or through aggregators requiring bilateral agreement.	Directly interested since load curtailment should be adequately addressed in the contracts of their customers.	Directly interested since DR can be part of their portfolio and its usage affects their daily activity.	Directly interested since ancillary services are a common charge to all users of the grid through a regulated methodology.	Directly interested since emergencies should be adequately addressed in the contracts of their customers.	Directly involved since load management through tariffs is an important day to day function for generating their revenues.
Aggregators	Directly involved since load management is part of their portfolio.	Directly interested since load curtailment should be adequately addressed in the contracts of their customers.	Directly interested since DR is part of their portfolio acting on behalf of the providers aiming to achieve the highest	Directly interested since ancillary services can be one of their aggregated products that they put forward in response	Directly interested since emergencies should be adequately addressed in the contract of their customers.	Lightly involved since their main portfolio is not tariff dependent.

			possible revenues.	to calls.		
Prosumers	Directly involved since load management is an option that they should explore for optimal energy management in meeting their needs.	Interested but unavoidable.	Directly interested since DR is one option for managing flexibility within their load synthesis for minimizing energy cost without losing comfort.	Directly interested since they can be providers through the aggregated services of their aggregators	Interested but unavoidable.	Directly involved since load management through effective use of tariffs can optimise their energy use cost.
Customers	Directly involved since load management is an option that they should explore for optimal energy management in meeting their needs	Interested but unavoidable.	Directly interested since DR is one option for managing flexibility within their load synthesis for minimizing energy cost without losing comfort.	Directly interested since they can be providers through the aggregated services of their aggregators.	Interested but unavoidable	Directly involved since load management through effective use of tariffs can optimise their energy use cost.
Regulator	Directly involved since market regulation is his / her responsibility.	Interested to see the aggregated effect as evidence for market and grid development.	Interested to oversee that the market is operating smoothly to the benefit of the end user.	Interested to oversee that the market and operators follow smoothly the respective policy / regulation on ancillary services.	Interested to see the aggregated effect of emergencies as correctly reflecting the targeted security of supply.	Directly involved since market regulation is his / her responsibility.

3.3 Influential Stakeholders

The primary stakeholders for Demand Response (those with high influence and power with respect to DR) include:

- TSOs/DSOs/Retailers
- Aggregators
- BMS & Energy Equipment Manufacturers
- Building Owners/Managers
- Policymakers

Secondary stakeholders for Demand Response (those without high power/interest but still playing an important role) include:

- Energy Service Companies (ESCOs)
- Building Designers
- Builders/Developers
- Maintenance Teams
- Building Occupants

The relevance of Demand Response alongside its challenges and benefits from the perspectives of the primary stakeholders are given in Table 2.

Table 2: Influential Stakeholders: Demand Response Relevance/Challenges/Benefits

Actor	Relevance	Challenges	Benefits
TSOs/DSOs/ Retailers	• Managers of power network and ensuring grid stability • Flexibility buyers • Retailers can become aggregators	• ICT infrastructure and forecasting • Incentives for energy efficiency solutions • DR potential knowledge	• Improving capabilities to manage reliability and grid imbalances • No further infrastructure investments • Satisfied customers
Aggregators	• Flexibility aggregation to deliver value to customers and interested parties • Give market access to end prosumers in order to become more active	• Recasting of market rules for balancing, reserves, capacity and wholesale market to include DR • Fair competition between market players • Allow Flexibility Service • Define the role and responsibilities of market participants	• Revenues from commercial agreements • Revenues from providing services to final-users • Revenues from associated services
BMS & Energy Equipment Manufacturers	Technology enabler DR implementation Visibility and control of the buildings assets	Monitoring of the state of energy demand and production Ability to accept and process DR signals Ensuring to maintain the comfort of the occupants • Interoperability	• Increased equipment sales • Revenues from proving services

Building Owners/Managers	Implementation of DR systems Know valuable information about building characteristics	Lack of interest for complex non-automated systems Training is essential for managers • Hesitation over future energy prices and regulations	Cost and electricity- savings Improved operation of equipment • Greener buildings/facilities
Policymakers	Policy enablers Offering a promising and stable DR environment	Having alignment between the National Energy Strategy and EU directives Granting non-discriminatory access to all market participants Raising awareness on DR benefits Accelerating the energy market development to foster future and upcoming changes	Establishing functional energy markets which will lead to growing economies Increase impact on network codes

3.4 DR Services in Europe

Following significant installation of renewable resources and the large increase of energy prosumers in the system, several private entities came into the market with a business model focus on the provision of Demand Response services. Companies such as Restore, KiWi Power and Lichtblik started providing Demand Response services in the UK, German, French and Belgian markets. These services are currently focused mainly on industrial scale consumers due to the relatively high technical unit rating. However, the technological solutions and IT systems infrastructure are essentially scalable and thus could in theory integrate smaller prosumer/consumers into the Demand Response services market.

An overview of Demand Response service providers in Europe and their geographic distribution (in 2015) is illustrated in Figure 9.

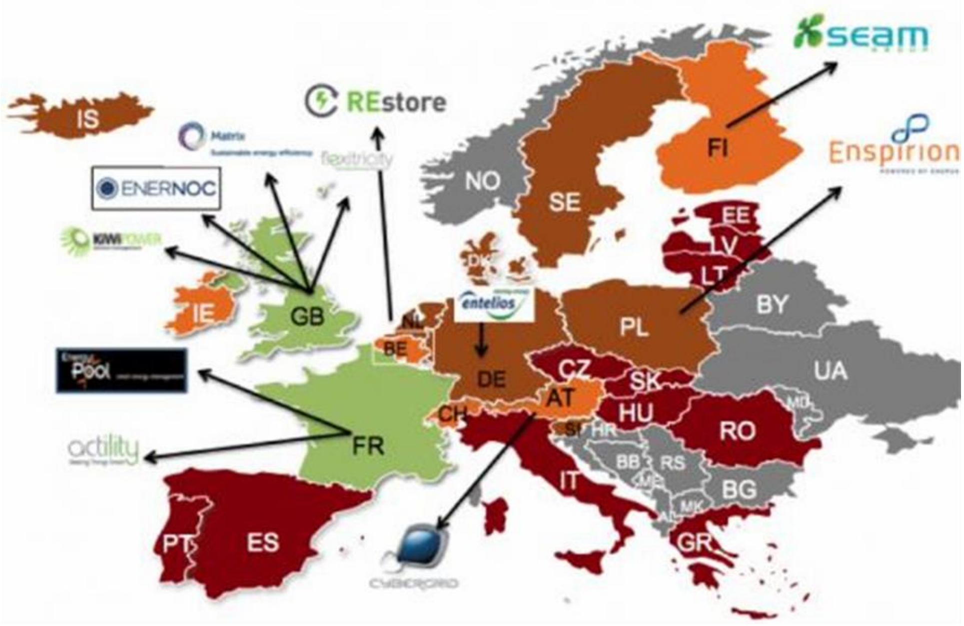

Figure 9: Demand Response Service Providers in Europe (2015) [8]

For reference, the state of development for explicit demand response in Europe in presented in Figure 10.

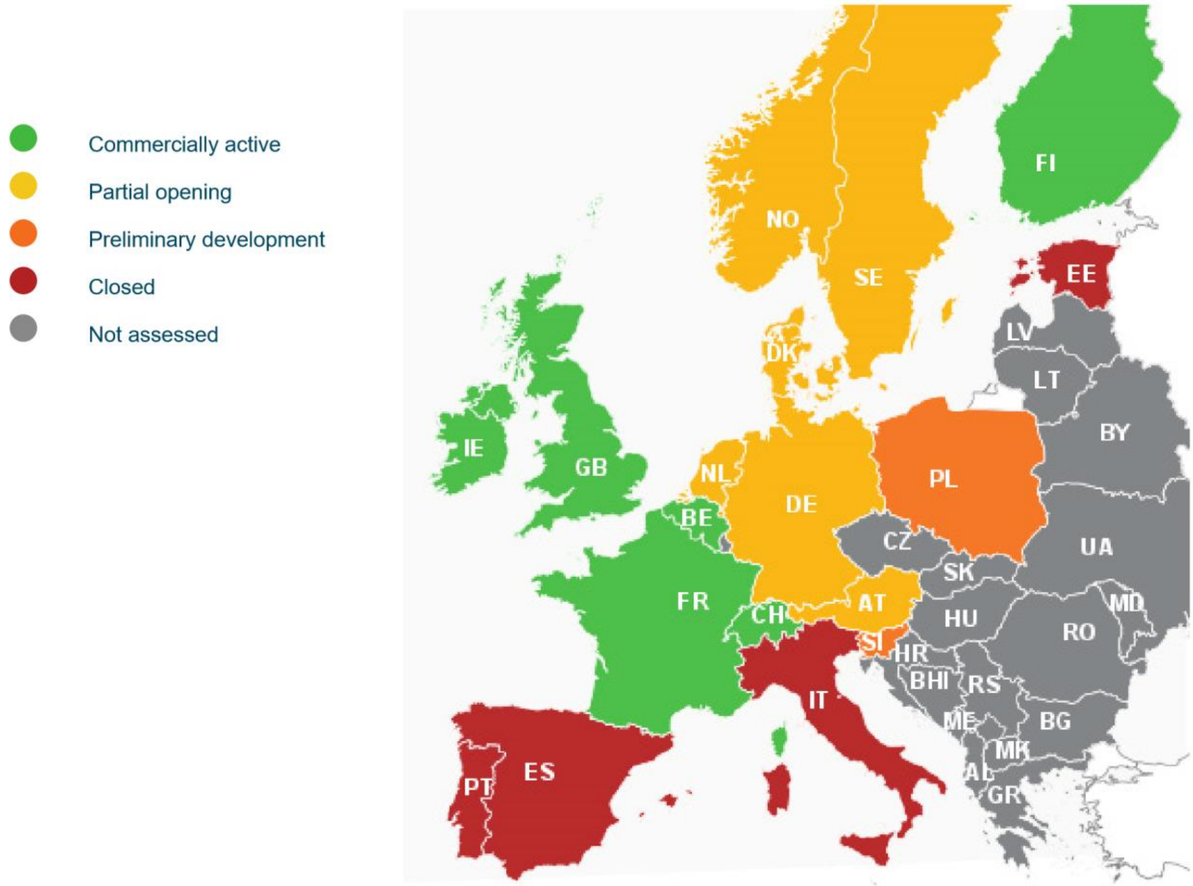

Figure 10: State of development of Explicit Demand Response in Europe (2017) [9]

There are several service providers who offer help to organisations that are looking to participate in demand response. Some can be classed as service facilitators, offering hardware and software solutions to provide a route to service provision and market participation; others offer more traditional consultancy services in the form of technical advice, business modelling and equipment design and specification. The available Demand Response Services are summarised alongside their relevance to the DELTA project in Table 3.

Table 3: Available Demand Response Services and Relevance to DELTA

Provider	Service	Region	Description	Relevance to DELTA
REstore	Flexpond Cloud Based Platform	Europe	Flexpond is a cloud-based platform that allows Commercial & Industrial consumers to participate in Demand Response programmes. (Demand Response programmes for industries in Europe, 2016)	High
EnerNOC	Implementation of DR programmes	Global	EnerNOC provide a range of consultancy services to support the design and deployment of DR solutions. (Energy Management - Control, Submetering & Monitoring., 2016)	Medium
Kiwi	Implementation	UK	Frequency Response Program, Capacity Reserves	High

Power **Flexitricity** **Origami Energy**	of DR programmes		program, Network constrain management (Kiwi Power, 2016) (Flexitricity, 2017) (Open Energi, 2017) (Origami Energy, 2017)	
Voltalis	Implementation of DR programmes	France	Frequency Response Program, Capacity Reserves program, Network constrain management (Voltalis, 2017)	High
Energy Pool	Service Provider and Implementation of DR programmes	France, Belgium, UK	DR potential assessment and implementation of DR programs. (Energy Pool, 2016)	High

There are many software packages on the market to enable participation in various forms of demand response for entities with sufficient potential. These vary significantly in cost, scope and sophistication and so careful research must be undertaken by prospective clients to ensure that the tool they purchase is appropriate for their needs. An overview of software solutions in the Demand Response framework and their relevance to DELTA is given in Table 4.

Table 4: Available Demand Response Related Software Solutions and Relevance to DELTA

Provider	Service	Region	Description	Relevance to DELTA
AutoGrid	Demand Response Optimisation and Management System	North America	Cloud-based Demand Response Management System platform that is scalable to millions of endpoints, secure, and can be easily integrated into any third-party system through web-services APIs. (Auto-Grid, 2016). There is a family of related products Demand Response Optimisation and Management System (DROMS, Distributed Energy resource Managements System (DERMS), Virtual Power Plant (VPP) Points of strength: It manages assets, costumer classes and DR programs for aggregators. It includes real-time forecasting, predictive control and event modelling.	High
	EnerNOC Site Server (ESS)	Global	ESS can be connected to existing meters and is equipped to read and record consumption or generation data. These data are then communicated back to a central location (Energy Management - Control, Submetering & Monitoring, 2016) Points of strength: can connect to existing monitoring systems and leverage the services of dedicated team.	Medium
	Advanced Energy Intelligence Software		Cloud-based software which enables scheduling, monitoring and analysis of DR capacity. (Energy Management - Control, Submetering & Monitoring, 2016) Points of strength: it identifies inefficiencies and opportunities and acts as central communication point across staff involved	Medium
GE	PowerOn Precision Solution	North America	PowerOn™ Precision Solution is a Demand Response Management System. It allows organisations to manage DR programmes, field	High

			assets and operational activities. (General Electric, 2016) Points of strength: it includes a range of features such as load forecasting, load shaping, dispatch, manage the load rebound effect after an event and ROI projection	
Honeywell	Demand Response Automation Server (DRAS)	Global	Provides a method of managing DR programmes, resources and events. It enables a wide range of DR programme types. . (Honeywell, 2016) Points of strength: it includes advanced aggregation of assets as well as forecasting, analysis and scheduling.	Medium
Enacto	Enacto™ Collect	Europe & Asia-Pac	Cloud-based energy management software with three core modules: 'Collect', 'Insight' and 'Analytics'. It provides a foundation for DR by enabling an organisation to understand its consumption profile in detail (Elster, 2016) Points of strength: It performs analytics to also understand where opportunities are for DR.	Low
GridPoint	GridPoint Energy Manager	North America	Energy Management software that enables users to have a single point of control to monitor and manage energy consuming assets, across numerous sites, ensuring operational consistency and predictable spend. (Comverge - IntelliSOURCE, 2016) Points of strength: it can manage assets across multiple sites in one single location.	Medium
Comverge	IntelliSOURCE	Global	Cloud-based software that gives utilities a single operational view into all of their demand response and energy efficiency programmes, as well as automating every phase of mass-market demand management programmes. (Comverge - IntelliSOURCE, 2016) Points of strength: it automates every stage mass-market DR programmes. It includes a Demand Response Management System that enables event control, pricing including cycling, temperature setback, critical-peak pricing etc. It also provides curtailment reporting and optimised dispatch. It is structured in modules for many specific needs and it also uses open API standards, which allows for connection to third party devices.	High
Siemens	SureGrid	Global	Siemens offers a fully automated cloud-based Intelligent Load Management solution. SureGrid can monitor and control major energy consuming devices, such as HVAC, lighting, refrigeration etc., SureGrid technology (Smart Consumption for Commercial Building Operators - SureGrid, 2016) Points of strength: It enables each building to dynamically interact with the electricity grid based on local business rules and real-time asset and environmental conditions. It can operate automatically	Medium
Siemens	Demand Response Management System (DRMS)	Global	Software platform that allows organisations to manage all aspects of their DR programmes through a single, open-standards-based system. DRMS is able to target "surgical" planned load curtailments at localised grid environments where	High

			localised grid stress is present. The software is aimed predominantly at utilities and large aggregators. (Demand Response Management System (DRMS) - Smart Grid Solutions, 2016) Points of strength: DRMS ensures that DR activity is scaled in a cost-effective manner; automating manual processes that are typically used to execute DR events and settlement. It can be fully integrated with both field and back office utility systems.	
Silver Spring Networks	UtilityIQ	Global	Demand Response Management solution that optimises load management across disparate DR programmes and systems, dispatch of load control events as well as a notification system for informing consumers of upcoming events. (Silver Spring Networks Unveils New High-Precision UtilityIQ® Demand Optimizer; Oklahoma Gas & Electric to Leverage for Pioneering SmartHours DR Programme, 2016) Points of strength: it offers real-time optimisation and forecast analytics.	Medium
Kiwi Power	Kiwi Power Client App	UK	Kiwi Power is a UK based aggregator who offers demand response services. Their system is based on the use of Kiwi Power's own smart meter known as 'PiP'. Installation of a PiP gives the user access to the 'Client App' web portal.. (Energy Intelligence and Smart Metering, 2016) Points of strength: it enables users to real-time monitor consumption, track DR events and calculate revenues generated	Low
Alstom	e-terraDRBizNet	Global	Demand Response Management System that provides command and control capabilities over a utility's entire portfolio of DR programmes, locations, and end devices for residential, commercial, and industrial customers. (Alstom Products and Services, 2016) Points of strength: Incorporates dynamic resource modelling, optimised dispatch, real-time resource tracking, and state-of-the-art performance evaluation techniques	High

4. Relevant State-of-the-art in DR Programs (DR Research Programs and Expected Outputs)

To aid in the differentiation between the DELTA solution and existing projects dealing with Demand response, this chapter presents a review of the state-of-the art, highlighting the business cases associated with research projects and leading to a mapping of the links between DELTA and other projects to identify considerations for the realization of business cases.

4.1 Review of existing relevant research projects

Towards indicating the value of the DELTA project and its expected outcomes, it is worth making a brief reference to other Demand Response related projects and their outputs. In the following sections, some of the most relevant ongoing EU projects are presented.

4.1.1 *DRIvE*

4.1.1.1 Overview

This project covers three cutting edge science areas concerning the Multi-Agent Systems (MAS), forecasting and cyber security in collaboration with innovative SMEs attempting first market penetration in EU DR markets. The MAS technology will support near real time operations, facilitating the transition from the control of a limited number of assets towards a decentralized management of numerous assets providing DR services to system stakeholders (prosumers, aggregators and DSOs). The main outcome of the project will be a fully-integrated, interoperable and secure DR Management Platform for Aggregators offering advanced hybrid forecasting, optimization, fast-response capabilities and enhanced user interaction in compliance with Open ADR following the market model for the trading and commoditization of energy flexibility (USEF). With this way, a cost-effective mass market business mode is empowered managing a large number of heterogeneous assets [10].

4.1.1.2 Demand Response Business Cases

Associated business cases for demand response in the DRIvE project are shown in Table 5.

Table 5 High-level DR Scenarios of DRIvE project [10]

ID	*Name of Scenario*	*Purpose of Scenario*
BS1	Load shifting and energy management though MAS	Demonstrate the benefits of flexibility trading, evaluate the integration of distributed generation (self-consumption) and indicate the costs reduction for prosumers.
BS2	Ancillary services, such as voltage control, frequency restoration or containment reserve and general power quality support	Demonstrate the added value services to the system administrator (DSO) and display the potential of Fast Demand Response (real-time with hardware-in-the-loop (HIL) methodology.

4.1.2 *DR-BOB*

4.1.2.1 Overview

The aim of this project is to display the economic and environmental benefits of Demand Response in blocks of buildings considering different key actors. The key functionality of the DR-BOB Demand Response energy management solution is based on real-time optimization of the local energy production, consumption and storage. The optimization process can be configured so as to maximize economic profit or to minimize CO2 emissions according to user requirements. The solution can be adapted to fluctuations in the energy demand/production according to dynamic price tariffs and the changing weather conditions [11].

4.1.2.2 Demand Response Business Cases

Associated business cases for demand response in the DR-BOB project are shown in Table 6.

Table 6 High-level DR Scenarios of DR-BOB project [11]

ID	*Name of Scenario*	*Purpose of Scenario*
BS1	Electric Demand Reduction (STOR Market)	Demonstrate automated DR fulfilling the requirements of UK's explicit DR market opportunity.
BS2	Electricity Demand Increase (DTU Market Product)	Evaluate the potential of operating CHP in DR mode to support renewable integration at time of low demand.
BS3	Electric Peak Demand Reduction (Explicit)	Demonstrate manually delivered explicit DR with significant human involvement through notifications.
BS4	Electric Peak Demand Reduction (Implicit)	Demonstrate manual, implicit DR.
BS5	Static Frequency Response	Evaluate the potential of locally monitored, low latency DR.
BS6	Virtual Microgrid of Sharing of Electric Energy inside the demonstration	Demonstrate of new use of local excess of energy: instead to be sold to the grid the over energy is proposed to be absorbed into the building host and to be virtually absorbed into neighbor buildings
BS7	Gas Demand Reduction	Evaluation the possibility of boiler low consumption
BS8	Virtual critical peak pricing with automated control	Rescheduling of use
BS9	Virtual ToU tariff with schedule response	Demonstrate benefits to consumers

4.1.3 *RESPOND*

4.1.3.1 Overview

The RESPOND project aims to deploy an interoperable energy automation, monitoring and control solution that will deliver demand response at a building unit, building and district level. Using smart energy monitoring infrastructure, RESPOND will be able to detect energy conservation opportunities and adapt to indoor and outdoor conditions and comfort levels in real time through optimal energy dispatching, taking both supply and demand into account [12].

4.1.3.2 Demand Response Business Cases

Associated business cases for demand response in the RESPOND project are shown in Table 7.

Table 7 High-level DR Scenarios of RESPOND project [12]

ID	*Name of Scenario*	*Purpose of Scenario*
BS1	Load control switches for smart appliances leveraging PV panels	Demonstrate how the energy coming from renewable sources is optimized, avoiding the need to sell it or having to consume from the electricity grid. This means that it is not necessary for the user to have them activated at a certain moment. The smart plugs will provide also valuable consumption information and user habits information that will be used to further personalize the prescriptions to dwellers.
BS2	Load control switches for smart appliances leveraging electricity price	This DR action consists in activating appliances in periods when the electricity price is lower. This way, the total expense for the electricity consumed is reduced. Furthermore, this DR action can also consist in activating appliances in periods when aggregated electricity demand peaks are avoided. This action is feasible for appliances which are flexible in terms of their moment of use. Thus, it is not necessary for the user to have them activated at a certain moment.
BS3	Smart thermostats for heating systems	This DR action consists in leveraging the thermal inertia of the room to minimize the heat consumption. For example, if it is forecasted that weather will be warm, the thermostat set point could be lowered or even deactivated in advance, thereby capitalizing on the thermal inertia of the buildings. By making it easier for the tenants to adjust the heating and making time schedules for every room, it is expected to motivate the tenants to reduce their

		overall heat consumption.
BS4	Ventilation control	This DR action consists in opening windows to ventilate a room when the indoor conditions demand it.
BS5	Thermal load shifting	This DR action consists in leveraging thermal inertia of the building to minimize the heat consumption in peak hours.
BS6	Load control switches for heat pumps	This DR action consists in activating heat pumps in periods when the PV panels are producing energy. This way, the energy coming from renewable sources is optimized, avoiding the need to sell it or having to consume from the electricity grid. Furthermore, this DR action consists in leveraging the thermal inertia of the room to minimize the use of heating systems.
BS7	Neighborhood electric load shifting	This DR action consists in shifting appliances activation to another time period to avoid aggregated electric demand peaks. This would allow negotiating lower index tariff (the price for each hour is different, depending on the wholesale market price) with electricity provider.
BS8	Thermal inertia for optimizing heating systems	This DR action consists in leveraging the thermal inertia of the room to minimize the use of heating systems. For example, if it is forecasted that weather will be warm, the heater could be deactivated. The equipment involved will depend on the room where this DR will be applied.
BS9	Thermal inertia for optimizing cooling systems	This DR action consists in leveraging the thermal inertia of the room to minimize the use of cooling systems. For example, if it is forecasted that weather will be cool, the air conditioner could be deactivated. Furthermore, this DR action can also consist in activating air conditioner in periods when electricity price is lower. This way, the total expense for the electricity consumed is reduced. The equipment involved will depend on the room where this DR will be applied.
BS10	Neighborhood Domestic Hot Water (DHW) shifting	This DR action consists in shifting the use of DHW to another period of time when the Thermosolar panels are producing energy. This way, the energy coming from renewable sources is used

		more efficiently, avoiding wasting it or having to a higher consumption from the gas grid. Furthermore, this DR action can also consist in shifting DHW use to another period of time to avoid aggregated DHW demand peaks. This would allow negotiating lower tariffs with DHW provider.

4.1.4 *BestRES*

4.1.4.1 Overview

The BestRES project aims to develop innovative business models for integration of renewable energy sources by aggregating distributed generation such as wind, PV, biogas, biomass, hydro, Combined Heat and Power (CHP) and combining this with demand side management and energy storage [13].

4.1.4.2 Demand Response Business Cases

Associated business cases for demand response in the BestRES project are shown in Table 8.

Table 8 High-level DR Scenarios of BestRES project [13]

ID	*Name of Scenario*	*Purpose of Scenario*
BS1	Automation and Control of ToU tariff with two periods	Demonstrate the quantification of the benefits of a nationwide rollout of the related business model in all households in the UK.
BS2	Supplying mid-scale consumers with time variable tariffs including grid charges optimization	Optimize the electricity consumption of mid-scale consumers to reduce their energy bill. The load schedule optimization considers both the time-of-use pricing and the peak load pricing component.
BS3	Providing decentralized units access to balancing markets	Optimize the participation of flexible decentralized generation assets on power and reserve markets in France. The BM specifically considers valorizing the asset’s available flexibility on the day-ahead market and the rapid reserve market.
BS4	Trading PV and Wind Power	The aim is to optimally trade the deviation on the intraday market while considering the imbalance price to increase the asset’s turnover.
BS5	Using flexibility of customers as third party	This business case specifically looks at the operation of the aggregator on the day-ahead market, the intra-day market and the positive tertiary reserve market.
BS6	Demand side flexibilization of small customers (residential load profiles under a two-period ToU	The upper and lower price, for respectively peak and off-peak consumption, is varied to analyze their

	tariff)	effect on the create value. In the baseline scenario the upper and lower price are the same.
BS7	Activation and marketing of end user’s flexibility	Manage and optimize energy consumption in the office buildings of Business-to-Business (B2B) prosumers to decrease the cost of electricity.
BS8	Pooling flexibility for local balancing market and energy service provision	By using net billing and net metering tariffs with Time-of-Use cost components the BM offers options to minimize energy cost through an effective use of local Renewable Energy Sources (RES) generation and storage.

4.1.5 *FLEXcoop*

4.1.5.1 Overview

FLEXCoop will introduce a complete Demand Response framework providing a tool suite for aggregators and residential electricity consumers, in order to enable aggregators to exploit the flexibility of end-users in an effective way and give the possibility to consumers to participate actively in the energy management [14].

4.1.5.2 Demand Response Business Cases

Associated business cases for demand response in the FLEXcoop project are shown in Table 9.

Table 9 High-level DR Scenarios of FLEXcoop project [14]

ID	*Name of Scenario*	*Purpose of Scenario*
BS1	Energy efficiency and comfort	Provide close to real time forecasting and information for possible participation into Time of Use (ToU) distribution tariffs combining increased comfort of end-user by using monitoring and control over the equipment and devices.
BS2	Consumption optimization of cooperatives resources: • Self-consumption optimization of Distributed Energy Resources (DER) • Consumption optimization of energy bought on wholesale market	• Demonstrate the role of cooperatives in using consumers’ flexibility, so as to manage better the coop’s generation assets. • Use of consumers’ flexibility by the cooperatives for proper matching of the anticipated prices on wholesale market.
BS3	Participation into balancing and ancillary services	Provision of services from Cooperatives to other system actors (TSO, DSO etc.) by using

		consumers' flexibility.
BS4	Microgrid as a Service	Evaluate the possibilities of generation-consumption management by employing real-time management of decentralized generation.

4.1.6 *Dominoes*

4.1.6.1 Overview

The DOMINOES project aims to design, develop, validate and deliver a scalable local energy market solution enabling the application of Demand Response programs, aggregation of resources, grid management and peer-to-peer trading services. The two main objectives are to show the role of active consumers in the energy markets and how DSO can dynamically and interactively manage grid balance in the evolving energy system where decentralized generation and microgrids will be the main components [15].

4.1.6.2 Demand Response Business Cases

Associated business cases for demand response in the Dominoes project are shown in Table 10.

Table 10 High-level DR Scenarios of Dominoes project [15]

ID	*Name of Scenario*	*Purpose of Scenario*
BS1	Decentralized billing and bidirectional power flow	Demonstrate that a group of residential consumers can consume power from the grid and be charged individually. This is the most common situation in the electric markets. There is also the possibility of bidirectional power flow if a customer also produces energy.
BS2	Centralized billing and unidirectional power flow	Evaluate the situation where a group of residential consumers are treated as a whole node. The individual consumption is registered using smart meters. The whole node can be treated as a local market where contracts, grid services and balance services are provided by a local administrator.
BS3	Centralized billing and bidirectional power trading with the grid	Demonstrate that prosumers and consumers participate in an environment corresponding to the previous scenario, sharing costs of the grid and taxes. The difference is that there is the possibility to export power to the rest of the grid.
BS4	Diverse environment including industrial and commercial buildings	In this scenario, commercial buildings and industries have been included within the community.

		These buildings have specific demand profiles and their involvement can significant influence on the performance of the local market.
BS5	Islanded systems that can connect and disconnect from the grid	This scenario aims to highlight the role of disconnection possibility from the grid compared to the conventional node. This business case shows the flexibility and resilience of the local market considering also the difficulties and regulations about this process.

4.1.7 *Sabina*

4.1.7.1 Overview

Sabina project aims to introduce new technological and business models to achieve effective combination and management of generation and storage assets towards exploiting the correlation between electrical flexibility and the thermal inertia of buildings. The main objective of the solution proposed in the project is to demonstrate the efficiency of the cheapest possible source of flexibility. This topic concerns the existing thermal inertia in buildings and the enabled coupling between heat and electricity networks. Thus, a necessary condition is the accurate estimation of the thermal inertia of various buildings [16].

4.1.7.2 Demand Response Business Cases

Associated business cases for demand response in the Sabina project are shown in Table 11.

Table 11 High-level DR Scenarios of Sabina project [16]

ID	*Name of Scenario*	*Purpose of Scenario*
BS1	Thermal Inertia Model	Evaluate the use of the thermal inertia of buildings towards enabling excess electrical energy to be converted to thermal energy. The ability to estimate in an accurate way the thermal inertia of a building will allow the maximum utilization of flexibility within the whole system. This will be achieved by exploiting the capability to predict the amount of energy that is necessary to keep the building within its comfort zone under all conditions.
BS2	Building Level Management	Demonstrate the value of complete building level management framework towards increasing the integration of renewables at local levels and exploiting the synergies between thermal and power grid technologies.
BS3	Guarantee Quality of Supply	Develop appropriate algorithms for computation of inverter parameters, in

		order to guarantee local grid stability in case of high penetration of renewables.
BS4	District Level Aggregation and Management	Demonstrate the connection between increased renewable generation and demand response services. The wide spread integration of distributed generation requires flexibility within any electrical system. One option to increase the necessary flexibility is to employ the potential of demand response services.
BS5	Novel Remote Terminal Unit	Design and development of a RTU that is compliant with the new functionalities of electric networks (monitoring, decentralization, aggregation).

4.1.8 *eDREAM*

4.1.8.1 Overview

eDREAM project aims to contribute to the transformation of traditional energy market concepts considering smart grid capabilities and novel decentralized and community-driven energy systems. The main goal is the exploration of local capacities, constraints and Virtual Power Plants. Optimization problems will be investigated towards local and secure grid nodes stabilization. The ultimate vision is the delivery of a novel near real time Closed Loop optimal blockchain based Demand Response ecosystem enabling DSO and aggregators to cooperate in an efficient and secure way [17].

4.1.8.2 Demand Response Business Cases

Associated business cases for demand response in the eDREAM project are shown in Table 12.

Table 12 High-level DR Scenarios of eDREAM project [17]

ID	*Name of Scenario*	*Purpose of Scenario*
BS1	Prosumer DR flexibility aggregation via smart contracts	Demonstrate how prosumers are able to offer via smart contracts (registration in DR programs) their flexibility resources, both production and loads modulation. Prosumers can be involved in the process via the aggregators. Through the use of specific mechanisms enabling both supply-demand matching and decentralized coordinated control, the DSO will be able to assess and track the share of contracted flexibility services.
BS2	Peer-to-peer local energy trading market	Define and develop a mechanism for decentralized energy trading, giving the possibility to prosumers to trade energy by means of peer-to-peer transactions. The trigger event for initiation of market transactions will be price variations depending on the availability of energy in the grid.

BS3	VPP in Energy Community	Demonstrate how multiple local generation assets can serve primarily local communities and export power at distribution network. The main objective is the exploration of VPPs operating on a profit maximizing function and providing flexibility services to the TSO/DNO, while supporting the needs of local prosumers and consumers.

4.2 Linkage between the DELTA project and the aforementioned DR related projects

4.2.1 *DR Interoperability Framework – Initial mapping of related Business Cases*

In this section, the common points between DELTA's business scenarios and those of other projects were identified and presented. This is an initial mapping that gives insights for potential future synergies between the DELTA project and the other recent/ongoing DR related projects. This mapping can be the basis for examining the DR interoperability framework among the emerging solutions/tools of the aforementioned projects. The initial mapping of related business scenarios is presented in Table 13. Further descriptions of the DELTA Business Cases can be found in the publicly available DELTA D1.1 report.

Table 13 Mapping of DELTA's Business Scenarios with those of other DR related projects

DELTA Business Scenario Index	*Brief Description*	*Related BS from other project*
BS1	**Provision of high efficiency Demand Response services through the use of Delta Virtual Node Platform and associated services layer**	• **DR-BOB**: BS2 • **RESPOND**: BS7, BS10 • **BestRES**: BS3, BS6 • **FLEXcoop**: BS1
BS2	**Secure, automated Demand Response services via block chain enabled smart contracts**	• **DR-BOB**: BS1, BS5, BS6 • **BestRES**: BS1 • **eDREAM**: BS1, BS2
BS3	**Self-optimised Demand Response services via DELTA Virtual Node and portfolio management**	• **DRIvE**: BS1 & BS2 • **DR-BOB**: BS3, BS4, BS7, BS8, BS9 • **RESPOND**: BS1, BS2, BS5, BS6, BS8, BS9 • **BestRES**: BS2, BS7, BS8 • **FLEXcoop**: BS2, BS7, BS8 • **Dominoes**: BS1, BS2, BS3, BS4 • **Sabina**: BS2, BS4 • **eDREAM**: BS3
BS4	**Secure, real time asset metering and control through FEID and DELTA Virtual Nodes**	• **DRIvE**: BS1 • **FLEXcoop**: BS1, BS4 • **Sabina**: BS2, BS5

Considering the matching between DELTA's business scenarios and those from other DR related projects, a preliminary investigation can be conducted towards identifying the common methods and components. The outcome of this process can be used for establishing a common terminology for the business cases to be addressed. This approach can be carried out effectively throughout the project lifetime as the main objectives begin to be realized.

5. Conflating analyzed DR programmes and strategies with the development of DR business models

5.1 Overview on generic DR business models

In the D2.1 Report "Energy Market Analysis and Regulatory Framework Specification" the project team has outlined a **set of generic DR business models** which define the different roles and responsibilities of DR stakeholders in a non-specific way. These business models are based on experience from DR markets in EU countries and set the frame for further development and configuration in the later phases of the DELTA-project. They are categorised with respect to the different of the related income streams. On the one hand, there exist two generic business models based on the explicit use of DR:

- **Explicit DR as stand-alone service:** In this business model a DR Aggregator is bundling DR potentials from different clients, which as stand-alone potentials are too small to be offered to the various flexibility markets. The income streams originate from payments either from the TSO/DSO or from the BRP, which are usually shared between the DR aggregator and the clients. In this business model the service of DR aggregation has no interlinkage to power supply or any other service for the client.
- **Explicit DR combined with energy efficiency services:** In this business model the DR aggregation service is embedded into a more comprehensive energy efficiency service (EES). This approach is sometimes referred to as "dual service" and requires clear and transparent definition of the ESCO's and the DR Aggregator's role.
- **Implicit DR service aiming at the optimal utilization of time-of-use (ToU) contracts:** This business model starts from the fact that already now a certain group of electricity customers have a tariff with different price levels depending on the time of consumption. As many customers will not able to exploit the full saving potential of ToU tariffs, an external service provider (we propose the term flexibility service company FLESCO) takes care of load shifts at the equipment of the client in a way that the client takes maximum benefit of an (existing) ToU tariff and is remunerated either by fixed or performance-based fees.
- **Implicit DR including power supply:** This business model combines DR with the role of a retailer on the electricity market. In addition to its usual function of selling electricity to customers the retailer has access to DR potential at the customers' sites. From the retailer's point of view the access to DR potential represents a value as it may lead to savings both in wholesale prices and in balancing energy payments. The savings achieved are shared with the customer – usually through favorable tariffs.
- **Microgrid management** is a specific DR business model for those cases where the regulatory framework allows for microgrids, here defined as a group of interconnected loads and distributed energy resources (such as distributed generators, storage devices, or controllable loads) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the (macro)grid.

These business models will be further developed and differentiated in the following work steps of the DELTA-project. In this chapter we will perform a next step of analysis by assessing in which way the DR programmes and strategies analysed in chapters 2, 3 and 4 can form an input for the detailed development of marketable business models. In Task 2.3 (Definition of DELTA Business Models) we will build on this assessment and will develop it further towards solidification of a limited number of practically implementable schemes (uses cases, business models), allowing small and medium prosumers to participate in the flexibility markets.

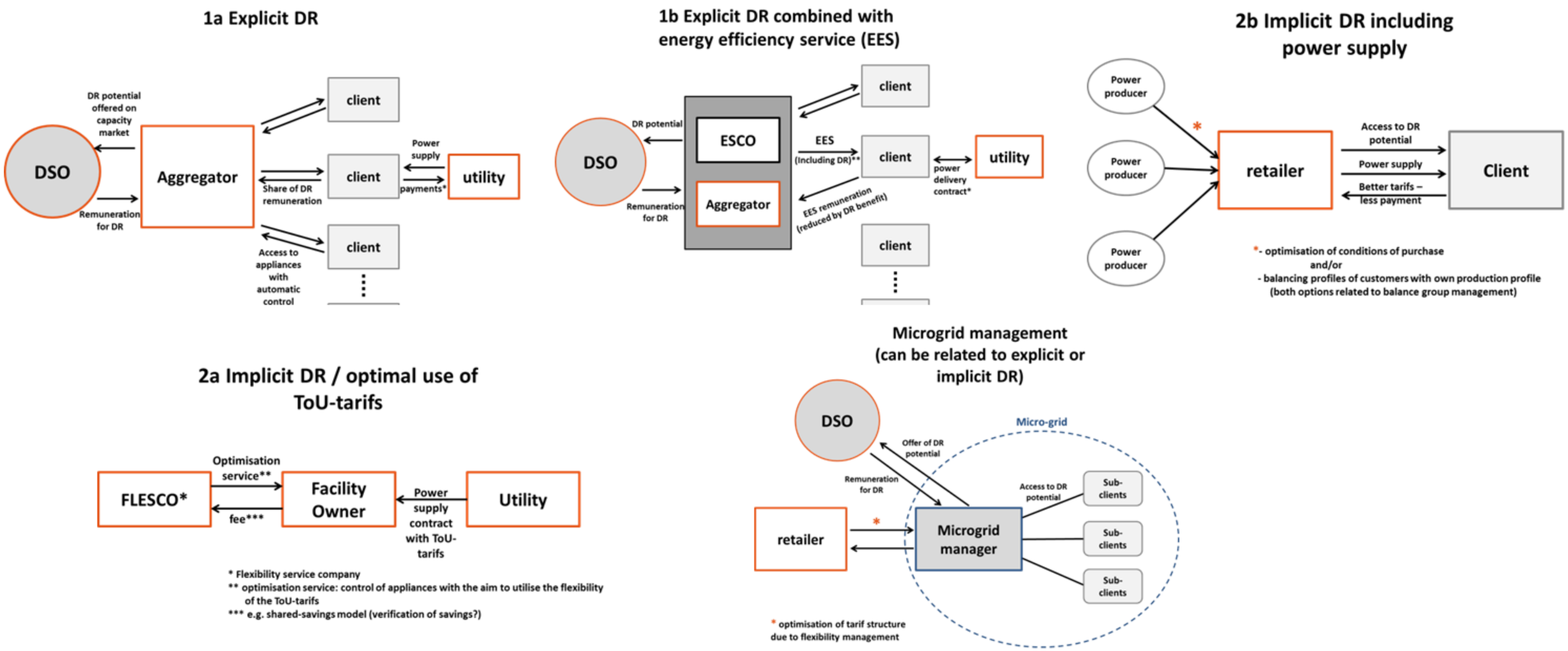

Figure 11 Main characteristics of set-up of generic DR Business Models

5.2 Linking analyzed DR programmes and strategies to business model development

One of the most common tools for business model development is the so-called business model canvas (BMC, cf. Figure 12). The BMC provides a framework helps to structure business ideas and to evaluate their marketability, still being flexible for adaptations and the integration of new elements.

The general structure of the BMC consists of the following parts:

- The right side summarizes those **business model elements that are connected with the costumer**: customer relationship, channels for customer approach, customer segments and revenue streams;
- The left side is related to business model elements that describe the **internal situation and challenges at the supplier's side**: Key activities connected with the implementation of the business model, key resources required to implement the key activities, key partners and cost structure;
- Both sides are connected by the most crucial element of each business model, the so-called **value proposition**, which refers to the following key questions: Which problems at the customer's side is the service/product helping to solve?, Which customer needs are satisfied by the service/product?, What is the specific offering?, What features or benefits match customer needs?.

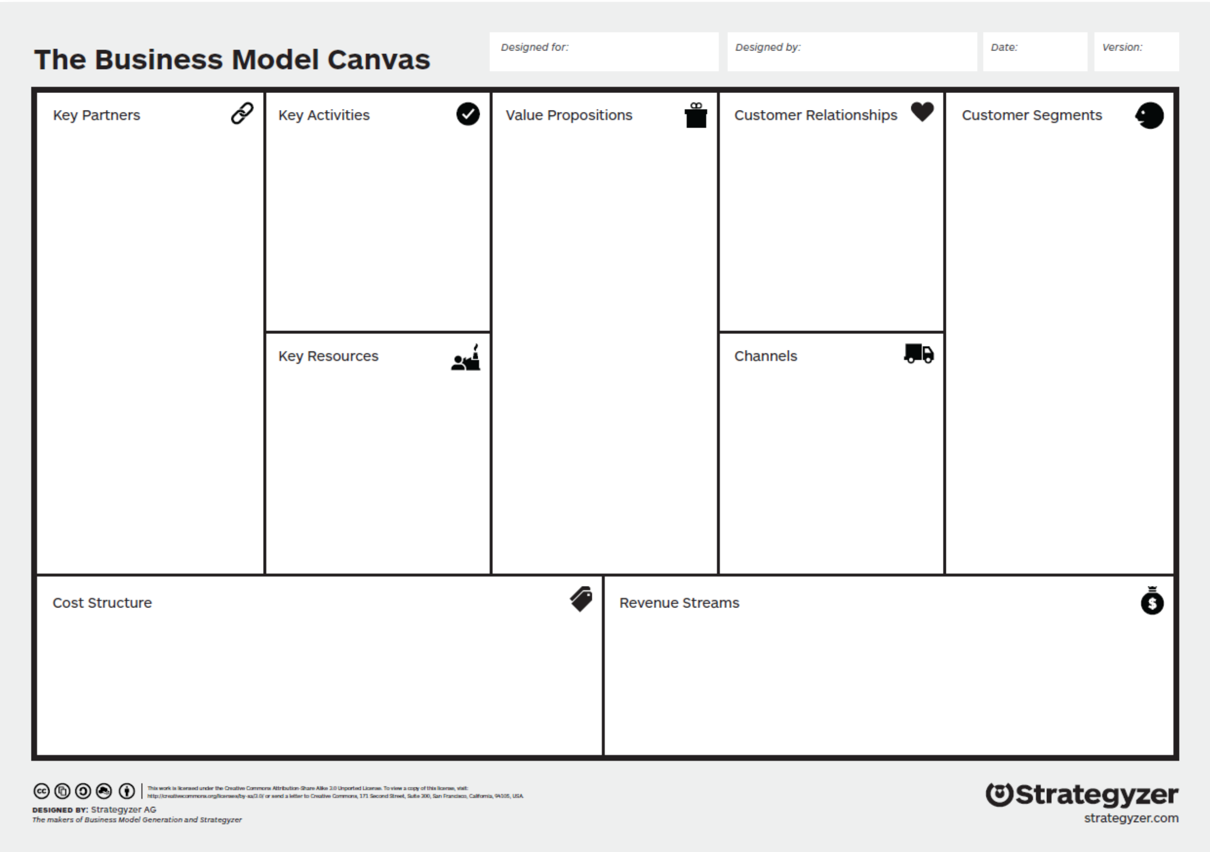

Figure 12 The business model canvas [18]

If we analyse the information gathered in chapters 2, 3 and 4 on DR strategies and programmes with respect to their relevance for the elaboration of DR Business Models in general, as well as for the formation of DELTA business models in particular – i.e. business models that refer directly to the application of the DELTA Virtual Node, we observe the following focus areas:

- The DR programmes strategies assessed in chapters 2 and 3 refer to key activities on the one hand and revenue streams and related with the generic business models on the other hand;
- The research projects analyzed in chapter 4 provide additional contributions on key resources related to the generic business models identified.

These aspects will be elaborated in more detail in the following sub-chapters.

5.2.1 *Key activities related to DR Business Model*

The DR programmes and strategies represent key activities which the implementer of a DR business model (DR Aggregator, retailer, microgrid manager, FLESCO) will need to implement:

- Direct load control, load curtailment, demand reduction bidding, ancillary service provision and emergency response can be seen as concrete activities that need to be implemented if explicit DR services are offered on the market. In the case of business models related to implicit DR the key activities include information of the clients on tariff signals as well as active dispatching at the clients' facilities, but usually they do not include activities at the interface to the TSO/DSO and or BRP. The sequence diagrams included in chapters 2.1 to 2.6 a detailed specification of key activities is presented.
- Not for all kind of DR services the whole range of possible activities will be relevant, but depending on the detailed definition of the DR services offered on the market, on the target group addressed and on the regulatory framework conditions in place a certain set of key activities will get into the focus. For example: The decision whether a business model will focus on the provision of ancillary services or on demand reduction bidding may depend on the selected target group as well as on the degree of freedom provided by the regulatory framework.
- The DR business implementer needs to have on the one hand all competences to perform the selected key activities; on the other hand, he needs the legal rights in line with the regulatory framework in place. In some EU the regulatory framework clearly limits the variety of implementable business models – for example, if the roles of market participants are not well defined, particularly the role of independent aggregators. Some markets only allow independent participation with the approval of energy utilities, complicating participation and increasing transaction cost.

5.2.2 *Specification of revenue streams related to DR Business Models*

The DR programmes and strategies assessed in chapters 2 and 3 define major revenue streams of the various generic DR business models:

- In the case of business models related to explicit DR the main revenue stream are the payments from TSO/DSO, BRP or retailers for the reservation of capacities for dispatch as well as for the actual dispatching. On the other hand, the terms and conditions will also include penalties for failure to curtail when called upon to do so. As the payments from TSO/DSO, BRP or retailers will have to be shared with the client (owner of the facility) it is not the gross payment that will arrive at the implementer of the business model, but only a somewhat reduced amount.
- In the case of business models related to implicit DR the revenue streams usually come from cost savings achieved through the full exploitation of ToU-tariffs. This means that the

Measurement and Verification (M&V) approach gains additional importance, as savings cannot be measured but only calculated (cf. chapter 5.2.3 below). It has to be noted that the precondition for the formation of revenue streams in this case is the availability of ToU-tariffs to the client. In EU countries electricity tariffs consist of one component related to electricity delivery and one component related to the utilization of the grid, where the latter is defined by regulation. Therefore, the ToU-structure of the tariff may relate either to one of these components or to both of them.

- In the business case of implicit DR including power supply the revenue streams represent a specific case as the savings come from more beneficial purchase conditions for the retailer on the electricity markets, both related to wholesale prices and to balancing energy payments. We suspect that this business model might be particularly suitable for DR integration of small and medium-sized prosumers as active participation of prosumers is practically not required in this case (reduction of transaction cost).
- In the business model of microgrid management there may be a combination of revenue stream for explicit and implicit DR. In this case, the limiting factor for the formation of revenue streams is the regulatory framework which in most EU countries is rather restrictive related to microgrids.

5.2.3 *Key resources related to DR Business Model*

The research programmes assessed in chapter 4 give valuable inputs with respect to key resources required for the implementation of the various generic DR business models. The term key resources in the BMC refers on the one hand to personal resources – including aspects such as education, competences and training – on the other it includes tools and instruments that the business model implementer needs to have at hand. In this context, we would like to underline the following important issues:

- One key resource for the implementation of expansion of DR business models to small and medium-sized prosumers will be a platform that is able to bundle smaller loads and implement DR-related activities in an automated, non-expensive and secure way. Therefore, the intended outcomes of the DELTA-project have to be seen in the context of other research projects that pursue similar objectives and may come up with the development of similar platform solutions.
- The aspect of key resources is closely linked with the equipment available at the clients' facilities. In this context the roll-out of smart devices and smart meters is important. Smart devices and potentially also smart meters can assist in real-time monitoring, automated remote control, measurement and verification. All of these benefits are central to integrating small and medium loads into flexibility markets.
- Several of the research projects assessed refer to testing of M&V approaches that may be applied for measuring the benefits of DR services with a focus on small and medium loads. From the point of view of business model development, the availability of reliable, but non-expensive M&V methods is crucial as the engagement of customers may be dependent in trust, whether the benefits of DR can be measured and thus shared among partners in a fair way.

5.3 Next steps towards implementable business models

The detailed analysis of DR strategies and programmes as performed in this report represents a first step toward the development of comprehensive and marketable DR business models allowing for the incorporation of small and medium-sized prosumers in the DR business. In overall terms, the detailed analysis of DR strategies and programmes leads to the following observations:

- The major input to business model development is related to key activities and key resources, i.e. on the in-houses processes of the business model implementer. We can derive from there that DR is still a rather “technology-driven” concept, where the stakeholders put major focus on technical and economic feasibility of DR in different sectors was well as on development of IT-tools and processes that enable pushing the boundaries of current DR applications towards new opportunities.
- For the moment, the current DR strategies and programmes provide rather limited insight in the “customer-side” of any business model: What is the value proposition that induces customers to join, because it addressed their needs?, What are the most promising customer segments?, How can customer groups be reached and kept, and how can they grow over time?, Which distribution and communication channels can be used? etc. Therefore, we see a clear need to focus on customer-related aspects of business model development in the next work step.
- The cost structure plays a crucial role in any business model and seems that only very limited information is available on this topic in current DR strategies and programmes. Altogether we have to underline, the success of any DR business model aiming at the residential and tertiary sector is largely dependent on cutting down transaction cost, as the expected revenues may be small for the single user.
- Finally, generic DR business models need to be further developed toward DELTA business models. This means that – based on the elaboration of promising business models for the expansion of DR towards small and medium-sized prosumers – we will also have to look closer at the business model behind the provision and operation of the DELTA platform. Who will be the most promising appliers of the DELTA platform? What are their specific needs? How can they best integrate the DELTA platform in their in-house processes? etc.

The above mentioned aspects represent crucial questions and challenges for the next work step in the DELTA project related to the enhancement of DR business models as well as DELTA business models (Task 2.3 Definition of DELTA Business Models; Deliverables 2.3 and 2.5 DELTA Business Models).

6. Barriers and Adaptation of DR Strategies to the Particularities of Cyprus Situation

6.1 Current Scenario

6.1.1 *Demand Response Participation Possibilities*

In the current operational framework in Cyprus, The University of Cyprus campus pilot site is/can be operated in just 2 of the Demand Response strategy clusters noted in Chapter 2, namely:

- Direct Load Control
- Implicit DR

6.1.1.1 Direct Load Control

Cyprus employs a direct load control system for water pumps and thermal storage units. Both are associated with different tariffs.

The water-pumping tariff states:

'This tariff is applicable, where electricity supply is solely used for Water-Pumping, for the purpose of water supply and/or irrigation and/or drainage of rain water. The supply of electricity shall be interrupted daily for a period of 4 hours during Peak Periods, between June and September, on weekdays only.'

The weekday peak periods between June and September in Cyprus are specified as: 09:00-23:00 and the current timeframe for disruption is 11:30-15:30.

Preferential tariffs are offered to customers operating within the Direct Load Control framework. The current (bimonthly) tariff is summarized in Table 14.

Table 14: Water-pumping Direct Load Control Tariff in Cyprus

Item	Charge
Energy Charge per kWh	c€ 9.44
Network Charge per kWh	c€ 3.00
Ancillary Services Charge per kWh	c€ 0.64
Bi-monthly Meter Reading Charge	c€ 0.98
Bi-monthly Supply Charge	c€ 4.76

In each bi-monthly period, the price of unit (kWh) charged shall be increased or decreased by the value of the Coefficient of Fuel Adjustment currently in force, for every 1 cent increase or decrease in the basic price of €300 per metric tonne of fuel cost, which cost shall be defined by EAC for the bi-monthly period, based on the purchase price of fuel.

The thermal storage tariff offers even more preferential rates to customers engaging in the Direct Load Control framework, yet the timeframe of operation is relatively complicated. The storage of thermal energy states:

'The Tariff for Storage of Thermal Energy is applicable where the electricity is used for the purpose of storage of thermal energy (storage heaters, water-heaters etc.) or for any other purposes approved by EAC, during the periods as EAC may prescribe.'

The hours of operation and supply restrictions are separated by geographical area with specific rates given to industry, as shown in Table 15.

Table 15: Cyprus Tariff for Storage of Thermal Energy Specifics Example for January to March 2019

AREA	GROUP LOAD (ATHALASSA)	GROUP LOAD DISTRIBUTION			HOURS OF SUPPLY		TOTAL HOURS OF SUPPLY
		GROUP	ADDRESS/ COMMAND	RECEIVER IDENTIFICATION	DAY	NIGHT	
NICOSIA - KYRENIA - MORFOU	Β	B	A02-12	NONE	15:15-17:00	23:15-07:35	10:05
	Γ	C	A03-12	• BLUE	15:25-17:10	22:15-06:20	9:50
	Δ	D	A03-13	•• BLUE	14:15-15:55	22:15-06:20	9:45
	Ε1	E1	A03-17	WRITTEN IN FULL	12:35-14:15	21:40-05:35	9:35
	Ε2	E2	A03-19	"	13:45-15:25	21:30-05:35	9:45
	Ε3	E3	A03-14	"	13:15-14:55	22:15-06:20	9:45
	ΣΤ1	F1	A02-10	"	12:55-14:40	23:15-07:00	9:30
	ΣΤ2	F2	A02-11	"	14:40-16:30	21:55-06:00	9:55
	ΣΤ3	F3	A02-14	"	13:30-15:15	22:55-07:00	9:50
	ΣΤ4	F4	A02-19	"	11:30-13:10	21:10-05:15	9:45
	ΣΤ5	F5	A03-20	"	14:55-16:40	23:30-07:25	9:40
	ΣΤ6	F6	A03-21	"	12:45-14:25	21:40-05:35	9:35
	ΣΤ7	F7	A04-6	"	12:20-14:10	22:35-06:40	9:55
	ΣΤ8	F8	A04-7	"	10:35-12:20	20:45-04:50	9:50
	ΣΤ9	F9	A04-8	"	10:35-12:20	20:45-04:50	9:50
	ΣΤ10	F10	A04-9	"	10:35-12:20	20:45-04:50	9:50
	Η	H*	A02- 7	"	13:10-15:00	21:20-07:35	12:05
	Ι	I(Potteries)	A02-13	POTTERY	11:30-16:30	22:45-08:00	14:15
LIMASSOL	Α2	A2	A02-18	NONE	12:15-14:00	21:20-05:15	9:40
	Ζ1	G1	A03- 8	WRITTEN IN FULL	14:25-16:10	22:25-06:20	9:40
	Ζ2	G2	A03-10	"	12:45-14:25	22:25-06:20	9:35
	Α4	G3	A03- 7	"	13:15-14:55	23:35-07:25	9:30
	Α5	G4	A02-22	"	11:30-13:10	21:55-06:00	9:45
	Α6	A6	A02-17	"	13:30-15:15	21:10-05:15	9:50
	Α7	A7	A03-11	"	10:50-12:35	21:30-05:35	9:50
	Α8	A8	A03-18	"	14:15-15:55	23:30-07:25	9:35
	Β1	B1	A03-6	"	15:25-17:10	23:10-07:10	9:45
	Β2	B2	A03-15	"	13:15-14:55	21:00-04:50	9:30
	Ε3	E3	A03-14	"	13:15-14:55	22:15-06:20	9:45
	Η	H*	A02- 7	"	13:10-15:00	21:20-07:35	12:05
	Ι	I(Potteries)	A02-13	POTTERY	11:30-16:30	22:45-08:00	14:15
PAPHOS	Α3	A3	A02-15	NONE	14:00-15:40	22:55-06:50	9:35
	Α5	G4	A02-22	WRITTEN IN FULL	11:30-13:10	21:55-06:00	9:45
	Κ	K	A02-8	"	12:55-14:40	21:10-05:15	9:50
	Μ	M	A03-22	"	10:50-12:35	21:00-04:50	9:35
	Μ1	M1	A03-9	"	13:45-15:25	23:10-07:10	9:40
	Ε3	E3	A03-14	"	13:15-14:55	22:15-06:20	9:45
	Η	H*	A02- 7	"	13:10-15:00	21:20-07:35	12:05
	Ι	I(Potteries)	A02-13	POTTERY	11:30-16:30	22:45-08:00	14:15
FAMAGUSTA - LARNACA	Α1	A1	A02-21	NONE	14:40-16:30	22:45-06:50	9:55
	Ζ1	G1	A03- 8	WRITTEN IN FULL	14:25-16:10	22:25-06:20	9:40
	Ζ2	G2	A03-10	"	12:45-14:25	22:25-06:20	9:35
	Α4	G3	A03- 7	"	13:15-14:55	23:35-07:25	9:30
	Α5	G4	A02-22	"	11:30-13:10	21:55-06:00	9:45
	Λ	L	A02-23	"	13:10-15:00	21:20-05:15	9:45
	Ν	N	A03-23	"	10:50-12:35	21:00-04:50	9:35
	Ν1	N1	A03-16	"	14:55-16:40	23:10-07:10	9:45
	Ε3	E3	A03-14	"	13:15-14:55	22:15-06:20	9:45
	Η	H*	A02- 7	"	13:10-15:00	21:20-07:35	12:05
	Ι	I(Potteries)	A02-13	POTTERY	11:30-16:30	22:45-08:00	14:15

The current (bimonthly) tariff is summarized in Table 16.

Table 16: Storage of Thermal Energy Direct Load Control Tariff in Cyprus

Item	Charge
Energy Charge per kWh	c€ 7.79
Network Charge per kWh	c€ 3.00
Ancillary Services Charge per kWh	c€ 0.64

In each bi-monthly period, the price of unit (kWh) charged shall be increased or decreased by the value of the Coefficient of Fuel Adjustment currently in force, for every 1 cent increase or decrease in the basic price of €300 per metric tonne of fuel cost, which cost shall be defined by EAC for the bi-monthly period, based on the purchase price of fuel.

6.1.1.2 Implicit Demand Response

There is no implicit demand response available to domestic users in Cyprus. Commercial and Industrial users, however, can choose between single rate or two-season two-rate tariffs. The available tariffs differ depending on the metering voltage. Three rates are offered covering low voltage (≤500 V), medium voltage (11-66 kV) and high voltage (≥66 kV).

With an 11 kV connection, the University of Cyprus would be considered a medium voltage commercial entity and would have the single tariff and two-season two-rate tariffs available as shown in Table 17 and Table 18, respectively:

Table 17: Medium Voltage Commercial Single Tariff in Cyprus

Item	Charge
Energy Charge per kWh	c€ 9.72
Network Charge per kWh	c€ 3.00
Ancillary Services Charge per kWh	c€ 0.64
Bi-monthly Meter Reading Charge	c€ 0.98
Bi-monthly Supply Charge	c€ 4.76

Table 18: Two-rate Commercial & Industrial Tariff for Medium Voltage Commercial and Industrial Entities in Cyprus

Charge per Unit cent / kWh						Monthly Charge €
Tariff Charges	**Periods**	**October - May**		**June - September**		-
		Week-days	**Week-ends and Holidays**	**Week-days**	**Week-ends and Holidays**	-
Energy Charge	Peak	9,02 cent	8,68 cent	13,97 cent	8,73 cent	-
	Off-Peak	7,71 cent	7,36 cent	8,61 cent	8,43 cent	-
Network Charge	Peak	1,89 cent	1,89 cent	1,89 cent	1,89 cent	-
	Off-Peak	1,89 cent	1,89 cent	1,89 cent	1,89 cent	-
Ancillary Services Charge	Peak	0,62 cent	0,62 cent	0,62 cent	0,62 cent	-
	Off-Peak	0,62 cent	0,62 cent	0,62 cent	0,62 cent	-
Meter Reading Charge	-					€0,49
Supply Charge	-					€2,38

The peak times are shown in Table 19:

Table 19: Peak and Off-peak Times in Cyprus Tariff System

Tariffs Structure				
Periods	**Description**			
	October - May		**June - September**	
	Weekdays	**Weekends and Holidays**	**Weekdays**	**Weekends and Holidays**
Peak	16:00 - 23:00	16:00 - 23:00	9:00 - 23:00	9:00 - 23:00
Off-Peak	23:00 -16:00	23:00 -16:00	23:00 - 9:00	23:00 - 9:00

Hence there is an opportunity to reduce energy expenditure in the October to May period by shifting energy use from peak to off-peak where possible for approximately 15% unit cost reduction.

6.2 Current Restrictions

6.2.1 *Regulatory Barriers*

6.2.1.1 Political/regulatory barriers

Regulatory barriers are defined here as those barriers which exist as a result of government policies, usually enacted through regulation. Such policies can lead to barriers for several reasons. Firstly, markets can be biased by the applicable tax code, which may treat various expenditures differently. Tax discrepancy between substitutable goods (such as electricity and gas, or types of heaters) can cause distortion in the operation of DR. Another tax-related barrier can arise from the installation of electricity storage. When such storage lies behind a meter, tax will be charged on electricity used for charging the battery, thus creating a barrier to the efficient use of the storage. Regulation may also cause distortion in markets if goods that are practicably substitutable (such as generation and consumption based operating reserve) are precluded from competing with each other.

Another barrier to DR is regulation which averts market price signals from reaching consumers. Such regulation not only prevents development of business cases for DR but also constrains the efficiency of markets. Further, regulatory restrictions on locational/ temporal price differentiation in markets will prevent consumers perceiving the true value of DR.

Finally, given the heavily regulated nature of energy network operators, the barriers to DR posed by the regulation of network operators must be mentioned. These include: the focus on historical performance, rather than future requirements; short regulatory periods; focus on the network operator, rather than system-wide effects; and the lack of recognition of the value of research and development. Short regulatory periods, and the lack of uncertainty on the benefits of capital investment can encourage capital expenditure grid expansion over operational expenditure DR, leading to substandard outcomes.

6.2.1.2 Monopoly environment

The traditional regulatory model for monopoly Private Utilities (PUs) considerably drives their decision making; they seek to maximize profits for their shareholders. It is well documented that PUs have a business model that is not eagerly conducive for the pursuit of activities, such as DR, that will increase costs, reduce revenues, or defer future capital investment. Nevertheless, starting with interruptible/curtailable tariffs and DLC programs that have moved towards more flexible and customer controllable technologies, some PUs have shown a readiness to pursue such DR opportunities precisely because regulators have been willing to alter the traditional utility business model. In addition, the utility no longer is required be the exclusive program provider, as technology has shaped prospects for subcontracting and the advent of wholesale electricity markets has generated opportunities for third-party DR program providers to arise as a viable competitor.

However, PUs face a rather different set of challenges when evaluating if a business case exists for creating and offering either expanded or new DR programs that target reserves and regulation services. DR programs that provide AS will produce financial benefits, but such benefits are difficult for the utility to capture. For example, savings in fuel and purchased power budgets from DR resources providing AS are generally passed directly through to customers via a fuel adjustment clause, leaving the utility with little to no ability to profit from any reductions in these costs. If DR resources are instead relied on to provide such services, the need to invest in this new capacity would be deferred or mitigated outright, thereby causing the utility to potentially relinquish a profit opportunity.

6.2.2 *Market Barriers*

6.2.2.1 Benefit to consumers uncertain

While the benefits of DR to the electricity market and system are clear, it is important for its realization that consumers also benefit. Nonetheless, it is doubted if the financial benefits from DR would be enough to encourage customers as not only may savings be limited, they are also uncertain. Furthermore, while pilot programs or other implementations of DR have shown that most customers benefit financially from dynamic tariffs, this is not the case for all customers. Consumers who use a larger share of their electricity demand during peak-price periods than the average customer and do alter their usage pattern, but not on a sufficient level, may have to pay more than they did before. This can be particularly difficult for low-income households that have difficulties to change their consumption pattern, and this redistribution across customers may be the most difficult barrier to the roll-out of DR. Thus, as the electricity price becomes variable, the benefit to consumers of DR is uncertain.

6.2.2.2 Lack of Defined Value of DR

Long-term Power planners do not project significant load growth in the foreseeable future. As a result, from a long-term planning perspective, Operators do not have an immediate capacity resource need that DR resources can fulfil. Experts also expressed that they do not have an explicit operational need for DR, while transmission side believe that other than the few areas of seasonal congestion that may be mitigated by localized DER, there is excess capacity and almost never congestion. As a result, it is considered that DR may only serve small-scale niche, situational purposes.

6.2.2.3 Baseline Profiles

DR performance is typically estimated as the difference in the actual demand level and a baseline level so, successfully, consumers are being paid for changing their regular energy patterns. However, it is naturally challenging to measure or calculate what would have occurred and thus, fundamentally baselines are inaccurate. Consequently, there are concerns regarding DR baselines and suggestions that the challenge of establishing a baseline may be a serious obstacle to the deployment of DR and to methodologies for defining the value of DR programs. It is possible to obtain a realistic baseline for commercial and industrial loads, where the loads can be directly controlled and closely monitored. However, for smaller devices and for domestic end-uses with irregular or unpredictable power consumptions, establishing a robust and accurate baseline can be more difficult. In the end, when a load is dependent upon consumer energy habits and where the power consumption cannot be directly controlled, it is typically more difficult to establish a baseline. Without a robust method for determining the baseline, program participants could be under compensated. This could reduce customer willingness to participate.

6.2.2.4 Lack of large suitable appliances

Currently, not many large flexible appliances are available at households and therefore the provided flexibility can be limited. Household loads such as wet appliances (tumble dryer, dishwasher and washing machine) as well as refrigerators and freezers offer insufficient flexibility for DR potential as those appliances can offer flexibility only for ToU tariffs and not for RTP or curtailable load mechanisms. In order to have a significant impact, either on the grid or on the market, controlling a very large number of these appliances would be required. However, this situation may improve as heat pumps and Electric Vehicles (EVs) will bring a large amount of flexible load that can be easily controlled.

6.3 Future Scenarios

Cyprus is currently in the handicapped position of having a fully open electricity market but without market rules functional and operational covering day ahead market and balancing market. There are market rules that are currently under design to be operational in July 2019. What is coming in 2019 is only dispatchable load and can be offered directly by customers or through their suppliers.

The market rules as planned, following the roll out of smart meters, will allow the operation of DR through aggregators as separate from suppliers offering demand flexibility both implicit and explicit covering the areas of Day Ahead Market (DAM), BM and reserves (FCR, FRR and RR1).

Thus it is plausible that, in the duration of the project, the University of Cyprus will be able to aggregate its flexibility and offer it to the actual market, although the actual timeframe for this is questionable and a proof of concept approach may have to be used for this pilot in DELTA with some assumptions made regarding the future rules and implementation.

The future market rules aim to respond to the call of the Agency for the Cooperation of Energy Regulators (ACER) which clearly dictates that TSOs should procure as many reserves as possible in the short term and as close to real time as possible, by limiting the duration of reserve contracts so that it facilitates participation of new entrants, demand response and renewable generators as well as small generators. Hence, the market rules are envisaging the introduction of the Integrated Scheduling Process that will act after the DAM to cover BM and Reserves.

7. Barriers and Adaptation of DR Strategies to the Particularities of the UK Situation

7.1 DR Access to Markets

The United Kingdom was the first country to open several of its markets to consumer participation in Europe. Unfortunately, in recent years it seems that the stakeholder process between providers, BEIS, Ofgem and National grid has not been as effective as would be expected in a mature market. As a result, the DSR market is not as functional as it could be due to various operational and procedural requirements. This makes the market difficult to access and reduces the potential number of demand-side MWs even as national generating capacity continues to decline.

Almost all ancillary services programmes in Great Britain are open to Demand response and aggregated load even though the design is currently not optimal for customer participation. There is also an issue with transparency as comprehensive data regarding the share of demand response in the various balancing services programmes is not available. Many services are procured not through open markets but rather through bilateral contracts or through tenders in which the buyer, National Grid, has a great degree of discretion. This lack of information make participation very risky for new entrants.

The System Operator (SO) is however determined to reduce risk in the DSR market and is taking steps towards achieving greater transparency. National grid launched a new stakeholder-backed initiative called Power Responsive, with the goal of stimulating participation of flexible technologies in the electricity system. The Power responsive report [19] gives greater detail as to the various demand side response participants engaged in the Non-BM. The report shows that onsite generation constitutes the majority (about 67%) of demand side flexibility technology which participates in DSR. This is followed by load response (28%), Generation for export only (3%) and Energy storage (1%).

The relationship between the BRP and aggregator in the UK is not yet fully resolved. Due to this, aggregators are unable to access the Balancing Mechanism or wholesale markets as it requires a bilateral agreement from the BRP/retailer. On the other hand, aggregators can access balancing services and the capacity mechanism as there is no prerequisite for an agreement between the retailer and aggregator. This means that the retailer (rather than the aggregator) is exposed to imbalance payments or costs resulting from customers actions [9]. In November 2016 Ofgem issued a call for evidence to inquire if a framework allowing independent aggregators access to the balancing mechanism should be initiated [20]. The results showed wide support for such a framework and a willingness by Ofgem to institute the desired measures [21].

The Association for Decentralised Energy (ADE) has also developed a voluntary industry led code of conduct for aggregators and suppliers. The proposal focuses on five areas i.e.

- sales and marketing;
- proposals and pre-contractual information;
- contract;
- technical due diligence and site visit;
- and complaint

and will aim to be implemented in 2018 [22]. The Association for Decentralised Energy (ADE) also undertook a self-reporting survey of aggregators and suppliers, to offer a more comprehensive picture of Demand Side Flexibility (DSF) participation in different markets (reserve, frequency response, capacity, wholesale and network cost avoidance). This considered the assets delivering flexibility, the sectors participating and the regional spread of activity across GB.

While National Grid has engaged in streamlining the participation requirements for balancing services and increasing transparency, DR still faces significant regulatory and operational challenges which limit the viability of the UK market for Demand Response providers.

The capacity mechanism, introduced at the end of 2014, did not place demand-side resources on an equal footing with generation. In the first market only one demand-side aggregator, of the approximately 15 in the market, secured a contract within the new market in the first auction. The most recent auction performed better with independent aggregators securing various MW of capacity and coal losing out. However a combination of low clearing price and derating factor means that battery storage finds it hard to compete with only 11% of projects securing capacity in the T-4 auction [23] and storage making up less than 2% of the capacity procured via the T1 auction [24].

The opportunity for Demand Response is in principle higher than ever. However, due to poor policy development and design choices, that opportunity has not yet been realised. And as pointed out in the Energyst research most of those who do not provide DSR would be interested in doing so if the route to the market was much clearer, if the complexity was reduced and the rewards were more certain and if it did not affect core business [25].

7.2 SO Product road mapping and further developments

7.2.1 *Access to Balancing Mechanism*

As a result to industry consultation rounds, National Grid published in the second part of 2018 an update to the "Wider Access to the Balancing Mechanism Roadmap". In essence, this provides guidance and plans to provide a wider access to this market (including for aggregators) by 2020. An illustration of how the Balancing Mechanism works in the UK market is provided below:

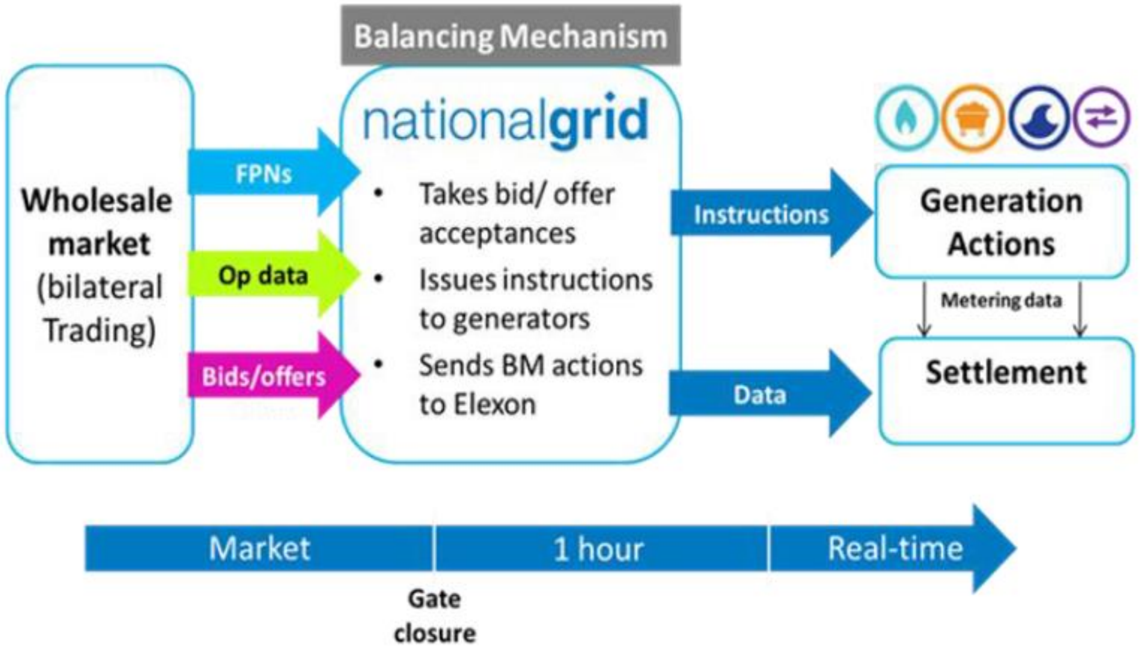

Figure 13: High level overview of the process in the BM in UK

There are currently four ways that parties can register Balancing Mechanism Units:

- Transmission connected generation BMUs
- Distribution connected generation BMUs
- Supplier Base BMUs
- Supplier Additional BMUs

As a result of the input received from the industry (including KiWi Power), National Grid recognized the importance of aggregation to potential new BM participants, as well as the fact existing BM participation routes are not straightforward for the aggregators, who may or may not already be a licensed supplier. The following flowchart depicts potential routes to market for aggregators.

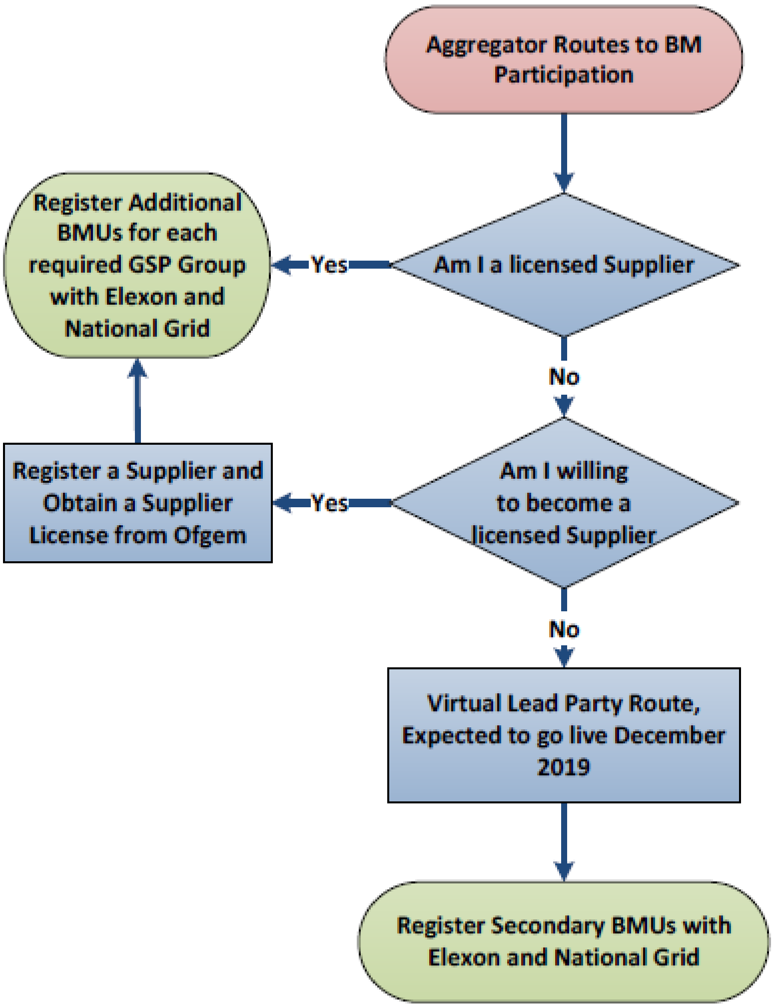

Figure 14: Aggregator route to BM participation

In parallel with providing new routes to access the BM, National Grid is committed to work on improving system and processes including the dispatch experience for small and aggregated units. As such, there are a number of actions linked to long term improvements related to existing and new routes to market:

Table 20: Commitments for the new routes to market

Roadmap commitments	When will it be done by?	Roadmap page
1. Increasing participation routes	Feb 2019	26
2. Clearer accession requirements	April 2019	28
3. Aggregated BMU participation in balancing services	In progress	30
4. Improved and clearer communications systems requirements	Dec 2019	31
5. Simpler data submission process - currently required at GSP level	Aug 2018	32
6. Improved ESO ability to optimise and dispatch aggregated BMUs	Dec 2019	33
7. Clearer and simpler metering requirements	Early 2019	35
8. Support industry work on providing and delivering against PNs (Elexon led)	Dec 2019	36
9. Support industry work on accurate settlement for behind the meter (Elexon led)	Dec 2019	37

Throughout the development of the DELTA project, KiWi Power will play a dual role: one to inform the project consortium on how current market developments in UK will impact demonstration of the DELTA Use Cases planed for UK and second – to inform National Grid of the latest technological developments on the delivery and aggregation of flexibility services to allow them to take into account new services for their roadmap development.

8. Conclusion

The analysis presented herein offers a review of the current and future scenarios in Europe for demand response.

The markets are reviewed in their current state with respect to the clustered demand response strategies identified and the established roles of actors. A convergence of actor roles and thus incentives for participation in the development of demand response strategies is found.

A review of the state-of-the-art in demand response has demonstrated that there are forthcoming solutions to barriers to deployment of demand response that will alleviate some of the concerns of market stakeholders. The DELTA project is shown have the potential to contribute significantly to the progression of demand response deployment into the future by addressing the concerns of market actors and building on business cases for the future resulting from the deployment of the DELTA system solution.

With respect to the pilot sites on the DELTA project, a review of the current scenarios for both the UK and Cyprus shows that the DELTA solution can be implemented with immediate benefits at both locations and that the solution will serve the needs of the pilot sites into the future offering approaches that satisfy future and potential future market developments in terms of business cases and opportunities for the provision of demand response.

Key points behind the DELTA solution and the associated business models derived from the current and future markets analysis are described below.

Key market actors that will benefit directly from the DELTA solution as it stands and should thus be considered in the context of its development are:

- DR Aggregators
- Retailers
- Microgrid Managers
- FLESCOs

Mechanisms that should be considered in detail to take advantage of market opportunities and ensure that the DELTA solution can be a constructive development in the future landscaper of demand response are:

- Measurement and Verification (M&V) processes

Questions around M&V arise when considering both the implementation of implicit response and general auditing requirements. These must be developed in a low-cost way in order to effectively activate small-to-medium loads in the demand response market. Smart technologies and metring solutions must be developed with such considerations in mind to be effective.

- Strategies for optimal market participation

The development of optimal strategies for market participation and thus returns seen for participants will depend heavily on the regulation of markets and rules for participation. There are significant differences found in market rules throughout Europe and thus optimal strategies are bound by deployment scenarios

- Customer engagement

Generally, demand response from the end user perspective is something that is lacking in the existing literature. Incentives for participation and methodologies for interaction can be developed with the DELAT platform through the Innovative Engagement tools. An analysis of the effectiveness of these measures at the pilot sites with constitute important data for future demand response systems.

9. References

[1]. J. Torriti, M. G. Hassan, and M. Leach, "Demand response experience in Europe: Policies, programmes and implementation," *Energy*, vol. 35, no. 4, pp. 1575–1583, 2010.
[2]. P. Bertoldi, P. Zancanella, and B. Boza-Kiss, *Demand Response status in EU Member States*. 2016.
[3]. European Commission, *EU Energy Markets*. 2014.
[4]. SEDC, "Explicit Demand Response in Europe," 2017.
[5]. E. de Espana, "T," *TSO Price Profile*, 2018. [Online]. Available: www.ree.es.
[6]. U S Department of Energy, "BENEFITS OF DEMAND RESPONSE IN ELECTRICITY MARKETS AND RECOMMENDATIONS FOR ACHIEVING THEM PURSUANT TO SECTION 1252," no. February, 2006.
[7]. ENTSOE-E, "THE HARMONISED ELECTRICITY MARKET ROLE MODEL," 2018.
[8]. SEDC, "Mapping Demand Response in Europe Today," *SEDC. Smart Energy Demand Coalit.*, no. September, p. 189, 2015.
[9]. SEDC, "Explicit Demand Response in Europe Mapping the Markets 2017," pp. 1–223, 2017.

[10]. https://www.h2020-drive.eu/
[11]. https://www.dr-bob.eu/
[12]. http://project-respond.eu/
[13]. http://bestres.eu/
[14]. http://www.flexcoop.eu/
[15]. http://dominoesproject.eu/
[16]. http://sabina-project.eu/
[17]. https://edream-h2020.eu/
[18]. strategyzer, "Strategyzer Business Model Canvas." [Online]. Available: https://assets.strategyzer.com.
[19]. Power Responsive, "Demand Side Flexibility Annual Report 2016," 2017.
[20]. Ofgem and Aurora Energy, "A SMART, FLEXIBLE ENERGY SYSTEM A call for evidence," no. November, p. 6, 2016.
[21]. Ofgem, "Ofgem's views on the design of arrangements to accommodate independent aggregators in energy markets," no. July, p. 3, 2017.
[22]. Association For Decentralised Energy, "Consultation | ADE Demand Side Response Code of Conduct July 2017," no. July, 2017.
[23]. L. Stoker, "T-4 auction clears at record low price as battery storage underwhelms," *Clean Energy News*, 2018.
[24]. L. Stoker, "EFR batteries and DSR victorious as coal exits T-1 auction," *Clean Energy News*, 2018.

[25]. The Energyst, "Demand Side Response: Shifting the balance of power," p. 2558, 2017.