H2020-LCE-2016-2017

EUROPEAN COMMISSION

Innovation and Networks Executive Agency

Grant agreement no. 731249

SMILE

Smart Island Energy Systems

Deliverable D5.1
Most Appropriate DR Services for each Pilot

Document Details

Due date	28-02-2018
Actual delivery date	28-02-2018 (rev0); 20-04-2018 (rev1);
Lead Contractor	VCHARGE
Version	Final rev1
Prepared by	VCHARGE
Input from	VCHARGE, AAU, Route Monkey, CERTH, PRSMA, RINA-C
Reviewed by	RINA-C
Dissemination Level	Public

Project Contractual Details

Project Title	Smart Island Energy Systems
Project Acronym	SMILE
Grant Agreement No.	731249
Project Start Date	01-05-2017
Project End Date	30-04-2021
Duration	48 months

The project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 731249

1 Table of Contents

2 Introduction

2.1 Disclaimer

This documents purpose is to provide a description of the most appropriate types of DSM services, based on the current information available. The demonstrator regions are not bound to offering the suggested services. The services and descriptions can be subject to revisions, changes and improvements as the partners involved with the delivery of each of the demonstrator regions further define project details over the coming months.

2.2 Scope and Objectives

This report aims to define the most appropriate Demand Response (DR) services for each of the SMILE regional demonstrators. This has been determined from an assessment of the grid issues faced by each of the three islands and the consideration of the specific Demand Response Assets installed at each pilot site. Namely Orkney regional demonstrator, Madeira Regional Demonstrator and Samsø regional Demonstrator.

The three islands in this project have different grid issues that need to be addressed if they are to meet their objectives for a sustainable energy future:

- Orkney is an archipelago of inhabited and uninhabited islands, interconnected by a distribution grid that was never designed to handle significant RES generation. As a result, a complex set of distribution-level constraints hampers its ability to meet its RES development targets.
- Samsø, with its extensive RES resources and strong interconnections to the mainland grid, is looking to optimise the local consumption - and local benefit of its renewable generation.
- Madeira, as a vertically-integrated distribution grid with no off-island network connections, has grid stability issues that are hampering its ability to develop its renewable resources.

Coupled with this, a diverse set of device types will be controlled in the SMILE trial. Different DR assets have different characteristics in terms of switching speeds, duty cycles, storage capabilities and charging times. The three islands also have different regulatory environments, market needs and technical constraints. Therefore, when making a choice about the most appropriate DR system to deploy, this combination of grid, technical, regulatory and asset availability needs to be considered.

The main objective of this report is therefore to provide a description of the control architecture/ algorithms for the pilot regions.

The report begins with providing an overview the current trends within the energy system and its increasing need for flexibility (Chapter 3). It then provides and overview of demand side response services available at a global scale, providing 3 case studies at national level. The aim is to demonstrate what is going on in different countries and how the market works for these examples (Chapter 4). It then goes on to describe the types of algorithms that will underpin all pilot regions and communicates VNet's ‘agents Based’ control approach, which can be used across all pilot regions.

The report then breaks up each of the pilot regions into sections, providing context on each of the case regions, taking information from previous SMILE reports submitted namely D2.1, D3.1 and D4.1 (Chapter 5, 6 and 7 respectively).

Each Pilot section also provides details on the assets installed, their associated dynamics and how this relates to Route Monkeys optimisation algorithms, PRISMA and VNet's agent based control approach.

2.3 Relationship with other deliverables and tasks

This report forming D5.1 will build on each of the demonstrators deliverables pre M10. The report has benefitted from input: from T2.1 Orkney Demand Side Management System Architecture Design - overall design concepts and architecture, T3.1 “Case study specification and assessment”, T4.1 “Madeira Pilot Case Study Specification and Assessment”, T4.2 “Infrastructure preparation and kick-off of the Madeira pilot” and T4.6 “Case study specification and assessment of EV with smart charging”.
The report will provide to the needed background data for setting up the control algorithms and architecture in T5.2, T5.3, T5.6 and T5.7. Further, the data and DR structures will give ideas for the dimensioning of the storage systems in T5.4. The Data and ideas for DR are also to be used in relation to T6.3 and T6.4.

2.4 Partner Contribution

The SMILE partners that have contributed to this document include:

- VCharge are task leader for this task, they have coordinated the writing of this report writing the Introduction/ Scope Objectives and the concluding comments.
    - Other sections written by VCharge include
        - Section 3 The Energy System and the increased need for Flexibility: Empowering the Consumer role thanks to DR.
        - Section 5 and 6 providing the contextual background to The Orkney and Samsø Demonstrators
        - Section 8 VNet's control approach with specific detail on their proposed for both Orkney and Samsø.
- AAU are WP5 leader. They provided a general overview on different types of Demand Response Methods and in turn related this to the different demonstration sites. This forms the beginning of Section 4.
- Route Monkey described their proposed control approach for EVs in all three demonstrator regions. This forms Section 9.
- CERTH provided an international view of different demand response applications this forms the latter part of Section 4. CERTH also provided input into the proposed Demand Response forming the later sections of 5, 6 and 7.
- PRSMA provided context on the Madeira pilot forming Section 7 and provided information on their proposed control approach forming Section 10.
- RINA Consulting are not in the core WP5 team but have been included in the deliverable as a reviewer for submission

3 The Energy System and the increased need for Flexibility: Empowering the Consumer role thanks to DR

Flexibility in the Energy System can be defined as “modifying generation and/ or consumption patterns in reaction to an external signal to provide a service within the Energy system and maintain security in of supply”[1]. Historically this flexibility has been mainly on the ‘supply- side’. However, due to the changing nature of our energy system it is becoming less and less practical both in financial terms and for system stability to continue to rely on supply side solutions. Therefore, flexibility through ‘demand side response’ (DSR) will become increasingly important as the energy system undergoes significant changes in the coming years.

3.1 Current trends in the EU Energy System

The EU Energy System, is undergoing significant changes[2]. Although the system is still evolving, three major trends are clear:

1. An increasing electricity demand as heat and transport sectors electrify will cause a rise in peak demand as consumption profiles shift.
2. The generation mix is becoming increasingly renewable and distributed, leading to a greater need for integration and balancing.
3. More change in terms of falling storage costs and new tech enablers, such as smart meters will further alter the system.

More demand	More intermittent generation	More change
• Increasing energy demand as heat and transport sectors electrify • Rising peak demand as consumption profiles shift	• Retirement of ⅔ of current capacity expected by 2030 • Growth of intermittent capacity (e.g. wind, solar)	• Increasing Dx generation • Falling storage costs • Tech enablers: smart meters, DSR platforms

Figure 2.1: Infographic showing the changing trends in the energy system

These trends are driven by the national and international decarbonisation commitments across power, heat and transport. The combination of policy driven changes and consumer adoption of new technologies will change the nature of both supply and demand for power.

All trends point towards the need for a much more flexible system in the future. This change will be enabled by the increasing use of existing and novel methods to enable flexibility in the energy market.

[1] "Electricity system flexibility | Ofgem." https://www.ofgem.gov.uk/electricity/retail-market/market-review-and-reform/smarter-markets-programme/electricity-system-flexibility. Accessed 13 Feb. 2018.
[2] "A policy framework for climate and energy - EUR-Lex - Europa EU." http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2014%3A15%3AFIN. Accessed 22 Feb. 2018.

There are three main types of technology that can provide the flexibility needed to support the evolving grid. These include: the traditional supply side, making use of flexible generation; demand side, making use of flexible demand and technologies that use both demand and generation flexibility[3]

3.2 Defining Demand Side Response Services for the purpose of the SMILE project

Demand Side Management, Demand Response Services, and Demand Side Flexibility are all phrases that are widely defined in the literature. It is not within the scope of this report to provide an analysis of all the different types of demand response definitions. For the purposes of this report and the SMILE project, a summary of definition is found below.

The National Grid in the UK defines "Demand Side Flexibility" to include 5 different types of asset[4]

These include:

- demand side response (flexible load) load
- demand side response by onsite generation (onsite)
- demand side response by onsite storage
- distributed generation (export)
- distributed storage (export)

For the purposes of this report and the SMILE project as a whole, Demand Side Response services can be defined as technologies that use both demand and generation flexibility when applicable.

3.3 Demand Response: A Brief Description of the Major Benefits, Enablers and Blockers

It is widely recognised that demand response is a critical resource for achieving an efficient and sustainable electricity system at a reasonable cost[5]. Demand Side Response Services will form one of the main ways to enable a more flexible energy system[3]. It is also likely to be an important enabler of security of supply, improved market competition and encourage consumer empowerment[6].

Demand Side Response requires the intentional modification of normal consumption patterns by end use customers in response to incentives from grid operators[5]. It will lower electricity use at times of high wholesale market prices or when system reliability is threatened. This can be achieved either by implicit (price based) or explicit (incentive based) demand side response[5]. These two approaches are described in detail in sections 4.1 and 4.2.

---

[3] "Roadmap for flexibility services to 2030 (Poyry and Imperial College ...." 30 Jun. 2017, https://www.theccc.org.uk/publication/roadmap-for-flexibility-services-to-2030-poyry-and-imperial-college-london/. Accessed 13 Feb. 2018.
[4] "Demand Side Flexibility Annual Report 2016 - Power Responsive." 31 Jan. 2017, http://powerresponsive.com/wp-content/uploads/2017/01/Power-Responsive-Annual-Report-2016-FINAL.pdf. Accessed 13 Feb. 2018.
[5] "Explicit Demand Response in Europe - Sedc." 6 Apr. 2017, http://www.smarten.eu/wp-content/uploads/2017/04/SEDC-Explicit-Demand-Response-in-Europe-Mapping-the-Markets-2017.pdf. Accessed 22 Feb. 2018.
[6]

Demand Side Response therefore requires consumer participation. Current estimates suggest only 10% of demand response potential in Europe is being tapped.[7] In light of this need and the associated benefits of DSR, the EU is doing everything it can in order to enable more penetration of DSR. The Energy Directive is calling that all member states should remove transmission and distribution incentives that may hamper demand response participation.[7] Member states should also ensure network operators are incentivised and tariffs are put in place by suppliers in encourage customer participation in demand response.[7]

The majority of research shows that there has been an overall increase of interest in enabling Demand Response in almost of all the countries examined in the EU[7]. There are, however some barriers that need to be overcome before we can expect to see wide-scale uptake of demand response solutions.[7]

The main obstacles include:

- Development of viable commercial aggregation applications
- Gaining consumer trust and encouraging participation
- Lack of detail metering and communication infrastructure[7]

Greater consumer participation can and is already being achieved by the creation of demand side products and programmes via the supply side and in the wholesale market. Smart meters are also due to have a massive impact on the accuracy of metering and and the communication infrastructure[7].

[7] "Demand response - empowering the European consumer - SETIS." https://setis.ec.europa.eu/setis-reports/setis-magazine/smart-grids/demand-response-empowering-european-consumer. Accessed 22 Feb. 2018.

4 General overview of Demand Side Response services and the control methods available

Despite the analysis that shows only 10% of Demand Response (DR) potential is being realised[7], it is already playing a key role in increasing the energy systems flexibility. DR is already enabling smart grids, due to its major contribution to the reduction of system costs and the improvement of system reliability. The main players in a DR scheme are customers/loads and the operating entity of DR (could be utility, retailer or an aggregator). DR techniques are generally set up based on either price signals or financial incentives. Accordingly, there are two main types of DR techniques, incentive based and price based[8], described in detail in the following section.

4.1 Incentive- based DR:

Incentive based DR programs encourage customer participation by providing payments to reduce/shift their demand at time of need, triggered by grid reliability issues such as grid congestions, voltage limit violations, peak-load reduction etc. There are various incentive based DR techniques that are in implementation described below[9].

- Direct Load Control (DLC) DR, where the customers sign up for an incentive based agreement in which utilities can remotely shutdown customer appliances during grid emergencies or high demand periods.
- Interruptible/curtailable DR, where customers are given prior incentives to curtail/shift their load consumption at pre-defined times of a day i.e., in response to the supply conditions. If failing to do so the customers will be penalized.
- Demand-bidding DR unlike interruptible DR, customers directly bid their specific load reduction in the wholesale electricity market. If their bid gets selected the customer should curtail the committed demand in order to avoid any penalty.
- Emergency DR, where customers are given incentives to reduce their demand during grid emergency conditions such as network voltage instability problems, operating reserve short falls etc.
- Capacity margin DR, where a day-ahead notice is given to interested customer to reduce pre-specified load reduction during any contingency case. Customers faces penalty if they fail to reduce the committed load.
- Ancillary service market DR, where customers bid their load curtailment as operating reserve in spot market. Customers are paid spot market price for standby and spot market energy price for load curtailment call.

[8] "Smart Grid Constraint Violation Management for Balancing ... - OSTI.gov." https://www.osti.gov/pages/servlets/purl/1375241. Accessed 13 Feb. 2018.
[9] "Benefits of Demand Response in Electricity Markets - Energy ...." https://eetd.lbl.gov/sites/all/files/publications/report-lbnl-1252d.pdf. Accessed 13 Feb. 2018.

4.2 Price- based DR

Price based DR gives customer time-varying rates which reflects the amount and price of electricity in different time periods. This flow of price signals between customers and DR entity takes place through Advanced Metering Infrastructure (AMI) and thereby, customers respond by reducing their consumption during high electricity price period and vice versa. There are three types of price based DR as explained below[9].

- Time of Use (TOU) pricing, where the price for per unit consumption of the electricity is varying for different blocks of time within a day.
- Real time peak pricing is the rate at which electricity price fluctuates hourly, reflecting the changes in the wholesale electricity prices. The customers are notified about the rates either on day-ahead basis or hour-ahead basis.
- Critical peak pricing is e a prespecified higher electricity consumption price superimposed on the TOU rates or normal flat rates. This pricing is generally applied during contingency cases or higher wholesale electricity prices for a limited number of days or hours per year.

4.3 DR control architecture

Once after knowing the type of DR that would be applicable for the pilots, the next step is to decide the control technique for implementing in the real-time system. Traditional power system control strategies are two types, centralized and decentralized controls based on where the response decision is made. [9]

- In centralized control, the control actions are initiated from the control center by system operators and therefore this control has got hour-ahead or intra-hour response.
- In decentralized control, the control actions are taken based on the signals detected locally as well as on the control logic in the each device. These decentralized control systems assure real time response and almost immediate action over the load disconnection.

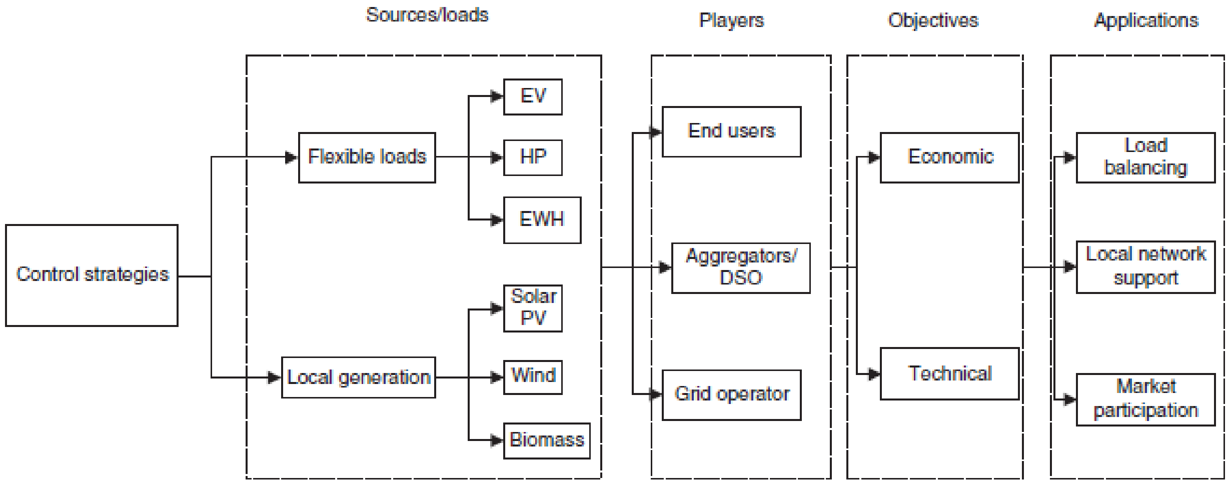


Figure 3.1: Block diagram for DR control strategies[10] [3]

Both centralized and decentralized control methods are combined in[11] such that the centralized control activates for hour ahead grid limit violations whereas decentralized control follows during intra-hour violations. The control structure for deploying the DR greatly depends on the Distribution System Operator (DSO) strategy, AMI availability and type of DR. The operation of control strategies should involve the interests of network/grid operators (achieving stability, maintaining voltage limits etc.), consumers (less power interruptions, low electricity prices etc.) and DR operator (either Aggregator or DSO in the form of cost benefits). In order to includes all these interests of all the actors/players in DR technique, a futuristic solution is to develop a hierarchical control architecture which can make appropriate decision about the type of control (centralized/decentralized) corresponding to the type of DR technique (incentive/price- based) for achieving the multi-objectives. The demand flexibility of Heat Pumps (HP) and EVs is evaluated with the help of simplified hierarchical

[10] "Aalborg Universitet Intelligent Control and Operation of Distribution ...." http://vbn.aau.dk/files/229829342/bishnu_prasad_Bhattarai.pdf. Accessed 13 Feb. 2018.
[11] "Smart Grid Constraint Violation Management for Balancing ... - OSTI.gov." https://www.osti.gov/pages/servlets/purl/1375241. Accessed 13 Feb. 2018.

control architecture in[12], where, the higher level controller is associated to control the State of the Charge (SOC) of EV and state of the energy of HP, and lower level controller counteracts in order to support network locally in real-time.

4.4 An international view: Examples of established DR Programs in North America and Europe

Some already started or established DR programs are presented below, categorized by continent and country.
As it was reported by the Transparency Market Research, North America was the leading region in the DR capacity market in 2013, accounting for more than 80% of the global market share, followed by Europe and Asia-Pacific[13]. For this reason, the section starts with an analysis of the United States and Canada and then follows into a detailed analysis of Europe.

4.4.1 United States

4.4.1.1 California.

California is the state with the greatest population in the U.S. reaching nearly 40 million people[14] and therefore, offers a considerable potential for the development of DR programs.
Pacific Gas & Electric Company (PG & E) offers the so-called “SmartAC” program to its commercial and residential customers, targeting at controlling ACs by cycling aggregated AC load during occasional summer peaks caused mainly due to the simultaneous operation of hundreds of thousands of ACs. For commercial customers PG & E ensures that the temperature in the working area will not exceed the nominal temperature setting by more than four degrees, while in case that the AC cycling event happens in an inconvenient time the customer can refuse to respond without facing a penalty. From a technical perspective, PG & E realizes this program by installing thermostats with communication capability that allows remotely raising the temperature setting of the enrolled ACs up to four degrees when necessary. A similar program offered to residential end-users provides 50$ for a 6-month participation period and the SmartAC remotely controllable device that directs the AC to run at a lower capacity during energy shortages for free. The AC settings can also be manually restored if the response to a DR event is inconvenient for the end-user. For larger customers, PG & E offers a range of DR programs such as peak day pricing, base interruptible program, demand bidding program, scheduled load reduction program, optional binding mandatory curtailment plan as business programs, aggregator managed portfolio and capacity bidding program as aggregator programs and automated DR incentive and permanent load shift as incentive-based programs. In the Peak Day Pricing Program (PDPD), a discount on regular summer electricity prices is offered in exchange for higher prices during the 9–15 Peak Pricing Event Days per year that normally occur during the hottest days of the summer, encouraging energy conservation during these days with higher demand. A surcharge is added to the regular time-of- use rate during the event and a pre-alert

[12] "2015 Index IEEE Transactions on Smart Grid Vol. 6 - IEEE Xplore." http://ieeexplore.ieee.org/iel7/5165411/7300477/07307271.pdf. Accessed 13 Feb. 2018.
[13] "Smart Demand Response Market Size | Industry Report, 2022." https://www.grandviewresearch.com/industry-analysis/smart-demand-response-market. Accessed 13 Feb. 2018.
[14] "List of states and territories of the United States - Wikipedia." https://en.wikipedia.org/wiki/List_of_states_and_territories_of_the_United_States. Accessed 13 Feb. 2018.

is sent to the end-user the day before in order to plan the energy conservation or shifting. A risk-free option is also proposed for the first 12 months providing a credit for the difference, if more is paid during the first year on PDPD. The Base Interruptible Program (BIP) offers an incentive to the end-user to reduce the load demand to or below a pre-selected level (firm service level – FIL). By giving an advanced notification of 30 min, an incentive of 8–9$/kW per month is provided while a monthly incentive payment is also given if no DR events occur. However, a charge of 6$/kW is imposed for the extra demand over the pre-selected level if the end-user fails to reduce its load to or below its FIL during an event. The limit of BIP is 10 events per month or 07 h per year. The Demand Bidding Program (DBP) is a day-ahead program that allows submitting load reduction bids on an hourly basis without imposing financial penalties if the customer fails to meet its committed reduction. DBP ensures a day-ahead notice by 12:00 p.m. and offers an incentive payment of 0.50$/kWh of load reduction, having the minimum requirement of load reduction bids of 10 kW for two consecutive hours. As the PG & E is not obliged to call a DBP event, there is not an incentive given if the end-user enrolled in the DBP is not called within the monthly period and there is no penalty if the end-user fails to reduce the energy during the event periods. The Scheduled Load Reduction Program (SLRP) offers a payment for a load reduction during pre-selected time periods for customers with a minimum average monthly demand of 100 kW by selecting one to three four-hour time periods between 8 a.m. and 8 p.m. on one or more weekdays with a committed load reduction of at least 15% of the average monthly demand. The load reductions are measured considering a baseline that is calculated by averaging the load demand of the selected time periods in the 10 previous normal operating days. The SLRP offers a payment of 0.10$/kWh per month for the actual energy reductions. The Optional Binding Mandatory Curtailment (OBMC) Plan of PG & E concerns customers that can reduce their electric load within 15 min after a call by achieving 15% load reduction below their established baseline that is calculated as in the SLRP. The benefit of the customer is not financial. PG & E requests rotating outages from all its customers in tight demand periods, while by enrolling in OBMC the customer is excluded from these rotating outages. The customers are notified via e-mail or text messaging for the load reduction ratio (5– 15%) and the beginning and ending times of the event, including both holidays and weekends. If the customer fails to reduce the load to the specified level in a call, a 6$/kWh penalty for each kWh above the power reduction commitment is imposed, while failing to respond to a second call entails the interruption of the participation in the OBMC Plan for five years. Notably, the Automated DR Program (ADRP) provides incentives for customers investing in automatic energy management technologies coupled with DR programs (PDPD, BIP, etc.). Customers participating in the ADRP receive signals from PG & E and are granted with an incentive of 200–400$/kW of dispatchable load, and therefore can recover their initial investment in the required infrastructure by a pre-payment of 60% of the total project cost initially and 40% after the verification of customer performance in an up-to 12 months period of DR performance evaluation session [15]. San Diego Gas & Electric Company (SDGE) offers a BIP based on monthly bill credits of 12$/kW or 2$/kW during certain periods of the year for customers with a minimum reduction of 100 kW or 15% of their monthly average peak demand after a notification lead time of 30 min, granting also a flat credit per month even if no DR event is activated. There is a penalty of 7.8$/kWh or 1.2$/kWh (related to the period of the year) in the BIP offered by SDGE for excess energy use above the FIL of the customer. SDGEalso offers Capacity Bidding, CPP, Permanent Load Shifting and Summer Saver Programs as well as Technology Incentive[15]. Southern California Edison (SCE) Company offers a more targeted program named “Agricultural and Pumping Interruptible Program” to temporarily suspend electricity from pumping equipment of the agricultural sector end-users during critical demand periods. A control device is installed to the pumping

[15] "Energy incentive programs - PG&E." https://www.pge.com/en_US/business/save-energy-money/energy-management-programs/demand-response/demand-response.page. Accessed 13 Feb. 2018.

equipment or the meter of the end-user that enables SCE to interrupt the electricity supply temporarily, until the critical demand period ends. Eligible customers should have a measured demand of at least 37 kW or an agricultural load of minimum 50 horsepower. The interruption event is limited to 6 h per event, while there is a maximum of 25 events or 32 h of interruption per year. The customer is awarded with 0.01102$/kWh as a base in the monthly electricity bill in terms of credit if enrolled in the program even if no event is called. The customer is also rewarded with additional credits up to 16.27$/kWh (in summer average on-peak period) during interruption events. SCE also offers ADRP, Permanent Load Shifting, TOU Base Interruptible Program, Capacity Bidding Program, DBP, Aggregator Managed Portfolio Program, CPP, OBMP, RTP, SLRP, Pumping and Agricultural RTP, as well as a Summer Discount Plan [16].

4.4.1.2 Texas

With a population of nearly 27 million[17], Texas is the second most populated State. The Electric Reliability Council of Texas (ERCOT) which is managing the flow of electric power for more than 90% of Texas area, enables the direct engagement of end-users to provide offers into ERCOT markets or to rationally reduce their energy usage by responding to wholesale market prices[18].

Currently, Controllable Load Resources are allowed to participate in the Non-Spinning Reserve Service Market after an assessment, which qualifies them to be dispatched by the Security Constrained Economic Dispatch. Moreover, a recent pilot project named “Fast-Responding Regulation Service” allows specific fast-acting demand side resources to participate in the Regulation Service Market.

Moreover, the Four Coincident Peak (4CP) Load Reduction Program that targets the four 15-min settlement intervals corresponding to the highest load in each of the four summer months (June, July, August and September) is available for Non-Opt- In Entities in the ERCOT jurisdiction area. For demand side resources, Emergency Response Service program that provides a valuable emergency service during grid stress conditions, such as rolling blackouts caused by several reasons including severe weather conditions, is also available. Transmission and Distribution Service Providers (TDSPs) in the region also provide different load management programs. Finally, Price Responsive DR Products including Block & Index, CPP/Rebates, RTP, TOU Pricing, Other Load Control and Other Voluntary DR Product are employed in the service area of ERCOT[19]. Apart from the DR schemes designed mainly for industrial and commercial end-users, ERCOT is also recommended to provide DR schemes

---

[16] "Demand Response | Savings & Incentives | Your Business | Home - SCE." https://www.sce.com/wps/portal/home/business/savings-incentives/demand-response. Accessed 13 Feb. 2018.

[17] "List of states and territories of the United States - Wikipedia." https://en.wikipedia.org/wiki/List_of_states_and_territories_of_the_United_States. Accessed 13 Feb. 2018.

[18] "Demand Response - Electric Reliability Council of Texas." http://www.ercot.com/services/programs/load. Accessed 13 Feb. 2018.

[19] "Demand participation in the restructured Electric ... - Frontier Associates." http://www.frontierassoc.com/wp-content/uploads/2015/01/DemandParticipation.pdf. Accessed 13 Feb. 2018.

specifically aiming at involving the residential end-users responsible for more than half of the energy usage in ERCOT area during peak summer periods due to AC load [20].

As a TDSP in the State of Texas, CPS Energy operates a voluntary load curtailment program designed for commercial and industrial customers by incentivizing them to shed their loads during extreme system conditions, especially during peak summer days. The program focuses especially on weekdays between 3 and 6 p.m. with a two-hour advanced notification. Customers willing to participate should demonstrate at least 50 kW of curtailable electric load in order to be qualified to enrol in the program [21]. CPS Energy has also a Smart Thermostat program for commercial and residential end-users, in which the control equipment is installed free of cost, while CPS Energy maintains the right to cycle off AC compressors for short periods of time by sending a radio signal to the smart thermostats during peak demand periods. CPS Energy does not provide the end-users with incentives but ensures a reduction in heating/cooling related costs of at least 10% because of the deployment of Smart Thermostats[22]. American Electric Power (AEP) Texas offers an Irrigation Load Management Program in collaboration with EnerNOC for the agricultural end-users with electric irrigation pumps of 50 hp or greater, willing to allow their irrigation pumps to be remotely shut down during peak demand periods in return for a financial incentive. This Program covers the time span from 1 p.m. to 7 p.m. on weekdays with a required duration of 1–4 h per event, following an advanced notification interval of 60 min. A maximum of 4 events are allowed per month in this program[23] . AEP Texas also provides Load Management Standard Offer Programs (SOPs) for customers with an installed power of 500 kW or higher, supplying them with incentives for load interruptions on short notice during peak demand periods.[24].

Austin Energy Company introduced a “Rush Hour Rewards” pilot program in the summer of 2013. There are 5 different options in this program regarding the maximum number and duration of interruptions enrolled approximately two thousand customers in Austin, Texas. The aforementioned program in collaboration with Nest Company, supplied the participating end-users with the purchase amount of smart thermostats together with additional incentives to avoid operating their ACs during “Rush Hours” of energy usage in summer periods. This was realized with remote control of the installed thermostats by increasing the temperature set point[25]. Reliant Energy Company has also a similar DR program[26]. Moreover, Austin Energy is currently running a program called the “Load Cooperative

---

[20] "Report - Texas Clean Energy Coalition." http://www.texascleanenergy.org/TCEC_Report%20Final%20Clean%2012%203%2013.pdf. Accessed 13 Feb. 2018.
[21] "Report - Texas Clean Energy Coalition." http://www.texascleanenergy.org/TCEC_Report%20Final%20Clean%2012%203%2013.pdf. Accessed 13 Feb. 2018.
[22] "Welcome to CPS Energy." https://www.cpsenergy.com/. Accessed 13 Feb. 2018.
[23] "FAQ - AEP Texas Irrigation Load Management Program | EnerNOC." https://www.enernoc.com/resources/datasheets-brochures/faq-aep-texas-irrigation-load-management-program. Accessed 13 Feb. 2018.
[24] "Load Management Standard Offer Program - AEP Texas." https://www.aeptexas.com/save/business/programs/sTX/LoadManagementProgram.aspx. Accessed 13 Feb. 2018.
[25] "Meet the Answer to Texas' AC Problem: Demand ... - StateImpact - NPR." 30 Jan. 2014, https://stateimpact.npr.org/texas/2014/01/30/why-texas-power-demand-is-slowing-meet-demand-response/. Accessed 13 Feb. 2018.
[26] ""Rubber-stamped regulation: The inadequate oversight of genetically ...." https://www.researchgate.net/publication/272166618_Rubber-

Program" in which the end-users are offered a payment of 1.25$/kWh for their curtailed load with a 60- min notification interval during summer peak periods[27] .
TECO and Progress Energy Company are offering on-site generation option based programs under two different names: "Standby Generator Program" and "Backup Generator Program", respectively. Both programs aim at enabling the control of an available on-site generator by a service provider in order to cover a portion of the end-users load demand by this generator in order to lower the demand from the grid in peak power periods. Progress Energy also offers a DLC program that enables the service provider to control selected equipment of the customer during critical periods, similar to the program offered by TECO[28] .
CenterPoint Energy Company offers a Commercial Load Management Program to commercial end-users for mandatory load curtailments in summer periods between June 1 and September 30 of each year from 1 p.m. to 7 p.m. on weekdays. Participating customer groups are required to provide an aggregated peak demand of 750 kW. Furthermore, each of the enrolled group members should have at least a normal peak demand of 250 kW plus the capability of curtailing at least 100 kW for a maximum of 5 curtailments per year. The enrolled customers are paid up to 35$/kW for the verified curtailed load.
This means the supply of at least the amount of curtailment agreed in the beginning of the contract year [29]. El Paso Electric Company has a Load Management Program for non-residential customers with a minimum of 100 kW of curtailable power capability upon notice between June 1 and September 30 of each year. The curtailment can last up to 5 consecutive hours per event. Nine forced curtailments or a maximum of 50 h of interruption per year together with scheduled curtailments are requested by the terms of participation in the program. The customers may gain up to 60$/kW for curtailed power during events in the mentioned program[30]. Furthermore, Oncor Company has a similar program called "Commercial Load Management Program" for commercial end-users who can render 100 kW of load available for curtailment.
There are also other load management programs for non-residential end-users offered by different service providers[30]. Another interesting example of DR applications in Texas is the "Free Nights or Weekends" program provided by TXU Energy. This program offers customers willing to participate, totally free electricity at night or during the weekends on the condition that they accept significantly higher daytime or weekday rates, which aims to shift more load to offpeak hours. The aforementioned program has engaged more than 100,000 participants[31].

---

stamped_regulation_The_inadequate_oversight_of_genetically_engineered_plants_and_animals_in_the_United_States_American_University_Sustainable_Development_Law_and_Policy_Journal-_Summer_2014. Accessed 13 Feb. 2018.

[27] "Energy Incentive Programs, Texas | Department of Energy." https://energy.gov/eere/femp/energy-incentive-programs-texas. Accessed 13 Feb. 2018.

[28] "Energy Incentive Programs, Florida | Department of Energy." https://energy.gov/eere/femp/energy-incentive-programs-florida. Accessed 13 Feb. 2018.

[29] "Commercial Load Management Program - CenterPoint Energy." http://www.centerpointenergy.com/en-us/business/save-energy-money/electric-efficiency-programs/for-commercial-facilities/commercial-load-management-program?sa=ho. Accessed 13 Feb. 2018.

[30] "Energy Incentive Programs, Texas | Department of Energy." https://energy.gov/eere/femp/energy-incentive-programs-texas. Accessed 13 Feb. 2018.

[31] ""Rubber-stamped regulation: The inadequate oversight of genetically ...." https://www.researchgate.net/publication/272166618_Rubber-stamped_regulation_The_inadequate_oversight_of_genetically_engineered_plants_and_animals_in

4.4.1.3 Florida

With a population of nearly 20 million[31], Florida is also one of the major States. DR programs in Florida are similar to the ones in California and Texas. For instance, Florida Power & Light (FPL) Company has a Commercial Demand Reduction Program which aims to seize direct control of large scale end-users' total load demand by an installed load control device that sheds the predetermined loads under a pre-notice by the FPL. For each kW of curtailment during events, FPL provides credits to the end-user together with a flat monthly payment for being enrolled in the program[32] . FPL has also an "On Call Program" for business areas that enables FPL to temporarily turn off ACs (15–17.5 min per 30-min period for a maximum 6-h time period) remotely in critical periods. FPL pays a flat monthly credit even if no DR event is called[33]. Tampa Electric Company (TECO) offers a load management program to control the selected equipment (ACs or any specialized equipment) in the end-user premises. TECO installs a remotely controllable device to shut down the equipment selected by the end-user during critical peak power periods in order to operate cyclic or continuous load management programs. As far as cyclic operation is concerned, the end-user earns 3$/kW, while for continuous operation of the curtailment the end-user earns 3.5$/kW for the curtailed load

4.4.1.4 New York

New York occupies a smaller geographical area compared to California, Texas and Florida. However, New York accommodates a population of 20 million and therefore is also a major State in terms of population [34]. New York Independent System Operator (NYISO) offers four different DR programs named "Emergency DR Program (EDRP)", "Special Case Resources (SCR)", "Day-Ahead DR Program (DADRP)" and "Demand Side Ancillary Services Program (DSASP)". EDRP and SCR programs offer incentives to industrial and commercial end-users in order to reduce their power in critical periods. DADRP enables end-users to bid their load reductions in the day-ahead market, which in turn allows NYISO to determine which offers are more economical to pay at the market-clearing price. Lastly, DSASP allows retail customers to bid their load curtailment in day-ahead and/or real-time market in terms of operating reserves and regulation service. The market-clearing price for reserve and/or regulation is paid for the scheduled load curtailment offers[35]. ConEdison Company offers also different DR programs. Customers enrolled in a 2-h or less pre-notification program named "Distribution Load Relief Program (DLRP)"receive 6$/kW or 15$/kW (considering their status) monthly and 1$/kWh for the reduced load during an event. As another DR program, the 21-h pre-notification program "Commercial System Relief Program (CSRP)" offers 10$/kW per month and 1$/kWh for the reduced load during event. The customers enrolled in either DLRP or CSRP are required to be involved in an one

_the_United_States_American_University_Sustainable_Development_Law_and_Policy_Journal-_Summer_2014. Accessed 13 Feb. 2018.

[32] "FPL | Business | Demand Response Program." https://www.fpl.com/business/save/programs/demand-response.html. Accessed 13 Feb. 2018.

[33] "FPL | Business | OnCall Program." https://www.fpl.com/business/save/programs/oncall.html. Accessed 13 Feb. 2018.

[34] "List of states and territories of the United States - Wikipedia." https://en.wikipedia.org/wiki/List_of_states_and_territories_of_the_United_States. Accessed 13 Feb. 2018.

[35] "NYISO (Markets & Operations - Market Data - Demand Response)." http://www.nyiso.com/public/markets_operations/market_data/demand_response/index.jsp. Accessed 13 Feb. 2018.

hour mandatory test every year and they should supply the load reduction for at least 4 h during actual events from 6 a.m. to 12 a.m., any day of the week[36].

Other states and territories of the U.S. There are also many DR programs with similar structure with the ones in California, Texas, Florida and New York, but with different rules and incentives applied in smaller States of the U.S.. For further information on these programs, readers may refer to [37], [38].

4.4.2 Canada

Apart from the U.S., Canada also demonstrates several applied DR programs and strategies. The Independent Electricity System Operator (IESO) of Ontario allows aggregators to manage demand side flexibility in order to maintain the balance of the grid together with the applied price-based grid balancing strategies. The aggregator pre-notifies its facilities to supply the required load reduction in order to ensure the request of the IESO in terms of total load reduction in critical periods [39]. ENBALA Power Networks Company is a leading aggregator that engages hospitals, wastewater treatment centers, universities, cold storage facilities, etc., to ensure the required load reduction in critical conditions. ENBALA aggregates specific loads of different end-user types such as pumps in water/wastewater treatment plants, compressors, evaporators, etc., in refrigerated warehouses, HVAC units including air handling and chiller equipment in hospitals, universities and colleges and commercial buildings through a platform named "GOFlex" [40]. There are many examples of ENBALA applied demand side solutions[41]. One of the most remarkable examples is the enrolment of the McMaster University Campus in Ontario in DR aggregation activities through GOFlex. GOFlex manipulates the temperature settings and therefore, the power usage of five chillers with a 16,000 t cooling capacity within the HVAC system of the McMaster University Campus. Through a communication panel employed in the end-user premises, the Building Management System (BMS) of the campus receives real-time requests and signals from ENBALA GOFlex platform and accordingly adjusts the aggregated settings of the chillers in order to reduce consumption in critical periods without a noticeable deviation from the normal comfort conditions. Many other LSEs across Canada offer classical DR programs. Toronto Hydro Corporation as a LSE and Rodan Energy Company as a DRP are such examples[42].

---

[36] "Energy Saving Programs | Con Edison." https://www.coned.com/en/save-money/energy-saving-programs. Accessed 13 Feb. 2018.

[37] "Energy Incentive Programs | Department of Energy." https://energy.gov/eere/femp/energy-incentive-programs. Accessed 13 Feb. 2018.

[38] "Demand Response Solution for Commercial Buildings - Intelligent ...." http://w3.usa.siemens.com/buildingtechnologies/us/en/energy-efficiency/demand-response/pages/demand-response-solution-commercial-buildings.aspx. Accessed 13 Feb. 2018.

[39] "ieso.ca." http://www.ieso.ca/. Accessed 13 Feb. 2018.

[40] "Enbala Power Networks Raises $12 Million to Transform Distributed ...." https://www.enbala.com/press_release/enbala-power-networks-raises-12-million-to-transform-distributed-energy-resource-market/. Accessed 13 Feb. 2018.

[41] "Enbala Power Networks Raises $12 Million to Transform Distributed ...." https://www.enbala.com/press_release/enbala-power-networks-raises-12-million-to-transform-distributed-energy-resource-market/. Accessed 13 Feb. 2018.

[42] "Demand Response | Toronto Hydro Electric System." http://www.torontohydro.com/sites/electricsystem/electricityconservation/businessconservation/pages/demandresponse.aspx. Accessed 13 Feb. 2018.

4.4.3 Examples of established DR Programs in Europe

Europe holds the second place in the DR market worldwide and the EU countries have recently demonstrated interest in occupying a wider portion of the DR market in the future. Many countries in EU are progressing towards implementing DR actions into their electric power system structures, as shown in Fig. 3.2[43]

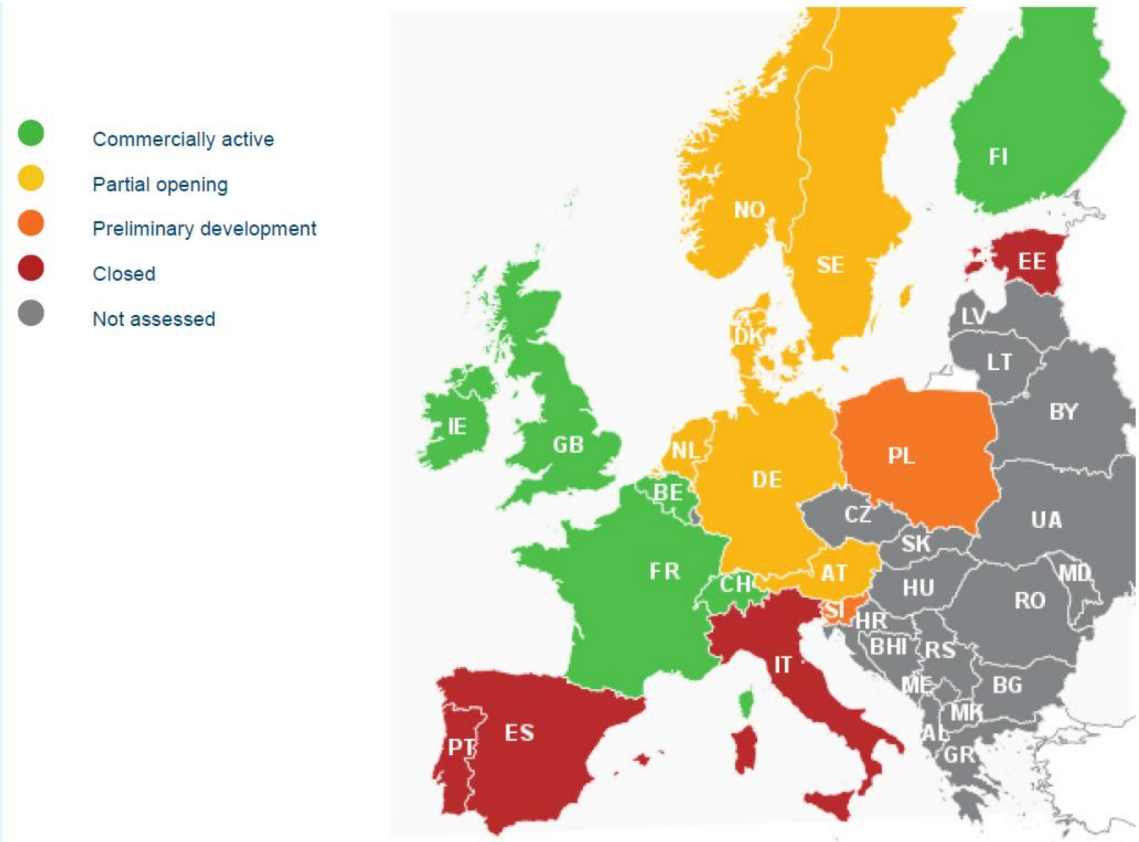


Figure 3.2: Map of Explicit (i.e. Incentive-based) DR development in Europe 2017.

There has been an overall increase of interest in enabling DR in almost of all the countries examined. Since 2015, regulatory changes have been implemented or are planned in many European countries. Notably, in the countries where DR has traditionally been almost non-existent, such as Estonia, Spain, Italy, there has been at least some regulatory interest in exploring its potential. The European countries that currently provide the most conducive framework for the development of DR are Switzerland, France, Belgium, Finland, Great Britain, and Ireland. Nevertheless, there are still market design and regulatory issues that exist in these well-performing countries. Switzerland and France have detailed frameworks in place for independent aggregation, including standardised roles and responsibilities of market participants.
In France, a new draft decree being reviewed by the Conseil d'Etat in early 2017 could provide for a new financial settlement framework whereby a significant of the payment to retailers with curtailed

[43] Paterakis, Nikolaos G., Ozan Erdinç, and João PS Catalão. "An overview of Demand Response: Key-elements and international experience." *Renewable and Sustainable Energy Reviews* 69 (2017): 871-891.

customers would be charged to retailers rather than to DR providers. However, issues persist around a standardised baseline methodology.

In both Belgium and Ireland, upcoming legislation should help to increase the participation of DR. New legislation addressing the role of the aggregator and independent aggregation will soon be put in place in Belgium, which will help to provide an equal footing for all market actors; a strong sign for the uptake of DR. However, there are still some issues regarding measurement and verification that inhibit the growth of DR. In Ireland, the new "Integrated Single Electricity Market" to be implemented in 2018, together with the DS3 programme, will open a range of markets for demand-side response, specifically the balancing market, and the wholesale market, as well as a newly designed Capacity Mechanism.

United Kingdom continues to have a range of markets open to demand-side participation. Independent aggregators can directly access consumers for ancillary services and capacity products, and the country recently has started considering a framework for independent aggregator access to the Balancing Mechanism. Yet, with relatively burdensome measurement and verification procedures in place for DR, it still has room to improve.

Finland stands out amongst the Nordic countries primarily as it allows independent aggregation in at least one of the programmes in the ancillary services, and due to its advanced provisions for measurement and verification. It will also be experimenting through pilot projects with independent aggregation in other parts of the balancing market starting in 2017.

Austria, Denmark, Germany, Netherlands, Norway, and Sweden are marked yellow as regulatory barriers remain an issue and hinder market growth. Although several markets in these countries are open to DR in principle, programme requirements continue to exist which are not adjusted to enable demand-side participation. Furthermore, a lack of clarity remains around roles and responsibilities of the different actors and their ability to participate in the markets. However, Germany, the Nordic countries and Austria have started processes to find a standard solution for the role of independent aggregation. One of the notable differences in this year's mapping was that Germany has moved from orange status in 2015 to yellow in 2017. This is primarily due to the fact that product definitions have been updated or are about to be updated, and balancing reserve markets are about to be opened for independent aggregation.

Slovenia, Italy, and Poland are coloured orange. In Slovenia and Poland, no major regulatory changes have been made within the past couple of years that would have allowed for further DR participation. Notably, Italy has upgraded its status from red in the previous SEDC DR Maps to orange today, as it has slowly started to take the regulatory steps needed for a solid framework for DR. However, despite the gradual opening of markets, significant barriers still hinder customer participation. For example, major sections of the market are still closed off and they lack a viable regulatory framework for DR overall.

Spain, Portugal, and Estonia are coloured red because aggregated demand-side flexibility is either not accepted as a resource in any of the markets or it is not yet viable due to regulation. Here, we see a critical disconnect between political promises and regulatory reality. Estonia may be an important country to watch in the future given that markets could open once they have disconnected from the IPS/UPS synchronous area[44].

A few more elaborate examples in DR implementation/promotion in EU countries are presented as follows

[44] Coalition, SEDC—Smart Energy Demand. "Explicit Demand Response in Europe—Mapping the Markets 2017." *SEDC: Brussels, Belgium* (2017).

4.4.3.1 United Kingdom

According to an interview published in the Reuters, “Longer term, UK’s aggressive renewable energy goals, fairly large size, and deregulated market structure make it one of the best potential regions for DR”, which clearly indicates the potential of the UK taking a leading role across Europe in DR applications.

KiWi Power Company offers a Demand Reduction Strategy (DRS) that presents similarities to existing programs in the U.S., aiming to temporarily reduce the consumption of certain end-user systems such as HVAC, lighting, etc. through the installation of a remotely controlled equipment in peak energy demand periods. KiWi Power offers different control systems for different end-user types in order to provide reductions when necessary. For example, airport chillers and air handling units (AHUs) in areas such as baggage halls and concourse areas are offered to be turned off while generators serving runway lights or communal retail areas can be also utilized during DR events. Besides, in the case of supermarkets, temporary reductions in the lighting level of retail areas or turning off refrigeration plant compressors in freezers are candidate strategies. Different solutions are also presented for hospitals, steel manufacturing, telecommunications, logistics, etc.[45].

The UK Power Networks Company has developed programs to enable the demand side participation in the UK. In the “Low Carbon London” project, the UK Power Networks Company works with Flexitricity, EDF Energy and EnerNOC companies as aggregator partners to enroll industrial and commercial participants for a DR trial in London aiming at inducing load reductions at the MW level during estimated high demand periods. Moreover, in the “Smarter Network Storage” project, storage systems in the MW/MWh level installed in the distribution system will play an active role in residential or commercial DR. Storage units will compensate the deficiency in production during peak periods in order to cover the demand, while they will absorb excess energy when renewable power plants provide high generation (in sunny or windy days) or in times in which the demand is low. The Smarter Network Storage units are planned to be integrated in the National Grids ancillary services market for providing Frequency Response and Short-Term Operating Reserve [46]. There are also different demonstration trials of DR solutions in the UK, which are expected to play an important role in the DR market both in Europe and globally in the future. [47]

4.4.3.2 Belgium

Belgium is a country that has also practically involved DR solutions in the daily electricity market operations. ELIA, as Belgian electricity TSO, accepts DR capacity to compensate mismatches between production and peak power demand [47], in which industrial customers are given vital importance as also supported by the Federation of Belgian Industrial Energy Consumers (FEBELIEC)[47]. DR aggregator companies, such as REstore [48]and Energy Pool [49], provide the required capacities to ELIA under stress conditions, to which hundreds of MWs have already been contracted in order to add flexibility to ELIA's operation in the Belgian power system.

---

[45] "Kiwi Power: Homepage." https://www.kiwipowered.com/. Accessed 13 Feb. 2018.

[46] "UK Power Networks - Demand side response." http://innovation.ukpowernetworks.co.uk/innovation/en/research-area/demand-side-response/. Accessed 13 Feb. 2018.

[47]https://lib.ugent.be/fulltxt/RUG01/002/165/121/RUG01-002165121_2014_0001_AC.pdf [Last accessed 22.03.2018]

[48] https://restore.energy/en/about-us/company [Last accessed 22.03.2018]

[49] https://www.energy-pool.eu/en/strategy-in-belgium/ [Last accessed 22.03.2018]

4.4.3.3 Denmark

Demand-side flexibility could represent an important tool for local congestion management. Several demonstration projects have been run by utilities focusing on the integration of intermittent energy into the grid. However, the Danish Distribution System Operator (DSO) for the time being have not encountered such high congestion similar to other countries, due to a general over-dimensioning of the low-voltage grid in Denmark, and therefore grid capacity is not expected to become a major challenge in the near future (even with more EVs and PVs). Therefore, demand response is not expected to become needed for grid capacity management, especially in the short term. As such, there is almost no pressure to purchase flexibility. Although there are several R&D projects examining the issue and a specific task force at ENTSO-E examining this issue at a European level. There are a number of relevant projects in Denmark currently analyzing the effective use of flexibility by DSO's, including EcoGrid and Ecogrid 2.0., iPower, and SmartNet [50].

In terms of investment management in general, regulatory schemes tend to favour investments in capacity (CAPEX) rather than operational costs, including costs related to the purchase of flexibility services (OPEX). However, the regulation is currently changing in Denmark, in terms of investment management. Currently DSO's are remunerated investment in CAPEX. But going forward, investments in DSOs assets that do not result in efficiency gains within the regulatory term of 5 years will result in a less attractive benchmark outcome for the particular DSO investing in new technology, and hence penalise the DSO financially. The expectation is therefore that DSOs will be less inclined to enter into new pilots of DR going forward. Furthermore, there are no concrete mechanisms for the DSO's to buy demand-side flexibility[51].

In Denmark there is a movement towards what they call the Market model 2.0 model set up by the Danish TSO Energinet.dk among others in 2015[52] [53]. The expected implementation of different market models, which will extend the existing energy markets in Denmark with aggregators who are taking care of demand responses from different costumers and will probably start already from 2018. So this new models and regulation is expected to make more demand response initiatives realistic from now on.

Since this have not been in place yet, only some few demonstrators has been running in Denmark exploring demand response initiatives. The most known is probably the ECO-grid project which have now version 2 running [54]. In this project, around 1000 costumers at the island of Bornholm are involved to test new control possibilities for demand response and gain flexibilities in the grid. The flexibility in the project is mainly focused on gaining flexibility from heat pumps and electric heating to counteract fluctuations in the wind power generation. Another project is Energylab Nordhavn in Copenhagen, where the project uses the area of Nordhavn as a full scale laboratory for demonstrating interactions between the electricity and heating systems and the electric transports for gaining flexibility and an

[50] Andersen, Frits Møller, et al. "Analyses of demand response in Denmark." *Risø National Laboratory, Risø* (2006).

[51] Christensen, Toke Haunstrup, and Freja Friis. "Case study report Denmark." (2017).
Coalition, Smart Energy Demand. "Mapping demand response in Europe today." *Tracking Compliance with Article* 15 (2014).

[52] https://en.energinet.dk/-/media/Energinet/Publikationer-TLU/Engelske-publikationer/Market-model/Final-report--Market-Model-20.pdf

[53] https://en.energinet.dk/-/media/Energinet/Publikationer-TLU/Markedsmodel/Market-models-for-aggregators.pdf?la=en

[54] http://www.ecogrid.dk/en/home_uk

optimized system [55]. In the project new business models are set up, households are equipped with electrical heating with storage facilities so power or heat can be stored at low prices, but also storage facilities at a power plant is invested. A third project to be mentioned here is the Parker project [56], where the electric vehicles provides grid-balancing services to support the electrical grid to ensure a higher share of renewable energy.

4.4.3.3 Portugal

The electricity market in Portugal is characterized by a high generation capacity margin; network access tariffs are used by consumers with different time periods; telemetering of customers with a contracted power above 41.4 kW; combined with the existence of the interruptibility service for consumers with contracted power above 4 MW, makes DR participation in the ancillary services market less appealing to market actors [57].

The regulator will carry out another regulatory review, which includes DR. This may produce some opening of the market. Within this context, ERSE, the Portuguese regulator, envisages the introduction of a series of revisions to give greater visibility to the possibility of DR participation in the ancillary services market.

It should be mentioned, that consumers have had access to a dynamic price of 3-4 price bands per day, since 1997, bearing some resemblance to a ToU DR program, though most of them have decided to remain on the flat controlled tariff scheme[58].

Currently, there no DSO driven DR programs. However, a new Automated DR (ADR) technology program has been announced on November 21st 2017, and will be carried out during approximately 3 years, by December 2019. The consortium involves three Portuguese companies: EDP Inovação – the Portuguese DSO's innovation department, Everis – provider of IT consulting and outsourcing solutions, and Efacec Energia – provider of engineered solutions for protection, control and management of electric power grids, and a Japanese air-conditioning supplier Daikin Industries. Efacec will be responsible for the implementation of an automated DR (ADR) solution, with a fast operation and based on OpenADR standard. Several products and solutions from Efacec will enhance this ADR solution [59][14].

However, in the mainland pilot projects to implement DR are starting to arise, namely Dynamic Tariffs [60] which it is supervised by the Portuguese Energy Services Regulatory Authority (ERSE). Due to the high integration of renewable production, constrains the electrical system difficulting TSO management. In order to undermine this constrains, the pilot will gather 100 VHV, HV and MV

---

[55] http://www.energylabnordhavn.dk/

[56] http://parker-project.com/

[57] Coalition, Smart Energy Demand. "Mapping demand response in Europe today." *Tracking Compliance with Article* 15 (2014)

[58] Bertoldi, Paolo, Paolo Zancanella, and Benigna Boza-Kiss. "Demand Response status in EU Member States." *Europa. eu: Brussels, Belgium* (2016).

[59] http://www.efacec.pt/en/automated-demand-response-technology-in-portugal/ [Last accessed 22.03.2018]

[60] http://www.erse.pt/pt/imprensa/comunicados/2018/Documents/Dossier%20de%20Imprensa_%20Tarifas%20Din%C3%A2micas_vfinal.pdf

volunteers starting in 1st June 2018 during a 1 year period. During the year 100 critical hours will be defined, consumers are previously notified about the grid constrains and consequent higher tariffs in those hours, which should incentivate the cap of electricity consumption or shifting to cheaper periods.

4.4.3.5 Austria

There have been several research and development projects in Austria, which are targeting the development of the future role of DSOs in providing flexibility to the grid. As an example, hybridVPP4DSO is investigating the use of a VPP for commercial trading activities combined with the technical management of the distribution grid [44], [57].

4.4.3.6 Finland

The pilot project Smart Grids and Energy Markets (SGEM) was run in 2014, to evaluate the potential of residential dynamic DR, focusing on the following five areas: Smart grid architectures and distribution infrastructure, Intelligent management and operation, Active resources, Market integration, and New business models. In addition, there was also a FLEXE pilot project with one of its objectives to define flexibility requirements for planning and operation of integrated energy markets load control of about 7000 electrically heated ToU partial storage houses in rural areas, showed a potential of about 10 MW, and dynamic load control capability was implemented in about 35 MW of full storage electrically heated houses, identifying a 14 MW potential for Demand Response. However, at present, there are no significant incentives for DSOs to procure Demand Response. The DSO's role in controlling flexibility is actually quite unclear. Moreover, in Finland, there are only incentives for OPEX; and OPEX incentives for R&D are approved as long as they do not exceed 1% of the allowed revenues. CAPEX for R&D and pilot projects are also treated as any other costs [44], [57].

4.4.4.7 France

Enedis, France's DSO, has 18 demonstration projects concluded or in progress. They aim to test programmes that could allow for better network management. The projects range from RES integration to evaluation of so-called active demand solutions. Apart from these projects, DSOs in general are not able to contract flexibility for constraint management. The current regulatory framework that governs the incentive structure takes into account the performance of the DSO including its operating costs (OPEX). Provided it includes an incentive for cost reduction and alternatives to network investment, this could open the door to the purchase of flexibility services by the DSO [44], [57].

4.4.3.8 Germany

Demand-side flexibility could offer an important tool for local congestion management. As in most European countries however, the possibility for DSOs to invest in the ability to use DR is very limited. Currently there are no market-based programmes operating on the distribution level. This is partly due to the fact that the incentive regulation favours CAPEX over OPEX, hence it is better from a DSO perspective to expand or enforce its network (and thus increase its capital base) than to contract with a Demand Response provider. There are, however, traditional Demand Side Management (DSM) measures in place in Germany. These stem from the pre-liberalization era and for the most part, cover domestic heating appliances (e.g. heat pumps or electric night-storage-heaters which are often quite load intensive). However, the current technical framework as well as the incentive scheme are both highly price-inelastic and thus, are not adequate to respond to the future system needs with high shares of renewable energy. These traditional schemes essentially need to be re-designed to work in a more flexible manner (e.g. allowing for the use of flexibility during day time). Today, substantial network fee reductions 128 steer the consumption patterns of these installations into the night hours (that traditionally used to have a low load profile). The steering mechanism (i.e., management based on ripple control) nowadays only works in relation to fixed restrictions given by the DSOs. In Germany, CAPEX vs TOTEX investment management (including "non -wire alternative services") is regulated by the Anreizregulierungsverordnung (ARegV = Incentive Regulation Ordinance). In early 2015, the German regulatory office for electricity (BNetzA) published an extensive evaluation report on the ARegV. This issue was discussed at length within the report and several changes were suggested by BNetzA. Many changes were included in the following legislative procedure to update the ARegV. However, the ARegV was debated extensively and many suggested changes were diluted or delayed by the legislators. Within the updated ARegV (which was adopted in September 2016), there has been some progress, but not enough to achieve significant change. In terms of exploring mechanisms for DSOs to buy demand-side flexibility there has been a lot of discussion in Germany but little progress in practice. Different trade associations have proposed different mechanisms, but nothing has yet been implemented. For instance, some of the newly installed SINTEG projects (funded by BMWi) have started to explore this possibility. BMWi is also in the process of launching a regulatory proposal that would change and substantiate the current section 14 (a) of the Energy Industry Act. These changes would propose a re-design of the mechanism to work in a more flexible manner [44], [57].

4.4.3.9 Greece

Overall, electricity prices have risen sharply in Greece both for residential and industrial consumers between 2012-2013 when it seems caps may have been reintroduced for some consumers (the application of rules has been uneven across the country). Greek electricity consumers should be given the opportunity to better manage their costs but the lack of smart meters makes this particularly difficult for residential customers. Efforts have therefore been concentrated on the larger Commercial and Industrial customers.

<u>High voltage consumers</u>
In Greece, the TSO has the right to interrupt load services of the eligible High Voltage consumers in the interconnected system for a specific period of time, at a pre-defined maximum load level. For its action, the TSO compensates the eligible High Voltage consumers in the interconnected system for the provision of the demand response measures. A Reserves Account for Security of Supply has been issued by the TSO and the financing of the account is based on a levy imposed to all the active generators. Interruptible load services (ILS) were provided to the Greek market for first time in 2016. The Greek TSO (IPTO), organized 5 auctions of two types of interruptible load services. ADMIE defined two offered types of interruptible load services, as follows:

Types of interruptible load services (ILS)	Warning time	Maximum time of order	Maximum time per year
1*	2 hours	48 hours	144 hours
2**	5 minutes	1 hour	24 hours

*Minimum time between two successive orders for the type 1 interruptible load services (ILS) is 1 day. Maximum no of orders of type 1 ILS is 3orders/month.
**Minimum time between two successive orders for the type 2 ILS is 5 days. And the maximum no of orders of the type 2 ILS, is 4 orders/month.

The table below summarizes all the auctions that were organized by IPTO, the periods they covered and the load capacity that was offered for each type of ILS. The allowed minimum bid offer of each participant was 3 MW. All auctions were successful.

Auction	**Period**	**Type 1 ILS**	**Type 2 ILS**
1	01/03/2016 - 31/03/2016	500 MW	500 MW
2	01/04/2016 - 30/04/2016	650 MW	650 MW
3	01/05/2016 - 30/09/2016	750 MW	900 MW
4	01/10/2016 - 31/12/2016	550 MW	650 MW
5	01/01/2017 - 31/03/2017	750 MW	900 MW

In December 2017, the Minister of Energy announced that the ILS were going to be prolonged for two other years until December 31st 2019, when the service and its impact will be re-evaluated.
Overall, the ILS has contributed significantly to the stability of the electrical system in Greece and to the security of supply for the consumers during emergency situations or during cases when the security and the stability of the system are jeopardized.

Low voltage consumers

For low voltage consumers, following article 28 of Hellenic Electricity Distribution Network Management Code, the legislative framework currently includes a provision, so that the Greek DSO (HEDNO) can make Demand Control Contracts (interruptible load) with any customer on LV network (upon agreement of National Regulatory Authority), as long as the customer's facilities are equipped with telemetered load technology and satisfy the necessary technical requirements set by the DSO. However, no contract like that has been put in place yet. Additionally, a type of implicit demand response exists in Greece for residential customers. The incumbent electricity retailer PPC in Greece has set a Residential Night Tariff that comprises of two charging prices, meaning that the consumption within the 24-hour period is calculated using two different prices. The consumption within the peak period is charged with the regular price (residential non-Off-Peak Tariff), while the consumption within the off-peak period is charged with a reduced price.
The timetable of the Residential Off-Peak Tariff is defined by the HEDNO as follow:
Winter period: November 1st until April 30th
02:00-08:00 and 15:00-17:00, for customers connected to the Mainland Network and for the islands interconnected to it.
02:00-08:00 and 15:30-17:30, for customers in the non-interconnected islands with segmented timetable
Summer period: May 1stuntil October 31st
23:00-07:00

By summing up, the Greek market is still under development and shifting from a regulated to de-regulated system. Issues remain concerning cross subsidies between sectors. The sharp increase in electricity costs during this period has caused further financial pain to the population and business. For the time being, the TSO has made good progress in creating a market based interruptible load service designed to complement their existing reserve markets. Smart grid investment must be undertaken under financial constraints and innovative Public/Private ownership schemes must be deployed to ensure that the benefits are realized in monetary terms for the low voltage customers as well.

5. The Orkney Regional Demonstrator

5.1 Technical Objective

The primary objective of the SMILE programme on the Orkney islands is to reduce the curtailment of specific renewable generators (at time of writing this was confirmed to be the Rousey wind turbine though this may be expanded), a problem caused by the islands' limited network capacity for exporting power. By optimally managing the schedules of flexible load, energy that would otherwise have been curtailed may be used to provide local benefits. If this can be demonstrated successfully, future commercial arrangements should see local energy consumers gain access to significantly cheaper energy, with subsequent increases in revenues for local renewable generator owners.

The major challenge faced by the utilities with high wind energy penetrations is the curtailed wind energy which Orkney is facing. The mitigation of curtailed wind energy with the help of energy storage and demand response is proposed in[61] for system generation cost reduction as the main objective using mixed-integer linear programming. The scheduling of incentive based DR and battery storage systems is carried out in such a way that higher demand periods are aligned with the higher wind energy periods thereby reducing the curtailed wind energy. The frequency signal is used for demand response and the utilities are allowed to reduce the demand for limited duration with incentive payments in return to customers. The more the degree of demand flexibility the higher the share of wind production. The effect of various DR techniques on system costs in the presence of high wind penetration levels is analyzed in [62]. As Orkney planned to install 30 units of EV smart charging stations it is also important when determining the type of DR that it is to be applied for charging.

5.2 Grid Issues/ Constraints

The Orkney distribution network is connected to the Scottish mainland network via two 33kV submarine cables. SSEN (Scottish and Southern Energy Networks) are the DNO for the area, as well as the rest of the north of Scotland, Figure 5.1. This allows generators in Orkney to export, electricity to the Scottish Mainland as well as importing when there is no generation. Within Orkney, there are smaller 11kV and LV circuits going to the North Isles and the Orkney mainland.

The total renewable energy capacity installed is around 57MW. Most of this is from wind energy, as well as some others from solar, biomass, tidal and wave. The winter peak demand is 34MW (Figure 3). Orkney still imports significant amounts of fossil fuels for domestic heating, transport (road, marine, air) and industry.

---

[61] "IEEE Xplore: IEEE Transactions on Sustainable Energy - (Current Issue)." http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=5165391. Accessed 14 Feb. 2018.
[62] "Demand Response in an Isolated System with high Wind Integration." http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.470.387&rep=rep1&type=pdf. Accessed 14 Feb. 2018.

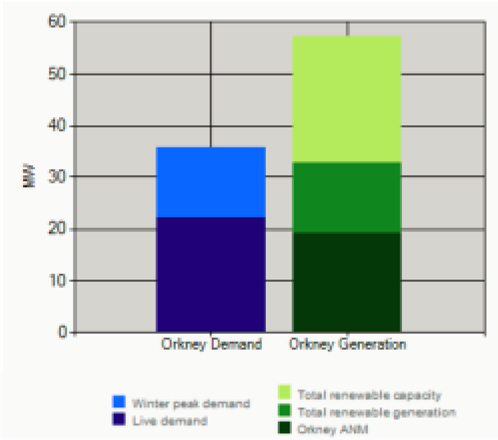


Figure 5.1: Graph showing Orkneys demand versus Generation

In 2009 an ANM system was set up operated by the DNO SSEN, and designed by Smarter Grid Solutions (SGS).
The ANM system allows conditional and actively managed grid export connections for generators.

Managed connections were the only option offered to some generators in Orkney by SSEN at the point of application, as the existing grid is not sufficient to offer firm connections. This restricts generators from putting power on to the electrical network at certain times. This is known as curtailment and the generator will have been given a curtailment assessment as part of the connection offer that they have accepted. Unfortunately, some of these estimates were considerably less than has been experienced in reality, and some generators are experiencing 30-80% of curtailment, 5-8 times their initial estimates; hence negatively impacted when their generation is greater than what the grid can support, or what is being used locally.

5.3 Market Context/ Legal and Regulatory

Participant Incentives

In the UK customers have a choice of a large number of suppliers. The are 66 active energy suppliers in the UK. 55 provide gas and electricity, 7 provide just gas and 4 provide just electricity.[63] The large number of options available to consumers in the UK has meant that there is quite a large price differential between the cheapest tariff available and the most expensive. In December 2017 the price difference between the cheapest tariff available and the cost of the average tariff available was over £300[64].

[63] "Smart Electric Heat - OVO Energy." https://www.ovoenergy.com/binaries/content/assets/documents/pdfs/newsroom/vcharge-smart-electric-heat-white-paper-2017.pdf. Accessed 13 Feb. 2018.
[64] "Infographic: Bills, prices and profits | Ofgem." 31 Jan. 2018, https://www.ofgem.gov.uk/publications-and-updates/infographic-bills-prices-and-profits. Accessed 13 Feb. 2018.

It has been confirmed that as it stands there is no budget as part of the project to include a rebate system or a sign up bonus for the participants. Unless this changes the current thinking by CES WP2 leader is to ensure customers are on a cheaper tariff than they were before.

In the future once there has been a proof of concept, other commercial arrangements with the generators or DSOs could be agreed. These commercial arrangements could take a variety of forms. As a result of the differential pricing created by the DSR supplies will be encouraged to create new time of use tariffs to further incentivise the customer.

Generator Incentives: Need for Government Incentives for Onshore Wind Generation

In recent times the UK government has introduced a variety of incentives for generation.
These incentives include:

- The Feed in Tariff (FIT) scheme is a government programme designed to promote the uptake of small-scale renewable and low-carbon electricity generation technologies. Introduced in 2010, the scheme requires participating licensed electricity suppliers (FIT Licensees) to make payments on both generation and export from eligible installations.
- The Renewables Obligation (RO) is one of the main support mechanisms for large-scale renewable electricity projects in the UK. The RO came into effect in 2002 in England and Wales, and Scotland, followed by Northern Ireland in 2005. ROCs are certificates issued to operators of accredited renewable generating stations for the eligible renewable electricity they generate. Operators can trade ROCs with other parties. ROCs are ultimately used by suppliers to demonstrate that they have met their obligation. It places an obligation on UK electricity suppliers to source an increasing proportion of the electricity they supply from renewable sources. The RO closed to all new generating capacity on 31 March 2017.
- The latest government subsidy for large-scale renewable energy generation is through the Contract for Difference (CfD) Scheme is the most recent with the first auction results announced in 2015. This process is different to both the FiT and ROCs as the funds are allocated through a competitive auction scheme to eligible technologies. Onshore wind was excluded from the list of eligible technologies after the first auction results in February 2015. It has been announced that non-mainland onshore wind projects would be eligible to apply in the next round planned for April 2019, as they are assessed as less established technology due to the increased costs for grid connections etc. The competitive nature of these Contracts however does not provide any confidence in the wind turbines securing these contracts.

5.4 Demand Response Proposals Orkney

A DR/DLC program is already in place via the Heat Smart Orkney Project [65] Via the SMILE program it would be further applied by using Primary heating (rather than supplementary heating), turned on during curtailment and at other times, as required by user or when electricity prices are favourable. This will be carried out on integrated space and domestic hot water heating systems and each EV charger.

The demonstrator will focus on installing the controllable demand within 1 zone of the of the ANM scheme, in order to maximise the impact on curtailed generation. The community owned wind turbines within zone 1 affected by curtailment are on Rousay (REWIRED ltd) and Eday (ERE ltd), Deploying DSM installations in this project is expected to have the most benefit on the curtailment of the Rousay turbine because of their position in the priority stack in the zone, so work is focussing on this generator although it is hoped to include the Eday turbine as part of the project and in the eventual benefit of curtailment abatement.

The same applies to the EV charging scenarios since the charging, especially for the domestic households, would be curtailment-triggered.

As discussed above in section 5.3 the consumer participation arrangements are still to be decided however they likely to be a combination of rebating system, technological cost reduction and potential value through grid services. Still agnostic to/using existing licensed energy supplier.

[65] Deliverable D2.1, Schematic and technical description of Orkney DSM system architecture

6 Samsø Regional Demonstrator

6.1 Technical Objective

On Samsø the objective is to maximise the self consumption from local renewable generation assets in order to minimise grid energy consumption. This objective is incentivised by the local tax regime which results in energy bought from grid being approximately seven times more expensive than renewable energy sold to grid. If the objective is achieved owners of small scale renewable generation should make financial savings through avoided grid power consumption. This would also help advance the island's environmental objectives as it should result in an increase in the overall fraction that renewable energy occupies in the island's consumption mix.

6.2 Grid Issues/ Constraints

The island produces more electricity than it consumes owing to offshore and onshore wind power, and 70% of the heat demand is covered by district heating based on biomass from local resources plus individual CO2 neutral heating solutions. While there is not yet an issue with curtailment of renewable generation in the energy system of Samsø, there are bottlenecks which present opportunities for better management of locally generated energy, taking into account local demand. Shifting peaks in energy demand, for example, can help to stabilize and reduce energy prices for residents and visitors, as well as providing a valuable service for the local distribution system operator (DSO) by helping them to manage and balance the grid (D3.1).

The problem that needs to be addressed is managing/adjusting the peak load caused by the boat chargings at the Marina especially in the summers. In the Marina of Ballen city, a Photovoltaic (PV) system and a battery storage system are going to be installed. Preliminary simulation studies are carried out with PV and BESS for Marina load. From the results, it was observed that the peak-load could not be met by the intermittent PV along with BESS.

However, utilizing these resources, proper DR techniques need to be proposed which helps the harbour master to overcome the peak-load situation. A direct load control incentive based DR technique is proposed in[66] for residential load peak-shaving. The impact of peak-loading on the distribution transformers caused by the charging of EVs is analyzed in [67] and an incentive based DR strategy is proposed to tackle this transformer overloading situation. The effectiveness of BESS is analyzed in [68] in order to enforce peak shaving and smoothing the load curve using nonlinear programming. With PV systems and BESS, a dynamic programming based peak shaving scheme at lower cost is proposed in [69] for a day-ahead power management. A real time smart charging algorithm

[66] "Strategies of residential peak shaving with integration of demand ...." http://ieeexplore.ieee.org/abstract/document/6837260/. Accessed 14 Feb. 2018.

[67] "Demand Response as a Load Shaping Tool in an Intelligent Grid With ...." 9 Nov. 2011, http://ieeexplore.ieee.org/document/6074980/. Accessed 14 Feb. 2018.

[68] "Load peak shaving and power smoothing of a distribution grid with ...." https://econpapers.repec.org/RePEc:eee:renene:v:86:y:2016:i:c:p:1372-1379. Accessed 14 Feb. 2018.

[69] "Optimal Power Flow Management for Grid Connected PV Systems ...." http://138.4.46.62:8080/ies/ficheros/2_52_ref19.pdf. Accessed 14 Feb. 2018.

is proposed in[70] where the charging scheme is able to reduce the peak demand by prioritizing the EVs which can be applicable for both commercial and industrial hosts. For the extensive peak shaving, this algorithm also considers the price signals from utility, local DR load control including both price based and incentive based schemes.

6.3 Market/ Regulatory / Legal Context

The Danish government taxes the consumed electricity — as stipulated in Elafgiftsloven (translation: the electricity tax law). However, renewable energy, which is directly consumed by the producer, is exempt from tax. Electricity tax represents two thirds of the billing cost for a private consumer.
It is therefore more economical to try and consume as much as possible of the renewable energy production.
The three conditions in the following list must be fulfilled in order to qualify for the tax exemption:

- The electricity is produced by RES.
- The consumption must be direct, and not passing through the public grid.
- The electricity must be consumed by the producer; they must be the same legal entity.

Nevertheless, it is possible to apply for hourly net metering at the transmission system operator (Energinet). In that case, both production and consumption are accumulated every hour by the meter, and the consumption is subtracted from the production before calculating taxes. That is, only the net sales are taxed.
A marina is allowed to mount PV panels (on a roof, for instance), and consume the electricity itself. This will not affect any other tax exemptions the marina may enjoy. However, if the marina sells some of the electricity to the grid, it may affect the tax status of the marina.
If a camp-ground sells electricity to the visitors – and bills them according to meters, according to a fixed daily price, or according to a lump sum – then the electricity is taxed. It is assumed that it is valid for marinas too, so that the boat owners are obliged to buy electricity at a rate that includes the tax.
In Ballen, the marina and ferry harbour parcels are separate. It is still unclear whether it would be legal to install a sea cable that connects the two parcels in order to create an internal connection that does not pass through the public grid.

6.4 Demand Response Proposals Samsø

In scenario 1, a DR/ToU program is proposed for the Marina users. More specifically, the marina users will receive lower fees from participating in the SMILE Energy program, when reducing their consumption to a certain level in peak hours and trying to adjust their load with the generation from the PV system. This can be encouraged by a system of different €/kWh per time-period of the day (e.g. at peak hours, and the rest of the day), reflecting the peak loads and the PV generation and, consecutively, the Marina import/export electric power balance from the main grid, in order to either further minimize the import/export balance or eliminating it altogether, making the Marina fully autonomous with respect to power consumption if possible. It should be remarked, that the intension is not to fully interrupt the loads, merely to adjust their consumption to a maximum level, ensuring that they have access to a certain level of kW all day.
If the priced-based model for the consumers is not valid, due to regulatory reasons and taxes for example, then as an alternative, an incentive based system could be used, i.e. behavioral-configurable load control. To be more specific, via a point system the customers would be encouraged to alter their

[70] "Optimal Charging Scheduling of Electric Vehicles in Smart Grids - MDPI." 17 Apr. 2014, http://www.mdpi.com/1996-1073/7/4/2449/pdf. Accessed 14 Feb. 2018.

electrical consumption, pairing that of the electrical generation, and in every bill a discount would be given, reflecting the alignment, or not, of the customer to the consumption required. For example, the boat owners will be given more points i.e. more discount in their bill if they charge their boats' batteries during midday, when the PVs to be installed generate more electricity, or during the night, when Wind Generators are probably generating and the rest of the grid-load is at its lowest.

For the cases which consider larger parts of the island (scenario 2, 3 and 4) a more straightforward approach could be required and not a voluntary one as the aforementioned. Then an incentive-based DR program could be proposed, and more specifically Direct Load Control (DR/DLC), in which case the users' load/consumption is controlled and is either charged normally/slowly, or even rapidly if possible, in order to follow the PV or wind generation and the actual loading in the grid.

In this way the electricity transaction with the rest of the Danish electrical Grid would be reduced, even to zero, making the Samsø island truly self-sufficient.

In the SMILE project only the 1st scenario of the Ballen marina will be carried out in real life whereas the other scenarios considering larger parts of the island will be handled theoretically.

7 Madeira Regional Demonstrator

7.1 Technical Objective

Madeira being an island with a considerable share in renewable production and also with a situation where a higher part of the electricity moves towards transportation, will challenge maintaining the balance between supply and load using EVs for demand response. Frequency and voltage control will be important issues in the systems with large renewable penetration due to the volatility in the supply. Frequency regulation requires higher quality of reserves, which can have fast response. The contribution of demand in frequency control reduces the dependency on thermal plants thereby reducing the operational costs. A review of demand response techniques in load frequency control is given in[71,72] for both the centralized and decentralized controls. A decentralized smart charging method is proposed [73] for EVs to participate in primary frequency control considering charging demands from EV customers which can provide both charging schedules and frequency regulation simultaneously. It is interesting to bring a group of EVs together via aggregators which acts as a coordinator between EVs and system operator. The regulation capability of the EVs is estimated by the aggregator using optimal bidding strategy and informs the EVs that are chosen for primary frequency control. Also the participation of EVs in the frequency regulation reduces the operational costs, a new distributed frequency control is proposed in[74] for randomized responses of EVs based on their locally measured frequency responses.

7.2 Grid Issues/ Constraints

Below an overview of the Madeira electric grid is presented and it provide some information concerning consumption and production patterns that are important for a better understanding of the grid issues.

Madeira's electric grid

Madeira is a true independent system with a small-scale and completely isolated electric grid.
The distribution extent of networks operating at HV (60 kV) and MV (30 and 6.6 kV) is respectively 99.15 km and 1479.39 km.
Low voltage distribution networks have considerable extensions (3161.59 km), especially in the rural areas. They are mainly of the aerial type and responsible of 5.6% losses of the total emission (the grid total losses amount to 8.6%).

---

[71] "Renewable and Sustainable Energy Reviews | Vol 41, Pages 1-1546 ...." https://www.sciencedirect.com/journal/renewable-and-sustainable-energy-reviews/vol/41. Accessed 14 Feb. 2018.

[72] "Renewable and Sustainable Energy Reviews | Vol 41, Pages 1-1546 ...." https://www.sciencedirect.com/journal/renewable-and-sustainable-energy-reviews/vol/41. Accessed 14 Feb. 2018.

[73] "Vehicle-to-Grid Control for Supplementary Frequency Regulation ...." 19 Dec. 2017, https://www.researchgate.net/publication/280631895_Vehicle-to-Grid_Control_for_Supplementary_Frequency_Regulation_Considering_Charging_Demands. Accessed 14 Feb. 2018.

[74] "Distributed frequency control in smart grids via randomized demand ...." https://pdfs.semanticscholar.org/d9ad/dfd085852169b26ef0246966cf1afba74cb7.pdf. Accessed 14 Feb. 2018.

Empresa De Electricidade Da Madeira (EEM) is the only DSO in Madeira, which is therefore responsible for all the activities related to production, transport, distribution and commercialization of electric energy.

Consumption

The region of Madeira has around 132.000 registered electric energy consumers and the distribution of final energy consumption between sectors is atypical compared to European average. In 2015, the highest volumes, amounting respectively to 45.78% and 30,70% of the total consumption (about 798 663 MWh), belonged to non-domestic and domestic sectors, while industry only accounted for 6,46%. [2]

The typical load demand for Madeira island (Figure 7.1) is characterized by a peak consumption between 19h00 and 21h00, which coincides with the periods of highest domestic demand, while the highest rise in consumption happens in the morning, mostly driven by the beginning of the activity of the commercial sector.

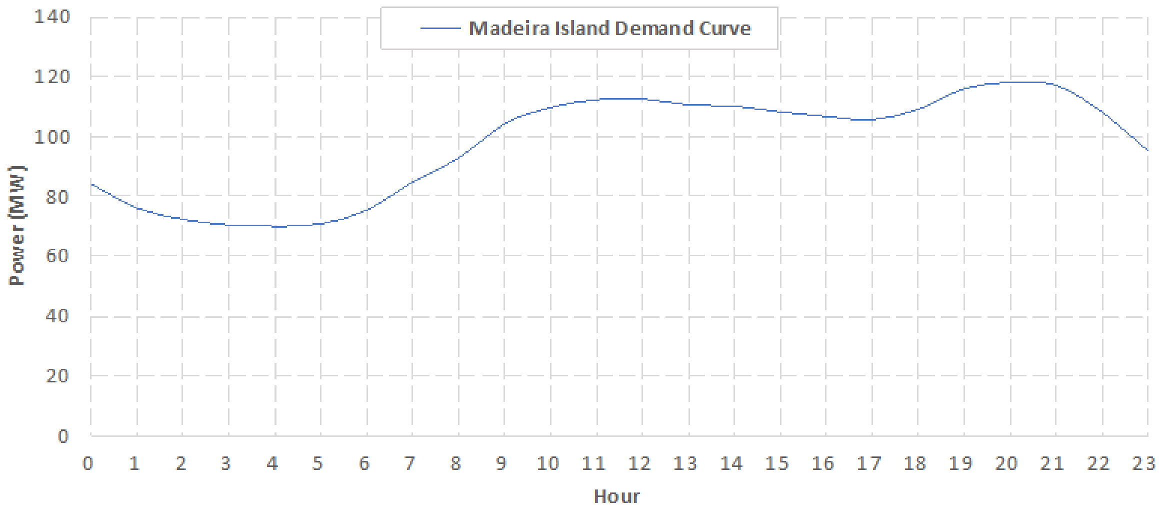


Figure 7.1: Typical load demand curve in Madeira island.

Due to the low temperature variation between seasons, no significant difference in load patterns is observed throughout the year.

Energy production

The electric grid in Madeira island is fed by five sources of energy, namely: hydro, wind, photovoltaic, solid waste incineration, and thermal energy from burning fossil fuels like diesel and natural gas.

Despite an already considerable renewable energy production (between July 2016 and June 2017, electricity production was made up by around 30% of renewable sources), the demand is largely covered by fossil fuels.

As of this writing, hydric power is the leading renewable energy production, followed by wind and solar power. As Figure 7.2 shows, the variation in renewable energy capacity and penetration is significant. The highest share of renewables in the mix usually happens between Winter and Spring, mostly driven by the increase in the production of the hydro plants.

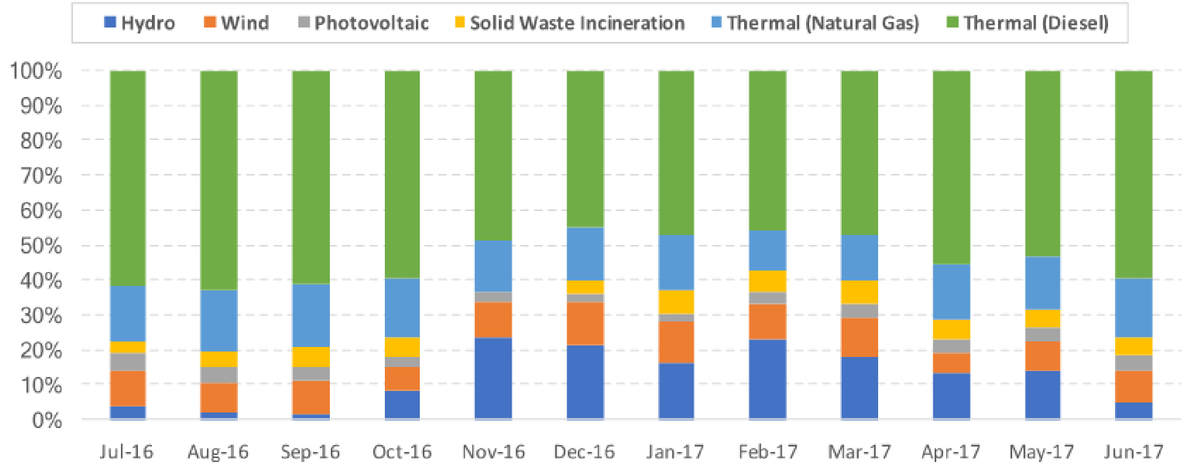


Figure 7.2: Monthly energy mix in Madeira island between July 2016 and June 2017.

Concerning independent producer installations, the predominant renewable energy is solar energy. As of this writing, there are around 783 distributed solar micro and mini-producers, with a total installed capacity around 20MW. In 2016, the global energy issued by these generating power systems was around 29 GWh.
The typical southern Mediterranean climate with high solar radiation characterizing Madeira, makes the Island a promising location for PV usage. Indeed, with an average of the daily solar energy incident that varies from 4 to 5 kWh/m2 and sunshine hours ranging from 1800 to 2600 per year, future scenarios predict an increase in its penetration.

Goals and grid constraints

One of the main objective of the local DSO is increasing the injection of renewables in the grid, as such sources can amount to an increase in provisioning security and efficiency benefits. At the same time, the instability of these sources represents the main blocking force for their penetration, especially in the case of a small-scale and completely isolated grid as the one of Madeira.
Particularly, the increase of solar energy (which is the most unpredictable renewable source), associated with low consumption and high production periods (normally around midday), low voltage distribution networks and dispersed production facilities, represents a very difficult business case for the local DSO, as it tends to result in the phenomena of voltage increase (VI) and frequency fluctuations (FF).
The fuzziness of the generation of PVs makes even more difficult the matching between generation and load demand, which leads to interruptions and bad power quality.
The frequency stability issue (currently addressed by the thermal and hydro plants) puts strain on the distribution grid and security of supply, and has led to the need of avoiding direct injection to the grid. Thus, in order to protect the grid from the impact of variations in the solar PV production, since 2014 new solar PV installations are only allowed in self-consumption mode and without injection to the grid. This imposition helps to maintain a stable grid, but is preventing the local DSO from achieving the desired 50% quota of renewables in the mix by 2020.

Addressing trade-off between the introduction of more RES in the mix and maintaining a stable grid (especially considering the planned increase of EVs) is one of the main motivations of the local DSO in the SMILE project.

In Madeira demonstrator, this issue will be addressed by introducing BESS, so to store energy excess and use it for frequency and voltage control. In this scenario, DR services are expected to support the matching between demand and generation.
In this regard, as reported in D4.1, it is important to remark that:
"Currently, there is no AMI deployed in Madeira electric grid. Instead, what is currently deployed is an AMR solution in the micro-production installations for monitoring and billing purposes" and "as of today, with exception of the monthly bill, no feedback is provided to the micro-production site owners".

7.3 Market Context

PV System

Decree-Law 363/2007 of 2nd November was probably the main stimulus to the PV market in Portugal, as it created the definition of small producers allowing the development of small (micro) and medium (mini) size production units [75].
PV system feed-in tariff scheme for micro production (up to 3.68 kW on-grid installations), started in Portugal in 2008. At that time, the feed-in tariff had a value of 0.65€/kWh. Since then, owing to the bad economic situation of the country and to the cost reduction of the PV systems, the feed-in tariff has been progressively reduced. In addition, since the publication of DL 64-B/2011, also fiscal incentives that allowed to benefit from a reduced VAT tax on all new equipment acquired have been removed. In this scenario, PV installations became progressively less attractive from an economic point of view. Since 2012, the number of new installations in the country is decreasing, owing to the publication of the Decree-Law 215-B/2012 that extinguished Feed-in Tariffs for utility scale renewable power plants [76], [77]
As mentioned above, after the publication of DL 153/2014, EEM does not accept new UPPs (Unidades de Pequena Produção – which are micro-producers obliged to sell all their production), while UPACs can only be installed without the energy injection to the RESP. This further reduces the advantages of small-scale production, especially considering that peak of production normally coincides with low consumption periods.
Despite having the incentives suspended for the production of renewables to both large and customers facilities, new mechanisms are being planned for next years.

Energy prices

As stated above, EEM is the only DSO in Madeira, thus it defines prices and tariffs for energy supply. Customers (LV supply)[78] can choose between three different tariffs:

---

[75] "iea-pvps.org - National Reports." http://www.iea-pvps.org/index.php?id=93&no_cache=1&tx_damfrontend_pi1%5BshowUid%5D=740&tx_damfrontend_pi1%5BbackPid%5D=93. Accessed 14 Feb. 2018.
[76] "Morgado Dias - Universidade da Madeira." http://www.cee.uma.pt/morgado/index.php?content=publications. Accessed 14 Feb. 2018.
[77] "iea-pvps.org - National Reports." http://www.iea-pvps.org/index.php?id=93&no_cache=1&tx_damfrontend_pi1%5BshowUid%5D=740&tx_damfrontend_pi1%5BbackPid%5D=93. Accessed 14 Feb. 2018.
[78] The dominant residential demand in Madeira is in the LV level grid (http://www.erse.pt/eng/electricity/tariffs/Documents/PESGM2006-001089%20Schedules.pdf)

- **Tarifa simples**: this is a single rate tariff, which means that there are no peak or off-peak periods so the consumers pay the same rate whatever time of day they use energy.
- **Tarifa bi-horária**: a time of use tariff which distinguishes electricity costs prices (peak and off-peak rates) between different times of the day.
- **Tarifa tri-horária**: a time of use tariff which distinguish electricity costs prices (peak, off-peak and half-peak rates) between different times of the day.

In the following tables, energy prices divided by tariffs and contracted power are reported[79]:

Rates – LV customers (<= 2,30 kVA)			
Power (€/day)	1,15	0,0656 €	Tarifa simples / bi-horária / tri-horária
	2,30	0,1163 €	
Active Energy (€/kWh)		0,1496 €	Tarifa simples
	Peak and half-peak	0,1894 €	Tarifa bi-horária
	Off-peak	0,0982 €	
	Peak	0,2153 €	Tarifa tri-horária
	Half-peak	0,1716 €	
	Off-peak	0,0982 €	
Rates – LV customers (> 2,30 kVA and <=20,70 kVA)			
Power (€/day)	3,45	0,1611 €	Tarifa simples
	4,60	0,2096 €	
	5,75	0,2560 €	
	6,90	0,3040 €	

[79] Prices here reported refer to Madeira and are valid for 2018 (https://www.eem.pt/media/324637/monofolha_tarif_btn_ts_2018.pdf)

	10,35	0,4478 €	
	13,80	0,5902 €	
	17,25	0,7326 €	
	20,70	0,8751 €	
	3,45	0,1643 €	Tarifa bi-horária and tri-horária
	4,60	0,2132 €	
	5,75	0,2590 €	
	6,90	0,3080 €	
	10,35	0,4532 €	
	13,80	0,5981 €	
	17,25	0,7436 €	
	20,70	0,8892 €	
Active Energy (€/kWh)		0,1629 €	Tarifa simples
	Peak and half-peak	0,1894 €	Tarifa bi-horária
	Off-peak	0,0982 €	
	Peak	0,2153 €	Tarifa tri-horária
	Half-peak	0,1716 €	
	Off-peak	0,0982 €	

Rates – LV customers (>20,70 kVA)			
Power (€/day)	27,60	1,0929 €	Tarifa tri-horária
	34,50	1,3389 €	
	41,40	1,5844 €	
Active Energy (€/kWh)	Peak	0,3068 €	
	Half-peak	0,1475 €	
	Off-peak	0,0742 €	

Taking into account the tables above, the so-called "cycle" is another variable to consider for determining energy prices according with Portuguese electricity tariff system. As Figures 7.3 and 7.4 show, in Madeira there are two different cycles[80] [11]:

- **Daily Cycle**, according which there is no distinction in terms of usage times (i.e. peak, off-peak and half-peak periods) between weekend and work-days;
- **Weekly Cycle**, where usage times for work-days, Saturdays and Sundays are different.

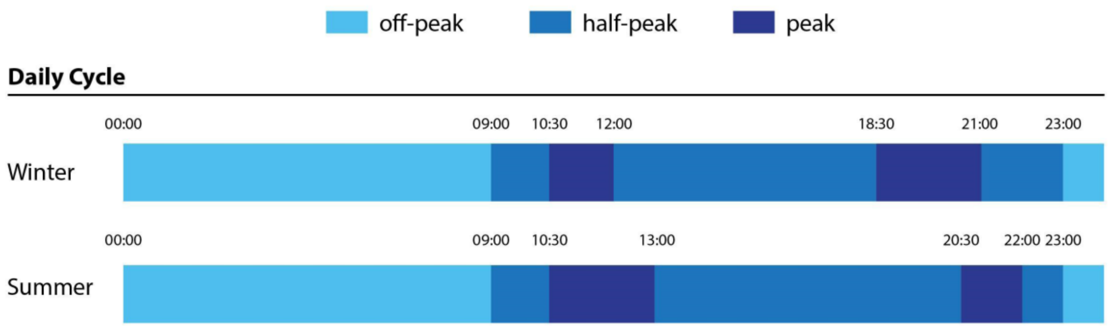


Figure 7.3: Daily cycle.

[80] "Tarifário 2018 - EEM." 4 Jan. 2018, https://www.eem.pt/media/324637/monofolha_tarif_btn_ts_2018.pdf. Accessed 14 Feb. 2018.

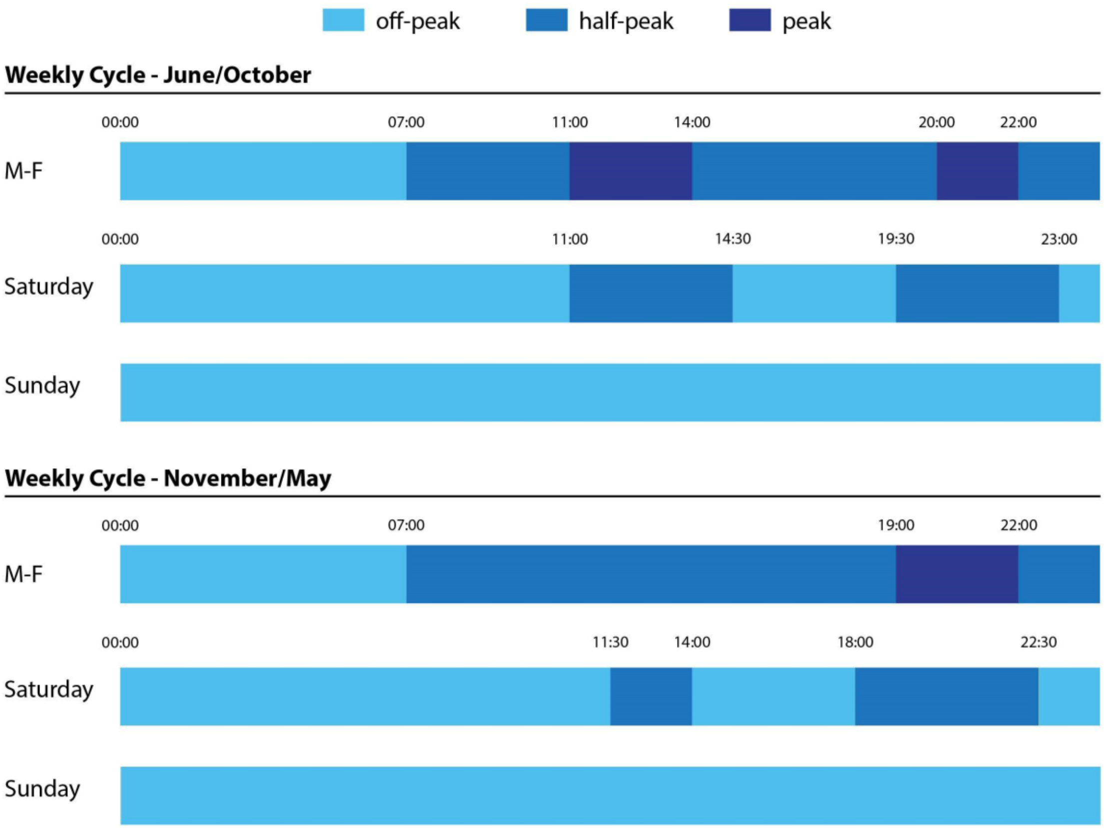


Figure 7.4: Weekly cycle.

EVs market

Considering the evolution of EV market in Portugal, it is expected that the shift towards electric mobility will reach 200000 EVs in 2020 [81]. To this regard, the Portuguese Government is promoting initiatives to increment the public charging network and provides incentives for the acquisition of EVs. In 2017, a subsidy of 2250€ was given to the first thousand people who bought a new, lightweight, 100% electric vehicle. For the present year, the Portuguese Government has planned to maintain such incentive in the scope of national CO2 emissions reduction measures[82]. In addition, tax benefits prior

[81] "Introduction of Electric Vehicles in Portugal A Cost-benefit Analysis ...." https://fenix.tecnico.ulisboa.pt/downloadFile/395142094915/Dissertacao_Manuel_Nina_52578.pdf. Accessed 14 Feb. 2018.

[82] "Incentivo à compra de carros elétricos mantém-se em 2018 – ECO." 12 Oct. 2017, https://eco.pt/2017/10/12/incentivo-a-compra-de-carros-eletricos-mantem-se-em-2018/. Accessed 14 Feb. 2018.

to 2017 are still in force. Specifically, there is neither Vehicle Tax (ISV) nor Circulation Tax (IUC) on EVs[68], and, in some cities, parking is free during charging[83] [84]
Regarding companies, the acquisition of an EV allows to benefit from IRC deductions[70], and, in addition, the expenses of electric vehicles are exempt from autonomous taxation rate that apply to company vehicles [71].
Also noteworthy is the fact that, even without considering government incentives, the EV has a lower Total Cost of Ownership (TCO) compared to a conventional fossil fuel-powered vehicle[85].

Main constraints to EVs penetration in Madeira

Currently, there are around 100 private EVs in Madeira island[86]. EEM is strongly committed in strengthening the electric vehicle supply network[73], however, there is still a lack of charging stations in Madeira island (only 7 public stations are currently available). Recently, private companies working in the energy sector started to offer also public charging stations installation as part of their services. As reported in Madeira D4.1, one private installation of a charging station was completed in Madeira island so far and several more are ongoing.
This lack of charging infrastructures is probably the main barrier affecting EVs penetration in Madeira island. However, another barrier has emerged during the first round of interviews with EVs drivers. Indeed, people interviewed pointed out that maintenance, both ordinary and extraordinary, is more expensive compared to traditional vehicles, as it requires high-specialized technicians.

7.4 Regulatory / legal Context

Regulation for micro- and self-production
The current legislation in Madeira for micro-production and self-consumption of energy is defined in Decree-Law nº 153/2014 of October 20th.
The DL defines two types of Units of Production:

- **Small Production Units**, called UPPs (Unidades de Pequena Produção). UPPs are units of micro/mini production of energy from renewable sources, based on a single production technology, which are obliged to inject the total amount of produced energy to the grid.
- **Self-Consumption Production Units**, called UPACs (Unidades de Produção em Auto consumo). UPACs are units of production of energy from the renewable or non-renewable source, by the production unit with or without connection to the Public Service Electric Grid (RESP). In the UPAC situation, the produced energy should be injected preferably in the consumption facility

[83] "Incentivos fiscais para carros elétricos e híbridos - KBB.pt - Sapo." 24 Sep. 2017, https://kbb.sapo.pt/detalhes-noticia/incentivos-fiscais-carros-eletricos-hibridos/?ID=55. Accessed 14 Feb. 2018.
[84] "Electric Vehicles in Urban Europe - urbact." http://urbact.eu/sites/default/files/import/Projects/EVUE/documents_media/EVUE_report_280912_FINAL.pdf. Accessed 14 Feb. 2018.
[85] "Introduction of Electric Vehicles in Portugal A Cost-benefit Analysis ...." https://fenix.tecnico.ulisboa.pt/downloadFile/395142094915/Dissertacao_Manuel_Nina_52578.pdf. Accessed 14 Feb. 2018.
[86] "EEM - Empresa de Eletricidade da Madeira." https://www.eem.pt/. Accessed 14 Feb. 2018.

(i.e., self-consumption). Eventual surpluses of instantaneous production may be injected into the RESP when applicable.

Before the DL 153/2014, which establishes the legal regimes applicable to the production of electricity for self-consumption, UPP was the only modality for micro-production accepted in Portugal (including Madeira Island).
As self-consumption is now allowed and regulated, since the publication of DL 153/2014, EEM does not accept new UPPs (but still maintains the old contracts for the installations that happened prior to this decision). Moreover, always because of the already mentioned grid constraints, in Madeira island UPACs can only be installed without the energy injection to the RESP. These imposition[87] is due to the isolated nature of the Madeira electric grid, that is very sensitive to variations in the energy produced by RES, and is made possible by the disposition of article 66 (1) DL 29/2006[88].
Such regulatory constraint has raised the need to optimize self-consumption since exceeding energy, that cannot be injected in the grid, is currently lost. Taking into account the current legislation, the solution to be tested in Madeira pilot for this purpose consists in the introduction of BESS. Indeed, despite the current legislation presents a number of constraints, there is nothing preventing the installation of batteries.

Quality of Service Regulation
Concerning the quality of service, EEM follows the Quality of Service Regulation (QSR) n.° 455/2014[89], published on 29th November 2013 in Diário da República (the Portuguese official gazette).
The QSR defines the indicators for the quality of electricity supply, with respect to:

- Continuity of Service (CS) - number and duration of supply interruptions (individual and general indicators[90]).
- Quality of Electric Energy (QEE) – voltage wave, evolution of frequency values, amplitude, harmonic distortion, imbalance etc.

---

[87] Such imposition was spread through several communication channels by EEM - https://www.eem.pt/pt/conteudo/sistema-el%C3%A9trico/produ%C3%A7%C3%A3o/produ%C3%A7%C3%A3o-descentralizada/ - and DRCIE (Direcção Regional do Comércio, Indústria e Energia). In addition, DRCIE published an official communication - https://www.eem.pt/media/135711/drcie-aviso.pdf - informing those interested in installing new production units, about the need to obtain advance permission for connecting to the grid.

[88] Article 66(1) of DL 29/2006 allows Autonomous Regions to adjust electricity market directives and policies from the central government according to their specific needs. Full text of DL 29/2006 (in Portuguese): https://dre.pt/web/guest/pesquisa/-/search/683861/details/maximized
[89] Available at: https://www.edpdistribuicao.pt/pt/qualidade/Documentao/Regulamento%20da%20Qualidade%20de%20Servi%C3%A7o%20do%20setor%20el%C3%A9trico.pdf
[90] General Indicators refer to a) the network operated by the transmission system operator; b) the network (or network area) operated by a distribution system operator; and/or c) a group of customers. Individual refer to each delivery point installation, including customers. (QSR Art. N.° 19).

- Commercial Quality (CQ) - service, information, assistance and evaluation of customer satisfaction.

Considering the issues of frequency instability and power imbalance caused by the increase of RES penetration in the local grid, particularly noteworthy to be mentioned here are the indicators (reported in the sections below) related to the first two items.

CS Indicators

These indicators are specific for the Autonomous Region of Madeira and concern:

- Energy transport network
- Energy MV distribution network
- Energy LV distribution network

Energy Transport Network	
General Indicators	
ENF - Energia Não Fornecida / Energy Not Supplied (in MWh)	
TIE - Tempo de Interrupção Equivalente / Equivalent Interruption Time (in minutes)	
SAIFI - System Average Interruption Frequency Index	
SAIDI - System Average Interruption Duration Index (in minutes)	
SARI - System Average Restoration Index (in minutes)	
MAIFI - Momentary Average Interruption Frequency Index	
Individual Indicators	
Indicator name	**Standards***
Number of Interruptions	6 (per delivery point per year)
Total Interruptions duration	2 (in hours, per delivery point per year)

Energy MV distribution network

<table>
<tr><td colspan="3">General Indicators</td></tr>
<tr><td>Indicator name</td><td colspan="2">Standards (per zone of quality of service)*</td></tr>
<tr><td rowspan="3">SAIFI - System Average Interruption Frequency Index</td><td>Zone A**</td><td>3 (n° per year)</td></tr>
<tr><td>Zone B**</td><td>5 (n° per year)</td></tr>
<tr><td>Zone C**</td><td>7 (n° per year)</td></tr>
<tr><td rowspan="3">SAIDI - System Average Interruption Duration Index</td><td>Zone A**</td><td>3 (hours per year)</td></tr>
<tr><td>Zone B**</td><td>4 (hours per year)</td></tr>
<tr><td>Zone C**</td><td>8 (hours per year)</td></tr>
<tr><td colspan="3">TIEPI - Tempo de Interrupção Equivalente da Potência Instalada / Installed Capacity Equivalent Interruption Time (in minutes)</td></tr>
<tr><td colspan="3">END - Energia Não Distribuída / Energy Not Distributed (in MWh)</td></tr>
<tr><td colspan="3">MAIFI - Momentary Average Interruption Frequency Index</td></tr>
<tr><td colspan="3">Individual Indicators</td></tr>
<tr><td>Indicator name</td><td colspan="2">Standards (per zone of quality of service)*</td></tr>
<tr><td rowspan="3">Number of Interruptions</td><td>Zone A**</td><td>8 (per client per year)</td></tr>
<tr><td>Zone B**</td><td>12 (per client per year)</td></tr>
<tr><td>Zone C**</td><td>18 (per client per year)</td></tr>
<tr><td rowspan="3">Total Interruptions duration</td><td>Zone A**</td><td>4 (in hours, per client per year)</td></tr>
<tr><td>Zone B**</td><td>8 (in hours, per client per year)</td></tr>
<tr><td>Zone C**</td><td>12 (in hours, per client per year)</td></tr>
</table>

Energy LV distribution network		
General Indicators		
Indicator name	**Standards (per zone of quality of service)***	
SAIFI - System Average Interruption Frequency Index	Zone A**	4 (n° per year)
	Zone B**	6 (n° per year)
	Zone C**	8 (n° per year)
SAIDI - System Average Interruption Duration Index	Zone A**	4 (hours per year)
	Zone B**	6 (hours per year)
	Zone C**	10 (hours per year)
Individual Indicators		
Indicator name	**Standards (per zone of quality of service)***	
Number of Interruptions	Zone A**	10 (per client per year)
	Zone B**	15 (per client per year)
	Zone C**	25 (per client per year)
Total Interruptions duration	Zone A**	6 (in hours, per client per year)
	Zone B**	10 (in hours, per client per year)
	Zone C**	17 (in hours, per client per year)

* Standards have been published by ERSE (the Portuguese Energy Services Regulatory Authority) in Diretiva N.º 20/2013 (available at https://www.iberdrola.pt/02sicb/gc/prod/pt_PT/aboutus/docs/RQS_Diretiva.pdf)

**[SS3] Standards which vary according to the zone of quality of service, established in Procedure n.° 1 of MPQS (Manual de Procedimentos da Qualidade de Serviço - Procedure Manual for Quality of Service), available at
http://www.erse.pt/pt/consultaspublicas/consultas/Documents/43_Docs_para_consulta/43-RQS-SE-2013-MPQS.pdf

QEE Indicators
In order to assess the Quality of the Electric Energy, the following characteristics of the supply voltage wave need to be measured:

- Frequency;
- Effective value of voltage;
- Voltage dips;§
- Swells;
- Flicker;
- Voltage Imbalance in 3-Phase Systems;
- Harmonic distortion.

Under normal operating conditions, these characteristics in LV/MV/HV shall comply with NP EN 50160. As imposed by article 72 of QSR, a report about the Quality of Service, assessed according with the abovementioned indicators and standard parameters, is published annually by EEM. In case EEM detects nonconformities with the standard values, the report should also include a quality improvement plan, describing activities to be developed in order to resolve those nonconformities and the agenda for their implementation as well.

7.5 Demand Response proposals Madeira

In pilot 1 "Getting Started with BESS and DSM" with domestic customers-prosumers, in addition to the installation of BESS to handle the energy produced by PVs, a DR program of **DR/ToU or even DR/RTP** could also be included to encourage the prosumers to a load shifting scheme, in which some of the consumption made during the afternoon would be shifted in midday, when the PVs are producing. Therefore, decreasing the peak load even more, and since the load would be shifted during PV generation time, more renewable generation penetration would be allowed, leading to the desired goal of 50% penetration. If an ToU or RTP program is not possible, an incentive-based behavioral program is proposed, as the point system described in the case of Samsø island.

EEM have confirmed agree with the RTP and ToU approach and proposals_**for modelling and data analysis purposes**. They believe it will be a very good outcome of the Project and a proposal to implement in the future.

The same could and should be applied in Pilot 4 "Electric Vehicles are our future". In the latter case, perhaps a DR program closer to a configurable load control program might be of use, where the charging of the load, an electric vehicle or fleet of electric vehicles, is controlled directly by the utility provider or Distribution System Operator directly, but within limits, set by technical constraints and quality of service requirements

8 VNet's Control Approach

VNet's involvement in the SMILE programme mainly concerns the Orkney islands and the island of Samsø. While VNet do not currently have a defined deliverable on the island of Madeira, VNet take a keen interest in its development and are happy to provide advice to fellow SMILE partners should it be desired.

The below sections describe, first, the general control approach used by VNet, followed by details and considerations of the probable assets under management in the Orkney and Samsø trials.

Control architecture and overview

VNet is a platform that enables energy consumers and producers to access the value of the latent flexibility in their energy consumption and production patterns. With intelligent control, flexible assets may be used to provide balancing or ancillary services to the power system, which in turn will facilitate the cost effective integration of renewable energy and electric vehicles into the power system. The VNet platform will be used to control flexible load assets in the SMILE programme.

A device (or more generally an electric load) may be said to have latent flexibility if it is possible for its operating schedule to be altered without detrimental impact to its user. Until recently, accessing this latent flexibility has not been possible as most electric loads have been managed manually or with only simple timers for scheduling. Technology and advances in algorithms now make it possible to both control and intelligently schedule devices to provide power system benefits without negatively impacting the services that the devices provide.

For example, the service that a storage heater provides is that of maintaining room temperature between some user defined comfort limits during some user defined periods of the day. In this case of the Orkney objective it would be the role of the control algorithm to define a charging schedule that maximises the heater's consumption of otherwise curtailed renewable energy while maintaining the room at a satisfactory temperature at the required times of the day. The latent flexibility of the heater is therefore manifest in its ability to either bring forward or delay the consumption of power without negatively impacting room temperature (from the point of view of the user).

A diverse set of device types will be controlled in the SMILE trial. Different device types have different levels of flexibility at different times of the day/week. This flexibility is defined by:

- the physics of the service the devices provide and
- the user's preferences as to when and to what level these services should be provided.

As VNet are optimising the control of devices to deliver a system wide benefit, there exists the potential for the control decisions made by one device to affect the control decisions of another device. For example, if we wished to avoid 10 kW of power curtailment and we have 20kW of potential local load available with which to do this, it would be necessary to use some criteria to choose which local devices should be dispatched in order to fill the 10kW of available power. In such situations we aim to make choices that maximise the total social welfare[91] of the users of the participating loads. Our algorithms, informed by the user's preferences as to when and to what level services should be provided, aim to quantify and maximise the value that dispatching a particular device will deliver to the user. As a consequence, higher value services may displace lower values services in the dispatch order. The interlinked nature of such scheduling decisions makes the overall control problem both large and complex.

VNet uses an agent based architecture to solve the overall control optimisation problem. A schematic of this architecture is illustrated in Figure 2.

Each device is connected to a physical controller that acts as the interface between the VNet platform and the device. Controllers may either be provided by third parties, with control access provided to the VNet platform via an API[92], or via a VNet provided control device. In both cases the objective it to provide the VNet platform with a way in which to remotely control the state of the device.

Within the VNet platform agents are assigned to each of the devices under VNet control. The agents are effectively AIs[93] that make control decisions on behalf of the device they represent in order to maximise value for the user of the device. In order to understand the overall state of the system, all device agents receive price signals that, either in real terms or conceptually, represent the cost of consuming power at a particular time in the future. These price signals therefore constitute the means by which agents may be controlled on aggregate to deliver specific power system objectives. Selecting the price singal that will result in the desired aggregate response form all agents is performed by a global price setting AI. The details of how the device agents and global price setting AIs work together to quickly deliver scheduling solutions that deliver benefits to both device users and the power system are one of the key innovations of the VNet platform.

[91] https://en.wikipedia.org/wiki/Welfare_economics
[92] https://en.wikipedia.org/wiki/Application_programming_interface
[93] https://en.wikipedia.org/wiki/Artificial_intelligence

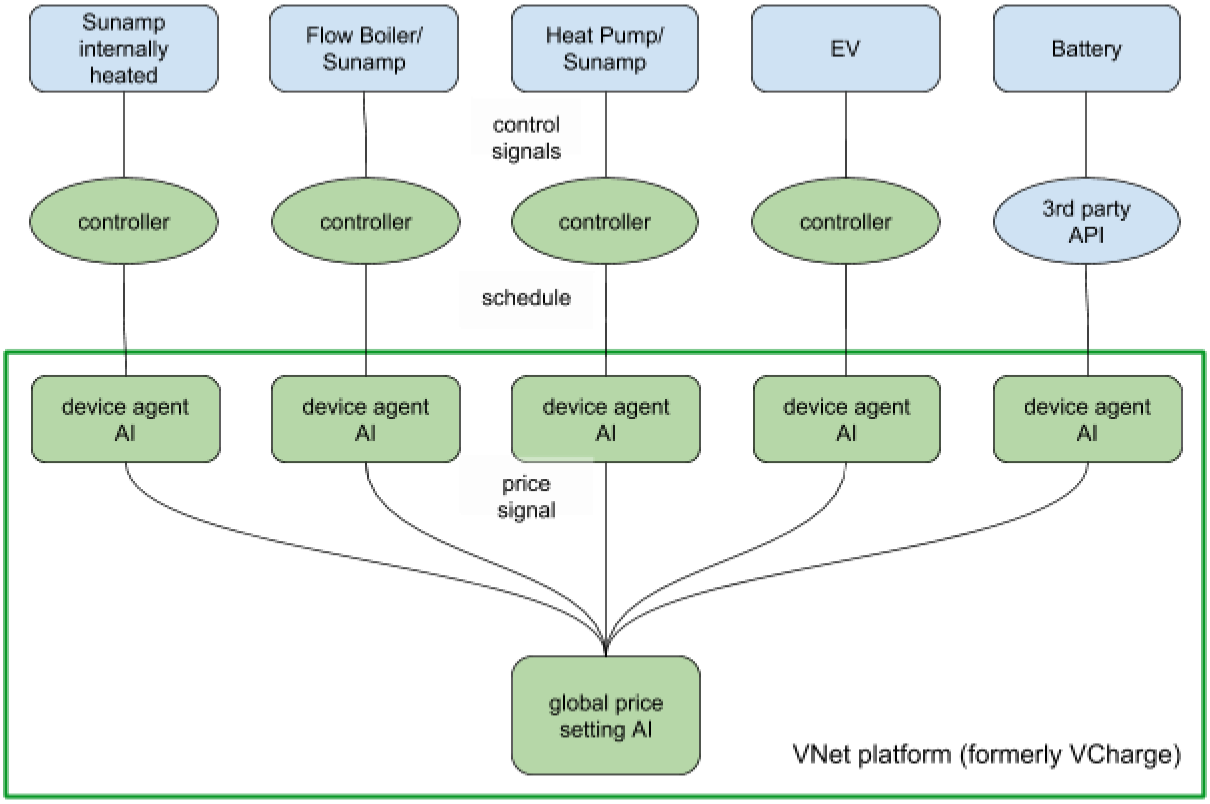


Figure 8.1: Illustration of VNet control architecture. A global optimiser sends prices signals to agents that perform local optimisations to maximise the value delivered by the devices they control.

In comparison to legacy, centralised optimisation approaches, the benefits of our architecture are that it is more:

- **scalable** – by solving many separate, smaller optimisation problems simultaneously we are able to scale our platform easily
- **fast** – the modular nature of the system means that computations are easily parallelised, allowing us to leverage modern multi-core cloud infrastructure to reach solutions much sooner than centralised, single threaded approaches would
- **robust** – our modular system has been designed so that a fault in one module will not destabilise the overall system
- general – our price controlled, agent based approach allows separation between individual device scheduling and the overall power system objectives (e.g. curtailment minimisation or self-consumption maximisation), thus allowing the same overall system to be used in multiple scenario

8.1 Orkney assets

This section provides a high level description and estimates of device characteristics for the key load/generation types that are expected to be included in the Orkney SMILE trial. These are:

- Rousey wind turbine generator
- Thermal storage batteries
- Heat pumps

- Hot water storage tanks with immersion heaters
- Battery electric storage
- Electric vehicle battery charging/discharging
- Hydrogen electrolyser

These devices will be operated both in stand-alone mode and as part of a consortium of devices within the same property.

8.1.1 Rousey wind turbine generator

Wind turbines convert kinetic energy in wind into electric power. For large wind turbines such as on Rousey, the power is fed immediately into the grid. This means that direct use of the generated power for self-consumption is not possible. However, because of the high levels of renewable power being injected into the Orkney network, there exists situations where the local network capacity is insufficient to export all generation to the GB grid. Currently, in such situations, generators must be curtailed. However, with appropriate demand management local network constraints may be mitigated by consuming more power locally, thus reducing the net flow from Orkney to the GB grid.

Model	Enercon E44
Charging power	NA
Discharge power	900 kW max
Energy storage capacity	NA
Energy output form	Electric
Dynamics	Can produces power when wind speed is between the minimum and maximum operating limits of the turbine. Due to correlation between wind speed and local heat demand, wind turbines may be used directly in local electric heaters.

8.1.2 Thermal Storage Batteries

These devices use phase change material to efficiently store heat energy for future use. Heat energy may be used for central heating or hot water.

Model	SunampCube (120cmX100cmX150cm). Smaller units can be used if needed.

Charging power	Multiples of 2.8 kW elements
Discharge power	Equal to hot water or central heating consumption rate. E.g. 7kW for sustained air heating
Energy storage capacity	65 kWh
Energy output form	Heat (water or air)
Dynamics	Can store useful energy for multiple hours. Will incur some energy loss over time due to heat diffusion.

8.1.3 Heat pump

These devices increase the effectiveness of energy conversion from electricity to heat by pumping heat out of the surrounding environment against the normal gradient (heat usually diffuses from hot to cold). In doing so they are able to provide a higher heat output per unit power than conventional resistive loads. This increased heat output is described by a quantity known as the *coefficient of performance (CoP)*, the ratio of the heat power output to the electric power input. E.g. for a 5kW heat pump with a COP of 2 would be able to provide the equivalent heat output as 10kW of conventional resistive heating.

Model	Daikin Altherma high temperature air-to-water heat pump
Charging power	Typically around 5 kW
Discharge power	Around 10 kW depending on conditions
Energy storage capacity	NA
Energy output form	NA
Dynamics	Coefficient of performance for heating is dependent of outside temperatures. The colder the outside the lower the CoP. Cannot store energy on its own.

8.1.4 Hot water storage tank with immersion heater

These devices store hot water in an insulated cylinder that is able to maintain useful temperatures for several hours without energy input. They also possess an internal electrical heating element that may be used to heat water as it enters the tank or top up heat levels during storage. Hot water may also be heated externally (e.g. by a heat pump) and then pumped into the tank for storage.

Model	Heatrae Sadia, Megaflow
Charging power	15–25 kW depending on model
Discharge power	Equal to the hot water consumption rate
Energy storage capacity	70–300 litres (roughly equivalent to 6–30 kWh of heating energy depending on conditions)
Energy output form	Hot water
Dynamics	Can store useful energy for multiple hours. Will incur some energy loss over time due to heat diffusion.

8.1.5 Battery electric storage

These devices store electrical energy in a chemical form that can be converted directly back into electrical energy when required. Electrical energy is considered to be the highest grade of energy as it can be used to power any electrical device, from electric heaters to home appliances. Load shifting with batteries can easily be achieved without requiring any change in a consumer's electrical power use schedule. However, use of battery electric storage has so far been limited by the high upfront cost of the battery unit.

Model	Tbd if it were Nissan
Charging power	3-6 kW
Discharge power	3-6 kW
Energy storage capacity	Up to 4.2 kWh
Energy output form	Electric
Dynamics	Can store energy over days. Will incur some efficiency loss between charge and discharge (typically around 80% efficiency). Charge and discharge cycles degrade the battery and so excessive cycling should be avoided. Potentially able to discharge to grid (sell energy back to the system), therefore able to engage in energy arbitrage. Ability to charge/discharge to grid at short notice makes batteries ideally suited to short term balancing services (e.g.

	frequency response).

8.1.6 Hydrogen electrolyser

The hydrogen electrolyser is able to convert electric power into stored chemical energy by splitting water into its constituent elements, hydrogen and oxygen. The hydrogen component may then be used as fuel in combustion engines or converted back into electricity in hydrogen fuel cells.

Charging power	500 kW (only one plant in Orkney, trial involvement TBC)
Discharge power	NA
Energy storage capacity	NA
Energy output form	Hydrogen
Dynamics	Energy stored as hydrogen is not convertible back into electric power by the electrolyser. It is therefore modeled as a load only device from a power system perspective. As hydrogen is a long term energy storage medium this load has high short term flexibility. Ramp rates and minimum on time may be a consideration as more data becomes available.

8.1.7 Electric vehicles VNet

In electric vehicles (EVs) the fossil fuel energy storage (petrol tank) is replaced by a large battery electric energy store, allowing them to run entirely with electric motors. When charging (i.e. connected to grid), the battery may also be used in the same ways as a static battery (described above). From a power system perspective, EVs can therefore be modelled as battery electric storage devices that have variable availability and physical location (as the vehicle may not always be charged in the same place).

Charging power	6 kW (for VCharge chargers)
Discharge power	6 kW (for VCharge chargers)
Energy storage capacity	40 kWh (based on Nissan Leaf), but usable capacity will be a fraction of this, e.g. 50%.
Energy output form	Electric
Dynamics	Can store energy over days.

	Will incur some efficiency loss between charge and discharge (typically around 80% efficiency). Charge and discharge cycles degrade the battery and so excessive cycling should be avoided. Potentially able to discharge to grid (sell energy back to the system), therefore able to engage in energy arbitrage. Ability to charge/discharge to grid at short notice makes batteries ideally suited to short term balancing services (e.g. frequency response). Availability and location of the asset will depend on the users schedule and uncertainty in that schedule.

8.2 Samsø assets

For the purposes of this report we focus on the first scenario described in SMILE report D3.1: “Specifications and Data Report for the Samsø Demonstrator”, chapter 2. This concerns the Ballen marina where boat battery charging and amenity buildings constitute the majority of the local load. Further developments of the programme on Samsø are described in subsequent chapters of D3.1 and VNet may play a role in their delivery, however there is some uncertainty as details of scope and funding are still evolving. As such VNet intend to address the specifics our involvement in these scenarios at a future date when details are confirmed.

This section provides a high level description and estimates of device characteristics for the key load/generation types that are expected to be included in the Samsø SMILE trial. These are:

- PV generation
- Battery electric storage
- Ballen marina load

8.2.1 PV generation

Photovoltaic panels convert sunlight into voltage across the terminals of the solar panel. They can therefore either directly supply DC powered devices or be combined with an inverter to supply AC power that may be consumed on site or fed into the grid if there is a surplus.

Model	TBC
Charging power	NA
Discharge power	30–60 kW

Energy storage capacity	NA
Energy output form	Electric
Dynamics	Can only generate when the sun is shining on the panels. If local power demand coincides with PV generation hours then power output may be consumed efficiently on site to displace grid energy requirement. For example, air conditioning is often at highest demand during daylight hours and when the sun is shining.

8.2.2 Battery electric storage

These devices store electrical energy in a chemical form that can be converted directly back into electrical energy when required. Electrical energy is considered to be the highest grade of energy as it can be used to power any electrical device, from electric heaters to home appliances. Load shifting with batteries can easily be achieved without requiring any change in a consumer's electrical power use schedule. However, use of battery electric storage has so far been limited by the high upfront cost of the battery unit.

Model	TBC
Charging power	50 kW
Discharge power	50 kW
Energy storage capacity	240 kWh (80%, 192 kWh available for operation)
Energy output form	Electric
Dynamics	Can store energy over days. Will incur some efficiency loss between charge and discharge (typically around 80% efficiency). Charge and discharge cycles degrade the battery and so excessive cycling should be avoided. Potentially able to discharge to grid (sell energy back to the system), therefore able to engage in energy arbitrage. Ability to charge/discharge to grid at short notice makes batteries ideally suited to short term balancing services (e.g. frequency response).

8.2.3 Ballen marina load

The Ballen marina's over all power demand is from multiple sources. Principally the service building, its sauna, the harbour master's office with a small electric heater, the seafood shop and diner with cooling and heating, lighting at the marina, and connections to yachts in the marina. We currently do not have the data to disaggregate these loads, however the trace of total power demand for year is shown in Figure 6.1.

Of the load sources mentioned we expect boat battery charging to offer the greatest flexibility.

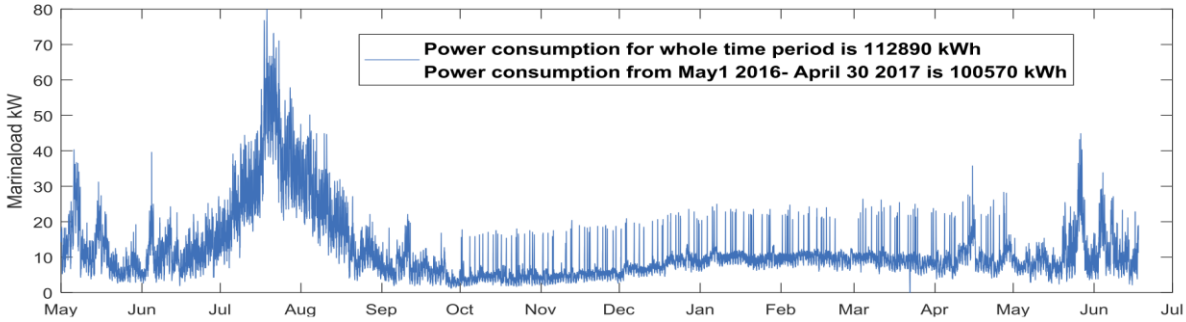


Figure 8.2: Example power demand of the Ballen marina, Samsø. Extract from SMILE report 3.1: "Specifications and Data Report for the Samsø Demonstrator".

8.3 Summary

VNet will use the same general control architecture for each of the two island trials (Orkney and Samsø).

The specifics differences between the island project's assets and objectives will be addressed at the level of the device agent when they pertaining to device physics or device user-preferences or, for optimisation objectives, within the global price setting AI.

The specific system objectives are:

- Orkney: minimise energy curtailment at the Rousay wind turbine.
- Samsø: maximise self-consumption of renewable generation at the Ballen marina.

9. Route Monkey's Control Approach

General Overview: The systems implemented at all pilot regions will be underpinned by two kinds of algorithms: *forecasting* algorithms and *control* algorithms. Both types of algorithms can be subdivided broadly into two categories, which can be dubbed *simple* and *smart*.

Forecasting algorithms provide estimates of the future values of key data streams (such as wind speed, electricity demand, and so forth); in a 'simple' forecasting algorithm, these estimates might simply be provided in advance (such as the case in a fixed time-of-use tariff, for example). Or they might depend in a straightforward way on historical data (for example, the algorithm may calculate an average value for each time of day based on the past two weeks of data, and use that as the forecast for given times of day in the future). In contrast, a 'smart' forecasting algorithm is much more sophisticated, tending to be (i) based on machine learning and/or advanced statistics, and (ii) continually adaptive. The machine learning/ advanced-statistics aspect means that the 'smart' forecasting algorithm is *model-based*; the forecasts themselves will be made by a 'model', which can be considered as a black box that considers input data, and then outputs its forecast estimates. Examples of models include: neural networks, decision trees, regression trees, or discriminant-based classifiers. Such a model has many parameters (often both structural and numeric), and these parameters must all be learned in a 'training' process which uses typically large amounts of historical data. The 'adaptive' element of a smart forecasting algorithm refers to the fact that the model will be continually automatically re-trained, by repeating the training process with updated historical data at regular intervals (e.g. overnight, or hourly).

Control algorithms consider a range of relevant data streams relevant to an operating system, and then output decisions that change the state of that system; in the current context, example control decisions might be 'pause EV charging' or 'switch input power to storage battery'. In a similar vein to forecasting algorithms, control algorithms vary along a spectrum from simple to smart. A 'simple' control algorithm is one that does little or no more than operate according to predefined static rules; for example, a standard thermostat switches between heating, cooling, or 'off', based on simple threshold temperature values. At the other end of the spectrum, a 'smart' control algorithm will typically have two key components: (i) a system simulation model, and (ii) an optimization module. The simulation module is a mathematical/digital representation of the system being controlled, which is manipulated by the algorithm to enable it to estimate the potential effects of different control actions; meanwhile, the optimization module wraps around the simulation module, aiming to find the control actions that will have the best outcomes in the present situation. The simulation module may be as simple as a set of predefined tables (e.g. providing cost of grid electricity in future time intervals) , or as sophisticated as a full-blown simulation (e.g. a Matlab module simulating a storage battery at the level of individual cells, estimating the battery's state-of-charge in response to a detailed charging profile, taking external temperature and other factors into account). The optimization module is simply an algorithm that will repeatedly access the simulation model, and can be anything from an exhaustive search to a sophisticated genetic algorithm, depending on the complexity of the control decisions to be determined, and the environmental time constraints.

9.1 Route Monkeys Proposed Control Approach Orkney

Route Monkey will provide a facility to remotely manage the charging of 15 of the 30 EV charge points within the Orkney trial, in accordance with local parameters such as electricity Time of Use (TOU) pricing, Demand Response, load management or frequency control for example. These parameters are to be defined.

The principle of approach for Route Monkey’s optimisation algorithms is:

- Establish current situation, related parameters, constraints, data sources
- Forecast next 24 hours
- Analyse current and forecast scenarios to determine optimised actions to make as a result

Route Monkey provides forecasts via an API in JSON format. The rules of operation and demand response scenarios for Route Monkey’s algorithm need to be established for each island: Orkney, Samsø and Madeira. In part, the contents of this document will inform this activity and the end deliverable.

If the incumbent commercial EV chargers for each island are already supplied by a third party, with charging controlled through an existing charge network membership card system (with potential structure to charge money to users per charge); in such cases, a back office would already exist and Route Monkey would not connect it to Route Monkey’s back office for control purposes.

A full battery electric vehicle (eg Nissan Leaf, Renault Zoe) has zero tail-pipe emissions. Using the existing UK Grid Carbon intensity, an electric mile is circa 40% less carbon intensive than an ICE (Internal Combustion Engine) mile. If, through the project, EV charging can be matched to locally produced renewable energy (wind, solar) then the emissions are effectively zero.

EV charge points must facilitate two-way comms for Route Monkey's optimisation interface. Implementation will require co-operation from CES, VCharge and Sunamp in order to create an interoperable architecture as indicated in the diagram above. Ability to control charging on public infrastructure is limited compared to at-home charging, since less is known about the vehicle, driver and requirement for recharging.

The current installed base of EV charging points on Orkney do not currently offer managed charging. Charging is on-demand as the user requires.

Effective implementation of optimised EV charging for Orkney will depend on local take up and affordability of EVs. Implementation is unlikely to provide the density of savings required to have a significant impact; however it will demonstrate the capabilities of the technology and benefits of future scaling up.

In 2015, under the Switched On Fleets initiative, Route Monkey collaborated with Transport for Scotland and the Energy Savings Trust to support local councils to make informed choices on electric vehicle deployment, such that these vehicles delivered cost savings as well as environmental benefits.[94] Route Monkey was able to identify “sweet spots” for potential electrification; model real world data to assess suitability for EVs; identify opportunity to utilise existing public re-charging infrastructure and make recommendations for future recharging infrastructure. In parallel this helped to develop an understanding of where & when demand for rapid charge will occur to plan infrastructure investment based on existing fleet duty cycles. For EV car fleets (car club, taxi, delivery etc), Route Monkey can assist with managing booking and schedule journeys according to availability of infrastructure.

Route Monkey will bring this experience and expertise to the SMILE project to support the wider demand response activities developed for Orkney. In this regard, Route Monkey plans to provide EV usage prediction, a demand response API, charging optimisation and web interface for the 15 EV charge points in the SMILE Orkney scheme. The specific data points, minimum response times and related parameters will be defined once the local EV drivers and their vehicles have been recruited by CES for the Orkney scheme (expected to start March/April 2018). Only at this stage will the local control hardware and EV charging infrastructure be known and as such ready to inform the parameters under which Route Monkey’s optimisation algorithms can operate.

[94] https://news.gov.scot/news/25-million-investment-to-reduce-vehicle-emissions (accessed 1/2/18)

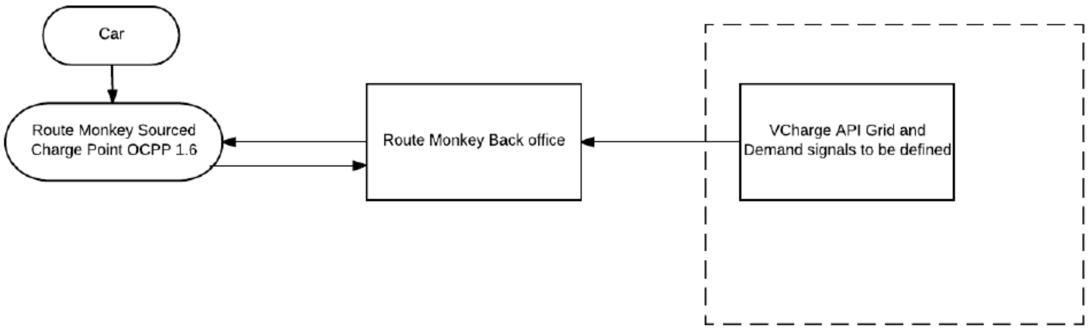


Figure 8.3: EV system architecture, scenario 2 (Route Monkey controlled) (ref D2.1 Orkney Demand Side Management System Architecture Design)

A key system at Orkney will be smart charging of around 15 electric vehicles at a specific collection of charge points. The objectives of this smart charging system are primarily to divert charging towards times of expected wind-power curtailment. The algorithms we expect to be researched and deployed for this case are:

- Smart forecasting of wind power: exploiting the location and specification details of the relevant individual wind turbines, and exploiting online sources for weather forecasts, a neural network will be implemented to forecast wind power 1--24 hrs ahead
- Smart forecasting of demand: Orkney grid demand will be estimated via access to real-time feed at selected locations; this will be correlated with weather and calendar data to build smart demand forecasting.
- Wind-power and grid demand forecasting (above) will feed in to a simple rule-based curtailment forecast.
- Smart forecasting of EV demand: for each monitored chargepoint, a database of usage will be accumulated and used as the basis of demand forecasting at that chargepoint.
- Smart control of EV charging (i.e. smart charging): EV demand forecasts per chargepoint will be used as the basis of a simple simulation model to estimate the charge time requirements and flexibility each time an EV plugin is sensed (or signalled via some other means); deciding when to charge (e.g. perhaps the choice of five specific 30 min blocks in a ten-hour window) will then be done by a smart control algorithm, which couples the EV demand forecasts with curtailment forecasts, and the optimizes to find an ideal charging schedule.

9.2 Route Monkeys Proposed Control Approach Samsø

A key Samsø system delivered in the project will be smart control of charging at the Ballen Marina. Up to 350 boats can use the Marina, and there are 200 power sockets. Boats generally arrive with their battery at a low state of charge, type Algorithms built to underpin this system will therefore be:

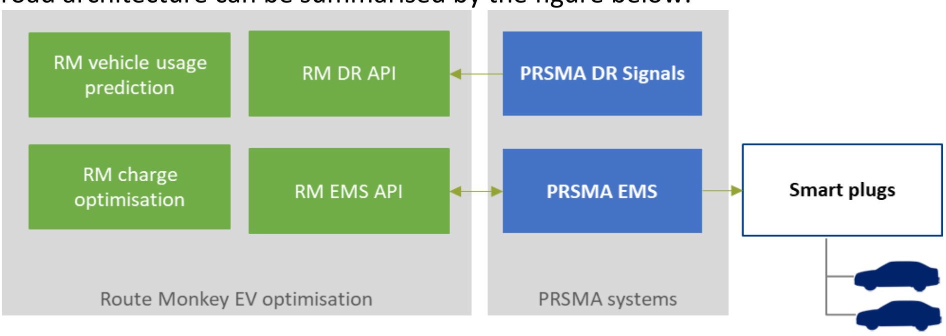
- Smart forecasting of solar power: exploiting the location and specification details of the Ballen PV, and exploiting online sources for weather forecasts, a neural network will be implemented to forecast solar power availability 1--24 hrs ahead
- Smart forecasting of demand: aided by data made available by Compusoft (who run the Marina back-office system, logging boat arrival/departure and charging sessions), a bespoke forecasting algorithm will be built to forecast charging requirements at the Marina, and the

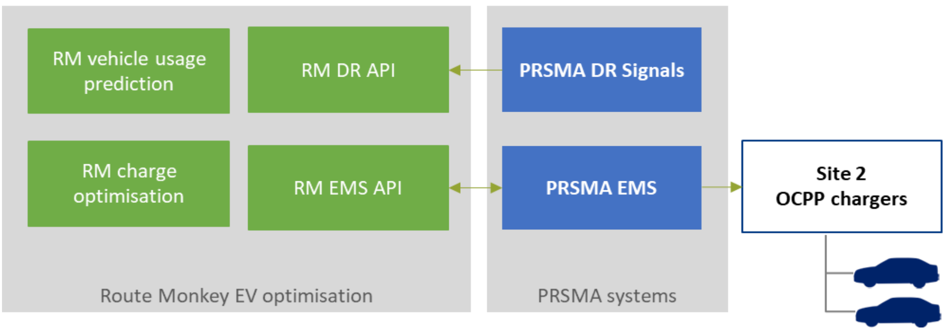
flexibility of those requirements. The practicalities of communication with Compusoft's backoffice are yet to be tested, so one of two algorithm scenarios will occur: (i) if near-real-time datastreams for Marina charging can be established, this will be exploited to deliver accurate, adaptive forecasting of charge requirements and flexibility. (ii) if not, we nevertheless have a rich base of historical data already provided, coupled with AAU's detailed account of event and habit-based demand drivers at the Marina; this will be used to derive uncertainty-quantified statistical profiles which will drive Marina demand forecasts.
- Smart charging of boat batteries at the Marina: it is unlikely that automatic charging control can be installed at the Marina given the current infrastructure constraints and current market offerings. Instead, charge-window suggestions (traffic-light based) will be provided via a web-dashboard, available to all on smartphones, tablets and Marina displays. This visualisation will deliver dynamically changing control recommendations, emphasising cost drivers. The underlying algorithm will be optimisation of potential charge schedules, based on the PV and demand forecasts, targeted towards maximising utilisation of good PV availability.

Following a site visit to Samsø (5/12/17) it was determined that the systems architecture development for the Samsø scheme was contingent on determining whether VCharge could interface with the incumbent Compusoft system for managing electricity supply to the boats moored in Ballen harbour. Consequently, the scenarios under which Route Monkey can add value for Samsø depend on the outcome of initial discussions between VCharge and Compusoft is expected in early 2018.

9.2 Route Monkey Control Approach in Madeira

Tuxi data expected by end Jan 2018. (+weather forecasting, generation forecasting).
Two main systems will be built in Madeira, one centred on smart EV charging at the EEM garage, and another based around charging of tourist 'Tuxi' EVs based at the Cristiano Ronaldo Museum. For both cases the broad architecture can be summarised by the figure below:





The upper figure concerns the 'Tuxi' system, in which EV charging is currently done via standard plugs in standard domestic-style sockets. For SMILE, this setup will be enhanced by the use of an intervening 'smartplug' system (likely a product called 'Plugwise') which can be controlled to switch power on/off to individual sockets. In the case of EVs at the EEM garage, instead we expect the installed chargers capable of control via an OCPP protocol.

The two systems will be implemented in exactly the same way at the back end, which is represented by the green and blue boxes, with algorithms primarily in the green boxes, designed and operated by Route Monkey, and hardware control / data handling in the blue boxes, designed and operated by PRSMA. Key algorithms implemented will be as follows:

1 Smart forecasting of wind power: wind-power is the predominant source of renewables supply on Madeira. Hydropower is also significant, and there is some PV, but we expect wind-power availability to yield a sufficiently significant signal which, when combined with demand estimates, can indicate potential vulnerability in the grid supply. Exploiting the location and specification details of the Madeira wind farms, and exploiting online sources for weather forecasts,a neural network will be implemented to forecast wind power 1--24 hrs ahead
2 Smart forecasting of demand: EEM will assist in supplying data streams that enable us to adaptively predict overall Madeira demand for electricity. We will correlate this data with calendar data, weather data (and weather forecasts) to fuel smart forecasting of overall Madeira demand via a decision-tree/neural network hybrid.
3 Smart forecasting of EV demand: for each monitored chargepoint at the EEM garage, and each socket at the Tuxi garage, a database of usage will be accumulated by PRSMA, and used as the basis of demand forecasting at that chargepoint via bespoke RM algorithms. Detailed algorithm design awaits the clarification of certain hardware issues; specifically, it is not clear at the moment whether we will have aggregate charging data or per-socket charging data at each site.
4 Smart control of EV charging (i.e. smart charging): EV demand forecasts at each site will be used as the basis of a simple simulation model to estimate the charge time requirements and flexibility of charge provision during the next several hours. These forecasts will be aligned with overall Madeira demand and renewables forecasts, the latter providing a basis for estimating the benefits or costs of charging (over the 'next several hours' window), in terms of grid frequency vulnerability, power costs, and/or renewables utilisation (also taking into account site constraints). A simple optimization algorithm will then find ideal charging profiles, and communicate these to PRSMA's controllers.

10. PRSMA's Control Approach

10.1 PRSMA's Proposed Control Approach Madeira

The following assets are currently being implemented:

10.1.1 Distribution Station

- Fluke high-frequency grid analyzer
- UPS / Surge protector
- Computer base station
- BESS
    - 1 x 60kWh 30kW 3 phase

In this particular case, Landis + Gyr meters already installed in the micro-production sites (with injection to the grid). As such, we don't need to monitor the micro-production ourselves.

10.1.2 Tuck-tuck Garage

- Plugwise sub-metering platform
    - active power at a frequency of about 0.5 Hz
    - remote ON / OFF capabilities

10.1.3 EEM Garage

- Fluke Meter providing three-phase measurements of the EV charging equipment (1 point every 5 minutes)
- Sub-metering platforms
    - plugwise
        - active power at a frequency of about 0.5 Hz
        - remote ON / OFF capabilities
        - can be used to monitor the charging of Renault Kangoo ?
    - EMotorsWerks JuicePlug
        - at least instantaneous power and amperage
        - remote ON / OFF
        - can monitor any EV that uses the standard J1772-standard charging cable (e.g., Nissan Leaf)

In the eventuality of also using EVs for frequency control, we are currently considering the possibility of installing frequency sensors in the Tuck-tuck and EEM garage.

In an isolated grid with many dispersed solar micro-production facilities that are intermittent sources by nature, the phenomenon of voltage fast increase and frequency fluctuations are bound to happen if the consumption and production are not properly balanced.

Voltage and Frequency Control with BESS

With the installation of a BESS in a transformation station with high penetration from RES, the aim is to mitigates this effects, thus improving the quality of service of the electric power supply.
Ultimately, we foresee three scenarios in which combining BESS and DR algorithms should be able to mitigated these two issues:

- **Voltage control;**
  - Inject or consume reactive power up to rated power to keep the voltage close to nominal values;
  - When the voltage is less than 10% of the nominal voltage, inject as much reactive as possible (nominal). Voltage ride through capability.

- **Frequency Control:**
  - Provide full active power when the frequency is below 49.5 Hz;
    - Minimum time for maximum power: 0.5 seconds;
    - Limited to maximum allowable voltage;
    - Limited to the power transit on transforming station;
  - No active power when the frequency is higher than 50.5 Hz.

- **Load/production support:**
  - Smoothing of load and output at the transformer output (low voltage);
  - Charge and discharge by set point from EEM Dispatch Service;
  - Charge and discharge by software control, using internal algorithms, which can be parameterized remotely or locally, through the load or distributed production etc.
    - Typically, the battery will be charged between 9 am and 5 pm (production time), and discharged between 6PM and 10PM (load peak time).

Frequency Control with EVs

Despite the relatively small-scale of the EV case studies in Madeira, this could be used as a proof of concept, for something that will inevitably happen in the next couple of years. To this end, together with Route Monkey, we are considering the installation of frequency sensing in the two EV pilot sites.

Unlike most demand side response, which requires centralised control, a frequency response requirement can be detected locally to every EV charging outlet by measuring the current grid frequency. Local detection and control action without the need for centralised system and near-real time communication could present a low cost alternative to complex demand side management. Our goal is to build a system that:

- Decreases charging when the frequency is below a certain threshold
- Increases charging when the frequency is above a certain threshold

Using the data gathered from the sensors, as well as other grid impacting data, such as wind and solar irradiation, we further hope to forecast future frequency oscillations and correlate frequency with other variables that will be monitored. This should allow us to build a more sophisticated solution, than a simple on/off response to frequency changes.

11 Conclusions

This report has outlined the most appropriate Demand Response (DR) services for each of the SMILE project's regional demonstrators, whilst also providing some context on the current EU Energy System and the significant changes that are taking place.
The report begins by introducing the EU energy system as a whole, providing context to the significant changes that are taking place nationally, across Europe and to a certain extent worldwide. Although it is understood the system is still evolving; increasing peak demand, more intermittent generation and the combination of policy driven changes and adoption of new technologies, will significantly change the nature of the energy system for both supply and demand.

It is now widely recognised across Europe that Demand Response is a critical resource for responding to these changes and achieving an efficient and sustainable electricity system. There are however, multiple and complex barriers and challenges that exist before mainstream up take of Demand Side Services is achieved.

The report describes the different grid issues/ constraints faced by each SMILE demonstrator. The technical objectives and their associated grid constraints and market context for each demonstrator has been covered in Sections 5, 6 and 7.

The specific demonstrators demand response system objectives are:

- Orkney: minimise energy curtailment at the Rousay wind turbine.
- Samsø: maximise self-consumption and manage peak load consumption at the Ballen marina.
- Madeira: apply frequency and voltage control by introducing BESS and potentially including a proof of concept with EVs.

The VNet platform as described in detail in Section 8 will be used to control flexible load assets in the SMILE programme. VNet uses an agent based architecture to solve the overall control optimisation problem. VNet's involvement in the SMILE programme mainly concerns the Orkney islands and to a lesser extent the island of Samsø. While VNet do not currently have a defined deliverable on the island of Madeira, VNet take a keen interest in its development.

A diverse set of device types will be controlled in the SMILE trial as the report describes different device types have different levels of flexibility. This flexibility is defined by:

- the physics of the service the devices provide and
- the user's preferences as to when and to what level these services should be provided.

VNet will aim to use the same general control architecture for each of the two island trials (Orkney and Samsø). The specific differences between the island project's assets and objectives will be addressed later at the level of the device agent, when pertaining to device physics or device user-preferences or, for optimisation objectives, within the global price setting AI.

Route Monkey have involvement in all 3 demonstrator regions. They will provide a facility to remotely manage the charging of 15 of the 30 EV charge points within the Orkney trial. They will also have a role in the smart boat charging in Samsø and they will manage the EV charging together with PRSMA at the EEM garage, and another based around charging of tourist 'Tuxi' EVs.

The systems implemented by Route Monkey at all pilot regions will be underpinned by two kinds of algorithms: *forecasting* algorithms and *control* algorithms. Route Monkey's algorithms are flexible enough to accommodate the different DR requirements for each island. It is possible to operate Route Monkey's algorithms in a background "learning" state while the local system reaches a state of business as usual. In this way we can mitigate risk by only introducing Route Monkey's algorithms once the local operating conditions are established and understood.

PRSMA will provide frequency and voltage control using BESS and potentially they will proving alongside Route Monkey some frequency control with EVs. The exact control architecture for this is still to be developed within the project.

The findings of this report suggest that the integration of demand side response solutions can be successfully achieved through the augmentation of aggregator platforms; such as VNet, and optimisation algorithms such as Route Monkey. There remain challenges in integrating these solutions in different geographical and regulatory contexts. However, the massive potential for the increased penetration and efficient use of low cost, intermittent renewables in the EU is more than worth rising to this challenge.