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SMILE

Smart Island Energy Systems

Deliverable D2.4
Design Specification for Orkney Demand Side Management System

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Abbreviations

AC	Alternating Current
ANM	Active Network Management
API	Application Programming Interface
ASHP	Air Source Heat Pump
BESS	Battery Energy Storage System
CES	Community Energy Scotland
CH	Central Heating
CfD	Contract for Difference
CoP	Coefficient of Performance
CPBO	Charge-Point Back Office
DHW	Domestic Hot Water
DNO	Distribution Network Operator
DSM	Demand Side Management
EMEC	European Marine Energy Centre
ERE	Eday Renewable Energy
EV	Electric Vehicle
kW	Kilowatt
LAN	Local Area Network
LiBal	Lithium Balance
OCPP	Open Charge Point Protocol
PCM	Phase Change Material
PLC	Programmable Logic Controller
PoA	Principles of Access
REWIRED	Rousay Egilsay Wyre Renewable Energy Development
RM	Route Monkey
SMILE	SMart IsLands Energy
SoC	State of Charge
SSEN	Scottish and Southern Energy Networks
WTG	Wind Turbine Generator

1 Introduction

1.1 Disclaimer

This document is an output of what has been developed in the first 18 months of the project in the framework of WP2, and serves as an update to Deliverable 2.1, complete with revisions, changes and improvements as the partners involved with the delivery of the demonstrator have further defined project details over the previous months, with the system installations now ready to be installed. In particular, the report provides the design specification for the Orkney DSM system.

1.2 Scope and Objectives

This document will summarise the background to the SMILE Orkney demonstrator project, first explained in D2.1; and look forward to what the demonstrator will set out to achieve in the proposed DSM system. This report, forming D2.4, describes the detailed design of the Orkney Demand Side Management (DSM) system. The report will particularly include a technical description of the overall system architecture for the heating and hot water installs, EV charging as well as an industrial load, along with schematics; to include the interaction and interfaces of the system components from various SMILE technologies providers, with input from all participating partners in WP2. Also included is an insight into data collection and parameters for analysis.

Within this framework, the main objective of the Orkney pilot project is to demonstrate ways to transform the existing semi-smart grid system (management of generation only) into a fully smart system (management of generation and demand), by using existing grid infrastructure and integrating new communications and control systems, as well as new controllable energy demand for heat, transport and industrial load.

Accordingly, the regional demonstrator involves the integration of demand side response and management, energy storage, and low-carbon heating and transport, across independent but integrating aggregation platforms, with an operational smart grid. By adjusting their individual and combined demand, the actively managed loads will locally react to the existing active management of local grid export of generation. The aim is to prevent generators from having their output restricted or 'curtailed' due to grid restrictions, at times and in areas where energy could actually be harnessed or stored when needed. The vision is to turn the existing necessary management of grid limitations into an opportunity to intelligently and locally use the abundance of renewable electricity available to meet local heat and transport needs.

1.3 Structure

- Section 2 outlines the Orkney Regional Pilot and what the Orkney demonstrator aims to implements from the SMILE project.
- Section 3 provides more in depth details about the domestic heat installs, giving an overview of the different heating systems, project house types, the technologies involved and the connectivity between them, as well as giving an insight into data collection and parameters for analysis, covering both pre and post installation.
- Section 4 relates to EV charging, providing information on both of the chosen EV scenarios, from small domestic chargers, to business/facility chargers. This section includes system architecture and schematic diagrams covering both the Route Monkey and VCharge (OVO) charging options, as well as details on data collection.

- Section 5 explains the industrial load/electrolyser smart switching, and provides a further insight into the LECF 'Surf 'n' Turf' project.
- Section 6 details a proposed basic rebate system in a 'business as usual' scenario, allowing the potential for participants to benefit from reduced energy costs by utilising the SMILE demonstrator technology.

1.4 Relationship with other deliverables

This Deliverable builds on and expands the system architecture initially outlined in D2.1, and provides an insight into detailed system design, both on a household level and overall DSM system level, and technology integration ahead of the system installs. The cross-partner integration of systems is a vital part of the DSM system and this deliverable aims to provide details on how these systems will interact with each other, as well as how they will cooperate and integrate within the existing Smart Grid. The systems detailed in this deliverable have initially been approved by the local DNO, but further impact studies will be outlined as part of D2.3 once available; and the required participant data has been passed on to the DNO in order for them to assess the impact the project will have on the local grid. The information within this deliverable has also played an important role in D2.2 on Participant recruitment, as participants have signed up to receive installs based on the systems detailed and explained within this deliverable.

1.5 Partner Contribution

The SMILE partners that have contributed to this document include:

- CES are WP2 package leader and are responsible for the overall project management and delivery of the Orkney demonstrator site. They have created and provided the overall and integrated architecture and diagrams, have been coordinating input from the other partners for this deliverable as well as the background information.
- VCharge (OVO) are a partner supplying DSM tools including the control systems, an aggregator platform and EV chargers to the project. They will gather signals from the local generation, along with other forecasting, to control local demand via the control systems connected to sources of heat and EV demand. VCharge (OVO) have been working in Orkney with CES and the local community generators since early 2014, looking at how local demand can be controlled to facilitate increased renewable energy generation in Orkney. VCharge (OVO) have provided detailed local system architecture diagrams, based on how they will control each source of demand with their platform.
- Sunamp are a partner supplying equipment (Phase Change Material (PCM) heat batteries for domestic heating and hot water) to the demonstrator site for the domestic heat installs. They have provided technical details of their systems and support in the system architecture diagrams.
- LiBal are a partner supplying batteries and the battery management system to the project, being used for the domestic heat installs. They have provided technical details of their systems and support in the system architecture diagrams.
- Route Monkey are a partner with a focus on optimising the EV charging side of the controllable demand. They have contributed to the architecture diagrams with VCharge (OVO) by adding knowledge about how their back offices will communicate with each other. The Route Monkey platform will offer the predictive behaviour algorithms to do the smart charging of electric vehicles alongside VCharge's (OVO) aggregator platform.
- RINA Consulting supervised the development of the deliverable by verifying the alignment with the DoA (Description of Actions) objectives and by making comments and suggestions for

improvement. The main scope of RINA in the framework of the WP2 activities and in the definition of design DSM system is to create the link with the activities of WP5 related to cyber security and control and automation methods for the network grid. RINA carried out the revision of the deliverable for submission purposes.

2 Orkney Regional Pilot Overview

This section explains the overall scope, remit and rationale of the Orkney demonstrator proposals, and gives an overview of what the Orkney demonstrator aims at implementing in SMILE. As well as the area of activity and the overall integrated architecture of the proposed communication, control and aggregation systems, the three different types of controllable demand will be described in detail, giving the specification, architecture overview, hardware and software requirements, and partner technologies in turn that will be implemented:

- Domestic heat installs;
- EV charging; and
- Industrial load.

2.1 Brief overview of the Orkney Grid and ANM

As illustrated in D2.1 (Chapter 2.1), 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. 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 1). Orkney still imports significant amounts of fossil fuels for domestic heating, transport (road, marine, air) and industry. Details about the energy sources and main areas of consumption within Orkney can be found in D2.1.

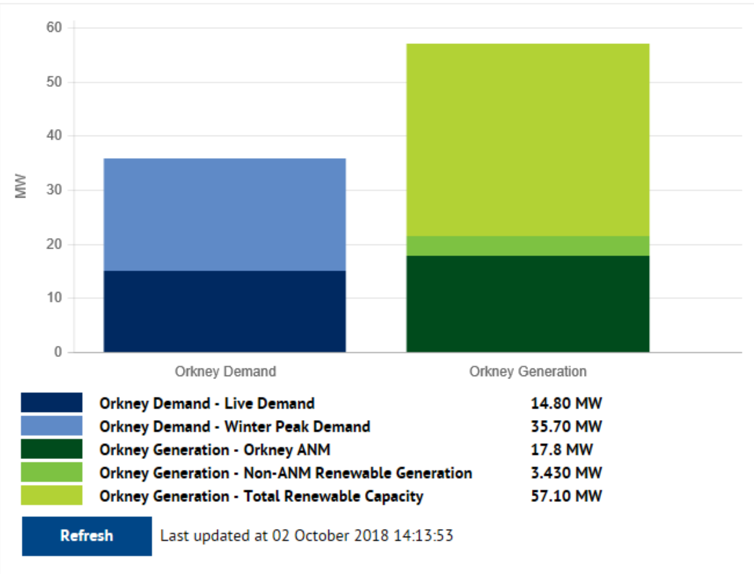

Figure 1: Orkney demand and generation (from live updates, taken on 02/10/2018 14:13:53) [1]

In 2009, an ANM system was set up which allowed generators to connect to the grid without substantial upgrades. The ANM system operated by the DNO SSEN, and designed by Smarter Grid

[1] https://www.ssen.co.uk/ANM/

Solutions (SGS) is frequently referenced to as a successful deployment of ANM in the UK. Before the deployment of ANM, Orkney was restricted in its ability to integrate more renewable generation due to the 33kV cables going to the mainland being at capacity. Against a conventional reinforcement cost of £30 million to install a new submarine cable, the £500,000 ANM scheme uses real-time automated controls to manage generation output while taking into account the export capacity at key bottlenecks within the local distribution grid. For the island generators, operating in the ANM zone brings both opportunities (a grid connection that would not be possible otherwise) and challenges (curtailment; of unpredictable and uncontrollable levels).

The network is divided into zones which reflect local areas of the 33kV grid that are potentially restricted upstream of these key bottleneck points in the network. The key limiting factor (e.g. maximum current flow) is measured at these key points, and the system receives real time information from the measurement points. The zones and their associated measuring points are identified in the map (Figure **2**).

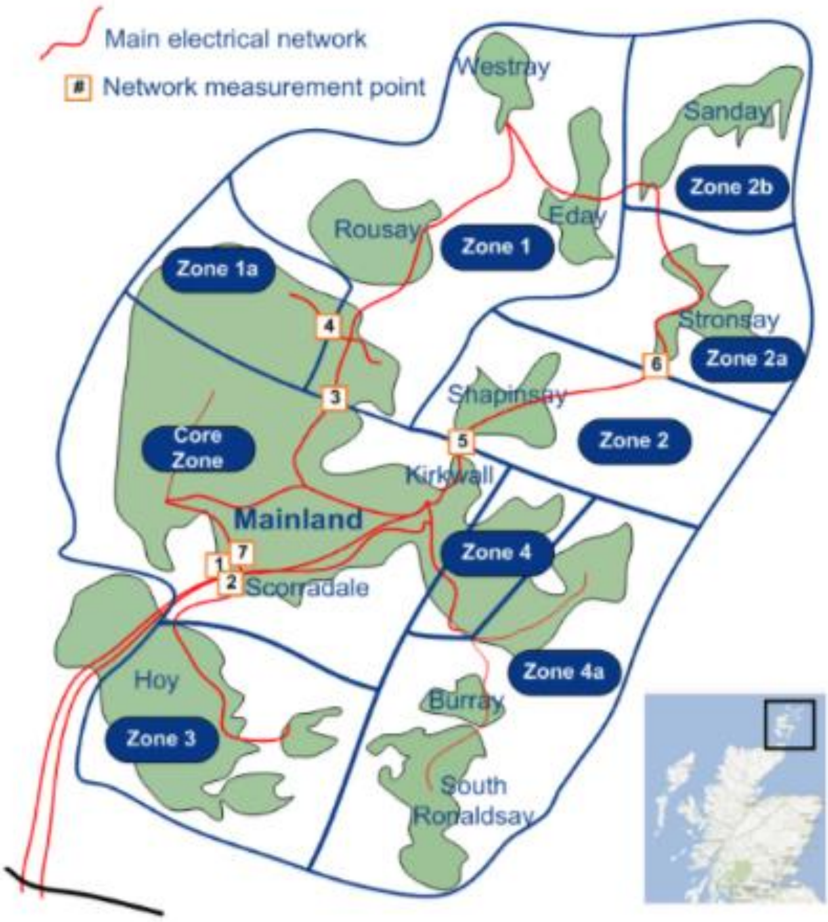

Figure 2: SSEN's diagram of the ANM zones and island grid network[2]

The ANM system allows conditional and actively managed grid export connections for generators. It uses real time network information to calculate safe levels of generation for managed connections in accordance with their commercial agreements and Principles of Access (PoA). The PoA is the mechanism by which the commercial arrangements are put in place to ensure the fair allocation of limited generation on the network. On Orkney, the Last in First off (LIFO) method has been used. The

[2] https://www.ssen.co.uk/ANMGeneration/

last generator to accept a connection offer is restricted before the first. This list of generators, ordered by their connection acceptance, is also referred to as the priority stack.

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 onto 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.

Since 11th Sep 2012, SSEN have not approved any new generation grid connections above G83 code (approximately maximum of 3.7kW per phase) as the current system is at capacity without major cable upgrades.

There are proposals from SSEN to upgrade the transmission connection to mainland Scotland with a 220kVA subsea connection, although timeline and feasibility for it is dependent on new renewable energy developments of this scale to be in the pipeline, which is not clear in the current market for the UK Government Contract for Difference (CfD) subsidy regime for remote islands. Additionally, it is confirmed that this would only provide new grid connections to new projects on Orkney and not help the existing generation without the further local reinforcement necessary to connect to these new higher voltage circuits.

2.2 Area in ANM zones for SMILE Demand Side Management

The SMILE demonstrator is focused on installing the controllable demand within zone 1 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), marked by the blue circles in Figure 3 below. 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 domestic heat installs, EV smart charging and large industrial load will support in increasing the electricity demand to reduce levels of curtailment in the right place at the right times. There are other community wind turbines in Orkney that are curtailed; on Stronsay and Shapinsay which could be included to the project; although to start with only turbines within zone 1 will be included to maximise the impact of the controllable demand. The other wind turbines could be recruited at a later stage depending on the results and impact of the turbines on Rousay and Eday and further recruitment of linked controllable load within the zone, hence noted as ‘option 2’/ green circles. Likewise, there are a number other privately owned generators within Zone 1 experiencing similar, or worse, levels of curtailment, however it is envisaged that they would only be included in a wider “business as usual” phase after this project, to both better optimise the opportunity of the controllable demand systems in place and provide further reduction in consumer electricity costs.

Figure 3 Geographical representation of zone 1 within the Orkney archipelago, including location of the community wind turbines

The extent and structure of the grid in Orkney has been mapped out beyond 33kV, to the 11kV and LV levels in Figure 4 below, with Zone 1 highlighted in yellow. This helps to define where demand can be added usefully, and so where the participant recruitment needs to take place, with respect to keeping within the relevant measuring points and feeders. Increasing the electricity demand locally, within the zone will help to improve the amount of curtailment that occurs to the wind turbine currently marginal in the 'stack' of generators. Hence, all installs will be focussed in this area, where possible. The solid "boundary" line in Figure 8 defines the same area on a geographical representation of zone 1 within the Orkney archipelago, and in relation to the location of the Rousay community turbine.

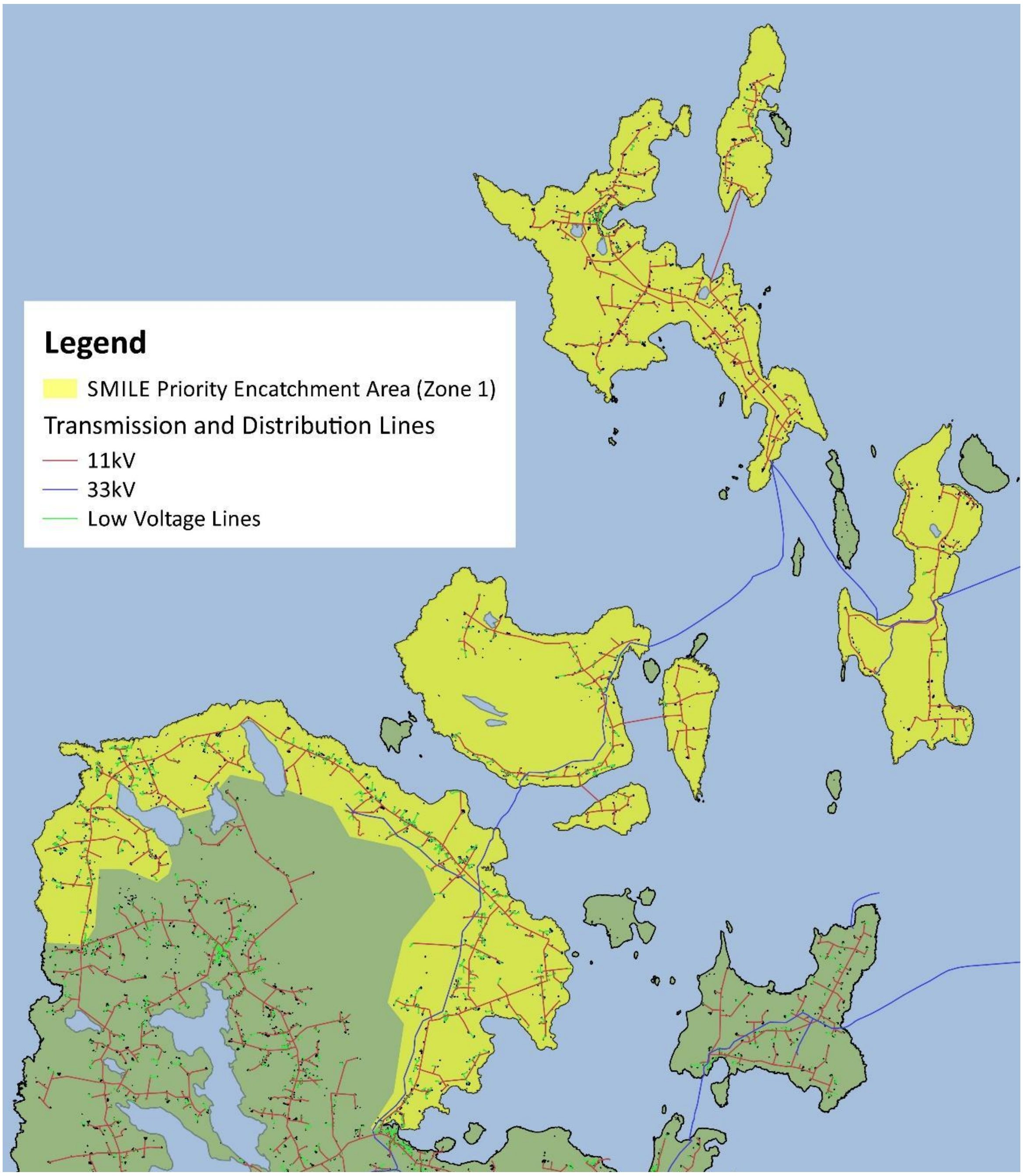

Figure 4 Detail of grid circuitry for ANM zone 1 at 33kV, 11kV and LV levels

2.3 Overall SMILE Architecture

The overall architecture defined in D2.1 for the Orkney-based SMILE demonstrator is presented in Figure 5. Dotted lines represent communications and solid lines represent electricity flows. This will be explained in further detail in the following sections.

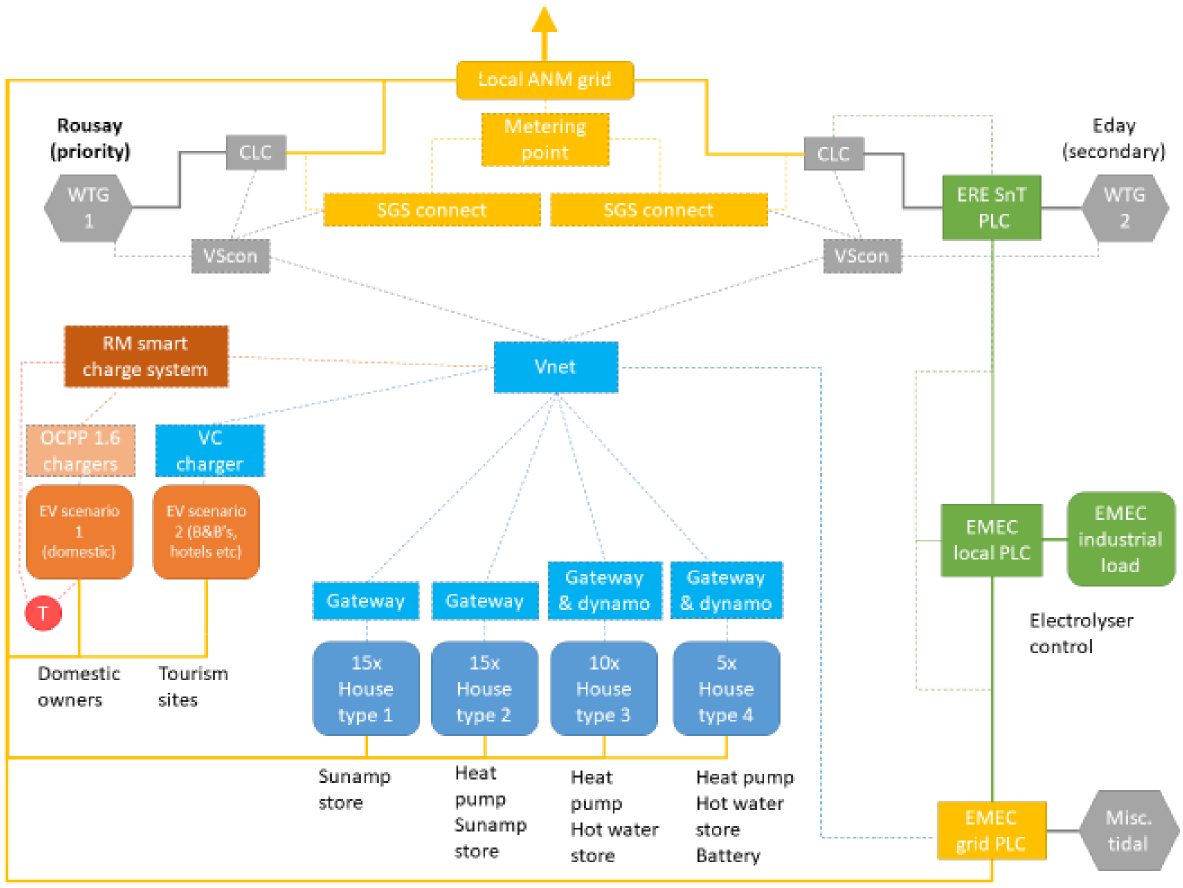

Figure 5 Overall architecture

2.3.1 Domestic Heat Installs

The domestic heat installs will consist of approximately 45 properties with a variety of different technologies to be implemented in four different combinations (described below), including: Air Source Heat Pumps (ASHP), Sunamp PCM heat battery thermal store, hot water tanks, and lithium-ion batteries. These will be combined with VCharge (OVO) Dynamos' and/or Gateway units, depending on the installed equipment, which will provide the capacity to remotely control the equipment from VCharge's (OVO) VNet system.

Installation types:

- 15 x Sunamp UniQ heat battery, VCharge (OVO) controls
- 15 x Air to water heat pump, Sunamp UniQ heat battery, VCharge (OVO) controls
- 10 x Air to water heat pump, hot water thermal store, VCharge (OVO) controls
- 5 x Air to water heat pump, hot water thermal store, Battery Energy Storage System (BESS) VCharge (OVO) controls

The types of houses and final quantities recruited will largely depend on the uptake of participants (household energy use, size, existing heating system) and their existing or preferred way of providing heat and hot water to their homes.

The heat pumps mentioned above will have an output between 11kW and 16kW, but due to the Coefficient of Performance (CoP) the load only equates to a load between 4kW and 6kW, respectively. Other forms of power demand are the heating elements within Sunamp heat batteries (2.8kW) and immersion elements within hot water cylinders (3kW); but with a CoP of 1. Furthermore, the various forms of energy storage will allow this load to be displaced out with peak periods on this grid.

2.3.2 Electric Vehicle Charging

The EV charge points will comprise of domestic households (scenario 1) and local tourism sites and accommodation (scenario 2) within Zone 1, that either have an EV that they currently charge at home, or a business/ facility that would benefit from being able to offer EV charging to customers/ visitors.

Some of the advantages of this dual approach are that it allows two independent but interlinked DSM systems to be demonstrated interacting and being coordinated to the same generation ANM system. With scenario 1, where considerable intelligence can be gathered on the patterns of charging and vehicle use, DSM curtailment response can be refined with predictive knowledge and learning algorithms in this situation. Whilst in parallel, DSM installations in scenario 2 can be best tested and shown to be robust, compatible and effective whilst being agnostic to the connected vehicle technologies and use patterns.

The specific detail of types of vehicles and quantities recruited in each scenario will depend to some degree on the uptake of participants (car type, charger type) and their existing or preferred charging methods. Where existing chargers are not able to be adapted to make smart connections, these could be upgraded under the scope of the SMILE project if budget allows and new controlled charge points will be installed in places where no charging is currently in place.

2.3.3 Large Industrial Load

The industrial load is proposed to be the smart control of the 11kV on-site switching and storage system, including the existing electrolyser (operational November 2017), which is owned by EMEC (The European Marine Energy Centre) and located on the island of Eday at their tidal energy test site. The electrolyser is currently a part of the Surf ‘n’ Turf project funded by the Scottish government CARES Local Energy Challenge Fund. The electrolyser (and potential other on-site storage) uses electricity from tidal energy at the test site and wind energy from the ERE turbine 600m away; SMILE will help implement the smart control of switching between the two generators and the local grid to maximise generation and hydrogen production from both of the sites (wind and tide).

3 Domestic Heat Installs

The following provides greater details about the heating solutions to be implemented as part of the Orkney-based SMILE demonstrator projects. This will include an overview of the different heating systems, the technologies involved and the connectivity between them.

3.1 House Type 1: Sunamp PCM Heat Battery

3.1.1 Detailed System Description

Since the release of Deliverable 2.1, the designed architecture of the Type 1 install has only seen a minor amendment; below will describe the use of a gateway controller, instead of a VCharge (OVO) Dynamo unit, which in turn will communicate with the Sunamp PCM heat battery via the Sunamp Qontroller unit. The install will still principally be based on the use of a suitably scaled Sunamp UniQ PCM heat battery with the capacity to be fed heat through the use of the properties existing heat source, or the battery's internally built-in heating elements. This configuration, or an amended version of, will be installed in 15 properties. Figure 6 below illustrates the configuration and components within the type 1 heating installations; those within the white background being those installed under SMILE, those with the grey background highlight pre-existing equipment.

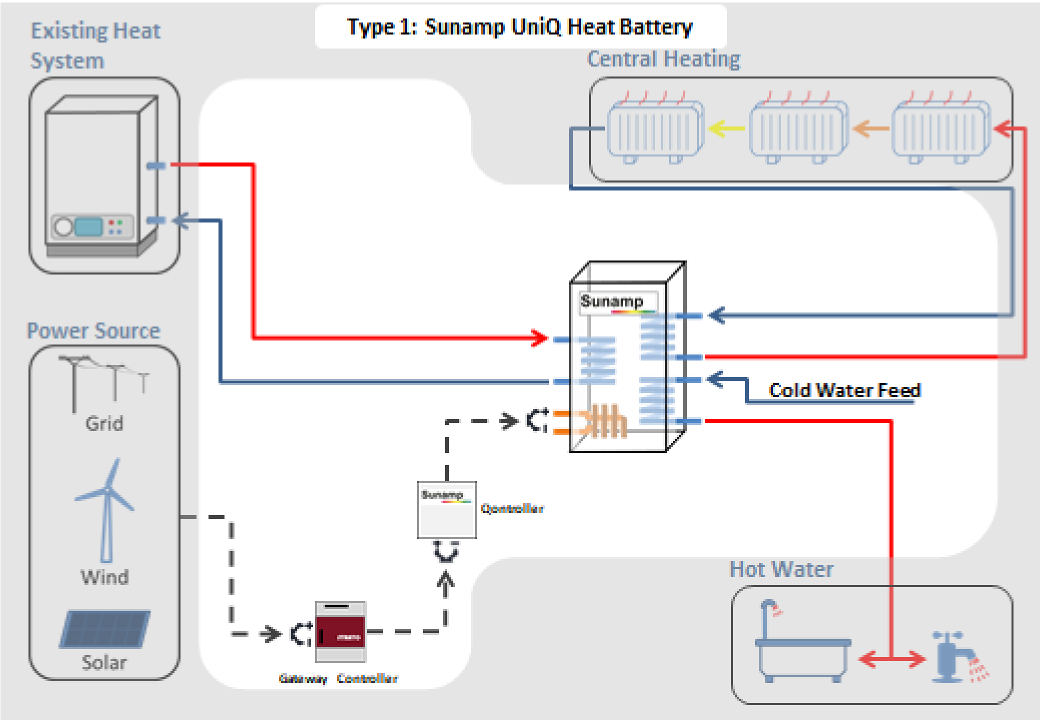

Figure 6: Type 1 Schematic Diagram

The power demand of the Sunamp PCM heat batteries available for installation are rated at approximately 2.8kW, or multiples of this if installed in conjunction with additional units in order to meet greater thermal demand. This is the same for all of the units available to the SMILE project. The storage capacity of the installed units can be scaled in order to meet the specific required of participating households; principally dependent upon the daily requirements on hot water. The scales that would be considered for this install configuration would be 3, 6, 9 or 12kWh. The models are designed for internal deployment, and in many cases can be installed in under-counter spaces. The four models all have the same footprint (370 x 575mm), but vary in height (410, 605, 815 and 1,025mm, respectively). For the storage capacity available, this requires approximately 1/3 of the cupboard space of an equivalent hot water thermal store in application.

For this installation, each property will also receive a single gateway device that will allow VCharge's (OVO) VNet to communicate with the Sunamp heat battery's Qontroller, a separate unit from the battery, and internal heating element. This will utilise the homeowners own internet connection in order to facilitate this communications link.

This type of install will have the benefit of:

- Being able to respond quickly to curtailment events;
- Prove a technological solution to homes not suitable for ASHPs;
- Potentially reduce the space required for thermal storage compared to conventional hot water cylinders;
- Reduced heat loss through higher efficiencies, and by extension, this has the potential to increase the effective use of property's pre-existing fossil fuel-based energy systems;

Potential disadvantages of the type 1 install include;

- Product is new from Sunamp and could have risks in deployment as it is not as tried and tested as other products;
- Coefficient of performance of 1 maximum, which is lower than the option with an ASHP (which has a value of 3) but may be better at responding to curtailment events;

3.1.2 Final Architecture Design

Figure 7, below, outlines the connectivity between the components installed under the type 1 heating and hot water system. While Table 1 outlines the details of the component parts of this installation type.

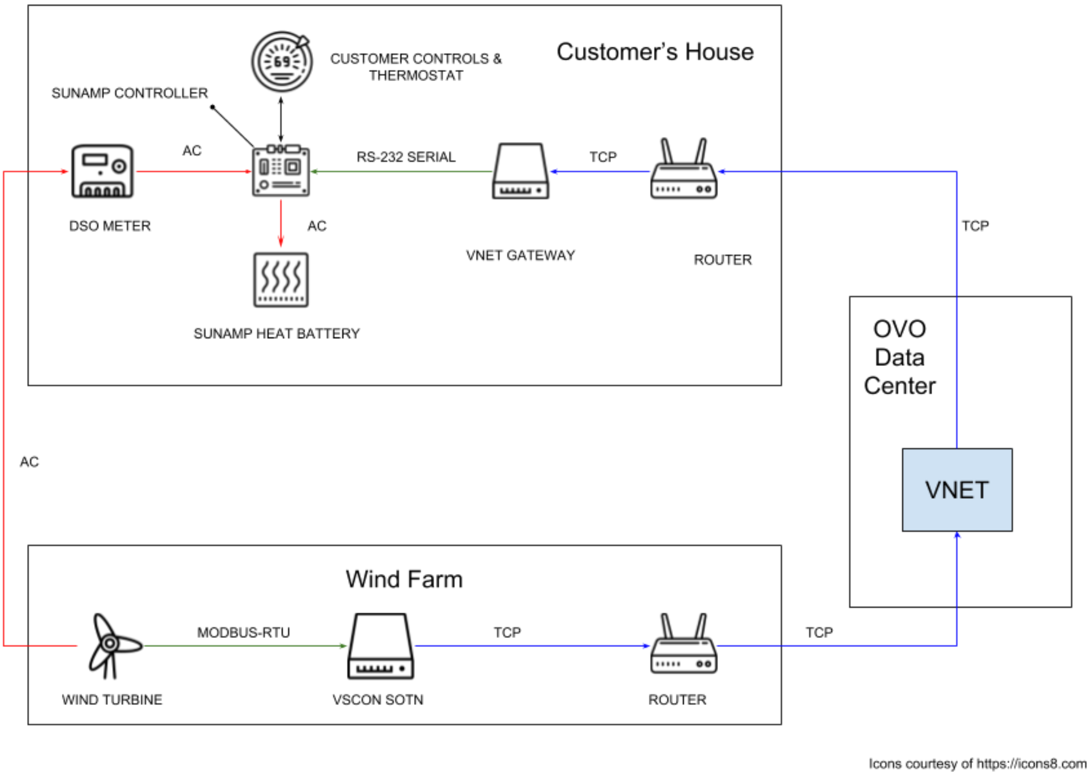

Figure 7: Type 1 Architecture

Table 1 Type 1 Component List

Component	Description/Specification	Connectivity	Location
VSCON	The VSCON unit builds upon the Raspberry Pi platform. It monitors for, and transmits curtailment information from the local smart grid.	Modbus-RTU from the wind turbine. Ethernet (TCP) to onsite router.	Wind Turbine
VNet	Cloud-base control aggregator responsible for the smart functionality controlling of all equipment (either directly or indirectly), on both the generation and demand side of the SMILE infrastructure.	TCP connection between internet routers located at wind farm and customer's home.	OVO Data Centre
VNet Gateway	The Gateway unit also builds upon the Raspberry Pi platform, and provides on-site control of equipment by relaying information from VNet, and also returning data back again for processing.	Ethernet (TCP) from onsite router, and RS-232 serial link to the Sunamp controller.	Customer's Home
Sunamp Qontroller	Controller unit dedicated to the control and monitoring of Sunamp PCM heat battery. In this configuration, the Qontroller is acts as the conduit between VNet control signals and the charge/discharge control of the PCM heat batteries.	Controlled by the VCharge (OVO) Gateway unit via RS-232 serial line.	Customer's Home
Sunamp PCM Heat Battery	Stores thermal energy. Scaled to required size in 2.8kW units, with storage capacities of 3, 6, 9 and 12kWh. Thermal energy stored in Phase Change	Controlled by Sunamp Controller via RS-232.	Customer's Home

	Material solutions in sealed blocks. Heat exchangers transfer either heat to or from water flowing through the battery depending on charging or discharging.		

3.1.3 Interaction of Partner Technologies

The subsection below outlines the communications links within the type 1 architecture.

3.1.3.1 Sunamp PCM Heat Battery- VCharge (OVO) VNet Interaction

VNet integrates with the Sunamp PCM heat battery by means of the VCharge (OVO) gateway unit. The gateway is a locally situated device that facilitates control of devices which are not already cloud-enabled. By supporting a variety of physical protocols (e.g. RS-485, RS-232), the Sunamp heat battery can be remotely controlled by VNet via TCP/IP.

The interaction between the Sunamp Qontroller and the VNet gateway is via RS-232, according to a proprietary control protocol developed by Sunamp. The commands supported are detailed in Table 2:

Table 2 Control protocol between VNet gateway and Sunamp PCM heat battery

Sunamp Command	Parameters	Purpose and use by VNet
Get Status	N/A	Retrieves the current status, including: ● State of charge (temperature of the PCM) ● Charging Status (on/off)
Override	On/Off	Switches the internal resistive heater on or off

The VNet gateway periodically sends telemetry packets to VNet reporting the state-of-charge (SoC) of the Sunamp PCM battery. VNet hence maintains an internal global view of the SoC of all assets connected to the system which can be used to determine where curtailed energy should be dispatched. In the case of this system configuration, when VNet receives notification of a curtailment event from the VSCON (located within the wind turbines), the curtailed energy can be dispatched to any Sunamp PCM batteries that have reserve capacity (i.e. PCM temperature is lower than the maximum PCM temperature). The dispatch message is sent to the VNet gateway where it is translated into the RS-232 serial protocol required to override (switch on) the internal resistive heater.

The customer comfort settings are maintained by the Sunamp controller according to the signal provided by a standard thermostat. This ensures that the customer comfort is maintained, irrespective of the availability of an internet connection.

3.2 House Type 2: Air Source Heat Pump and Sunamp PCM Heat Battery

3.2.1 Detailed System Description

The designed architecture for type 2 has similarities with type 1, through the use of a Sunamp PCM heat battery as the main form of energy storage, however using an Air to Water Heat Pump to be the principle form of heat generation, in place of using the pre-existing heat source. Furthermore, the design has been altered since the release of Deliverable 2.1; the design now will install PCM heat batteries with internal heat elements, which allow the battery to charge from an electrical source, as well as the pumped hot water source, even though the PCM heat battery also has internal heating elements. As such, the previously described use of VCharge (OVO) Dynamos to control the installed equipment will be replaced by the use of a gateway controllers. This configuration, or an amended version of, will be installed in 15 properties, and outlined in Figure 8 below.

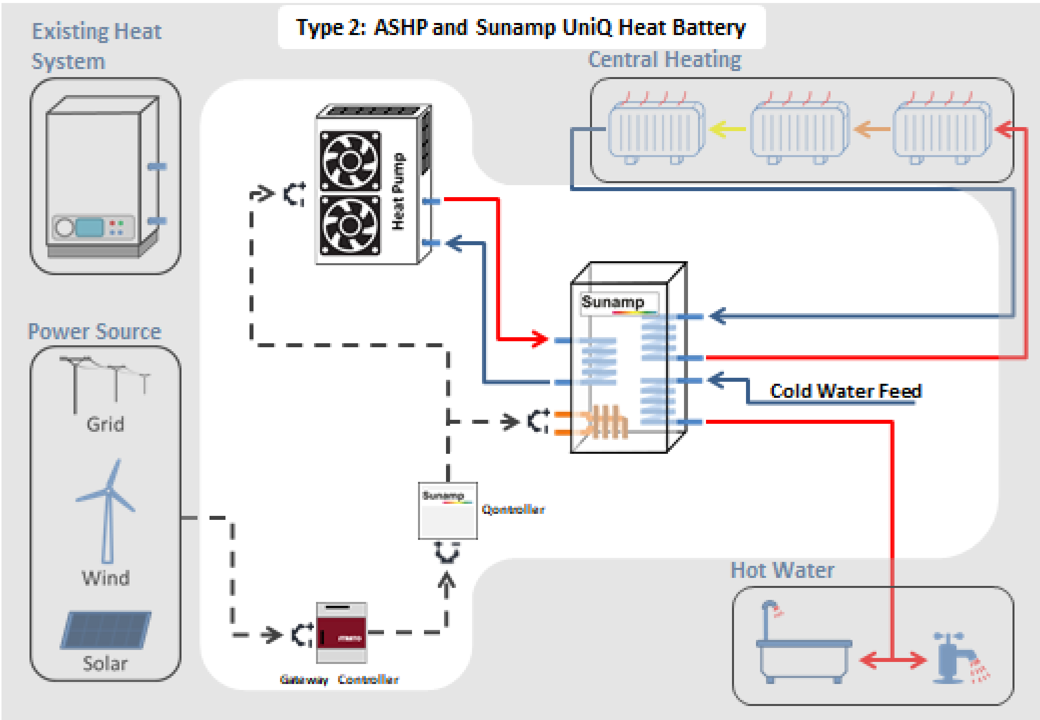

Figure 8 Type 2 Schematic Diagram

For this installation, a VCharge (OVO) gateway unit will allow communication between VCharge's (OVO) VNet aggregator system and the property's heating and hot water system. This will utilise the homeowners own internet connection in order to facilitate communication links to the controllers of the ASHP and the Sunamp heat battery.

The electricity demand of the install will be determined by the size of the heat pump suitable for the property, and the rating of heating elements within the Sunamp PCM heat battery. The principle design will call for installation of high temperature air to water Daikin Altherma heat pumps. Typical installs will have a thermal output of between 11kW and 16kW; with rated power inputs of between 4kW and 6kW, respectively.

In comparison, the power demand of the Sunamp PCM heat battery is rated at approximately 2.8kW; this is the same power demand for the units available to the SMILE project. However, these units can be deployed series with additional units to meet greater demand. As such, power demand could be 5.6kW, or even 8.4kW. The individual units can be suitably scaled in order to meet the specific requirements of participating households; principally dependent upon the daily demand on hot water. The scales of units that would be considered for this install configuration would be 3, 6, 9 or 12kWh. The models are designed for internal deployment, and in many cases installed in under counter spaces. The four models all have the same footprint (370 x 575mm), but vary in height (410, 605, 815 and 1,025mm, respectively).

The advantages to type 2 installations are:

- Well proven combination of hardware within Sunamp pre-existing projects;
- Coefficient of performance of up to 3 through the use of ASHPs;
- Charging electrically will allow for quick response to curtailment; and
- Compact heat store, due to the high energy efficiencies compared to conventional hot water cylinder.

Potential disadvantages to this approach include:

- Product is new from Sunamp and could have risks in deployment as it is not as tried and tested as other products; and
- Heat pump response to curtailment (how often they can be turned on and off; when first started they have to run for a certain time, and also when turned off they have to wait for some time before they can be turned on again)

3.2.2 Final Architecture Design

The line diagram below (Figure 9 outlines the architecture (both data and hardwire connections of the equipment within the type 2 installations, followed by Table 3.

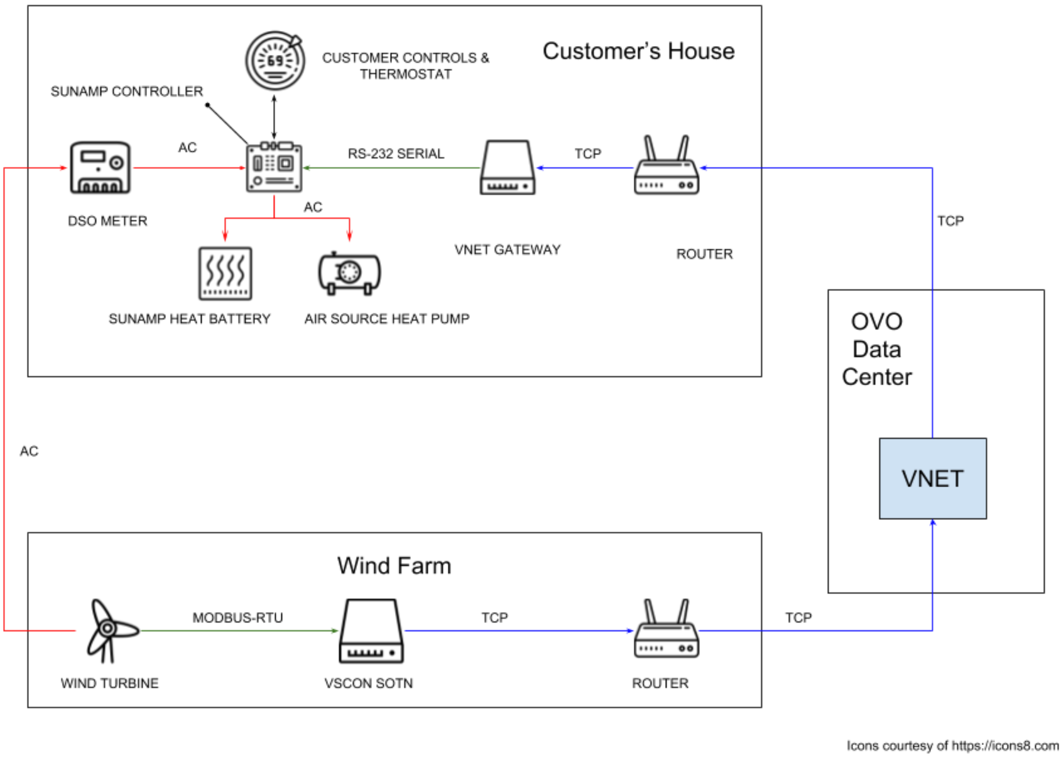

Figure 9: Type 2 architecture

Table 3 Type 2 Component List

Component	Description/Specification	Connectivity	Location
VSCON	The VSCON unit builds upon the Raspberry Pi platform. It monitors for, and transmits curtailment information from the local smart grid.	Modbus-RTU from the wind turbine. Ethernet (TCP) to onsite router.	Wind Turbine
VNet	Cloud-base control aggregator responsible for the smart functionality controlling of all equipment (either directly or indirectly), on both the generation and demand side of the SMILE infrastructure.	TCP connection between internet routers located at wind farm and customer's home.	OVO Data Centre
VNet Gateway	The Gateway unit also builds upon the Raspberry Pi platform, and provides on-site control of equipment by	Ethernet (TCP) from onsite router, and RS-232 serial link to the Sunamp controller.	Customer's Home

	relaying information from VNet, and also returning data back again for processing.		
Sunamp Qontroller	Controller unit dedicated to the control and monitoring of Sunamp PCM heat battery. In this configuration, the Qontroller is acts as the conduit between VNet control signals and the charge/discharge control of the PCM heat batteries.	Controlled by the VCharge (OVO) Gateway unit via RS-232 serial line.	Customer's Home
Sunamp PCM Heat Battery	Stores thermal energy. Scaled to required size in 2.8kW units, with storage capacities of 3, 6, 9 and 12kWh. Thermal energy stored in Phase Change Material solutions in sealed blocks. Heat exchangers transfer either heat to or from water flowing through the battery depending on charging or discharging.	Controlled by Sunamp Controller via RS-232.	Customer's Home
Air Source Heat Pump	Principal source of heat. Daikin Altherma high temperature split block unit with a rated power input between 4kW and 6kW, and a rated output between 11 and 16kW, respectively.	Direct plumbed closed-loop hot water loop. Comms link between Sunamp Qontroller and Daikin ASHP controller.	Customer's Home
Daikin Controller	Daikin controller will provide control of the ASHP by responding to data transmitted from VNet, via Dynamo. The controller will also process data from the hot water storage and signal the ASHP and hot water pumps accordingly.	Modbus-RTU comms connection with VCharge (OVO) Dynamo and Daikin ASHP.	Customer's Home

3.2.3 Interaction of Partner and 3rd Party Technologies

The following subsections go into detail on the connectivity between the individual components within the type 2 installation.

3.2.3.1 Sunamp PCM Heat Battery - Daikin Air Source Heat Pump Interaction

For the SMILE installation arrangement using the Daikin Altherma High Temp (HT) ASHP and Sunamp UniQ heat batteries, the ASHP will be controlled directly by the Sunamp Qontroller, an external unit from the heat batteries. In this arrangement, power will always available to the ASHP, but effectively the “call to heat” signal is not sent by the Sunamp Qontroller to the ASHP until the following two conditions are met:

1. The curtailment signal has been intercepted by VCharge (OVO) and communicated to the Qontroller; and
2. The Sunamp heat batteries require charging (i.e. not already fully charged).

Once these conditions are met the ASHP will be signalled to operate, and it will draw a varying amount of power as it ramps up and down to achieve the temperature set point and power required to charge the Sunamp heat batteries with the required thermal energy. In this way the heat batteries will only be charged when a curtailment event is happening.

The Call to Heat signal, in the case of a Daikin Altherma HT, the signal is 5V switched to ground to signal the ASHP to run, and if required a 0-10V analogue signal to control the temperature set point.

The domestic hot water (DHW) and central heating (CH) support is drawn directly from the heat stored in the batteries themselves as and when required by the home and occupants, independently of whether there is a curtailment happening or not.

Having said that, the system will be set to trigger a re-charge using “premium / peak” electricity (out with a curtailment event) if the State of Charge (SoC) drops below a pre-set threshold to ensure the occupants always have enough heat in reserve. Discussions on a case-by-case basis with selected participants will gather further detail and help establish such thresholds, and whether one is required, from current heating and hot water duty cycles. However, participants will be provided to option that charging will only occur during off-peak tariffs hours with the exception of the use of a boost button facility as required.

3.2.3.2 VCharge (OVO) VNet - Daikin Air Source Heat Pump Interaction

In this configuration there are two potential recipients of curtailed energy: the heat pump and the heating element in the Sunamp PCM heat battery. Whereas the heat battery’s heating element is well matched to the variability of curtailment events (which are unpredictable in timing and duration), this is not the case for the heat pump.

The heat pump has several constraints that restrict how it can be switched on and off. Specifically:

- It takes between 6 and 8 minutes following a demand signal for the heat pump to produce usable heat output.
- Cycling the compressor in the heat pump in over short durations is known to wear out the internal components and shorten the life of the heat pump. Therefore, when the demand for heat is switched off, subsequent demands should not be issued for at least 6-8 minutes.

One potential solution to the mismatch between curtailment events and the heat pump constraints would be to have a greater visibility around the status of curtailment of neighbouring wind turbines in the curtailment order stack. For example, say a curtailment has proceeded to the turbine in a position 3 levels below the currently curtailed turbine, this may provide some indication that the curtailment event will exceed a specific duration and hence, dispatching curtailed energy to a heat pump would be more likely to result in useful heat output being generated.

In the absence of a mechanism to predict the duration of curtailment events, the ability to dispatch curtailed energy to heat pumps directly may result in wasted energy (if the curtailment event is so short that the heat pump does not produce any useful heat output), or increased wear on the heat pump (if the curtailment events are so frequent that the heat pump is rapidly cycled).

Another potential solution would be to start the heat pump when curtailed energy is available, and keep it running for a minimum time (e.g. 30 minutes), regardless of the length of the curtailment event.

The system has therefore been designed in order to support the direct dispatch of energy into the heat pump should there be a mechanism to do so in such a way that useful heat output is generated. If it transpires that it is not possible to work around the heat pump constraints, the curtailed energy can still be dispatched into the resistive heating element in the hot water cylinder. However, this scenario would see a lower energy efficiency due to the CoP of the ASHP compared to the lower CoP of the hot water cylinder's immersion element.

Depending on the specific heat pump selected, the VNet gateway will communicate with the controller either via MODBUS-RTU, or via local LAN.

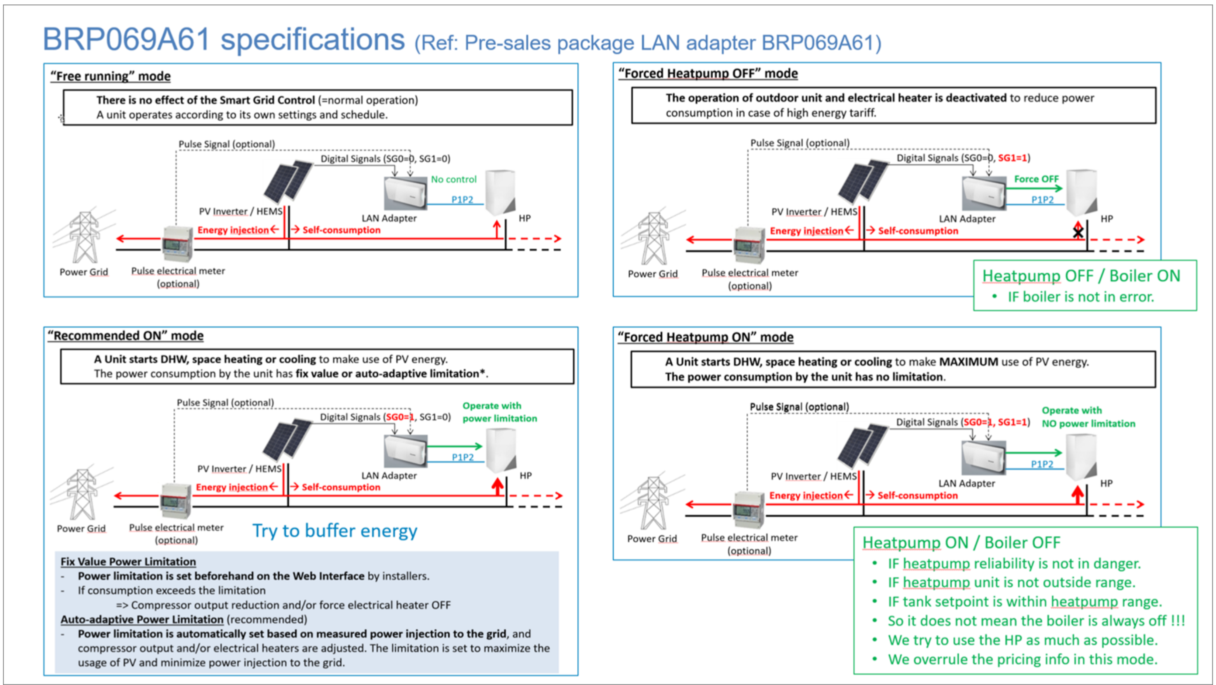

Figure 10 Smart grid modes supported by the Daikin heat pumps

As illustrated in Figure 10, Daikin heat pumps support a 'Smart grid' function. Using this function in 'Recommended ON' mode would allow the curtailment signals to be dispatched to the Daikin LAN adapter. This would cause the heat pump to operate the unit with a fixed power consumption (which can be scheduled from VNet based on the amount of curtailed energy available).

Since the thermostat and programmer are natively supported by the Daikin controller in addition to the Smart grid function, the customer's comfort is maintained by the Daikin controller, independent of any VNet control. Hence, if internet constraints mean that VNet is unavailable, the system will still meet the customer's heating requirements.

The addition of a Dynamo in this configuration also allows curtailed energy to be dispatched into the resistive heating element in the hot water cylinder as a 'backup plan' in the case that curtailment events are incompatible with the constraints of the heat pump.

3.3 House Type 3: Daikin Air Source Heat pump and Hot Water Store

3.3.1 Detailed System Description

The configuration for type 3 will pair an Air to Water Heat Pump with hot water storage; similar to type 2 but testing the effectiveness of hot water storage in compared to Sunamp PCM heat batteries. This configuration, or an amended version of, will be installed in 10 properties and outlined below in Figure 11.

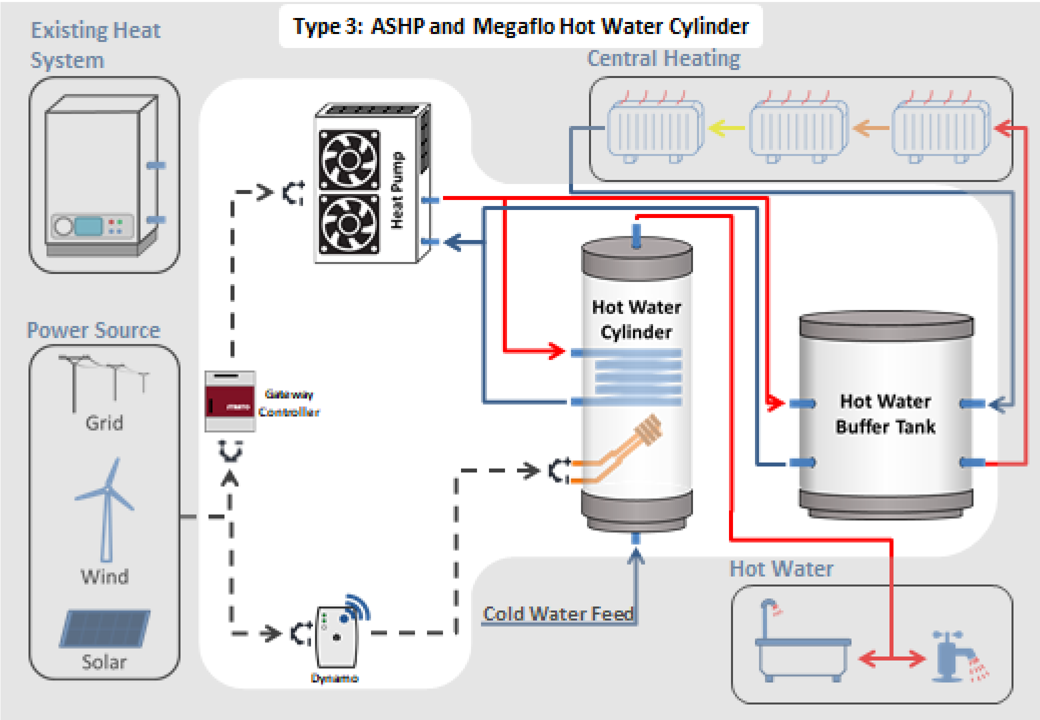

Figure 11 Type 3 Schematic Diagram

For this installation, each property will also receive a single VCharge (OVO) Dynamo as well as a gateway controller; the latter being an amendment to schematic of this installation type as described in Deliverable 2.1. The dynamo controlling the power to the immersion element and the gateway controller determining the call for heat from the ASHP. This will allow communication between VCharge's overarching aggregator system (VNet) and the properties' heating and hot water system; both will utilise the homeowners own internet connection in order to provide this communications link.

The electricity demand of the install will be determined by the size of the heat pump suitable for the property, and the rating of immersion element(s) of the hot water cylinder. The scale of these and that of the energy storage will be based on the properties requirements.

The principle design will call for installation of high temperature air to water Daikin Altherma heat pumps. Typical installs will have a thermal output between 11kW and 16kW; with rated power inputs of between 4kW and 6kW, respectively.

The chosen hot water cylinders for this installation type will be from the Megaflo range manufactured by Heatrae Sadia. This is an unvented and indirect hot water cylinder, equipped with a bottom 3kW immersion element in every model, with some also fitted with a 3kW top immersion element.

A further amendment to the installation designs outlined with Deliverable 2.1 is the inclusion of buffer/accumulator tanks into the central heating systems. In order to meet the thermal requirements for a properties wet heating system over a 24-hour period, being fed from a ASHP responding to curtailment events, large capacity hot water tanks should be incorporated. It is anticipated that it is unlikely that properties will have the internal space available to house a tank of this scale, so these will be made available to properties with adequate outdoor space.

The advantages to this are:

- Well proven combination of hardware; and
- Coefficient of performance of up to 3 through the use of ASHPs.

Potential disadvantages to this approach are:

- Heat pump response to curtailment (how often they can be turned on and off; when first started they have to run for a certain time, and also when turned off they have to wait for some time before they can be turned on again);
- Potentially higher heat losses compared to Sunamp PCM heat battery solutions; and
- Large space required in property for hot water store.

3.3.2 Final Architecture Design

The line diagram below (Figure 12) outlines the architecture of the type 3 installations. While Table 4 outlines the component pieces of the installation type.

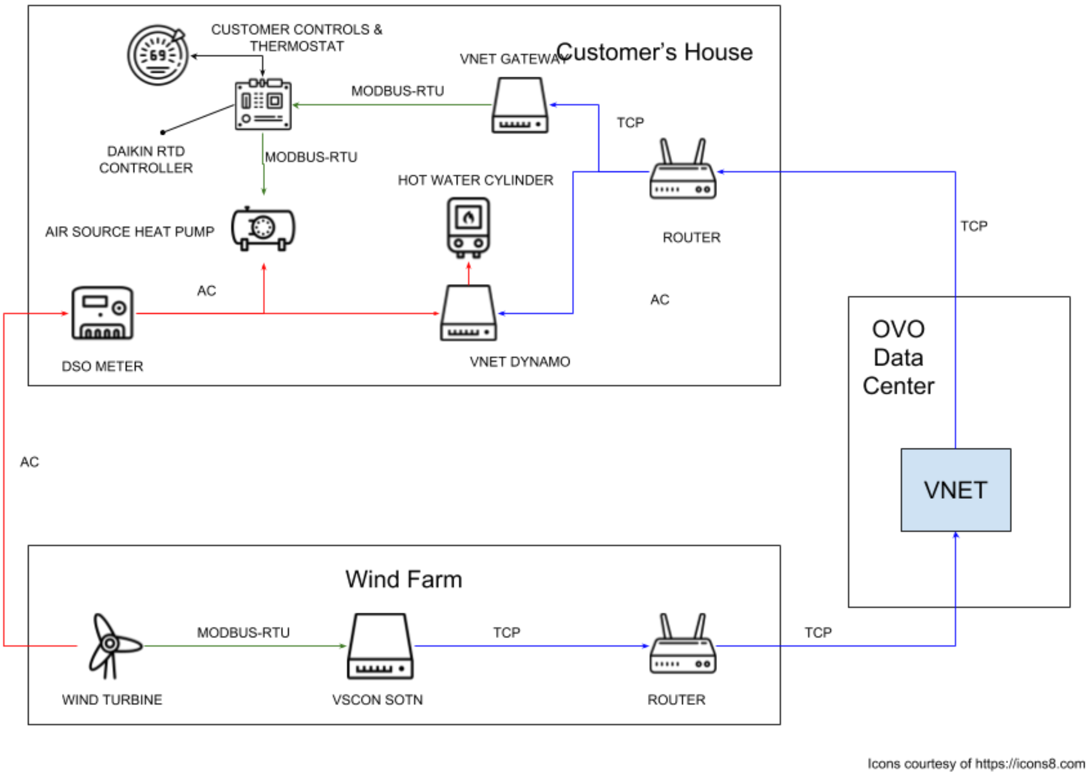

Figure 12 Type 3 Architecture

Table 4 Type 3 Component List

Component	Description/Specification	Connectivity	Location
VSCON	The VSCON unit builds upon the Raspberry Pi platform. It monitors for, and transmits curtailment information from the local smart grid.	Modbus-RTU from the wind turbine. Ethernet (TCP) to onsite router.	Wind Turbine
VNet	Cloud-base control aggregator responsible for the smart functionality controlling of all equipment (either directly or indirectly), on both the generation and demand side of the SMILE infrastructure.	TCP connection between internet routers located at wind farm and customer's home.	OVO Data Centre
VNet Gateway	The Gateway unit also builds upon the Raspberry Pi platform, and provides on-site	Ethernet (TCP) from onsite router, and RS-232 serial link to the Sunamp controller.	Customer's Home

	control of equipment by relaying information from VNet, and also returning data back again for processing.		
VCharge Dynamo	A separate unit which provides remote control of the hot water cylinder's immersion element.	Connects to the VCharge (OVO) Data Centre via the customer's home's internet router.	Customer's Home
Hot Water Cylinder (Heatrae Sadia Megaflo, or equivalent)	Hot water storage typically ranges in capacity between 100 and 300L. Heated in-directly from ASHP. Each cylinder, depending on the model with either have a single or double immersion element; each equating to a power consumption of 3kW. High level of inbuilt insulation provides lower levels of heat loss in comparison to conventional hot water cylinders. Will supply hot water to taps, showers and baths.	Connection to, and controlled by VCharge (OVO) Dynamo. Plumbed closed-loop hot water connection with ASHP.	Customer's Home
Hot Water Buffer/Accumulator Tank	Will be directly fed with hot water from the heat pump. It will have no immersion element or indirect heating coil. Hot water will supply central heating systems. Expected to be between 500-1,000L storage capacity; providing at least 24 hours of heating capacity. High level of thermal insulation will allow tank to be situated outside or in garage.	Physical open-loop hot water connection with ASHP.	Customer's Home
Air Source Heat Pump	Principal source of heat. Daikin Altherma high temperature split block	Direct plumbed closed-loop hot water loop. Comms link	Customer's Home

	unit with a rated power input between 4kW and 6kW, and a rated output between 11 and 16kW, respectively.	between Sunamp Qontroller and Daikin ASHP controller.	
Daikin Controller	Daikin controller will provide control of the ASHP by responding to data transmitted from VNet, via Dynamo. The controller will also process data from the hot water storage and signal the ASHP and hot water pumps accordingly.	Modbus-RTU comms connection with VCharge (OVO) Dynamo and Daikin ASHP.	Customer's Home

3.3.3 Interaction of Partner and 3rd Party Technologies

The subsections below go into detail to describe how the individual connected components transfer data and energy as part of the whole system of type 3 installation.

3.3.3.1 Daikin Air Source Heat Pump - Hot Water Store Interaction

The interaction between the ASHP and the hot water storage (megaflo hot water tank and buffer/accumulator tank) will be completely independent from VNet control. With the use of a standard Daikin system programmer, thermostat and associated valves and pumps, the ASHP and hot water stores will operate in a completely standalone manner. This is beneficial as the system will continue to operate even in the face of an unreliable internet connection.

The system programmer can be configured such that the hot water tank and buffer tanks are charged during off-peak periods, with the controller responsible to directing the flow of hot water to either hot water tanks through the use of pumps. While hot water will be drawn from the hot water tank as and when required, the system programmer will engage a central heating pump to circulate hot water from the buffer tank through the radiators during the period(s) that the customer requires the radiators to heat the living space to a temperature defined by the local thermostat.

The interaction with VNet is as described in the following section - in addition to the scheduled periods of heat pump operation as defined by the system controller, the heat pump can also be engaged during periods of curtailment, provided the pattern and duration of curtailments is compatible with the constraints of the heat pump.

3.3.3.2 VCharge (OVO) VNet - Daikin Air Source Heat Pump Interaction

This installation solution has been designed in order to support the direct dispatch of energy into the heat pump should there be a mechanism to do so in such a way that useful heat output is generated. Depending on the specific heat pump selected, the VNet gateway will communicate with the controller either via MODBUS-RTU, or via local LAN.

Daikin heat pumps support a ‘Smart grid’ function. Using this function in ‘Recommended ON’ mode would allow the curtailment signals to be dispatched to the Daikin LAN adapter. This would cause the heat pump to operate the unit with a fixed power consumption (which can be scheduled from VNet based on the amount of curtailed energy available).

Since the thermostat and programmer are natively supported by the Daikin controller in addition to the Smart grid function, the customer’s comfort is maintained by the Daikin controller, independent of any VNet control. Hence, if internet constraints mean that VNet is unavailable, the system will still meet the customer’s heating requirements. Section 3.2.3.2 outlines the specific connectivity and option considerations between VNet and the ASHP in greater detail.

3.4 House Type 4: Battery, Heat Pump and Hot Water Store

3.4.1 Detailed System Description

The type 4 installation (Figure 13) will further build upon the type 3 installation, with the use and benefits of electrical storage, air to water heat pumps and hot water storage. With the exception of the stationary electrical battery, the type 4 installation is the same as that of type 3. The battery will further allow for quick response to curtailment signals, while also supplementing the energy requirements of the ASHP with power stored from off-peak periods.

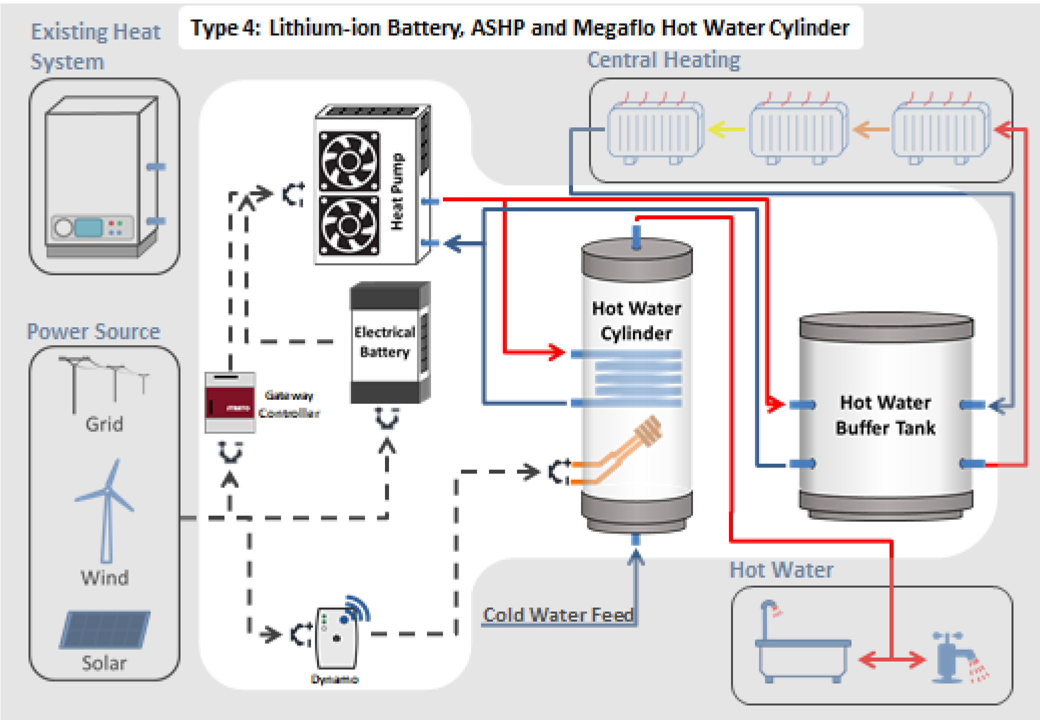

Figure 13 Type 4 Schematic Diagram

The electricity demand of the install will be determined by the battery’s rated power, the size of the heat pump suitable for the property, and the rating of immersion element(s) of the hot water cylinder. The scale of which, and that of energy storage, will be based on the properties requirements.

The lithium-ion battery bank provided by Lithium Balance will have a rated power of 3.6kW with a total storage capacity of 7.5kWh. This battery will be dedicated to the powering of the ASHP. The battery itself will have a data connection to the LiBal Data Centre, via the customer's home's internet router, in order to provide remote monitoring and management.

The principle design will call for installation of high temperature air to water Daikin Altherma heat pumps. Typical installs will have a thermal output between 11kW and 16kW; with rated power inputs of between 4kW 6kW, respectively.

The chosen hot water cylinders for this installation type will be from the Megaflo range manufactured by Heatrae Sadia. This is an unvented and indirect hot water cylinder, equipped with a bottom 3kw immersion element in every model, with some also fitted with a 3kW top immersion element.

A further amendment to the installation designs outlined with Deliverable 2.1 is the inclusion of buffer/accumulator tanks into the central heating systems. In order to meet the thermal requirements for a properties wet heating system over a 24-hour period, being fed from a ASHP responding to curtailment events, large capacity hot water tanks should be incorporated; it is expected that these tanks will range in capacity between 500-1,000 litres. It is anticipated that it is unlikely that properties will have the internal space available to house a tank of this scale, so these will be made available to properties with adequate outdoor space.

As highlighted above in Figure 13, and similarly to type 3 installation, the system will be controlled locally by a gateway unit controlling the ASHP and a Dynamo unit controlling the immersion heater with the hot water cylinder.

The advantages to this are:

- The battery can be charged quickly during curtailment events; and
- Coefficient of performance of up to 3, as a result of the ASHP.

Potential disadvantages to this approach are:

- Additional system complexity from the addition of more components;
- Large space required in property for electrical and hot water storage; and
- Potentially high heat losses and higher costs to run.

3.4.2 Final Architecture Design

The following line diagrams (Figure 14) and component list (Table 5) illustrates the power and data links within the type 4 installation and the individual component parts.

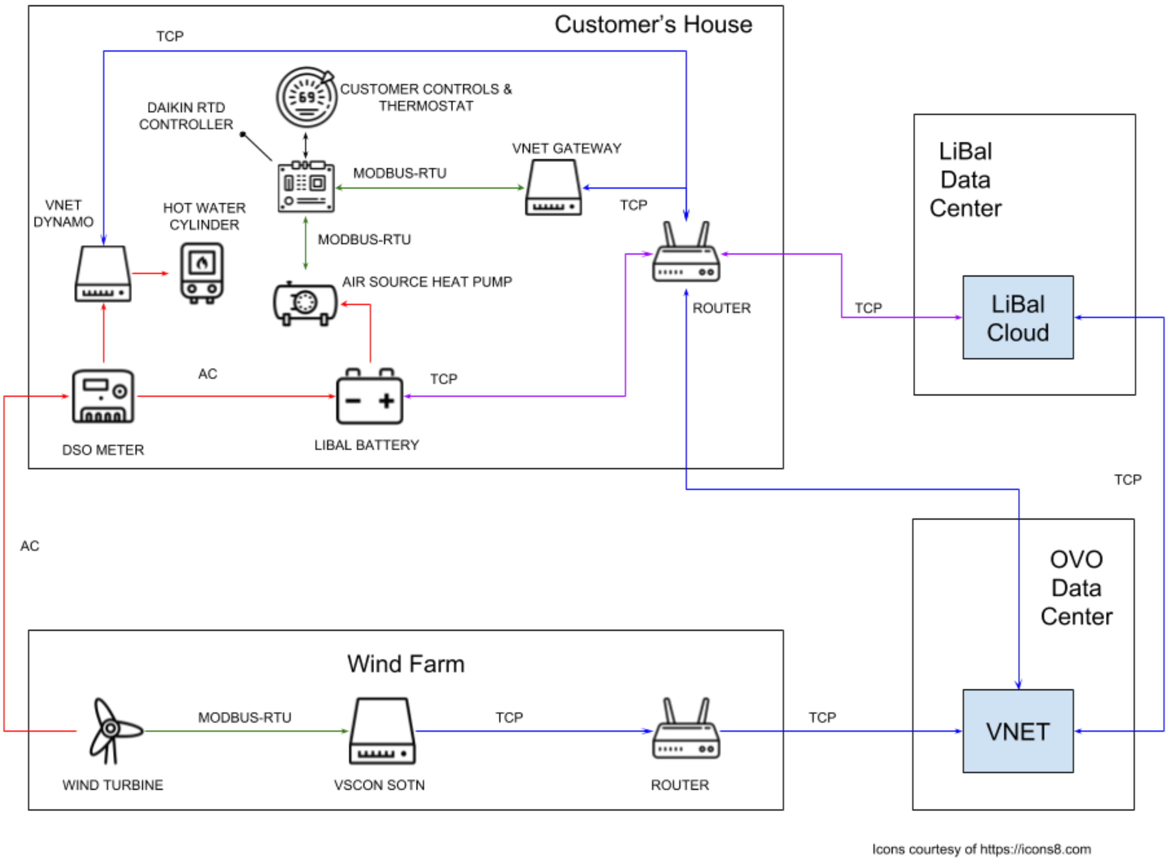

Figure 14 Type 4 Architecture

Table 5 Type 4 Architecture

Component	Description/Specification	Connectivity	Location
VSCON	The VSCON unit builds upon the Raspberry Pi platform. It monitors for, and transmits curtailment information from the local smart grid.	Modbus-RTU from the wind turbine. Ethernet (TCP) to onsite router.	Wind Turbine
LiBal Cloud	To provide remote control of charging/discharging events of lithium-ion battery, while also acting as remote monitoring.	TCP internet link between VCharge (OVO) data centre and the customer's home's internet router	LiBal Data Centre
VNet	Cloud-base control aggregator responsible for the smart functionality controlling	TCP connection between internet routers located at wind farm and	OVO Data Centre

	of all equipment (either directly or indirectly), on both the generation and demand side of the SMILE infrastructure.	customer's home.	
Gateway	The Gateway unit also builds upon the Raspberry Pi platform, and provides on-site control of equipment by relaying information from VNet, and also returning data back again for processing.	Ethernet (TCP) from onsite router, and RS-232 serial link to the Sunamp controller.	Customer's Home
VCharge Dynamo	A separate unit which provides remote control of the hot water cylinder's immersion element.	Connects to the VCharge (OVO) Data Centre via the customer's home's internet router.	Customer's Home
LiBal Lithium-ion Battery (Scenario 1)	3.6kW/ 7.5kWh battery. This will monitor and match the instantaneous power demand of the ASHP to reduce the net power demand to zero until discharged. The aim of which is to charge the battery at off-peak times to allow ASHP to operate during peak times; giving a great level of DSM to meet curtailment events.	Connected to the LiBal data centre via the customer's home's internet router. This helps dictate when the battery charges from the grid and provides power to the ASHP, while also sending back data.	Customer's Home
Hot Water Cylinder (Heatrae Sadia Megaflo, or equivalent)	Hot water storage typically ranges in capacity between 100 and 300L. Heated in-directly from ASHP. Each cylinder, depending on the model with either have a single or double immersion element; each equating to a power consumption of 3kW. High level of inbuilt insulation provides lower levels of heat loss in comparison to	Connection to, and controlled by VCharge (OVO) Dynamo. Plumbed closed-loop hot water connection with ASHP.	Customer's Home

	conventional hot water cylinders. Will supply hot water to taps, showers and baths.		
Hot Water Buffer/Accumulator Tank	Will be directly fed with hot water from the heat pump. It will have no immersion element or indirect heating coil. Hot water will supply central heating systems. Expected to be between 500-1,000L storage capacity; providing at least 24 hours of heating capacity. High level of thermal insulation will allow tank to be situated outside or in garage.	Physical open-loop hot water connection with ASHP.	Customer's Home
Air Source Heat Pump	Principal source of heat. Daikin Altherma high temperature split block unit with a rated power input between 4kW and 6kW, and a rated output between 11 and 16kW, respectively.	Direct plumbed closed-loop hot water loop. Comms link between Sunamp Qontroller and Daikin ASHP controller.	Customer's Home
Daikin Controller	Daikin controller will provide control of the ASHP by responding to data transmitted from VNet, via Dynamo. The controller will also process data from the hot water storage and signal the ASHP and hot water pumps accordingly.	Modbus-RTU comms connection with VCharge (OVO) Dynamo and Daikin ASHP.	Customer's Home

3.4.3 Interaction of Partner Technologies

The following breaks down the subsections, within this installation type, the relationships between the individual components; both in regards to power and communications.

3.4.3.1 VCharge (OVO) VNet - LiBal Battery Interaction

VCharge (OVO) will control the LiBal battery via a cloud-to-cloud interface provided by LiBal. Telemetry containing the battery state will be received via an Event Hub hosted in Microsoft Azure cloud and control commands (charge/discharge) will be dispatched to a HTTP API hosted by LiBal.

Simplistically, a typical control mechanism for the battery and heat pump may work as follows:

- SoC of the battery is received by VNet from the LiBal Event Hub;
- Energy available during curtailment events is used to charge the battery by issuing a command to the LiBal API (Application Programming Interface);
- The battery is instructed to charge (top-up) during off-peak periods to meet the expected demand of the heat pump during the following on-peak period(s), Two approaches for top-up charging will be investigated. During the first one, top-up charging will be realized at fixed hour of the day (e.g. 9pm) with fixed value of charging power. During the second one, top-charging will be realised at variable hour of the day and controlled by VCharge (OVO) and with variable value of charging power (based e.g. on current energy prices); and
- The battery is instructed to discharge when the heat pump is running at a rate equivalent to the power consumption of the heat pump; with the effect of reducing the net power demand of the ASHP to zero, without the battery directly power the ASHP itself. This may be achieved locally with the use of a current sensing device (such as a CT clamp) to avoid the round-trip latency of issuing discharge commands from VNet.

3.4.3.2 VCharge (OVO) VNet - Daikin Air Source Heat Pump Interaction

This installation solution has been designed in order to also support the direct dispatch of energy into the heat pump should there be a mechanism to do so in such a way that useful heat output is generated, and the LiBal's battery is completely discharged. Depending on the specific heat pump selected, the VNet gateway will communicate with the controller either via MODBUS-RTU, or via local LAN.

Daikin heat pumps support a 'Smart grid' function. Using this function in 'Recommended ON' mode would allow the curtailment signals to be dispatched to the Daikin LAN adapter. This would cause the heat pump to operate the unit with a fixed power consumption (which can be scheduled from VNet based on the amount of curtailed energy available).

Since the thermostat and programmer are natively supported by the Daikin controller in addition to the Smart grid function, the customer's comfort is maintained by the Daikin controller, independent of any VNet control. Hence, if internet constraints mean that VNet is unavailable, the system will still meet the customer's heating requirements. Section 3.2.3.2 outlines the specific connectivity and option considerations between VNet and the ASHP in greater detail.

3.4.3.3 LiBal Battery - Daikin Heat Pump Interaction

In regards to the hardwired infrastructure of the LiBal Battery Energy Storage Solution (BESS), there are two scenarios which exist: Scenario 1 is based on indirect communication between the LiBal BESS and ASHP; and Scenario 2 is based on direct communication between LiBal BESS and ASHP. The provision of the two implementation scenarios mitigates against the potential of time lost in further development if priorities or functionality change as a result of ongoing whole system R&D.

Scenario 1: The LiBal BESS will be connected to the ASHP on the AC side as it is illustrated in Figure 15. LiBal system will indirectly communicate with the ASHP through VNet interface. The advantage of this solution is smarter control (e.g. recharging battery system in time instances of low energy price, the better utilisation of the wind power). However, a disadvantage to this might be related to latency in the control of the battery.

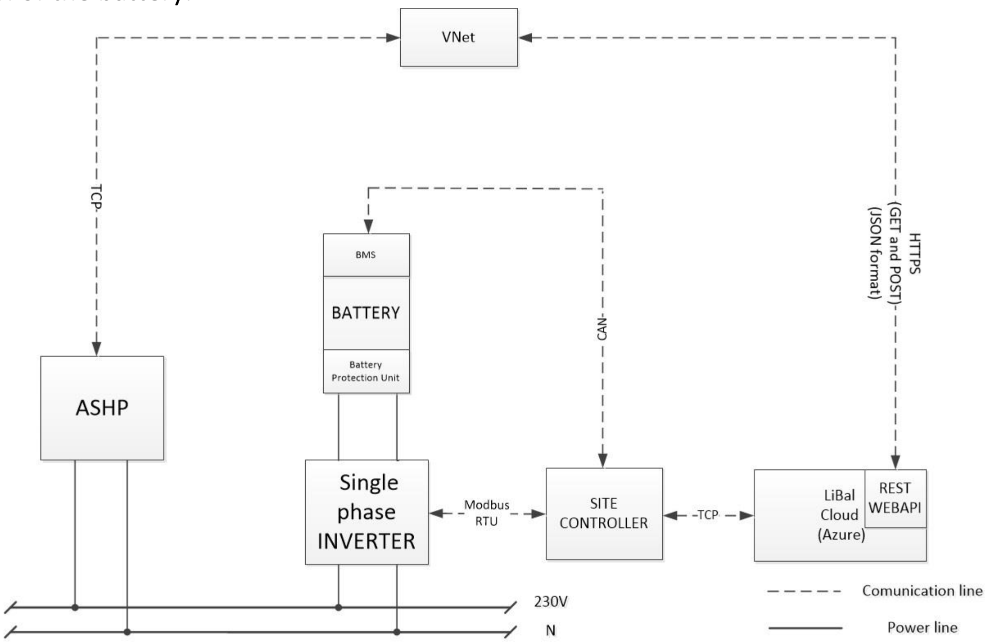

Figure 15 Scenario 1: Lithium Balance - ASHP Connectivity Line Diagram - Indirect control

Scenario 2: The LiBal BESS will be connected to the ASHP on the AC side as it is illustrated in Figure 16. The LiBal system will directly communicate with ASHP power meter in order to implement load following functionality. In this approach, the VNet interface is not needed for LiBal system control but it might still exist due to telemetry. Main advantage is faster control resulting in better ASHP load following. Disadvantage is the loss of flexibility and higher cost (e.g. recharging of battery at high energy prices).

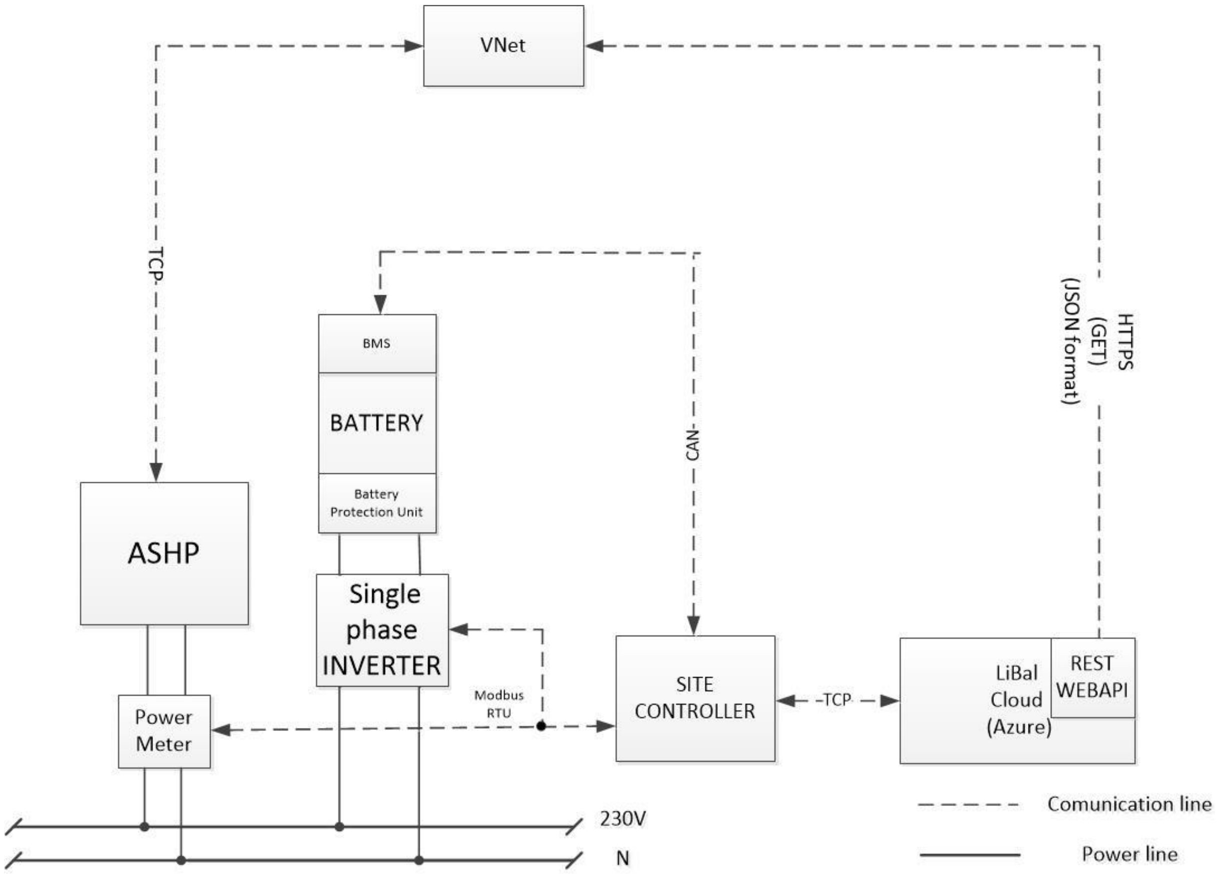

Figure 16 Scenario 2: Lithium Balance - ASHP Connectivity Line Diagram - Direct control

Both control scenarios are possible from LiBal side and both are expected to be tested in the field in terms of latency and performance. Scenario 1 offers higher control flexibility. However, if ASHP power demand is changing dynamically, then Scenario 2 is expected to provide better results in terms of load following. In either scenario, a power export limiter should be implemented in order to remove the chance of power being exported to the grid. This would be counterproductive to the aims of the project, and also require export permitting from SSEN, the local DNO.

3.4.3.4 Daikin Heat Pump - Hot Water Store Interaction

The interaction between the ASHP and the hot water storage (Megaflo hot water tank and buffer/accumulator tank) will be completely independent from VNet control. With the use of a standard Daikin system programmer, thermostat and associated valves and pumps, the ASHP and hot water stores will operate in a completely standalone manner. This is beneficial as the system will continue to operate even in the face of an unreliable internet connection.

The system programmer can be configured such that the hot water tank and buffer tanks are charged during off-peak periods, with the controller responsible to directing the flow of hot water to either hot water tanks through the use of pumps. While hot water will be drawn from the hot water tank as and when required, the system programmer will engage a central heating pump to circulate hot water from the buffer tank through the radiators during the period(s) that the customer requires the radiators to heat the living space to a temperature defined by the local thermostat.

The interaction with VNet is as described in the following section - in addition to the scheduled periods of heat pump operation as defined by the system controller, the heat pump can also be engaged during periods of curtailment, provided the pattern and duration of curtailments is compatible with the constraints of the heat pump.

3.5 Data Collection and Parameters for Analysis

An important part of the architecture, in regards to the technical assessment of the project as well as proving the feasibility in replicating the project, is the ability to gather data from the local power grid, the incorporated renewable power sources, and enrolled properties. The following outlines what steps have been taken so far and those which be employed as the project progresses further.

3.5.1 Overall Grid

3.5.1.1 Prior to Installation

Out with the per-property energy consumption data, the data from the community wind turbines, that make up the key factor of the Orkney-based demonstrator project, has been collected consistently for years. This includes high resolution generation profiles and curtailment data for the turbines, as well as the local grid as a whole.

3.5.1.2 Post Installation

The data collection methodology from prior install will remain the same during post the installation phase. These data sets, both before and after the installations of SMILE equipment, will provide evidence-based proof on the capacity of the model to reduce grid constraints while providing unobstructed service to homeowners.

3.5.2 Domestic Level

Complementing the data gathered on the grid as a whole is the per property data. The pre and post equipment installation data gathering is described in detail below:

3.5.2.1 Prior to Installation

Prior to the installation of equipment within participating properties various data sets have been and will continue to be collected to ensure the suitable deployment of equipment in the most suitable properties. By understanding the baseline conditions, it is possible to make the most accurate predictions upon the impacts as a result of the projects installations.

Furthermore, data gathering will provide a level of security to the project partners against reputational risks as a result of potential inaccurate reporting from 3rd parties on impacts (positive and negative) as a result of the demonstrator projects. For example, understanding the typical energy consumption prior to the installation of a new heating system, it will be easily provable if the energy consumption afterwards is reasonable or not; and data gathering will allow project partners to provide unequivocal evidence-based answers either way; the same is also true to recording thermal comfort level pre and post installation of SMILE project equipment.

Data collection methods prior to installation are principally in the forms of:

- Questionnaires and data gathering property visits; and

- Electricity and temperature monitoring.

Participants enrolling in the project must complete and submit questionnaires to the local team with relevant and necessary information, which in turn will inform and provide the bases of further data gathering during visits to the properties in question, by both the project team and also technical assessors.

In conjunction to portions of the previously described data gathering, energy and temperature monitoring will be conducted. This will be done through the use of Efergy electricity monitors (Figure 17) and Logtags temperature recorders (Figure 18). The data gathered from these devices will help to both corroborate the information gathered from the participants as well as more details that are not automatically available, such as higher resolution time series patterns of power demand and temperature levels over a daily, weekly and monthly cycles. The energy and temperature monitoring equipment will not have a blanket coverage of all the enrolled properties, but a selected number (approximately half) of properties that represent a suitable proportion of Orkney's demographic.

Figure 17 Efergy Energy Monitoring Kit

Figure 18 LogTag Temperature Recorder

3.5.2.2 Post Installation

Post installation data gathering will principally originate from VCharge (OVO) equipment and VNet functionality. This will include data on the geographical and timed demand response during curtailment events for each of the different configurations and asset types.

The data gathered by VCharge (OVO) will be used to analyse how efficiently the curtailed energy has been dispatched to the various heat configurations installed in participants' houses. Given the mismatch between the unpredictability of curtailment events and constraints of the heat pump in terms of warm-up times, this could additionally include data related to how the heat pump performs related to the use of curtailed energy.

Additional inline heat meter, such as those manufactured by Kamstrupp, within the wet heating system is also being investigated as a potential inclusion within appropriate installs. This could provide further evidence base to draw conclusions on the whole system efficiency of the four types of heating systems.

The inline monitors would measure the heat being delivered through the heating system, and effectively provide data on the output energy of the system to draw comparisons against the data on the energy inputted.

The previously described energy and temperature that will provide data gathering prior to installation of heating systems will also run in parallel with VCharge (OVO) data gathering, for at least a period of time, in order to both qualify the quality of the data gathering as well as provide an additional backup and whole system analysis of the installed heating systems. Again, the energy and temperature recording will only occur in an approximately half of the registered properties.

4 Electric Vehicle Charging

The following section outlines the two EV charging scenarios as part of the Orkney-based SMILE demonstrator; the charging of homeowner's EV(s), and the charging of visitor EVs. This will include an overview of the systems, the technologies involved and the power and data connectivity.

4.1 Finalised EV Charging Scenarios

The current scope for EV charging is to undertake smart charging with domestic/small scale 7kW chargers. These chargers will be OCPP (Open Charge Point Protocol) 1.6 compliant; which allows for the charger's power to an EV to be controlled remotely.

The EV charge points will comprise of domestic households (Type A), which have an EV that participants currently charge at home; and local tourism sites and accommodation (Type B), a business/facility that would benefit from being able to offer EV charging to customers/visitors.

Type A, principally delivered by Route Monkey, will rely partially upon on-board telematics (Figure 19) within the EV in question to transmit details to their Charge-Point Back Office (CPBO); this will in-turn inform estimation of the level of charge to be delivered in order to meet the requirements of the EV owner. To a degree, this scenario will be automatic and require less regular input from the driver to feed into each charging event. The T-10 telematics unit is installed by the car owner directly into the OBD2 (On-Board Diagnostics) port. Due to the differing wire configurations of these ports among EVs, recruitment has been limited to those with Nissan or Peugeot platforms. The information captured by the T10 Micro is directly transmitted back to the Trakm8 and Route Monkey for analysis; the results of which will informed the level of charge required by the charge point at the EV owner's property.

Figure 19: Trakm8 T10 Micro Telematics

By comparison, Type B, in the example of local tourism sites, it would be the case that multiple drivers/ visitors would use the charger with different vehicles and have different demand patterns, as opposed to the same EV always being charged at one property, which is more typical in scenario 1. As such, the solution must be agnostic to the EV being charged. In order to then feed into the aggregator system, to in turn control the EV charger, each user will be required to submit information via a mobile/tablet app user interface for each individual charge event. This charging scenario will be principally delivered by VCharge (OVO).

There is a target of 30 smart chargers to be installed across 30 individual properties, dispersed across the project area (Zone 1). The chargers will be divided across the two previously described scenarios, with one set of the chargers being controlled by Route Monkey and the other set by VCharge (OVO), as detailed in Table 6. As highlighted within Table 6, depending upon recruitment numbers, some domestic properties (Type A chargers) could receive VCharge's (OVO) (Type B) chargers; but with emphasis remaining on meeting the demand for EV charging across suitable business premises.

Table 6 EV scenarios

Type	Target	Type	Control signal from	Chargers managed/ optimised by	Charger type	User interface
A (RouteMonkey)	15	Domestic households	Vnet platform	Route Monkey CPBO	OCPP 1.6 Compliant	Not required – telematics installed in EV
B (VCharge (OVO))	15	Local tourism sites/accom.*	Vnet platform	Vnet platform	VCharge (OVO) API compliant	User interface. Details to be confirmed

*Some domestic EVs could be included, depending on recruitment number

4.1.1 Route Monkey Architecture

Route Monkey intends to deploy the Route Monkey Charge Post Back Office (CPBO) with 15x domestic chargers. The solution will have the following properties:

- Monitoring of the charging profiles for the 15 chargers;
- Prediction of future charging patterns; and
- Ability to provide base charging information to the VCharge (OVO) system via an API.

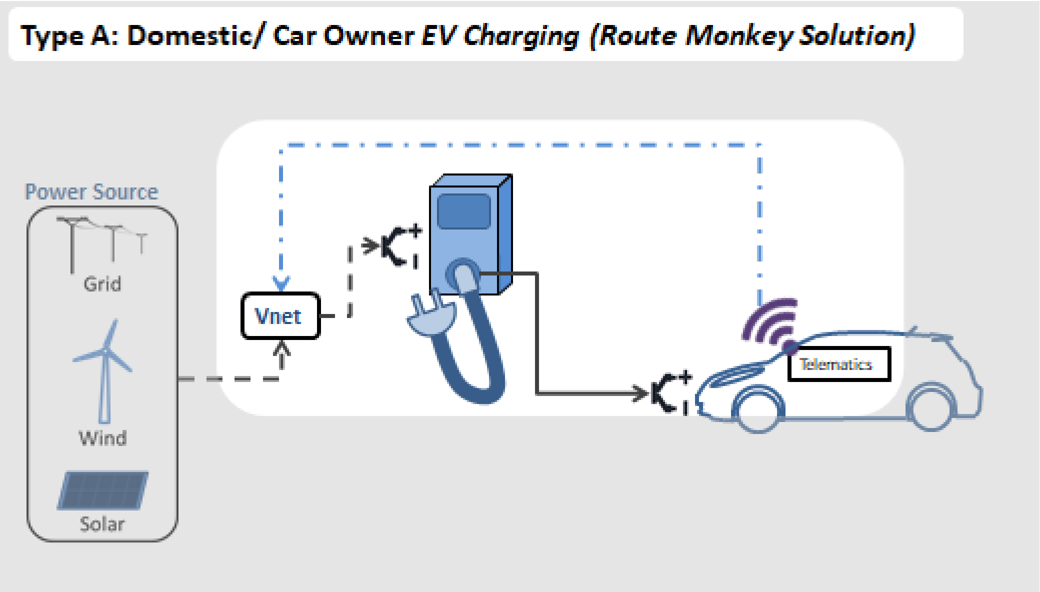

Figure 20 Type A Schematic Diagram

For this system (Figure 20), 15 domestic EV charging solutions will rely upon the use of telematics solutions to ensure a relatively automatic charging interaction between the EV owner and the VNet control algorithm. Route Monkey's predictive algorithm will feed into VNet to provide data on the level of charging required.

The decision of make and model of charging points was left to contractor, to hopefully be decided before the deadline for this deliverable; but research and discussions with manufacturers remain in progress to find all viable options prior to the final decision.

The line diagram below (Figure 21) outlines the structure of architecture within this installation type. Table 7 outlines the components parts of this installation.

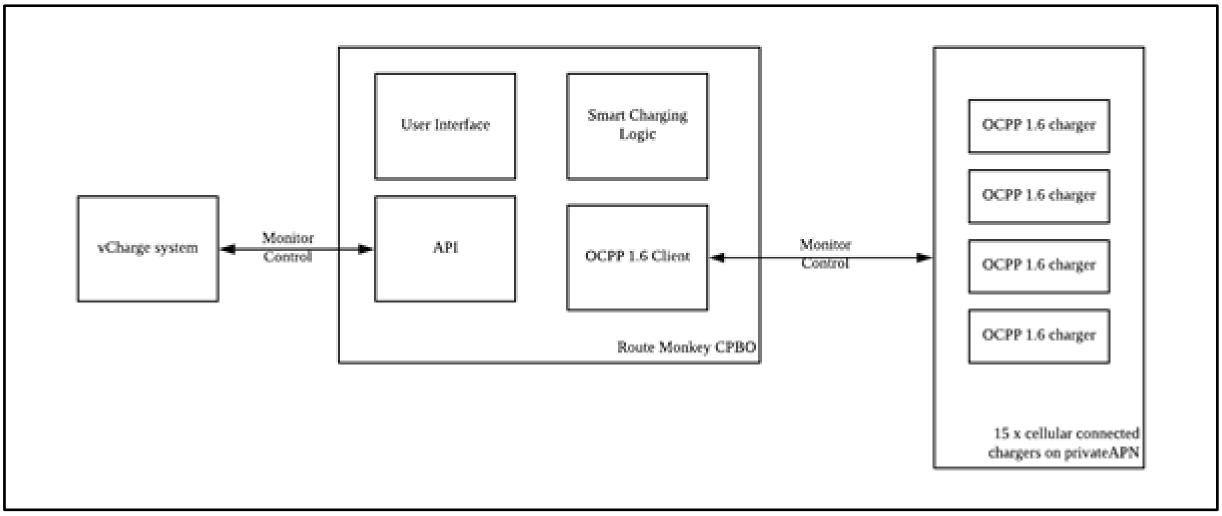

Figure 21 Type A Line Diagram

Table 7 Type A Component List

Component	Description/Specification	Connectivity	Location
VCharge system	The VCharge (OVO) system, which includes the VSCON and VNet infrastructure, monitors and processes curtailment information, and also relays corresponding load control.	Modbus-RTU from the wind turbine. Ethernet (TCP) to onsight router.	Wind Turbine
Route Monkey CPBO	To provide control of charging events of lithium-ion battery	TCP internet link between Route Monkey's data centre and the customer's home's internet router	Route Money Data Centre
VNet	Cloud-base control aggregator responsible for the smart functionality controlling of all equipment (either directly or indirectly), on	TCP connection between internet routers located at wind farm and customer's home.	OVO Data Centre

	both the generation and demand side of the SMILE infrastructure.		
OCPP 1.6 Charger	7kW Electric Vehicle charger enabled with OCPP 1.6 protocols; allowing for the remote controlling of charger output	3G/GSM, or connection to properties internet router, allowing comms link to Route Monkey/Trakm8 Data Centre.	Route Monkey Data Centre
Trakm8 Telematics	Trakm8 T10 Micro in-car telematics unit is a self-installed box that is plugged into the vehicle's OBD2 port. The unit transmit data via GSM back to the Route Monkey Data Centre	Physical connection with car. Wireless GSM comms connection with data centre.	EV's OPB 2 Port

4.1.1.1 Interaction of Partner and 3rd Party Technologies

As illustrated in Figure 21, Route Monkey will provide a cloud-hosted RESTful API that VCharge (OVO) can query to receive aggregated dispatchable capacity over a given period (e.g. the next 15 minutes). VCharge (OVO) will query this API at regular intervals in order to determine how much load is available should a curtailment event occur.

When a curtailment event occurs, available energy (up to the maximum of the aggregated load presented by Route Monkey) can be dispatched by calling the Route Monkey API with appropriate parameters and payload. Route Monkey will internally determine how to distribute the aggregated dispatched energy between the individual smart chargers.

4.1.2 VCharge (OVO) Architecture

The 15 system installed under VCharge (OVO)'s architecture (Figure 22 and Table 8) will predominantly target the business and accommodation properties across the project area. This system will allow:

- EV owners to inform the VNet system on the level of charging required;
- Monitoring the charging through 15 EV chargers; and
- Provide data on the geographical and temporal charging partners.

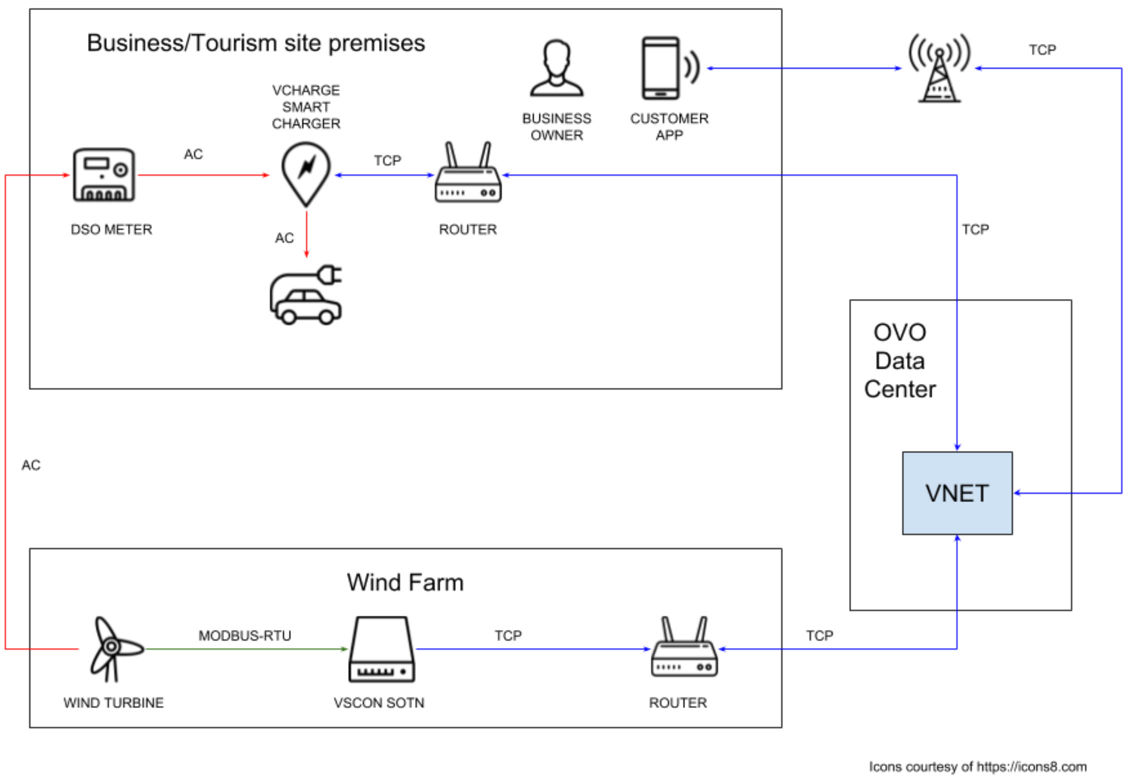

Figure 22: Type B Line Diagram

Table 8: Type B Component List

Component	Description/Specification	Connectivity	Location
VSCON	The VSCON unit builds upon the Raspberry Pi platform. It monitors for, and transmits curtailment information from the local smart grid.	Modbus-RTU from the wind turbine. Ethernet (TCP) to onsite router.	Wind Turbine
VNet	Cloud-base control aggregator responsible for the smart functionality controlling of all equipment (either directly or indirectly), on both the generation and demand side of the SMILE infrastructure.	TCP connection between internet routers located at wind farm and customer's home.	OVO Data Centre
Customer App	The app will be installable and operable on a smartphone or tablet that will allow property	Operate via participant's wi-fi or mobile comms network, and	Business/ Tourism Site premises

	owners to inform the VNet system the quantity of charging required and when by.	transmit the data to the OVO Data Centre for processing	
VCharge Smart Charger	The 7kW charger will meet OCPP 1.6 protocols and allow for remote communications to control the rate of charger of a plugged in EV. The charger will be a universal untethered charger in order to accommodate any EV.	Power connection to the properties distribution board, with a comms link via either a LAN or wifi connection to the properties router.	Principally businesses/ tourism site premises, with potential for some domestic properties.

Control of the VCharge (OVO) vehicle charger will be provided by a customer application that runs on a smartphone. Typically, the owner of the business or premises will control the smart charger via the customer app - making charge available for EV owners when requested.

Due to issues such as vehicle warranties, limitations in charging protocols, and differences in implementations of charging protocols between different manufacturers, it may not be possible to directly dispatch curtailed energy into connected electric vehicles. For example, rapidly cycling an electric vehicle between charging/idle states is not recommended by vehicle manufacturers as it places undue stress and wear on internal mechanical components.

Therefore, the specific mechanism of control is yet to be established based on the number and locations of the devices installed. However, one possible approach would be to charge connected vehicles at a rate lower than the maximum capacity accepted by the vehicle to provide headroom for accepting energy from curtailment events.

For example:

- The EV parks at the charging station and connects the charging cable
- The charger enters ‘idle’ mode (trickle charge at a low current, e.g. 6A)
- When a curtailment event occurs, the car is given the option to charge at a higher rate (e.g. 32A). Since the car is in control of charging, the smart charger can only advertise the availability of a higher current to the car - it cannot force the car to take it.
- If the EV owner needs to charge their vehicle more quickly, or have the vehicle available at a specific time, they can press the ‘override’ button on the fascia of the smart charger. This causes the car to charge at the maximum possible rate until the battery is full.

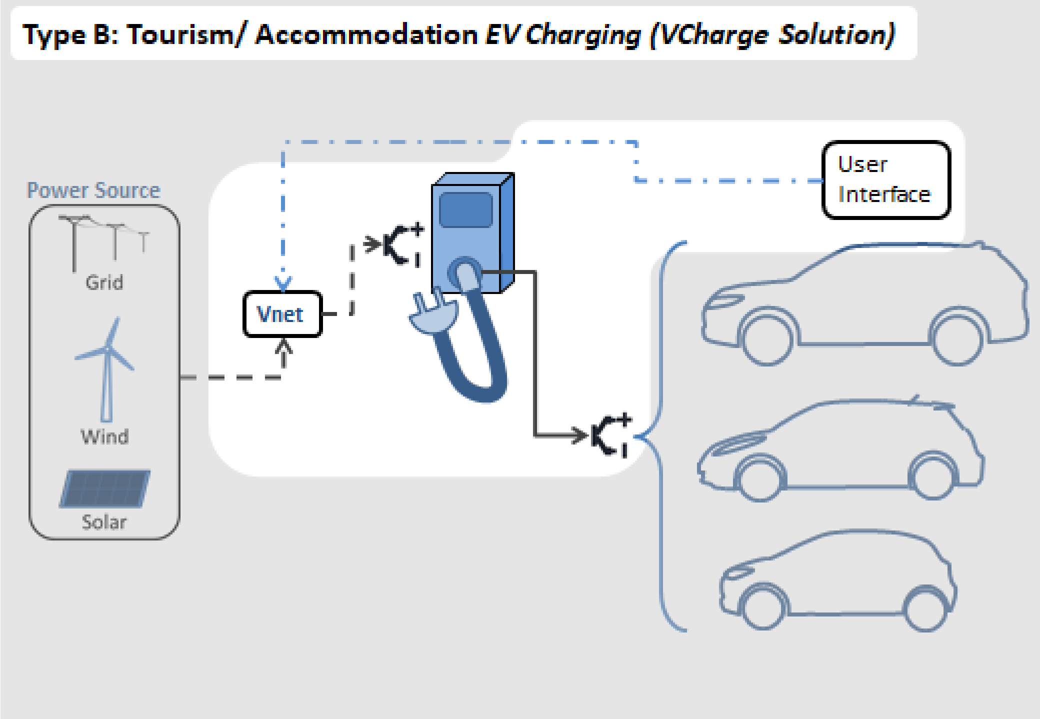

Figure 23 Type B Schematic Diagram

4.1.2.1 Interaction of Partner and 3rd Party Technologies

As illustrated in Figure 22, VCharge (OVO) will utilise a customer user interface (app) cloud-hosted API that they can query to receive aggregated dispatchable capacity over a given period (e.g. the next 15 minutes). VCharge (OVO) will query this API at regular intervals in order to determine how much load is available should a curtailment event occur.

When a curtailment event occurs, available energy, up to the maximum of the aggregated load, can be dispatched by calling the API with appropriate parameters and payload. VCharge (OVO) will internally determine how to distribute the aggregated dispatched energy between the individual smart chargers; this will take into consideration to loads presented to the system at this time and the requirements on quantity and time requested via the participant’s interface.

4.2 Data Collection

4.2.1 Prior to Installation

Prior to the installation of EV charging equipment CES conducted a series of data gathering exercises, similar to that previous described in section 4.5.2.1 for the heating system installations. Online questionnaires submitted to registered participants gathering information on their property, the EV they own, typical use of the vehicle and usual charging practise. After this the property in question were visited to gather further information on the suitability on the installation of an EV charger.

Additionally, once a participating property has been deemed to be suitable for the trials, and also signed a contract to take part, the participant will receive telematics unit to install in their vehicle. This will begin to gather data on typical driving and charging patterns prior to the installation of the EV charging unit.

4.2.2 Post Installation

Type A - Scenario 1

The 15 EV drivers recruited to Scenario 1 (section 4.1.1) will be offered Trakm8 telematics units to collect data about these drivers and their EVs. However, selected participating EV owners will be required to allow for a telematics unit to be installed within their specific EV in order for the smart functionality of the charger to work.

Trakm8 telematics data can be downloaded from Trakm8's Insight portal (Figure 24) in several formats including csv, Excel, pdf, html, or in a user configurable report scheduled at user defined intervals. Reporting topics include safety, driving efficiency, vehicle utilisation, time sheets, data breakdown summaries and personalised dashboards. Each individual EV driver will only be able to view their own data. CES in the role of "fleet manager" will be able to view all 15 EV driver's data in the trial.

The following data items will be available:

Journey Summary Data:
- Start / End location
- Drive time
- Idle time
- Engine time
- Distance travelled
- Total Journeys in a given period

Journey Detailed Data
- As above but data taken every 60 seconds when the vehicle is in motion

Speeding:
- Event
- Location
- Speed of vehicle
- Road speed limit

Driver Behaviour (measured in events / 100km):
- Harsh Acceleration
- Harsh Braking
- Harsh Cornering
- Over RPM
- Max Throttle

Figure 24 Trakm8 Insight portal and example reports

Type B - Scenario 2

VCharge (OVO) will collect data from curtailment events and EV charging profiles throughout the project. The data will allow analysis of the amount of curtailed energy that was consumed to charge EVs. This would include an investigation into the suitable matching of EV charging in visitor accommodation and visitor attractions with curtailment events.

5 Industrial Load

5.1 Description of Electrolyser Smart Switching

Control of EMEC's 11kV switching and storage system is the scope for the industrial load in SMILE. This would involve improving the switching mechanism and electrolyser production to work more intelligently than the existing system in operation. Since the production of Deliverable 2.1 the scope of this has been amended. SMILE infrastructure will incorporate the connection to a 11kV bus bar at the EMEC site rather than directly switching between the electrolyser and the WTG.

As a summary of the capacity of each part of the system that will be located on Eday:

- Wind 900kW (curtailed on ANM system);
- Tide 4000kW (no curtailment but limited to this capacity). Current maximum peak generation as of November 2017 around 2000kW on spring tides (during tidal ebb and flood cycles);
- Electrolyser 500kW; and
- Potential additional energy storage.

The existing switching between wind and tide is solely off-grid and is controlled by a switch that can be operated manually or via the Programmable Logic Controller (PLC). By improving the control of the switching between the two forms of generation, it will help to maximise the amount of hydrogen that is produced. It will also future-proof access for the 900kW wind Turbine Generator (WTG) to the electrolyser if/when tidal generation exceeds 4MW, based on the predictable tidal cycles, and providing the potential for the large demand assets to be more flexible through smart grid connection. Figure 25, below, demonstrates the architecture of the industrial load within the SMILE infrastructure.

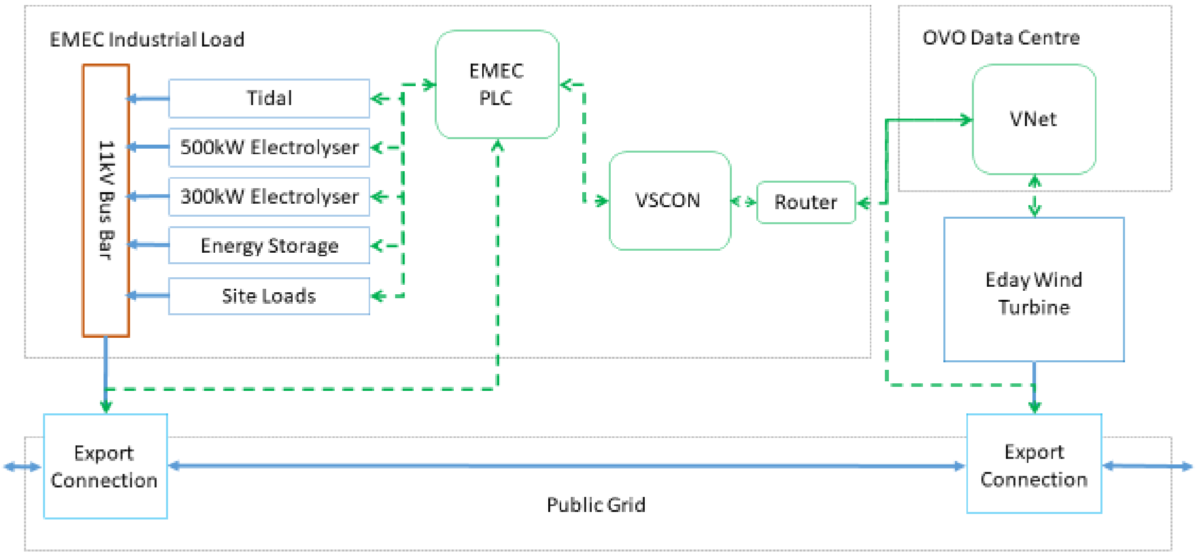

Figure 25 Industrial Load Architecture

5.1.1 LECF project: Surf 'n' Turf

SMILE builds on the Surf 'n' Turf project, funded by the Scottish Government's LECF. This is led by CES, with project partners EMEC, ERE, ITM Power and Orkney Islands Council. EMEC invested in an electrolyser that will use power from tidal turbines operating at the company's test site off Eday to produce hydrogen. To build on this, CES and partners created Surf 'n' Turf, so that power from the community wind turbine in Eday can also be used to produce hydrogen using EMEC's electrolyser, and then this energy (gas) is transported to where it will be used elsewhere in Kirkwall, as illustrated in Figure 26. The project is also part of the BIG HIT project.

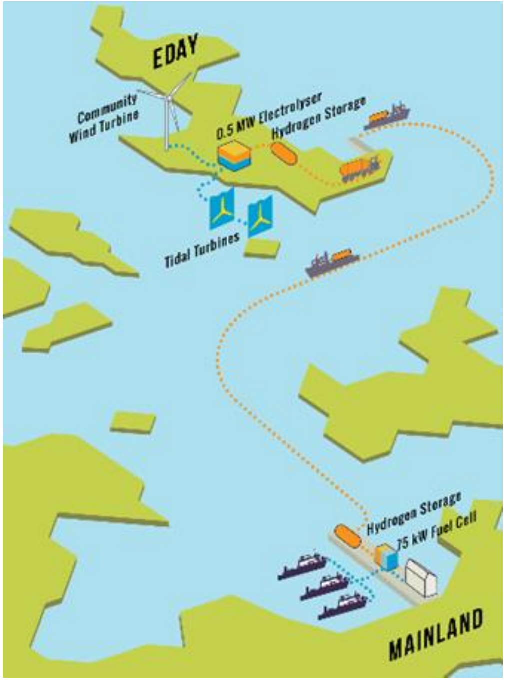

Figure 26 Surf 'n' Turf logistic diagram

The existing electrolyser itself is a 500kW PEM electrolyser supplied by ITM Power. Additionally, there is 500kg of high pressure storage at 200 bar and three mobile storage units which can each carry 250kg of hydrogen at 200 bar (see Figure 26). Hydrogen is transported to Kirkwall where it is converted back to electricity in a 75kW fuel cell to provide auxiliary power for the island internal ferries while docked.

5.2 Interaction of Partner and 3rd Party Technologies

The communications link on-sight at the EMEC industrial load will centre on the continued use of VSCON units providing comms and control remotely from the VNet system. This will both make the timed production of hydrogen more efficient and the matching to local power generation greater.

6 Basic Rebate System

While not being offered to participants during the duration of the SMILE project, work has been started on creating a rebate system, where in a 'business as usual' scenario, a rebate can be offered to project participants in order to offset their heating costs, which may become higher due to an increase in more expensive electric heating rather than their existing solid fuel systems. This principle builds upon the work carried out as part of the Heat Smart Orkney project, and it is hoped that once the SMILE demonstrator has proven itself as a valid technological option to alleviate curtailment, the increased revenue from the generators can help to offset project participants heating costs, providing them with a more affordable source of heating.

The Orkney Islands have historically had one of the highest rates of fuel poverty in Scotland, with figures from 2014 suggesting that 63% of households across the islands suffered from fuel poverty (Council, 2017). It is possible that this figure is even higher within the SMILE project area, given that much of Zone 1 of the Orkney ANM is made up of islands, which experience higher fuel costs due to additional transportation and the logistics required for getting fuel to these islands. It is hoped that through the technologies demonstrated in the SMILE project, there can be a more affordable method of electric heating provided to project participants, with electricity prices offset by the increased generation of local generators.

6.1 Target

Building upon the principles of the existing Heat Smart Orkney project, which operates within the same Zone 1 grid area, a potential SMILE project rebate system would aim to offset any electric heating costs to participants, to a level of at least 10% less than their current heating system costs on a price per kWh basis.

The project area is entirely off the gas-grid network, with oil and electric heating being the two primary sources of heating. In the more rural areas such as the SMILE project area, oil is more prominent as a heating source than electric. Oil prices in the county average out at roughly £0.46p/litre, equivalent to 4.67p/kWh, considerably cheaper than the cost of electricity per kWh, which normally ranges from a minimum of 10p/kWh for off peak tariffs, to a maximum of roughly 20p/kWh for on peak tariffs. Many SMILE project participants may have to switch from their regular oil heating to the new electric systems, which despite the improvements in system efficiency is not guaranteed to be a cost-effective method of heating when compared to their existing system, thus the development of a potential rebate system in a 'business as usual' scenario.

The following section show a rebate mechanism for consideration in a 'business as usual' model that uses the SMILE demonstrator technology.

6.2 Mechanism

The rebate mechanism for consideration mimics the Heat Smart Orkney project, where a survey and analysis of the properties existing heating methods, sources and systems across the entire previous year allows for a price/kWh of delivered heat to be calculated across all systems. This figure provides a properties' '**historic cost**' per kWh, which can then aim to be reduced from participation in the project. The initial aim of this would be to reduce this historic cost by a minimum of 10%.

For example:

Table 9 Rebate Example

The **historic cost per kW delivered** (electricity, solid fuel, oil, etc.) is calculated as:	15.00p
Through increased generation, the generator can offer a **10% reduction on this figure** which is referred to as the **target price;** and this is the cost of the electricity which will be used in the project systems.	
This would make the **target price** for electricity used through project devices:	13.50p
The properties **current electrical tariff** price per unit is:	20.00p
A rebate is offered to reduce to cost per unit from the **current electrical tariff** to the **target price**. Therefore, for each unit of electricity used in the project systems, the property receives a rebate of:	6.5p

This example assumes a standard tariff rate of 20p per unit, and while this allows for a general rebate figure to be offered, the models flexibility is limited when it comes to off-peak or split rate tariffs such as Economy 7 or Economy 10. One of the main benefits of the SMILE project systems however, is the possibility to time-shift demand into cheaper off-peak times using heat storage or battery storage, hence a preference for project participants to have off-peak or split rate tariffs.

For a rebate system to be implemented there must be a financial mechanism running effectively to pay for it. In this scenario, the smart load response of SMILE equipment would reduce the level of curtailment experienced and thus greater revenues generated by affected wind turbine operators. It would be this revenue that would stand as the financial backing to the rebate system.

7 Conclusions

This report builds upon the system architecture outlined within Deliverable 2.1 (Orkney Demand Side Management System Architecture Design). As in the previously highlighted report, this one described the whole system architecture, while also breaking this down into the three component types:

- Domestic Heating and Hot Water;
- Electric Vehicle Charging; and
- Industrial Load.

Within each of these types, subsections go into further detail. These include:

- Overview and description of the installation;
- System architecture, including connectivity and communication links;
- Component/ equipment list, including technical specifications where available;

7.1 Domestic Heating and Hot Water

The majority of the fundamentals in the architecture design reported in Deliverable 2.1 remain correct as detailed within this report. In regards to the heating and hot water installations, approximately 45 individual properties remain the target number for the Orkney-based demonstrator. This will be through the implementation of four different installation types; which are a different combinations of equipment from partners and 3rd party manufacturers, as described below:

- **House Type 1:** 15 x Internally heated Sunamp PCM heat battery thermal store, VCharge (OVO) controls
- **House Type 2:** 15 x ASHP, internally heated Sunamp PCM heat battery thermal store, VCharge (OVO) controls
- **House Type 3:** 10 x ASHP, hot water thermal store(s), VCharge (OVO) controls
- **House Type 4:** 5 x ASHP, hot water thermal store(s), LiBal's Battery Energy Storage System (BESS), VCharge (OVO) controls

The final tally of houses recruited for heating and hot water types installed will remain dependent upon the success of the recruitment exercises (as outlined in Deliverable 2.2) and the suitability of the properties of those who have registered interest. As of the production of this report, 81 individual properties registered their interest in being part of the heating and hot water project; after taking screening into consideration, this is believed to be suitable to finding the 45 properties required.

Once the current heating systems of each participating property has been outlines, it will be possible to then design a heating system among the four types outlined above to meet both the requirements of the project as well as the participants as well. The majority of the system components can be scaled in order to meet the personal requirements of the participants; including the ASHP, internally heated Sunamp PCM heat battery, and hot water storage. As such, it is only after this design phase that it will be possible to accurately understand the additional DSM loads that will be added to the local grid under the SMILE architecture. However, it is possible to gain an approximate understanding of this by assuming an electrical load of 5.6kW from the Sunamp internally heated PCM heat battery; 5kW from the ASHP; and 3kW from the immersion elements within hot water storage.

7.2 EV smart charging

The architecture reported for the EV charging trials within Deliverable 2.1 remains accurate, as again detailed in this report. The targeted 30 EV charge points will comprise of 15 domestic households **(type A)** and 15 local tourism sites and accommodation **(type B)** within Zone 1, that either have an EV that they currently charge at home, or a business/ facility that would benefit from being able to offer EV charging to customers/ visitors.

As with the heating and hot water trials, the number of installations will be reliant upon the ability of the recruitment phase of the project to attract EV owners and suitable visitor attraction and accommodation properties to register interest. To date, 30 individuals have registered to be part of the domestic EV charging trial (Type A), while 17 business premises have registered to part of the project (Type B).

Some of the advantages of this dual approach are that it allows two independent but interlinked DSM systems to be demonstrated interacting and being coordinated to the same generation ANM system. With type A, where considerable intelligence can be gathered on the patterns of charging and vehicle use, DSM curtailment response can be refined with predictive knowledge and learning algorithms in this situation. Whilst in parallel, DSM installations in type B can be best tested and shown to be robust, compatible and effective whilst being agnostic to the connected vehicle technologies and use patterns.

Type A, principally deliverable by Route Monkey, will gain information from the registered EV through an in-car telematics unit which will transmit data to VNet that will inform on the level of charging required. A user interface will inform VNet when the car would be required by. So when the car is plugged in and the load is available to VNet, charging during curtailment event scan occur. In comparison, Type B (delivered by VCharge (OVO)) will solely rely upon a user interface in the form of a mobile app that can be used by the participant to inform VNet on how much charge is required and when it is required by; thus allowed VNet to monitor for curtailment events and charge the EV appropriately.

The specific detail of types of vehicles and quantities recruited in each scenario will depend to some degree on the uptake of participants (car type, charger type) and their existing or preferred charging methods.

Where existing chargers are not able to be adapted to make smart connections, these could be upgraded under the scope of the SMILE project if budget allows and new controlled charge points will be installed in places where no charging is currently in place. Both pre-existed and new chargers must meet particular operating parameters to be able to respond to start/stop/ramp up/ ramp down signals from VNet. In both Type A and Type B installations, chargers will be rated at 7kW, with communications to VNet operating via the properties internet router.

7.3 Large industrial load

The industrial load is proposed to be the smart control of the 11kV on-site switching and storage system, including the existing 500kW electrolyser (operational November 2017), on Eday which is owned by EMEC (The European Marine Energy Centre). It is currently a part of the Surf 'n' Turf project funded by the Scottish government CARES Local Energy Challenge Fund and also a FCH JU funded project called BIG HIT. The electrolyser (and potential other on site storage) uses electricity from tidal energy at the test site and wind energy from the ERE turbine 600m away; SMILE will help implement the smart control of switching between the two sites and the local grid to maximise generation and hydrogen production from both of the sites (wind and tide).

7.4 Summary

The proposed infrastructure outlined within this report, under the SMILE Orkney-based demonstrator project, will have the potential to make significant impacts upon the local constrained electrical grid. It will add significant quantities of DSM loads that will automatically respond to curtailment event in real-time.

As highlighted previously, it is too early to report on the actual power demand that will be added to the grid as the recruitment and installation design phase must be completed first. However, Table 10 below outlines an approximation of this load assuming the previously outlined number of installations and likely power ratings.

Table 10: Total controllable demand

Load type	No	kW	Total kW
Domestic heat installs type 1	15	5.6	84
Domestic heat installs type 2	15	5	75
Domestic heat installs type 3	10	5	50
Domestic heat installs type 4	5	5	25
EV smart slow chargers	30	7	210
Industrial load (500kW electrolyser)	1	500	500
TOTAL			**944**

It should also be noted that as more information is gathered, the installation architectures outlined within this report may see further minor alterations in order to meet individual circumstances. This may result from bespoke factors found within participating properties, or from gaining a further understanding of how such equipment will operate together in this manner.

The next stage will be to identify the final participating properties and have installations designed that both meet the needs of the project and the participants; followed by which will be the installation and data gathering phases.