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Consolidated Trial Description

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Abstract:

The Consolidated Trial Description represents the first public deliverable in the FINESCE project. It gives an overview of the infrastructures being used for the FINESCE field trials.

Keyword list:

API, Building Management System, Demand Side Management, Demand Side Response, Distributed Energy Resources, End-user engagement, Electric Vehicle Charging, Energy Management, Information and Communications Technology, Marketplace, Metering, Microgrid, OPST, Portfolio Manager

Disclaimer:

All information provided reflects the current status of the trial site testbeds at the time of writing and may be subject to change.

Executive Summary

The FINESCE project is performing field trials of the use of FI-WARE Generic Enablers (GE) in the smart energy sector and provides an Application Programming Interface (API) which allows the development of Applications which access the trial infrastructure, supporting the creation of a network of smart energy application developers.

The FINESCE trials comprise 5 vertical work packages (WP) covering Smart Energy areas which are expected to gain most from the use of Information and Communications Technology (ICT).

This report is the first public deliverable of FINESCE and is written eleven months into a two-year project. It contains a consolidated Trial Description and Testbed Manual covering the five FINESCE work packages' infrastructures. It describes the working and tested trial infrastructures which are ready for the integration of the relevant generic and domain specific enablers and the performance of the trials themselves.

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1. Introduction

This report is the consolidated output of the Trial Preparation Task, whose purpose is to provide working and tested trial architectural components, ready for the integration of the relevant generic and domain specific enablers and the performance of the trials themselves, both of which will be undertaken in separate tasks.

The activities in the task are:

- the preparation of an implementation plan for the build-out, defining the work to be undertaken, allocating responsibilities, defining training requirements, and identifying dependencies and risks;
- the preparation of a test plan to ensure that the completed components will function as anticipated;
- the procurement of all necessary items including: equipment, software, infrastructure, services and accommodation, required for the assembly of the trial components;
- the deployment, test and handover of the completed Trial components.

The FINESCE trials comprise 5 vertical work packages (WP) covering Smart Energy areas which are expected to gain most from the use of Information and Communications Technology (ICT):

- development of demand side response and demand-side management solutions for mixed-use buildings in a city district;
- efficient grid utilisation through demand-side management of prosumers;
- industrial demand side response interworking with a cross-border Virtual Power Plant (VPP);
- development of an energy marketplace to provide demand side response to varying energy production from Distributed Energy Resources (DER);
- controlling electrical vehicle charging to balance DER supply and improved utility communications.

This report is the first public deliverable of FINESCE and is written eleven months into a two-year project. It contains a consolidated Trial Description and Testbed Manual covering the five FINESCE work packages' infrastructures. It describes the working and tested trial infrastructures which are ready for the integration of the relevant generic and domain specific enablers and the performance of the trials themselves.

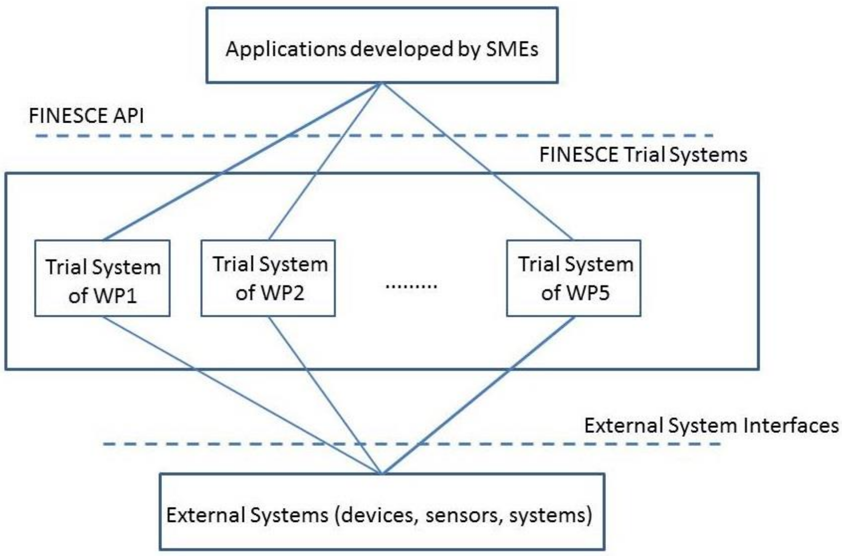

Figure 1 FINESCE Trial System Functional Architecture

The generic functional architecture of the FINESCE trial systems is shown in Figure 1. The external interfaces of the trial systems are the northbound FINESCE API and miscellaneous southbound interfaces to external systems. The trial systems shown comprise the totality of the FINESCE trials, i.e. the seven physically and logically separate trial systems developed by the five WPs, with WPs 2 and 5 both developing two trial systems, as detailed in subsequent chapters. The seven trial systems will be accessible to application developers via a unified FINESCE API. Each trial system is composed of a number of subsystems which interact together to implement the functionality. The subsystems contain FI-WARE Generic Enablers (GEs) which are integrated into the trial system and FINESCE Domain Specific Enablers (DSEs) whose functionality is considered trial-specific but may also be considered applicable outside the trial for other applications in the energy domain/sector.

The external systems can be devices (EVs, house management systems, sensors) or systems (aggregators, grid management systems). The FINESCE trials communicate with each particular external system using the appropriate particular system interface.

The FINESCE API provides a set of services which supports remote access to the project trials and infrastructures, monitoring of experiments and the creation and validation of FI energy applications. The services which it exposes allow external SMEs to develop Apps based on the live FINESCE trial systems, through which they access the external systems.

2. Testbed Description WP1

The trial will test an integrated approach of energy carriers in order to demonstrate Demand Side Management and Demand Side Response tests based on either price or energy mix (CO_2) for both heat and electrical loads. The trial site is in the district of Hyllie in the city of Malmö, Sweden.

The ambition is to incorporate 2 to 5 buildings in WP1. As for now (read January 2014), agreements have been reached with two external building owners; Roth Fastigheter, a residential building of 53 apartments, and MKB, a residential building of 81 apartments. The Roth Fastigheter building was incorporated into WP1 in November 2013 and the MKB building will be incorporated in April 2014. Moreover, agreement is close to being reached with a third commercial building, the Skanska headquarters, and a fourth building, Malmö Arena, looks promising. The latter two are commercial buildings, which means that they have different kinds of loads with varying patterns that may be incorporated into the trial.

The main driver behind incorporating multiple buildings is to get a critical mass of load that can be steered in a smart way, i.e. load that can be shifted in time (optimized) and generate business values for E.ON and the customer. This will feed into WP1's secondary objective: to demonstrate the optimization of supply and demand across different energy carriers.

Enrolment of external buildings to WP1 began several months prior to the actual construction of the buildings, thus a long time before the FINESCE project started. A short version on the process for the enrolment of newly built buildings is outlined below.

1. **Introduction to the transformation of the energy system** E.ON explains the main advantages for the building owner to participate in a trial.

2. **Pre-design of building's automation system**
   Include an option on "smart grid ready" building in the request for proposal linked to the building's automation system, i.e. connection to the E.ON Energy Management System in Hyllie was incorporated into the request for proposal.

3. **Reach agreement with building owner**
   Reach an agreement with building owner concerning the general scope of the trial, on top of contracts linked to power and district heating, for example.

4. **Design of building's automation system**
   E.ON initiates discussions with the building owner and BMS supplier in order to decide on different aspects, e.g. what loads to include in the trial. The preparation also concerns adjustments to the BMS, such as specific signals, which have to be added to the interface between the BMS and the Energy Manager. Offsets to set-points and activation of features are two examples of specific signals.

5. **Connection of Energy Manager to BMS**
   The Energy Manager is connected to the BMS during the last phase of construction. This step also includes initial communication tests between the Energy Manager and BMS in order to make sure that everything works as planned.

2.1 Infrastructure

The functional architecture, as depicted in Figure 2, is split into two distinct parts; Portfolio Manager and Energy Manager. Portfolio Manager is responsible for the centralized portfolio management capability and the Energy Manager is responsible for the distributed energy management capability. The main components in the trial are shown in Figure 2 below.

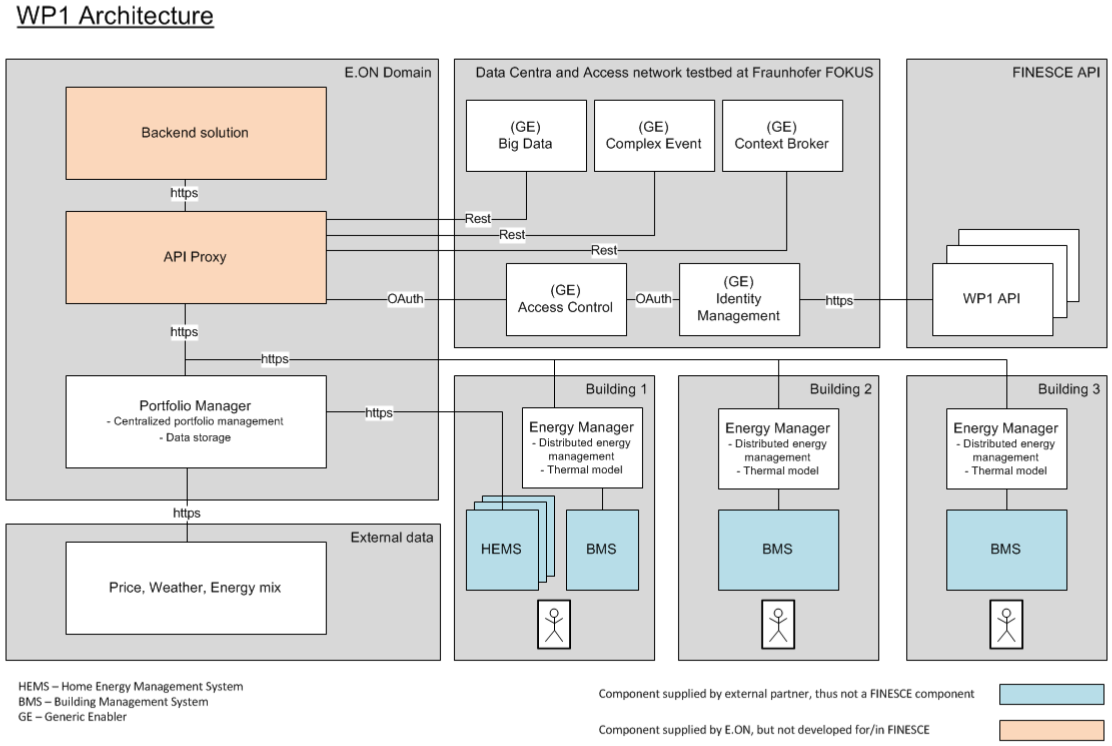

Figure 2: WP1 Trial Architecture

2.1.1 Portfolio Manager

The Portfolio Manager is responsible for the centralized portfolio management capability and it is a back-end server platform. The platform will communicate via a web service interface with both the Energy Manager, which will be installed on building level, and the Home Energy Management System (HEMS). HEMS will be installed in each apartment in the first building, Roth Fastigheter.

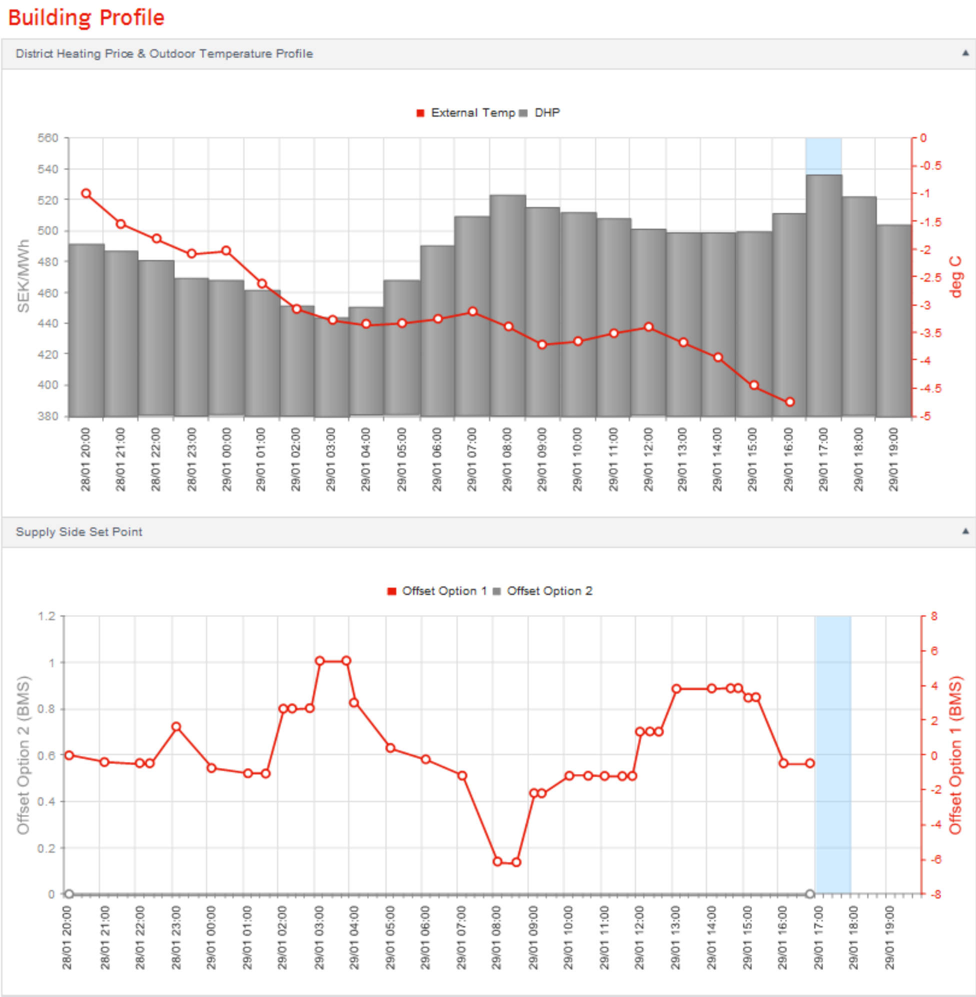

Figure 3: Portfolio Manager's admin web portal (print screen examples)

The Portfolio Manager is currently hosted on a server located in one of E.ON's data centres, but it is of interest to potentially put the server in the cloud at a later stage. Collected data from the Energy Manager, for example, will be logged in a SQL database or in a private cloud.

The Portfolio Manager's admin web portal, see Figure 3, will allow monitoring of alarm status, system health, visualization of data, which includes reports for analytics, as well as configuration of the Energy Manager(s).

2.1.2 Energy Manager

Each building that will be incorporated in WP1 will have an Energy Manager, which is responsible for the distributed energy management capability, optimizing the building's heat consumption, for example. The Energy Manager will get signals, e.g. weather information or price data, from the Portfolio Manager which will be used in the optimization according to defined Use cases.

As for the optimization of the building's heat consumption, it will be necessary to develop a thermal model in order to replicate the thermal load performance of the building. The model, which will be implemented in the Energy Manager, has to consider parameters such as actual consumption level, outdoor temperature and thermal building inertia. The building inertia is used to change the energy usage in time in order to reach the goal of price or emission reduction, for example.

The Energy Manager is connected to the BMS, to give control signals that adjust the steering of different processes. This connection is also used to acquire logging data into the Energy Manager. To obtain weather information or price data, the Energy Manager accepts connection from the Portfolio Manager over the Internet. The logged data and events are sent to the Portfolio Manager for storage and analysis later on.

An industrial computer has been chosen to host the Energy Manager, for the first building Roth Fastigheter. This is a component of small size that can be installed in a device cabinet next to the BMS equipment. There is a serial connection using RS-485 between the Energy Manager and BMS. A standard Ethernet is also in the hardware for connection to the Internet. The current unit has an ARM processor of 200 MHz and 64 MB of RAM. Local storage is available in form of 1 GB flash. The unit is powered from the device cabinet through 12 V DC.

2.2 Interfaces

2.2.1 Portfolio Manager / Energy Manager

There is an HTTPS server in the Energy Manager that the Portfolio Manager connects to. This server exposes a RESTful web service for the parts of the Energy Manager that the Portfolio Manager needs. The communication is secured by authentication and encryption through TLS 1.0.

2.2.2 Energy Manager / BMS

The Modbus protocol is used to communicate over the serial connection. There is a building-specific set of signals that are exchanged, including control and data signals. The BMS is Modbus master and the Energy Manager is Modbus slave.

3. Testbed Description WP2 Horsens Denmark

The overall objectives of WP2 are:

- To enable value added services through an open FI based platform with FINESCE APIs offering rich data on energy needs and consumption patterns.
- To promote energy efficiency via incentives from energy market place and dynamic tariffs.

The WP2 trial in Horsens consists of a community of single family households in a small town near Horsens, in Denmark. The town is located outside the collective (district heating) heating supply area, and the houses are characterised by originally having individual oil or gas-fired boilers.

All selected houses have been equipped with the latest equipment within energy and ICT connected in a Smart Grid. The energy production and consumption of the houses is controlled and monitored via an intelligent IT cloud, which is also connected to external services, including weather information and electricity prices. Collectively these constitute the test bed of the Horsens trial, a living lab for testing, integrating and interacting with technologies. Locally, the Horsens trial site goes by the name 'Insero Live Lab'. The test-bed houses are configured with the following energy equipment and components:

- Heat pump – four different types (gas hybrid, air-to-water and two types of ground source) are used depending on the individual house
- A photovoltaic system
- A thermal solar collector, consisting of 4m^2 of solar panels and a 4kW inverter (used in combination with only the ground source heat pump)
- Electric vehicle and charger station
- Indoor air quality (indoor climate) meters
- Home automation system

Each house is also equipped with energy meters and multiple gateways for communication. The entire energy system is connected through a FI-WARE platform.

Building the testbed of the Horsens trial has been a process with many steps, and the main challenge has been to find and select a community of 25 households, , the number 25 being the original goal for the trial site in this WP. The aspects of this challenge include:

- Finding 25 well-suited households located in a geographically close proximity interested in participating in the project.
- Evaluating the houses and determining if they have the right characteristics to match the project, and making the most suitable energy equipment configuration and offer to the specific house.
- Preparing contracts, dialogue with users up until contract signing

Another major activity has been the planning and preparation of project offers to all potential trial participants as well as house examinations, coordination with craftsmen and equipment suppliers. Last but not least there has been considerable focus on the planning of user involvement and methods for securing relevant and necessary data.

3.1 Infrastructure

3.1.1 Energy equipment

The energy equipment, installed in each household, and which is the focus of this project, includes a heat pump, a photovoltaic system, a thermal solar collector, an electric vehicle (EV) and a home automation system. There are four different heat pump configurations: gas-hybrid heat pump, air to water heat pump, ground source heat pump with horizontal ground source and a sun well (vertical ground source) heat pump.

The equipment is assembled in different configurations; common for all configurations is that they include a photovoltaic system, an EV and charger, a home automation system and one of the four heat pump configurations. Depending on the heat pump configuration also the thermal solar collector is included. The configuration includes a 4kW photovoltaic system, except a single case where a larger (6kW) system is provided.

The different configurations are necessary, because the heating systems in the houses vary considerably and houses have different characteristics. Some have underfloor heating and some have radiators. This influences the conditions under which the heat pump has to operate. In addition, not all households have sufficient physical space to establish a ground source and not all households want the outdoor part of an air-to-water heat pump located outside.

Each participating household is equipped with an EV, a Nissan Euro Leaf (2013), which is installed with a data logger to enable the project to precisely monitor the movement pattern of the EV and thereby also the household's usage of the EV. In addition, each household will have a local charger installed to enable charging of the EV at all times during the day and night. The EV holds a battery with a capacity of 24 kWh. By selecting default charging, charging time is 6-7 hours at 3.7 kW (16A + 230V). Quick charging is from 0 to 80% in approx. 30 minutes at 44kW (100A + 440V). The goal is to enable the project to monitor, change and impact the usage of how individual households use an EV in a daily life situation. As the battery in the EV is a heavy part of the household's total electricity consumption it is expected to play a major part in relation to the Smart Grid balancing investigation.

3.1.1.1 Decision process regarding equipment for each house

During contact with the users, different investigations and tests have been carried out in order to determine the most suitable equipment in each specific case. When a family has declared reasonable interest in participating in the project, the house in question is evaluated. The first step in the evaluation is to determine, whether the house can be heated with a heat pump, either in its current condition or by carrying out improvements. If neither is possible, the potential participant is excluded.

The evaluation parameters include the energy needs of the house, the state of the climate effects of the house, if the house has underfloor heating or not and if not, the dimensions of the radiators in the house. Taking the characteristics of the house and the opinion of the house owner into account, the most suitable configurations are chosen and presented to the user. In addition the users are offered consultancy regarding sustainable renovation of the house combined with this project. Based on the evaluations and the choices of the user, a plan for carrying out the work is set up. The plan for carrying out the equipment installation combined with the offer for an EV is drawn up as a final offer in a contract, which the user needs to accept before the installation work begins.

3.1.2 Software

The software architecture is shown in Figure 4. It consists of two main components and a number of external services.

Generic Enablers: Two GEs, Publish Subscribe Context Broker and Identity Management, are integrated into the core test bed functionality. The Publish Subscribe Broker GE provides distribution of data using NGSI. The Identity Management GE performs authorization for access to data. During the trials additional GEs will be integrated in the software architecture.

Insero Live Lab Platform: The Insero Live Lab Platform consists of a web service for controlling and monitoring the test bed environment and trials, two components implementing the FINESCE API, and four internal components. These elements are listed and explained below.

- *Management Interface (web service):* This component provides a web interface for controlling and monitoring the test bed and the trials executed in the test bed. Some of the key features are managing the HW configuration of the individual houses, managing the SW configuration of the deployed system, status overview of both HW and SW in the complete system, and display of energy production and consumption.

- *Control Service and Historic Data Service*: Both components implement a REST interface to the trial. The Historic Data Service implements part of the FINESCE API where datasets can be requested. The Control Service allows for setting basic parameters for controlling the house that are available for the residents.

- *API Mediator:* The API Mediator is responsible for mediating the different APIs exposed from the web services that gather the data from the devices. It is then able to mediate it into an appropriate format that can be exposed as NGSI or be stored in a database. It is designed to be highly extensible (hence, it being a specific enabler) such that plugins can be developed for it, allowing additional data flows and protocol translations.

- *Configurator:* This component allows configuration to be distributed across the network. This is important especially for the API Mediators, which there may be any number of, all of which have configuration that must be centrally managed.

- *Optimization Algorithm Service:* This component represents the service that will utilize measurements from the houses, simulation of heat loss for the individual houses, weather prognosis, and energy production/usage prognosis from various services in order to optimize the way energy is used in the smart grid as a whole. Control instructions for the houses are decided in this component.

- *Distributed Data Layer:* This component provides the communication bus facilitating the exchange of measurement data, queries and control messages between the components and the Data Warehouse. It features a distributed platform providing location-transparent communication between components.

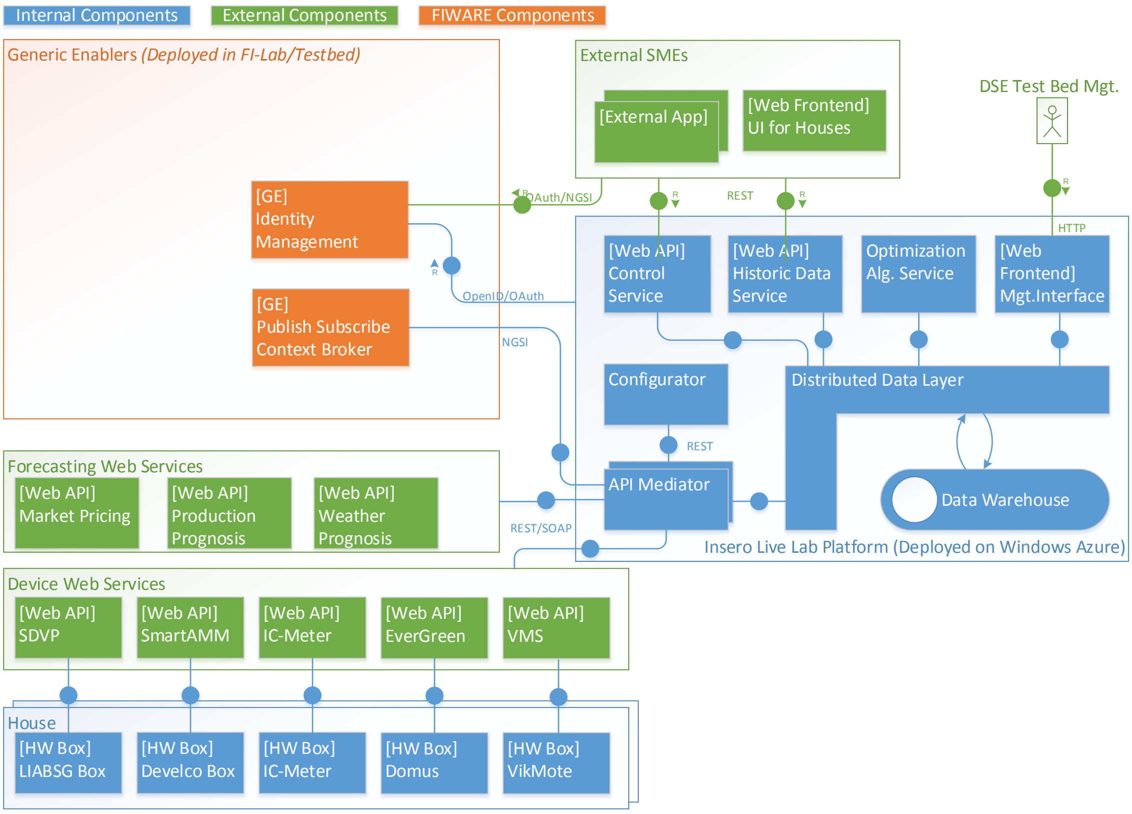

Figure 4: Software Architecture

The web roles and cloud services are deployed in a PaaS (Platform as a Service) environment on Windows Azure. The virtual machines (VMs) are deployed in an IaaS (Infrastructure as a Service) environment, likewise on Windows Azure.

3.2 Interfaces

3.2.1 Communication (High level)

Each house is equipped with devices and sensors as listed in Table 1. To communicate with the equipment, and to retrieve data measured from the individual devices/sensors, five main interfaces are utilized in each house.

- IC Meter - Indoor Climate Meter from http://www.ic-meter.eu
- LIAB Controller Box from http://www.styrdinvarmepumpe.dk
- Develco ZigBee Gateway from http://www.develcoproducts.com
- EverGreen Domus EV Charger from http://www.vikingegaarden.dk
- VikMote EV DataLogger from http://www.vikingegaarden.dk

Please note that the names of the above devices and sensors are vendor specific. These names are used internally to ensure understanding between local partners and therefore not changed in the formal documents.

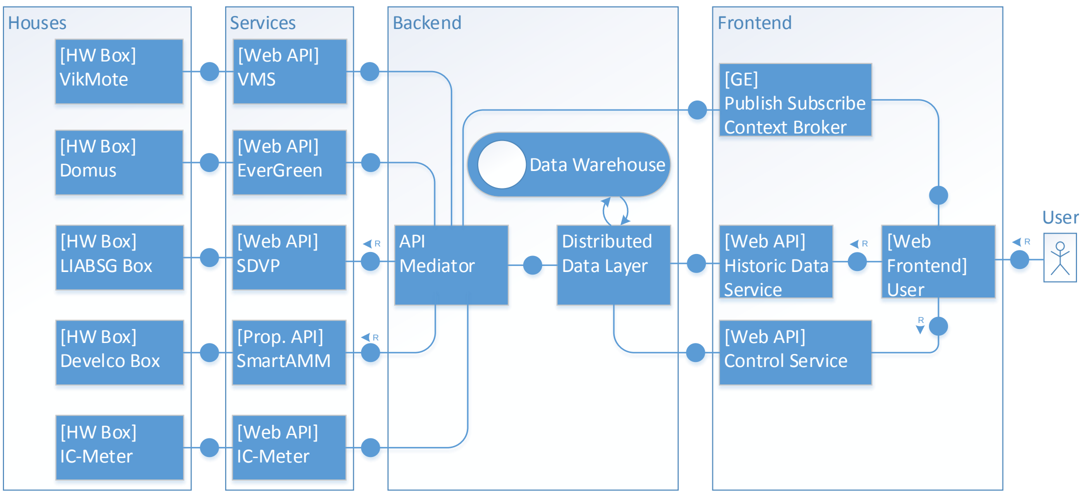

Figure 5: Data Flow

Each device aggregates measurements from a wide range of sub-sensors and devices installed throughout the house, and in the immediate vicinity.

Inside the houses that make up this trial site the different components and equipment communicate with the trial test bed through multiple gateways as described above. The gateways communicate with proprietary cloud services, which in turn are interfaced through the API Mediator Service in the Insero Live Lab platform.

	Internal (House / Electrical Vehicle)			**Cloud / Internet**	
Manufacturer	**Sensor / Actuator**	**Internal Protocol / Media**	**Gateway (Service)**	**Media / Connection**	**API Mediator Endpoint**
Develco	Echelon MEP	ZigBee	Develco ZigBee Gateway (SmartAMM)	Wired Ethernet	Proprietary Service
Kamstrup / Develco	MULTICAL 602 with Develco ZigBee Module*	ZigBee	Develco ZigBee Gateway (SmartAMM)	Wired Ethernet	Proprietary Service
Develco	PIR Sensor	ZigBee	Develco	Wired	Proprietary

			ZigBee Gateway (SmartAMM)	Ethernet	Service
Kamstrup	MULTICAL 602*	S0 / Pulse Converter	LiabSG Controller (SDVP)	Wired Ethernet	Rest Based Web Service
Vikingegaarden	Build in EV charger power meas.	N/A	Domus (VMS)	GSM	Rest Based Web Service
Vikingegaarden	EV DataLogger	N/A	VikMote (EverGreen)	GSM	Rest Based Web Service
Liab ApS	Temperature Sensor Board	RS-485 modbus	LiabSG Controller (SDVP)	Wired Ethernet	Rest Based Web Service
IC-Meter	Indoor Climate Meter	N/A WIFI	IC-Meter (IC-Meter)	Wired Ethernet	Rest Based Web Service
Danfoss	DLX PV Inverter	S0 / Pulse Converter	LiabSG (SDVP)	Wired Ethernet	Rest Based Web Service

Table 1: Devices and sensors installed in each house

*) The Kamstrup MULTICAL 602 Heat Meter is interfaced by the LIABSG box as well as the Develco ZigBee gateway for testing purposes.

3.2.2 Data Definition

The data gathered by the sensors installed throughout the houses (and in the Electrical Vehicle), are listed in Table 2.

Manufacturer	**Sensor / Actuator**	**Data**	**Update Frequency**
Develco	Echelon MEP	Instantaneous Demand	10 sec.
		Current Summation Delivered	10 sec.
		Current Summation Received	10 sec.
Develco	Kamstrup MULTICAL 602	Current Summation Delivered	10 sec.
		Current Inlet Energy Carrier Summation	10 sec.
		Current Inlet Energy Carrier Demand	10 sec.
		Inlet Temperature	10 sec.
		Outlet Temperature	10 sec.
		Status	10 sec.
Develco	PIR Sensor	Temperature	10 sec.
		Illuminance	10 sec.
IC-Meter	Indoor Climate Meter	Temperature	5 min.
		Relative Humidity	5 min.
		CO_2 Level	5 min.

		ABH (AnyBody Home / PIR)	5 min.
LIAB	LIABSG Controller Box	Heat Flow	5 min.
		Hot Water Flow	5 min.
		Inlet Temperature	5 min.
		Outlet Temperature	5 min.
		Cold Water Temperature	5 min.
		Hot Water Temperature	5 min.
		Heat Pump Energy Usage	5 min.
		Solar Inverter Production	5 min.
		Heat Energy Usage	5 min.
		Water Heating Usage	5 min.
		Indoor Temperatures	5 min.
		Outdoor Temperature	5 min.
		Storage Tank Temperature	5 min.
		Energy Usage (Total)	5 min.
Vikingegaarden	Domus EV Charger	Charging State	20 min / 1 min when not charging / charging
		Charging Mode	
		Current Energy Usage	
		Energy Usage Summation	
Vikingegaarden	VikMote EV DataLogger	Route Points	1 sec. sampling in EV, update “fast as possible” when EV turned on
		State of Charge (SoC)	
		Current Speed	
		Total Mileage	

Table 2: Data Gathered in the Test Bed

4. Testbed Description WP2 Acciona Madrid

The trial site is in an office building which integrates energy generation and a management system with remote real time monitoring. The building is equipped with the following elements which can be interacted with via FINESCE API services:

- Building Control Service: gathers information from different subsystems inside the building such as energy meters, air conditioning systems, comfort measurement devices, etc.
- Micro-Grid: comprises different elements such as PV panels, battery storage system,
- Sub-Metering infrastructure: provides granular energy metering inside the building to have more detailed information about the power consumption in different areas at building level.
- Weather Forecasting module: this service provides weather forecasting information from different Internet services.

4.1 Infrastructure

4.1.1 Building Control Centre (BCC)

The office building has a centralized system for HVAC. A thermal power system generates heat or air conditioning depending on the weather conditions. This system feeds the thermal demands of three circuits:

- Primary air conditioners to offices (1^{st} and 2^{nd} floors),
- Perimeter fancoils on office floors. (1^{st} and 2^{nd} floors),
- Heaters for conditioning laboratories (ground floor and basement).

Figure 6 shows the centralized architecture for the Madrid trial facilities, where both circuits (high and low temperatures are specified).

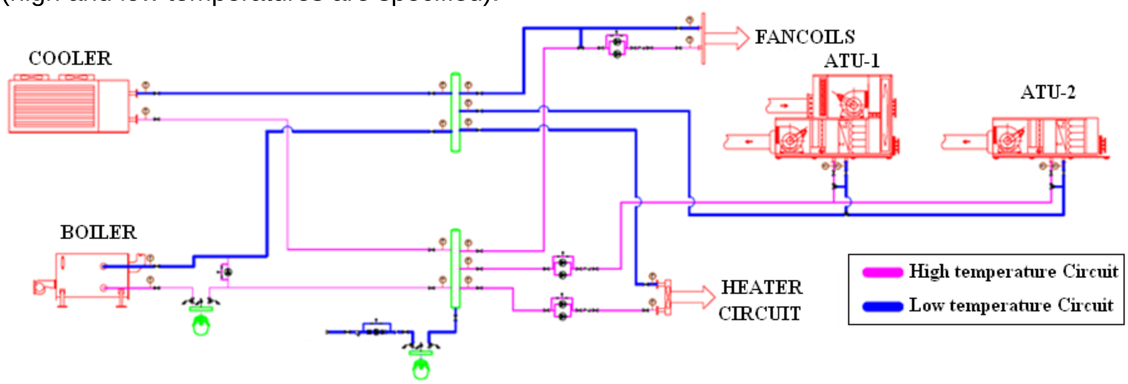

Figure 6: Hydraulic Diagram of Centralised Facilities

Since having a control system for building facilities is a basic requirement to achieve certain energy efficiency and comfort conditions, a Building Energy Manager was installed. The Building Control Center includes devices which monitor energy consumption in the building.

The complete system is provided at two levels:

1. Facility Control Level: This level is running in Trend environment (which is a set of PLC equipment together with sensors and actuators), all together from the same technology.

2. Monitoring Level: Monitoring architecture which collects data from monitoring devices which are not involved in facility control, but provide information on the energy consumption and environmental conditions in the building. Furthermore, the BCC monitors signals that the Building Manager System generates.

4.1.2 Wireless Sensor Network

The Wireless Sensor Network comprises

- Wireless Sensor nodes, which are embedded devices deployed throughout the building. These IEEE 802.15.4 based wireless nodes consist of ultra-low consumption µController to process the data provided by the sensors (Temperature, Humidity, luminance, power consumption), memory to store temporary information, and an RF transceiver, which provides wireless communication capabilities
- Repeaters, for cases where the communication between the sensor nodes and the root node has coverage problems,
- Root node: gathers all the information from the wireless sensor network, and sends it to the gateway via serial communication.
- Gateway: based on an embedded computer, which provides local storage capability to the network and acts as a protocol translator to upload all the measurements to the server installed in the cloud via IP communications.

4.1.3 Micro-Grid

The Micro-Grid module comprises a Battery charger module (with 30kW capacity) an inverter module, a Photovoltaic module performing MPPT for three independent 15 kW solar units and a Wind Module which manages three wind MPPT inputs of 15kW each.

4.1.4 Weather Forecasting System

The weather forecasting system is a software module providing weather forecasting information to the Building Control Center, so that building energy management could be performed with more accurate measurements, refining HVAC set points, and forecasting energy demand.

4.2 Interfaces

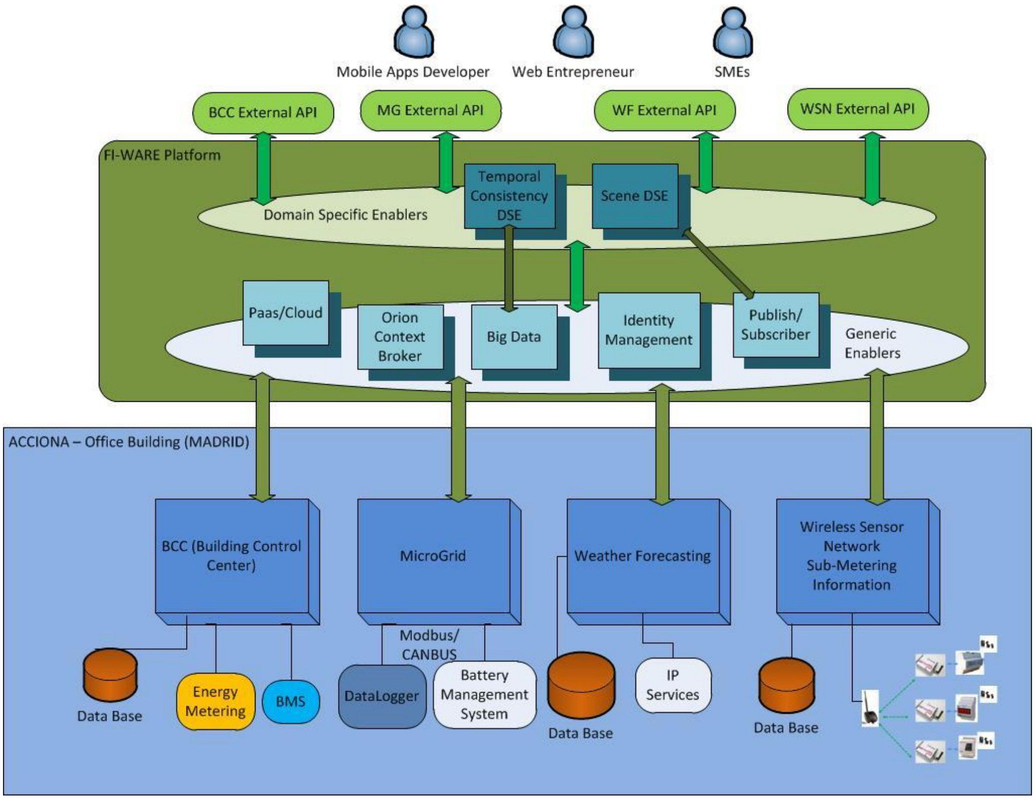

Figure 7: FINESCE Madrid Trial Architecture

The software architecture is shown in Figure 7. It consists of different layers: the external API, GEs and DSEs. The External API: offers services to 3rd-party developers. The BCC External API: provides information about the Building Control Center parameters. The MG External API provides information from both Microgrid data loggers and from the battery management system. The WSN External API provides climate information from different parts of the building. The WF External API offers Weather Forecasting information.

4.2.1 Building Control Center (BCC)

The BCC infrastructure is shown in Figure 8, where three different layers have been defined:

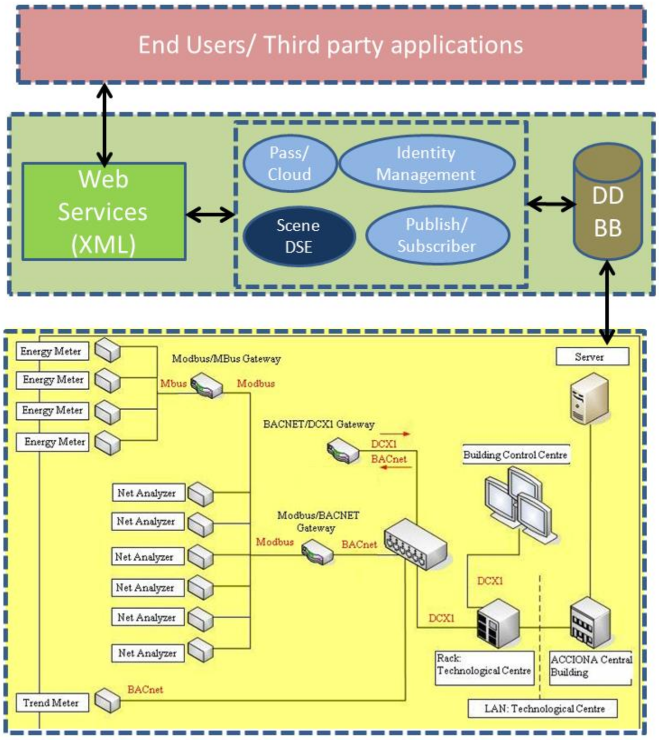

Figure 8: Building Control Centre FINESCE Testbed architecture

4.2.2 Wireless Sensor Network

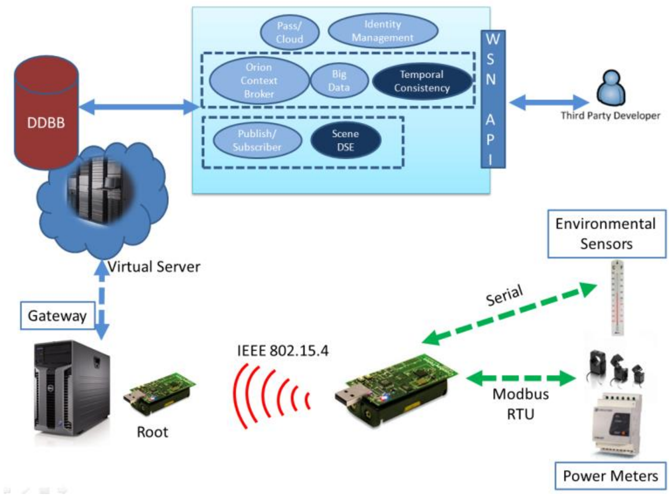

Figure 9: WSN Architecture

Figure 9 shows the different protocols which are involved in the WSN architecture. Environmental sensors and power consumption meters are connected via serial port to wireless nodes. Their measurements are sent via radio fulfilling IEEE 802.15.4 wireless protocol to the root node. Once this information reaches the root node, it is sent via UART port to the gateway, which processes it, stores it in a local data base, and once consistency is assured, this information is sent to the cloud, where is stored on a database. This server then can make it accessible via its web interface, so the data can be monitored in “real time”.

4.2.3 Micro-Grid

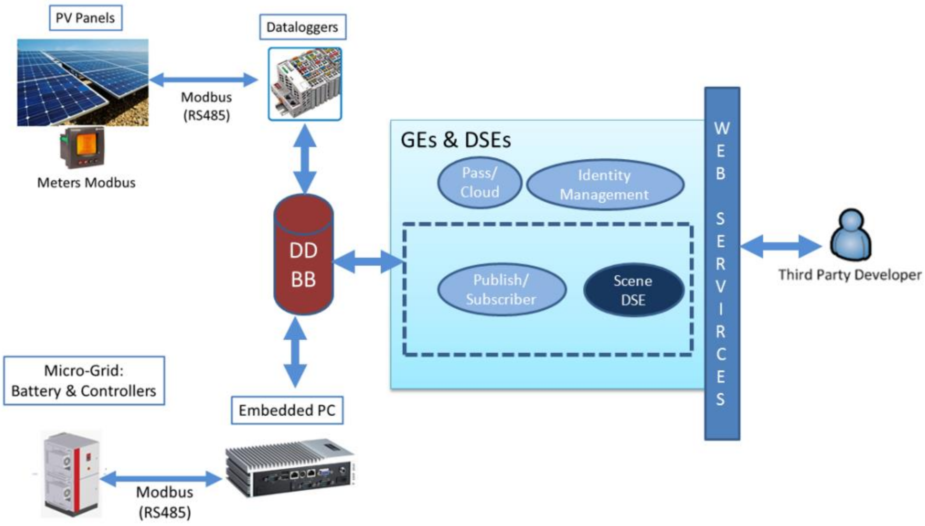

Figure 10: Micro-Grid Architecture

Figure 10 shows the ICT infrastructure where the information from the Photovoltaic System and the Controllers and Battery Array System is stored into a database, so that it can be accessed via third party developers via FINESCE API (through XML web services).

4.2.4 Weather Forecasting

The weather forecasting module gathers information from different internet web services, processes it and stores it in a database, as shown in Figure 11.

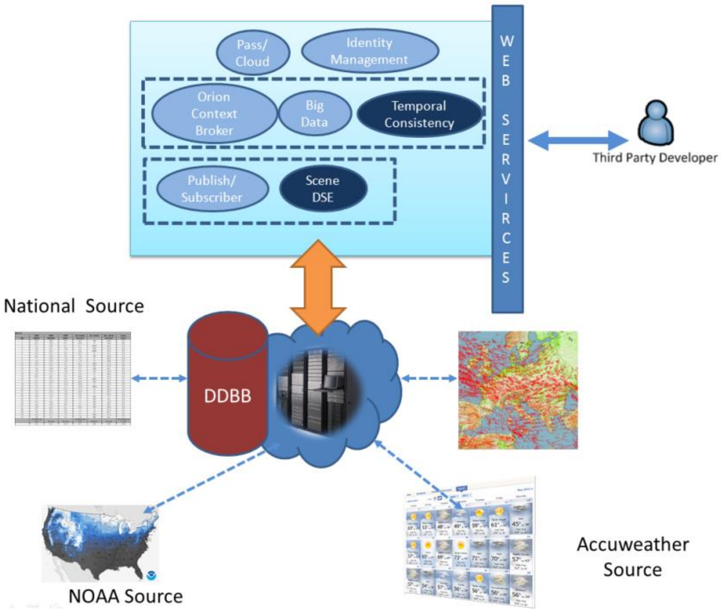

Figure 11: Weather Forecasting Module Architecture

5. Testbed Description WP3

Within WP3, the value provided by FI GE-Technologies in a B2B electricity eco-system will be demonstrated and evaluated. Two interlinked streams of activities cover industrial demand-side management and a cross-border Virtual Power Plant (VPP). A VPP connects several small to medium sized power plants such that they are manageable as a single larger one.

The objective of the first stream is to investigate and exploit the opportunities of energy management in a factory in terms of monitoring and demand flexibility, to understand and optimize the relationship between the production process and energy usage and to gain insights into how industry can take advantage of the flexible electricity tariffs which, in the future, may result from the more volatile energy production due to an increased share of renewables. The Smart Factory testbed will investigate the technical integration of energy monitoring equipment in the shopfloor, the integration of monitoring equipment with the planning and control systems of the factory and the use of open interfaces to communicate with the VPP.

The objective of the second stream is to investigate and leverage the future potential of regional cross-border cooperation and coordination for supply-side management of renewable energy sources, i.e. a cross-border VPP. The interlinking of a regional VPP with industrial production via specific and generic enablers promises synergies on a local and regional grid level. As the VPP sites and the factory are in regional proximity and the control functionality for both streams is implemented on the same platform, the trial will analyse the impact of joint supply and demand balancing in an industrial environment. The cross-border VPP testbed will investigate the technical and logical connection of different power sources to the cloud platform to combine them to one virtual power plant.

5.1 Infrastructure

5.1.1 Demonstration factory at RWTH Aachen Campus

The factory is a special demonstration plant which will produce real goods in small series such as framework parts for the StreetScooter (electric vehicle). The production environment of the demonstration plant is available for research purposes and provides access to already installed intelligent information systems and technology (controller of machine tools, SAP ECC 6.0) and real-time transaction data (e.g. information about produced goods, material flow). For this purpose, an energy monitoring system is implemented by collecting a high amount of data via sensor technology (working with bus communication and deploying smart metering) within the factory. Energy data from energy suppliers outside of the factory, here represented by the VPP stream, is made available for the demand-side to allow the production to react to shortages, price changes and other events.

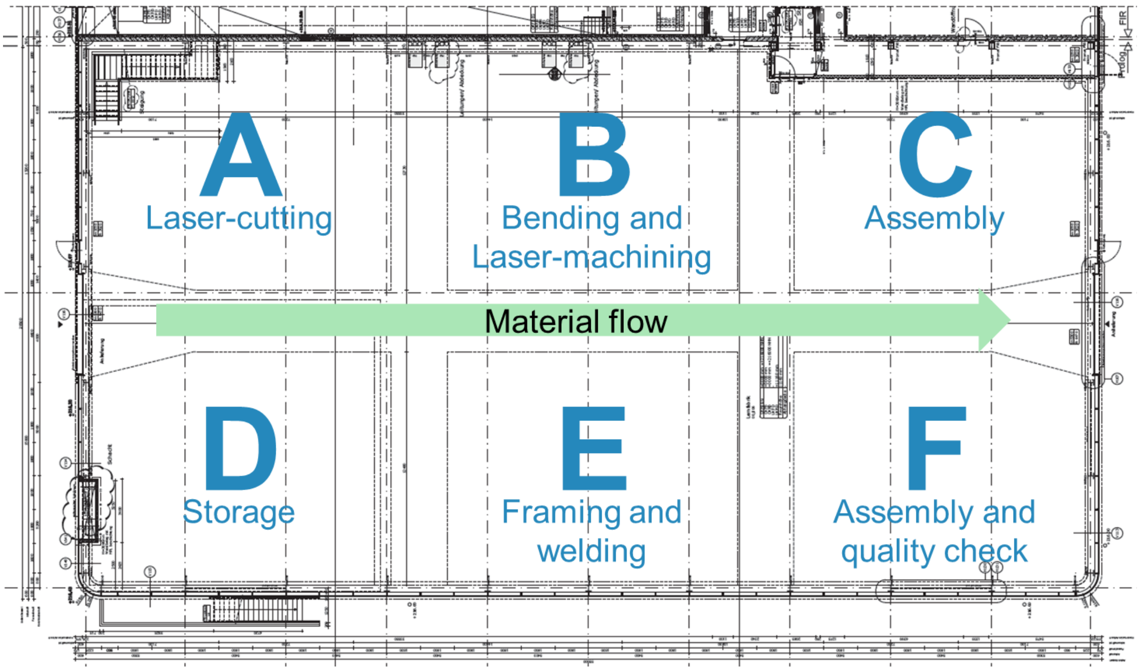

Figure 12: Schematic Overview of Material Flow and Factory Layout

Figure 12 gives an overview of the factory layout, which consists of six sections dedicated to specific tasks. Production flows are routed in a single direction through the factory in order to allow for improved efficiency. For monitoring of electrical energy, especially those sections with machine tools are relevant.

Material flow for production starts in the storage area, where the raw goods are kept. Sections A and B are only required for producing the StreetScooter steel frame, but not for other goods. Area C contains assembly stations for specific tasks and need to be realigned with changing production schedules. The StreetScooter steel frame is assembled in section F, whereby a quality check is performed. The steel frames are produced on demand and directly forwarded to the next production step in another factory also in the region of Aachen.

#	Sec.	Machine tool	Controller	Monitored
1	**A**	TRUMPF TruLaser 5030 fibre (incl. TRUMPF LiftMaster)	Siemens Sinumerik 840D	yes
2	**B**	TRUMPF TruBend 5085S	TASC 6000	yes
3	**B**	TRUMPF TruDisk 4001	/	yes
4	**B**	Reis Robotics RV 60-60	/	yes
5	**E**	MAG Welding station	/	no
6	**E**	Framing station	/	no
7	**C & F**	Assembly stations	/	no

Table 3: Production Equipment in the Smart Factory

Monitoring device	Interfaces	Used on #
Weidmüller Power Monitor	MODBUS (RS485, max 1,200 bps)	1, 2, 3
Siemens SENTRON PAC3200	1x RS 485, 1x Ethernet	4

Table 4: Energy Monitoring Devices Deployed in Factory

Table 3 gives an overview of the production equipment being used in the factory. The four main consumers of electrical energy are monitored in terms of their status and energy consumption. The information is gathered directly from the machine tools – where possible – and additionally by external energy monitoring devices, which are described in Table 4. They connect to the local production database via Ethernet.

GE	GEi	Application	Deploy
Gateway Data Handling	Esper4-FastData	Data gathering	Locally
Gateway Device Management	Gateway Device Management	Data gathering	Locally
Complex Event Processing	Proactive Technology Online	Data interpretation	Cloud
Publish/ Subscribe Broker	Orion Context Broker	Data interpretation	Cloud
Application Mashup	WireCloud	Data exploitation	Cloud

Table 5: GEs used in the smart factory

The ICT infrastructure in the factory mainly consists of three domains. On shopfloor level, where the data gathering happens, the machine tools and energy monitoring devices are connected via a LAN based on Modbus and PROFINET with the production site server, where the GE Gateway Data Handling and GE Gateway Device Management are deployed locally on a Dell PowerEdge M620 Blade Server. By means of a standing TCP Socket using the MsgPack framework, shopfloor information is forwarded to the Gateway server, whose role is to act as a connector between the secure local network and the internet. The gateway server pushes this information to the GE Complex Event Processing deployed in the FI-cloud. This GE is used in its default configuration with the GE Publish/Subscribe Broker, also used in the cloud. Lastly, the GE Application Mashup will be used to collect aggregated events coming out of the Complex Event Processing GE and provide them for the local ERP system.

5.1.2 Cross-border VPP

In the second stream, DERs are connected to the Cloud platform to enable joint monitoring and control and to form a virtual power plant (VPP). The 10+ connected sources of renewable energy are located in Germany and Belgium, in proximity to the border. They comprise wind turbines, solar power plants and biogas power plants.

Each DER source provides its actual energy production data. The data are collected at 10 to 15 minutes intervals for further analysis and aggregation. The DERs are equipped with electric meters e.g. pulse meters, which provide the raw data for the generated energy. Each meter is connected to a gateway, collecting the data.

The gateways are embedded systems based on ARM processor technology, equipped with the appropriate electric meter interface. They were developed by QSC AG outside the FINESCE project. The meters and the gateways are installed within the FINESCE Project. The gateways collect the data via the electric meter interface. Then the data are encrypted, temporarily stored and transmitted to the gateway server. The gateway server collects the encrypted data from all the DERs and stores it.

The gateways and the gateway server are developed for infrastructure like DERs and form a closed system within which all data are encrypted. The connection to the cloud is via the gateway server, which will transmit the energy generation data.

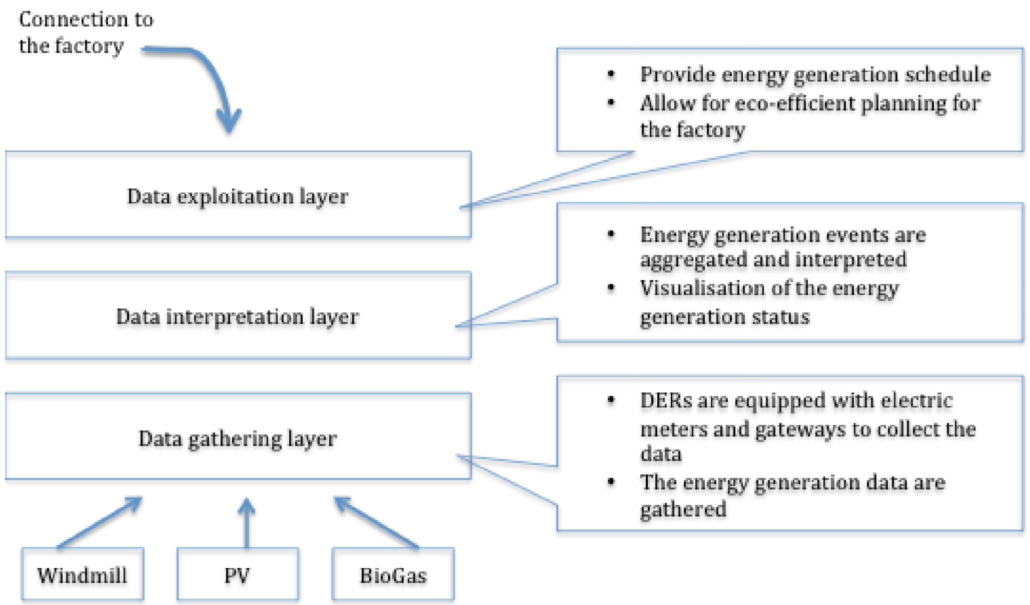

Figure 13: Three layers of data handling in WP3 VPP

The overall data gathering and data handling is divided into three layers, as shown in Figure 13: layer 1, the data gathering layer, layer 2, the data interpretation layer and layer 3, the data exploitation layer. All the provided data from the DERs are collected in layer 1, the data gathering layer, and stored in the cloud as shown in Figure 14. In layer 2, the data interpretation layer, the collected data is aggregated and interpreted. Into this layer the GE Complex Event Processing will be integrated. Layer 3, the data exploitation layer, will be the connecting layer to the factory feeding back the interpreted data to the management of the factory and the VPP.

5.1.3 Cloud Infrastructure

The two streams are realised on a common cloud-based Future Internet platform, using FI-WARE technology. The DER sites will be connected to the Cloud-based controller platform using a highly secure gateway that is already being developed by QSC. Minor adaptions to the gateway due to the different technical and legal requirements in the two involved countries have to be implemented in the project.

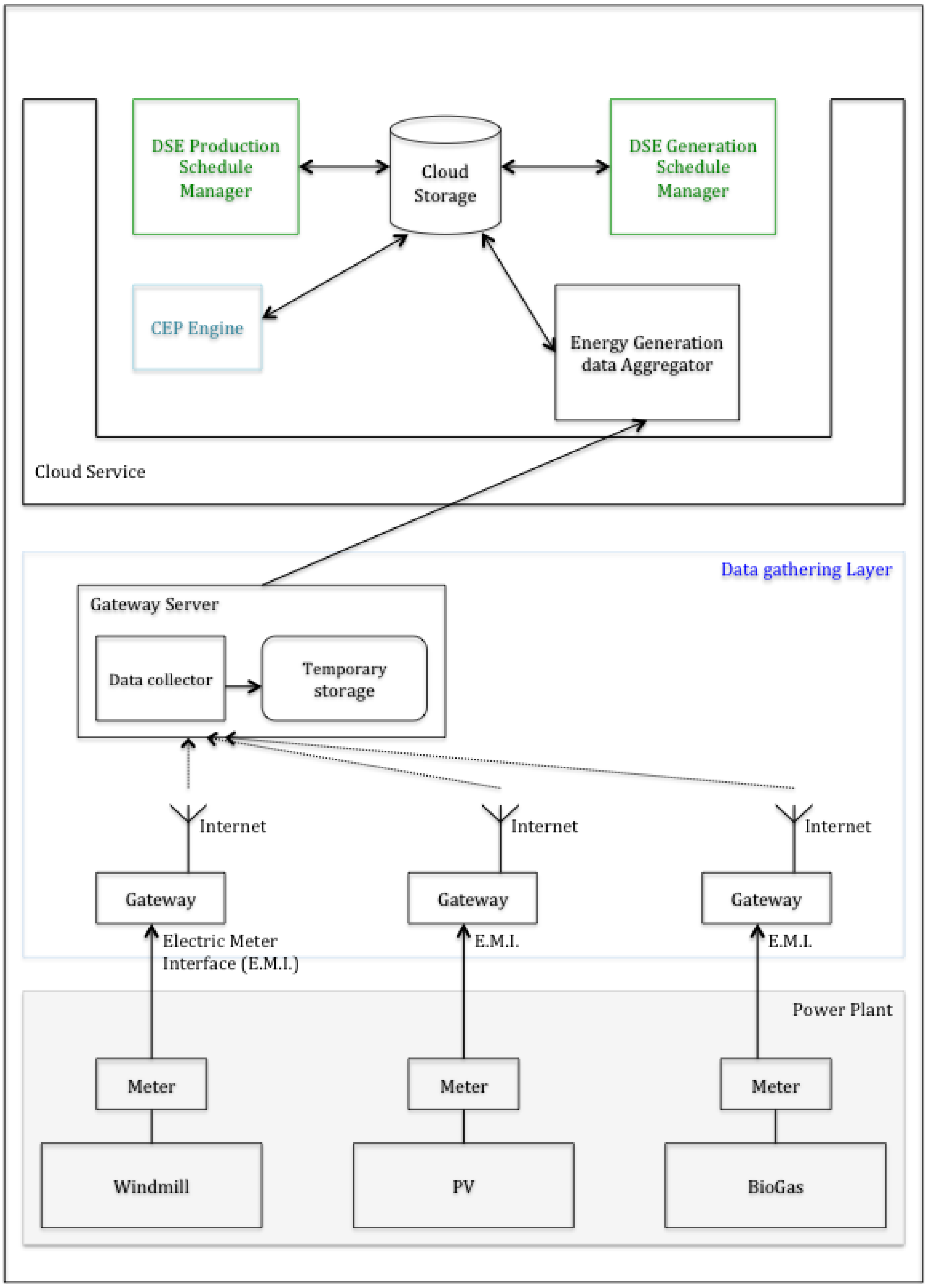

Figure 14: WP3-VPP Architecture

5.2 Interfaces

Internet technology connects the gateway server to the central communication node within the trial site, which is provided by a FI-WARE-based cloud infrastructure. It acts as an information broker, providing centralised identity and storage management and generic functionalities required by the factory and the VPP.

5.2.1 Transmission Channels Between Components

The link from factory to the cloud is performed over TCP/IP and HTTP with TLS/SSL and is based on standard telecommunications infrastructure. Within the factory, the data from the different machines is aggregated and provided to the cloud to be stored via a specific interface (MODBUS). This communication is triggered by the factory. Information available in the cloud which can be consumed in the factory is either pushed over a HTTP interface or pulled by the factory as well over HTTP on demand.

The gateway (located at the DER site) use the Internet technology available at the DER, e.g. cellular, to communicate with the dedicated gateway server. This communication is using an https secured connection. The gateway server was also developed by QSC AG outside the FINESCE Project.

5.2.2 Provided and Consumed Data of Components

On the factory side each machine equipped with a measurement- or model-based power acquisition system provides data on its mean active, reactive and apparent electrical power input. Siemens Sentron PAC measuring devices with additional embedded boards have been used in order to continuously record the machine power consumption (active, reactive and apparent power). Additionally, the actual machine status, i.e. “power on”, “ready to operate” and “working”, is provided as a parameter. Since only a few machine systems have the capability to provide controllable operating modes (i.e. standby of subsystems or of the whole machine) it is not necessary to realise a bidirectional communication with every machine. For those machines which support operating modes with a reduced energy conversion, a specific interface to trigger these modes (based on the industrial standard PROFIenergy) is used.

On the VPP side the actual energy production data is provided by each energy source. The actual date, the planned data, the historical production and location data are provided. Both the current production data and the historical data are provided. Control data for the joint monitoring and controlling is generated through the continuous gathered data of the different supplies. There is a continuous comparison between the planned and actual schedules.

6. Testbed Description WP4

The trial site is implemented in Terni, Italy by ASM Terni (the local DSO) on a MV/LV branch network with a high presence of distributed energy resources which are difficult to manage due to the variability of external factors such as weather conditions. Consequently, as side effects, there arise both reverse power flows through the secondary substation and reduced operational efficiency of the involved components (e.g. power losses in MV/LV transformers and reduced lifecycle). The main objective of the marketplace application is to enable a demand response mechanism aiming at the minimisation of reverse power flow effects, by trying to shift the demand during peaks of production, through the active participation of the consumers, together with all the other marketplace actors (e.g. DSOs, Aggregators, Retailers).

The proposed marketplace application is enabled by a near-real-time smart metering infrastructure that provides the possibility to proactively face the problems of the grid which occur due to the fluctuating power production in the LV network. The huge amount of data collected also from external sources and their analysis provides the possibility to understand how to align the consumption to peaks of production.

A testbed procedure will be applied to check the components and to validate the data and the results of the trial itself. This procedure requires that the applications and grid equipment are able to communicate together in an automated and standardized way without interfering with the normal operating activities of the grid.

6.1 Infrastructure

The purpose of WP4 is to design, implement and validate a near-real-time energy marketplace involving all the marketplace actors. In order to limit the complexity, the marketplace participants are consumers located in a specific neighbourhood area. All these consumers are fed by one specific secondary substation called "SCOV", which feeds a low voltage grid in the west area of the city of Terni. The main features of this secondary substation are:

- small number of customers;
- large photovoltaic plant
- strongly variable bidirectional power flows.

The other features of "SCOV" networks are:

- it covers 68.182 m^2 with a 250kVA MV/LV transformer
- 1,1 km with 0.4 kV lines (eleven main feeders);
- it supplies 263 kW (contractual power) to 20 commercial/residential/industrial customers (3.9 W/m^2 load density, with 147m supply radius);
- two customers are producers with 215kW installed active power.

6.1.1 Installation of New Generation Smart Meters

The challenging objective of the project is to collect the meter readings every 5 minutes. It could be really complex with the currently used meters. In order to deploy a 5 minutes near-real time reading, it has been decided (for reasons of efficiency and time constraints) to adopt a meter with a GSM/GPRS modem. WP4 envisions two different time plans in order to experiment and operate the trial with the usage of different meters.

The meter selected for the implementation of the pilot is called Lennt P2. The constructor is Landis + Gyr Spa. The main features of this meter are:

- GSM/GPRS communication;
- collection of the load profile curves every 15 minutes with the possibility of implementing on-the-spot readings every 5 minutes;
- partial integration in the Advanced Meter Management (ARM).
- conforms to CE Directive, IEC EN 62052-11, EN 50570 series

The partial integration within the current AMM existing in ASM Terni makes the starting phase of pilot experimentation faster and cheaper.

A second kind of meter that will be tested in the trial is ZXF. It is a smart meter which provides load profile curves every 5 minutes. The main meter output interface for automatic readout is GSM/GPRS or Ethernet. ZXF has a module that uses the DLMS protocol (Device Language

Message Specification) according to IEC 62056 for data readout, service functions and parameterisation.

Various device manufacturers have, together with related organisations, compiled the language specification (device language message specification) and committed themselves to use it in their equipment (devices, tariff units, systems, etc.). This specification is standardised in:

- IEC 62056-42: DLMS physical layer
- IEC 62056-46: DLMS link layer (HDLC definitions)
- IEC 62056-53: DLMS application layer (COSEM)

The objective of DLMS is to use a common language for data exchange in the energy measurement and other sectors. In addition to end units such as devices, tariff units, etc., DLMS also concerns the interfaces, transmission channels and system software.

ZXFs aren't integrated in the Advanced Meter Management. A main objective of WP4 is to build and integrate a new Automatic Meter Reading for near real-time reading for ZXFs.

Specific communication modules provide TCP/IP communication over Ethernet or GPRS/GSM between meters and a central system. Up to four multi energy devices can be connected via M-Bus.

For meters and communication modules, no specific acceptance tests are foreseen. The tests are executed by the supplier and a certificate of conformity to the standards is delivered with each component.

6.1.2 Information Providers

6.1.2.1 Meteo predictive model

Weather conditions influence the consumption of electricity and affect the production capacity of a photovoltaic power plant, introducing temporal fluctuations or limiting the production capabilities for extensive periods. In order to better deal with such situations, we foresee that the Marketplace application will be interconnected with an external system (through a request/response interface) to get weather forecast information.

6.1.2.2 Social events *and similar* information flow

The organisation of social events, such as live concerts, trade fairs/exhibitions or even popular TV shows can influence the consumption of electricity over certain time periods. Hence, we also foresee the need to have some interface with external systems, so as to get information about social events that can potentially alter the demands for electricity.

6.1.3 Customer Engagement

The use of incentives and other DR pricing and programme strategies will be explored during the trial with the aim to help reduce reverse power flow in the secondary substations and, consequently, to save money by the reduction of losses in the MV/LV transformers and along the distribution lines. Customers generally have limited knowledge of how to operate their facilities so as to reduce their electricity costs under a DR programme. There is a lack of useful and user friendly information systems/devices to inform the customers of the best time to consume the energy.

The trial applies Manual Demand Response (MDR), which involves manually turning off or changing comfort set points at each equipment switch or controller. Modifications to the site’s electric load shape can be achieved by modifying end-use loads. Demand response activities are triggered by specific actions set exclusively manually by the users according to a dynamic pricing or demand bidding forwarded in the Incentives Plan from the Retailer.

The main thrust of the WP4 experimentation is aimed at developing a near real time metering retrieval and analysis system and an information and communication system to provide users with useful information through an easy dashboard to make them able to consciously manage their consumption. The lever to achieve this is the incentives granted as reward for compliance with the resolution plan of consumption supplied by the Aggregator.

6.1.4 Human Machine Interface (HMI) for the Marketplace Stakeholders

Most of the marketplace stakeholders (DSO, Consumers, Energy retailers and Aggregators) will interact with the marketplace information system by using a web-based interface (that might be enriched with ancillary services such as statistics and graphs). By using it, each stakeholder will be able to view data and, eventually, to perform basic “accept vs. reject” actions. Only for a few stakeholders, email will be used to acknowledge that new series of data or updated data are available. The following sections explain what will be shown to each of the stakeholder that will interact with the marketplace application.

6.1.4.1 Aggregators

This class of stakeholders will use the web-based interface to access a private area where the following information will be available:

- Historical series of consumption data in the form of graphs, for each of the meters as well as the concentrator meter.
- Historical series of production data in the form of graphs, for each of the meters as well as the concentrator meter.
- Event alerts (about weather and social events) that can affect consumption/production in a certain area.
- Alert on energy distribution system costs.

All these data will be used by the aggregators to formulate a Resolution Plan to be sent to the DSO for approval.

6.1.4.2 DSO

This class of stakeholders will use the web-based interface to access a private area where the following information will be available:

- Historical series of consumption vs. production data for each of the meters, as well as for the concentrator meter, that will be useful in understanding possible excess production.
- Historical data of consumption in both “no resolution plan provided” and “resolution plan provided” (that will be useful in evaluating the effect of suggested consumer behaviour on consumption).
- Availability of a new/updated resolution plan to be accepted or rejected.

6.1.4.3 Energy Retailers

This class of stakeholders will use the web-based interface to access a private area where the following actions can be performed:

- View of new/updated resolution plans (assembled by the Aggregator).
- Production of incentive plans tailored to each class of consumer that will be translated into an incentive offer list that will be available to the consumers.

6.1.4.4 Consumers

Different ways will be used to reach users and to send them the Resolution Plan. The most common personal communication channels should be used. The methods developed for the trial are the following:

- e-mail - used for alert messages informing the consumers that a new incentive offer is available which details can be accessed via the web-based interface;
- a web-based interface with which it will be possible for the consumers to:
    - view their own consumption trends and forecast;
    - view the incentive offers proposed by the Retailers;
    - eventually accept an incentive offer.

6.1.5 Components

Table 6 below lists the trial components, indicating whether they are existing or new components.

Domain	System	New in trial	Component/Device
Distribution	• Power Grid HW (Secondary Substation, Cables) • SCADA • AMI/AMR	No No Yes	N/A, existing device N/A, existing device Sensors P2 Ax-E Sensors ZxF100Ax/Cx Comm. Mod. AD-FE Comm. Mod.AD-xG URM
Distributed Energy Resources	• PV Solar Panel • Inverter	No No	N/A, existing device N/A, existing device
Customer Premises	• Agreement • Incentives	Yes Yes	Electricity Consumption Plan Electricity Production Plan Electricity Incentives Plan

Table 6: Trial Components

6.1.6 Data

Table 7 below lists all the sets of data that the Marketplace application processes.

Data	Description	Source
Electricity consumption levels and Load Profile	This is a set of data regarding the instantaneous consumption of electricity (each 5-mins) and the load profile (each 15-mins) per customer. This dataset is coming from the metering devices that are installed at the end-user and on the MV/LV transformer.	DSO/AMR
Electricity production levels and Production Profile	This is a set of data that determines the levels of instantaneous electricity produced (each 5-mins) and the production profile (each 15-mins). It actually defines the total electricity supply.	DSO/AMR
Electricity consumption cost	This is a set of data that defines the unit cost of electricity consumed. This cost may vary depending on various parameters.	Retailer through the electricity market
Incentives	This is a set of data that determines the incentives that the Aggregator is willing to provide in order to achieve some kind of shift in the consumption or production of electricity.	Aggregator
Price policies	This is a set of data that define price policies that could be applied based on the amount of consumed electricity, the time of day, the previous behaviour of the customer, and possibly other factors.	Retailer
Consumer profile	This is a set of data that determines the characteristics of the Consumer. This	DSO: historical data from metering

Data	Description	Source
	dataset is based on the statistical analysis and aggregation of the metering data for each end-user.	
Producer profile	This is a set of data that determines the characteristics of electricity production. This dataset is based on the statistical analysis and aggregation of the electricity production levels of TSO, DER operator and Prosumer.	DSO: historical data from metering
Weather conditions	This is a set of data defining the weather conditions of the immediate future (the next 2-3 days).	Weather forecasting service, i.e. https://developer.forecast.io
Social events	This is a set of data regarding future social events that can influence the consumption of electricity.	Social events service
Resolution Plan	This is a set of data that determines the resolution plan that the Aggregator provides to the DSO for approval and that is consequently used by the Retailer for releasing incentives.	Aggregator

Table 7: Marketplace Data

6.2 Interfaces

Figure 15 provides an overview of the business relationships among the Actors of the Marketplace application, showing how the actors will operate in an energy market with the presence of the aggregator. Each Actor has been defined by a number. Each relationship is represented by a unidirectional arrow that departs from the active part/entity of the relationship and reaches the actor that receives the results of the relationship. Additionally, each relationship is also characterised by a code defined as follows:

- the first number is the reference (red number) of the Actors that supply the info
- the second number is the reference of the Actor that receives the info
- the third character is a progressive letter

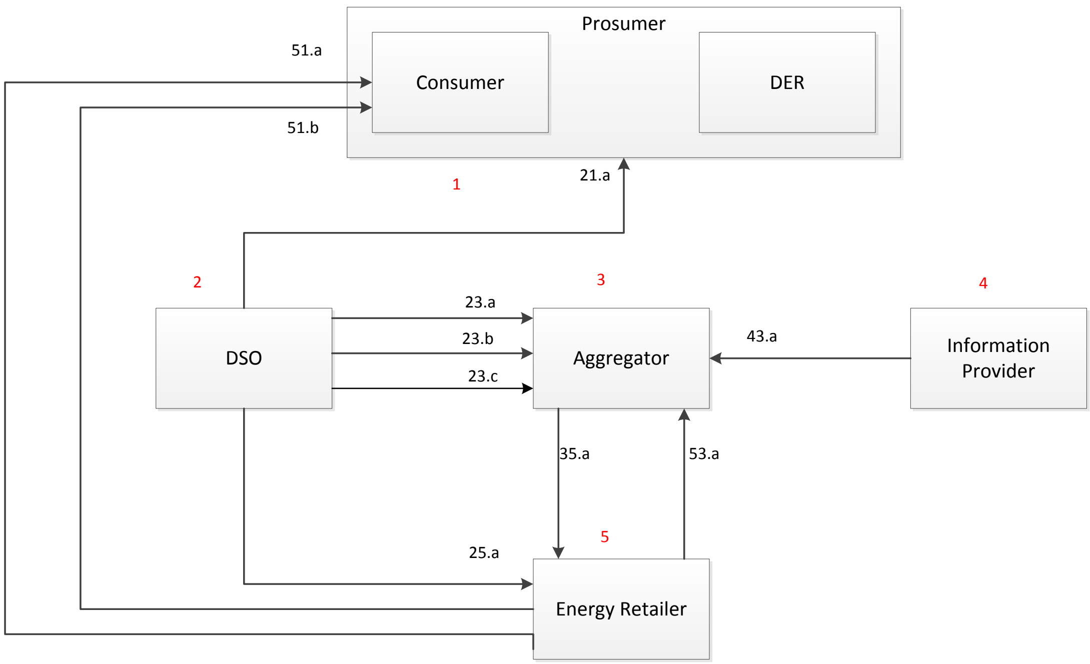

Figure 15: Actors Relationship

In order to simplify the diagram, the Prosumer in Figure 15 is depicted as an entity that incorporates two other actors, the Consumer and DER. Thus, any relationship that is valid for the Consumer or DER is also valid for the Prosumer.

Starting from the coding shown in Figure 15, Table 5 describes the interfaces, i.e. the exchange of information between the actors, with the categories and types of tests to run respectively in the last two columns

Item	Actor	Role	Info/Data	I/O
1	Prosumer	acts both as a consumer and as a producer of electricity. A variety of sources can be utilised for the production of electricity, such as solar energy, wind, etc.	Invoice Incentives Metering	51.a_I 51.b_I 21.a_I
2	DSO	distributes electricity to the actual end-users. A DSO is responsible to take the electricity from the transmission system through the secondary substations and deliver it to the end-users. Moreover, the DSO is responsible for regional grid access and grid stability, integration of DER at the distribution level and regional load balancing.	Metering Metering Stability info Resolution plan approval Metering	21.a_O 23.a_O 23.b_O 23.c_O 25.a_O
3	Aggregator	constitutes the principal business actor in the context of the proposed energy marketplace framework. It is responsible for offering the overall strategic electricity pricing/incentives schemes that will be later used by the Retailer	Information Contract info Metering Stability info Resolution plan approval Resolution plan	43.a_I 53.a_I 23.a_I 23.b_I 23.c_I 35.a_O
4	Information Provider	manages Weather forecasting and Social events services that influence in the production and consumption of electricity	Information	43.a_O
5	Energy Retailer	is the entity authorised to sell energy on the market. It manages the electricity exchange to buy and sell at the best conditions	Metering Resolution plan Incentives Elec. invoice Contract info	25.a_I 35.a_I 51.a_O 51.b_O 53.a_O

Table 5: Marketplace Interfaces

7. Testbed Description WP5 Stream 1

The FINESCE WP5 Stream I trial site is an integration of public and private test-bed facilities in Ireland. It is primarily operated and supported by ESB as an industry partner and WIT/TSSG as an academic partner and, as such, it makes use of existing infrastructure from HEAnet (Ireland's National Research and Education Network) to provide interconnection services. Partner organisations, such as ALUD, RWTH and Ericsson can connect to the testbed platform via WIT using the API.

The testbed will allow FINESCE to build capabilities in data analytics, that is the manipulation of data with the goal of discovering useful information, and in smart energy usage associated with Electric Vehicles and Future Internet technologies (i.e. Generic and Specific Enablers).

7.1 Infrastructure

Figure 16 gives an overview of the trial infrastructure. The trial aims at setting up a charging optimisation system for domestic home charging taking into account several criteria such as customer experience, grid friendliness and renewable energy usage. Two kinds of wireless access technologies will be evaluated during conduction of the trial: WiMAX and LTE.

The heart of the charging optimization system is located at WIT premises in Waterford, Ireland, hosting a central database containing all data collected during the trial as well as configuration data to be taken into account by the charging optimisation algorithm. The management and control software of the Electric Vehicle Supply Equipment (EVSE) are being developed and hosted by WIT. Additionally an API is provided allowing access to trial data for internal partners and also SMEs or other third parties that want to use these data.

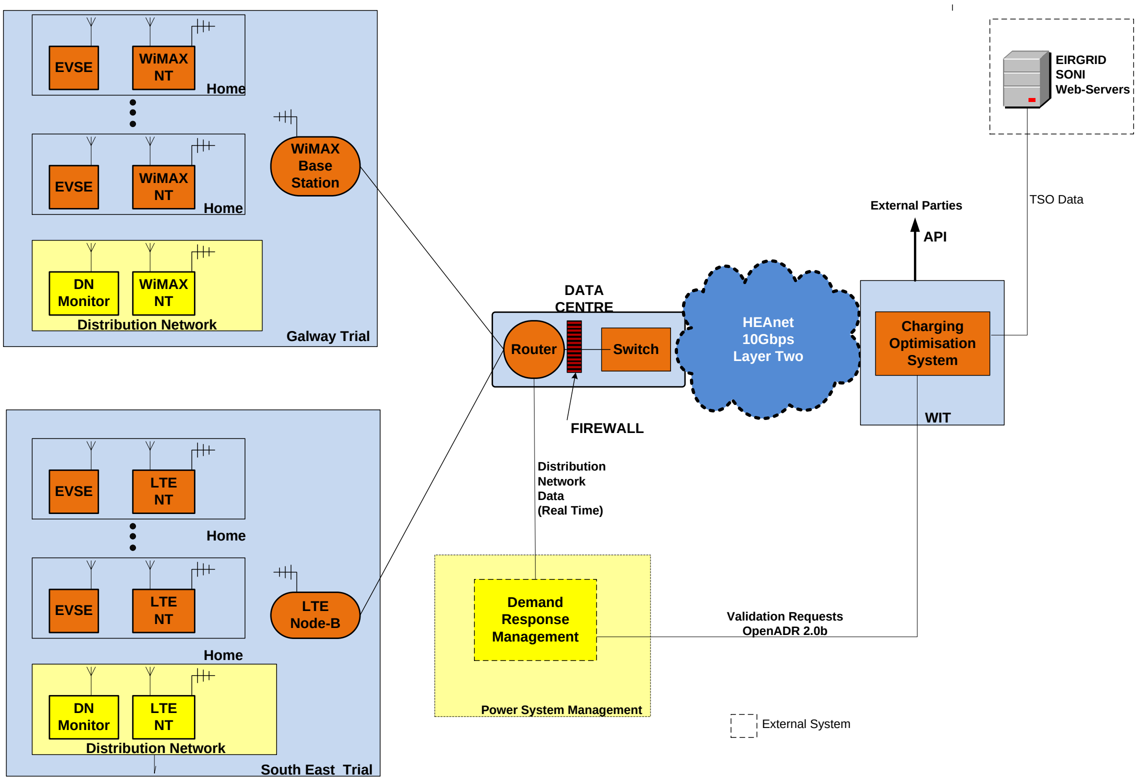

Figure 16: WP5 Stream I Architecture

The selection of ten households participating in the trial (in Roscam, Galway and in Wexford town) is underway and the preparatory work to make the planned EVSEs accessible through the trial infrastructure has been conducted. ESB is offering potential EV user candidates contracts that will allow for the centralised control of their EVSEs.

The hardware involved in realising this testbed is listed in Table 8. A significant number of hardware elements were required to implement the trial design for Stream I. These included, electric vehicle related charging, security and communications devices, core network security equipment, network clock equipment, and Linux servers to host the charging optimisation system. The approach to procuring each of these devices is set out in in Table 8 below:

Item	Resp.	Manufacturer	Qty	Procurement method
Smart Charging Device	ESB	M2C	20	Pre-existing framework contract with M2C
Wi-Fi router and security firewall	ESB	FORTINET	20	Pre-existing framework contract with Eircom
Wi-MAX Network Termination Device	ESB	Airspan	10	Pre-existing framework contract with Airspan
LTE Network Termination Device	ESB	Cradlepoint	10	Pre-existing framework contract with Vodafone (Ireland) Ltd.
High Performance Layer-2 firewall	ESB	FORTINET	1	Pre-existing framework contract with Eircom
PowerEdge C6220 Servers plus Backplane	WIT	Dell	4	Used WIT tendering process (€10,000 to €25,000 six written quotes were required)

Table 8: Items procured - Stream I Trial

7.2 Interfaces

7.2.1 External Interface

Figure 17 illustrates the WP5 API that is being developed. It is an External-facing API as it will act as the management layer through which the EVSEs can be controlled (turned on or off) or data can be retrieved from the database by external stakeholders e.g. other partners in WP5 (or SMEs and Start-ups in the Open Call).

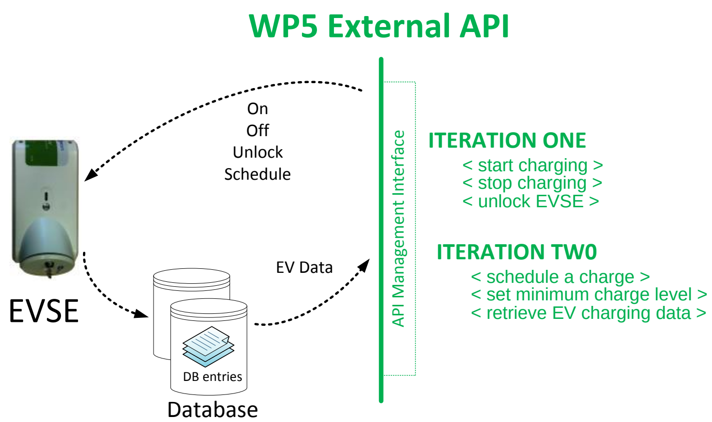

Figure 17: FINESCE EVSE API

Different roles and permissions can be assigned to the different end-user groups to effectively manage the access to functionality and data.

7.2.2 Internal Interface

A second, internal API will act as a middleware component to handle the internal interaction with the chargepoints (EVSEs) – as a result this is called the *EVSE API*.

The EVSE API is an API that interfaces with the EVSEs to handle data records, update the EV database (show in Figure 17 above) and also to interact with the external API in order to issue control commands.

In the FINESCE trials, WP5 is only working with one make of EVSE (from an Irish SME). Of course there will be other EVSEs in the market, so the EVSE API will allow the Charging Optimisation System (COS) to be adapted to work with other EVSE models.

8. Testbed Description WP5 Stream 2

WP5 Stream 2 is deploying and evaluating a new utility communications architecture primarily for teleprotection purposes but also for other utility operational applications.

In general, circuit-switched communication is used in teleprotection applications for high voltage transmission networks today. Packet-switched architectures cannot yet reproduce some of key latency and jitter characteristics of circuit-switched architectures in high voltage teleprotection applications. IEC61850 uses an Ethernet-based architecture and can be easily adopted by utility applications using a packet-switched architecture. However, high-voltage teleprotection primarily uses a circuit-switched (point-to-point) architecture which cannot be equipped with broadcast features. This is a problem for IEC61850 in high voltage teleprotection networks. Packet switching can not deliver the low latency and jitter characteristics required, while the circuit-switched architecture cannot support the broadcast features and is more expensive.

Therefore the ultimate utility communications network is a single communications network which can simultaneously support a utility's primary function of providing a reliable energy network, using high voltage teleprotection, and its secondary objective of enabling energy efficiency via load balancing, distributed generation, AMI and other advanced systems.

OPST (Optical Packet Switch and Transport) is a new emerging communications architecture, which has the potential to solve Utilities' stringent communications requirements. It provides all of the circuit-switched features of SDH and all of the flexibility and economics of packet-switched architectures such as MPLS. OPST supports both a distributed switched meshed topology for Teleprotection applications and a centrally-switched tree topology for Energy Efficiency applications such as Load Balancing and distributed generation applications.

This trial will demonstrate new, innovative use-cases such as IEC 61850 over OPST, Teleprotection over OPST, SCADA over OPST and advanced layer two security.

8.1 Infrastructure

The main facilities include

1. ESB Portlaoise – Substation and Training Centre
2. ESB Dunstown – 400kV Substation
3. ESB Citywest – 110kV Substation
4. Intune Networks – Exemplar Labs test facility

All of these facilities will be integrated together using ESB Fibre infrastructure to form a futuristic smart grid communications network.

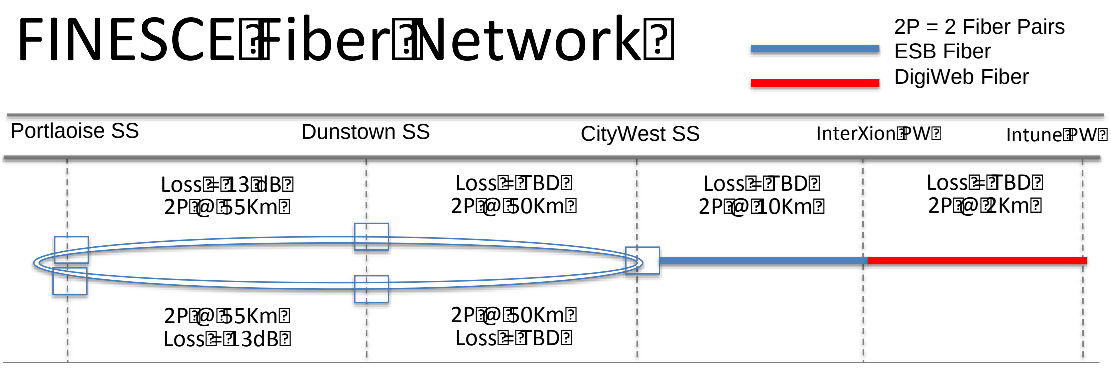

Figure 18: Fibre Connectivity between Sites

ESB Portlaoise is the primary test and integration facility. The other Substation facilities are passive facilities. Their function is to extend the network reach to a representative inter-substation WAN size but not directly connected to relay or grid equipment. Network infrastructure has been integrated into both Dunstown and Citywest, but is not readily accessible as both facilities are live operational high voltage facilities. The project also connects Citywest to Intune, Park West via a fibre link. Basic Teleprotection use-cases don't require this fibre connection but more advanced use-cases such as Utility Business services and throughput testing do require it.

Intune and ESB have setup several teleprotection configurations. Future Utility networks must support both Legacy and next-generation interfaces including IEC61850, Legacy Protection and Legacy SCADA. These represent 3 different architecture configurations and are illustrated in Figure 19 below. Each of the three different Test Series (Future 61850, Legacy Differential and Legacy SCADA) will be trialled sequentially on the same OPST topology.

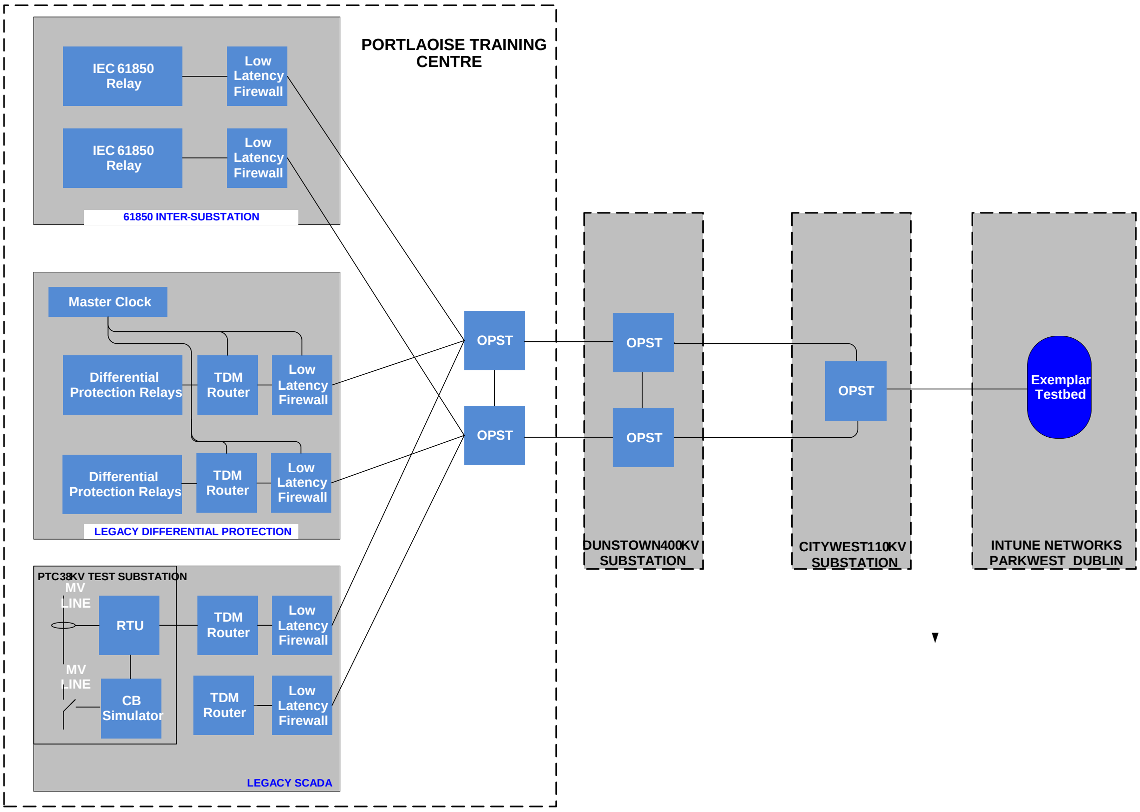

Figure 19: Stream II Architecture and Configuration

The major infrastructure items in realizing this test bed are listed in Table 9 below:

Item	Resp.	Manufacturer	Qty	Procurement method
OPST Equipment	Intune	Intune	5	Internal Procurement
Traffic Analyser	Intune	Spirent	1	Internal Procurement
Aggregation Switches	Intune	Netgear	3	Internal Procurement
IEC 61850 Relays	ESB	ABB	2	Provided on loan, free of charge by ABB.
High Performance Layer-2 firewall	ESB	FORTINET	1	Pre-existing framework contract with Eircom
High Performance Router	ESB	Cisco	1	Pre-existing framework contract with Eircom
Fibre Services from Intune to ESB	Intune	DigiWeb	1	Internal Procurement
Safety Training for working within High Voltage Substations	Intune	Contractor	1	Internal Procurement

Table 9: Items procured - Stream II Trial

8.1.1 Low Latency Firewall

The function of the Low latency Firewall is to listen to the network and filter out spurious messages originating from irrelevant sources, thus securing the substation operation. The approach is in line with NERC-CIP[1] security requirements.

8.1.2 TDM Router

The router provides protocol conversion and legacy interfaces.

8.1.3 IEC 61850 Relay

Two IEC 61850 relays, provided by ABB, are used. A 40km bench test of these relays has been undertaken with promising results. The test of the technology on a larger network, using operational fibre wrapped on high voltage lines will be a more realistic and challenging test.

8.1.4 Differential Protection Relay

Differential protection will be demonstrated using the OPST network by interconnecting two Toshiba GRL 100 relays over the 200 km OPST ring, and utilizing the continuous monitoring and measurement capability of the relays to show the viability of this approach. To interface the relatively low speed legacy communications protocol to the OPST network, a Cisco router, implementing TDM circuit emulation will be used. The router will be connected via the high performance firewall to the OPST.

8.1.5 SCADA Trial

The transport of Remote Terminal Unit (RTU) traffic, used to monitor and control the electrical network via the OPST network is also planned. To provide a trial of the transport of SCADA traffic that is as realistic as possible, it is planned to utilise traffic from a commissioned and live, but non-operational, 38kV station, whose outputs are normally fed into the front-end processors of the grid control system in exactly the same manner as all live and operational substations, wind farms and generators. The normal communication path will be diverted via the OPST for the trial.

8.2 Interfaces

8.2.1 OAM (Operation, Administration, and Management) Interfaces

All infrastructure components feature either a GUI (Graphical User Interface) or a CLI (Command Line Interface) and are individually accessed via an IP address via a standard 10/100 port.

8.2.2 Client Interfaces

Infrastructure Client Interfaces include,

- OPST = 10GE Optical
- Firewall = 10GE Optical & 1GE Copper
- TDM Router = 10GE Optical, 1GE Copper, G703, X.21, V.24
- Relay 61850 = Fast Ethernet Copper
- Relay Differential = X.21
- SCADA = V.24

[1] North American Electric Reliability Corporation - Critical Infrastructure Protection. See www.nerc.com

9. Conclusions and Outlook

An overview of the FINESCE trial site systems has been presented. The focus of this report is on the sites infrastructures themselves. Seven trial site systems have been described on an overall level, but also giving details of the equipment and interfaces. The overall FINESCE functional architecture has been outlined. Details of the GEs and DSEs which will be integrated into the trial site infrastructures and of the FINESCE API are not included in this report.

The trial site infrastructures described here form the basis on the next task in the FINESCE project, the integration of GEs and DSEs into the trial sites, which is the final task before the performance of the trial experimentation itself.

10. List of Abbreviations

B2B	Business to Business
BCC	Building Control Center
BMS	Building Management System
DEMS	Decentralised Energy Management System
DER	Distributed Energy Resources
DR	Demand Response
DSE	Domain Specific Enabler
ERP	Enterprise Resource Planning
ESB	Electricity Supply Board
FI	Future Internet
GE	Generic Enabler
HEMS	Home Energy Management System
HVAC	Heating, Ventilation, Air Conditioning
IaaS	Infrastructure as a Service
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
LV	Low Voltage
MPLS	Multiprotocol Label Switching
MPPT	Maximum power point tracking
MV	Medium Voltage
NGSI	Next Generation Services Interface
OPST	Optical Packet Switch and Transport
PaaS	Platform as a Service
PV	Photovoltaic
SaaS	Software as a Service
SCADA	Supervisory Control and Data Acquisition
SDH	Synchronous Digital Hierarchy
SME	Small & Medium-Sized Enterprise
VPP	Virtual Power Plant
WP	Work Package