Programme Area: Smart Systems and Heat

Project: Data Management and System Architecture

Title: SSH International ICT Initiatives Report, Review of UK/EU ICT Directives

Abstract:

The principal objective achieved within the reports is the identification from other relevant projects of architectural techniques that can be applied to the SSH data architecture design and to identify and assess UK and EU directives, protocols, and legislative initiatives that may impact upon delivery of the SSH Programme.

Context:

This project specified the data system functionality and architecture that would fulfil the information and service requirements of a smart energy system. This included data security and privacy aspects. Hitachi Europe and energy & sustainability consultants DNV Kema worked independently on two £100,000 contracts to identify any data system constraints that need to be incorporated into smart energy systems. The projects were launched in February 2013. The envisaged ETI Smart Systems and Heat system will depend on Information and Communications Technology (ICT) for its efficient design, operation and management. The ICT system will need to provide functionality right along the energy delivery chain: from supply to the end consumer. It will also need to support commercial activities such as billing, and to support academic analysis and review of the system during trials and proving.

Smart Systems and Heat: Data Management and Overall System Architecture (WA3)

WP1a - International ICT Initiatives Review Report

DELIVERABLE (D.DK3.1)

Energy Technologies Institute

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Executive Summary

The Energy Technologies Institute (ETI) recently appointed DNV KEMA to deliver a package of work within work area three (WA3) of its Smart Systems and Heat (SSH) Programme. This is one of two initial reports which set the scene for WA3 (which focuses on Data Management and Overall System Architecture). It provides a review of relevant international smart energy projects (in particular, those with a strong ICT aspect to them) and discusses some of the common features and overlaps. It further looks at areas which do not appear to have been addressed yet and therefore may be worth considering in the context of the SSH programme.

There are now hundreds of smart energy projects underway (or that have been completed) globally. The magnitude and complexity of these projects often depends on a number of factors; not least local Government policies, the regulatory environment and the source or type of funding involved. DNV KEMA has carried out both an internet search and a detailed analysis using its internal databases.

The main body of the report has been structured around three key themes: interoperability, system control and cyber security which provided a sensible grouping given the common features and overlaps that were found.

High-level conclusions that can be drawn from this work are as follows:

1. Interoperability is a vital prerequisite for a successful trial and a workable, enduring smart energy system;
2. New system control techniques will be essential for performing groundbreaking functions in a dynamic, bi-directional energy environment;
3. Due regard should be paid to what data needs to be transferred from within, and between, the various tiers of the smart energy system, and what security should be in place to ensure that critical national infrastructure and customer information is appropriately protected.

Throughout the analysis, it was found that few projects cover the integration of both electricity and heat, clearly highlighting the uniqueness of the SSH programme. Furthermore, cyber security has more often than not been placed into the ‘too difficult to do’ box. However, given the country-wide focus of the SSH programme this issue will need to be tackled.

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1 INTRODUCTION

During the first quarter of 2013, DNV KEMA has been commissioned by the ETI to deliver a number of work packages which set the scene for WA3 of the SSH programme. The focus of this work is around Information Communication Technologies (ICT) and a detailed overview of the programme can be found in Appendix I.

This particular report is one of two formal deliverables within work package 1a (as highlighted in Figure 1). Together with two further elements (being developed by the University of Surrey and Delta-ee respectively) the building blocks for an ICT Technology Roadmap will be created. This is further illustrated below:

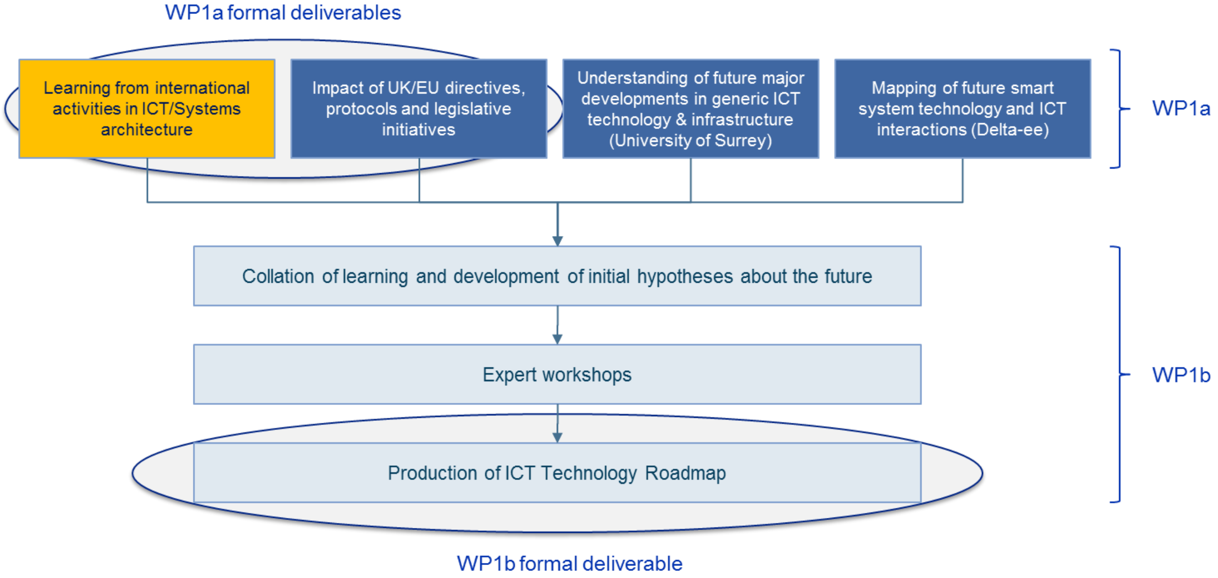

Figure 1: Interactions between work packages 1a and 1b.

The findings discussed in this report will have a significant bearing on the ICT Technology Roadmap work that follows in work package 1b. The findings not only highlight areas where mistakes have already been made in the past (and thus can avoided going forwards), but where little evidence has been gathered as to the viability of a specific ICT element.

2 METHODOLOGY

There are many initiatives that have been undertaken (or that are on-going) in the smart energy system domain and DNV KEMA has considered projects from Europe, the Americas and Asia in compiling this review. Given the sheer number of initiatives, our methodology for choosing which projects to reference within the text was based on the following criteria:

- A project start date from January 2007 onwards;
- At least two key technologies involved;
- At least two stakeholders were involved;
- Contains at least one significant finding in the ICT domain.

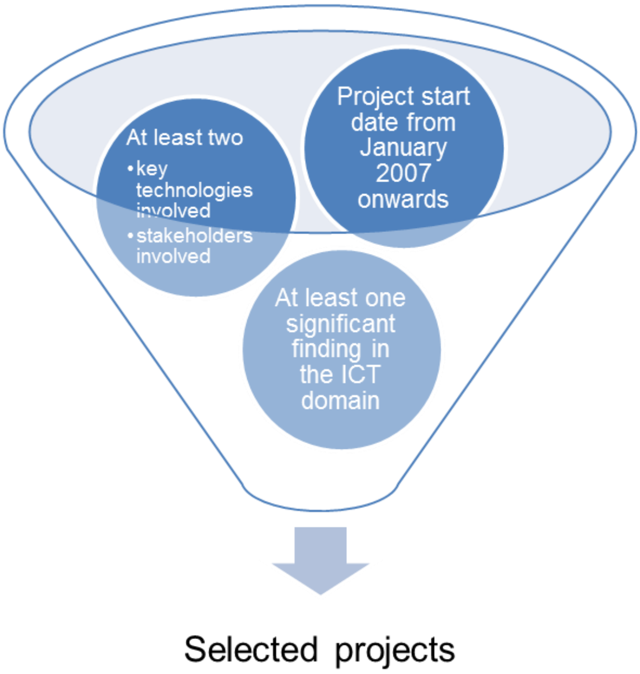

Figure 2: Filtering criteria

2.1 Assumptions/Caveats

Given the pace that ICT develops, DNV KEMA felt it appropriate to focus only on projects that have taken place since 2007. Moreover, the focus for the SSH programme is on quite a broad spectrum of technologies that will need to be integrated and thus DNV KEMA has tried to look at projects of a reasonable magnitude and those that have multiple stakeholder involvement. Lastly, given the emphasis on ICT, DNV KEMA has only selected projects that have a key ICT finding.

The report does not cover (in any detail) smart metering projects, of which there are many (particularly in the US) given the SSH programme has a much broader focus. And, due to the international focus of this review, UK projects (including those funded by Ofgem's Low

Carbon Network Fund) have been excluded. Moreover, in many instances, availability of information regarding project outcomes was an issue. It should also be noted that there are one or two other projects discussed in the report which are exceptions to the rules above which had particular relevance.

2.2 Referencing convention/further details

The full list of projects explored (268 projects) and the filtering that has been applied can be found in Appendix II. In the main body of the report, project references throughout are grouped by continent and the following annotation applies:

- **EUR = European project**
- **AME = American project**
- **AP = Asia Pacific project**

Having applied the filtering, 29 projects (from a possible 268) have been referenced in the main part of the report. These are listed below (**Error! Reference source not found.**):

REF	Project	Area	Start	End	Key ICT element
AME 1	Fort Collins Renewables and Distributed Systems Integration Project	USA	2009	2012	Platform acting as a Network Operating System for the DER allowing the necessary communication and control infrastructure to interface with existing Building Automation Systems and SCADA systems
AME 2	Smart Study Together	USA	2010	2011	Programmable thermostat and a web portal
AME 3	SmartGridCity	USA	2008	2011	Integrated Volt/VAr control at distribution feeders
AP 1	Smart Grid, Smart City	Australia	2010	2013	4G/LTE platform for machine to machine communications
AP 2	Yokohama City	Japan	2010	2014	Building and Energy Management Systems and Home Energy Management Systems to enable DR
AP 3	Intelligent Energy System	Singapore	2010	2013	Pre-programming of automation devices and smart meter appliances
AP 4	Smart Village Program	Australia	2010	2012	Home Area Networks (HANs) to provide real-time information on the energy consumption of individual appliances and remotely monitor and control the appliances online
AP 5	Electric vehicle charging station	China	2010	n/a	Protocols for EV charging stations
AP 6	Demand Response System Pilot	China	2012	n/a	Automated demand response, advanced energy management, and sub-metering
EUR 1	European Distributed Energy Partnership	FR, ES, CY, LV, BE, DE, GR, SE, HU, TR, FI, GR, UK, AT, Pl, CZ	2004	2009	Decentralised multi-agent software solutions to control DER
EUR 2	eTelligence	Germany	2008	2012	Agent-based algorithms to balance demand and supply, aggregate data and make it anonymous

EUR 3	ADINE	Finland	2007	2010	System operating on protection, decentralised control and area control levels. Management system includes three layers: protection system, automatic control system (decentralised) and area control level (centralised).
EUR 4	MERGE	ES IE EL DE BE NO UK PT	2010	2011	Intelligent based approach for EV charging involving full use of ICT, to manage and control them in the electrical network, event and alarm management system
EUR 5	Beywatch	Spain, Greece	2008	2011	Software comprised of: i) agent based scheduler & controller; ii) home energy framework which provide services to the scheduler; iii) the Machine to Machine (M2M) communications interface
EUR 6	Cell Controller Pilot Project	Denmark	2005	2011	VPP configuration and operation software
EUR 7	Model City of Mannheim	Germany	2008	2013	'Energy internet' created in the project cities by using the electricity grid for data transmission
EUR 8	SmartHouse/SmartGrid	Netherlands, Germany, Greece	2008	2011	Multi - agent software allowing agents to negotiate for the cheapest power, sell generated power at the best price and try to get the maximum benefit from each source of power consumption
EUR 9	RegModHarz	Germany	2008	2012	Generic data model enabling the automated assimilation of systems in energy management
EUR 10	Growders	FR DE ES NL	2008	2011	Optimisation model assessing the best application of a storage system in a electricity grid
EUR 11	Power Matching City	Netherlands	2009	n/a	Coordination of hybrid heat pumps, CHPs, EVs and smart appliances in a single generic ICT solution
EUR 12	Kythnos Micro-Grid	Greece	2006	2009	Centralised and decentralised control strategies in island mode. Multi- Agent system concept for decentralised control
EUR 13	EDISON	Denmark	2009	2011	Algorithms for the external control of EVs charging include 'driving pattern generators'
EUR 14	Address	ES FR IT CH SE NL UK FS BE D RO	2008	2012	Software interfaces have been developed to control air conditioning and electric heating systems
EUR 15	Virtual Fuel Cell Power Plant	Germany	2001	2005	System communication with on-site energy management application allowing utilities to control the micro-CHPs
EUR 16	AURA NMS	UK	2007	2010	Peer-to-peer network controllers/decision-makers placed in substations
EUR 17	Evora InovCity	Portugal	2007	2017	Energy boxes to apply home energy management
EUR 18	Smart City Malaga	Spain	2009	2013	Advanced telecommunication systems and remote control operate in real time
EUR 19	FENIX	ES UK SI AT DE NL FR RO	2005	2009	Scalable and hierarchically flexible information and communication architecture
EUR 20	Twenties	DE, NO, UK, IE, ES, IT, BE, DE, NL, FR	2010	2014	VPP system is divided into several system components, each with its own responsibility and purpose (modular design).

Table 1: List of project analysed

Further details of the 29 projects that have been reviewed have been provided in Appendix III (Summary table) and IV (Short description of each project).

2.3 Structure

During the analysis it became apparent that common ICT features contained within the projects analysed could be broadly assigned to three key themes: interoperability, system control and cyber security – arguably essential prerequisites for a smart energy system. The subsequent sections deal with each of the themes as shown below (Figure 3):

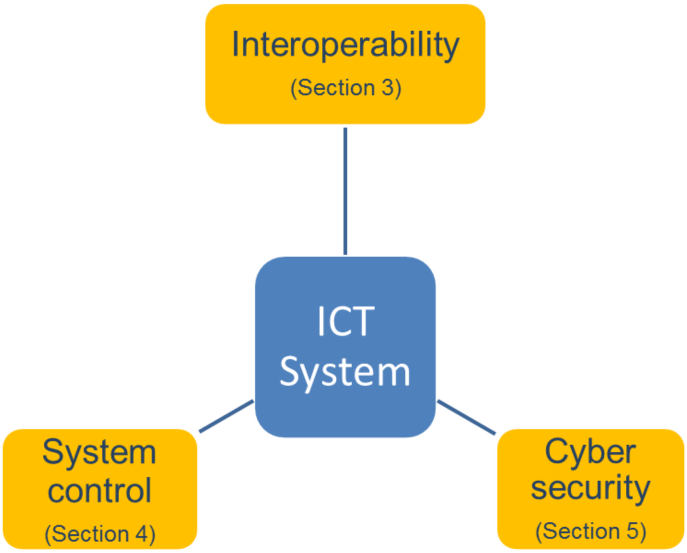

Figure 3: Key themes analysed

Each section starts with a definition of the term and a description of the areas where common features were identified. It then goes on to list a series of findings which are further substantiated by the relevant project details. Finally, areas worthy of further exploration (gaps) in the context of the SSH programme are discussed.

3 INTERPERABILITY

3.1 Overview

Interoperability is a term widely used within the smart energy arena. Interoperability is a 'desired state' - whereby elements of a system that need to interact, do so seamlessly. This 'desired state' is harder to achieve when the products that make up that system are provided by different manufacturers or where different standards are used. If a device complies with a particular standard, it does not necessarily mean that it will safely co-exist in its intended environment with other 'compliant' products. This is because standards can be interpreted in different ways. Interoperability can only be guaranteed with a comprehensive testing regime based upon 'one agreed version of the truth'. The focus of such a regime is to look at each functional element in isolation (and then within its intended context/environment) to verify that it is performing its job correctly. Interoperability does not just apply within systems but between systems as well. In a smart energy system context, there could be multiple stakeholders, with multiple systems. Therefore the failure of one element could be hugely damaging and have physical or indeed financial consequences.

Integration of systems developed by different parties is an issue that a number of projects (AME 1, AP 3, EUR 3, EUR 10, EUR 19) identify as crucial. Also, standardisation was a key trend for many of the projects, and was seen as key success factor (EUR 1, EUR 4, EUR 5, EUR 6, EUR 11, EUR 20). The next section pulls out some of the key findings making reference to the relevant projects.

3.2 Findings

Finding 1: Establishing and testing (as early as possible) communication protocols and standards is key in order to ensure interoperability within and between systems.

The importance of interoperability is recognised in the Intelligent Energy System project (AP 3) with attention paid during the first phase of the project to establish the communication protocols and standards. Similarly in the Growders project (EUR 10), the importance of communication for the remote control of Distributed Energy Resources (DER) turned out to be a learning point in the first pilot projects. Subsequent pilots were installed with an improved ICT system.

Finding 2: A scalable and flexible ICT architecture alleviates difficulties with regards to systems integration.

Due to a lack of standardisation, difficulties were faced in the Twenties project (EUR 20) pertaining to the ICT system integration for a Virtual Power Plant (VPP) architecture featuring parties responsible for balancing as well as Distribution Network Operators (DNOs). Moreover, local units looking to integrate their operations within the VPP were faced with high integration costs. The initial development of the VPP architecture was custom-made to match the functionality of the ICT systems it would be interfaced with. The workflows (e.g. a workflow for converting consumption flexibility into bids for price-independent base load) were developed to comply with external systems. These external interfaces were time-consuming to integrate with due to strict ICT security regulations. Highly specialised systems operated by those responsible for balancing were also difficult to integrate with. Using lessons captured from the first VPP system, the next iteration of the architecture is intended to be a much more flexible and robust solution. It is expected the future architecture will be more modular (enabling increased flexibility and updates without affecting the rest of the system). Low coupling is expected between modules with interfaces between modules being built around open communication protocols. This will allow easier third party module integration. Moreover, the FENIX project (EUR 19) has tested common information architecture to build the different forms of aggregation needed for DER.

Finding 3: Control software prototypes should be made available for partner review early on in a pilot.

In the Fort Collins Renewables and Distributed Systems Integration project (AME 1) it was seen that limited feedback capabilities of DER assets and firewall issues led to unexpected asset response rates. This shows that care needs to be taken when choosing communication and control infrastructure. Different partners in the same project may use a variety of systems and the means of communication needs to be compatible with any existing infrastructure. In this instance, DER site partners lacked confidence in the control software - partners had other responsibilities, and wanted to integrate with this software without any disruption to normal operations.

Finding 4: Existing standards can be extended to allow new systems to be incorporated, but this takes time.

The Kythnos Micro-Grid project (EUR 12) has implemented the micro-grid concept on a small scale. Extensions to the IEC 61850-7-420 standard have been made in order to incorporate other equipment that was not in the standard. Similarly, in the RegModHarz project (EUR 9), the IEC 61850 standard was extended to enable the simple and secure connection of systems to a joint control station.

Finding 5: Use of open interfaces and standardised protocols (for the implementation of active network management) is needed to ensure seamless systems integration.

The ADINE project (EUR 3) revealed that the integration of new “active” devices into existing systems is an important issue. When transitioning to a smart energy system it is not possible to replace the whole automation/ICT system in one go as the network has to keep running - therefore creating a more active network requires continuous evolution as opposed to a revolution. Hence, the integration of active devices should be based on open interfaces and standardised protocols to avoid the need to replace vital parts of the system every time a new component/function is implemented.

Finding 6: In developing Virtual Power Plants (VPPs), due regard should be paid to the different communication methods/protocols that may be deployed in different parts of the energy system and how to bring these together.

The Cell Controller Pilot Project (EUR 6) revealed that in order for technical VPPs to interact successfully, they must use the same open communication standards. In this project, a technical VPP was developed which takes into account the technical aspects of the local distribution network and coordinates control using the 'Cell Controller', a control system specifically developed for this project. The 'Cell' is defined as the 60kV distribution grid below each 150/60kV transformer. Each 'Cell' can act as a virtual generator with the same or better control capability than a power station of the same size. The 'Cell Controller' has been designed such that each 'Cell' can be combined with other cells to comprise the grid area covered by DNOs (and even Transmission System Operators (TSOs)). A Supervisory Control and Data Acquisition (SCADA) system using the Omron specific protocol is used to communicate with the Cell Controller. Using this it is possible to enter external signals to dynamically set voltage and frequency settings. Since it is necessary to maintain continuous communication with substations and assets for monitoring the system and issuing commands, a communications method compatible with the DNO's existing communication system must be implemented. In this project a wide area communication systems consisting of DSL, GPRS and fiber communications was used, with CHP and wind turbine sites being retrofitted with communications capabilities.

Finding 7: It may be more appropriate to keep machine-to-machine communications independent from the wider system to ensure a future proof solution.

In the Beywatch project (EUR 5), software for home energy management was tested. This can only optimise consumption with exact knowledge of the behaviour of the devices it is connected to, or at the least the energy load curve that is related to the behaviour. However, because no common standard has been adopted with respect to white goods, each appliance had to be configured independently making installation difficult. Moreover, as home automation standards do not yet exist, the outcomes from this project imply that aspects of machine-to-machine communications should remain independent from the rest of a home energy management solution. Although this may increase cost, it will ensure a future-proof solution.

Finding 8: Software platforms for energy management can be effective in enabling the integration of a diverse range of communication systems.

An open software platform for energy management was developed in the RegModHarz project (EUR 9). It enables the integration of the most diverse communication systems (e.g. the EEBus for communication with household appliances) and has already laid the foundation now and for the future to develop numerous applications for optimising power and heat supply.

Finding 9: Particular attention might be needed when it comes to standards dealing with flexible loads (demand side response).

In order for demand side response to be introduced into the market, more needs to be done with regards to standardising control systems. Currently, retro-fitting costs are higher than returns generated from flexible loads according to the findings from the European Distributed Energy Partnership project (EUR 1). When developing control and monitoring solutions, a large amount of cost and time went into creating a custom-made installation for each location. The project recommended bringing in standards for control systems (that are currently being produced), to enable easy integration of new installations for flexible loads. This would be much cheaper than retro-fitting control systems (which had not been designed with load flexibility in mind). The high costs not only arose from retro-fitting the control systems, but also the costs of site surveys and electrical planning. Standardisation of equipment as well as installation and interface requirements would clearly drive down these costs, and allow smaller loads to enter the demand response market. Lessons can also be taken from the Power Matching City project (EUR 11), where load flexibility provided by the various technologies can be treated in a similar way which facilitates a move towards standardised interfaces.

Finding 10: To enable "plug-and-play" charging for electric vehicles, ICT stage requirements might need to be standardised.

The MERGE project (EUR 4) revealed that for plug-and-play charging of electric vehicles, ICT stage requirements need to be standardised. More specifically, the means of communication between the entities involved in the charging process and the payment methods for charging electric vehicles should follow defined standards. The EDISON project (EUR 13) contributed to the development of international standards (IEC TC69 WG4 (EV Power supplies and chargers), IEC/ISO JWG (Vehicle to the Grid (V2G) Communication Interface)). Lastly, in the Electric vehicle charging station project (AP 5), significant effort has been undertaken to establish standards for EV charging stations to support the development of the EVs.

3.3 Gaps identified

When determining the design criteria for ICT it is necessary to determine what balance is desirable between 'flexibility of the functionality' versus the lifespan of the underlying ICT and electronics. In other words: how long will the technology that is to be implemented have to last? Moreover, there would appear to be a lack of open protocols for the switching of 'smart appliances' and 'smart heat pumps' as these markets are not yet mature.

4 SYSTEM CONTROL

4.1 Overview

System Control refers to a set of functions that are performed to routinely monitor and/or operate a system (for example a network management system). Such functions could be ensuring the ongoing integrity of the system or responding to its ad-hoc demands. In a smart energy system, the number or frequency of functions being performed is likely to increase exponentially, due to a massive increase in the number of connected devices.

Agent-based algorithms seem to offer enhanced system control functionalities in balancing demand and supply (EUR 2, EUR 5, EUR 7, EUR 9) as well as in congestion management, critical operations, load shedding and the integration of new assets such as EVs (EUR 4, EUR 8). Domestic demand response has been explored (AP 6, EUR 2, EUR 17) as it is expected to have an important role to play in a smart energy system. Similarly EVs are envisaged to be important and their integration to the grid is being tested in several projects (EUR 4, EUR 13, EUR 18). Lastly, the role of forecasting energy demand and supply is highlighted (EUR 2, EUR 5, EUR 7, EUR 9). The next section pulls out some of the key findings making reference to the relevant projects.

4.2 Findings

Finding 1: Agent-based control is an effective way to match energy supply and demand.

The RegModHarz project (EUR 9) has used agent-based control to successfully incorporate the control of multiple renewable sources. Forecasting systems that can predict how much electricity will be generated from renewable sources enables the timely provision of generating capacities (e.g. biogas facilities) or the early initiation of consumption adjustment (e.g. more cooling on reserve). This would inherently relieve the stresses on the distribution networks, reduce reinforcement needs and increase regional value added. However, this calls for considerable efforts in energy technology and above all in information and communications technology. The ICT solutions developed in the project help to ensure that locally produced power is also increasingly consumed locally, which will ease the burden on the grid.

Results from the Model City of Mannheim project (EUR 7) revealed that supply and demand can be more effectively balanced by implementing more ICT. Similarly, an ICT platform for distributed control in electricity grids at aggregated levels has been developed in the Power Matching City project (EUR 11). A generic design has been developed that allows coordination of hybrid heat pumps, CHPs, EVs and smart appliances such as freezers in a single ICT solution. The various technologies used in this project provide flexibility without impacting the overall comfort to the end-user, allow interoperability between components, and the ability to grow the system organically. Measurements from the micro-CHP systems and the hybrid heat pumps indicate that the system responds quickly to fluctuating demands, and maintains an appropriate fill level for each household over the long term. An ICT infrastructure was successfully designed and implemented enabling end-users to have feedback on the operation of their own system and system operators to control their respective clusters.

Lastly in Yokohama City, a project (AP 2) which provides every participating household with photovoltaics and a home energy management system will be initiated, thereby producing energy to be consumed locally, by controlling home electronics and devices that create and store energy. Furthermore energy management systems for entire apartment buildings will be included to manage demand response. Rather than optimising each device separately, the controls will focus on entire buildings that have different types of load patterns, depending on purpose and size, whilst maintaining comfort levels. In practice, Demand Response (DR) availability will be communicated between the various building energy management systems, indicating the surplus of energy per building after which DR controls will be carried out with regard to the home energy management systems.

Finding 2: Technical VPP can be an effective method to control a system with a very high penetration of intermittent renewables.

With a very high penetration of renewables, VPP can be an effective solution. The Cell Controller Pilot Project (EUR 6) successfully demonstrated operation of a technical VPP (allowing for decentralised control of technically aggregated resources in a distribution network). As described in Section 3.2, the Cell Controller system includes cells that can act as a virtual generator with the same or better controllability than a power station of the same size. This allows increased services for the distribution network such as voltage control as well as reactive power import/export. For each cell, a layered control hierarchy is used, utilising distributed agent technology and a high speed network. Each agent is either an industry central processing unit (CPU) a high-end remote terminal unit (RTU) or an intelligent meter depending on the level at which the agent is found in the system. The agent is an independent unit which is authorised to control a group of sub-units. It can act independently, according to a pre-defined set of rules or according to orders received from superior agents. Overall, the project allowed technical activation of resources to be carried out in parallel (without disruptions) with normal power market operation. In the UK it is expected that the penetration of intermittent renewables (especially wind) will become increasingly prevalent, making the VPP concept appealing.

Finding 3: Central remote control of domestic CHP units is an option for alleviating peak demand.

In the Virtual Fuel Cell Power Plant project (EUR 15) a Central Control System was developed to enable the operation of the residential CHP-units. The system communicates with the on-site energy management application and allows utilities to control the micro-CHPs in the event of a power spike and/or defined load profiles. The load profiles were sent via GSM deploying radio ripple control. Software interfaces have also been developed to control air conditioning and electric heating systems in the Address project (EUR 14).

Finding 4: Active management of the distribution network has knock-on implications (or benefits) for planning and asset management procedures.

The AURA NMS project (EUR 16) has explored a means to gradually devolve control authority from the existing central control room (which is semi-automated and semi-manual) by using a peer-to-peer network of controllers/decision-makers placed in substations. The controllers can: a) open and close remotely controlled switches to shift loads to different parts of the network; and, b) use local small-scale generation to help regulate the voltage magnitude. Significant progress has been made with regard to voltage control, thermal ratings and restoration algorithms based on the DNO requirements. One of the key lessons was that 'technical' solutions for managing changing network requirements only address part of the problem: DNOs also need to develop the appropriate planning and maintenance procedures and processes for the entire life cycle of active network management schemes. In SmartGridCity project (AME 3), integrated Volt/VAr control was carried out on 2 feeders. 10-12 sensors per feeder were used and these were located at strategic points where customer voltage was expected to vary most from feeder voltage. The voltage was regulated up or down automatically in real-time based on voltage measurements through the system. It was seen that the impact of distributed automation on reliability benefits is high. However, data accuracy was essential to the functionality of the system.

Finding 5: Agent-based control could improve network congestion.

In the SmartHouse/SmartGrid project (EUR 8), congestion management as well as support for islanding/black starts was tested with the use of JAVA based software, implementing intelligent agents. For congestion management purposes, the intelligent agents monitored the system and provided other agents and the aggregator with system data such as consumption and production levels, voltage levels etc. The system also produces a list of loads that can be shed. The operation of the algorithm showed that the system was able to predict a disturbance such as an overload before it occurred and take action (unlike a simple algorithm which would only react when the overload is actually detected). A warning time of 15 minutes was enough for the system to respond to and prevent any disturbance.

Finding 6: Energy boxes could be used to apply domestic demand response.

The Beywatch project (EUR 5) developed and tested the implementation of load management schemes. The project proved that (in enterprises and large municipal energy consumers) load management is technically and commercially feasible. As the complexity of dynamic rates precludes a manual response to price incentives the task is instead performed by an energy management system using energy-boxes. The energy-boxes receive price signals or request the current price before switching on an appliance via standardised interfaces. In the Smart Village Program (AP 4), Home Area Networks (HANs) are installed to provide real-time information on the energy consumption of individual appliances and remotely monitor and control the appliances online - including air conditioning, hot water systems, solar power systems, lighting, and entertainment and laundry appliances. Moreover, in the Smart Study Together project (AME 2), a programmable communications thermostat allows customers to choose a “cost/comfort” balance and, combined with the price rates, enables automated load reduction. Lastly, in the Demand Response System Pilot project (AP 6), the installed equipment manages energy supply and demand and automatically adjusts electricity consumption. Automated Demand Response puts in place an automatic system of technology checks and balances taking into account peak hours and higher electricity prices.

Finding 7: Care should be taken when choosing device communication methods.

Similarly, the Evora InovCity project (EUR 17) uses energy boxes, which were developed especially for the project. Every household will require such a device to connect to the grid. The communications structure that was selected for installation was PLC DCSK. This technology has served the majority of functionalities but there are limitations in terms of its capability to support future features, particularly demand-side management, mass use of electric vehicles and micro-generation. There are a range of other PLC technologies gaining market share but until such time as a data model has been created to assess the full latency requirements for a smart energy system it will be impossible to determine whether or not these will have sufficient capability.

Finding 8: Decentralised agent-based energy management systems appear to be a credible and more powerful alternative to centralised control of Distributed Energy Resources (DER) and load shedding.

Decentralised multi-agent software solutions may be applied and implemented for in-home appliances as part of a home energy management solution as suggested in the European Distributed Energy Partnership project (EUR 1). This is a credible alternative to centralised DER control, as it will most likely lead to better customer acceptance given decisions are taken locally. Similarly, a load shedding schedule was created based on criticality of consumption loads (and consumer willingness to pay) and appliances were able to operate in island mode in the SmartHouse/SmartGrid project (EUR 8). It was shown that with a smart agent-based energy management system, no excessive load shedding took place in houses (unlike a simple algorithm in a centralised system which can only monitor total consumption and only has the ability to carry out “block commands”).

Finding 9: There would appear to be strong opposition from manufacturers to allowing full remote control of white goods.

Part of the Beywatch project (EUR 5) involved the design and implementation of an agent-based scheduler and control software. The complexity involved in optimising home energy was a key finding, given the large number of factors influencing the behaviour of connected devices: different modes of operation, different consumptions per mode, different times and constraints in each state. This is an even more complex problem when the various energy tariffs, different generation forecasts, different energy forms and the human element are taken into account. Currently, white good manufacturers are not willing to provide full remote control functionality of their appliances (as pausing/delaying operations may influence quality of the service provided and hence their product quality and reputation). It was therefore concluded that the project should begin by tackling remote control scheduling functions - limited to program-start activity. In doing so, only the starting time and mode of operation was chosen by the scheduler whilst the operation of the device and its performance was left to the manufacturer. Similarly, in the Intelligent Energy System project (AP 3), the consumer is offered the pre-programming of automation devices and smart meter appliances to function during off-peak hours (when electricity prices are lowest). Although this is not optimal, it is at least an intermediate step towards “home energy optimisation” and should be considered in the framework of the SSH programme.

Finding 10: Use of agent-based algorithms further facilitates 'plug-and-play' capabilities.

In the European Distributed Energy Partnership project (EUR 1), agent-based algorithms demonstrated 'plug-and-play' capabilities; new production units could be easily added or removed without having to re-calibrate the control system repeatedly.

Finding 11: Externally controlled charging of EVs may be the best approach.

Large scale electric vehicle deployment can be performed without any major concerns if an intelligent approach is adopted - involving full use of ICT to manage and control the presence of EV consumers in the network as highlighted in the MERGE project (EUR 4). Moreover, outputs from the EDISON project (EUR 13) suggest that only externally controlled charging of EVs is appropriate. A mixed strategy is being looked at; balancing cost versus performance and various other criteria. The algorithms are still being developed including ‘driving pattern generators’. The Smart City Malaga project (EUR 18) is also deploying external control when it comes to EV management. Vehicles are considered as loads that can be managed, but also as small sporadic generators, responding to the needs of the network operator.

Finding 12: Forecasting techniques can improve accuracy within, and operational performance of, control systems.

According to outcomes from the RegModHarz project (EUR 9), the more that is known about when and how much electricity is being generated, the easier it is to integrate. This is why forecasting systems play an important role (in combination with agent-based control) in the smart energy system. Moreover, the Beywatch project (EUR 5) suggested that forecasting programs should be improved to provide greater confidence in the optimisation algorithms. Regardless of how good the forecasting is, a problematic area remains the lack of predictability when it comes to the end user, who can deviate from a predicted schedule. It was suggested that in order to account for potential deviations from the schedule, schedules which are slightly less optimal could be chosen which need very little modification (and so are more stable). This is likely to lead to greater end-user acceptance.

4.3 Gaps identified

Whilst a variety of projects have looked at active network management techniques, more trials are needed to reduce future implementation risks and costs. Moreover, research into the development of new control algorithms for balancing demand and supply in networks with a high penetration of wind generation is in its infancy.

With regard to the whole system, self-healing functions (that are able to detect malfunctions and automatically run correction procedures) and self-configuration capabilities (ability to retrofit new devices to the system easily) should be further explored. Not many trials have incorporated such elements to date. Furthermore, there is no solid evidence to prove or disprove that the ICT products available today can handle and process the data that a smart energy system produces, although given what has been done in other industries it is tempting to jump straight to this conclusion.

There would also appear to be a need to develop an optimisation model which can cost-efficiently or carbon-efficiently operate the networks at different system levels (street, neighborhood, city, regional, national, international). There is also no strategy when it comes to how smart energy system devices coming onto the system should be logged (in terms of their physical presence) which will be important from an operational and an asset management point of view.

Lastly, there would appear to be a gap when it comes to the design and standardisation of models to control the charging process for EVs. As the impacts of EVs on the energy system could become significant very quickly, an appropriate strategy needs to be in place.

5 CYBER SECURITY

5.1 Overview

Cyber Security: is becoming an increasingly prevalent term. Cyber Security refers to the technology or process that protects the elements of the ICT system from unauthorised access or 'hacking'. Cyber Security is often closely linked to risk management and cost. The level of risk is dependent on what needs to be protected and the controls that have been put in place. In general terms, the more valuable the information is, the higher the risk, and, the more it will cost to protect. There are two key elements when it comes to Cyber Security – these are a) protecting data when it is stored electronically and b) protecting it when it is in electronic transit. With regards to a), appropriate access controls should be in place to protect valuable data when it is being stored. This includes authentication procedures (or 'handshakes') to confirm that the person is who they say they are, as well as measures to ensure that only the data that they are allowed access to can be obtained. As far as b) is concerned, any time data is in transit, there is a risk of that data flow being intercepted, imitated or copied and appropriate measures should be in place to de-risk this.

Not many of the projects that DNV KEMA has reviewed have significant findings to present, which illustrates the lack of progress in this area to date. The next section pulls out some of the key findings making reference to the relevant projects.

5.2 Findings

Finding1: An event and alarm management system effectively improves data security.

Communication architectures should be designed to ensure the necessary performance of data exchange in terms of availability, reliability, security and speed. Given the high number of events generated in a smart energy system, outcomes from the MERGE project (EUR 4) suggest that it is necessary to rely heavily on an event and alarm management system. To use one example, alarms generated by a smart meter can signal critical events that could adversely affect the whole system. In the SmartGridCity project (AME 3), alerts to the Distribution Control Centre were also recommended as it would allow an engineer to determine whether a "no-response" from an asset was down to hardware, software or communication problems.

Finding 2: A 'logical' test might be needed to prevent resubmission of measurements.

During the SmartHouse/SmartGrid project (EUR 8), it was observed that duplicate meter readings arrived at the head-end on numerous occasions. This was because no asset management tool was available for the smart meters used in the trial. Although this did not cause a problem with the actual experiment (because the data was given a timestamp) when written to the database, it does highlight a potential problem that can arise. It shows that data should not only be checked in terms of its conformance to a defined format, but also be subject to a 'logical' check. Without this, security and performance could be comprised and there would inevitably be cost implications.

Finding 3: A 4G/Long Term Evolution standards platform seems to offer increased data security.

In the Smart grid, Smart City project (AP 1), a 4G machine-to-machine communications network using WiMAX and Long Term Evolution (LTE) standards is being built across approximately 150 sites in Sydney, the Central Coast and Hunter Valley regions. One of the major benefits for choosing a 4G/LTE platform has been deemed to be its approach to tackling data security.

Finding 4: An authentication procedure may be needed to assist the connection of electric vehicles (or other smart devices) to the grid.

In order to tackle security issues for EVs, the MERGE project (EUR 4) emphasises that there should be an authentication procedure whereby EVs must register when accessing the utility energy services. The network will either authorise or refuse an (approved) EV connection. The network management system will then assign a unique ID to each EV user once it has successfully registered. The same principle could apply to any other smart energy system device.

Finding 5: Data could be made anonymous, aggregated and/or encrypted to ensure data privacy.

ICT could help in dealing with the privacy issues that arise as a result of smart metering data in particular. To prevent any inferences being made on personal lifestyles, the eTelligence project (EUR 2) aggregates data and makes it anonymous, provided it is not needed for invoicing purposes. No more data is collected than is actually needed for billing and for monitoring the grid state. If it must be gathered, it is not stored for longer than necessary. This is consistent with the relevant legislation and thinking as it currently stands. Privacy issues related to EVs are tackled in the MERGE project (EUR 4). Data exchanged between the EV and the aggregator must be encrypted to ensure privacy and resistance to tampering, especially in shared medium communications networks which are prone to eavesdropping.

5.3 Gaps identified

In all of the projects explored, there has been no hint of a drive for a consistent security strategy. This would appear to be a fundamental gap, which has an even bigger relevance when taking a longer term view (as is the intention for the SSH programme). Further trials will be required to determine what the best approach is for delivering a secure ICT infrastructure. It also remains to be seen as to whether the use of symmetric or asymmetric encryption is more appropriate.

6 SUMMARY OF FINDINGS

This section contains a summary of the key findings that were discussed in Sections 3, 4 and 5. There are clear lessons that can be drawn from these findings and fed into the continuing SSH programme design phase.

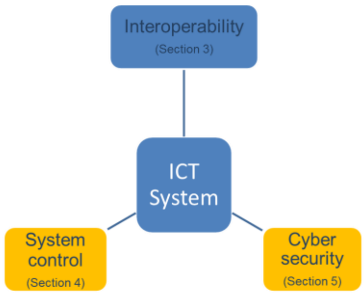

Table 2: Key findings and gaps - Interoperability

Potential areas of focus for the SSH programme
1. Establishing and testing (as early as possible) the communication protocols and standards is key in order to ensure interoperability within and between systems. 2. A scalable and flexible ICT architecture alleviates difficulties with regards to systems integration. 3. Control software prototypes should be made available for partner review early on in a pilot. 4. Existing standards can be extended to allow new systems to be incorporated, but this takes time. 5. Use of open interfaces and standardised protocols (for active network management) is needed to ensure seamless systems integration. 6. In developing Virtual Power Plants (VPPs), due regard should be paid to the different communication methods/protocols that may be deployed in different parts of the energy system and how to bring these together. 7. It may be more appropriate to keep machine-to-machine communications independent from the wider system to ensure a future proof solution. 8. Software platforms for energy management can be effective in enabling the integration of a diverse range of communication systems. 9. Particular attention might be needed with regards to standards dealing with flexible loads (demand side response). 10. To enable “plug-and-play” charging for electric vehicles, ICT stage requirements might need to be standardised.
Potential areas of focus for the SSH programme
• Look at how to strike the right balance between ‘flexibility of the functionality’ versus the lifespan of the underlying ICT and electronics. This requires an understanding of what is delivered by the hardware and what can be changed over time by developing new firmware. • Development of open protocols for the switching of 'smart appliances' and 'smart heat pumps' – this appears to be a key gap at present as these markets are not yet mature.

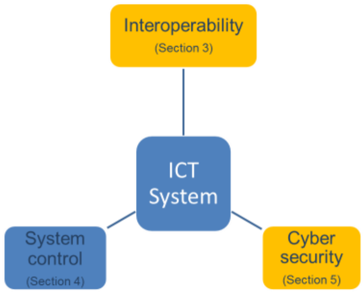

Table 3: Key findings and gaps - System control

Potential lessons for the SSH programme arising from previous activities
1. Agent-based control is an effective way to match energy supply and demand. 2. Technical VPP can be an effective method to control a system with a very high penetration of intermittent renewables. 3. Central remote control of domestic CHP units is an option for alleviating peak demand. 4. Active management of the distribution network has knock-on implications (or benefits) in terms of planning and asset management procedures. 5. Agent-based control could improve congestion network management. 6. Energy boxes could be used to apply domestic demand response. 7. Care should be taken when choosing device communications methods. 8. Decentralised agent-based energy management systems appear to be a credible and more powerful alternative to centralised control of Distributed Energy Resources (DER) and load shedding. 9. There would appear to be strong opposition from manufacturers to allowing full remote control of white goods. 10. Use of agent-based algorithms further facilitates 'plug-and-play' capabilities. 11. Externally controlled charging of EVs is considered more appropriate for the future. 12. Forecasting programs can improve accuracy within, and operational performance of, control systems
Potential areas of focus for the SSH programme
• Development of a system that can be controlled more autonomously - where intelligent adjustments can be made to maintain the voltage quality and to optimise energy management. • Consider new control algorithms for balancing demand and supply with a high penetration of intermittent renewable resources. • Address how ICT should handle the large amounts of data that a smart energy system produces. • Explore self-healing functions (detect malfunctions and automatically run correction procedures) and self-configuration capabilities (ability to add new devices to the system easily) for the whole system • Develop a model that allows different system levels (street, neighbourhood, city, regional, national, international) to run in an optimal way for the benefit of the whole system. • Create an information system to capture what and where demand side resources are available to provide response services. • Design models and standards for the charging process for electric vehicles.

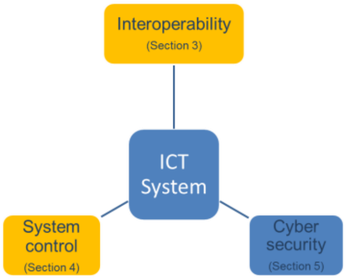

Table 4: Key findings and gaps - Cyber Security

Potential lessons for the SSH programme arising from previous activities
1. An event and alarm management system effectively improves data security. 2. A 'logical' test might be needed to prevent resubmission of measurements. 3. A 4G/Long Term Evolution standards platform seems to offer increased data security. 4. An authentication procedure may be needed to assist the connection of electric vehicles (or other smart devices) to the grid. 5. Data could be made anonymous, aggregated and/or encrypted to ensure data privacy.
Potential areas of focus for the SSH programme
• Design and implement a security strategy for all ICT elements of a smart energy system. • Determine whether the use of symmetric or asymmetric encryption is more appropriate to prevent hacking.

Glossary

CHP	Combined Heat and Power
CPU	Central Processing Unit
DER	Distributed Energy Resources
DNO	Distribution Network Operator
DR	Demand Response
EC	European Commission
ETI	Energy Technologies Institute
EU	European Union
EVs	Electric Vehicles
GPRS	General packet radio service
GSM	Global System for Mobile Communications
HAN	Home Area Network
ICT	Information and Communication Technologies
PLC	Power Line Communication
RIIO	Revenue = Incentives + Innovation + Outputs
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SES	Smart Energy System
SSH	Smart Systems and Heat
TSO	Transmission System Operator
UK	United Kingdom
V2G	Vehicle to the Grid
VPP	Virtual Power Plant
WiMAX	Worldwide Interoperability for Microwave Access

Appendix I – Overview of the programme

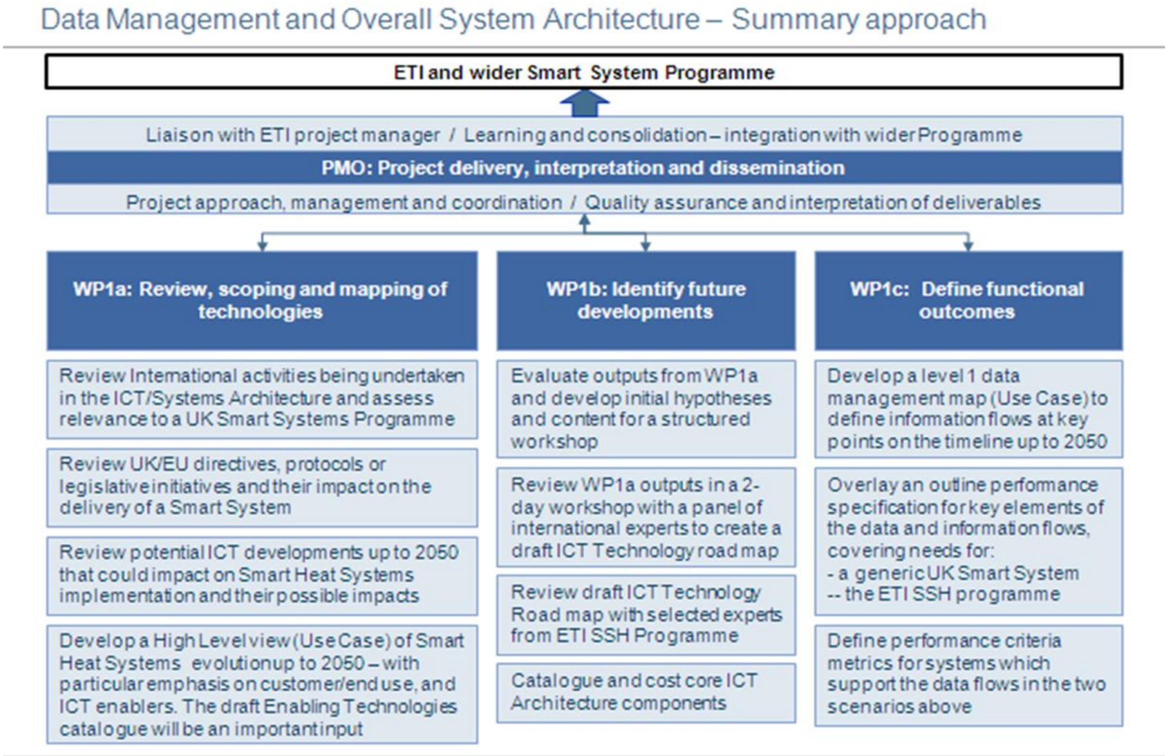

Figure 4: DNV KEMA's scope of work

Appendix II – List of projects

NB: Where all text is bold – project has been shortlisted

Project	Region	Country(ies)	Start	End	Availability of information	Start > 1-1-2007	≥ 2 technologies	≥ 2 stakeholders	Exclude smart meter projects	≥ 1 significant finding in ICT domain
Cities of the Future (CEMIG)	Americas	Brazil	2009	2014	-	+	+	+	+	
Companhia Paranaense de Energia (COPEL)	Americas	Brazil	2010	2014	-	+	+	+	+	
Micro Grid of Sustainable Energy (CELESC)	Americas	Brazil	2011	2015	-	+	+	+	+	
Smart Grid in Sao Paulo	Americas	Brazil	2010	2012	-	+	+	+	+	
Distribution Automation Project	Americas	Canada	2009	2011	-	+	-	+	+	
Energy Storage (2 x 1MW batteries)	Americas	Canada	2011	2012	-	+	-	+	+	
GRID IQ Innovation Center	Americas	Canada	2011	2012	-	+	+	+	+	
GridSmartCity	Americas	Canada	2010	2014	-	+	+	+	+	
Powershift Atlantic	Americas	Canada	2010	2014	-	+	+	+	+	
Smart Meters	Americas	Canada	2011	2013	-	+	-	+	-	
Smart Meters FortisAlberta	Americas	Canada	2011	2013	-	+	-	+	-	

Smart Zone	Americas	Canada	2010	2013	-	+	+	+	+	
20 MW flywheel energy storage frequency regulation plant	Americas	USA	2010	2013	-	+	-	+	+	
2012 State of the Consumer Report	Americas	USA	2012	2012	+	+	+	+	+	-
44 Tech Inc. Smart Grid Storage Demonstration Project	Americas	USA	2010	n/a	-	+	-	+	+	
Advanced Compressed Air Energy Storage	Americas	USA	2010	2014	-	+	-	+	+	
Advanced Implementation of Energy Storage Technologies	Americas	USA	2010	2014	-	+	-	+	+	
Advanced Metering Infrastructure and Smart Grid Development Program	Americas	USA	2012	2012	-	+	+	+	+	
Advanced Underground Compressed Air Energy Storage	Americas	USA	2010	2018	-	+	-	+	+	
AEP Smart Grid Demonstration Project: Virtual Power Plant Simulator (VPPS)	Americas	USA	2009	2013	-	+	+	+	+	
Amber Kinetics, Inc. Smart Grid Storage	Americas	USA	2010	2014	-	+	-	+	+	

Demonstration Project										
Arizona Cooperative Grid Modernization Project	Americas	USA	2009	2013	-	+	+	+	+	
Arizona Public Service (APS) Community Power Project Flagstaff Pilot	Americas	USA	2010	2015	-	+	+	+	+	
ATK Launch Systems RDSI Demonstration Project	Americas	USA	2009	2013	-	+	+	+	+	
Bangor Hydro Smart Grid Initiative	Americas	USA	2009	2011	-	+	+	+	-	
BPA Pacific Northwest GridWise Demonstration Project	Americas	USA	2006	2007	+	-	+	+	+	
Burbank Water and Power Smart Grid Project	Americas	USA	2011	2013	-	+	+	+	+	
CCET—Technology Solutions for Wind Integration	Americas	USA	2010	2015	-	+	+	+	+	
CERTS Microgrid Demonstration	Americas	USA	2008	2012	+	+	+	+	+	
City of Anaheim Smart Grid Project	Americas	USA	2013	2014	-	+	+	+	+	

City of Naperville Smart Grid Initiative	Americas	USA	2010	2013	-	+	+	+	+	
Colorado Springs Utilities	Americas	USA	2005	2010	-	-	+	+	+	
Connected Grid Project	Americas	USA	2010	2013	-	+	+	+	+	
Consolidated Edison Company of New York, Inc. Smart Grid Regional Demonstration Project	Americas	USA	2010	2013	-	+	+	+	+	
Customer application program pilot	Americas	USA	2010	2011	+	+	+	+	+	-
Customer Driven Design of Smart Grid Capabilities	Americas	USA	2010	2013	-	+	+	+	+	
Detroit Edison Company Smart Grid Project: Smart Currents	Americas	USA	2009	2012	-	+	+	+	+	
Distributed Energy Storage System	Americas	USA	2010	2013	-	+	-	+	+	
Distribution Automation Project	Americas	USA	2010	2011	-	+	+	-	+	
Dominion Virginia Power AMI Project	Americas	USA	2009	2010	-	+	+	-	-	
Duke Energy Business Services, LLC Smart Grid	Americas	USA	2010	2013	-	+	-	+	+	

Storage Demonstration Project										
Duke Energy Smart Grid Deployment Project	Americas	USA	2009	2013	-	+	+	+	+	
East Oahu Switching Project	Americas	USA	2010	2012	-	+	+	-	+	
East Penn Manufacturing Co. Smart Grid Storage Demonstration Project	Americas	USA	2010	2015	-	+	-	+	+	
Electric Distribution System Automation Program	Americas	USA	2010	2012	-	+	+	-	+	
Electric Power Board of Chattanooga Smart Grid Project	Americas	USA	2010	2014	-	+	+	+	+	
Energy Smart Florida	Americas	USA	2010	2012	-	+	+	-	+	
EPRI Consumer Engagement Project	Americas	USA	2011	2011	+	+	+	+	+	-
FirstEnergy Smart Grid Demonstration Project: Integrated Distributed Energy Resources (IDER)	Americas	USA	2008	2012	-	+	+	+	+	

Management										
Flow Battery Solution for Smart Grid Renewable Energy Applications	Americas	USA	2010	2013	-	+	-	+	+	
Fort Collins Renewables and Distributed Systems Integration Project	**Americas**	**USA**	**2012**	**2013**	**+**	**+**	**+**	**+**	**+**	**+**
Georgia Power PoweRewards	Americas	USA	2008	2009	-	-	-	-	+	
Golden Spread Electric Cooperative, Inc. Smart Grid Project	Americas	USA	2010	2012	-	+	+	-	+	
Green Impact Zone Smart Grid Demonstration	Americas	USA	2010	2014	-	+	+	+	+	
Grid Self--Healing and Efficiency Expansion	Americas	USA	2010	2012	-	+	+	-	+	
gridSMARTSM Demonstration Project	Americas	USA	2010	2013	-	+	+	+	+	
Guam Power Authority Smart Grid Project	Americas	USA	2010	2013	-	+	+	-	+	
Implementation of Smart Grid Technology in a	Americas	USA	2010	2013	-	+	+	-	+	

Network Electric Distribution System										
IPC Smart Grid Program	Americas	USA	2009	2013	-	+	+	-	+	
ISO-NE Demand Response Reserve Pilot	Americas	USA	2006	2010	+	-	+	+	+	
Isothermal Compressed Air Energy Storage	Americas	USA	2010	2013	-	+	-	+	+	
JEA Smart Grid Project	Americas	USA	2010	2012	-	+	-	-	-	
Knoxville Utilities Board Smart Grid Project	Americas	USA	2011	2013	-	+	+	-	+	
Lafayette Consolidated Government, LA Smart Grid Project	Americas	USA	2011	2013	-	+	+	-	+	
Lee County Electric Cooperative Smart Grid Project	Americas	USA	2010	2013	-	+	-	+	-	
Leesburg Smart Grid Investment Grant Project	Americas	USA	2010	2012	-	+	+	+	+	
Long Island Power Authority Smart Grid Regional Demonstration Project	Americas	USA	2010	2015	-	+	+	+	+	

Los Angeles Department of Water and Power Smart Grid Regional Demonstration Project	Americas	USA	2010	2015	-	+	+	+	+	
MEAG Smart Grid Distribution Automation Project	Americas	USA	2010	2013	-	+	+	-	+	
Modesto Irrigation District Smart Grid Project	Americas	USA	2010	2013	-	+	+	-	+	
National Rural Electric Cooperative Association Smart Grid Regional Demonstration Project	Americas	USA	2010	2013	-	+	+	+	+	
nDanville, a broadband infrastructure to support Danville's Smart Grid Energy Initiatives	Americas	USA	2007	2011	-	+	+	+	+	
New Hampshire Electric Cooperative Smart Grid Project	Americas	USA	2010	2014	-	+	+	-	-	
NSTAR Electric & Gas Corporation Smart Grid Regional	Americas	USA	2010	2013	-	+	+	+	+	

Demonstration Project										
NSTAR Electric & Gas Corporation Smart Grid Regional Demonstration Project (2)	Americas	USA	2010	2014	-	+	+	+	+	
NV Energize	Americas	USA	2010	2014	-	+	+	+	+	
Oncor Electric Delivery Company, LLC Smart Grid Regional Demonstration Project	Americas	USA	2010	2013	-	+	-	+	+	
Oncor Smart Texas Program	Americas	USA	2009	2012	-	+	+	-	-	
Optimized energy value chain	Americas	USA	2010	2013	-	+	+	+	+	
Pacific Northwest Smart Grid Regional Demonstration Project	Americas	USA	2010	2015	-	+	+	+	+	
Pecan Street Project, Inc. Smart Grid Regional Demonstration Project	Americas	USA	2010	2015	-	+	+	+	+	
PNM Smart Grid Demonstration Project: High-Penetration PV through Grid	Americas	USA	2009	2013	-	+	+	+	+	

Automation and Demand Response										
Powder River Innovation in Energy Delivery Project	Americas	USA	2010	2011	-	+	+	-	+	
Power Authority of the State of New York Smart Grid Regional Demonstration Project	Americas	USA	2010	2012	-	+	-	+	+	
PowerCentsDC Program	Americas	USA	2008	2011	+	+	+	+	+	-
PPL Electric Utilities Corp. Smart Grid Project	Americas	USA	2010	2012	-	+	+	-	+	
Primus Power Corporation Wind Firming Energy farm	Americas	USA	2010	2015	-	+	-	+	+	
Public Service Company of New Mexico PV Plus Battery for Simultaneous Voltage Smoothing and Peak Shifting	Americas	USA	2010	2014	-	+	-	+	+	
Rappahannock Electric Cooperative Smart Grid initiative	Americas	USA	2010	2013	-	+	+	+	+	
RDSI - Allegheny Power	Americas	USA	2009	2014	-	+	+	+	+	

Demonstration Project - West Virginia Super Circuit										
RDSI - Con Edison Smart Grid Demonstration Project: Interoperability of Demand Response Resources	Americas	USA	2008	2011	-	+	+	+	+	
RDSI - Fort Collins Demonstration Project "3.5 MW Mixed Distributed Resources for Peak Load Reduction"	Americas	USA	2008	2011	+	+	+	-	+	
RDSI - IIT Perfect Power Demonstration	Americas	USA	2008	2013	-	+	+	+	+	
RDSI - Maui Grid Modernization	Americas	USA	2008	2011	-	+	+	+	+	
RDSI - SDG&E Beach Cities Microgrid	Americas	USA	2009	2012	-	+	+	+	+	
RDSI - UNLV Demonstration Project - Integrated PV, Battery, Storage, and Customer Products with Advanced Metering	Americas	USA	2008	2013	-	+	+	+	+	

Sacramento Municipal Utility District Smart Grid Project	Americas	USA	2010	2014	-	+	+	+	+	
Seeo Inc Solid State Batteries for Grid-Scale Energy Storage	Americas	USA	2010	2014	-	+	-	+	+	
SGIG Distribution Automation project	Americas	USA	2010	2013	-	+	+	-	+	
Smart Future Greater Philadelphia	Americas	USA	2011	2013	-	+	+	-	+	
Smart Grid Deployment Project	Americas	USA	2010	2013	-	+	+	-	+	
Smart Grid Distribution Automation	Americas	USA	2010	2013	-	+	+	+	+	
Smart Grid Infrastructure Modernization of Electrical Distribution System	Americas	USA	2009	2013	-	+	+	-	+	
Smart Grid Initiative	Americas	USA	2011	2012	-	+	+	+	+	
Smart Grid Modernization Initiative	Americas	USA	2010	2014	-	+	+	-	+	
Smart Grid Team 2020 Program	Americas	USA	2010	2012	-	+	+	+	+	
Smart Study TOGETHER	**Americas**	**USA**	**2010**	**2012**	**+**	**+**	**+**	**+**	**+**	**+**
SmartGRID Project	Americas	USA	2011	2012	-	+	+	+	+	

SmartGridCity	**Americas**	**USA**	**2008**	**2012**	**+**	**+**	**+**	**+**	**+**	**+**
Southern California Edison Company Smart Grid Regional Demonstration Project	Americas	USA	2010	2014	-	+	+	+	+	
Southern Company Services, Inc. Smart Grid Project	Americas	USA	2012	2013	-	+	+	+	+	
Spokane Smart Circuit	Americas	USA	2010	2013	-	+	+	-	+	
SRP Smart Grid Project	Americas	USA	2003	2013	-	-	-	+	-	
Tehachapi Wind Energy Storage Project	Americas	USA	2010	2015	-	+	-	+	+	
The Boeing Company (Boeing Smart Grid Solution)	Americas	USA	2010	2013	-	+	+	+	+	
Town of Danvers, MA Smart Grid Project	Americas	USA	2010	2014	-	+	+	+	+	
Transverter "One house at a time"	Americas	USA	2010	2011	+	+	+	+	+	-
Vanadium Redox Battery Demonstration Program	Americas	USA	2010	2014	-	+	-	+	+	
Vermont Transco, LLC Smart Grid Project	Americas	USA	2010	2013	-	+	+	+	+	

Vineyard Energy Project	Americas	USA	2010	2011	-	+	+	+	+	
Wabash Valley Power Smart Grid Project	Americas	USA	2010	2012	-	+	+	+	+	
Waukesha Electric Systems Smart Grid Regional Demonstration Project	Americas	USA	2010	2015	-	+	-	+	+	
Westar Energy, Inc. Smart Grid Project	Americas	USA	2011	2012	-	+	+	-	+	
Advanced Electricity Storage Technologies Program	Asia Pacific	Australia	2009	2012	+	+	+	-	+	
Cool Change Trial	Asia Pacific	Australia	2007	2011	-	+	-	+	+	
Green Town Project	Asia Pacific	Australia	2010	2014	-	+	+	-	-	
IN Community - Bega Valley	Asia Pacific	Australia	2011	2012	-	+	+	+	+	
Renewable Remote Power Generation Program	Asia Pacific	Australia	2008	2011	-	+	-	-	+	
Smart Grid Smart City	**Asia Pacific**	**Australia**	**2010**	**2013**	**+**	**+**	**+**	**+**	**+**	**+**
Solar Cities Program	Asia Pacific	Australia	2004	2013	+	-	+	+	+	
Townsville Commercial Demand Management Pilot	Asia Pacific	Australia	2005	n/a	-	-	+	+	+	

Victoria Smart Meter Project	Asia Pacific	Australia	2008	2013	+	+	-	+	-	
Smart Village Program	**Asia Pacific**	**Australia**	**2010**	**2012**	**+**	**+**	**+**	**+**	**+**	**+**
+/-660kV Ningdong - Shandong DC Line Project	Asia Pacific	China	2009	2010	+	+	-	+	+	
750 kV /+/-400 kV AC and DC Grid Interconnection	Asia Pacific	China	2005	2010	+	-	-	+	+	
800 kV UHV DC Converter Station	Asia Pacific	China	2009	2009	+	+	-	-	+	
Demand Response Pilot Project	**Asia Pacific**	**China**	**2012**	**n/a**	**+**	**+**	**+**	**+**	**+**	**+**
Pilot Substations (74 to be set up, 20 already operating)	Asia Pacific	China	2011	2015	+	+	-	+	+	
Power System Digital Real-Time Simulation	Asia Pacific	China	2009	2009	-	+	+	+	+	
Smart Community Demonstration Project	Asia Pacific	China	2010	2010	+	+	+	+	+	-
Tianjun EcoCity	Asia Pacific	China	2008	2013	+	+	+	+	+	
UHVAC Demonstration Project 1000kV Jindongnan-Nanyang-Jingmen	Asia Pacific	China	2006	2009	+	-	+	+	+	

+/-500kV DC Power Transmission Project	Asia Pacific	China	2008	2010	+	+	-	+	+	
Electric Vehicle Charging Stations	**Asia Pacific**	**China**	**2010**	**n/a**	**+**	**+**	**+**	**+**	**+**	**+**
Xiangjiaba-Shanghai 800 kV UHV DC Transmission Pilot	Asia Pacific	China	n/a	2010	+	-	-	+	+	
Bangalore DRUM Project	Asia Pacific	India	2012	2015	+	+	+	+	+	-
Maharashtra Pilot Project	Asia Pacific	India	n/a	n/a	-	+	+	+	-	
Mangalore Pilot Project	Asia Pacific	India	2012	2015	-	+	+	-	-	
Rabirashmi Abasan Housing project	Asia Pacific	India	n/a	2008	-	-	-	+	+	
SA Habitat and Valence Energy	Asia Pacific	India	n/a	2009	-	+	-	+	+	
AMI introduction	Asia Pacific	Japan	2008	n/a	-	+	-	+	-	
Kitakyushu-City	Asia Pacific	Japan	2010	2015	-	+	+	+	+	
Kyoto Keihanna District	Asia Pacific	Japan	2010	2015	-	+	+	+	+	
Next generation electricity grid project in isolated islands	Asia Pacific	Japan	2009	2012	-	+	+	+	+	
Ota City Demonstration Site	Asia Pacific	Japan	2002	2007	-	-	+	-	+	
Rokkasho village smart	Asia Pacific	Japan	2010	n/a	-	+	+	+	+	

grid project										
Smart grid project in Tokyo Institute of Technology	Asia Pacific	Japan	2010	2012	-	+	+	+	+	
Toyota City, Aichi	Asia Pacific	Japan	2010	2015	-	+	+	+	+	
V2X, Electric Vehicle Smart grid Pilot	Asia Pacific	Japan	2011	2014	-	+	-	+	+	
Wakkanai and Hokuto Solar demonstration sites	Asia Pacific	Japan	2006	2010	-	-	+	-	+	
Yokohama City, Kanagawa	**Asia Pacific**	**Japan**	**2010**	**2015**	**+**	**+**	**+**	**+**	**+**	**+**
Consumer portal system	Asia Pacific	Korea	2005	2010	+	-	+	+	+	
Energy management system (IT)	Asia Pacific	Korea	2005	2010	+	-	+	+	+	
Intelligent Distribution management system	Asia Pacific	Korea	2005	2010	+	-	+	+	+	
Intelligent Transmission network monitoring and operation system	Asia Pacific	Korea	2005	2010	+	-	-	+	+	
IT based control system	Asia Pacific	Korea	2005	2010	+	-	-	+	+	
PLC ubiquitous technology	Asia Pacific	Korea	2005	2010	+	-	-	+	+	
Power equipment monitoring	Asia Pacific	Korea	2005	2009	+	-	+	+	+	

system										
Power semiconductor for dispersed generation and industrial inverter application	Asia Pacific	Korea	2005	2010	+	-	-	+	+	
Prototype advanced substation automation system	Asia Pacific	Korea	2005	2011	+	-	+	+	+	
Smart Grid Test Systems	Asia Pacific	Malaysia	2010	2015	-	+	+	+	+	
Intelligent Energy Systems	**Asia Pacific**	**Singapore**	**2010**	**2013**	**+**	**+**	**+**	**+**	**+**	**+**
AMIS	Europe	AT	2005	2012	-	-	+	+	+	
Building to Grid (B2G)	Europe	AT	2010	2013	-	+	+	+	+	
DG Demonet Smart LV Grid	Europe	AT	2011	n/a	-	+	+	+	+	
DG Demonetz Validierung	Europe	AT	2006	2013	-	+	+	+	+	
Isolves PSSA-M	Europe	AT	2009	2012	-	+	-	+	+	
More PV2Grid	Europe	AT	2010	2013	-	+	-	+	+	
Smart Web Grid	Europe	AT	2011	2013	-	+	+	+	+	
Vehicle to Grid – Interfaces	Europe	AT	2010	2011		+	-	+	+	
Vehicle to Grid - Strategies	Europe	AT	2010	2012		+	-	+	-	
Belgium east loop active network management	Europe	BE	2010	2011		+	-	+	+	

Electrical vehicles impacts on the grids	Europe	BE	2010	2011		+	-	+	+	
LINEAR	Europe	BE	2011	2014	-	+	+	+	+	
Decentralized customer-level under frequency load shed-ding in Switzerland	Europe	CH	2010	2012		+	-	+	+	
Smart Region	Europe	CZ	2011	2014	-	+	+	+	+	
ADELE Project AA-CAES	Europe	DE	2009	2013		+	-	+	+	
E-DeMa	Europe	DE	2009	2014	-	+	+	+	+	
ETelligence	**Europe**	**DE**	**2009**	**2012**	**+**	**+**	**+**	**+**	**+**	**+**
IRIN	Europe	DE	2009	2011	+	+	+	+	+	-
Model City Manheim	**Europe**	**DE**	**2008**	**2012**	**+**	**+**	**+**	**+**	**+**	**+**
NET-ELAN	Europe	DE	2008	2011	-	+	+	+	+	
Netze der Stromversorgung der Zukunft	Europe	DE	2008	2011	-	+	+	+	+	
Regenerative Modellregion Harz	**Europe**	**DE**	**2008**	**2012**	**+**	**+**	**+**	**+**	**+**	**+**
Smart Watts	Europe	DE	2008	2012	-	+	+	+	+	
Virtual Power Plant	Europe	DE	2008	2010	-	+	+	+	+	
Web2energy	Europe	DE	2010	2012	-	+	+	+	+	
Grid4EU	Europe	DE	2011	n/a	-	+	+	+	+	
Virtual Fuel Cell Power Plant	**Europe**	**DE**	**2001**	**2005**	**+**	**-**	**+**	**+**	**+**	**+**
Cell Controller Pilot Project	**Europe**	**DK**	**2005**	**2011**	**+**	**-**	**+**	**+**	**+**	**+**

Application of smart grid in photovoltaic power systems, ForskEL	Europe	DK	2010	2013	-	+	+	+	+	
Automation systems for Demand Response, ForskEL	Europe	DK	2006	2009		-	+	+	+	
Charge stands	Europe	DK	2010	n/a	-	+	-	+	+	
DataHub project	Europe	DK	2009	2012		+	-	+	-	
Demand response medium sized industry consumers	Europe	DK	2009	2011	-	+	+	+	+	
Development of a Secure, Economic and Environmentally friendly Modern Power System	Europe	DK	2010	2014	-	+	+	+	+	
EcoGrid EU	Europe	DK	2011	2014	-	+	+	+	+	
EDISON	**Europe**	**DK**	**2009**	**2012**	**+**	**+**	**+**	**+**	**+**	**+**
Energy Forecast, ForskEL	Europe	DK	2007	2010	-	+	-	+	+	
Flex power - perspectives of indirect power system control through dynamic power price	Europe	DK	2010	2013	-	+	+	+	+	
Flexcom, ForskEL	Europe	DK	2008	2010		+	-	+	+	

Heat Pumps as an active tool in the energy supply system, ForskEL	Europe	DK	2010	2012	-	+	-	+	+	
Intelligent Remote Control for Heat Pumps, ForskEL	Europe	DK	2010	2011	-	+	+	+	+	
iPower	Europe	DK	2011	2016	-	+	+	+	+	
Large-scale demonstration of charging of electric vehicles, ForskEL	Europe	DK	2011	2013	-	+	-	+	+	
Price elastic electricity consumption and electricity production in industry	Europe	DK	2006	2010		-	+	+	+	
Price elastic electricity consumption as reserve power - a demonstration project in the horticultural sector	Europe	DK	2006	2010		-	+	+	+	
Project —Intelligent home‖	Europe	DK	2009	2011		+	+	+	+	
Project —The Island of Fur on the map‖	Europe	DK	2010	2020	-	+	+	+	+	
Prøv1Elbil	Europe	DK	2009	2012	-	+	-	+	+	
Second1 - Security	Europe	DK	2010	2011	-	+	+	+	+	

concept for DER										
Smart neighboring heat supply based on ground heat pumps, ForskEL	Europe	DK	2011	2012	-	+	-	+	+	Q
Trials with heat pumps on spot agreements	Europe	DK	2010	2011		+	-	+	+	
TWENTIES	**Europe**	**DK ES FR BE**	**2010**	**2013**	**+**	**+**	**+**	**+**	**+**	**+**
Micro-Request-Based Aggregation, Forecasting and Scheduling of Energy Demand, Supply and Distribution (MIRACLE)	Europe	EL DE PT NL DK CH IT ES FR PL MK UK	2010	2013		+	+	+	-	
Almacena	Europe	ES	2009	2013	-	+	+	+	+	
DER-IREC 22@Microgrid	Europe	ES	2009	2011	-	+	+	+	+	
GAD	Europe	ES	2007	2010		+	-	+	+	
Hydrogen - Sotavento projects	Europe	ES	2005	2011		-	-	+	+	
Smart City Malaga	**Europe**	**ES**	**2009**	**2013**	**+**	**+**	**+**	**+**	**+**	**+**
Address	**Europe**	**ES FR IT CH SE NL UK F S BE D RO**	**2008**	**2012**	**+**	**+**	**+**	**+**	**+**	**+**
Open Node	Europe	ES FR PT NL DE AT	2010	2012	-	+	+	+	+	

MERGE - Mobile Energy Resources in Grids of Electricity	**Europe**	**ES IE EL DE BE NO UK PT**	**2010**	**2011**	**+**	**+**	**+**	**+**	**+**	**+**
G4V - Grid for Vehicles	Europe	ES PT NL FR DE SE IT UK	2010	2011	-	+	+	+	+	
FENIX	**Europe**	**ES UK SI AT DE NL FR RO**	**2005**	**2009**	**+**	**+**	**+**	**+**	**+**	**+**
Mirabel Project	Europe	EU	2010	n/a	-	+	+	+	+	
More Microgrids	Europe	EU	2006	2009	-	-	+	+	+	
Smart grids and energy markets	Europe	FI	2009	2014	-	+	+	+	+	
Sustainable urban living	Europe	FI	2009	2013		+	-	+	+	
BeAware	Europe	FI IT SE	2010	2013	-	+	+	+	+	
Adine	**Europe**	**FIN**	**2007**	**2010**	**+**	**+**	**+**	**+**	**+**	**+**
OPTIMATE	Europe	FR DE ES BE DK IT UK	2009	2012	-	+	+	+	+	
GROWDERS, Demonstration of Grid Connected Electricity Systems	**Europe**	**FR DE ES NL**	**2009**	**2011**	**+**	**+**	**+**	**+**	**+**	**+**
EU-DEEP	**Europe**	**FR EL UK DE BE ES SE PL LV AT HU IT FI CY CZ TR**	**2004**	**2009**	**+**	**-**	**+**	**+**	**+**	**+**
LASTBEG - Large Scale Tool for Power Balancing in	Europe	FR LT UK DE ES HU	2009	2009	-	+	+	+	+	

Electric Grid										
Kythnos Micro-Grid	**Europe**	**GR**	**2006**	**2009**	**+**	**-**	**+**	**+**	**+**	**+**
Distributed connected wind farms	Europe	IE	2009	2012	-	+	-	+	+	
REALISEGRID	Europe	IT NL AT FR RU DE UK SI BE	2008	2011		+	-	+	+	
Demonstration project Smart Charging	Europe	NL	2010	2011	-	+	-	+	+	
Easy Street	Europe	NL	2011	2014	-	+	+	+	+	
Field trial Mobile Smart Grid	Europe	NL	2010	2011		+	-	+	+	
Smart Energy Collective	Europe	NL	2010	2013	-	+	+	+	+	
Power Matching City	**Europe**	**NL**	**2009**	**n/a**	**+**	**+**	**+**	**+**	**+**	**+**
Smart House / Smart Grid	**Europe**	**NL D GR**	**2008**	**2011**	**+**	**+**	**+**	**+**	**+**	**+**
E-price	Europe	NL IT CH	2010	2013	-	+	+	+	+	
IMPROSUME - The Impact of Prosumers in a Smart Grid based Energy Market	Europe	NO CH DK	2010	2011	+	+	+	+	+	
AMI	Europe	PL	2010	2017	-	+	+	+	+	
EVORA INOVCITY	**Europe**	**PT**	**2007**	**2011**	**+**	**+**	**+**	**+**	**+**	**+**
Stockholm Royal Seaport	Europe	S	2012	2025	-	+	+	+	+	
Charging Infrastructure	Europe	SE	2008	2010		-	-	+	+	

for Electric Vehicles										
Elforsk Smart grid programme	Europe	SE	2011	2014	-	+	+	+	+	
Smart Grid Gotland	Europe	SE	2010	2015	-	+	+	+	+	
Advanced Systems of Efficient Use of Electrical Energy - SURE	Europe	SI	2011	2014	-	+	+	+	+	
Kybernet	Europe	SI	2009	2011	-	+	-	+	+	
Supermen	Europe	SI	2009	2011	-	+	+	+	+	
ENERGOZ	Europe	SK	2010	2013	-	+	+	+	+	
BeyWatch	**Europe**	**SP GR**	**2008**	**2011**	**+**	**+**	**+**	**+**	**+**	**+**
AURA NMS	**Europe**	**UK**	**2007**	**2010**	**+**	**+**	**+**	**+**	**+**	**+**

Table 5: List of total projects explored

Appendix III – Summary table of projects analysed

REF	Project	7	Start	End	Stakeholders	Aim	Energy system	Scale	Key ICT element	Cost
AME 1	Fort Collins Renewables and Distributed Systems Integration Project	USA	2009	2012	City of Fort Collins Operation Services, CSU Department of Facilities Management, Larimer County Facilities Department and New Belgium Brewing Company,CSU EECL and InterGrid Laboratory, CSU Engineering Department, Brengle Group Inc., Spirae Inc., Woodward Inc., Advanced Energy Industries Inc., Eaton Corporation	Develop and demonstrate a way of reducing the peak load through the coordinated use of DER	DER	5MW of DER connected to 2 distribution feeders	Platform acting as a Network Operating System for the DER allowing the necessary communication and control infrastructure to interface with existing Building Automation Systems and SCADA systems	-
AME 2	Smart Study Together	USA	2010	2011	Oklahoma Gas & Electric, Silver Spring Networks	Investigate the potential for demand response to reduce system peak load in order to defer investment in new generation	DR	3,100 customers (2,400 residential, 700 small commercial)	Programmable communicating thermostat and a web portal	-
AME 3	SmartGridCity	USA	2008	2011	Xcel Energy and the following partners: Accenture, Current Group, GridPoint Inc., OSIsoft, Schweitzer Engineering Laboratories, SmartSynch Inc., Ventyx.	Identify the best way to modernize the existing electricity grid	DER, EVs, Active management of distribution network	1,264 In-Home Smart Device systems, 4,000 customers new tariff structure, 23,000 equipped with smart meters	Integrated Volt/VAr control at distribution feeders	$100M (75M EUR)

AP 1	Smart Grid, Smart City	Australia	2010	2013	Ausgrid, EnergyAustralia, Landis + Gyr, GE Energy, Grid Net, IBM, CSIRO, TransGrid, Sydney Water, Hunter Water, the University of Newcastle, the University of Sydney, the City of Newcastle and Lake Macquarie City Council	Better understand the benefits and costs of different smart grid technologies	DER, EVs, Storage	30,000 households	4G/LTE platform for machine to machine communications	$100M (77M EUR)
AP 2	Yokohama City	Japan	2010	2014	NEDO, Toshiba, Panasonic, Meidensha, Nissan, Accenture, Tokyo Gas, Accenture, Meiden, DENSO, TEPCO	Understand the difficulties in developing smart energy systems in existing cities where infrastructure cannot be easily reformed	DER, DR, EVs, Storage	4,500 smart houses, 2,000 electrical vehicles, 27 MW PV	Building and Energy Management Systems and Home Energy Management Systems to enable DR	74 Billion JPY (710M EUR)
AP 3	Intelligent Energy System	Singapore	2010	2013	Accenture, ST Electronics (Info-Comm Systems), Singapore Power, Oracle, Hewlett-Packard, Power Automation, GreenWave Reality, Control4, Nanyang Technological University and several government agencies such as the Economic Development Board (EDB), Agency for Science, Technology and Research (A*STAR), Housing and Development Board, Infocomm Development Authority (IDA) and the National Environment Agency (NEA)	Test a range of smart grid technologies to enhance the capabilities of Singapore's power grid infrastructure	DER, DR	4,500 smart meters will be installed in various residential, commercial and industrial location	Pre-programming of automation devices and smart meter appliances	$30M (22,4M EUR)

AP 4	Smart Village Program	Australia	2010	2012	Energy Australia, Sydney Water, University of Newcastle, University of Sydney	Improve understanding of water and energy use and can communicate incentives and advice that will easily reduce consumption, bills and greenhouse gas emissions	DER, Storage, DR, Evs	1,000 smart meters and 100 Home Area Networks	Home Area Networks (HANs) to provide real-time information on the energy consumption of individual appliances and remotely monitor and control the appliances online	-
AP 5	Electric vehicle charging station	China	2010	n/a	SGCC, National energy bureau, Chinese ministry of Industry, National car standard committee	Support the country's policies on energy-efficient and new-energy vehicles policies	EVs charging	75 public charging stations, 6,209 AC charging spots and some battery replacement stations	Establish protocols for the EV charging stations	-
AP 6	Demand Response System Pilot	China	2012	n/a	State Grid Company China, Honeywell	Monitor and manage electricity use in commercial buildings	DR	-	Automated demand response, advanced energy management, and sub-metering	-
EUR 1	European Distributed Energy Partnership	FR, ES, CY, LV, BE, DE, GR, SE, HU, TR, FI, GR, UK, AT, Pl, CZ	2004	2009	GDF Suez, Iberdrola, EAC, Latvenergo, Tractebel, RWE Energy, EPA Attiki,IEA/LTH, FEEM, VEIKI, RTU Laborlec, TUBITAK, AUTh, CENTER, Enersearch, SEAES, IIE-UPV, ICCS/NTUA, VTT, Labein, STRI, KULeuven, FIT, CRES, Imperial College, Bowman, MTU, Siemens PTD, Heletel,Technofi, Transénergie, Axiom, KAPE	Understand how to create the necessary conditions for sustainable DER expansion	DER	-	Decentralised multi-agent software solutions to control DER	30M EUR

EUR 2	eTelligence	Germany	2008	2012	EWE AG, BTC AG, OFFIS e.V., Energy & meteo systems GmbH, Oldenburg, Germany, Fraunhofer Energy Alliance, Freiburg and Ilmenau, Germany, Öko-Institut	Improve the current energy supply system and enable broad integration of renewable energy sources	DER, DR	650 Households	Agent-based algorithms to balance demand and supply, aggregate data and make it anonymous	-
EUR 3	ADINE	Finland	2007	2010	Hermia Ltd, AREVA T&D Ltd, ABB Oy Distribution Automation, AREVA Energietechnik GmbH, ComPower Ab, Tampere University of Technology, Department of Electrical Energy Engineering, Lund University, Department of Electrical Measurements and Industrial Electrical Engineering Automation	Demonstrate and validate a new method for the active management of a distribution network and the enabling solutions to support it	DER, Active management of distribution network	-	System operating on protection, decentralized control and area control levels. Management system includes three layers: protection system, automatic control system (decentralized) and area control level (centralized).	3,2M EUR
EUR 4	MERGE	ES IE EL DE BE NO UK PT	2010	2011	INESC Porto, ICCS/NTUA, TU Berlin, Cardiff, Comillas, AVERE, Ricardo, IMR World, C4D, InSpire, PPC, REE, REN, Iberdrola, ESB, RAE	Evaluate the impacts that electric vehicles will have on EU electric power systems with regard to planning, operation and market functioning	EVs charging	-	Intelligent based approach for Evs charging involving full use of ICT, to manage and control them in the electrical network, event and alarm management system	4,5M EUR

EUR 5	Beywatch	Spain, Greece	2008	2011	EDF, Sigma Orionis, GL, Gorenje, Telefonica, Fagor, Universita degli studi di Palermo, Synlexis	Design, develop and evaluate an energy-aware and user-centric solution, capable of providing interactive energy monitoring, intelligent control and power demand balancing on a home and neighbourhood level	Home appliances control, renewable energy sources at building level		Software comprised of: i) agent based scheduler & controller; ii) home energy framework which provide services to the scheduler; iii) the Machine to Machine (M2M) communications interface	
EUR 6	Cell Controller Pilot Project	Denmark	2005	2011	Energinet.dk, SE Syd Energi Net, Energynautics GmbH, Spirae Inc (USA) Other Partners: Billund Varmeværk, Bramming Fjernvarme, Hejnsvig Varmeværk, Holsted Fjernvarme, 47 private wind turbine owners, Tjæreborg Industri, Pon Power, Rolls-Royce Marine, Siemens Denmark	Deployment and demonstration of the operation of the technical VPP	DER	28,000 households, business and institutions, 5 CHP units, 47 large wind turbines and 12 substations (60/10kV).	VPP configuration and operation software	-
EUR 7	Model City of Mannheim	Germany	2008	2013	MVV Energie AG, DREWAG - Stadtwerke Dresden GmbH, IBM Deutschland GmbH, Power PLUS, Communications AG, Papendorf Software Engineering GmbH, University of Duisburg-Essen, ISET - Verein an der Universität Kassel e.V., ifeu Heidelberg GmbH and IZES GmbH	Prove the feasibility of an energy system with high penetration rate of DER	DER, EVs, Smart appliances	3,000 end customers	Energy internet' created in the project cities by using the electricity grid for data transmission	20M EUR

EUR 8	SmartHouse/SmartGrid	Netherlands, Germany, Greece	2008	2011	SAP, IWES, MVV, TNO, ICCS-NTUA, PPC	Validate and test how ICT-enabled collaborative technical-commercial aggregations of Smart Houses	DER, Evs, Smart appliances	Trial A: 25 households Trial B: 100 households Trial C: 220 cottages	Multi - agent software allowing agents to negotiate for the cheapest power, sell generated power at the best price and try to get the maximum benefit from each source of power consumption	-
EUR 9	RegModHarz	Germany	2008	2012	RegenerativKraftwerk Harz GmbH & Co KG, E.ON Avacon Netz GmbH, Siemens AG, in.power GmbH, ISET e.V., Vattenfall Europe Transmission GmbH	Enable joint marketing of regionally available renewable producers and DR grouped into a VPP on different markets	DER, DR, Storage	-	Generic data model enabling the automated assimilation of systems in energy management	16M EUR
EUR 10	Growders	FR DE ES NL	2008	2011	Continuon, Iberdrola, MVV, EAC, CEA-INES, IPE, Exendis, SAFT, Chloride, DNV KEMA	Demonstrate the technical and economical possibilities of existing electricity storage technologies	DER, Storage		Optimisation model assessing the best application of a storage system in a electricity grid	
EUR 11	Power Matching City	Netherlands	2009	n/a	DNV KEMA, ECN, Essent, Enexis, Humiq, TNO	Understand the benefits from both central and decentralized energy sources	DER, Evs, Smart appliances	42 households	Coordination of hybrid heat pumps, CHPs, EVs and smart appliances in a single generic ICT solution	-

EUR 12	Kythnos Micro-Grid	Greece	2006	2009	Centre for Renewable Energy Sources and Saving (CRES), ICCS/NTUA, ANCO, ISET, SMA Regelsysteme GmbH	Evaluate the technical feasibility of micro- grids	DER, Storage	12 households	Centralized and decentralized control strategies in island mode. Multi- Agent system concept for decentralized control	-
EUR 13	EDISON	Denmark	2009	2011	Danish Energy Association, Østkraft, Dong Energy, IBM, Siemens, Eurisco, DTU CET	Develop optimal system solutions for EV system integration, including network issues, market solutions, and optimal interaction between different energy technologies.	EVs charging	-	Algorithms for the external control of EVs charging include 'driving pattern generators'	49M DKK (5,9M EUR)
EUR 14	Address	ES FR IT CH SE NL UK FS BE D RO	2008	2012	Enel Distribution, EDF, Iberdrola, Vattenfall, ABB, Landis+Gyr, ZIV, Philips, Electrolux, RLtec, Ericsson, Alcatel, Current, University of Manchester, Universidad Pontificia Comillas, Università di Siena, Università di Cassino, VTT, VITO, Labein, DNV KEMA, Consentec	Contribute to the development of interactive distribution energy networks	Smart appliances, Evs, DER, Storage	France: 100 households Italy: - Spain: 300 households	Software interfaces have been developed to control air conditioning and electric heating systems	16M EUR
EUR 15	Virtual Fuel Cell Power Plant	Germany	2001	2005	Initiative Brennstoffzelle (IBZ), Vaillant, Plu Power Holland, Cogen Europe, Instituti Superior Tecnico (IST), University of Essen, DLR, Sistemas de Calor, Gasunie, E.ON Ruhrgas, E.ON Energie, EWE.	Develop, install, test and demonstrate VPP	DER	VPP consisting of 31 decentralized stand-alone residential fuel cell systems	System communication with the on-site energy management application allowing utilities to control the micro- CHPs	-

EUR 16	AURA NMS	UK	2007	2010	Scottish Power, EDF, ABB, Imperial College	Produce a control structure and set of control algorithms that realize the notion of an active distribution network and enhance the service a network operator provides to load and generation customers, improving network performance	DER	-	Peer-to-peer network controllers/decision-makers placed in substations	6M POUNDS (7,1M EUR)
EUR 17	Evora InovCity	Portu gal	2007	2017	EDF Distribution, Insec Porto, Efacec, Logica, Janz	Develop a set of functionalities and new devices that can be installed on the network to facilitate a more active role for the management of the distribution system	DER, Smart applianc es, Evs, DR	30,000 customers	Energy boxes to apply home energy management	-
EUR 18	Smart City Malaga	Spain	2009	2013	Endesa, ERDF, Enel, Acciona, IBM, Sadiel, Ormazábel, Neometrics, Isotrol, Telvent, Ingeteam, Greenpower and several universities	Objective is to achieve a 20% energy saving, a reduction of 6.000 tons of CO2 per year, and an increase of renewable energy consumption	DER, Storage	-	Advanced telecommunication systems and remote control operate in real time	31M EUR

EUR 19	FENIX	ES UK SI AT DE NL FR RO	2005	2009	Iberdrola, EDF, EDF Energy Networks, Areva, ECRO, ECN, Labein, Gamesa, IDEA, Imperial College London, ISET, Korona, National Grid Transco, Poyry Consulting, Red Electrica de Espana, ScalAgent, Siemens, University of Manchester, Vrije Universiteit Amsterdam, ZIV PmacC	Boost DER by maximizing their contribution to the electric power system, through aggregation into Large Scale VPP and decentralized management	DER	-	Scalable and hierarchically flexible information and communication architecture	14,7M EUR
EUR 20	Twenties	DE, NO, UK, IE, ES, IT, BE, DE, NL, FR	2010	2014	DONG ENERGY, Energinet, DTU Energy, TenneT, Fraunhofer IWES, 50 HzT, SIEMENS Wind Power, ELIA, EWEA, CORESO, University Liege, University Leuven, Universite Libre Bruxells, RSE, Red Electrica De Espana, Iberdrola, ITT Comillas, Gamesa, ABB S.A., Inesc-Porto, UCD, Alstom Grid, University of Strathclyde	Show the benefits and impacts of technologies needed to improve the pan-European transmission network, allowing Europe to integrate a higher capacity of renewables whilst keeping current reliability levels	Large scale renewab les	-	VPP system is divided into several system components, each with its own responsibility and purpose(modular design).	56,8M EUR

Table 6: Summary of projects analysed

Appendix IV – Details of projects analysed

AME 1	Fort Collins Renewables and Distributed Systems Integration Project
Geographical area	Colorado, USA
Timeframe	2009 – 2012
Involved	Fort Collins Utilities (Project Management, Technology and R&D) Site Partners: City of Fort Collins Operation Services, CSU Department of Facilities Management, Larimer County Facilities Department and New Belgium Brewing Company. R&D/Technology partners: CSU EECL and InterGrid Laboratory, CSU Engineering Department, Brengle Group Inc., Spirae Inc., Woodward Inc., Advanced Energy Industries Inc. and Eaton Corporation.
Summary	The Ft. Collins project was undertaken in response to a Department of Energy funding opportunity announcement by a diverse group of local government, higher education and business organizations. The primary objective of the project was to develop and demonstrate a way of reducing the peak load on 2 distribution feeders by 20%, through the coordinated use of Distributed Energy Resources (DER). The DER consisted of generation such as PV, steam turbine generators, biogas gensets and diesel gensets. Options for load shedding including Heating, Ventilation and Air Conditioning (HVAC), thermal storage and a small percentage from Plug-in Hybrid Electric Vehicles (PHEV). Nine months of load data was collected to provide a baseline for calculating peak load (14.35MW on the 2 feeders) prior to the demonstration phase. Approximately 5MW of DER was established to provide the 20% reduction envisaged (although 3MW was required, extra resources were included to provide buffer capacity). Ultimately the peak load reduction during the testing phase reached a high of 14.2%. The infrastructure deployment and asset integration established in this project serves as a jump start for the FortZED project which aims to create the largest active net zero energy district in the world, offsetting energy from a 50MW peak demand. In order to coordinate the DER in this project, the ‘Bluefin platform’ was developed by one of the project partners which acted as a Network Operating System for the DER. This privately-owned operating platform allowed the necessary communication and control infrastructure to interface with existing Building Automation Systems (BAS)

	and SCADA systems already being used by the utility and site partners. Each site partner was equipped with a Gateway (Bluefin embedded) PC that acted as a communication and control portal to the existing management infrastructure. The Bluefin platform was implemented in such a way that each of the participating partner sites retained ultimate control of their DER asset. A custom control algorithm was written for the purposes of the 'Peak Load Management' software used in this project. This operated in conjunction with the Bluefin enterprise backend server and utilized the Bluefin platform to observe the total load on the feeders. If the load on the feeders exceeded a pre-assigned set point, then a calculation would be made as to how much load needed to be offset to bring the system below the set point. The software used a prioritization scheme which called upon DER-assets based on their availability, emission characteristics, and also on the basis of fairly distributing operation of assets (i.e. the same asset would not be chosen first every day).
References	http://www.smartgrid.epri.com/doc/Ft%20%20Collins%20RDSI%20Final.pdf

AME 2	Smart Study Together
Geographical area	Oklahoma – USA
Timeframe	2010 - July 2011
Involved	Oklahoma Gas & Electric, Silver Spring Networks
Summary	The Smart Study TOGETHER project investigated the potential for demand response to reduce system peak load (in order to defer investment in new generation). For this purpose different technology options and price rates were utilized and their impact on demand reduction was analysed. For the study, a sample group of approximately 3,100 customers (2,412 residential, 712 small commercial) was used. The four technology options tested were: (1) a programmable communicating thermostat (PCT), (2) a web portal, (3) an in-home display, or (4) a combination of all 3 technologies. These options were combined with either the Variable Peak Pricing (VPP) rate or Time-of-Use rate, to create a total of 8 rate-technology groups. For both of these tariffs a Critical Price (CP) component was incorporated - which was issued during critical peak periods. A control group was used to eliminate effects of weather, economic conditions, fuel prices etc. Customers were allowed to choose their own balance of cost versus comfort, and no direct control was taken of any appliances. Participation in the study was voluntary.
References	http://www.silverspringnet.com/pdfs/SilverSpring-OGE-Results.pdf http://www.occeweb.com/pu/SMARTGRID/GEP%20OGE%20Summer%202011%20Report.pdf

AME 3	SmartGridCity
Geographical area	Colorado – USA
Timeframe	2008 – 2011
Involved	Xcel Energy and the following partners: Accenture, Current Group, GridPoint Inc., OSIsoft, Schweitzer Engineering Laboratories, SmartSynch Inc. and Ventyx.
Summary	The SmartGridCity project was designed with the intention of knowing the best way to modernize the existing electricity grid. The demonstration tested various capabilities in order to know which investments were feasible and how they helped in aspects such as reliability, sustainability, efficiency etc. Customers residing within the SmartGridCity were also expected to see the benefits of this project through increased service options, service level improvements, rate options and energy use reductions. The costs of the SmartGridCity project were mostly expected to be covered by the partners involved, however these were higher than expected (the total cost of this over-budget project is now over $100 million). Since then Boulder city officials have been in dispute with Xcel Energy on the premise that the project has not delivered the value to consumers (e.g. not enough control over home power use). Xcel is currently in the process of trying to recoup losses. Whilst the project provides useful lessons learned, the SmartGridCity project itself is an interesting example of a Smart Grid project which has not gone to plan. Although the bulk of the Smart Grid infrastructure has now been built, it has not yet been fully paid due to not meeting an apparent standard of consumer engagement. The final ruling on this remains to be decided.
References	http://smartgridcity.xcelenergy.com/ http://www.metavu.com/UserFiles/File/MetaVu-SmartGridCity-Evaluation-Report.pdf http://www.smartgridnews.com/artman/publish/news/Boulder-Xcel-promised-more-than-SmartGridCity-delivered-shouldn-t-get-16-5M-4964.html

AP 1	**Smart Grid, Smart City**
Geographical area	Australia
Timeframe	Commenced late 2010, to be finalized end of 2013.
Involved	Ausgrid, EnergyAustralia, Landis + Gyr, GE Energy, Grid Net, IBM, CSIRO, TransGrid, Sydney Water, Hunter Water, the University of Newcastle, the University of Sydney, the City of Newcastle and Lake Macquarie City Council.
Summary	Following a competitive process, the Australian Government chose Ausgrid to lead the $100 million initiative across five sites in Newcastle, Sydney and the Upper Hunter. Smart Grid, Smart City creates a testing ground for new energy supply technologies. At least 30,000 households will participate in the project over three years. The demonstration project gathers information about the benefits and costs of different smart grid technologies in an Australian setting. Building a smart grid involves transforming the traditional electricity network by adding a chain of new, smart technology. It includes smart sensors, new back-end IT systems, smart meters and a communications network. The results of this project will be used for the government's plan for a national smart grid rollout.
References	http://www.smartgridsmartcity.com.au/ http://www.ret.gov.au/energy/Documents/smart-grid/smartgrid-newdirection.pdf Budde (2011) Research & Markets: Australia - Smart Grid - Smart Grid-Smart City Project

AP 2	Yokohama City
Geographical area	Japan
Timeframe	2010 – 2014
Involved	NEDO, Toshiba, Panasonic, Meidensha, Nissan, Accenture, Tokyo Gas, Accenture, Meiden, DENSO, TEPCO
Summary	The demonstration project in Yokohama City, is one of the four Smart Community Projects that were initiated in 2010. The other projects are Toyota City, Kyoto Keihanna District and Kitakyushu City. Each project has a slightly different focus. The focus of this project is on existing cities where infrastructure cannot be easily reformed. The Yokohama project involves a community energy management system integrating three different areas, 4,500 smart houses, 2,000 electrical vehicles, 27 MW PV, Building and Energy Management Systems (BEMS) and Home Energy Management Systems (HEMS). The Yokohama project has a budget of 74 billion JPY (710 million EUR), the four Smart Community Projects together 127 billion JPY (1.2 billion EUR). Currently all demonstration sites are still under construction.
References	http://www.city.yokohama.lg.jp/ondan/english/pdf/initiatives/master-plan-of-yscp-press.pdf http://www.4thintegrationconference.com/downloads/Session%202-1_Watanabe.pdf http://www.egnret.ewg.apec.org/meetings/egnret37/(E2)%20JAPAN.pdf

AP 3	Intelligent Energy System
Geogrraphical area	Singapore
Timeframe	The IES pilot will be conducted in two phases. Phase 1 (2010 - 2012) focuses on the implementation of the enabling infrastructure for the IES. Phase 2 (2012-2013) will focus on the smart grid applications.
Involved	Accenture, ST Electronics (Info-Comm Systems), Singapore Power, Oracle, Hewlett-Packard, Power Automation, GreenWave Reality, Control4, Nanyang Technological University and several government agencies such as the Economic Development Board (EDB), Agency for Science, Technology and Research (A*STAR), Housing and Development Board, Infocomm Development Authority (IDA) and the National Environment Agency (NEA). In phase 2 additional partners will be involved.
Summary	In 2010 the Energy Market Authority (EMA) launched a pilot project for an ― Intelligent Energy System‖ (IES). The project will test a range of smart grid technologies to enhance the capabilities of Singapore's power grid infrastructure. Accenture is leading the consortium that executes the IES project of 30 million USD. Specifically, the IES pilot project seeks to develop and test the following components of a smart grid: Advanced metering and communications infrastructure, demand response management systems and management systems for distributed energy sources.
References	http://www.ema.gov.sg/ies/ http://www.nedo.go.jp/content/100085920.pdf http://www.smartgridobserver.com/n10-26-10-1.htm http://www.accenture.com/us-en/Pages/success-singapore-intelligent-energy-system-project.aspx http://www.cleantechinvestor.com/portal/smart-grid/5860-spotlight-on-singapore-smart-grid-city.html

AP 4	Smart Village Program
Geographical area	Australia
Timeframe	Started in February 2010.
Involved	Energy Australia, Sydney Water, University of Newcastle, University of Sydney
Summary	The program installed 1,000 smart meters with two-way communication and 100 Home Area Networks in selected Newington properties to create state-of-the-art homes with intelligent controls, renewable energy technology and storage. The smart meters enable Ausgrid to communicate savings tips, discounts and incentives to change the way households consume energy. For some customers, they also bring new control to household energy and water consumption and allow homeowners to remotely turn off appliances through the internet. The new smart metering infrastructure installed in homes will be integrated into an intelligent electricity network, which includes remote monitoring and control.
References	www.ausgrid.com.au/Common/Network-projects/Network-projects/Smart-grid-projects/Smart-Grid-Smart-City/Newington-Smart-Village.aspx http://www.smarthomefamily.com.au/

AP 5	Electric vehicle charging station
Geographical area	China
Timeframe	Multiple projects have been initiated starting from 2010
Involved	SGCC, National energy bureau, Chinese ministry of Industry, National car standard committee
Summary	SGCC plans to fully unfold the building of electric vehicle charging stations in 27 licensed regional and provincial companies in 2010. Seventy-five public charging stations, 6,209 AC charging spots and some battery replacement stations are projected, aiming to support the country's 'Energy-efficient and New-energy Vehicle Pilot Program'. State Grid has finished writing 6 industrial standards like Electric Vehicle Charging Station General Technical Requirements, Electric Vehicle Charging Station Design Guidance, Electric Vehicle Charging Station Power Supply System Standards. State Grid compiled Electric Vehicle Charging and Discharging Facilities Construction Guidance to standardize the building technology, equipment installation and intellectual supervision of the stations, basically solving issues appeared in the pilot projects, and creating a positive environment for a successful development of the charging stations. State Grid created various standards for EV charging stations from 2009 to 2011, but all of them are Chinese version. Recently 4 unified standards were released by the National Ministry of Industry and Information, they are EV conduct charging connection device part I, II, III, communication protocol between battery management system and EV charger (not vehicle mounted), from 2010 to 2011. About 25 EV charging standards were issued by state grid and southern grid. State grid prefers swap stations to exchange EV batteries, whereas southern grid prefers battery charging. There are 2 different concepts and development directions. At this moment, the general trend is to go along the swap station direction, as State Grid is the largest stakeholder.
References	http://www.sgcc.com.cn/ywlm/gsyw-e/218933.shtml

AP 6	**Demand Response System Pilot**
Geographical area	China
Timeframe	Started in January 2012
Involved	State Grid Company China, Honeywell
Summary	This project is China's first smart grid pilot project and feasibility study to monitor and manage electricity use in commercial buildings. The project will focus on DSM, and will utilize state-of-the-art smart grid technology, including automated demand response, advanced energy management, and sub-metering. The project is part of an agreement between the U.S. Trade and Development Agency (USTDA) and the State Grid Electric Power Research Institute (SGEPRI). The project is to be developed and implemented by Honeywell.
References	http://honeywell.com/News/Pages/Honeywell-And-TEDA-Launch-China%E2%80%99s-First-Demand-Response-Project-Under-United-States-China-Smart-Grid-Cooperative.aspx

EUR 1	European Distributed Energy Partnership (EU - DEEP)
Geographical area	FR, ES, CY, LV, BE, DE, GR, SE, HU, TR, FI, GR, UK, AT, Pl, CZ
Timeframe	2004 – 2009
Involved	Utilities: GDF Suez, Iberdrola, EAC, Latvenergo, Tractebel, RWE Energy, EPA Attiki, GASAG Research Centres: IEA/LTH, FEEM, VEIKI, RTU Laborlec, TUBITAK, AUTh, CENTER, Enersearch, SEAES, IIE-UPV, ICCS/NTUA, VTT, Labein, STRI, KULeuven, FIT, CRES, Imperial College Manufacturers: Bowman, MTU, Siemens PTD, Heletel Professionals: Technofi, Transénergie, Axiom Regulators: KAPE
Summary	The EU-DEEP project was a comprehensive project regarding the deployment of Distributed Energy Resources (DER) in Europe, with a consortium of 42 partners from 16 countries. The project looked at how to create the necessary conditions for sustainable DER expansion. Both technical and non-technical barriers of DER for stakeholders across the energy value chain were considered, for example, issues around market integration, regulation and connection to the grid. Five one-year field tests were carried out to validate the tools and methodologies used to feed proposed business models with real world costs and revenue data. These 5 field tests were as follows: 1. Testing the integration of a composite CHP system for market interaction, ―office buildings‖ segment, Grenoble France; 2. Testing the integration of a composite tri-generation system for market interaction, ―educational buildings‖ segment, Athens Greece; 3. Testing the technical feasibility of aggregating 10 kW to 1.5 MW scale DER in the UK commercial market segments; 4. Testing the technical feasibility of aggregating Micro-CHPs in the German residential sector; 5. Testing the technical feasibility of a decentralized control architecture for aggregation of load and generation (Greece). RWE, GDF Suez and Tractebel Engineering have launched ExpandDER, an association to disseminate the EU-DEEP results and to manage the intellectual property of the project after its end. ExpandDER has taken charge of a book which synthesis the knowledge from the project.
References	http://www.eudeep.com http://cordis.europa.eu/documents/documentlibrary/124772261EN6.pdf

EUR 2	**eTelligence**
Geographical area	Germany
Timeframe	The project was launched in Autumn 2008; in 2010 a field test began with around 650 households and selected business enterprises.
Involved	The eTelligence consortium is comprised of partners from science and research, the energy sector and IT specialists: EWE AG, Oldenburg, Germany (Utility, Lead Partner) BTC AG, Oldenburg, Germany (IT Consulting and Software Development) OFFIS e.V., Oldenburg, Germany (Research IT) energy & meteo systems GmbH, Oldenburg, Germany (SME, Virtual Power Plant, energy meteorology) Fraunhofer Energy Alliance, Freiburg and Ilmenau, Germany (Research CHP integration and distribution grid) Öko-Institut (Research Evaluation)
Summary	In an extensive field test eTelligence explores and demonstrates various approaches of using modern ICT and advanced operation to improve the current energy supply system and to enable broad integration of renewable energy sources like wind, photovoltaic and biomass. In the model region of Cuxhaven, electricity producers (wind, photovoltaics and biomass) are coupled with consumers who serve as either energy storage facilities or can flexibly adapt their electricity consumption to the generated power. Taking the example of a refrigerated warehouse: in times of wind surplus, deep-frozen fish can be cooled down to up to minus 24 degrees centigrade. In times of wind calm, cooling can be turned off until the temperature has risen to minus 18 degrees centigrade. Sewage treatment plants, swimming pools and private households are also participants in the system of intelligent integration of renewable energies into the power grid.
References	http://www.etelligence.de/etelligence.php Conrads (2012) Smart metering field trial eTelligence – Energy efficiency and load shifting potential.

EUR 3	ADINE
Geographical area	Finland
Timeframe	October 2007 – 2010
Involved	Hermia Ltd (Finland), AREVA T&D Ltd (Finland), ABB Oy Distribution Automation (Finland), AREVA Energietechnik GmbH (Germany), ComPower Ab (Sweden), Tampere University of Technology, Department of Electrical Energy Engineering (Finland) and Lund University, Department of Electrical Measurements and Industrial Electrical Engineering and Automation (Sweden).
Summary	This project develops, demonstrates and validates a new method for the active management of a distribution network and the enabling solutions to support it. The solutions operate as active components in managing the network to enable an easy interconnection of different DER units. The solutions cover the protection of the network, planning and information systems, and voltage and reactive power control. The aim of ADINE project is to develop new methods for the electric distribution network management including DER i.e. management of active distribution network to maintain networks within acceptable operating parameters. The ADINE project has demonstrated in real-life several technical solutions that make integration of DER easier.
References	www.hermia.fi/@Bin/746242/ADINE_SmartGrid_Bryssel_05032008.pdf www.hermia.fi/in_english/services/coordination-of-programmes-and-p/adine/materials/ www.hermia.fi/@Bin/761640/ADINE_D54_25112010_rev1+0.pdf www.hermia-fi-bin.directo.fi/@Bin/6446a9214514add14babc83fb780a1e3/1336956987/application/pdf/761570/ADINE_D63_01122010_rev1.pdf www.hermia.fi/@Bin/761640/ADINE_D54_25112010_rev1+0.pdf

EUR 4	MERGE
Geographical area	ES IE EL DE BE NO UK PT
Timeframe	January 2010 – December 2011
Involved	5 leading research institutes/universities (INESC Porto, ICCS/NTUA, TU Berlin, Cardiff and Comillas), 5 automotive connected partners (AVERE, Ricardo, IMR World, C4D and InSpire) and 6 System Operators/Regulatory Entities (PPC, REE, REN, Iberdrola, ESB and RAE).
Summary	Merge is a EUR 4.5 million, 16-partner collaborative research project aiming to evaluate the impacts that electric vehicles will have on EU electric power systems with regard to planning, operation and market functioning. The MERGE project does this in two key ways: 1. development of a management and control concept that will facilitate the actual transition; 2. development of an evaluation suite that consists of methods and programs of modeling, analysis and optimization of electric networks into which electric vehicles and their charging infrastructure is integrated. From the studies performed so far in the MERGE project, it is possible to conclude that large scale EV deployment can be performed without major concerns if one adopts an intelligent based approach, involving full use of ICT, to manage and control the presence of EV consumers in the electrical network.
References	www.ev-merge.euBower, E.T., et al (2012) Initial Findings of Merge, International Journal of Automotive Engineering 3 (2012) 35-40.

EUR 5	**Beywatch**
Geographical area	Spain & Greece
Timeframe	December 2008 - June 2011
Involved	EDF, Sigma Orionis, GL, Gorenje, Telefonica, Fagor, Universita degli studi di Palermo, Synlexis
Summary	Beywatch was a project focused on ICT tools for environmental management and energy efficiency. The aim of the project was to design, develop and evaluate an energy-aware and user-centric solution, capable of providing interactive energy monitoring, intelligent control and power demand balancing on a home and neighborhood level. The Beywatch system implemented for this project consisted of several subsystems: Beywatch Agent – this software was hosted on a Residential Gateway and comprised of: i) the Agent Scheduler & Controller; ii) the Home Energy Framework which provide services to the scheduler; iii) the Machine to Machine (M2M) communications interface. Supervisor – software for energy control and load balancing on a neighborhood level, and also to preserve customer contract agreements; Custom energy-aware, remote-controlled white goods - a washing machine and dishwasher were equipped with Zigbee interfaces and a refrigerator with a Wifi interface was used in this project; Metering Modules – which includes smart meters and also 'watchers' (i.e. smart plugs). This subsystem excludes the metering embedded inside the white goods; Combined Photovoltaic Solar (CPS) system, producing both electric and thermal energy (the thermal energy is used to supply hot water); Business Support Software – web-based software providing energy consumption information and also capable of initiating a social network group on energy consumption, and also 'eco-games’ between energy prosumers in the same area. Both global system tests and standalone device tests were carried out to validate the system developed as a whole. The agent controller has incorporated two key concepts the: 1. Hierarchical Propagation - incentives/counterincentives for the purposes of DR were propagated hierarchically according to spatial scope and the 2. Semantic translation - the incentives/counterincentives being propagated needed to be 'translated' so as to be consistent with the scope of the hierarchical level.

References	http://beywatch.eu/ http://beywatch.eu/docs/Beywatch_D6%204_TID_FF_20110805.pdf http://beywatch.eu/pub.php http://beywatch.eu/docs/Beywatch_WhitePaper.pdf

EUR 6	Cell Controller Pilot Project
Geographical area	Denmark
Timeframe	2005 - October 2011
Involved	Main Partners: Energinet.dk, SE Syd Energi Net, Energynautics GmbH, Spirae Inc (USA) Other Partners: Billund Varmeværk, Bramming Fjernvarme, Hejnsvig Varmeværk, Holsted Fjernvarme, 47 private wind turbine owners, Tjæreborg Industri, Pon Power, Rolls-Royce Marine, Siemens Denmark
Summary	The Cell Controller Pilot Project (CCPP) has shown the development, deployment and successful demonstration of the so-called Cell Controller. To date it is the biggest complete prototype of an advanced control, regulation and monitoring system for the smart grid. The 'Cell' is defined as the 60kV distribution grid below each 150/60kV transformer. It is an autonomous region fully automated by the cell controller which is able to communicate with decentralized CHP plants, wind turbines, transformers and load feeders. The amount of DG installed is such that local generation meets or exceeds local loading comfortably. One of the main objectives of this project was to use the system developed to coordinate distributed energy resources – in particular distributed generation (which is in abundance in the Danish distribution grid) for grid reliability and power-flow applications. Additionally by using CHP plants, wind turbines and load control, VPP functionality was envisaged to provide ancillary services such as power balancing, import/export of active and reactive power, and voltage control. The final objective was to provide fast islanding capabilities of the Cell, with grid operation continuing using local resources. The project took place over 7 years, with each new capability of the cell being tested first via simulations and laboratories, and then with a field test. The field test was carried out over a 1,000 km2 area in cooperation with a distribution company, using 28,000 households, business and institutions, 5 CHP units, 47 large wind turbines and 12 substations (60/10kV).
References	http://energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/Forskning/Cell%20Controller%20pilot.pdf

EUR 7	Model City of Mannheim
Geographical area	Germany
Timeframe	2008 – 2013
Involved	MVV Energie AG, DREWAG - Stadtwerke Dresden GmbH, IBM Deutschland GmbH, Power PLUS Communications AG, Papendorf Software Engineering GmbH, University of Duisburg-Essen, ISET - Verein an der Universität Kassel e.V., ifeu Heidelberg GmbH and IZES GmbH.
Summary	The Model city of Mannheim project concentrates on an urban conurbation with a high penetration rate in which renewable and decentralized sources of energy are used to a large extent. Within the framework of the E-Energy project, a representative large-scale trial is being conducted both in Mannheim and in Dresden to demonstrate the project can be applied and translated to other regions. The trial uses new methods to improve energy efficiency, grid quality, and the integration of renewable and decentralized sources of energy into the urban distribution network. The focus is on developing a cross-sector approach (involving electricity, heating, gas and water) to interconnect the consumption components with a broadband power line infrastructure. Communication between the model customers and the energy marketplace will be via the real-time, broadband powerline system of Mannheim project partner Power Plus Communications. An 'energy Internet' will be created in the project cities by using the electricity grid for data transmission. Customers will be assigned an 'energy butler' being developed by ISET and Papendorf SE for their energy management needs.
References	http://www.modellstadt-mannheim.de/moma/web/en/home/index.html http://www.e-energy.de/en/95.php http://www.e-energy.de/documents/E-Energy_Interim_results_Feb_2012.pdf

EUR 8	**SmartHouse/SmartGrid**
Geographical area	Netherlands/Germany/Greece
Timeframe	Q3 2008 - Q3 2011
Involved	SAP, IWES, MVV, TNO, ICCS-NTUA, PPC
Summary	The SmartHouse/SmartGrid (SHSG) project used houses as a way of creating intelligent networked collaborations alongside distributed generators for example. Intelligent agent and e-market techniques for decentralized control and optimization at network level formed a large part of the work. TRIAL A - Hoogkerk, Netherlands: – The Hoogkerk micro grid (which includes 25 interconnected houses) was used to show that the SHSG concept was scalable, and could handle the large-scale communication between thousands of smart energy devices. PowerMatcher software developed by the ECN was used as the core intelligence for this system. TRIAL B - Mannheim, Germany: – A small cluster of participants (100 households) was used to test the automated response of household devices, and observe consumer behavior to variable electricity prices. A Bidirectional Energy Management Interface was used to optimize local power consumption and generation automatically, using both locally available information as well as central information. TRIAL C - Meltemi, Greece: – The purpose of this field trial was to demonstrate how a decentralized system could handle critical situations such as islanding or a black start. To test critical grid operations, a MAGIC (Multi-Agent Intelligent Control) system was used to monitor the available distributed generation and create a load shedding schedule based on forecasts and criticality of loads, as well as consumer willingness to pay for running appliances during the island mode.
References	http://www.smarthouse-smartgrid.eu http://www.smarthouse-smartgrid.eu/fileadmin/templateSHSG/docs/SHSG_D5.5_PublicReport.pdf http://www.smarthouse-smartgrid.eu/index.php?id=146&L=kpuujhoppy

EUR 9	RegModHarz
Geographical area	Germany
Timeframe	November 2008 - Octomber 2012
Involved	RegenerativKraftwerk Harz GmbH & Co KG, E.ON Avacon Netz GmbH, Siemens AG, in.power GmbH, ISET e.V., Vattenfall Europe Transmission GmbH.
Summary	The RegModHarz project is mainly concerned with the joint marketing of regionally available renewable producers and DR grouped into a VPP on different markets. The control room at the renewable energy combined-cycle power plant in the Harz region receives real-time information on the energy situation in the region. With a complete overview of power generation, storage and consumption, it is possible to make forecasts, and optimum use can be made of the renewable energy sources. The Harz model region boasts extensive sources of renewable energy, ranging from wind farms and solar power systems to hydroelectric power stations. For this, the IEC-61850 standard was extended to enable the simple and secure connection of systems to a joint control station. This newly developed generic data model enables the automated assimilation of systems in energy management. With the innovative 'regional renewable energy rate' created as part of the project and now being tested in the field trial, consumers in the Harz region can obtain regional electricity from renewable energy sources, such as wind, sun or biogas. The rate is geared to minimize the residual load within the region so that the customers can make an active contribution to balancing out production and consumption. It is processed in part automatically through an energy management system and smart household applications. The project demonstrated that the storage requirements for energy could be reduced through short-term wind forecasts. Load shifts on the consumer side help to improve voltage regulation in the distribution grid and compensate for forecast errors. The newly developed pool coordinator to bundle and market the locally generated electricity will play a central role on the new markets.
References	www.regmodharz.de http://www.regmodharz.de/uploads/tx_sbdownloader/RegModHarz-Infoblatt-Broschuere.pdf www.e-energy.de/en/97.php www.e-energy.de/documents/E-Energy_Interim_results_Feb_2012.pdf

EUR 10	Growders
Geographical area	FR DE ES NL
Timeframe	2009 – June 2011
Involved	DNV KEMA, Continuon, Iberdrola, MVV, EAC, CEA-INES, IPE, Exendis, SAFT, Chloride
Summary	GROWDERS demonstrates the technical and economical possibilities of existing electricity storage technologies. Transportable storage provides a flexible asset for network management introducing possibilities for deferral of investments in expensive switchgear and creates possibilities to integrate DER and RES. The assessment tool 'PLATOS' has been developed to assess the benefits of various storage systems in generic electricity grids. Objective of the tool is to select the optimal application of a storage system in a electricity grid.
References	http://www.growders.eu http://www.growders.eu/papers/CICED%202010%20paper.pdf

EUR 11	Power Matching City
Geographical area	Netherlands
Timeframe	Phase I has ended (started in 2009). Phase II started February 2011.
Involved	DNV KEMA, ECN, Essent, Enexis, Humiq, TNO
Summary	An example of local matching of generation and demand. Field test covering the day-to-day market trading (Virtual Power Plant (VPP) operation), network congestion management, In-home optimization and integration of intermittent renewables. Production and consumption of electricity are constantly matched by generating electricity as much as possible at high demand loads and switching on (or off) electrical devices at times of high (or low) generation. The demonstration project has been around since 2009 in Hoogkerk, a neighborhood in the city of Groningen. At the first stage, 25 households took part. In 2011, the second phase of Power Matching City initiated. Nowadays 42 households have joined the program.
References	http://www.powermatchingcity.nl

EUR 12	**Kythnos Micro-Grid**
Geographical area	Greece
Timeframe	2006 – 2009
Involved	Centre for Renewable Energy Sources and Saving (CRES), ICCS/NTUA, ANCO, ISET, SMA Regelsysteme GmbH
Summary	An interesting example of a micro-grid scheme that has been successfully deployed is in a small valley on the Greek island of Kythnos. T The project aimed at the increase of penetration of microgeneration in electrical networks through the exploitation and extension of the Microgrids concept, involving the investigation of alternative microgenerator control strategies and alternative network designs, development of new tools for multi-microgrids management operation (involving Distribution Management System architectures and new software adaptation) and standardization of technical and commercial protocols. The system is a single phase micro-grid composed of the overhead power lines and a communication cable running in parallel electrifying 12 vacation houses. This network is used to test centralized and decentralized control strategies in island mode as well as communication protocols that are a major challenge for such micro-grids. In the Centralized approach the work focused in the development of online security and forecast modules as well the adaptation of scheduling functions for laboratory needs. In the Decentralized approach the Multi- Agent system (MAS) concept was adopted. For the Decentralized Control system, algorithms and general implementation structures were developed based on common used platforms (Jade) The focus in this project has been on technical feasibility rather than large scale demonstration.
References	http://www.microgrids.eu/index.php?page=kythnos&id=2 http://www.microgrids.eu/documents/esr.pdf

EUR 13	EDISON
Geographical area	Denmark
Timeframe	2009 – 2012
Involved	Danish Energy Association, Østkraft, Dong Energy, IBM, Siemens, Eurisco, DTU CET
Summary	E.D.I.S.O.N. is an abbreviation for 'Electric vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks'. In the EDISON project Danish and international competences will be utilized to develop optimal system solutions for EV system integration, including network issues, market solutions, and optimal interaction between different energy technologies. Furthermore, the Danish electric power system provides an optimal platform for demonstration of the developed solutions. Work packages include 1. EV Technology, 2. System Architecture design for EV systems, 3. Distributed Integration Technology development, 4. Central fast-charge and battery swapping development, 5. EV communication and physical charging post, 6. Functional testing and field testing.
References	www.edison-net.dk

EUR 14	Address
Geographical area	ES FR IT CH SE NL UK F S BE D RO
Timeframe	2008 – 2012
Involved	Enel Distribution, EDF, Iberdrola, Vattenfall, ABB, Landis+Gyr, ZIV, Philips, Electrolux, RLtec, Ericsson, Alcatel, Current, University of Manchester, Universidad Pontificia Comillas, Università di Siena, Università di Cassino, VTT, VITO, Labein, DNV KEMA, Consentec
Summary	This project aims to contribute to the development of interactive distribution energy networks. It is a local energy balancing project, one of the building blocks of a Distribution System Operator. Central theme of this wide-scale project is DR, i.e. allowing the participation of demand in power system markets and in service provision to different power system participants. This allows for increased power system efficiency and integration of renewable energy sources. There are three field test locations: in France, Spain and Italy.
References	http://www.addressfp7.org http://www.addressfp7.org/config/files/Nordac10_ADDRESS.pdf http://www.addressfp7.org/config/files/Paper_ID59.pdf http://www.addressfp7.org/config/files/ADD-WP5-T5%201-Evaluation%20of%20AD%20benefit.pdf

EUR 15	Virtual Fuel Cell Power Plant
Geographical area	Germany
Timeframe	2001 - 2005.
Involved	Initiative Brennstoffzelle (IBZ), Vaillant, Plu Power Holland, Cogen Europe, Instituti Superior Tecnico (IST), University of Essen, DLR, Sistemas de Calor, Gasunie, E.ON Ruhrgas, E.ON Energie, EWE.
Summary	The Virtual Fuel Cell Power Plant (VFCPP) is a series of decentralized residential micro-CHPs using fuel cell technology, installed in multi-family-houses, small enterprises, public facilities etc., for individual heating, cooling and electricity production. Centrally controlled and grid-connected, these elements of the virtual power plant contribute to meet peaking energy demand in the public electricity grid and act as a virtual power plant. The objective of the project was to develop, to install, to test and to demonstrate a virtual power plant consisting of 31 decentralized stand-alone residential fuel cell systems, i.e. to transform laboratory technology into an everyday technology.
References	http://ec.europa.eu/energy/efficiency/industry/doc/euvpp.pdf

EUR 16	AURA NMS
Geographical area	United Kingdom
Timeframe	January 2007 - June 2010.
Involved	Scottish Power, EDF, ABB, Imperial College and various universities
Summary	AURA NMS (Automated Regional Active Network Management System) is a multi-party project addressing active network management to facilitate distributed generation connection and operation. It has a strong theme directed towards practical applications, including the real world limitations imposed by the need to integrate new approaches with existing plant, equipment and controls. This project aims to produce a control structure and set of control algorithms that realize the notion of an active distribution network and enhance the service a network operator provides to load and generation customers, improving network performance (asset use, etc.).
References	http://www.ofgem.gov.uk/Networks/Techn/NetwrkSupp/Innovat/ifi/Documents1/Scottish%20Power%20IFI%20Report%202007-8.pdf http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/E003583/1 http://www.aura-nms.co.uk/ AuRA-NMS: Davidson et. al (2010) An autonomous regional active network management system for EDF energy and SP energy networks, IEEE

EUR 17	**Evora InovCity**
Geographical area	Portugal
Timeframe	2007 -2017
Involved	EDF Distribution, Insec Porto, Efacec, Logica, Janz
Summary	The project scope aims at developing a set of functionalities and new devices that can be installed on the network to facilitate a more active role for the management of the distribution system. The main objectives of the project include: i) bringing about the liberalization of electricity markets in Portugal, ii) developing a customer-focused market, iii) inducing demand modulation, iv) improving security of supply and v) promoting the renovation of grids and their operation. Expected benefits from this project are that regulators will see better implementation of conditions that support market developments, with positive implications on energy costs. The proposed implementation is as follows: start in 2007, pilot with 500 customers in 2009, installation phase 1, 50,000 customers in 2009-2010; installation phase 2, up to 600,000 customers 2010-2011 and roll-out from 2011 to 2017 for the whole of Portugal. Half way through 2011, roughly 30,000 customers have been included with an 'energy box'.
References	http://www.inovcity.pt/en/Pages/inovgrid.aspx http://www.metering.com/node/19904 http://ec.europa.eu/research/conferences/2009/smart_networks/pdf/messias.pdf

EUR 18	Smart City Malaga
Geographical area	Spain
Timeframe	July 2009 – 2013
Involved	Endesa, ERDF, Enel, Acciona, IBM, Sadiel, Ormazábel, Neometrics, Isotrol, Telvent, Ingeteam, Greenpower and several universities
Summary	Smart City Malaga is a 31 million EUR project that offers a new energy management model in cities. The objective is to achieve a 20% energy saving, a reduction of 6.000 tons of CO_2 per year, and an increase of renewable energy consumption. Renewable energy sources will be linked up to the grid to more closely match generation to consumption. Furthermore there will be energy storage systems in the form of batteries. The installation of advanced telecommunication systems and remote control will operate in real time and automatically on the distribution network, enabling a new energy management and increasing the quality of service.
References	http://portalsmartcity.sadiel.es/EN http://portalsmartcity.sadiel.es/EN/documentos/100204_%20Smartcity_ENDESA_Eng3.pdf

EUR 19	FENIX
Geographical area	ES UK SI AT DE NL FR RO
Timeframe	2005 - 2009
Involved	Iberdrola, EDF, EDF Energy Networks, Areva, ECRO, ECN, Labein, Gamesa, IDEA, Imperial College London, ISET, Korona, National Grid Transco, Poyry Consulting, Red Electrica de Espana, ScalAgent, Siemens, University of Manchester, Vrije Universiteit Amsterdam, ZIV PmacC
Summary	The objective of FENIX was to boost Distributed Energy Resources (DER) by maximizing their contribution to the electric power system, through aggregation into Large Scale Virtual Power Plants and decentralized management. FENIX conceptualized, designed and demonstrated a technical architecture and commercial and regulatory framework that enable DER units to become the solution for the future.
References	http://fenix.iwes.fraunhofer.de/home.htm http://fenix.iwes.fraunhofer.de/docs/documents/Project_Fenix_2009-07-06_WP3_2_5_RegulatoryFramework_FullReport_Dafydd_Elis_v1.pdf http://fenix.iwes.fraunhofer.de/docs/att2x/2009_Fenix_Book_FINAL_for_self printing.pdf

EUR 20	**Twenties (VPP work package)**
Geographical area	DE, NO, UK, IE, ES, IT, BE, DE, NL, FR
Timeframe	2010 – 2014
Involved	DONG ENERGY, Energinet, DTU Energy, TenneT, Fraunhofer IWES, 50 HzT, SIEMENS Wind Power, ELIA, EWEA, CORESO, University Liege, University Leuven, Universite Libre Bruxells, RSE, Red Electrica De Espana, Iberdrola, ITT Comillas, Gamesa, ABB S.A., Inesc-Porto, UCD, Alstom Grid, University of Strathclyde
Summary	The TWENTIES project consortium aims to conduct large scale demonstrations (6 in total) for the purposes of showing the benefits and impacts of technologies needed to improve the pan-European transmission network, allowing Europe to integrate a higher capacity of renewables whilst keeping current reliability levels. Although much of the work is focused on the transmission level, of particular interest for this report is the Large Scale VPP Integration work package being conducted by Dong Energy. The VPP demonstration in Denmark aims to show how through distributed generation and through aggregated load units at low voltage levels, ancillary services can be provided for the purposes of flexibility and balancing intermittent renewable energy. The VPP system is divided into several system components, each with its own responsibility and purpose, in order to comply with the Twenties goal of having a modular design. The purpose of the modular design is to more easily change specific modules into other technologies or market-specific components, if the need arises during implementation in other countries or market situations
References	http://www.twenties-project.eu/system/files/Deliv_10_2.pdf