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MODELS OF FINANCING SMART GRID PROJECTS ABROAD

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Tutkimuksen taustan pohjana on maailmanlaajuinen sähköverkon uudistus. Uudistuksen yksi merkittävimmistä tekijöistä on tietotekniikan yhdistäminen sähkönjakeluun siten, että se mahdollistaa molemminpuolisen tiedonkulun asiakkaiden kanssa. Yhdistettynä vaihtoehtoisiin energialähteiden ja uusien teknologioiden hyödyntämiseen, näillä tiedoilla voidaan muun muassa kehittää hinnoittelumalleja, jotka kannustavat sähkönkulutuksen vähentämiseen kysyntähuippujen aikana. Valtaosa projekteista saa julkista rahoitusapua Tekesin kaltaisilta organisaatioilta tai Euroopan aluekehitysrahastoilta. Esimerkiksi Vaasassa toimii Vaasan Energiainstituutin RE Form-hanke. Tämän tutkimuksen tarkoitus on edesauttaa paikallisia hankkeita ja sidosryhmiä esittämällä otoksia maailmalla esiintyvistä rahoitusmalleista sekä hankkia mahdollisimman paljon tietoa yleisistä trendeistä ja sähköasiakkaiden osallisuudesta projekteihin.

Teoriaosuus koostuu kahdesta kokonaisuudesta. Ensimmäisessä osiossa käydään läpi älyverkkojen merkittävimmät ominaisuudet sekä teknologiasovellutukset, jotka on pääasiassa kerätty tuoreista sähköisistä lähteistä. Toisessa osiossa käydään läpi EU:n ja Yhdysvaltojen liittovaltion tarjoamat kehitysrahastot, sillä niillä todettiin olevan tärkeä osa älyverkkoprojektien rahoituksessa näin aikaisessa vaiheessa. Toinen osio käsittelee rahoituksen teoriaa, jota seuraa energiaprojektien rahoituksen teoria. Kvalitatiivisia ja kvantitatiivisia tutkimusmenetelmiä käytettiin ensinnäkin toistensa tukemiseksi, ja toiseksi kunkin tavan täydentämiseksi.

Tutkimuksessa kävi ilmi, että pääorganisaatiolla on päävastuu rahoituksen suunnittelussa ja jakamisessa, mutta riski on aina osittain jaettu usean yhteistyökumppanin kanssa konsortiossa. Tukirahastot auttavat tekemään sijoituskohteesta houkuttelevan antamalla suunnilleen konsortion omaa sijoitusta vastaavan tuen. Yleisesti asiakkaat ovat osallisina tällä hetkellä noin puolessa älyverkkoprojekteista, dynaamisen hinnoittelun ollessa yleisin asiakkaiden sitouttamismenetelmä.

Avainsanat: älyverkko, rahoitus, hajautettu tuotanto, energia, saarekekäyttö

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ABSTRACT

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The basis for the study is the worldwide modernization of the electricity grid. One of the most significant factors in the modernization is to interconnect IT-technology with the grid so that it enables two-way communication between suppliers and consumers. Combined with alternate energy sources and other technologies it enables, for example, construction of pricing models that encourages off-peak-hours electricity usage. Most of the ongoing projects receive public funding from the likes of Tekes or European funding agencies. For example, Vaasa Energy Institute runs a project called RE Form. The aim of this research is to help local stakeholders and projects by showcasing samples of select financing models and to gain as much intelligence as possible on general trends in smart grid financing and electricity consumer engagement.

The theory consists of two entities. First, the fundamental features and technologies of smart grids are described. Second, EU and U.S. funding programs are characterized, followed by general financing and energy project financing theory. Qualitative and quantitative research methods were utilized, first of all, to support, and secondly, to complement each other.

It was revealed that the lead organization has the main responsibility in planning and allocation of funds, but the risk is partly divided with multiple partners in the consortium. Public funds help in making the investment decision more compelling by providing approximately a matching investment against the consortium investment. The end-customers are affiliated in about half of the current smart grid projects, dynamic pricing being the most common consumer engagement method.

Keywords: smart grid, financing, distributed generation, energy, islanding

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1 INTRODUCTION

The thesis is being made in order to aid the RE Form-project in the energy industry on a national level here in Finland and it is partly funded by agencies such as Tekes. The main objective of the research is to find out how Smart Grid projects designated for consumers and households are being financed. The research then can be used to understand the possible effective models of financing Smart Grid technology here in Finland by contrasting the results to the local environment. The study should be beneficial for local companies interested in Smart Grid industry as well, especially for small to medium sized enterprises that do not have sufficient resources for research and development.

The subject is especially intriguing for the Vaasa region, since it operates a remarkable part of the Finnish energy cluster and the area also provides and produces more energy-related know-how in its educational institutes. Therefore, being the trailblazer in smart grid technology in Finland could be remarkable for Vaasa: increased employment, increased numbers of students and increase in the population and economy. (Vaasa Energy Institute, 2012)

Tekes is the most important publicly funded expert organization for financing research, development and innovation in Finland. Besides funding technological breakthroughs, Tekes also emphasizes the significance of service-related, design, business, and social innovations. Tekes works with the top innovative companies and research units in Finland. Every year, Tekes finances some 1,500 business research and development projects, and almost 600 public research projects at universities, research institutes and polytechnics. Research, development and innovation funding is targeted to projects that create in the long-term the greatest benefits for the economy and society. Tekes does not derive any financial profit from its activities or claim intellectual proprietary rights. (Tekes, 2011)

1.1 Key Drivers for Smart Grid Development

European Technology Platform published Strategic Research Agenda (SRA) on Smart Grids in 2007 (2012). The document identified the main areas requiring investigation in the short and medium term in the European grid. It served as a decisive input to the European Electricity Grid Initiative (EEGI), laying out Smart Grids research, development and deployment needs to achieve the EU's 20-20-20 targets by 2020. The SRA has another role as well: it could serve as key input to the next 2014 upcoming EU Framework Program for research and innovation, as well as other smart grids research, development and deployment initiatives both on national and European level. (European Technology Platform SmartGrids, 2012)

The goal of these activities proposed by SRA 2035 is to create the basis for a high quality, economically affordable and sustainable electricity supply transition from present with the help of the progress achieved through the EEGI and other European Strategic Technology Plan (SET-Plan) initiatives by 2020, on the way to the energy and electricity system of 2035, and then leading to a carbon-dioxide free electricity system by 2050.

Smart Grid SRA is part of The European Electricity Grid Initiative. EEGI seeks to develop, demonstrate and validate, at scale, the technologies, system integration and processes to enable the transmission and distribution of up to 35% of electricity from distributed and concentrated renewable sources by 2020 and make electricity production completely CO2-free by 2050.

EEGI, again, is a part of EU's even larger scale plan, the SET-Plan. The main idea in the SET-Plan is to make low-carbon technologies affordable and competitive. The driver for the plan is the worldwide climate change. EU is tackling the challenge through a policy where the target is the transformation of the entire energy system, with far-reaching implications on how energy is being sourced and produced, transported and traded, and consumed. There are ten other initiatives besides EEGI. (European Commission, 2010)

Correspondingly, in U.S., with the provision of the energy independence and security act of 2007, support for Smart Grids has become federal policy. Energy Independence and Security Act provided the legislative support for Department of Enerrgy's smart grid activities and strengthened its role in leading and coordinating national grid modernization efforts. Department of Energy (DOE) (2013) states that the provisions of Title XIII sections include:

- Establishment of the *Smart Grid Advisory Committee* and *Federal Smart Grid Task Force* at DOE.
- Authorizes DOE to develop a “Smart Grid Regional Demonstration Initiative.”
- Directs the National Institute of Standards and Technology, with DOE and others, to develop a Smart Grid Interoperability Framework.
- Authorized DOE to develop a “Federal Matching Fund for Smart Grid Investment Costs", later to be known as Smart Grid Investment Grant Program.

A funding of $ 100 million per fiscal year from year 2008–2012 was then approved, establishing a matching program to states, utilities and consumers to build smart grid capabilities and creating a grid modernization commission to assess the benefits of demand response and to recommend needed actions. Development of smart grid standards will be coordinated by, which will later spread through to official rulemakings. Smart Grids gained even more support with the provision of the American Recovery and Reinvestment Act of 2009 (ARRA), which set aside 11 dollars billion for the creation of a smart grid. (Hashmi, 2011, 55,56)

1.2 Research Problem

The research problem is to find out models of financing smart grid projects globally. The ways in which the financing is carried out may vary significantly, since the projects investigated are first of its kind. According to PVGroup (2012), the term smart grid had not actually even really existed in 2004.

The following research questions are derived from the initial research problem:

- What are the current trends in Smart Grid financing?

- To what extent are the common energy project financing alternatives utilized in Smart Grid projects?
- What are the methods used to engage consumer/prosumers in the projects?
- How do consumers contribute into financing Smart Grids?

1.3 Limitations of the Study

The smart grid has been deployed to some extent in most of the developed countries in the world. Since there is a lack of common framework for data sharing and analysis, it is difficult to compare the Smart Grid project (Giordano & Bossart, 2012). Especially different continents with their still-evolving standardization efforts question the comparability and the current status of the Smart Grids between continents. That is why only European and U.S. Smart Grid projects are being discussed to avoid the research becoming too complicated.

Under the label ‘Smart Grid’ there are several types of technologies, stakeholders and types of involvement (Giordano & Bossart, 2012; European Technology Platform SmartGrids, 2012; Rackliffe, ABB Smart Grid Update with Gary Rackliffe, 2012). This can make comparison of different projects difficult.

All efforts were put in completing the study, because on most occasions progress of the thesis was lagging from the original schedule. Therefore, no promotion of the thesis was made to, for example, local companies.

When giving the results, evaluating the success of each project is either left out or considered carefully, because every source of information is coming from a smart grid stakeholder of some kind, so the stance taken in the reports or articles is most often biased by the role that the source has in the Smart Grid industry.

1.4 Information Sources

Electronic publications are extensively utilized in the technology introductions, since the recent nature of the subject makes finding valid and up-to-date information from such resources more effective compared to the traditional sources. Even during the construction of the thesis, more reports on the subject became available. Scientific papers about Smart Grids were significant sources and the EU and U.S. governmental documents are used throughout the thesis to improve the validity of the information. In the financing section, Financial Management: Principles and Practice by Gallagher and Andrew (2007) is used. In energy project specific section, Energy Project Financing: Resources and Strategies to Success by Thumann and Woodroof (2009) is used as the main reference. Empirical section of the thesis was constructed according to the principles in Research Methods in Business Studies by Ghauri and Gronhaug (2010).

2 THEORETICAL FRAMEWORK: SMART GRID

In short, Smart Grid is an entity that compiles new, tested technologies in to the grid, making it more reliable, efficient and safer. A prominent feature in the Smart Grids is the possibility for active two-way communication between the customers and suppliers. Now, in 2013 smart meters, distributed generation and renewable energies play a central role in the current development of Smart Grids. At a consumer level the most significant tangible technologies are micro grid technologies, home area networks and plug-in hybrid cars. Pittman (2012) says that *"A smart grid is an electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of energy".* In this research smart grid is used as a definition of the process, and therefore, there will be no distinction between 'Smart Grid' and 'Smarter Grid'. See Figure 1 below.

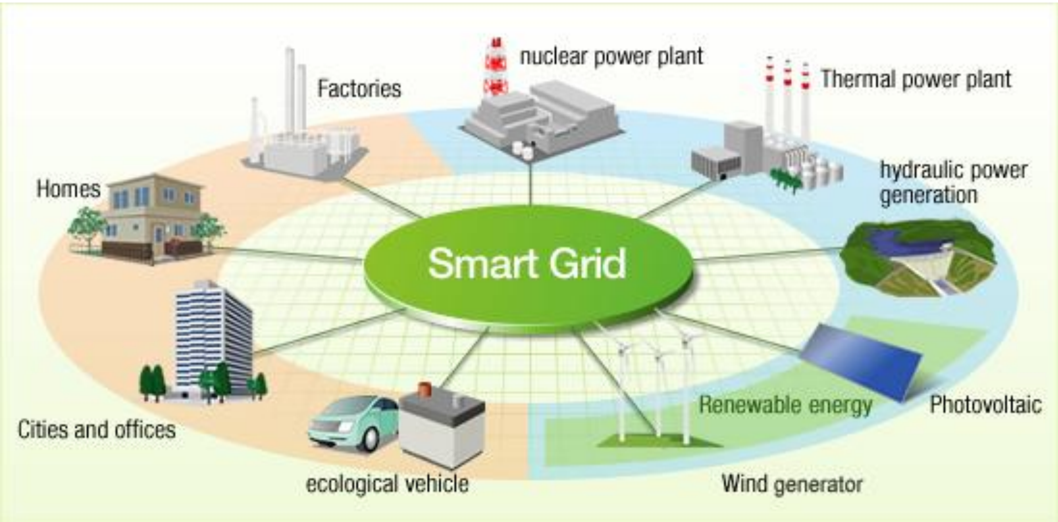

Figure 1. Smart Grid: Big Picture. Hitachi, 1994-2013.

A smart grid is felt to be necessary for the integration of distributed generation, renewable energy sources and plug-in hybrid electric vehicles into the electricity grid. Utilization of demand-side management is a driver for improvements in overall system efficiency, in ways such as avoiding investments in peak generation, and customer tariff systems with incentives. (Hashmi, 2011, 54)

Hashmi (2011) states that the definition of Smart Grid is global. Despite that, Smart Grid technologies are varying from country to country. Therefore the actual Smart Grid deployment plan would likely be differentiated based on the country or the region's own particular circumstances. A simple way to understand Smart Grid by U.S. Department of Energy (2013) is to think of it as the internet brought to electric system. The term smarter grid is mentioned to stress the point that no single technical solution or gadget turns a regular grid into a smart grid. Therefore, Smart Grid is more of a continuous process or an evolution, the term 'smarter grid' may be preferred by some.

According to EEGI (2010, 15) Smart Grid European Technology Platform defines a smart grid as an "*electricity network that can intelligently integrate the actions of all the users connected to it – generators, consumers and those that do both, in order to efficiently deliver sustainable economic and secure electricity supply"*. Since several definitions already exist, instead of definition the focus of the EEGI has developed a model to guide in the process of defining the functionalities and the needed projects, to make sure all critical issues are covered and avoid overlaps. (European Electricity Grid Initiative, 2010)

2.1 Stakeholders

Asking a number of people for the definition of Smart Grids usually gives the same amount of different answers (Rackliffe, 2012). Furthermore, that is not because the people would be ignorant or uninformed, but because there are different stakeholders. This means that smart grid has different benefits for different individuals (2012). USA has defined its stakeholders into six broad groups, which are (Office of Electricity Delivery & Energy Reliability, 2009):

- Consumer advocates
- Environmental groups
- Utilities
- Regulators
- Technology providers
- Policymakers

The European Union has basically the same definition of stakeholders but the categories are more specific in nature and proved out to be more useful in this research. The main non-research related technological stakeholders are discussed in the below and are determined by SRA 2035 (European Technology Platform SmartGrids, 2012, 24-25). Main system needs and roles are described under each stakeholder:

Consumers: Consumers of energy products and services. Consumer is the end-user of electricity. Categories of consumers are residentials, households, and communities. SMEs, industries and electricity-intensive industries are also considered as consumers. An example of a consumer category is the set of users with specialized mobility requirements for hybrid or pure electric vehicles. Those users need mobility interfaces with quality and security of supply of the electricity system.

Prosumers: Consumers with additional role of own electricity generation and/or storage for private, daily-life needs, comfort and SME business needs.

Energy Retailers: Sales of energy and related services and products to consumers. Retailers will develop consumer oriented programs and offerings.

Aggregators: Energy broking on behalf of a group or groups of prosumers.

Energy Service Companies (ESCO): Provision of a broad range of comprehensive energy solutions, including designs and implementation of energy savings projects, energy conservation, energy infrastructure outsourcing, power generation and energy supply and risk management.

Electric Appliance users: The use of electrical appliances at consumer sites both for daily life and business needs will increase due to substitution of fossil based space heating requirements. In the future the users will be required to accomodate their needs with quality and security of supply needs of the electricity system.

Electric Vehicle users: A hybrid or right-out electric vehicle is a specialized electricity consumer with mobility requirements.

Generators: Large scale centralized generation (includes wind farms).

Distributed Generators: Small- and medium-scale generation of electricity either for third party consumers or for own consumption. Distributed generation is mostly renewable based.

Storage Providers: Delivery of storage products and services. Includes the maintenance and operation, thereby shifting electricity and energy consumption in time either for third parties or own purposes.

Ancillary Service Providers: Provision of services. Ancillary Srervice Providers includes services such Power Balancing, Voltage Profile Support, Frequency and Time and Blackstart.

ICT equipment and systems providers: Sales of Information and Communication Technology products and services.

Telecommunications providers: Provision of telecommunication services based on either dedicated or public infrastructure.

Data processing service providers: Provision of data processing services respecting consumer privacy

Energy Equipment & Systems Manufacturers: Sales of Electro-technology System products and services.

Distribution System Operators (DSOs): Provision of services towards secure, efficient and sustainable operation of electricity distribution systems. DSOs have a legal obligation of a high quality, secure planning, operation and maintenance of the distribution grid.

Transmission System Operators (TSOs): Provides services to achieve a secure, efficient and sustainable operation of transmission system. TSO has a legal obligation of a high quality, secure planning, operation and maintenance of the transmission grid.

Wholesale Electricity Market Traders: Provides market based prices for products and services by liquid electricity markets.

Policy makers, Regulators: Setting up and control of natural monopoly requirements and for highly effective electricity markets.

Electricity Market Operators: The operators of market places for energy and other energy commodities.

2.2 Technological Priorities

In EU, the following technological priorities for research, development and deployment (RD&D) to support the smart grid systems 2035 are proposed by the SRA 2035 (2012):

- Small- to medium-scale distributed storage systems
- Real-time energy use metering and system state monitoring systems
- Grid modeling technologies
- Communication technologies
- Protection systems for distributions systems

In U.S., the ten elements of the Title XIII define the outline for the developmental direction of Smart Grid (Office of Electricity Delivery & Energy Reliability, 2009):

1. Increased use of digital information and controls technology.
2. Optimization of grid operations and resources, with full cyber-security.
3. Deployment and integration of distributed resources and generation, including renewable resources.
4. Incorporation of demand response, demand-side resources, and energy efficiency resources.
5. Deployment of ‘smart’ technologies for metering, communications concerning grid operations and status, and distribution automation.
6. Integration of ‘smart’ appliances and consumer devices.
7. Deployment and integration of advanced electricity storage and peak shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning.
8. Provision to consumers of timely information and control options.
9. Development of standards for communication and interoperability of appliances and equipment connected to the electric grid.
10. The lowering of unreasonable or unnecessary barriers to adoption

2.3 Technology Introduction

The sub-sections will introduce different technologies and concepts of the Smart Grid entity. Here is a glimpse of technologies that are evaluated to have the most significance in the near future, based on the SRA 2035 (European Technology Platform SmartGrids, 2012, 22), U.S. Department of Energy Smart Grid Research & Development Multi-Year Program Plan 2010-2014 (U.S. Department of Energy, 2012, 17-19)

2.3.1 Islanding

Islanding refers to a condition where a facility runs on its own alternative power source when energy is not coming from a common grid. Such power source can also feed energy back into the grid. The term refers to the isolation of such a self-sufficient facility, as distinct as an island, away from the main continents. Islanding can either happen as the result of a power black-out or be set up intentionally. (Conjecture Corporation, 2003-2013)

The process of islanding is implemented by a distributed generator. This is the name for the alternate power source that enables the facility to function independently, solar power being the most common source (see section 2.3.2). Some facilities use more than one form of alternative energy when islanding. One popular configuration is a building that uses both solar panels and wind power generated from turbines. A system like this can be more effective because the two power sources often are complementary, one compensating for the weaknesses of the other. Some distributed generators can also be used along with the power from an electrical utility. (Conjecture Corporation, 2003-2013)

2.3.2 Micro Grid, Distributed Generation and Net Metering

Micro grids are modern, small-scale versions of the grid, as opposites to the centralized electricity system. They achieve specific local goals, such as reliability, carbon emission reduction, diversification of energy sources, and cost reduction, established by the community being served. (Galvin Electricity Initiative, 2012)

Distributed generation is an approach that employs small-scale technologies to produce electricity close to the end users of power. In many cases, distributed generators can provide lower-cost electricity and higher power reliability and security with fewer environmental consequences than can traditional power generators. The conventional centralized power plants have many disadvantages. In addition to the transmission distance issues, these systems contribute to greenhouse gas emission, the production of nuclear waste, inefficiencies and power loss over the lengthy transmission lines, environmental distribution where the power lines are constructed, and security related issues. Many of these issues can be mediated through distributed energies. Distributed generation is often produced by small modular energy conversion units like solar panels. These units can be stand-alone or integrated into the existing energy grid. Frequently, consumers who have installed solar panels, will contribute more to the grid than they take out resulting in a win-win situation for both the power grid and the end-user. Other possible sources of energy include wind, coal, and nuclear energy. Some generators can be run by fossil fuels, but these are extremely expensive for larger facilities. (Consortium on Energy Restructuring, Virginia Tech, 2007)

Related to this, net metering is a special metering and billing agreement between utilities and consumers facilitating the connection of small, renewable energy-generating systems to the power grid. Net metering programs encourage using small-scale, renewable energy systems. The agreement includes installation of renewable energy-generating systems to for example the consumers' backyard. The agreements also ensure that consumers always have a reliable source of energy from the grid during times when their renewable generators are not producing energy. (State Environmental Resouce Center, 2012)

2.3.3 Peak Load Management, Demand Response

Load management has been already available since the early 1980s. Moreover, direct load control, peak shaving, peak shifting, and various voluntary load management programs have been implemented by many utilities with varying degrees of success and now with the push for energy conservation and demand-side management as a key strategy for environmental compliance, demand response is taking on new realities. (Ipakhchi & Albuyeh, 2009, 58).

Demand response is end-use customers reducing their use of electricity in response to power grid needs, economic signals from a competitive wholesale market or special retail rates (PJM, 2013). In other words, demand response gives businesses and households an opportunity in affect energy bill by adjusting the time and intensity of electricity used. Demand response relies on dynamic pricing as opposed to traditional fixed electricity pricing. Demand response pricing tariffs function according to the principles of the correlation of supply and demand.

2.3.4 Smart Meter: Automatic Meter Reading (AMR) and Advanced Metering Infrastructure (AMI)

A smart meter is a good example of an enabling technology that makes it possible to extract value from two-way communication to support distributed technologies and consumer participation (U.S. Department of Energy, 2008). Therefore, smart meter is an essential part of the smart grid, alongside other features. The meters in Advanced Metering Infrastructure (AMI) systems are usually referred to as smart meters (Digi International Inc., 2008).

Automatic Meter Reading (AMRs) were the original devices that only collected meter readings electronically and matched them with accounts. The primary drivers in North America for AMR originally were to reduce the cost of collecting data and to increase the accuracy of data collected. (Digi International Inc., 2008). Because of the limitations of the initial AMR implementations, the trend in the past years has been on defining methods of communication that allow two-way and real-time data collection. AMI is the new term made up to represent the networking technology that surpasses AMRs and go more into remote utility management. Also, the AMI initiatives have risen to prominence with federal policies (Energy Policy Act of 2005, 2005).

The Advanced Metering Infrastructures (AMIs) being deployed by many utilities around the developed world and it enables the implementation of targeted dynamic tariffs, management of demand-side energy resources, and integration of retail demand-side capabilities with wholesale energy markets, in addition to traditional load management. Many expect that dynamic and market-based rates will become the default retail tariff in many regions that have AMI capability (Ipakhchi & Albuyeh, 2009). However, most AMI architectures require a combination of public and private network services, in an effort to leverage existing deployed technology and to optimize operational costs. (Digi International Inc., 2008).

Finland is a pioneer market for smart meters, and the service- and business concepts born in the process would then make it possible to gain a specific competitive advantage, since the market in the rest of the world would only open later on. This development of new services and business practices will further be aided by the act that obligates the network companies to deliver the hourly metering data to either the customer or a third party authorized by the customer. (Jatiko, 2011, 4)

2.3.5 Demand-Side Management, Home Area Networks (HAN)

Demand-side management category represents the amount of consumer load reduction at the time of system peak due to utility programs that reduce consumer load during the year. Examples include utility rebate and shared savings activities for the installation of energy efficient appliances, lighting and electrical machinery, and weatherization materials. (Office of Electricity Delivery & Energy Reliability, 2009)

Home Area Network (HAN) is seen as one of the last zones of technologies that complete the modern smart grid as envisioned by utilities and technology developers. HAN are localized systems of hardware and software that enable enhanced energy management to take place inside apartments with the help of in-home control devices and smart appliances. (Navigant Consulting, 2012)

The HAN leverages consumption information provided by smart meters, because it enables consumers to access consumption data. When reacted upon, it may result in reduced use of energy and lower costs. HAN devices can take advantage of the consumption information provided by smart meters, usually resulting in energy and cost savings for the consumer. (Navigant Consulting, 2012).

Utilities have taken a cautious approach to HANs, because primary efforts are concentrated on the deployment of smart meters. Some utilities in North America have started to promote HANs as they move beyond demonstrations and attempt to reduce overall consumption through demand response programs. In Europe, HAN adoption has been slow as well, with the exception of the United Kingdom, where regulations require basic HAN gear to be part of new smart meter deployments. (Navigant Consulting, 2012)

2.3.6 Grid-Integrated Vehicle (GIV) and Vehicle to Grid (V2G) Technologies

The conventional view expects battery vehicles to be plugged in to charge their batteries. Hybrid and fuel cell vehicles generate electricity from the fuel in their tanks. Plug-in hybrids can either run from fuel or can charge from the grid. The main point is that in the conventional view is that the electricity never flows from vehicle to the grid. See Figure 2. (University of Delaware, 2011-2012)

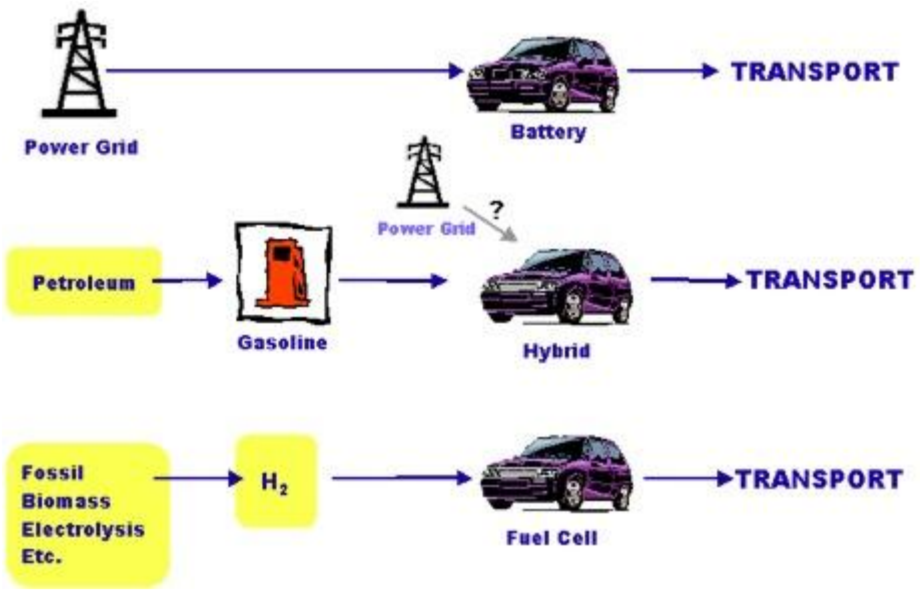

Figure 2. Conventional View. University of Delaware, 2011-2013.

Electric-drive vehicles, no matter if they're powered by batteries, fuel cells, or gasoline hybrids, have within them the energy source and power electronics capable of producing the 60 Hz (in U.S.) or 50 Hz (in Europe) Alternating Current electricity that powers homes and offices of the consumers. Vehicle to grid, abbreviated V2G, means that when connections are added to allow electricity to flow from those cars to power. See Figure 3. (University of Delaware, 2011-2012)

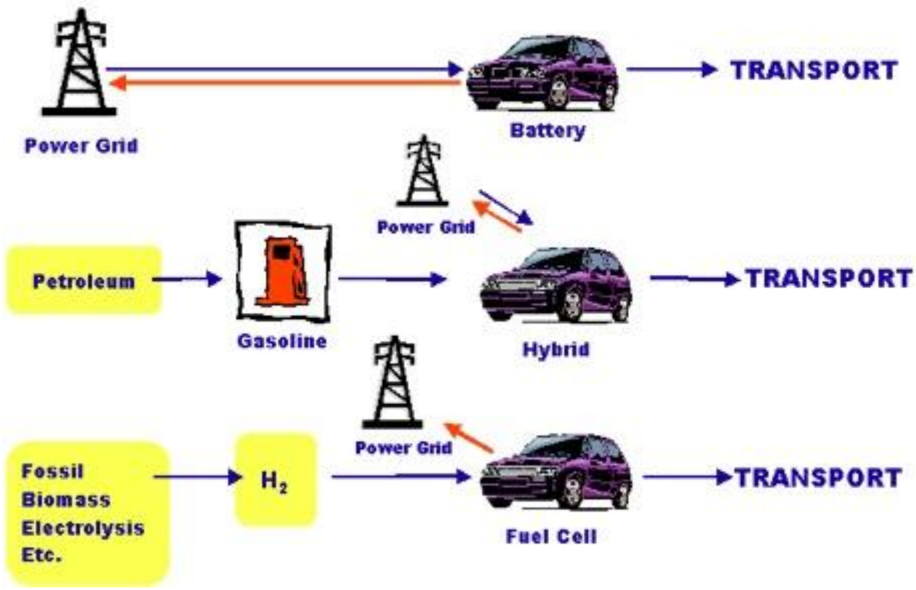

Figure 3. Vehicle to Grid, V2G. University of Delaware, 2011-2013.

2.3.7 Electric Energy Storage

Electric energy storage (EES) uses forms of energy such as chemical, kinetic, or potential energy to store energy that will later be converted to electricity. Such storage can provide basic services such as: supplying peak electricity demand by using electricity generated during periods of lower demand; balancing electricity supply and demand fluctuations over a period of minutes or even seconds, and; postponing expansions of electric grid capacity, including generation, transmission and distribution elements. (Pew Center on Global Climate Change, 2011)

Electric energy technologies come in many forms. Concept of electric energy storage is not new, because it has existed in form of e.g. batteries and pumped hydro. Advances in materials, electronics, chemistry and information technology have resulted in a number of new and upcoming storage technologies. These new technologies have the potential to reduce the overall costs on a larger scale. (California Public Utilities Commission, 2010)

EES can encompass a diverse range of categories, following is a list of examples. The list does not, however, include all existing or potential storage technologies:

Pumped Hydro: Pumped hydro storage uses low-cost electricity generated during periods of low demand to pump water from a lower-level reservoir such as a lake to a higher-elevation reservoir. The water is released to flow back down to the lower reservoir while turning turbines to generate electricity, similar to conventional hydropower plants. Pumped hydro storage can be constructed on a large scale with capacities of 100-1000s of megawatts and discharged over periods of time from four to ten hours. (California Public Utilities Commission, 2010)

Compressed Air: Compressed air energy storage plants use electricity to compress air into a reservoir. The high pressure air is released from underground and used to help power natural gas-fired turbines. The pressurized air allows the turbines to generate electricity using significantly less natural gas. The compressed air can be stored in several types of underground mediums, including porous rock formations, depleted natural gas or oil fields, and caverns in salt or rock formations. (California Public Utilities Commission, 2010)

Batteries: Several different types of large-scale rechargeable batteries can be used for EES including sodium sulfur, lithium ion, and flow batteries. Batteries are a known technology, so the utility industry is generally familiar with them. Battery systems for electricity storage use the same principles as batteries used, for example, in automobiles, but in much larger and higher power configurations. EES systems based upon batteries can be portable.

Thermal Energy Storage: Two types of thermal energy storage (TES) exist: TES applicable to solar thermal power plants and end-use thermal TES. TES for solar thermal power plants stores solar energy in the form of heat collected by solar thermal power plants, enabling smooth power output during daytime cloudy periods and extending power production to 1-10 hours past sunset. Solar thermal plants consist of synthetic oil or molten salt that, where energy is bieng stored.

End-use TES stores electricity by using hot or cold storage in underground aquifers, water or ice tanks, or other materials. Then, End-use TES uses this energy to reduce the electricity consumption of building heating or air conditioning systems when needed. (California Public Utilities Commission, 2010)

Flywheels: A conventional flywheel stores energy as the kinetic energy of a massive disk spinning on a metal shaft. To get the stored energy from the flywheel, the process is reversed with the motor acting as a generator powered by the braking of the rotating disc. (California Public Utilities Commission, 2010)

Ultracapacitors: In general, capacitors are suitable for shorter term applications like providing backup power during brief interruptions. Advanced capacitors are useful for stabilizing voltage and frequency. Ultracapacitors are electrical devices that consist of two oppositely charged metal plates separated by an insulator. The ultracapacitor stores energy by increasing the electric charge accumulation on the metal plates and discharges energy when the electric charges are released by the metal plates. (California Public Utilities Commission, 2010)

2.3.8 Comparison of Technological Developments

Outdated design and ageing issues have put limitations for the old grids to serve the energy needs today. Another factor in Europe is energy security. Europe is relatively deficit in traditional fossil energy resources and therefore has high reliance on import. In 2006, most of oil, natural gas and hard coal consumed by EU were imported, Russia being a major supplier with countries in Middle East and Africa supplying as well (Hashmi, 2011). In other words, besides non-pollution, renewable energies are beneficial for Europe in terms of increased security. According to European Commission statement (European Commission, 2012) *"...renewable energy will enable the EU to cut greenhouse emissions and make it less dependent on imported energy"*. To reduce risk, Europe has a specific need to develop complementary energy supply. This partially explains why Europe has been the forerunner in terms of renewable energy deployment.

However, it can be seen, for example, that the differences in investment in different technologies between European countries are affected by national regulations and country specific conditions (Giordano & Bossart, 2012). See Figure 4.

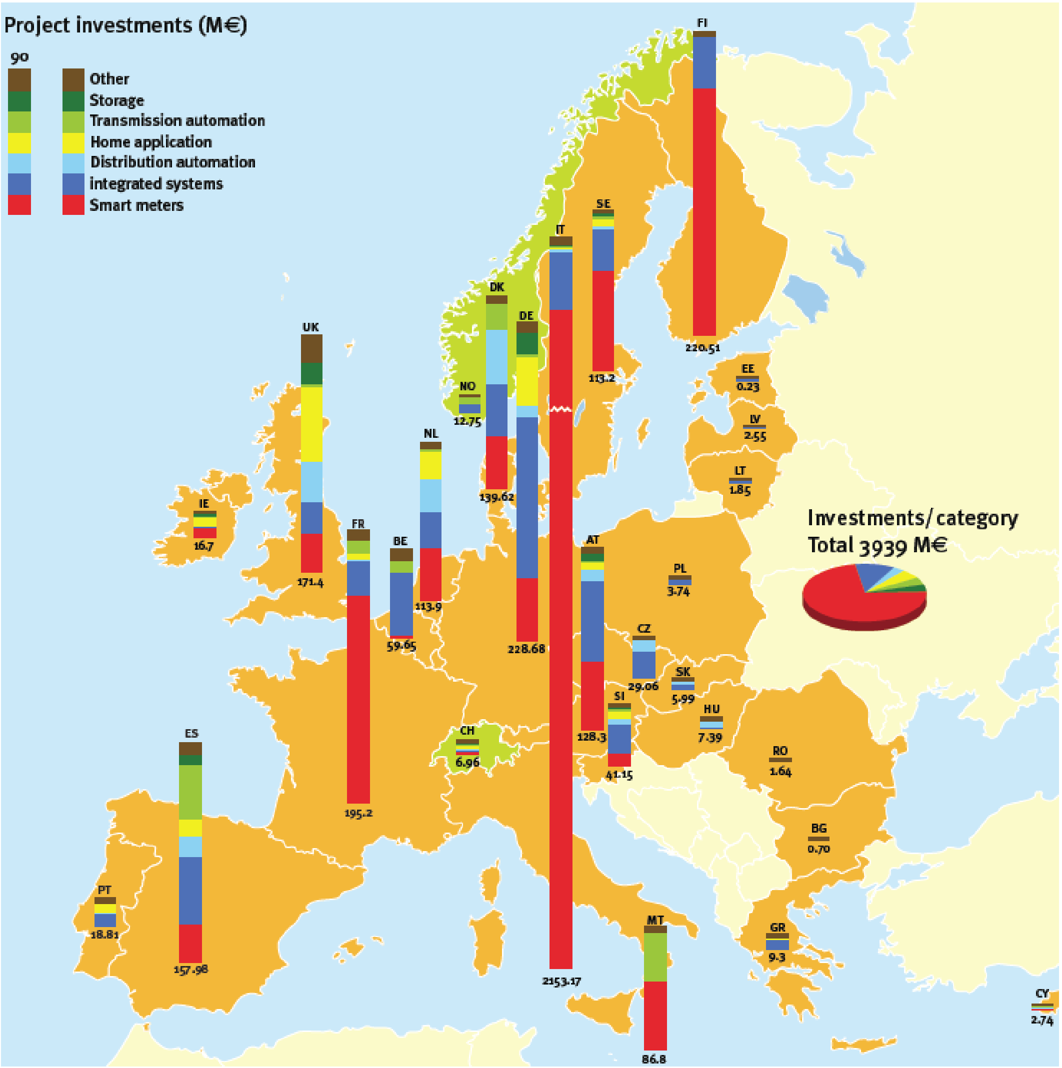

Figure 4. Europe Geographical distribution of investments and project categories. Joint Report EC JRC – US DOE, 2012.

Taking U.S. into consideration, while the conceptual model presented in the most recent report to National Institute of Standards and Technology (NIST), generic and universal, the depth of discussions about different domains vary. For example, the user-end discussions are comprehensive, but analysis about transmission is relatively light. That is so partly because The U.S. system is more mature and the design orientation focuses more heavily on users and services integration. It could be a factor as well that the US grids are operated by many individual players so it is difficult to enforce unified changes throughout, as opposed to single grid owner in European countries. (Hashmi, 2011, 54)

Three years ago, around 2009, the federal funding for the DOE Smart Grid Investment Grants was largely focused on AMI projects, and smart grid was said to have been focused to AMI (Rackliffe, ABB Smart Grid Update with Gary Rackliffe, 2012). Rackliffe (2012) states that this happened for three reasons: 1) Politically, customer engagement is important and many consumers associate the meter on the side of their house with the grid and hopefully link a smart meter to a smarter grid, 2) for many utilities, the business case for AMI is generally positive or at least break even. The business cases looked even better with the federal grants covering up to 50% of the project costs. Finally, 3) AMI technology can be deployed within the three-year time frame required by the grants.

So far, many investments in distributed energy resources applications such as distributed generation in form of solar photovoltaic installations, distributed energy storage, and electric vehicle charging infrastructure, are mostly pilot projects to demonstrate the technologies, quantify the benefits, and gain operational experience. However, investment interest is growing in the segment. Many utilities are also finding a business case for distribution grid management investments built around improving operational reliability and efficiency improvements. (Rackliffe, 2012)

3 FINANCING AND ENERGY CLUSTER THEORY

This chapter describes the financing and investment theory considered relevant for the construction of the empirical study. Public funding plays a major role in accelerating Smart Grid investments and therefore the main U.S. and European public funding departments are introduced more thoroughly. Then, the financing theory considered relevant for the study and finally the special characteristics of energy project financing are presented.

3.1 U.S. Smart Grid Investment Trends

According to a blog post by the ABB vice president for smart grids, Mr. Gary Rackliffe (2012), in North America the focus seems to shift to different stakeholders and technologies. Furthermore, when looking at the smart grid implementations, new investment trends are arising. The trickier question is which trend is driving the most implementation and what benefits utilities are able to capture.

Rackliffe (2012) explains that the two biggest investment drivers at the moment is the need to improve utility operational effectiveness and connecting renewable energy resources to the grid. Operational effectiveness encompasses *advanced metering infrastructure*, *distribution grid management*, *utility analytics*, and *distributed energy resources*. In all of those cases, drivers such as aging infrastructure and operational cost pressures are increasingly compelling for utilities to invest in new solutions to meet new, more demanding expectations of customers, shareholders, and regulators.

3.1.1 Smart Grid Investment Grant Program (SGIG)

The Smart Grid Investment Grant (SGIG) program is authorized in Title XIII of the Energy Independence and Security Act of 2007 and is funded by the American Recovery and Reinvestment Act of 2009 (ARRA). SGIG is a 3,4 billion dollar initiative seeking to accelerate the transformation of the country’s electric grid by deploying smart grid technologies and systems. The SGIG program and related

ARRA activities are managed by the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, which orchestrates the national efforts to modernize the U.S. electric grid. (U.S Department of Energy, Electric Delivery and Energy Reliability, 2012, ii)

The SGIG program is structured as a public–private partnership to accelerate investments in grid modernization. The 3,4 billion dollars in federal ARRA funds are matched on a one-to-one basis at minimum by private sector resources, taking the total investment in SGIG projects to 7,8 billion dollars in total. ARRA chose 99 projects that were eligible for the SGIG program. They were competitively selected from more than 400 proposals submitted by utilities and other eligible organizations. The size and scope of a project depends on multiple factors that can vary by location and circumstances, including regulatory policies, market conditions, customer mixes, levels of experience with advanced technologies, levels of maturity of existing systems, and forecasts of electricity supply and demand (U.S Department of Energy, Electric Delivery and Energy Reliability, 2012, 2). Hundreds of billions of dollars will be needed over the next two decades for smart grid investments to fully modernize the U.S. national electric grid. During this time, additional and long-lasting commitment will be needed from industry, government, states, and other stakeholders to realize the vision of smarter grid. The SGIG projects were launched in early 2010. All projects are expected to complete equipment installation in the time frame of 2013 through 2014. Data analysis and reporting is expected to be completed by 2015. (U.S Department of Energy, Electric Delivery and Energy Reliability, 2012, iii)

3.1.2 Other U.S. Smart Grid Funding Programs

It must be noted that sustainable grid modernization requires more than just replacing aging grid assets and the deploying advanced technologies. Initiatives are needed also to tackle the policy, market, and institutional barriers that currently inhibit investments by the private sector. The SGIG program discussed earlier represents only the technology deployment portion of the ARRA funds appropriated to DOE Office of Electricity for grid modernization activities (U.S

Department of Energy, Electric Delivery and Energy Reliability, 2012, 1). To address these needs, DOE initiated a programs portfolio that complements the SGIG and helps ensure its success by getting markets ready for grid modernization (U.S Department of Energy, Electric Delivery and Energy Reliability, 2012). For more, see Table 1.

Major Smart Grid Program Activities	Total Obligations ($Million)
Smart Grid Investment Grant	$3,425
Smart Grid Regional and Energy Storage Demonstration Projects	$685
Workforce Training and Development Program	$100
Interconnection Transmission Planning	$80
State Assistance for Recovery Act Related Electricity Policies	$49
Enhancing State Energy Assurance	$44
Interoperability Standards and Framework	$12
Enhancing Local Government Energy Assurance	$8

Table 1. U.S. Initial Federal Recovery Act Funding for Major Smart Grid Program Activities. Smart Grid Investment Grant Program: Program Report, July 2012.

3.2 EU Smart Grid Funding and Financing Instruments

A number of EU funding and financing programs and instruments are available in Europe, supporting activities of research, development, demonstration and deployment of Smart Grid projects, but they also offer direct investments in needed infrastructures. (European Technology Platform, 2012)

Below is a list of the main funding and financing instruments for the EU according to the European Technology Platform (2012):

- Smart Grids ERA-Net
- 7th Framework Program (FP7)
- Competitiveness and Innovation Framework Program (CIP)
- European Investment Bank (EIB)

- European Energy Program for Recovery (EEPR)
- Trans-European Energy Networks (TEN-E)
- NER 300

The Smart Grids ERA-NET comprises a consortium of partners representing several European countries. It is said to be an essential criterion for the transnational collaboration and research activities necessary to achieve the Smart Grid's planned targets. ERA-NET will resolve research and strategic gaps and act across the network to deliver well planned, coordinated calls for funding proposals, so that funding efforts are sensible. The ERA-NET facilitates a process in which both challenges and opportunities are assessed before approving the funding proposals. It is done in a synchronized manner across Europe. (SmartGrids - European Technology Platform, 2012)

The scope of the ERA-Net groundwork is vast, and requires the commitment and engagement of numerous stakeholders. According to ETP (2012) this kind of research may include specific studies for example into electrical transport systems. Other example includes assisting Europe's more than 3 000 DSOs in sustaining electricity supply.

The Seventh Framework Program (FP7) bundles all of the research-related EU initiatives together under a shared roof. It plays a significant role in reaching the goals of growth, competitiveness and employment; along with a new Competitiveness and Innovation Framework Program; Education and Training programs, and; Structural and Cohesion Funds for regional convergence and competitiveness. (SmartGrids - European Technology Platform, 2013)

The broad objectives of FP7 have been split to four categories: co-operation, ideas, people and capacities. There is a specific program for each objective corresponding to the main areas of EU research policy. All programs work together to promote and encourage the creation of European poles of scientific excellence.

Competitiveness and Innovation Framework Program (CIP): With small and medium-sized enterprises as its main target, the CIP supports innovation activities, provides better access to finance and delivers business support services in the regions. It encourages a better take-up and use of information and communication technologies and helps to develop the information society. It promotes the increased use of renewable energies and energy efficiency. The CIP runs from 2007 to 2013 with an overall budget of about 3,6 billion euros. (SmartGrids - European Technology Platform, 2012)

The CIP is divided into three operational programs. Each program has explicit objectives, aiming at contributing to the competitiveness of enterprises and their innovative capacity in their own areas:

- The Entrepreneurship and Innovation Program
- The Information Communication Technologies Policy Support Program
- The Intelligent Energy Europe Program

The European Investment Bank (EIB) is the European Union's financing institution. Its shareholders are the 27 member countries of the Union, which have together subscribed its capital. EIB Board of Governors is composed of the Finance Ministers of these member countries. The EIB's role is to provide long-term finance in support of investment projects. (European Technology Platform, 2012)

Inside the European Union, according to European Energy Platform (2012), the EIB supports the EU's policy objectives in these areas:

- *Small and medium-sized enterprises:* stimulation of investment by small businesses.
- *Cohesion and convergence*: addresses the economic and social imbalances in disadvantaged regions.
- *Fight against climate change*: mitigation and adaption to the effects of global warming.

- *Environmental protection and sustainable communities*: investment in a cleaner natural and urban environment.
- *Sustainable, competitive and secure energy*: production of alternative energy and reduction of dependence on imports.
- *The knowledge economy*: promoting an economy that stimulates knowledge and creativity through investment in information and communication technologies, and human and social capital.
- *Trans-European networks*: construction of cross-border networks in transport, energy and communications.

European Energy Program for Recovery provides (EEPR) for the granting of financial assistance to the energy sector, in order to remedy the effects of the financial and energy crises which affect the European economy, targeted measures should be undertaken, especially for the introduction of interconnection infrastructures, energy production based on renewable sources, and carbon capture. The EEPR helps in speeding up and securing investments on infrastructure and technology projects in the energy sector; improves the security of supply of the Member States; speeds up the implementation of the 20/20/20 objectives for 2020. (European Technology Platform, 2012)

Trans-European energy networks (TEN-E) lists and ranks projects that are eligible for Community assistance. TEN-E's emphasis is on the interconnection, interoperability and development of trans-European networks for transporting electricity and gas are essential for the effective operation of the internal energy market in particular and the internal market in general. It is said that users should have access to higher-quality services and a wider choice as a result of the diversification of energy sources, at more competitive prices. Therefore closer links should be established between single member states national markets and the EU as a whole. As a result, the new member states have been fully incorporated into the Community TEN-E guidelines. (European Energy Platform, 2012)

Additional functions of TEN-E (SmartGrids - European Technology Platform, 2012) include:

- Ensures the security and diversification of supply
- Interoperability with the energy networks of third countries such as accession and candidate countries and other countries in Europe, in the Mediterranean, Black Sea and Caspian Sea basins, and in the Middle East and Gulf regions.
- Helps in reducing the isolation of the less-favored, island, landlocked or remote regions, strengthening territorial equality in the European Union
- Improves the links between renewable energy production installations and using more efficient technologies, reducing losses and the environmental risks associated with the transportation and transmission of energy.

NER300 is the nickname of a financing instrument managed jointly by

- The European Commission
- European Investment Bank
- Member countries

EC's Emissions Trading Directive contains the provision to set aside 300 million allowances, in other words rights to emit 1 000 kilograms of carbon dioxide with one 'allowance' in the so-called New Entrants' Reserve of the European Emissions Trading Scheme. The 'allowance' income would then be used for subsidizing innovative renewable energy technologies and carbon capture and storage. The allowances will be sold on the carbon market and the money raised. For example if each allowance would be sold for 15 euros, 4,5 billion euros could be raised. (European Technology Platform, 2012)

3.3 Finance

This chapter will introduce the principle theory and formulas in finance, that are essential while structuring the empirical study, and in understanding the results. The emphasis will be on finance, and risk management is handled less. This section will not be energy-specific.

When making decisions, financial managers apply two practices when selecting capital budgeting projects: *accept/reject* and *ranking.* The accept/reject method focuses on the question of whether the proposed project would add value to the firm or earn a rate of return that as acceptable to the company. The ranking decision lists competing projects in order to of desirability to choose the best one. Capital budgeting techniques are usually used only for large projects. Small investment decisions are usually made by relying on intuition. For instance, if office supply of pencils is runs low, more is being orders without further analysis. The cost of buying pencils is justified without undergoing capital budgeting analysis. (Gallagher & Andrew, 2007, 264-265)

3.3.1 Capital Budgeting Decision Methods

First, the four formal capital budgeting decision methods by Gallagher and Andrew (Capital Budgeting Decision Methods, 2007, 265) are presented, which are payback, net present value, internal rate of return and modified internal rate of return. For simplicity, only payback, net present value and internal rate of return will be presented.

Payback Method: One of the simplest capital budgeting decision methods. To use payback method, analysts find a project's payback period, i.e. the number of time periods it will take before the cash inflows of a proposed project equal the amount of the initial project investment. To calculate the payback period, simply add up a project's projected positive cash flows, one period at a time, until the sum equals the amount of the project's initial investment (Gallagher & Andrew, 2007). See Table 2.

		Cash Flows			
	Initial Investment	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Project A	-3000	1000	2000	1000	1000
Project B	-5000	1000	2000	2000	2500

Table 2. Payback Method Example. Gallagher & Andrew, 2007.

Project A has a payback time of two years, and project B has payback time of three years. A company must decide what is the acceptable payback time period. If the set period is two years, then project A should be chosen, and project Y should be rejected (Gallagher & Andrew, 2007, 266). Furthermore, if the company allows three year payback period and if the projects are independent, then both projects are accepted. Payback method does not take time value of money into consideration.

Net Present Value (NPV): converts the worth of that future dollar into what it is worth today. NPV converts future cash flows by using a specified discount rate. For example, at 10%, 1 000 dollars received one year from now is worth only 909,09 dollars today. In other words, if you invested $909,09 dollars today at 10%, in one year it would be worth 1 000 dollars. (Thumann & Woodroof, 2009)

The description is also applicable to any other currency. NPV is useful in determining whether or not the investment is acceptable. See formula 1 below to take look how NPV formula looks like.

$$NPV= -C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_T}{(1+r)^T} \qquad (1)$$

$-C_0$ = Initial investment

C = Cash flow

r = Discount rate

T = Time

Internal Rate of Return (IRR): IRR is the estimated rate of return for a proposed project, considering the project's incremental cash flows. Exactly like the NPV method, the IRR method considers all cash flows for a project and adjusts for the time value of money. Note however that the IRR results are expressed as a percentage, not a dollar figure (Gallagher & Andrew, 2007). The IRR can be calculated using a modified NPV function. The IRR must be found out through trial and error by alternating discount rate r and the correct rate is the one that is 0 or closest to it. That is how IRR is found out. See formula 2 below.

$$NPV = 0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_T}{(1+r)^T} - C_0 \qquad (2)$$

$-C_0$ = Initial Investment

C=Cash Flow

r = Discount rate

T = Time

3.3.2 Opportunity Cost of Capital

The cost of capital is the cost of investing in a project or an asset. In the world of capital budgeting, not all projects can be approved so financiers must come up with a reason to reject or accept a project. The opportunity cost is the percentage return lost for rejecting one project and accepting another. (Bryant, 2013)

The goal is to accept the project with the lower cost of capital, which delivers the highest return on investment. The best way to calculate the opportunity cost of capital is to compare the return on investment on two different projects. Opportunity cost can occur in other areas besides capital. Opportunity costs are incremental cash flows that financial managers consider in a capital budgeting decision. (Bryant, 2013; Gallagher & Andrew, 2007).

3.3.3 Weighted Average Cost of Capital (WACC) (Capital Structure)

Weighted average cost of capital is the firm’s average cost of capital, as a function of the proportion of different sources of capital: Equity, Debt, preferred Stock, etc. (Thumann & Woodroof, 2009, 48)

$$\mathrm{WACC} = w_d k_d (1 - T) + w_s k_s + w_{ps} k_{ps} \quad (3)$$

k_d = Before tax cost of debt

k_s = Cost of common equity

k_{ps} = Cost of preferred stock

w_i = Weight of capital source i

T = Tax rate

$k_d(1 - T)$ = After-tax cost of debt

3.4 Energy Project Financing

Most facility managers agree that energy management projects are good investments. Generally, Energy management projects (EMPs), reduce operational costs, have a low risk-to-reward ratio, usually improve productivity, and even have been shown to improve a firm’s stock price (Wingender & Woodroof, 1997). However, despite these benefits, many cost-effective EMPs are not implemented due to financial constraints. A study of manufacturing facilities by U.S. Department of Energy (1996) revealed that first-cost and capital constraints represented over 35% of the reasons cost-effective EMPs were not implemented. Many times, the facility manager does not have enough cash to allocate funding or cannot get budget approval to cover initial costs. Financial arrangements can minimize the facility’s funding constraints and thus allow additional energy savings to be realized. However, most facility managers use simple payback analyses to evaluate projects, which do not reveal the added value of after-tax benefits. (Thumann & Woodroof, 2009)

3.4.1 Common Energy Project Financing Alternatives

The main job of chief financial officer of the organization is to reduce risks. The risk analysis of an energy project is not fulfilled unless all technical and financial options have been explored and understood (Thumann & Woodroof, 2009, 139). Some of the most common financing alternatives according to Thumann and Woodroof (2009) are commercial bank loan, general obligation bond, lease and energy savings performance contracting.

Commercial Bank Loan: The first alternative is approaching the local business bank and applying for a loan. The bank will review the company's credit history and financial statements in order to make a decision. Most of the time interest rates based on the prime rate plus a margin for the bank. Most often banks prefer to lend to businesses in the form of credit lines which can be used by the company as needed. (Thumann & Woodroof, 2009, 139-140)

General Obligation Bond: A bond is a security instrument representing an obligation to pay by the issuer to the buyers (the public or investment companies). Bonds are secured by certain assets or by the good faith and credit of the issuer. General obligation bonds (GOBs) are specialized bonds issued by local and state government entities in order to raise money for general business operations. The interest rate paid by these bonds is based on the current overall interest rate market, as well as the credit quality of the state or local government issuer. The process of preparing and issuing a general obligation bond is long and complicated, but the interest rate that the issuer will have to pay is relatively low. (Thumann & Woodroof, 2009, 140)

Lease: Leasing, in common terms, means borrowing someone else's property against a payment. At the end of the specified lease period, the leased commodity is taken back to the owner. Example of a lease is a lease of a movie from a video rental. In the energy cluster, the leases for equipment have added a substantial benefit of not having to make a large down payment, and therefore cash can be spared for company's daily operations (Thumann & Woodroof, 2009, 141).

The most leased equipment in the energy cluster use the *capital lease* structure, Capital leases are regarded as equivalent to a sale by the lessor, and a purchase by the lessee (WebFinance, Inc., 2013).

Capital lease can include any of the following (Thumann & Woodroof, 2009, 141): transfer of ownership of equipment at the end of the lease; a buyout clause at the end of lease; a lease term corresponding to for example 75% or more of the economic life of the equipment; the net present value of the lease payments equaling or being for example 90% of the value of the equipment.

Energy Savings Performance Contracting (ESPC): an organization can contract ESCO for energy efficiency project, but it will be ESCO that will have to incur the cost of the implementation of the energy savings measures. This kind of contract will give benefits to both parties, forming a win-win situation, because ESCO will get reimbursed based on the savings made a consequence of the energy efficiency project (Thumann & Woodroof, 2009). See Figure 5 below**Virhe. Viitteen lähdettä ei löytynyt.**

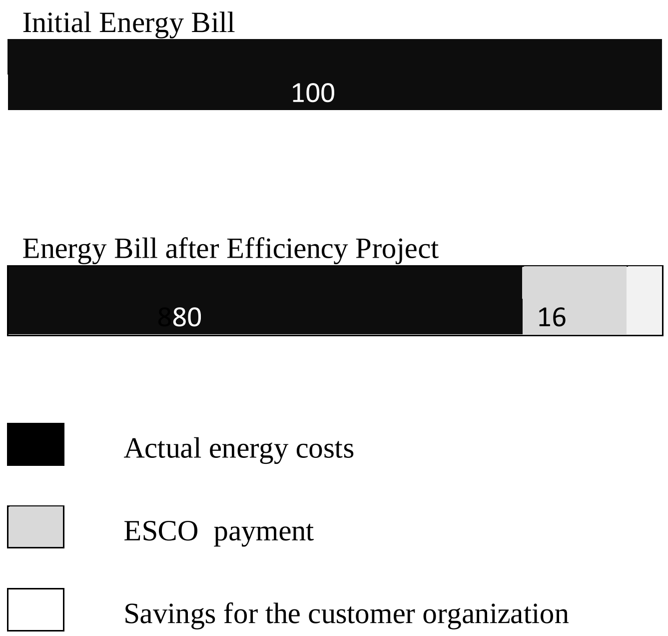

Figure 5. Energy Savings Performance Contracting Principle.

According to Thumann et al. (2009, 143) bankers and specialized investment companies are increasingly becoming involved in ESPC. This means that they are offering an innovative loan program, which is in this case known as *full-recourse project financing.* The bank will review the financial statements of both the ESCO and also the customer organization before making the lending decision.

If lenders become more ivolved with energy projects, they may want to structure something that is called *non-recourse project financing.* The loan is given to a single-purpose entity made up by the bank, which therefore owns the equipment of the project and makes a contract with the ESCO to perform the energy services (Thumann & Woodroof, 2009). The projects of this type are characterized by high capital expenditures, long loan periods, and uncertain revenue flows. Analyzing them requires knowledge of technical domain as well as financial modeling skills (Investopedia US, A Division of ValueClick, Inc., 2013). In non-recourse project financing, according to Atoll Financial Group (2013) the lenders/ investors look mainly to the revenue projections for the repayment of its loan. In this type of case, the project sponsors are not held personally liable for the payments on the loan if the project doesn't generate enough profit. Instead, the project assets are the collateral in non-recourse project financing.

4 EMPIRICAL STUDY

The research process was started by gaining knowledge about Smart Grids and related technologies. After that since the research problem itself to begin with was clear and due to the fact that the rules of financing were clear, the current knowledge allowed the structuring of the theory first (Ghauri & Kronhaug, 2010, 33). The research problem was picked and defined through observations and assumptions in cooperation with the thesis supervisor. The research problem remained namely the same during the process but the additional research questions were affected through the knowledge gained while becoming familiar to theories, concepts and facts of Smart Grid industry (Ghauri & Kronhaug, 2010, 34). During the construction of the theoretical section of the thesis part when moving on to the planning of empirical study it became clear that the Smart Grids have been heavily studied during the last few years, mainly in the U.S. and in Europe: there was numerous studies publicly available about Smart Grids. Some of the studies were helpful, but none of them would resolve the research problem nor really be used in the theoretical study. However, they aided in adjusting the construction of the empirical section.

Even though the principles of financing are relatively unchanging in the current world, incorporating the theory about Smart Grids and financing was a task in itself. Since no previous studies were found about the coherence of the two, it gradually became one of the research questions: what is the relation of conventional energy project financing to Smart Grid financing alternatives?

4.1 Research Methodology

Since it would have been difficult or even impossible to get the desired information about some aspects of Smart Grids by doing an independent research, a decision to first conduct an unstructured interview with the European Commission’s in-house science service Joint Research Centre for Smart Electricity Systems and Interoperability organization (SES in a Nutshell, 2013) seemed sensible (Ghauri & Kronhaug, 2010, 126). The interview was conducted via email due to lack of time on JRC’s side and due to the fact that the information caught was better explained via graphs and text. It was agreed that the representative stayed anonymous even though no confidential information was being shared. The goal of the interview was to gain some general facts about financing of the projects, especially data concerning public and private funding, because it was realized that a private unauthorized person would not be able acquire such information from project lead organizations or from other partners. The secondary goal was to get clues for the quantitative survey before sending it out to the respondents.

The second empirical section takes a look at five Smart Grid projects and their respective financing models. The case projects were chosen based on their relevance to the Smart Grid industry and finance characteristics. The secondary aim was to choose projects with varied attributes, based on geographical location, scale, and technologies used. It was a desired factor that the project was already affiliated with consumers. Availability of information and the willingness of the staff to co-operate was a practical factor as well when choosing the projects. The method is qualitative, and the information caught is based on cross-researching various articles to improve reliability, interviews by e-mail and extensive surveys.

The third part will be a structured interview, a survey, where a standard format of interview is used with an emphasis on fixed response categories combined with quantitative measures and statistical methods (Ghauri & Kronhaug, 2010, 126). The survey has a focus on consumer engagement, since some information about financing was found out in the first empirical interview with JRC. Concentrating on the few specific cases in the prior section helped in constructing the survey as well, by aiding in adjusting the questions to be answerable to all types of Smart grid projects. The survey was sent to all Smart Grid projects in the Europe and in the U.S., reported in two sources, one in each area (Joint Research Centre - Institute for Energy and Transport, 2011; Smart Grid Information Clearinghouse, 2013). The only exceptions not included were the projects that were being reported to be worked on across the nations in Europe, due to their expanding complexity compared to those functioning in a single country. Finnish projects were excluded as well. Therefore, the total of amount of projects contacted was

406: 208 European and 198 U.S. projects. The survey was sent to all of the projects and no specific sampling based on project type was done, because of the low response expectancy in the first place.

4.2 Joint Research Centre Introduction

The Joint Research Centre is the in-house scientific and technical department of the European Commission. It provides scientific advice and technical know-how to support a wide range of EU policies. The JRC has seven scientific institutes, located at five different sites in Belgium, Germany, Italy, the Netherlands and Spain. (Joint Research Centre - Institute for Energy and Transport, 2013)

Officially named ‘Action’, the Smart Electricity Systems and Interoperability team is part of the Energy Security Unit at the JRC Institute for Energy and Transport, located in Ispra, Italy and Petten, Netherlands. (Joint Research Centre - Institute for Energy and Transport, 2013)

The Smart Electricity Systems team acts as European Commission’s in-house consultant, performs independent scientific research and supports EU policy-making on transformations towards smarter electricity systems. Some of the achievements of Smart Electricity Systems team include Europe-wide smart grids inventory, European-wide electricity grid model, cost-benefit analysis of smart grids, Real time simulation for hardware in the loop testing and interactive tools and maps. (Joint Research Centre - Institute for Energy and Transport, 2013)

5 RESULTS

This chapter will specify the results of the implemented research. First the interview with Joint Research Centre representative will be analyzed. After that case company presentation with their financing models, and last the results and the findings of the survey part are explained.

5.1 JRC Interview Analysis

It was told that financing characteristics such as budget, budget sources, consumer engagement information are most often sensitive information for smart grid companies. It was stated by the JRC representative that even they at the European Commission had faced problems in getting those figures even though they are the ones funding the projects.

There was research information available on some investment characteristics of European Smart Grid projects. The research data had been acquired from 281 projects. The organizations had been classified into eight different stakeholder categories:

- DSO/utilities/energy companies
- TSOs
- universities/research centres/consultancies
- manufacturers
- IT/telecoms
- Aggregators/service providers
- Generation Company
- Other (engineering companies, municipalities/public authorities, associations)

Some questions were answered from the initial draft of survey that would be conducted after the interview. The information gained contributed greatly to making the survey faster for the respondents, thus in getting more responses: The projects in Europe have seven participating organizations on average. For most projects, information on the budget share of each participating organization was not available. Therefore, in the next figure it is assumed for the sake of making the comparison that the budget of the project is allocated entirely to the lead organization. That gave an idea of the share of the total investment in the catalogue for which each organization was responsible (see Figure 6 below).

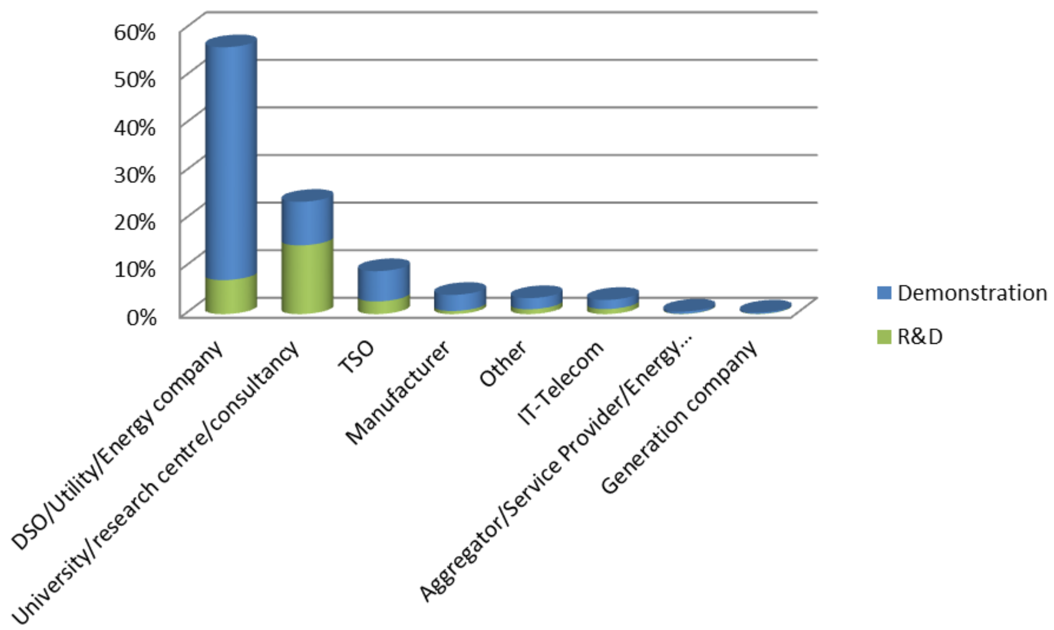

Figure 6. Budget Share of Projects by Type of Lead Organization.

The overall budget of the projects in the JRC catalogue, 55 % (€ 974 million) comes from various sources of funding and 45 % from private capital. Around 80% of the projects have received some form of public funding. The figures indicate that decisions to invest in smart grids are not yet being taken independently at this point and that project coordinators still rely on funding institutions to invest in research, development and deployment in smart grid projects

Next, the sources of funding have been categorized as European, national and regulatory:

Regulatory funding considers specific smart grid programs managed by regulators to support innovative smart grid projects. For example:

1) More than 50 % of the Danish projects in the catalogue are supported by the Forskel program, which is financed from tariffs.
2) Since 2010, the UK regulator OFGEM has set-up the low carbon network fund (LCNF) to provide regulatory funding for particularly innovative smart grid projects. In other countries, regulators are supporting the development of smart grids with specific tariff schemes guaranteeing an additional rate of return on smart grid investments.
3) In Italy, an additional 2% rate of return is given for smart grid investments which fulfill certain innovation criteria.

National funding in smart grid investments have received increasing amounts of support in several European countries, funded by innovation or energy ministries (e.g. the E-ENERGY Program in Germany). These funding initiatives are targeting RD&D projects across different countries and technological applications.

European funding for Smart Grids has received wide support through different channels such as the 6th and 7th Framework Programs and European Regional Development Plan.

There is a steady increase over the years in cumulative total and funding source budgets. Generally speaking, during the life span of Smart Grids the most significant back-up funding to private investments comes from European Commission’s and national funding. However, there is only a slight difference between the different funding sources: According to the data, through year 2012, out of the 55% from funding sources, 20,5 % is national funding, 18,5% is regulatory and 16 % is EU funding.

Typically, projects are co-financed from a single funding source (national, European or regulatory) alongside private investments. However, projects use a mix of the funding sources as well. National funding provides the highest rate of co-financing combined with private funding, followed by European funding and then regulatory funding. There are only a few projects which have received both

EC and national funding, whereas the combination of regulatory support and EC or national funding is even rarer (see appendix).

5.2 Smart Grid Cases

Hypothesis on Smart Grid cases is that the considerable amount of variables associated with the Smart Grids (cf. sections 2.1; 2.3; 5.3.1) in this stage favors non-standardized approach. In other words, the projects have to adjust their financing based these local variables and project-related factors. Projects are expected to have their challenges and opportunities as well.

5.2.1 SmartGridCity. Boulder, Colorado

This case is patched up from several sources since the interpretation of the results and success rate differ depending on the source. For example, according to Jaffe (2012), Karen Hyde, vice president for rates and regulatory affairs at Xcel subsidiary Public Service Company of Colorado stated that Boulder project provided successes most of their customers do not see. However, critics say Boulder project is weakly planned, weakly managed and a failed experiment. For example, Boulder based Smart Grid analyst, Tim Schoechle states that *"You didn't have to spend 44 million USD to learn what Xcel did"*. The project is officially finished and partnership between Xcel Energy and Boulder municipality is finished but the aftermath is still ongoing.

In January 2008 Xcel Energy announced that it joins seven high-tech and engineering companies to from a consortium of partners which would participate in the project and share the costs to build SmartGridCity. In March Boulder, Colorado was announced as a site for SmartGridCity and the work began on May 2008 (Jaffe, 2012). SmartGridCity was to be a 100 million dollar project, the utility's share being 15,3 million dolllars, with consortium partners picking up the rest. However, a week earlier at an internal Xcel corporate-finance meeting Xcel's share of the project's cost already appeared to have doubled from the original amount.

According to Excel Energy (Xcel Energy, 2011) SmartGridCity was a technology pilot that allows exploration of Smart Grid technologies in real world environment. Boulder, Colorado's SmartGridCity is one of the most widely publicized experiments in building smart grid systems to an entire city (Fehrenbacher, 2010). As part of SmartGridCity, Xcel Energy has installed approximately 23 000 automated smart electric meters in Boulder, the goal of the project were (Xcel Energy, 2011): which energy-management and conservation tools customers want and prefer; determine which technologies are the most effective at improving the way power should be delivered; how best to incorporate smart-grid technology into consumers' business operations to improve efficiency, reduce carbon emissions and modernize the energy delivery system, and; how to roll out the most promising Smart Grid components on a wider scale.

Xcel initially assured customers that the most of the project's cost would be covered by its private partners. However, once work began on grid installation, Xcel's portion of the cost rose to about 44,5 million dollars, see Boulder, Colorado summary of cost overruns in the appendix. In part these additional costs were caused by challenges of installing underground fiber-optic cable in the rocky terrain under Boulder (Jaffe, 2012).

At the end of 2009, Xcel asked the Public Utilities Commission, which regulates the utility, for permission to raise the rates of all Colorado customers to regain the investment in the smart grid. After a lengthy process, involving Xcel proving that the smart grid had been a reasonable investment, the commission gave Xcel permission in 2011 to begin recovering part of the total bill of 27,9 million dollars divided to all of its 1,4 million Colorado customers.

Harry DiDomenico, a Public Utilities Commission analyst, testified (Jaffe, 2012) that the project *"…was conducted outside of normal budgeting processes and was therefore never subject to normal budget reviews, policies and internal audit procedures"*. However, on December, 2011 Xcel Energy further filed to the Public Utilities Commission to recover the remaining 16,6 million dollars, which was withheld from collection until Xcel could show customer benefits. (Snider, 2012)

5.2.2 Grid4EU - Demo 4, Italian Demonstration

Grid4EU brings together a consortium of 6 European energy distributors, all from different countries ERDF (France), Enel Distribuzione (Italy), Iberdrola (Spain), CEZ Distribuce (Czech Republic), Vattenfall Eldistribution (Sweden) and RWE (Germany). Grid4EU consists of six demonstrators, which will be tested over a period of four years in each of the European countries represented in the consortium. Grid4EU utilizes the knowledge of each company's individual industrial and scientific partners, enhancing the number of contributors to 27 partners from ten different EU countries. Duration of the project is 51 months from November 2011 to January 2016. The emphasis is on advancing complementarity between the projects, and on promoting cross-research and sharing of results between the different energy distributors involved. (Grid4EU, 2012)

One of the six distributors, Enel Distribuzione SpA of Italy was reached and a comprehensive interview form was filed and acquired from their representative. The name of the Enel proportion of Grid4EU demonstration project is called 'Demo 4'. As all of the other main partners, Enel is a Distribution System Operator. According to Enel representative, the project was initiated by many factors. However, the forecasted future scenarios related to renewables, distributed generation development and international cooperation on Smart Grids were specified as highly prominent drivers for the initiation of the project.

The main scope of Demo 4 is Italy, nevertheless other countries where the solution could be replicable, may be interested in implementation. These countries would then likely be ones with similar climate and landscape. The completion rate of the project is currently 20-29%, and should be done in 2016.

EU's role, besides regulatory framework, is that Grid4EU is co-funded by EU's Seventh Framework Programme. Other investments are made by the companies involved in Demo 4. The partners of Enel in Demo 4, including the type of resources invested by them are:

- Cisco Systems International BV: Personnel, Equipment, etc
- RSE SpA: Personnel, Simulation Tools, etc
- Selta SpA: Personnel, Equipment, etc
- Siemens AG: Personnel, Equipment, etc

No investment amounts were forfeited. Payback time or financial key ratios were not given either. In Demo 4, medium voltage customers will be involved in the experimentation. However, consumers don't have a chance to participate in the project financing. Considering non-financial participation of consumers to experimentation, at the moment there are no economic incentives, but the expected benefits in terms of power quality improvement coming from the experimentation are supposed to be a first incentive. Other methods are under development.

5.2.3 Pecan Street Demonstration, Austin, Texas

Pecan Street Inc. is a unique University of Texas-based non-profit research and development organization founded by the City of Austin, Austin Energy, The University of Texas, the Austin Technology Incubator, the Greater Austin Chamber of Commerce and Environmental Defense Fund in 2008. It is focused on developing and testing advanced technology, business models and customer behavior surrounding advanced energy management systems. In late 2012, the institute has expanded to other parts of Texas and into local small businesses, churches and synagogues and public schools. The institute is now expanding to other states as well. The current partners besides the originals are Freescale, Green Mountain Energy, Intel, Landis + Gyr, LG, Oncor, Oracle, Sony, Sun Edison, Texas Gas service and Whirlpool. (Pecan Street Inc., 2010)

Pecan Street Inc.'s most considerable effort is the Pecan Street Demonstration, a smart grid research project in Austin's Mueller community. People in Mueller community are early adopters. There, for example, 250 homes have their energy use monitored, 200 houses have had solar panels installed. All the houses are green-built. Participation for testing the new add-ons to the grid is voluntary for the residents.

Pecan Street Inc. has received a 10,4 million dollar SGIG grant for the smart grid demonstration project at Mueller for creating a micro grid that will, to begin with link 1 000 residential smart meters, 75 commercial meters, and plug-in electric vehicle charging sites. An additional funding of 297 000 dollars was received from Department of Commerce economic development grant through the Capital Area Council of Governments (CAPCOG) to fund a portion of the organization's operating expenses. (Smart Grid Information Clearinghouse, 2013)

Mueller also functions as a test-site for private companies to test their technologies. The research organization usually rebates the households for buying and testing new technologies by putting attractive compensation in place. For example GM recently went on to test new electric vehicle technology in Mueller, the buyers of new Chevrolet Volt in the area were given a 7 500 dollar federal rebate, and 3 000 dollars for a three year lease. (John, 2012; Pecan Street Inc., 2010)

5.2.4 Self-sufficient Village. Feldheim, Germany

The village of Feldheim is a part district of the town of Treuenbrietzen, located about 60 kilometers southwest from Berlin. The project is set up jointly by Energiequelle GmbH, the town of Treuenbrietzen and the villagers of Feldheim. The towns infrastructure consists of residential homes, farming, some light industry and communal buildings. The village deploys alternate energy sources: local wind farm has 43 operating wind turbines, biogas plant, biomass plant, district heating, solar farm. Feldheim is the only place in Germany that is fully CO2-neutral and that has a fully independent, distributed energy supply. (Förderverein des Neue Energien Forum Feldheim e.V., 2012)

The Village functions according to islanding principle, and the grid consists of two entities, the smart power grid and district heating grid. The owner of the local district heating grid, comprehending biogas and biomass factories, is Feldheim Energie GmbH & Co. KG, a limited partnership formed by 45 of the connected households, enterprises and the municipality of Treuenbrietzen. All partners have full personal liability. To join the partnership each participant has to to pay 3 000 euros and, by law, be a home or land owner of Feldheim. The smart power grid, on the other hand, is owned by Energiequelle GmbH and Co. WP Feldheim 2006 KG and it deploys wind power and solar power for its excess electricity production, electricity storage.

The district heating grid is co-financed by regional government and EU subsidies, along with regular financing methods. The smart power grid is owned and financed by by Energiequelle GmbH and Co. WP Feldheim 2006 KG with no further subsidies.

Smart Grid expansion of 450 000 was funded completely by the owner of the grid, Energiequelle GmbH. Total funding of 1,725 million for district heating grid was distributed as follows (Förderverein des Neue Energien Forum Feldheim e.V., 2012):

- Limited partnership resources: 138 000
- Subsidies: 830 000
- Regular financing (bank loan etc.): 757 000

5.2.5 Elforsk, Sweden

Elforsk is a Swedish Electrical Utilities’ R & D Company, and is set up by Swedish national grid, Association of Swedish Electric Utilities’ and Swedish Power Grid Association. Elforsk’s work is conducted in the form of coordinated framework programs and as individual projects. Proposals for R&D come from their customers, Elforsk staff members, and from external parties they work with. Shared financing of R&D projects makes it possible for the Elforsk’s individual owner groups to participate in extensive programs with a significant return on investment. (Elforsk, 2012)

Generally speaking, Elforsk identifies needs and formulates development projects and programs. Programs and projects are offered to prospective customers within and outside the owner companies, the Swedish Energy Agency being an important stakeholder. The price offered includes payment for Elforsk's own collaboration. If enough customers have responded positively to the offers, Elforsk arranges the implementation of activities in accordance with the offer specification. Orders are placed in collaboration with the sector's own consulting firms and experts, educational establishments and freelance consultants. In many cases, announcements are made in which potential performers for the projects are allowed to propose activities, especially in programs in which students perform researches. After quality assurance, Elforsk passes on the results to customers. (Elforsk, 2012)

The company's actions and investments are divided into five programs, Smart Grid development belonging to transmission and distribution (see **Figure 7**). In 2012, there was approximately 35 projects in these five categories.

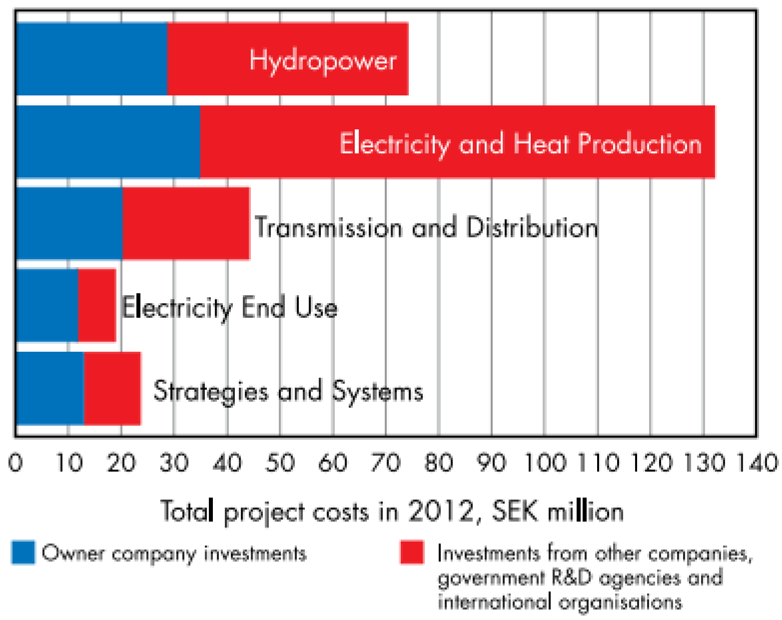

Figure 7. Elforsk Investment Graph. Elforsk, 2012.

A survey filed by Elfrosk reveals that they represent all technology provider stakeholder groups (see section 2.1), which makes sense since it is formed by three national companies with natural monopoly and operates in multiple aspects of the energy distribution system.

Elforsk's 'Smart Grids' program works mostly on the IT-part of Smart Grids: its aim is to use two-way information flows, advanced models and control functions to optimize operation and network architecture in such a way as to deliver efficiency, cost savings, reliability at a lower environmental cost. This particular project should be done in 2014 and is currently about 75% done. Full-recourse project financing is used for the project.

5.3 Survey Analysis

Out of the 411 survey enquiries sent, 22 responses were returned. That is close to the number that was initially estimated likely returns based on the previous experience of the attempted contacts with the projects. The amount of responses was in line with the estimation of Joint Research Centre feedback as well. Out of the 22 respondents, 18 respondents allowed their company and project name to be mentioned in the research. This was in line with the JRC observation: even though most the time companies are reluctant to give out financial information, they are still very willing for publicity as long as financial information is not included. All of the four projects that were not willing to give out their names were from the United States. Nine of 22 answers were form U.S. and the rest, thirteen, were from Europe.

5.3.1 Participant Project Data

The spread of research areas was good, considering that, for example, both in U.S. and in Europe, more than half of the Smart Grid projects are smart meter/AMI related. Therefore, in the worst case it could have been that most or even all of the projects being smart meter/AMI related. However, three categories were left empty. Two of the categories that turned out to be empty were expected since, for example, in the U.S. there are only two projects categorized as 'Equipment

Manufacturers' (Smart Grid Information Clearinghouse, 2013) and 'Socio-Economics and Ecosystems' is a category that is only specified in Europe, and even there only a few projects belong to that category (Joint Research Centre - Institute for Energy and Transport, 2011). The absence of the third research area, 'Smart Electricity Transmission Systems' seems surprising, considering that six of the respondents were reported to be Transmission System Operators (TSOs).

The spread of the responses by project type was ideal: There was close to equal amount of responses from each project type: research and development; demonstration, and; deployment. There was slightly fewer demonstration responses, but that goes in line with the lower number of demonstration projects globally (Joint Research Centre - Institute for Energy and Transport, 2011; Smart Grid Information Clearinghouse, 2013).

In the survey the lead organization's stakeholder status in Smart Grids was asked. There was a possibility to choose from 16 technology stakeholder categories, with a chance to choose more than one option. At least one response from each stakeholder was received (see Figure 8). The lead organizations of the projects participating in the survey belonged, on an average, to three stakeholder groups.

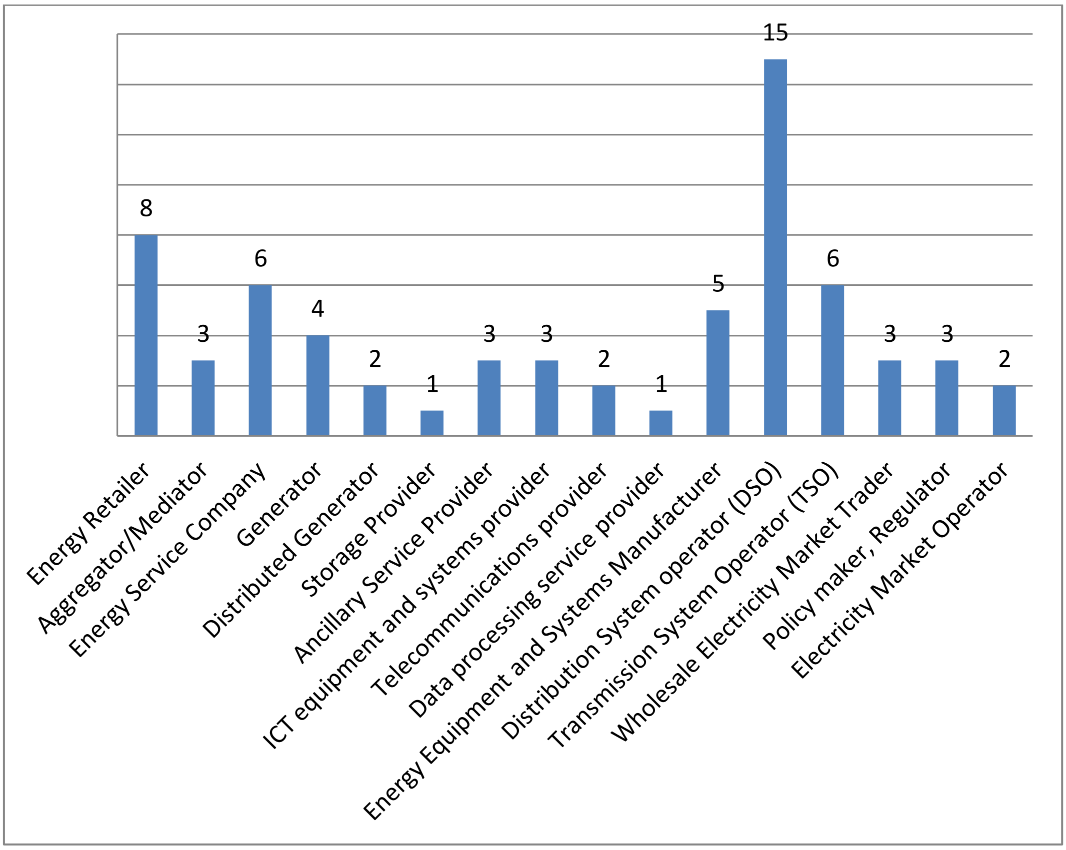

Figure 8. Lead Organization's Stakeholder Status.

The completion rate of the project was considered in the survey, to see if it would play a role in interpretation of consumer engagement. There was a sufficient spread of projects with different completion phases participating in the study, although the percentage of already completed projects reached 36%. This could be because of partly outdated information in the databases, where already completed projects are yet to be erased. Furthermore, out of the 22 projects, eight were already done, four are going to finish during 2013 and the remaining ten are going to finish during 2014-2016.

Half of the respondents did not use any of the traditional energy project financing methods which included commercial bank loan, general obligation bond, lease, Full-recourse project financing and non-recourse project financing. Out of the projects not undertaking any traditional energy project financing methods seven were European and four were from the U.S. None of the projects used more than one method. General obligation bonds were the most popular and they were mostly used in the United States. The usage of bank loan was relatively sparingly used, and. Full-recourse and non-recourse project financing methods were used specifically in Europe, but also a small amount in the U.S. as well. Lease contracts were reported as not being used at all, see Figure 9.

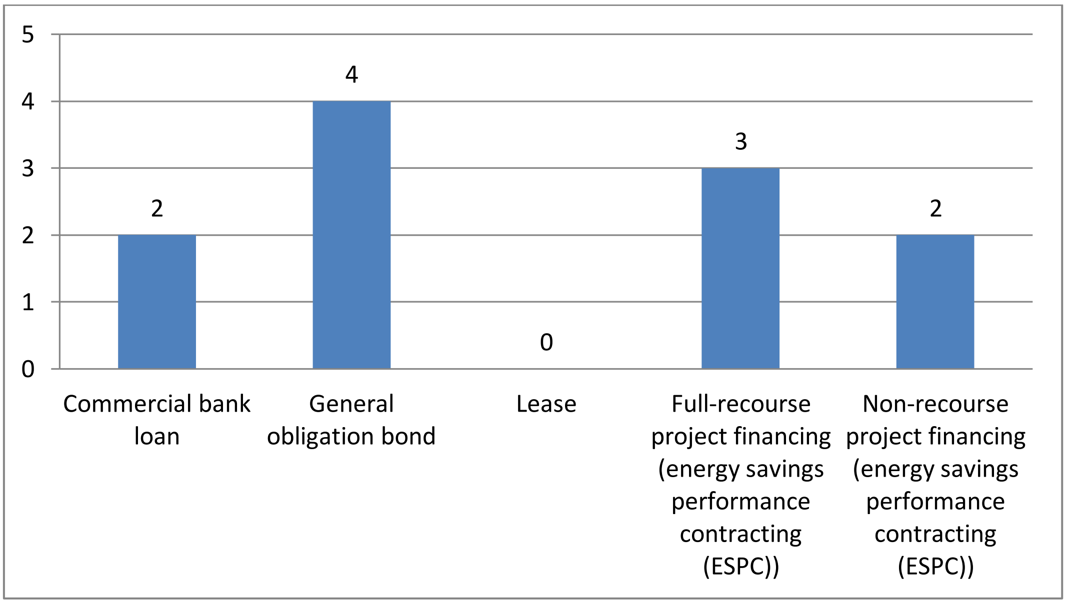

Figure 9. Utilization of Common Energy Project Financing Methods.

5.3.2 Consumer Engagement Data

Exactly half of the respondents were affiliated with consumers, the spread being the same with inside continents so half of the European and half of U.S projects deal with consumers. Demonstration projects had the highest consumer affililation with 80%, compared to that of only 37,5% of both R&D and deployment projects. Between research areas there was no significant correlation except that most Smart Retail and Consumer Systems, Smart Meter/AMI and Integrated Systems projects are affiliated with consumers.

Out of the consumer affiliated projects, 4 out of 11 respondents reported that consumers are not able to participate in any other way after signing the electricity transmission contract and paying the bills afterwards. Though it looks as if the two-way communication that Smart Meters should enable consumer engagement, it is primarily still one-way communication towards the electricity company. The possibility of consumers or households to participate in project financing is rare, but it was possible in one of the projects. There is a start-up cost for joining the Smart Grid network on 27% of the consumer affiliated projects. See Figure 10 below.

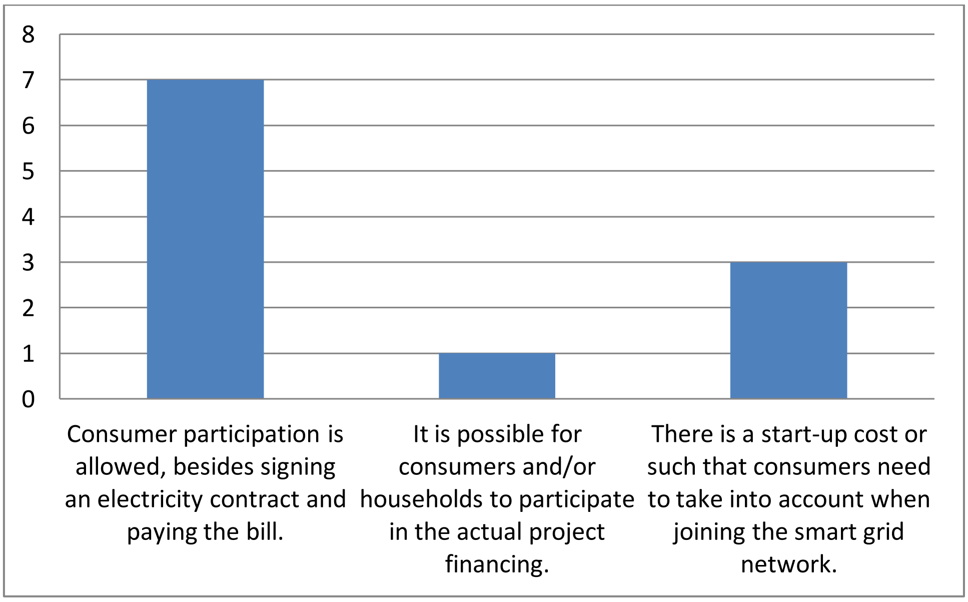

Figure 10. Consumer Engagement Data.

All of the consumer affiliated respondents used some type of encouragement method. Most of the projects utilized one of the options given to encourage consumer engagement. Additionally 36,3% had another encouragement method. Dynamic pricing was the single most common encouragement method (54,6%), see Figure 11.

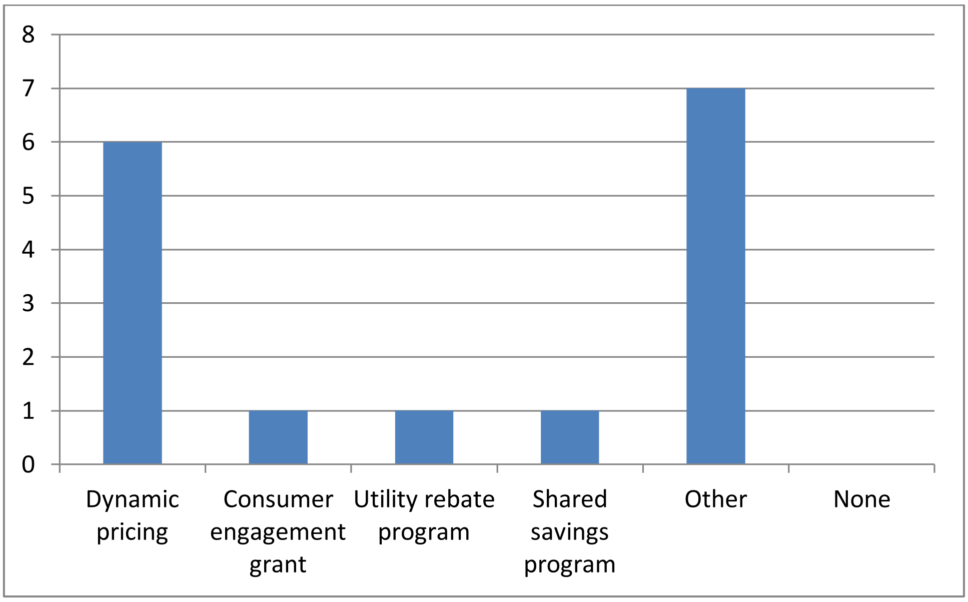

Figure 11. Consumer Engagement Encouragement Methods.

On a significant number of the consumer affiliated projects (54,55%) the data about consumers is in question 16, 17 and 18 is based on estimates:

16. What is the real or expected payback time for consumers in years, i.e. when are the technology acquisition costs and other costs offset by reduction in energy bill?

17. How much time does an average household spend on a monthly basis (optimization of energy usage, communication with the grid, selling electricity etc.) to fully benefit from the smart grid technologies?

18. According to the experiences from the project so far, is the current consumer/household behavior enough or is there something that needs to be adjusted before a large scale adaptation of smart grid technologies?

The data gained from question 16, the projected payback time for consumers varies between three years or less to 10-11 years. However, most likely payback time according to the respondents' answers was 4-5 years. Moving on to question 17, most respondents chose this question being 'not applicable' to their project. All of the projects who were concerned with this issue had reported the time required for optimization of energy usage being less than an hour on a monthly basis. In question 18, out of the projects where consumer engagement was seen to be sufficient, 75% was based on estimates and 25% was based on the combination of estimates and actual data. However, when based on *actual data*, current consumer behavior is was always evaluated not being enough, reasons being that consumers are lacking understanding in the energy system or they are *"not really interested in energy management, more in other services with energy included"*.

6 CONCLUSIONS

Smart Grid projects offer a significant amount of openly available data on the Internet by research organizations such as universities, regulatory bodies, governments and even some companies (University of Delaware, 2011-2012; European Electricity Grid Initiative, 2010; U.S. Department of Energy, 2008; House of Representatives of the United States of America in Congress Assembled, 2005; Rackliffe, 2012).

In Europe about 55% of total investment comes from various sources of funding, which can be divided into regulatory, national and European funding and the rest, 45% is private capital (see section 5.1). The funding financing instruments are all concentrated on their own areas, which has the potential of allocating funds accurately (for more information, see section 3.2). The funding markets are therefore unbundled because there are many sources of funding.

In U.S., Smart Grid Investment Grant program is structured as a public-private partnership. It provides up to half of the project costs for deployment of Smart Grid Technologies. The private sector investment amounted to 55% of the total investments in the U.S. By March 31st 2012 roughly two thirds of the federal funds had been expended, as planned. Other funding programs are also orchestrated by American Recovery and Reinvestment Act. There are seven other federally funded major Smart Grid programs, which amount to about 1 billion dollars (see Table 1. U.S. Initial Federal Recovery Act Funding for Major Smart Grid Program Activities. Smart Grid Investment Grant Program: Program Report, July 2012.). The aim of these programs is to make the electric grid development established by SGIG sustainable in the long run. Federal funds are the main accelerators for Smart Grid investment, so U.S. is often called a bundled market in terms of public funding.

In the case projects that were looked into more thoroughly, the ones that *seemed* to implement their finances successfully had a high degree of innovation in the financing and an ability to readjust to local specifications. It seems as well that the will to change has to spur from the individuals who are going to be consumers of the Smart Grid. Company/consortium has to be well aware of the area where the grid is being built and be in close co-operation with the end-users from the beginning, by for example educating consumers. The consortium partners need to be also strong: even if some of the less significant partners leave the consortium, it can be devastating for the consortium finance, which can end out to be a burden for the end-users, as seen in the case of Boulder, Colorado.

From the quantitative survey it can be seen that there are no standardized models for financing Smart Grids based on research area, project type, lead organization stakeholder status or completion rate. However, other facts could be realized from the survey. All the current projects are going to conclude in the year 2016 at latest and as it turns out, the average duration of a project until finished is three to four years (see section 5.3.1). According to the survey results the most common energy project financing methods commercial bank loan, general obligation bond, lease and energy savings performance contracts were not very popular in Smart Grid financing, although it could have been the case that the respondents didn’t know or didn’t want to give the answer to that specific question. On vast majority of the projects the end-customers don’t have the chance to take part in the actual project financing. However, in the sample there was one municipality run project where consumers could take part in the financing, so it is plausible. Dynamic pricing is the most significant method of encouraging consumer engagement. Consumer engagement grants, utility rebate programs and other methods are also being used but to a lesser extent. There are other engagement methods as well that are, however, not as well documented as the before mentioned ones are.

All in all, as doing research implies that something is added to present knowledge that exists, or creating insights (Ghauri & Kronhaug, 2010), this research can be called successful, since it provides insights to current projects or prospective companies interested in Smart Grids.

6.1 Ethical questions, Reliability and Validity

Knowledge reported in the thesis about European and U.S. funding is as reliable as it can be at this point, as the information was from official sources. However, those funds originate from taxpayers, so even if the Smart Grid projects or their financing methods were alarmingly flawed, it would not be reported to avoid consumer attitudes turning negative.

Significant amount Smart Grid information, including the ones that can be found from the official sources, are often based on optimistic visions, estimations or forecasts. The researches have constantly been conducted by an organization who is a Smart Grid stakeholder.

In the research, especially in the case project research, comparing the projects with each other is difficult since the information that could be gained from the case companies varied. Therefore, the point of this research goes more into acquiring as much information from each project as possible, instead of trying find general correlations and assumptions based on the study.

The conclusions about common private financing methods are cautious because there are many variables that can alter the reliability of the answers. For example, the survey could have been answered by a person who is not aware of which methods are used or the receiver of the initial enquiry e-mail could even have been a company that is not the lead organization and, therefore, not responsible for the financing. Even if the lead organization or the 'correct' personnel would have answered the survey, there is a chance that the lead organization is a large or otherwise dysfunctional corporation where financing department and the Smart Grid project representatives are not in close cooperation. Furthermore, since the number of responses to the qualitative survey was not high, no assumptions should be made based on it. However, the survey results were still enough to be able to identify some trends in Smart Grid financing. Otherwise, the data itself can be called reliable and valid since the survey did not ask any opinions, just facts.

6.2 Possibilites for Further Studies

There are a lot of ongoing Smart Grid related researches with a significant budget going on. The ongoing researches will be concluded in the next few upcoming years and they will spur yet another set of researches. At this point the financing of Smart Grids will remain a sensitive subject until its market potential is being realized.

However, for business students, company cases could be made for local small and medium sized electricity enterprises that do not have resources for comprehensive research and development but that, for example, want to expand their operations abroad or who need help in joining a consortium of Smart Grid projects.

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APPENDIX 1: JRC INTERIVIEW SUMMARY

Q: I am making a research on financing models of smart grid projects with additional interest to consumer participation. I found a lot of the stuff found on the JRC pages very useful for my research. Unfortunately I am having a hard time getting in touch with the projects, so I am asking if you people would have any clues that I could capitalize on in contacting them?

JRC: These things need to be discussed on the phone. Sadly I don't have that much time to answer in detail. I will respond just for a few issues you raised.

Q: Additionally, here is a link to my questionnaire. Any comments are more than welcome.

JRC: Regarding the questionnaire:

1. You ask for sensitive information (budget, budget sources, consumers etc.) from the Smart Grid companies. Nobody will give you these (or just a few). Even us (the European Commission) faced a lot of issues getting these numbers, and we are funding them. We published a questionnaire like your, more complex though. We got 300 responses.

2. We will publish a comprehensive report containing information that you may need in about 1-2 weeks.

Q: Now I can already narrow down my questions a bit, and know what I can excpect. The layout for the questionnaire now is still quite extensive because the first plan was to make the research qualitative for just 4-6 projects, and because my initial knowledge of the industry is limited.

JRC: I would say that it is better to wait for our report. I will send it to you in 1 week or so if you remember me. You will get some interesting information out of it.

Q: I changed my questionnaire into a quick survey that does not ask for sensitive info like the previous form. I am asking if it is possible for you to send contact information of the smart grid projects in Europe to me?

JRC: Sadly I can't give you that information. Your survey isn't that sensitive anymore. You may get some results.

Q: Since I can't have the contact information, maybe you could send the survey link to project representatives on JRC database with a motivational sentence or two. (Again, I acknowledge that this might not be possible.)

JRC: Can't do that. You are not the only one asking for this. We need to respect their privacy.

Q: Would it be a good idea to remove the lead organization etc. questions from the survey to make the survey completely anonymous, to boost the number of answers?

JRC: If you make it too anonymous nobody will complete your survey anymore. How can they advertise their work?

APPENDIX 2: JRC ADDITIONAL DATA (UNEDITED)

2.6 Who is investing?

The 281 smart grid projects in the catalogue have an average of seven participating organisations. The organisations have been classified into different categories: DSO/utilities/energy companies, TSOs, universities/research centres/consultancies, manufacturers, IT/telecoms, etc.

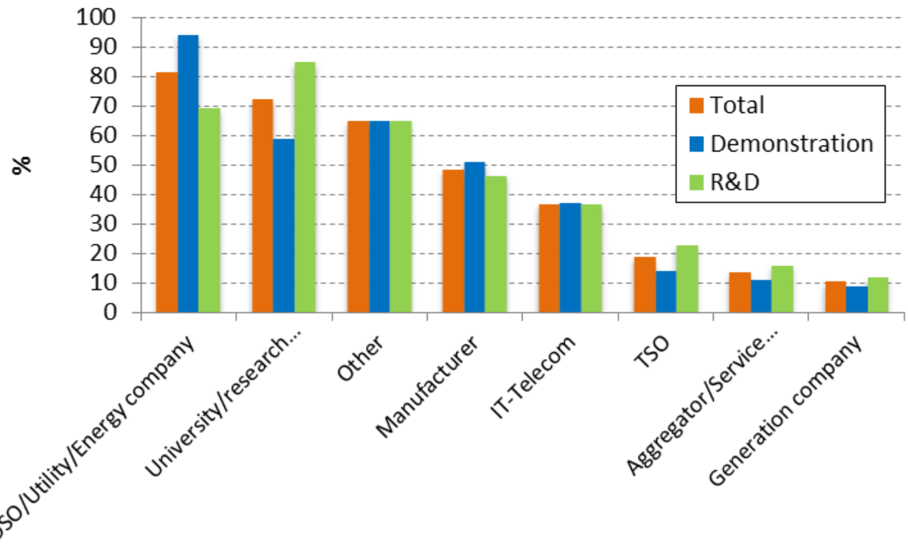


Figure 26 – Participation by type of organisation (proportion of projects with at least one representative of respective types of organisation)

Figure 26 shows participation by type of organisation as the proportion of projects with at least one representative of the respective types of organisation. It shows that DSOs/utilities/energy companies are involved in over 80 % of the projects. Universities/research centres are involved in over 70 % of the projects, followed by manufacturers (over 45 %) and IT/telecoms (over 35 %).[1] TSOs are involved in around 20 % of the projects.

For most projects, information on the budget share of each participating organisation was not available. We have therefore assumed that the budget of the

[1] The 'other' category includes a diverse set of organisations such as engineering companies, municipalities/public authorities, associations, etc.

project is allocated entirely to the lead organisation. This gives us an idea of the share of the total investment in the catalogue for which each organisation was responsible (Figure 27).

The data seem to confirm the leading role of DSOs and distribution utilities in promoting smart grid development in Europe. DSOs/utilities/energy companies are taking the lead in a total of 115 projects (DSOs: 70; utilities/energy companies: 45) with investment equal to 57 % of overall investment in smart grid projects.

Projects led by universities/research centres/consultancies account for to 23 % of overall investment and those led by manufacturing companies, IT & telecom companies, TSOs and others for 20 %.

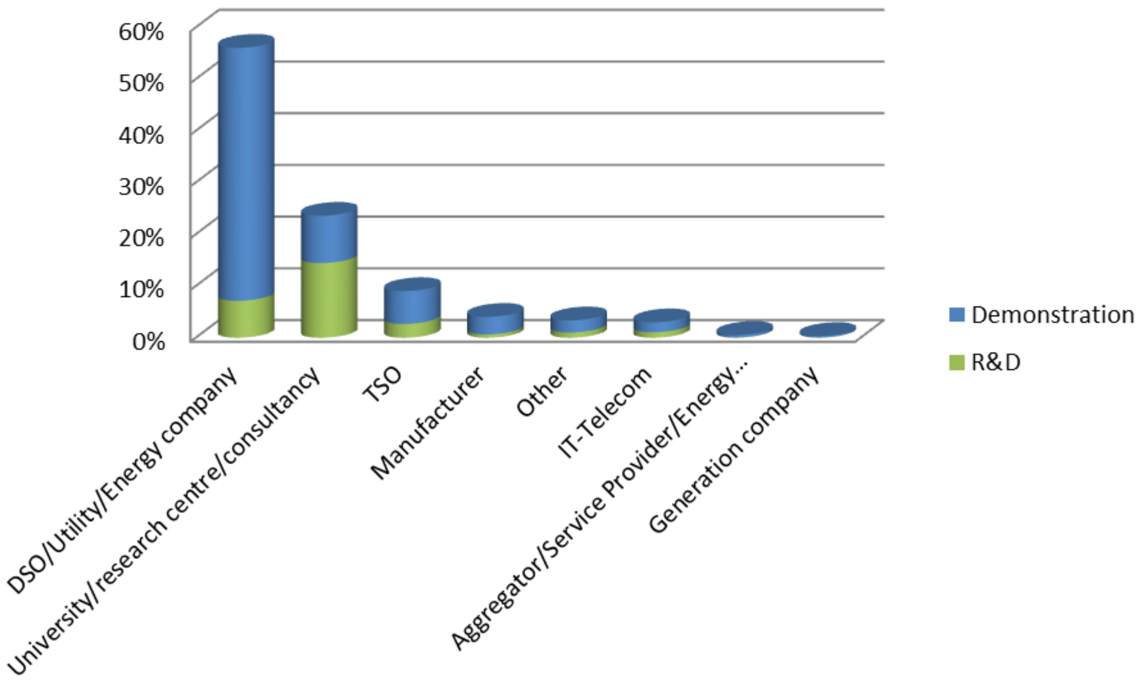


Figure 27 – Budget share of projects by type of lead organisation

2.7 *Sources of funding*

The role of funding for smart grid projects is very important. Of the overall budget of the projects in the JRC catalogue, 55 % (€974 million) comes from various sources of funding and 45 % from private capital. Around 80 % of the projects have received some form of public funding.

These figures indicate that decisions to invest in smart grids are not yet being taken independently/autonomously and project coordinators still rely on funding institutions to invest in RD&D smart grid projects.

For the purposes of the analysis, funding sources were categorised as European, national and regulatory.

Regulatory funding — In this category we consider specific smart grid programmes managed by regulators to support innovative smart grid projects. For example, more than 50 % of the Danish projects in the catalogue are supported by the Forskel programme, which is financed from tariffs.

Since 2010, the UK regulator OFGEM has set-up the low carbon network fund (LCNF) to provide regulatory funding for particularly innovative smart grid projects. In other countries, regulators are supporting the development of smart grids with specific tariff schemes guaranteeing an additional rate of return on smart grid investments. In Italy, for example, an additional 2 % rate of return is given for smart grid investments which fulfil certain innovation criteria [Delfanti et al. 2011].

National and European funding — At the European level, smart grid initiatives have been receiving wide support through different channels (6th and 7th Framework Programmes, European Regional Development Plan). In several European countries, smart grid investments are receiving increasing levels of national support funded by innovation or energy ministries (e.g. the E-ENERGY Programme in Germany). These funding initiatives are targeting RD&D projects across different countries and technological applications.

Figure 32 shows the cumulative value of the total budget and of the different funding sources over the years. In plotting the curves, it has been assumed, for the sake of simplicity, that the total budget and the funding of a project are distributed evenly over the duration of the project. The area under each curve represents the budget allocated by funding type for smart grid projects over the years.

A relative steady increase over the years can be observed in the cumulative total and in the funding source budgets. The fact that the curves have decreasing trends in the future is misleading: the only information that can be gleaned from the future side of the graph concerns the funding already allocated for ongoing projects.

The most significant back-up to private investment comes from national and EC funding. A sharp increase in regulatory funding can be noticed in 2011 following the launch of OFGEM's Low Carbon Fund initiative in the UK.

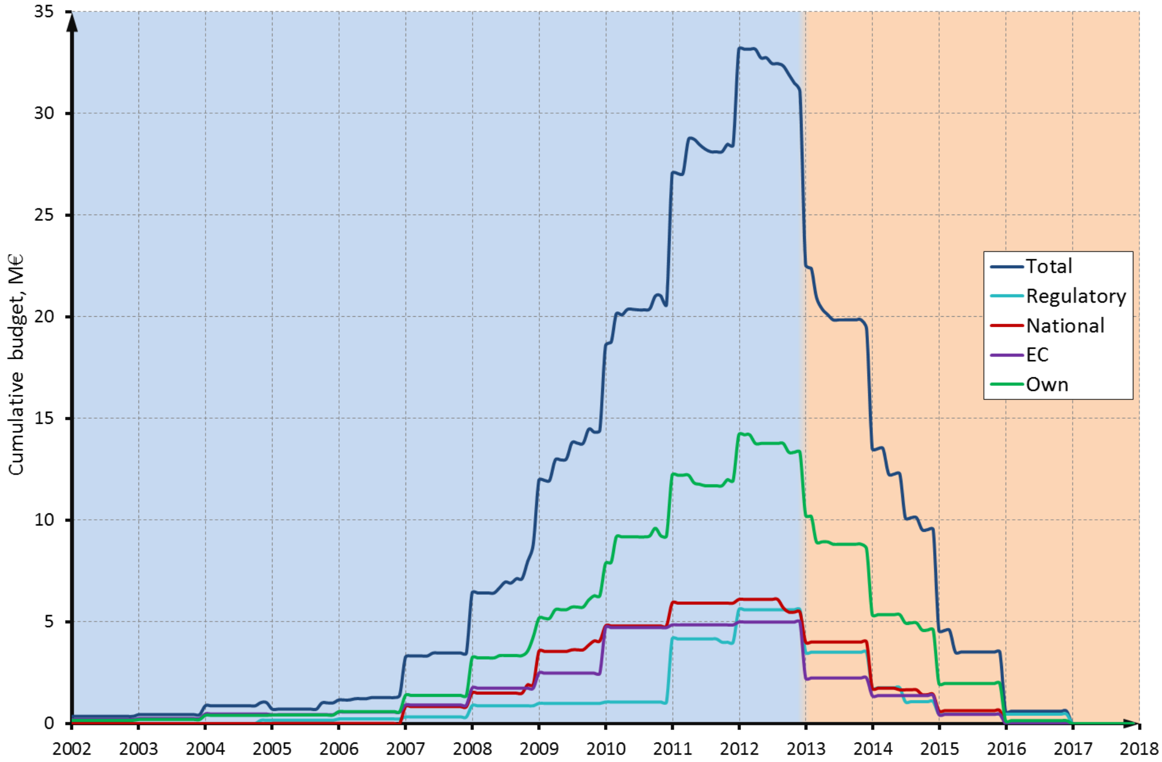


Figure 32 — Allocated funding over the lifespan of SG projects

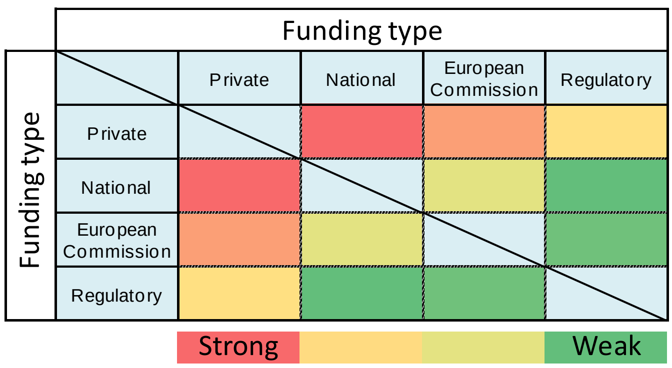
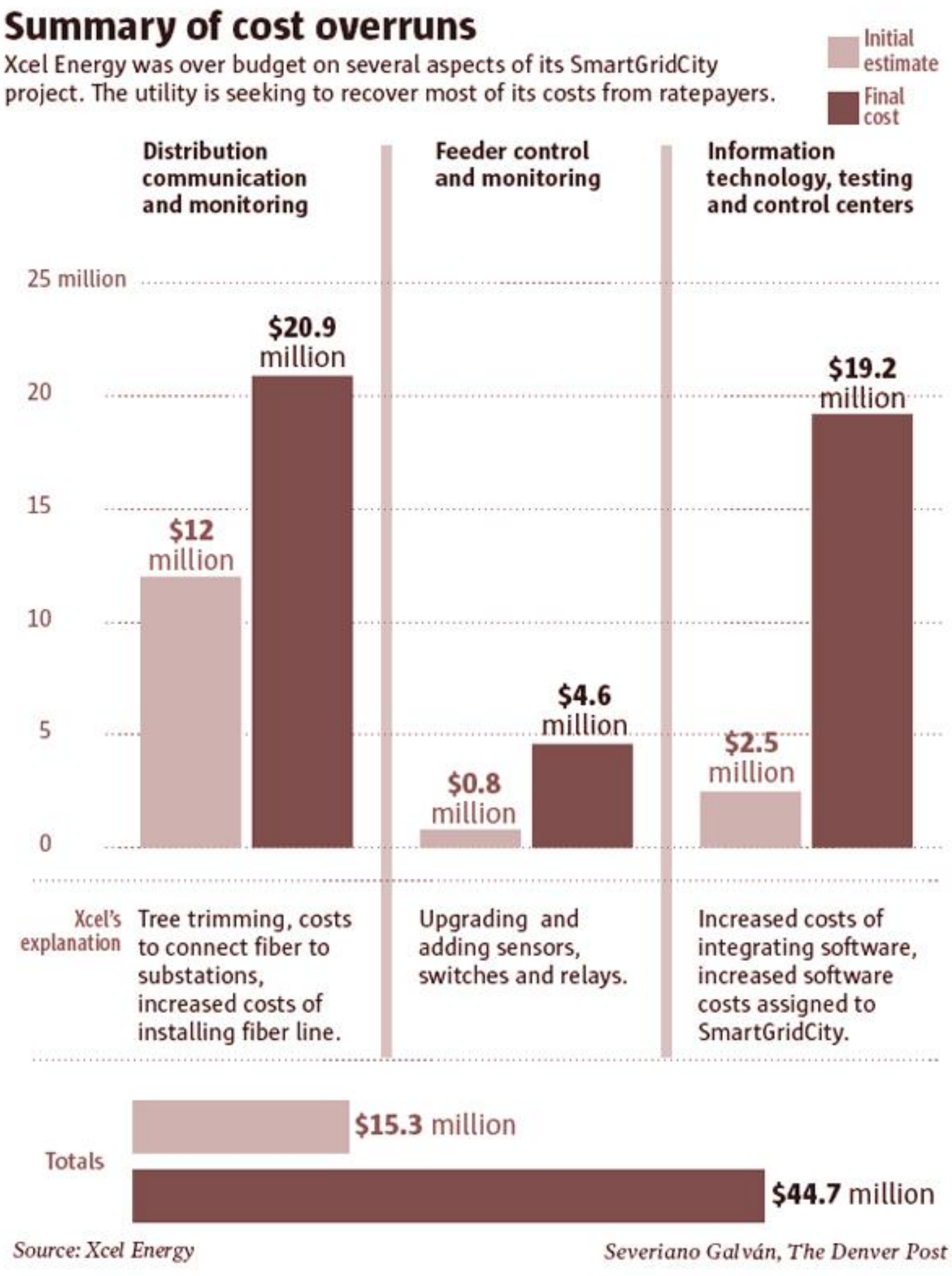


Figure 33 — Combination of funding sources in the project budget

Figure 33 shows the most common combinations of financing across the projects.

Typically, projects are co-financed from a single funding source (national, European or regulatory). National funding provides the highest rate of co-financing combined with private funding (red cell in Figure 33), followed by European funding (orange) and regulatory funding (yellow). Figure 33 also shows that there are a few projects which have received both EC and national funding (light green), whereas the combination of regulatory support and EC or national funding is rare (dark green).

APPENDIX 3: BOULDER, COLORADO SUMMARY OF COST OVERRUNS



APPENDIX 4: SURVEY

Company and Project

1. Check the box if the company and project name can be mentioned in the research. ☐

2. Lead organization name and form: [ ]

3. Name of the smart grid project: [ ]

4. Owner of the grid: [ ]

5. Continent: --Select--

6. Research area of the smart grid project: --Select--

7. Project type: --Select--

8. What the project lead organization's smart grid stakeholder status? Multiple options possible.

- ☐ Energy Retailer
- ☐ Aggregator/Mediator
- ☐ Energy Service Company
- ☐ Generator
- ☐ Distributed Generator
- ☐ Storage Provider
- ☐ Ancillary Service Provider
- ☐ ICT equipment and systems provider
- ☐ Telecommunications provider
- ☐ Data processing service provider
- ☐ Energy Equipment and Systems Manufacturer
- ☐ Distribution System operator (DSO)
- ☐ Transmission System Operator (TSO)
- ☐ Wholesale Electricity Market Trader
- ☐ Policy maker, Regulator
- ☐ Electricity Market Operator

9. What is the estimated completion rate of this smart grid project right now? --Select--

10. If not already, when should the project be ready? --Select--

11. Which of these, if any, traditional energy project financing alternatives are being used in this project?

- ☐ Commercial bank loan
- ☐ General obligation bond
- ☐ Lease
- ☐ Full-recourse project financing (energy savings performance contracting (ESPC))
- ☐ Non-recourse project financing (energy savings performance contracting (ESPC))

12. Customers/consumers are affiliated in this project: Yes

When answered 'Yes' to question 12, questions 13-18 will be unlocked:

Consumer/Prosumer Participation

13. Check if the statement is true:

- [ ] Consumer participation is allowed, besides signing an electricity contract and paying the bill.
- [ ] It is possible for consumers and/or households to participate in the actual project financing.
- [ ] There is a start-up cost or such that consumers need to take into account when joining the smart grid network.

14. What kind of methods are being used to encourage consumer engagement? Choose at least one of the option.

- [ ] Dynamic pricing
- [ ] Consumer engagement grant
- [ ] Utility rebate program
- [ ] Shared savings program
- [ ] Other
- [ ] None

15. Please select:

	Estimates	Actual data	Estimates and actual data
The following consumer information is based on:	○	○	○

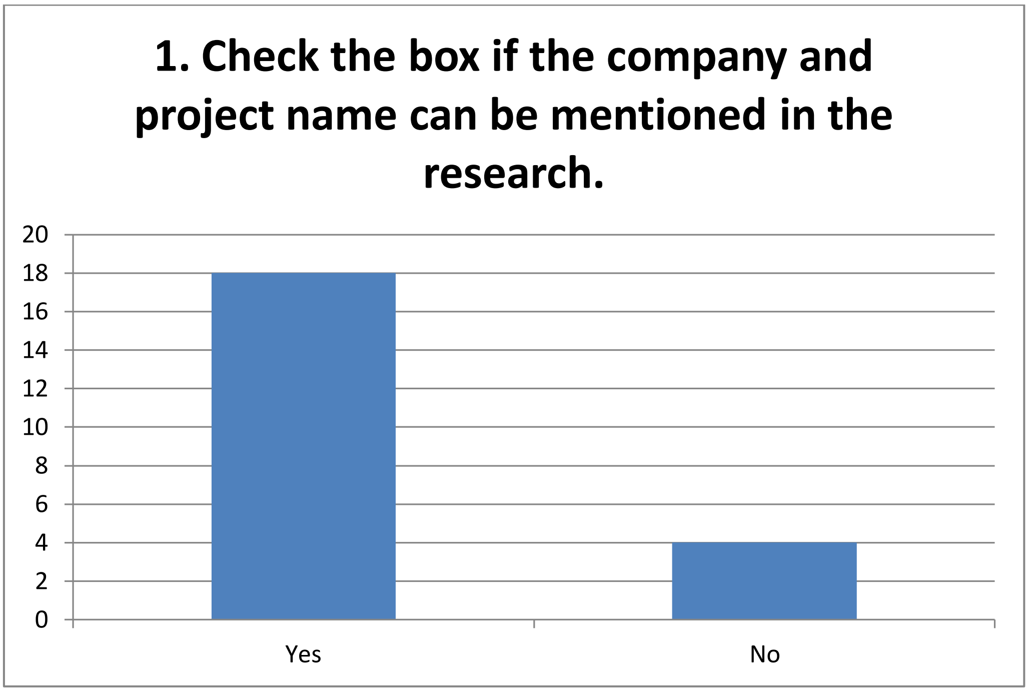
16. What is the real or expected payback time for consumers in years, i.e. when are the technology acquisition costs and other costs offset by reduction in energy bill? [--Select--]

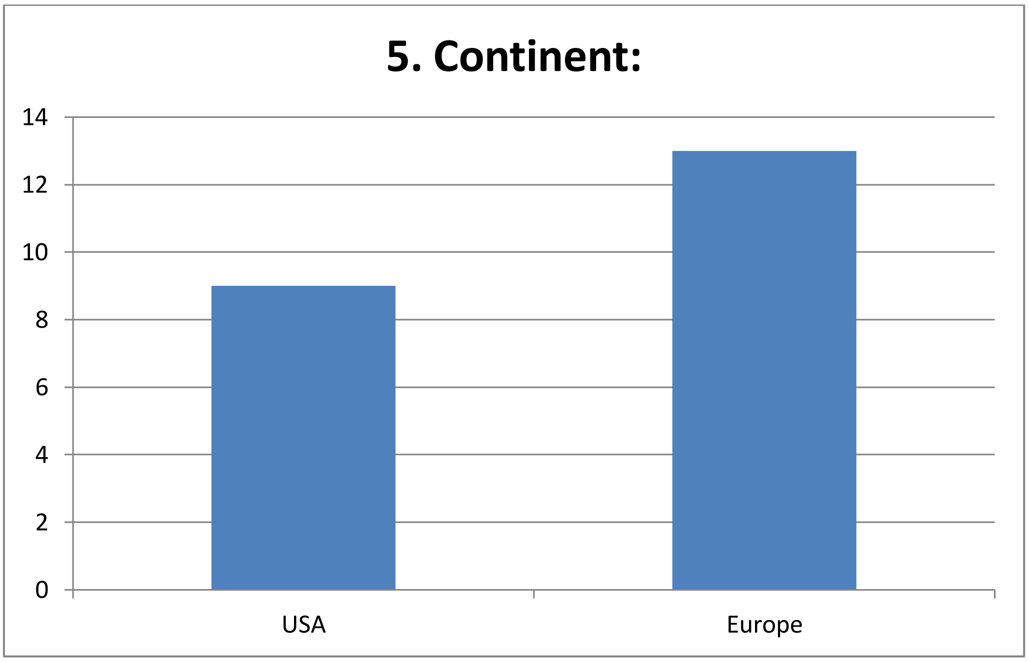
17. How much time does an average household spend on a monthly basis (optimization of energy usage, communication [--Select--]

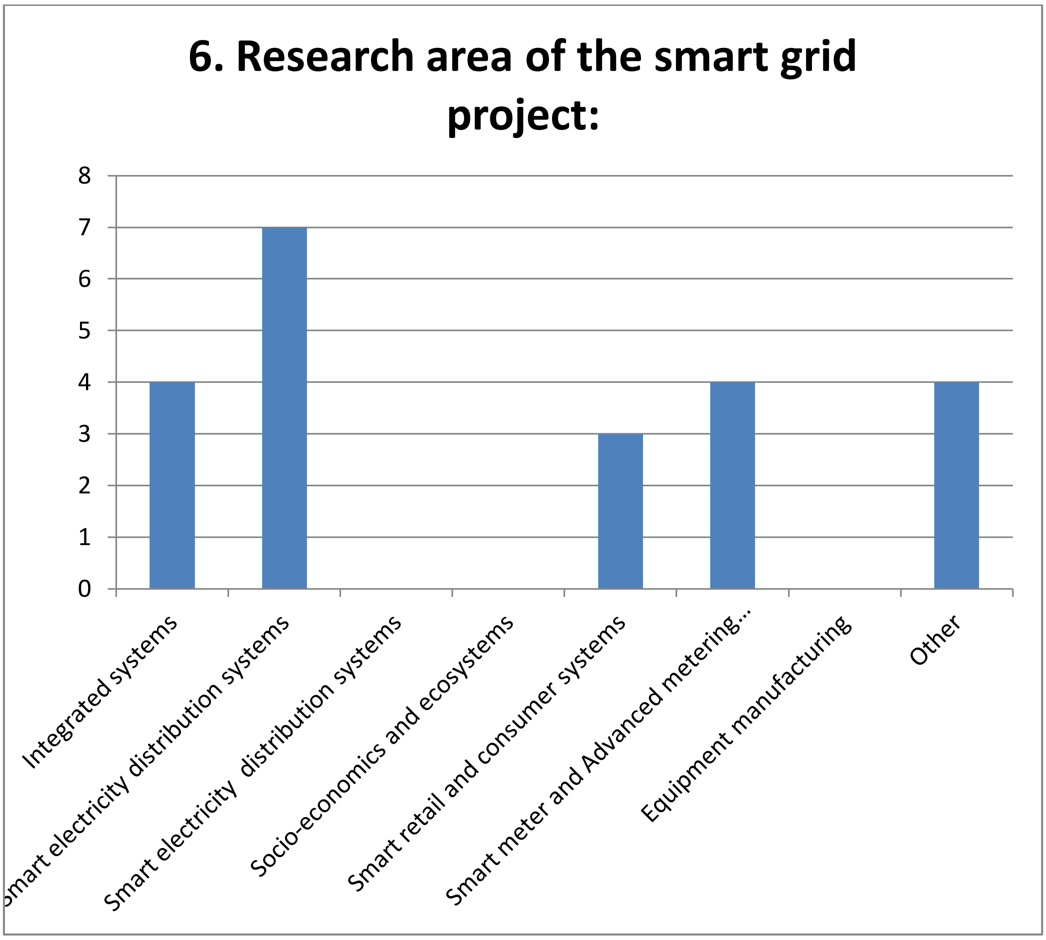
18. According to the experiences from the project so far, is the current consumer/household behavior enough or is there something that needs to be adjusted before a large scale adaptation of smart grid technologies?

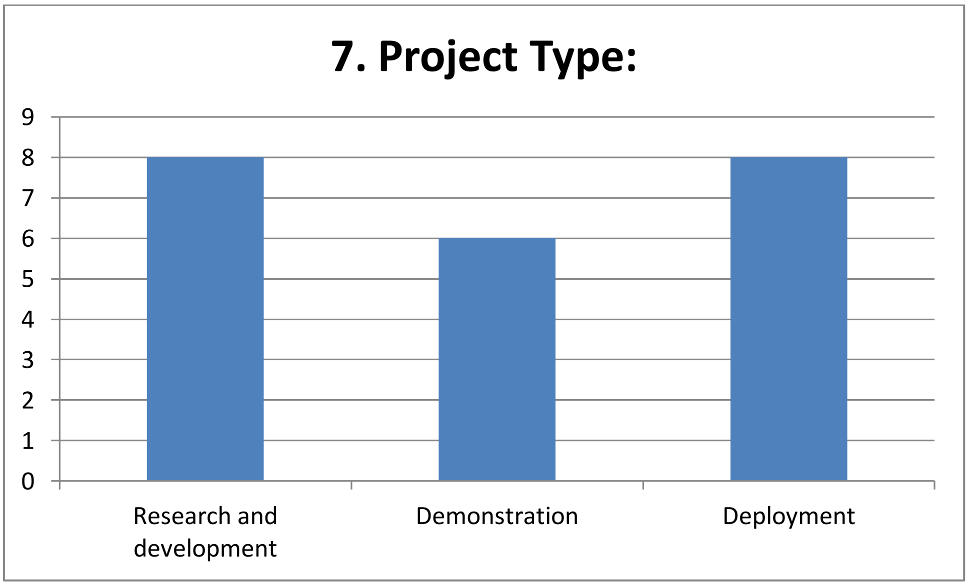
	Yes	No	Why not?
The current consumer behavior is enough?	○	○	[ ]

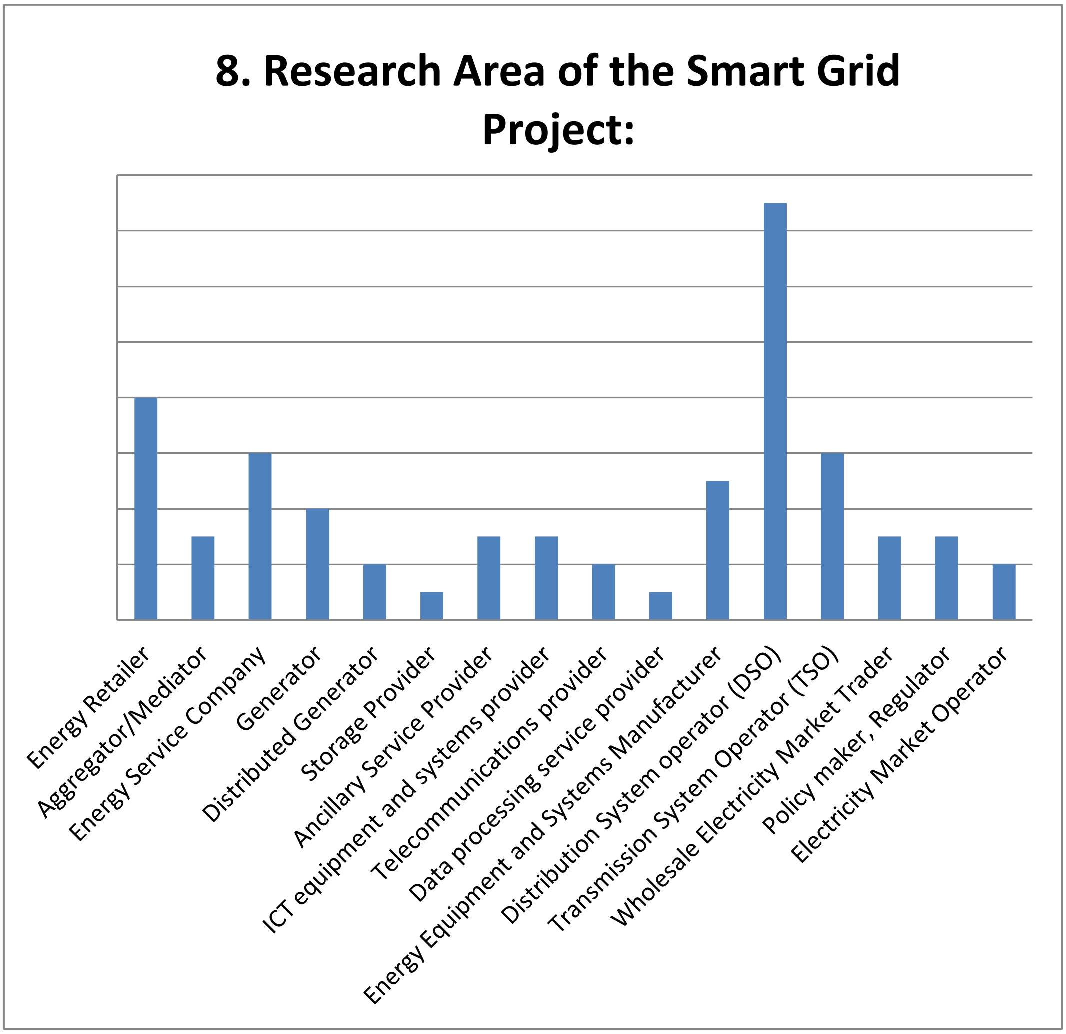
APPENDIX 5: GRAPHS OF SURVEY RESULTS

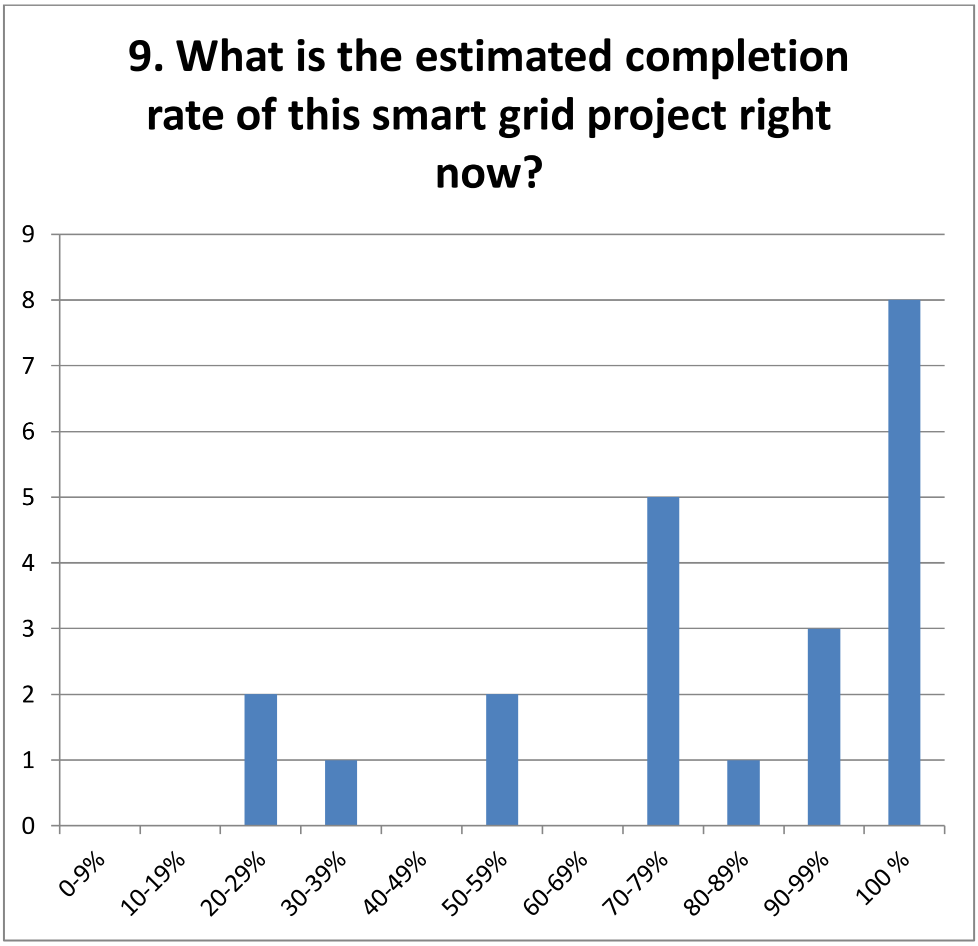


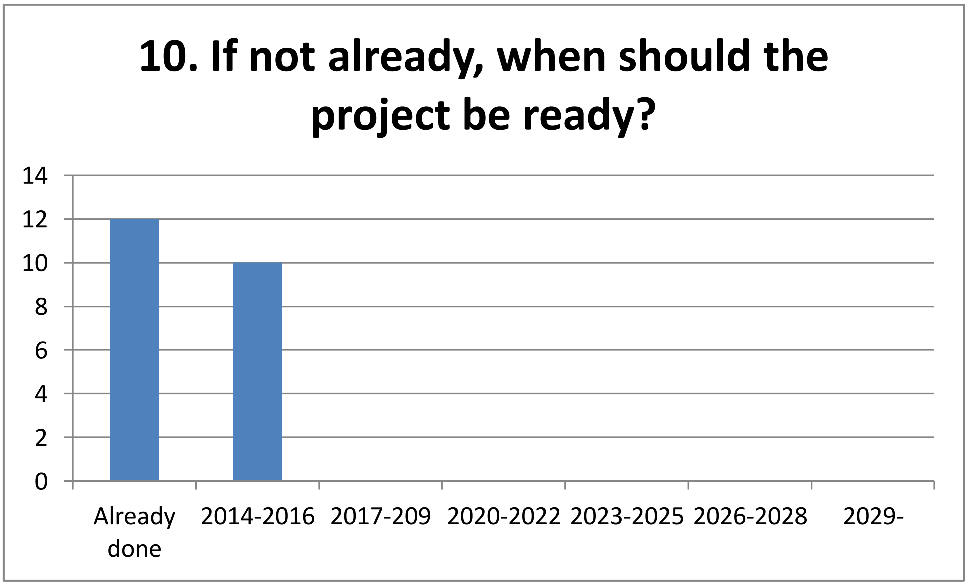


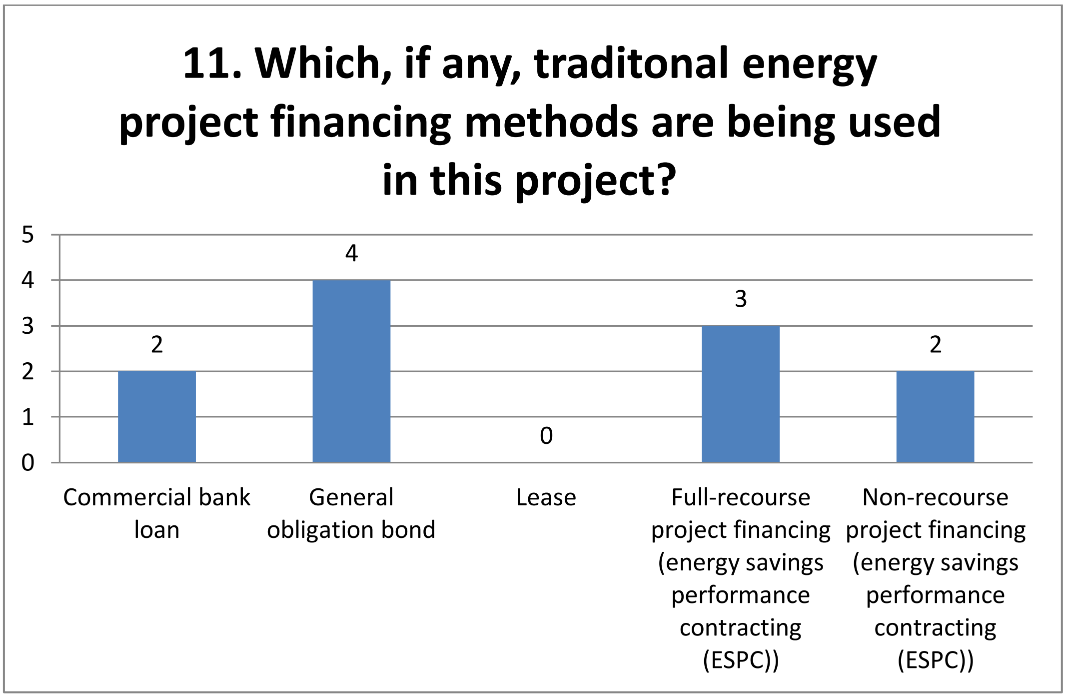

6. Research area of the smart grid project:
0
1
2
3
4
5
6
7
8
Integrated systems
Smart electricity distribution systems
Smart electricity distribution systems
Socio-economics and ecosystems
Smart retail and consumer systems
Smart meter and Advanced metering...
Equipment manufacturing
Other

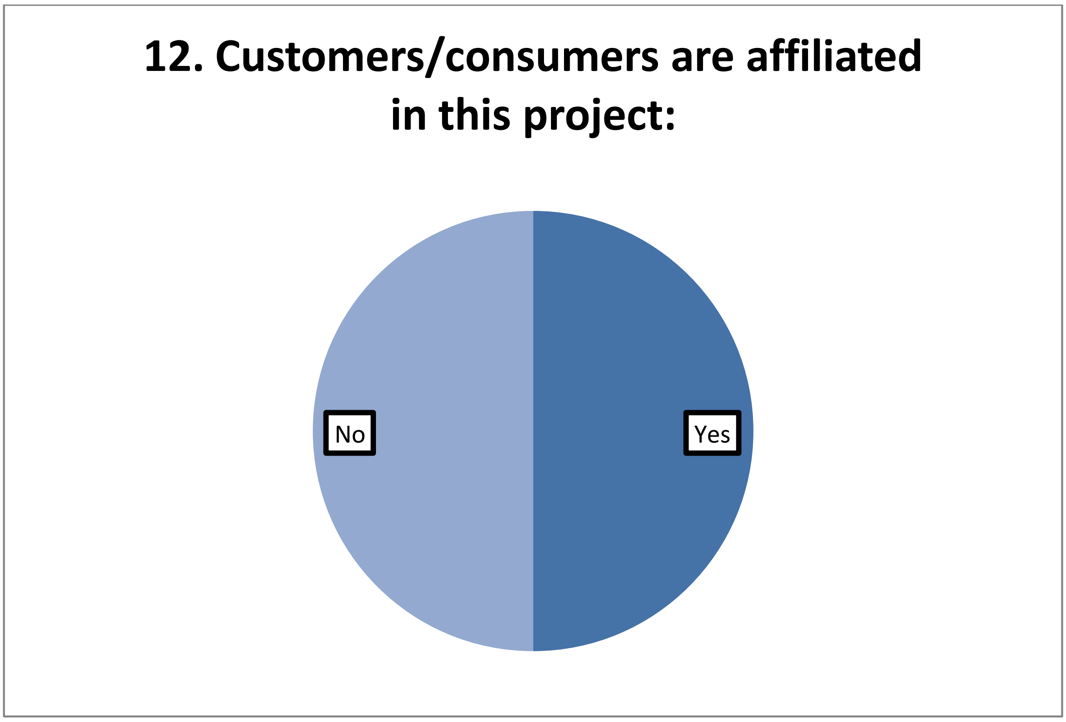

7. Project Type:
0
1
2
3
4
5
6
7
8
9
Research and development
Demonstration
Deployment

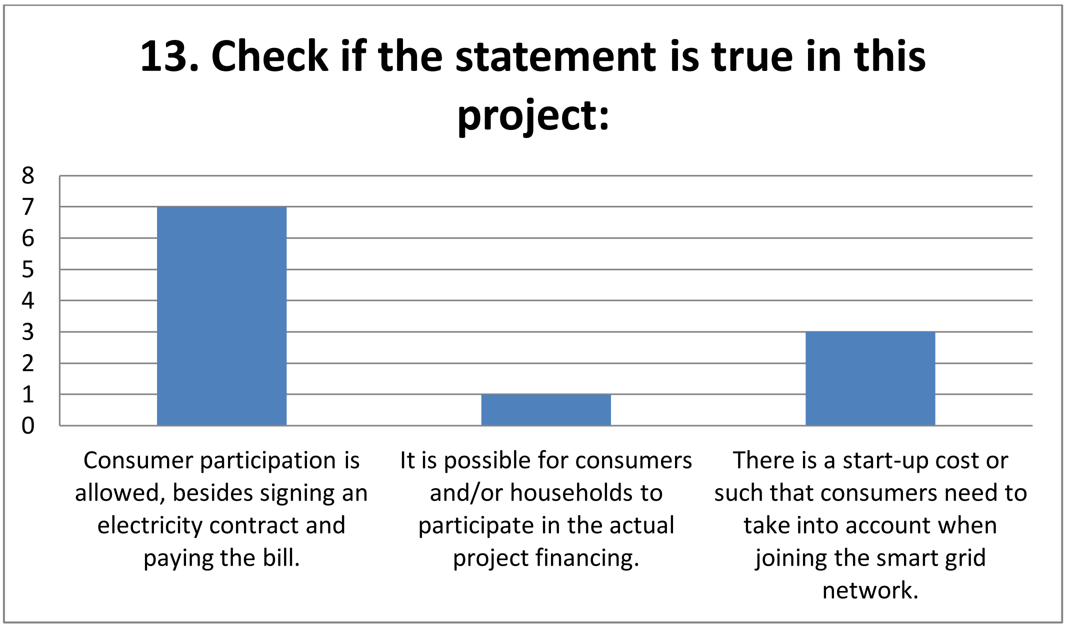

8. Research Area of the Smart Grid Project:
Energy Retailer
Aggregator/Mediator
Energy Service Company
Generator
Distributed Generator
Storage Provider
Ancillary Service Provider
ICT equipment and systems provider
Telecommunications provider
Data processing service provider
Energy Equipment and Systems Manufacturer
Distribution System operator (DSO)
Transmission System Operator (TSO)
Wholesale Electricity Market Trader
Policy maker, Regulator
Electricity Market Operator

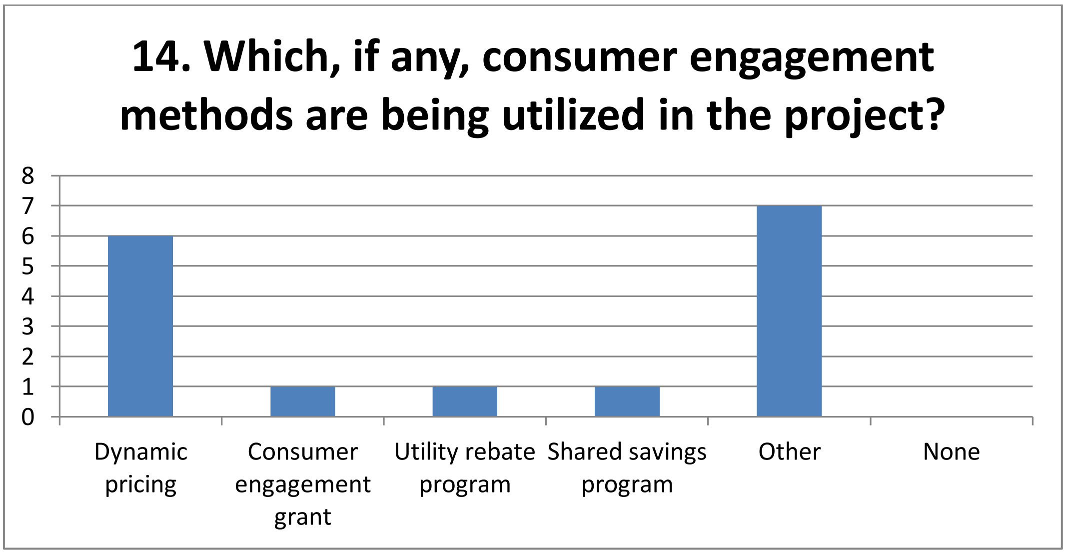

9. What is the estimated completion rate of this smart grid project right now?
9
8
7
6
5
4
3
2
1
0
0-9%
10-19%
20-29%
30-39%
40-49%
50-59%
60-69%
70-79%
80-89%
90-99%
100 %

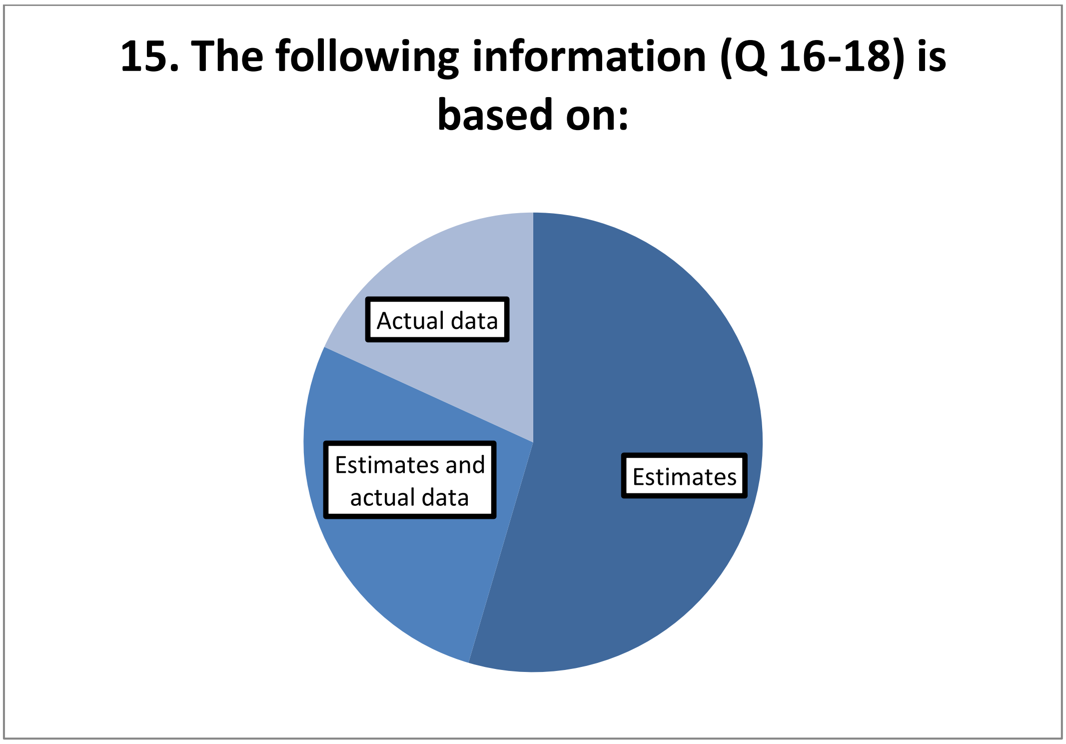

10. If not already, when should the project be ready?
14
12
10
8
6
4
2
0
Already done
2014-2016
2017-209
2020-2022
2023-2025
2026-2028
2029-


11. Which, if any, traditonal energy project financing methods are being used in this project?
5
4
3
2
1
0
2
4
0
3
2
Commercial bank loan
General obligation bond
Lease
Full-recourse project financing (energy savings performance contracting (ESPC))
Non-recourse project financing (energy savings performance contracting (ESPC))

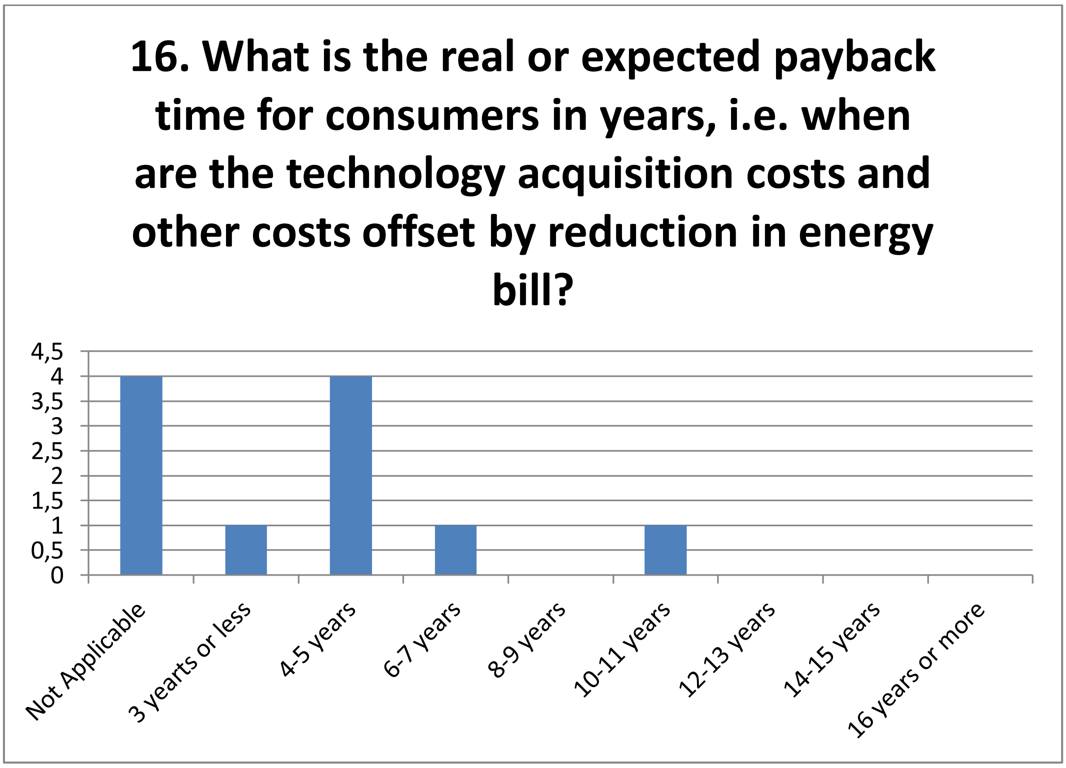

12. Customers/consumers are affiliated in this project:
No
Yes


13. Check if the statement is true in this project:
8
7
6
5
4
3
2
1
0
Consumer participation is allowed, besides signing an electricity contract and paying the bill.
It is possible for consumers and/or households to participate in the actual project financing.
There is a start-up cost or such that consumers need to take into account when joining the smart grid network.

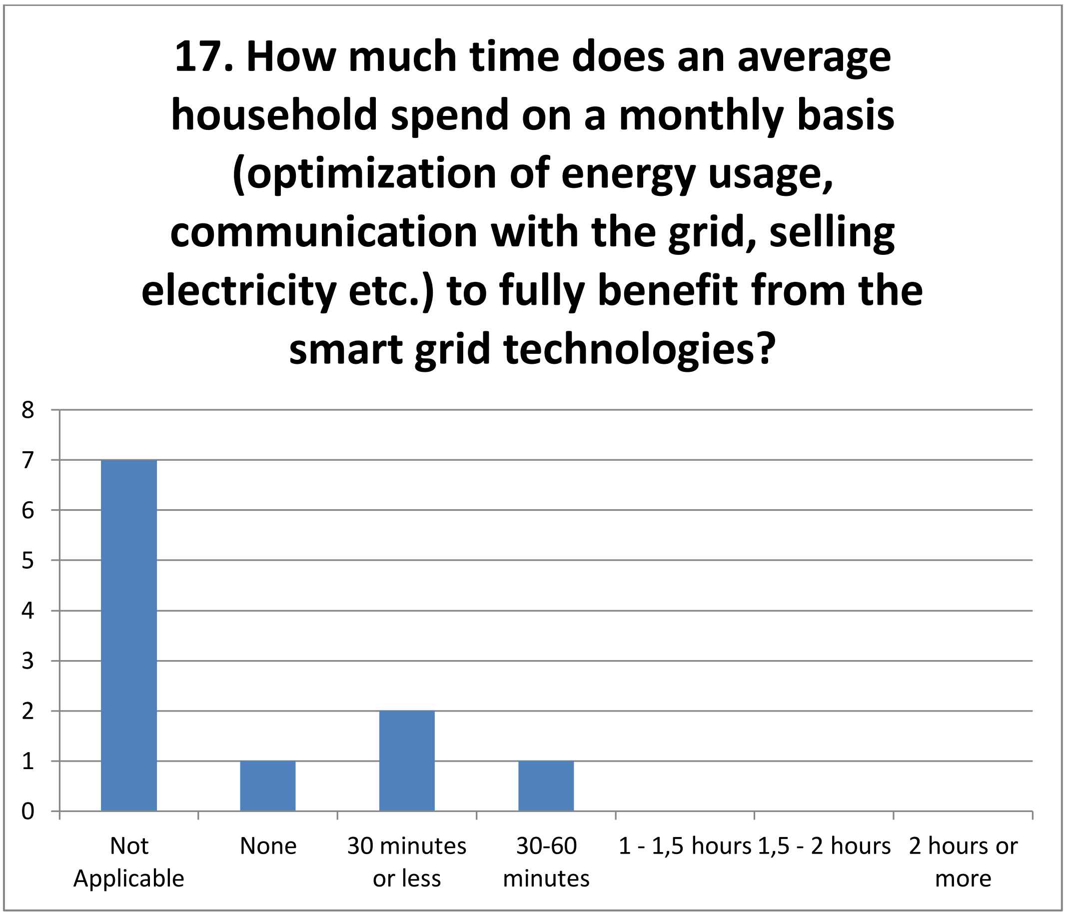

14. Which, if any, consumer engagement methods are being utilized in the project?
8
7
6
5
4
3
2
1
0
Dynamic pricing
Consumer engagement grant
Utility rebate program
Shared savings program
Other
None

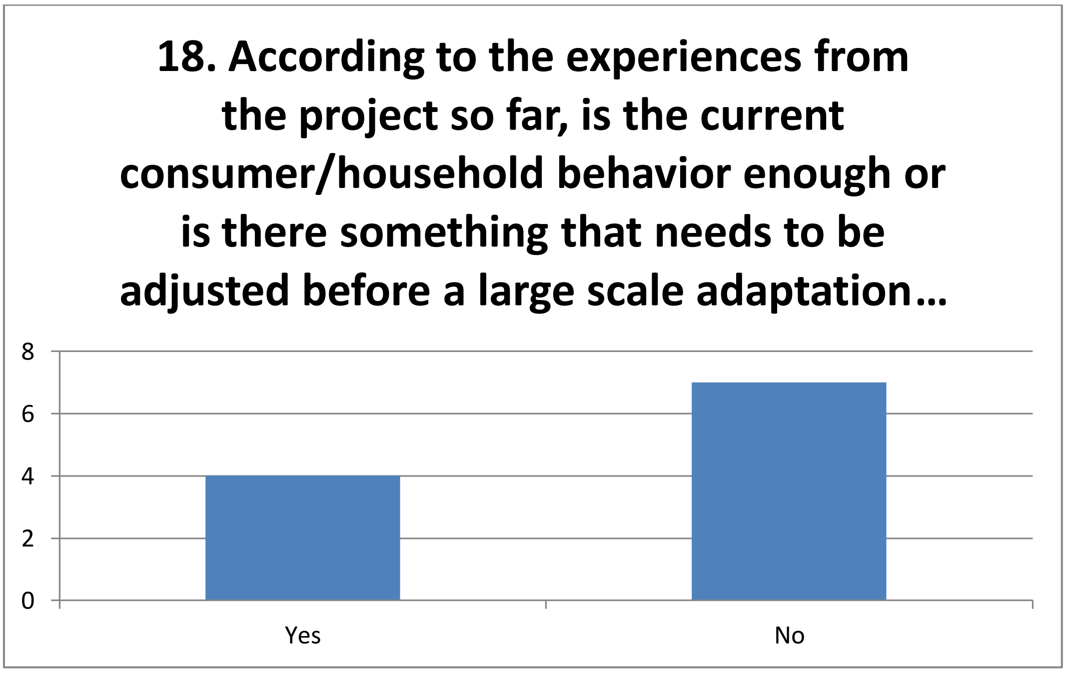


15. The following information (Q 16-18) is based on:
Actual data
Estimates and actual data
Estimates



16. What is the real or expected payback time for consumers in years, i.e. when are the technology acquisition costs and other costs offset by reduction in energy bill?
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
Not Applicable
3 yearts or less
4-5 years
6-7 years
8-9 years
10-11 years
12-13 years
14-15 years
16 years or more


17. How much time does an average household spend on a monthly basis (optimization of energy usage, communication with the grid, selling electricity etc.) to fully benefit from the smart grid technologies?
8
7
6
5
4
3
2
1
0
Not Applicable
None
30 minutes or less
30-60 minutes
1 - 1,5 hours
1,5 - 2 hours
2 hours or more


18. According to the experiences from the project so far, is the current consumer/household behavior enough or is there something that needs to be adjusted before a large scale adaptation...
8
6
4
2
0
Yes
No