EIT KIC InnoEnergy Master's Programme

Renewable Energy - RENE

MSc Thesis

The Pathway to Smart Grid: Policy Predevelopment and Opportunities for Entrepreneurs

Haris Rehman

Supervisors:

Dr. Enrique Velo

Universitat Politècnica de Catalunya, Spain

September 2013

MSc RENE is a cooperation between

Universitat Politècnica de Catalunya, Spain | KTH-Royal Institute of Technology, Sweden

Instituto Superior Técnico, Portugal | École Polytechnique (ParisTech), France

Acknowledgment

The thesis would not have been possible without the support of many people. I would like to express my gratitude for my supervisor and coordinator, Dr. Enrique Velo, who provided me with the excellent productive environment for the research work enabling me to work with freedom and follow my interests and eventually reflecting it in the thesis. Also for his continuous support in all related matters, his meetings always left me motivated and encouraged.

I owe a very important debt to KIC InnoEnergy for providing me with this opportunity of higher studies in a consortium of some of the most prestigious educational institutions of the world, my friends for their continuous support and my class mates for creating a friendly and competitive environment which enabled me to think out of the box in order to produce something original.

And most importantly, my parents and siblings for their unconditional love and support throughout my life, giving me the confidence and courage to go out there and strive to make the difference.

Abstract

The thesis gives a brief overview of the key policy development traits in connection to the smart grid development and deployment. Role of key stakeholders and the issues and problems which have to be take care of by the policy makers. Some of the opportunities for entrepreneurs are also identified which can result by the right environment created by defining regulations in different areas and how these opportunities can facilitate the deployment of new smart grid technology mass roll out with increased customer acceptance. These opportunities are identified in the areas of electric vehicle infrastructure and distributed renewable generation, which are two of the key components of smart grid technology.

Executive Summary

The energy industry and policy makers have been advocating the smart grid as the key to achieve the goal of minimizing GHG and carbon dioxide emission, switching from fossil fuels to renewables and managing the electricity demands in the most efficient way possible. It has been established as the most efficient way to integrate distributed renewable generation, peak demand management, automated metering and most importantly, for a country or a region, to be able to become politically independent for their energy demands.

The goal is not easy to achieve, a lot of investment is required along with the highly professional technical and managerial practices. Even though the advent of smart grid is inevitable in a few years down the line, the process is slow. There are certain issues hampering the physical roll-out of smart grid technologies. Factors such as public acceptance for sharing their data regarding electricity usage have been a major issue in developed countries. The need is to find a trade-off where all the stakeholders get acknowledged for their concerns and can enjoy the pros of smart grid implementation at the same time.

The thesis highlights the policy issues related to smart grids, importance of interoperability, externalities adjustment and DSO's new mission incorporation for the whole electricity value chain involved in the process. How and why it is important to regulate issues related to smart grids and to what extent, not everything needs to be regulated, the requirement is to create incentives so that new players can step in and contribute along with the already existing entities. This is not only important to avoid the monopoly exploitation of the benefits but is also important for public awareness and participation, where entrepreneurs can provide innovative solutions for the existing problems. There is a gap which has

to be filled with innovative product and services introduced by entrepreneurs, academic research and consumer involvement.

The smart grid consists of the following components, a) Advanced metering Infrastructure (AMI), b) Demand response (DR) systems, c) Energy management services / Home automation networks (HAN). d)Distribution automation (DA), e)Distributed and renewable electricity generation (DG/RES), f) Advanced energy storage, g) Electric vehicles (EVs) charging infrastructure, h) Systems management and data security, i) Information and Communication Technologies (ICT). This research work considers two major components in particular i.e. electric vehicle charging infrastructure and distributed renewable generation, to identify business opportunities during the process of achieving the smart grid goal and after it has been implemented on the greater scale.

Electric vehicle charging infrastructure is the most important factor for rolling out electric vehicles and for the consumers to get off the reluctance of preferring electric cars over conventional fossil fuel based cars. They are not only going to reduce the carbon footprint associated with transport sector but the batteries of these electric cars will also serve as distributed storage units and voltage stabilizers when required. Investment in this sector is lucrative and promises returns once the electric vehicles become an economy of scale. Level 3 mobile charging stations, installation of charging equipment on private domains i.e. homes and offices, public domain charging stations where electric vehicles are concentrated in higher numbers such as parking lots, shopping malls etc. are some of the revenue generating prospects highlighted in details in this research work.

Similarly in renewable distribute generation's case, there are a lot of technicalities involved. Incentives are promised from governments to facilitate the small scale electricity generation. Concepts such as 'rent-a-roof' are already in

place for some time now. Professional expertise to manage and operate these facilities is required. There is a huge potential for entrepreneurs for facilitating such processes. Activities can involve identifying suitable locations for RDG units, providing with maintenance and operation services, training of staff working on those installations, upgrading activities and taking care of legal aspects for the private investors involved are the things which can generate revenue for companies and simplify the process as a whole for everyone involved.

Electricity generation is a concept which is not commonly associate with entrepreneurs given the ‘for granted perception’ that they have limited resources to start with. Collaborations at huge scales involving billions are not normally considered by them when starting up their ventures. But at the same time, conservation of energy, energy management and facilitating the processes where private bodies and small scale investors are involved, entrepreneurs can play a very affective role by bringing in their innovative approach and technical and professional skills. These ventures will not only have a considerable impact on the economy but will also increase the consumer involvement by spreading awareness about smart grid at consumer level and eventually facilitating the whole process of smart grid deployment.

Table of Contents

Table of Figures

1. Abbreviations

SG	Smart Grid
AMI	Automated Metering Infrastructure
AMR	Automated Meter Reading
GHG	Green House Gases
DSO	Distributed System Operators
HAN	Home Automation Network
DA	Distributed Automation
DG	Distributed Generation
RES	Renewable Energy System
EV	Electric Vehicle
ICT	Information and Communication Technologies
RDG	Renewable Distributed Generation
PV	Photovoltaic
WEF	World Economic Forum
EEGI	European Electricity Grid Initiative
SEAI	Sustainable Energy Authority of Ireland
HVDC	High Voltage Direct Current
CS	Customer (Side) Systems
DMS	Distributed Management Systems
DR	Demand Response
TA	Transmission (Enhancement) Applications
AO	Asset Optimization
DER	Distributed Energy Resources
CHP	Combined Heat and Power
LAN	Local Area Networking
WAN	Wide Area Networking

DOE	Department of Energy
GIS	Geographic Information System
SCADA	Supervisory Control and Data Acquisition
TSO	Transmission System Operators
DG	Distributed Generation
AC	Alternative Current
DC	Direct Current
RDG	Renewable Distributed Generation
NIMBY	Not in my back yard
BANANA	Build absolutely nothing anywhere near anything
MDMS	Meter Data Management System
TCP	Transmission Control Protocol
IP	Internet Protocol

2. Introduction

Large scale introduction of renewable energy sources such as wind, PV etc. and new loads are posing a great challenge for the already existing electricity distribution infrastructure, globally. To solve this issue, either the old distribution channels have to be reinforced by replacing them with heavier cables and lines or revamping of the current grid infrastructure has to be taken into account. Another solution is to upgrade the existing grid infrastructure with a more intelligent grid, equipped with much stronger information and communication technologies (Geert P.J. Verbong, 2012). A grid equipped with such capabilities is widely known as the 'Smart Grid'.

In this thesis, the policy related aspects and their effects on entrepreneurial landscape are taken into account. The relationship between users and smart grids, the various smart grids concepts, applications and implications in different parts of the world where the concepts are already in practice on practical grounds, either on commercial or on research level.

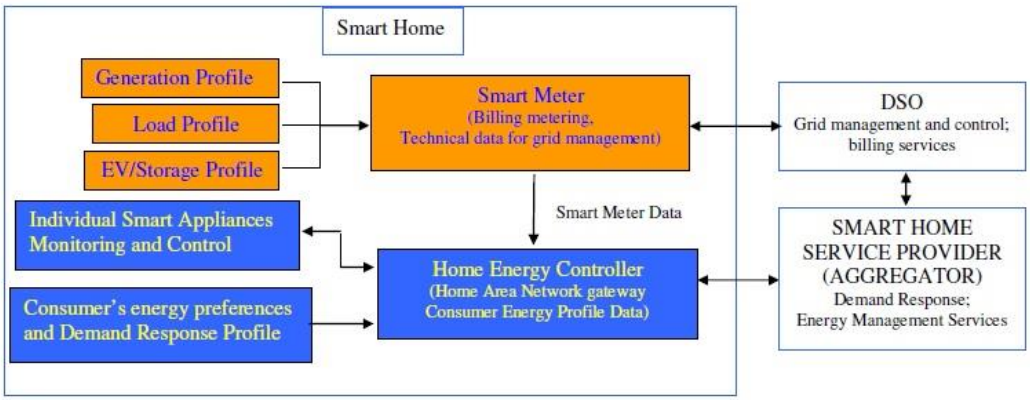
Since there has been no consensus on what a smart grid is, the perspectives range from the concept of European super grid to the loosely linked micro grids (Verbong, 2010). The idea of a smart grid is incomplete without the mention of renewable energy sources, for instance, natural sources like Wind Energy, comes with the 'gift' of considerable variations, these are mainly seasonal variations. Some parts are windy in winters and others are in summers. Smart grids are not only a solution for providing stability in the supply but also the most efficient solution for integrating distributed generation.

There are several examples of smart grid applications and business models related to smart grids application around the globe. According to (WEF, 2010)), the present grid technologies, business models and regulations are out of sync with the smart grid vision. Now the challenge is to mobilize market forces in

connection with the energy policy goals and to provide the required massive investments over the years to come. The need is to device more suitable business models and regulations to help the smart grid vision get materialized, these ideas have to mutually synchronize in order to be significantly effective for the power sector to fulfill the ever increasing requirements of electricity (Vincenzo Giordano, 2011).

Smart grid comes with the possibility to measure and monitor the detailed electricity consumption, which means, the electricity bill at the end of the month can be detailed in terms of individual appliance usage, such as hours of TV, air conditioning hours, cycles of washing machine etc. This approach has the tendency to make the consumers more interested in services obtained through electricity instead of electricity itself also it will make it possible for the suppliers to segment the consumers by their electricity usage profile (Vincenzo Giordano, 2011). This will be a huge step towards sustainable usage of energy, since consumers will be able to identify the amount of energy they actually require and hence will make it easier to manage it efficiently. The figure shown below gives a brief infrastructure of a smart house.

Figure 1: Smart Home Infrastructure

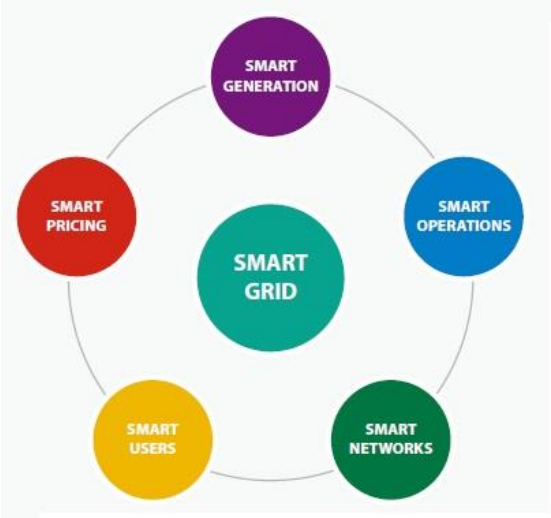


Source: *Vincenzo Giordano n, Gianluca Fulli 2011*

Segmenting consumers according to their user profile will enable the power suppliers to provide customized services and that will be one of the greatest achievement of smart grids applications, a huge step forward towards sustainability.

Smart grid is not just a fancy name for a grid equipped with highly efficient information and communication technologies; it is a combination, rather a process of smart activities. The figure below gives a brief idea of what a smart grid can actually be constituted of.

Figure 2: Smart Grid Constituents



Source: *Sustainable Energy Authority of Ireland - SEAI*

Smart grid is basically a combination of Smart pricing, smart users, smart networks, smart operations and smart generation. This set of 'smart' approaches, collectively is the basis of smart grids. Adoption of smart grid is a matter of changes at landscape level. Most of the work being carried out in the present years is on niche level, i.e. the technological advancement. The needful is to revamp the whole structure, through systematic changes, changes that are

acceptable and adoptable socio-technologically. This process certainly demands time but is the most effective pathway towards achieving sustainability goals.

In this thesis, certain aspects of energy policy will be discussed in connection with the implication and application of a functional smart grid. Also discussed are the business opportunities where new players can come and contribute in the process through their innovative entrepreneurial ventures.

2.1. Background

The research work is in the field of power sector management, particularly about new grid technologies that incorporate the smart grid. Power sector is currently facing an evolutionary process in its value chain, which incorporates generation, transmission, distribution, management and consumption. All these activities have a one stop solution in shape of the smart grid. Regulatory framework affecting the development and deployment of smart grid technologies is under discussion. Also the business opportunities arising during the process of the evolution of power sector value chain.

Electricity demand has continued to increase with the industrialization and advent of modern technologies, almost everything is based on electricity. It is also an important factor while estimating the economic growth of a country, i.e. how much electricity is being consumed in different sectors. It is the commodity which needs to be addressed on immediate basis in order to sustain the growth in any sector.

The ever increasing demand of energy has to be taken care of by incorporating renewable generation, it is also important since the fossil fuels are diminishing at an expedited rate. Targets have been set by regulatory authorities under certain agendas such as 20-20-20, to eliminate the carbon footprint, increase the energy security and self-sufficiency with in a region by increased integration of renewable energy generation in the existing power sector infrastructure.

Increasing concerns on factors like environment, sustainability, energy security and management efficiency has made the smart grid deployment mandatory.

It is important to understand why the adaption of smart grid technology is essential and how does it affect the whole value chain, including the consumer. The research work is aimed to highlight the policy predevelopment issues and in response to those regulatory definitions, what business opportunities arise for new players.

2.2. The Thesis Statement

Smart Gird development and deployment has been hampered by many factors, those factors are from diversified sectors and caused by various different components of the electricity value chain. Regulatory authorities are defining regulations to facilitate the matter and expedite the development. There is one very important dimension is the involvement of new players in the value chain and offering of innovative products and services. The regulations are supposed to incentivize the deployment by creating space for new players in the industry. These new players are referred to as entrepreneurs in this research work.

2.2.1. Main Research Question

How can the development of smart grid in Europe be facilitated by entrepreneurial ventures from entrepreneurs, future entrepreneurs, students, academia and industry relationship and collaborations?

To answer this question, a further question needs to be answered first, i.e.

2.2.2. Sub-research Question

What are the possible opportunities lying for entrepreneurs in smart grid development and the in what particular areas?

Key regulations and policy pre development factors are identified through extensive literature review and studying the existing smart grid models all over

the world. In wake of those new regulatory frameworks, some of the business opportunities have been identified in the sector.

2.3. Methodology and Analytical Framework

It is a well-known fact that the opportunity lies in the problem. Explaining it further brings us to the fact that necessity is the mother of invention. Whenever there is a problem, it demands for solutions, those solutions if not present already needs to be extracted out of innovation and thinking out of the box. Another way of solving a problem is to give incentives to the work force, without planning the details for them and eventually they will find a solution for the problem. The nature of the solution can vary from being a simplest change to the existing methods to the introduction of a very innovative concept.

The ideas for entrepreneurial ventures, i.e. services and products highlighted in this thesis are motivated by those problems that are being faced during the process of achieving the smart grid goal. Not just the problems, also the drivers, the factors which exist that can help expedite the process; the drivers in this case are synonyms with the incentives given by the government and/or the regulatory authorities.

The thesis has been done as a partial requirement of completing the master's degree. The methodology adopted is mainly based on extensive literature review, following up news articles, latest technological and policy developments affecting smart grid development. The main constituents of the methodology and the analytical framework used in this research work are listed below:

- Analysis of energy policies of countries making significant progress in smart grid development and applications
- Survey of literature related to policy development and defining the regulatory framework

- Interpolating and extrapolating long and short term effects of ongoing energy policies and economic policies in connection with the smart grid
- Survey and analysis of success rate of ongoing smart grid applications in developed countries
- Identification through literature reviews and surveys the possibilities and opportunities for business applications and revenue generating streams
- An extensive study into the technical aspects of smart grids to understand various functions and traits of key smart grid components
- Identifying entrepreneurial opportunities by deepening and broadening the knowledge of the major technical and managerial aspects of smart technology evolution and infrastructure
- Understanding the policy factors affecting the value chain of power sector to analyze the regulatory framework, propose recommendations and identifying opportunities created by those factors
- Social aspects of smart grid deployment in order to understand the barriers caused by public reluctance to accept the smart grid technologies and embrace the changes it is going to reflect in the society
- Inspection of services and products available in connection to smart grids, its development, deployment and to build the support infrastructure
- Extensive literature review to understand the externalities and interoperability standards for distributed renewable integration and electric vehicle support infrastructure

The literature analysis was mainly conducted over the internet and includes the following types of documents:

- Policy development guidelines on electricity value chain
- Business models for existing smart grid infrastructure
- Technical documents with specifications for understanding electric vehicle support infrastructure requirement

- Reports and white papers from NGO's, consultancy agencies and regulatory authorities
- News articles from various websites dedicated to spread awareness regarding smart grid evolution and the advent of new technologies, innovative concepts and all possible up grading activities
- Progress reports on smart grid deployment from already functional infrastructures

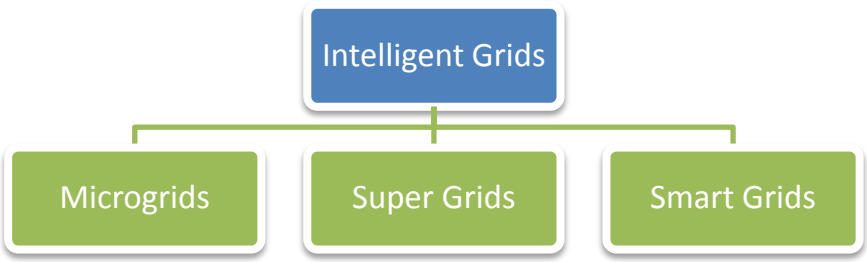
2.4. Scope and Limitations

The concept of smart grid is not new and it is a combination of constantly evolving technologies and every day new innovative concepts to incentivize its deployment and development are being devised. This research work mainly focuses on the pre policy development factors, not the details of implementation. In addition to that, the entrepreneurial opportunities identified cover parts of two key components of smart grid technology, i.e. Electric vehicle infrastructure and distributed renewable generation. These business opportunities are basically identified for entrepreneurs in order for them to step in contribute in this landscape changing evolution of electricity value chain. These opportunities are identified keeping in view the minimum capital investment cost, where instead of huge capital, innovative ideas for products and services are the main drivers.

3.1. What is the smart grid?

In order to define smart grid, we will first take a look into the word 'smart'. Smart is referred to as intelligent in this case. There are basically three kinds of intelligent grids as defined by Van de Putte in his work "Battle of the Grids, Report 2011". He has classified the intelligent grid in further three types as follows (Jan Van De Putte, 2011).

Figure 3: Classification of Intelligent Grids



3.1.1. Micro Grids

The term micro gird is normally used for the grid for a confined geographical area, such as islands, where the distribution grid is incorporated with the total control infrastructure that includes monitoring as well, and it uses local electricity generation resources. The object is to provide for the local power requirements in the most efficient way possible.

3.1.2. Super Grids

The technology of super grids is HVDC (High voltage direct current) based, where large energy loads are transported between countries or regions to provide for the large electricity demands.

3.1.3. Smart Grids

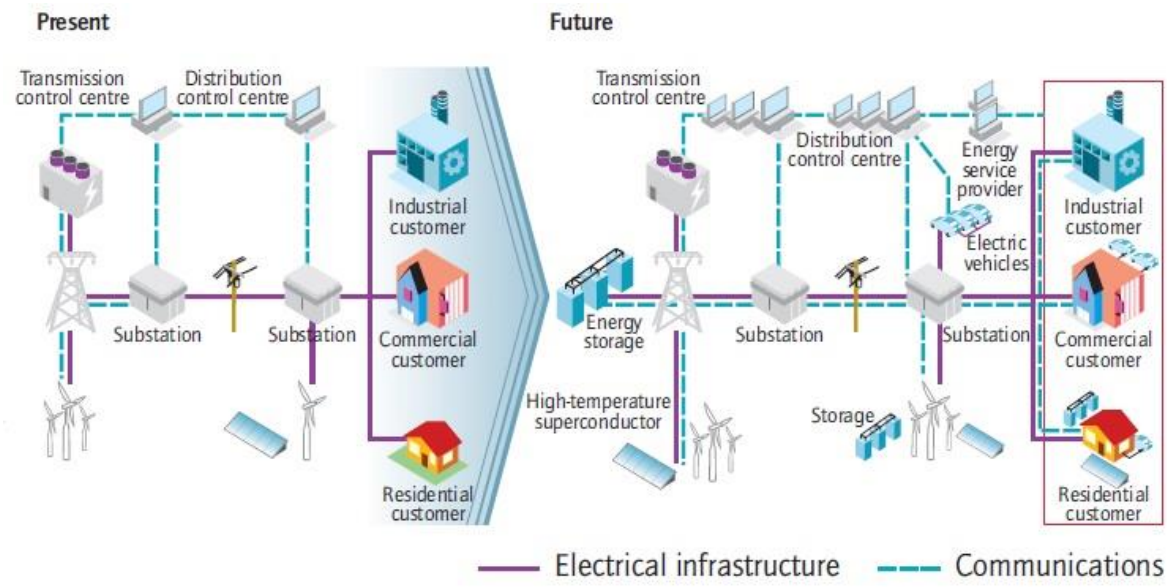
Smart grid uses advanced information and communication technologies (ICT's) for the integration of distributed generation, supply to the consumer, energy management and load balancing.

3.2. Comparison of Traditional Grid with the Smart Grid

Smart grids are different from the traditional grid in many ways but one of the most prominent and distinguishing feature is the use of advanced information and communication technologies. Apart from that, there are certain distinguishing traits of smart grid from the traditional old grid technologies. The communication patterns are just one way in case of traditional grid but smart grids communicate both way, from and to the consumer to the distribution grid, they have extensive customer interaction which is facilitated by the modern smart meters whereas old grids have limited interaction with the consumer of electricity. As far as metering is concerned, old grids use electromechanical technology for the purpose in comparison with the SG which uses digital metering which enables real time pricing and net metering. Equipment checks and maintenance is done manually in old grids whereas smart grids use remote monitoring technologies with time based maintenance after regular time intervals. One of the main advantage of smart grid is the ability to integrate distributed as well as centralized generation, whereas traditional grid technologies are associated with centralized generation of electricity. Smart grids are much more reliable, equipped with automated and pro-active protection which prevents outages before they happen with the help of advanced energy management techniques and technologies, traditional grid is prone to failures especially when it comes to outages and in case of failure of any sort, restoration processes are carried out manually in contrast with the smart grid which is capable of self-healing. The most expensive and complex capability

of smart grid is to communicate in different directions, multiple power flow pathways, the network incorporation which enables it to foresee several different aspects of the value chain at the same time, whereas traditional grid's system topology is radial, which generally allows just one way power flow.

Figure 4: Comparison of Old Traditional Grid and Smart Grid



Source: *IEA – Technology Roadmap: Smart Grids, 2011*

3.3. Technology Solutions Associated with the Smart Grids

The smart grid is normally associated with certain technologies, the technologies which incorporate a fully function smart grid; they are also termed as the key components of the smart grid. (National Energy Technology Laboratory, 2010)

- Advanced Metering Infrastructure (AMI)
- Customer Side Systems (CS)
- Demand Response (DR)
- Distribution Management System/Distribution Automation (DMS)

- Transmission Enhancement Applications (TA)
- Asset/System Optimization (AO)
- Distributed Energy Resources (DER)
- Information and Communications Integration (ICT)
- Electric Vehicle (EV) Infrastructure

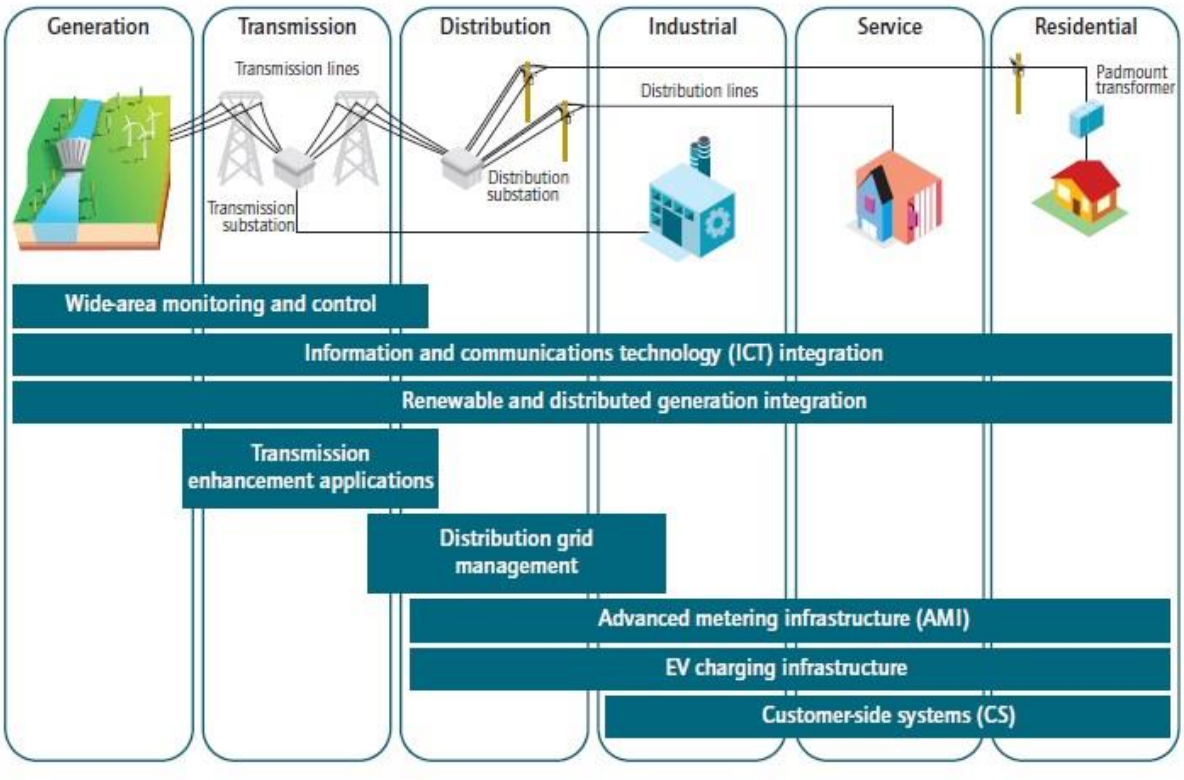
All these technology solutions associated with the smart grid take care of certain responsibilities that a fully functional SG is supposed to offer. In simpler words, it can be stated as the traits of the smart grid, the capabilities of the smart grid, the value proposition this complex combination of advanced communication and information technology offers. There are certain responsibilities of the smart grid identified by the U.S. Department of Energy in 2008 (National Energy Technology Laboratory, 2008). They include:

- Accommodating all generation and storage, whether centralized or decentralized options. These include renewables, small scale CHP etc. Integration of these components will increase rapidly all along the value chain, from suppliers to distributors and finally to the consumers.
- Providing for all the electricity requirement of the consumer demands with the power quality they need. Different consumers of electricity have different requirements, residential consumer have different priorities than the commercial and/or industrial consumer. Smart grid will provide for all their needs respectively by using its advanced monitoring technologies.
- Self-healing in case of failures by predicting a disturbance before it happens and to respond to it accordingly. In case of natural and artificially induced catastrophic conditions (i.e. e.g. cyber-attacks), capable of returning to the original position, recovering automatically. These self-capabilities of the smart grids result in reduced interruptions and in turn an

improved quality of services for the consumer. The idea is to isolate the problematic component from the system in case of failures and ensure the interrupted supply to the consumer, intelligence incorporated.

- Providing means for active participation of the consumer, i.e. interaction between the consumer and the distribution grids. These capabilities of the smart grid come as a result of consumer having choices for going for the most suitable purchasing patterns for their consumption. Consumer participation and interaction also ensures the reliability by giving them the control to be able to decide the way they use and purchase services.
- Facilitate the advent of new products and services in electricity generation and consumption value chain. This also includes providing the consumer with an opportunity to choose their service providers and the products they deem appropriate for their consumption.
- Optimizing the utilization of assets and ensuring the functionality of operations at maximum efficiency. Smart grid is equipped with the technologies that can be adjusted to reduce losses of any kind and can eliminate congestion. This also includes allowing assets to be used at greater loads by continuously sensing and rating their capacities.

Figure 5: Smart Grid Technology Areas



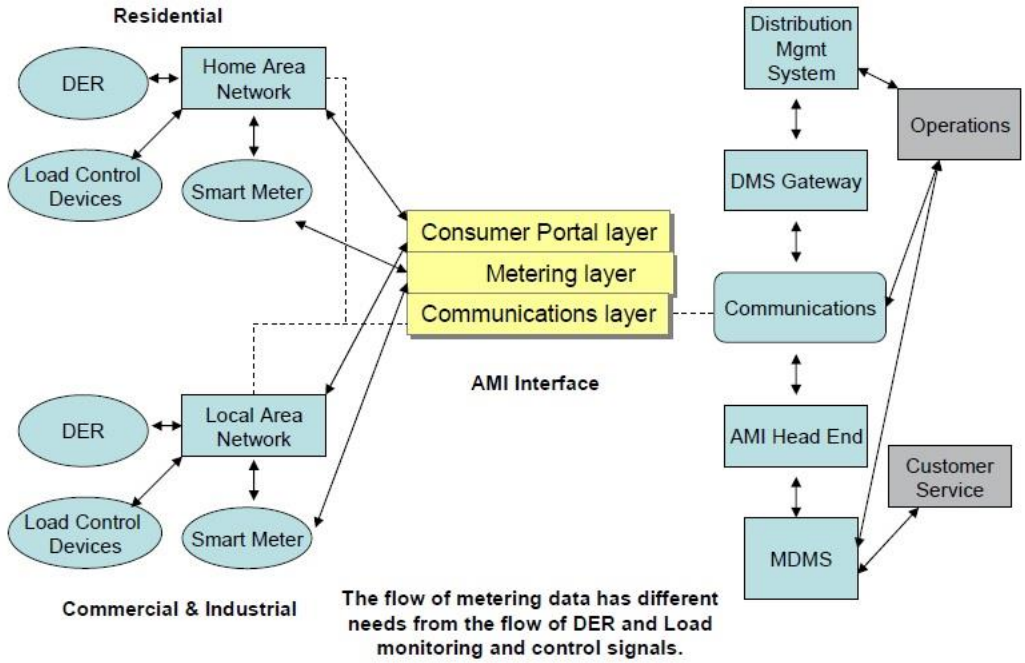
Source: *Technology categories and descriptions adapted from NETL, 2010 and NIST, 2010 - adapted from IEA – Technology Roadmap: Smart Grids, 2011*

3.3.1. Advanced Metering Infrastructure – AMI

One of the main traits of smart grid is its capability to interact with the customer, the capability of two way information and data sharing. Advanced metering infrastructure makes these operations possible. This infrastructure is not just one component but a combination of certain technologies. Smart meter is the equipment which enables the smart grid to have this capability. The purpose of AMI is to establish communication with the consumer. As mentioned earlier, it is a combination of several technologies, hence the term infrastructure. An AMI is

comprised of several different technologies and applications that have been integrated to perform as one. These technologies and applications include smart meters, wide area communication infrastructure, home area networks which can also be termed as LAN, meter data management systems (MDMS) and operational gateways (National Energy Technology Laboratory, 2008). The consumer is connected with the grid through the smart meter which incorporates information and data flow with the distribution grid. The distribution grid is connected with distributed generation systems, transmission grid, any other generation plants etc. and these connections and data sharing is also incorporated by advanced metering infrastructure. Similarly, commercial and industrial consumers are also attached with LAN, smart meter, load control devices and distributed energy resources. At the consumer level, smart meters communicate consumption data to both the user and the service provider (National Energy Technology Laboratory, 2008).

Figure 6: Overview of AMI



Source: *The U.S department of Energy, 2008*

3.3.2. Demand Response – DR

Demand response is a major tool for smart grids which enables it to do energy balancing i.e. shifting load in peak hours by managing the generation and supply for the consumers. Electricity consumers are charged different price at different times, depending on the time of the day or weather conditions or under any other conditions which directly affect the consumption rate of electricity. The advanced technology applications enable the system to monitor and control the cycles of air conditioning, water heating or any other electricity consumption activity depending upon the nature of consumer and empowers the grid to control the flow of power for energy management purposes. Today these operations are carried out manually but technological developments enable smart grid to control the use through the communication technologies incorporated. All these activities are carried out by keeping in view the comfort impact on the consumer.

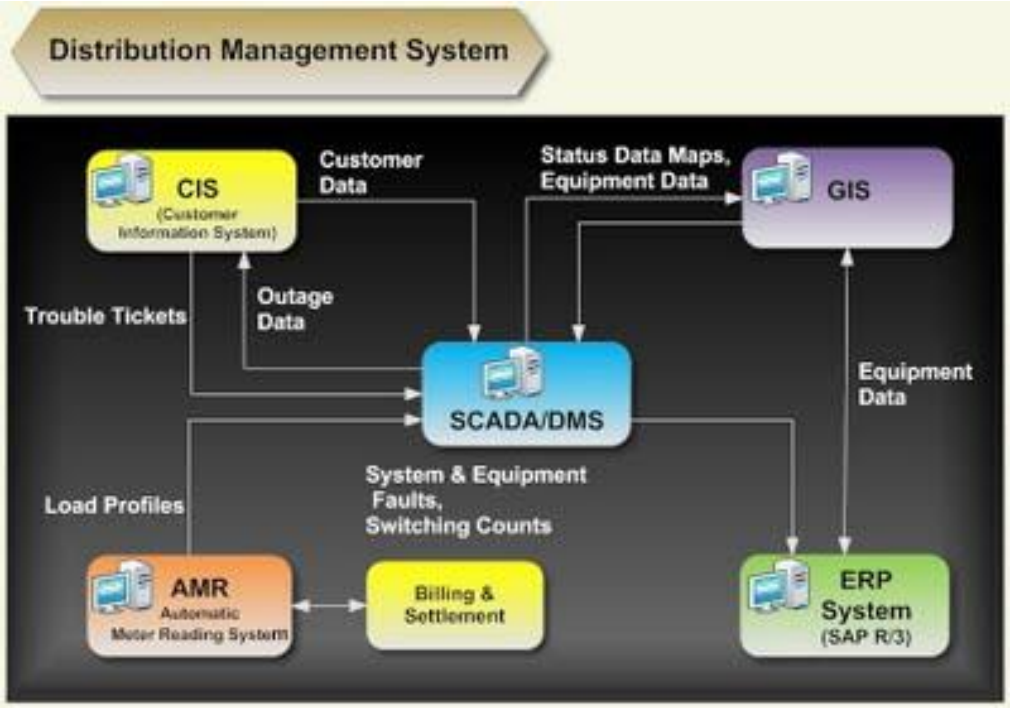
3.3.3. Distribution Management System (DMS) and Data Security

Managing the quality of power supply required by the customer is made possible by smart grids through its distribution management system technologies. The applications and technology enables the smart grid to monitor the real time network operational statistics along with the ability to make decisions dynamically, hence improving the reliability and efficiency of the grid and the network as a whole. The primary benefits of distribution management system are prevention of extended outages, maintaining the quality of the supply in terms of voltage levels and acceptable frequency management and control. Major technologies which incorporate the DMS are geographical information system (GIS), customer information system (CIS), automatic meter reading system (AMR) etc. Key deliverable expected for the technology are increased customer satisfaction and operational efficiency and identification of outage location, which

enables the system to take the preventive measure in advance so that further failures can be avoided. DMS is also termed as supervisory control and data acquisition (SCADA).

Huge data is collected and processed in the smart grid, the security of this data is essential in order to make sure the mass roll out of smart grid technologies and its deployment. Consumer's data privacy has to be taken care of in order to increase the customer base and acceptance on the global scale.

Figure 7: Distribution Management System Schematic



Source: *http://distributionmanagementsystem.blogspot.com.es/, retrieved August 2013*

3.3.4. Distributed Energy Resources - DER

Distributed energy resources are the small scale, decentralized energy generation and/or storage resources. The challenge of integrating these small

generation/storage resources has been overcome by smart grid technologies. These resources do not only provide for the electrification needs and add up to the grid along with the centralized energy resources but has also made possible the participation of new players in the energy value chain. This thesis also highlights the opportunities in the sector which can be exploited by entrepreneurs and small and medium size enterprises. Most commonly used distributed energy generation sources are photovoltaic, wind power, biogas power plant, combined heat and power plants, concentrated solar power plants and fuel cells. Improved quality of supply in terms of consistency and affordability has been made possible due to the advent of distributed energy resources and their integration through smart grid technologies.

3.3.5. Information and Communication Technologies - ICT

Information and communication technologies are one of the most important tool incorporated in smart grids. Some term it as the back bone of the SG as well. Information collection, processing, data collection, transferring of data, communication with the consumer, distribution and transmission grid, distributed generation and storage facility management and monitoring, smart utility processes, smart energy consumption, smart infrastructure operations, all this is made possible by information and communication technologies incorporated in the smart grid.

3.3.6. Electric Vehicles – EVs

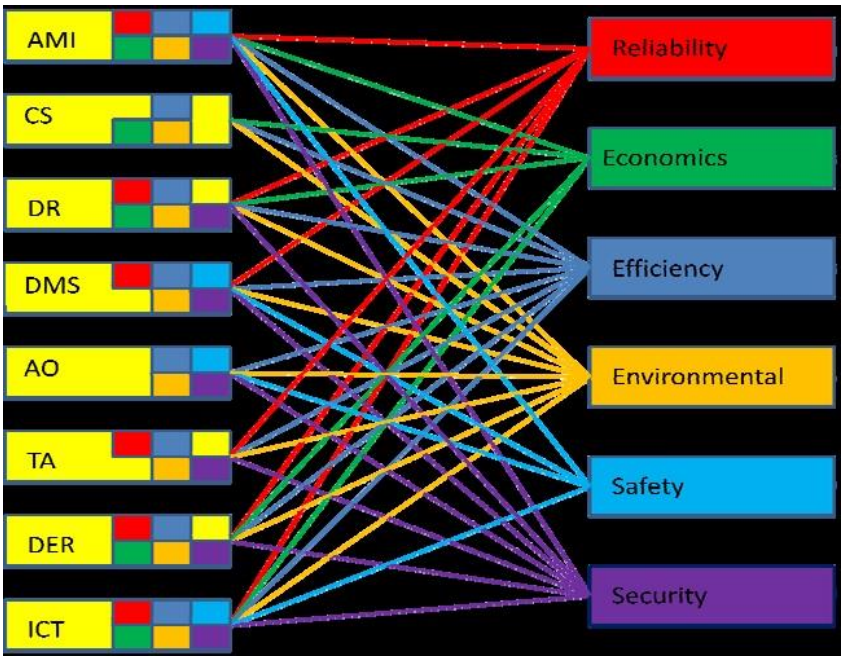
Electric vehicles and smart grids are closely related. Smart grids are not only necessary to provide for the electrification needs of the future and present but are also important to achieve the environment goals. Reducing carbon footprint is one of these goals. Replacement of fossil fuel based vehicles with electric vehicles is essential to save the environment. These electric cars will not only

serve this purpose but when connected with the grid during the hours when they are not in use, will also serve as the distributed storage facilities for the grid. They are considered as a useful tool for the smart grid especially for the purposes of energy balancing. To make these electric vehicles just as common as the petroleum based cars are these days, infrastructure development is inevitable. In this thesis, business opportunities offered by this development process are also highlighted.

3.4. Benefits of Smart Grid

All these technological areas are expected to provide benefits in six value areas in particular. These areas are reliability, economics, efficiency, environmental, safety and security, as explained by the Integrated Electric Power Systems Division of National Energy Technology Laboratory (National Energy Technology Laboratory, 2010).

Figure 8: Technology Solution — Key Value Area Relationships



Source: *Understanding the Benefits of the Smart Grid, Smart Grid Implementation Strategy, 2010 by the Integrated Electric Power Systems Division of National Energy Technology Laboratory.*

The figure shown above gives a brief overview of how different smart grid technologies are connected to the respective benefits provided by them. These technologies are ensuring reliability of energy supply, security of energy supply which in turn liberates from the political insecurity which is caused by fossil fuel dependence for many countries. Also the safety of the supply with increased efficiency, accelerated economic growth and the environmental benefits which is one of the main goals of deploying smart grid in the society. These benefits are directly related to the consumer and society as a whole is the biggest beneficiary.

4. Incentivizing Smart Grids – Policy framework

Regulations need to be adopted throughout the value chain of electricity generation, starting from the generation of electricity by power plants to the end consumer. Several factors in between are needed to be taken into account. The purpose of these regulations should be incentivizing smart grids and the goal of smart grid needs to be facilitated by these regulations in a way that it does not just serve the monopoly structure but every part; every entity involved in the value chain should be able to get their share of the pie. The regulations are needed to be defined, to create the right environment for the development of smart grids. Only that is when the opportunities for entrepreneurs will be created. In this thesis, the regulative framework is going to be the key to identify such business opportunities that are not just for the big players but small and medium size enterprises can also take part in the process.

There are several factors that are needed to be taken into account in order to achieve the smart grid goal. A number of barriers are needed to be taken care of; incentives are needed to be provided for the electricity value chain to facilitate the introduction of new technologies and practices. These steps demand regulatory framework surrounding smart grid deployment.

The Union of the Electricity Industry - EURELECTRIC is the sector association which represents the common interests of the electricity industry at pan-European level, plus it affiliates and associates on several other continents. The association has highlighted some of the key aspects in its report “Regulatory framework to incentivize smart grid deployment, Eurelectric’s view”. (EURELECTRIC) (Lorenz, 2009)

- ***DSOs have a new mission - The regulatory framework must adopt to this***
- ***Not all technology related activities must be regulated regulation must also facilitate a market development***
- ***Adding "smartness" to the regulatory framework***

In this chapter, these three aspects have been explored in order to understand the policy factors associated with smart grids in a better way.

Regulations in these areas to incentivize smart grid will create opportunities for entrepreneurs, such opportunities can be products, as well as services.

4.1. "DSOs have a new mission - The regulatory framework must adapt to this" (Lorenz, 2009)

Distribution system operators or alternatively called network operators are facing a challenge in pursuit of their new mission that leads to smart grid deployment and roll out of the related technologies at the greater scale. Though there are some pilot projects running in certain parts of the globe but it wouldn't be wrong to term these initiatives at this level to be at demonstration phase.

There are several components in the electricity generation to consumption value chain; all these components have to play their role in an effective and efficient way to materialize the smart grid deployment goal.

The need is to develop policies which prevent the abuse of monopoly position (Lorenz, 2009). Incentivizing smart grids deployment in a way that it does not just benefit the monopoly position but the whole value chain gets benefited from the profits. Utilities are the most important stakeholders in the process and they are the ones making the heftiest investments. They need cost compensation for the investment they will make in the process. Regulations must incentivize such

investments in a way that return of investment is ensured. Covering capital cost is also very important factor when it comes to utility's role in the process. Their priority is to recover the capital cost, incentivized investment opportunities and cost compensation which will eventually come through the mass roll out of the SG technology and increased consumer engagement. Once the consumer is engaged actively, new products and services can be introduced by the utilities to recover their cost and get returns on their investment which they will be making by upgrading the existing traditional grid with the smart grid.

At the same time, consumer's and network user requirements are, the affordability and quality of the supply. They need assurance of uninterrupted and high quality electricity services provision at low prices. It is an established fact that the smart grid deployment will change the entire course of our approach towards the energy perspective; this will be a huge change in the society itself. The prices which are comparable with the existing infrastructure will be one of the most important factors making consumer get more involved and will increase their acceptance level to the new technology and ways.

Figure 9: Requirements of the Utility and the Consumer

Utility	Customer/Network User
Cost Compensation	**Low Prices**
Investment Incentives	**Quality**
Cover Capital Cost	

Source: *Regulatory framework to incentivize Smart Grids deployment – EUROELECTRIC views, June 2009, Gunnar Lorenze*

The new mission of DSO's affects other entities involved in the value chain as well, they will have certain priorities and in some cases increase requirements and roles to play. Suppliers will have to come up with the new products to cover the capital cost and to match the requirements of the newly adopted technologies, similarly they will have to come up with the new processes involving customer switching. Distributed renewable generation integration in the grid will require new processes to be implemented. Energy balancing is one of the key benefits of smart grids, customer switching is an effective and efficient tool to carry out energy balancing, in peak hours at one place, the energy can be provided from the places where there it is required in lesser amounts at a particular time.

Society will have its own environmental benefits, such as reduced emissions of carbon dioxide. Carbon footprint reduction is going to be stimulated by replacing traditional fossil fuel based cars with electric vehicles and renewable integration with the grid. DG will come up with the benefit of energy efficiency. The efforts to make the climate better by reducing GHG and CO_2 emissions certainly adds to the necessity of adapting to the new mission of DSO's.

Figure 10: New Mission of DSO's, EU Market and Climate Packages

New Mission (EU market and climate packages)	
Supplier	**Society/Environment**
New Products	**Reduce Emissions**
Processes (Customer Switching)	**Renewable Integration**
	Increase energy efficiency

Source: *Regulatory framework to incentivize Smart Grids deployment – EUROELECTRIC views, June 2009, Gunnar Lorenze*

Hence, the regulatory framework, which has to be defined to facilitate smart grid deployment, has to take care of all these factors which DSO's has to go through. In a nutshell, these factors include integrating environmental goals which the society is going to get benefited from, as a whole. Similarly incentivizing regulations which does not only remove the barriers in between but also to improve the efficiency of functions related to the retail market. Incentivizing the technological innovation is also a very important factor in DSO's new mission to integrate SG in with the society. These technological investments come from research and development activities in the industry as well as in the academia. Collaborations must be facilitated in this area.

4.1.1. Policy Makers

Policy makers have their own agenda to achieve the environmental goals; these goals include energy efficiency, CO_2 reduction i.e. reducing the carbon footprint to the maximum possible extent which is only possible through excessive renewable integration in the electricity generation value chain. Renewable integration has been one of the most important factors which have to be addressed in regulations in such a way that maximum participation from the stakeholders can be ensured. Traditional power plants are large in capacity, require huge investments and need extended periods of time from conception to eventually get operational. In contrast, distributed renewable generation is a concept which is the most relevant with smart grids. Regulations are required to facilitate such installations on public and private owned properties. Some governments have already given incentives through their energy policy to encourage deployment of distribute generation plants. The global energy agenda has three main constituents, the energy has to be clean, affordable and secure (Peter Vaessen, 2007)]. Renewable integration ensures the cleanliness and

security of the energy but to make it affordable, it has to be incentivized. Feed in tariff is one of the incentive provided by many countries concerned about their energy future, Spain is one of them. The major indicator of affordability of energy is when electricity produced through renewable sources reaches grid parity. Carbon footprint attached with the transportation sector is been taken care of by creating incentives for mass roll out of electric vehicles and its infrastructure development. All these factors will eventually contribute to achieve the environmental goal. The path is to adapt to the global agenda of clean, affordable and secure energy.

4.1.2. Consumers

Electricity consumers want control on their electricity needs. Blackouts are a serious concern. They also need convenience which can be ensured through the two way communication with the distribution grid. Smart grids provide for these needs. According to the definition, smart grids are incorporated with ICT's (Information and communication technologies) which provide with the attributes such as two way communication between the consumer and distribution grid and between the electricity generation units and the distribution grid likewise. Energy management is made much easier with the deployment of these technologies. Regulations are needed to be defined on such issues that ensure this communication patterns and provide the consumer with what they need. Consumer needs control on their electricity usage and in turn the money they are paying for this commodity. Smart meters enable them to do so, by providing them with the detailed information on their electricity usage for all their electricity consuming activities, either they are hours of air conditioning or the cycles of the washing machine. Smart grid deployment does not only ensure this but also educates the consumer through their involvement in the process. These technologies provide control and convenience to the customer by allowing them to contribute in optimizing the operation of the system since they know where

they are consuming what amount of electricity, also, by providing them with much more information that they ever had about the options and choices of their electricity supply. Along with all these positive attributes, there are some downsides as well when it comes to the consumer engagement with smart grid deployment. Where these technologies provide them with the detailed information about their usage, this data is also transmitted to the distribution grid and can have loopholes within the process of transferring of data which can eventually lead to the miss use of their electricity usage information. The information includes the peak hours of electricity as well as the times when they are not using it at all. This data and information can show when they are at home and when they are not at home. Data security is one of the issues which are making consumers reluctant in their engagement with the technology. By agreeing to use this technology, they are agreeing to disclose their vulnerable personal information to the supplier. In developed countries, this matter is of great concern. Policies and regulations are needed to be defined to overcome this issue for the consumer, to make them comfortable enough to use these technologies, with the surety that their information is not going to be misused in any way. Once this problem gets taken care off, smart grid deployment will be rewarded with increased consumer engagement and eventually will lead to the mass roll out of the technology.

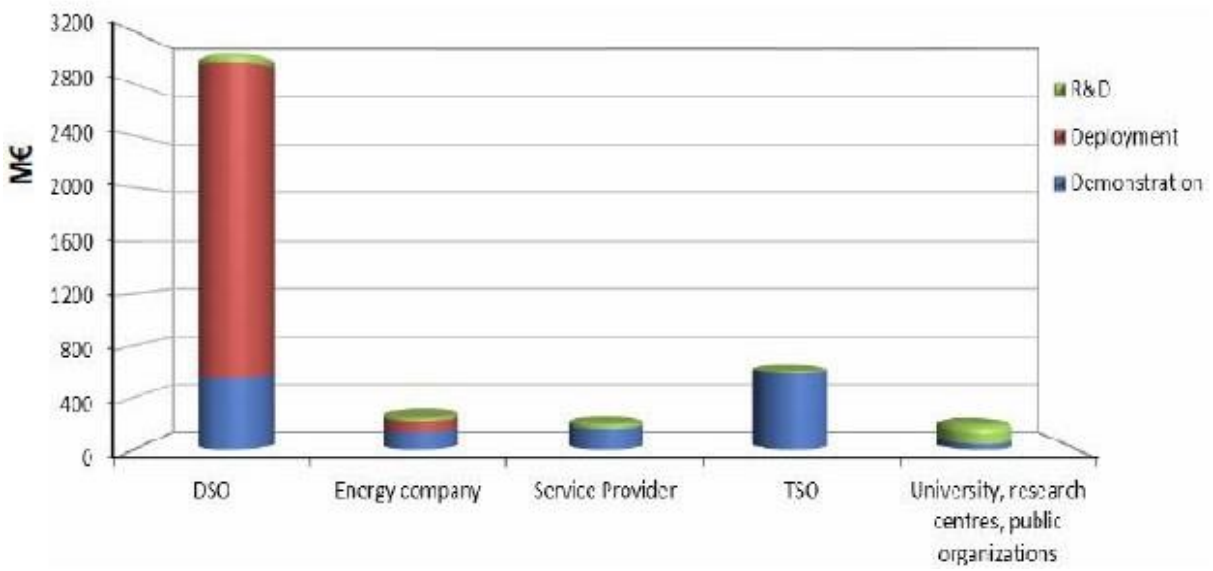
4.1.3. Generators

Regulations are needed to be defined to facilitate the generators in wake of their requirement of reliable and flexible grid. Smart grid offers the highest degree of flexibility to the generators because of its ability to share information at a level which is unparalleled in the history of electricity grids. SG is also supposed to be most reliable grid since it is equipped with the state of the art renewable generation integration technologies.

4.2. "Not all technology related activities must be regulated, regulation must also facilitate a market development" (Lorenz, 2009)

Not everything related to the newly developed technology needs to be regulated; sometimes regulations can play a tricky role and in turn can become a barrier instead of the driver to achieve a certain goal. But at the same time, there are some areas that must be regulated to ensure the productivity and growth. Investment from smart grids will benefit many components of the value chain, almost all of them, but most of this investment comes from the DSO's.

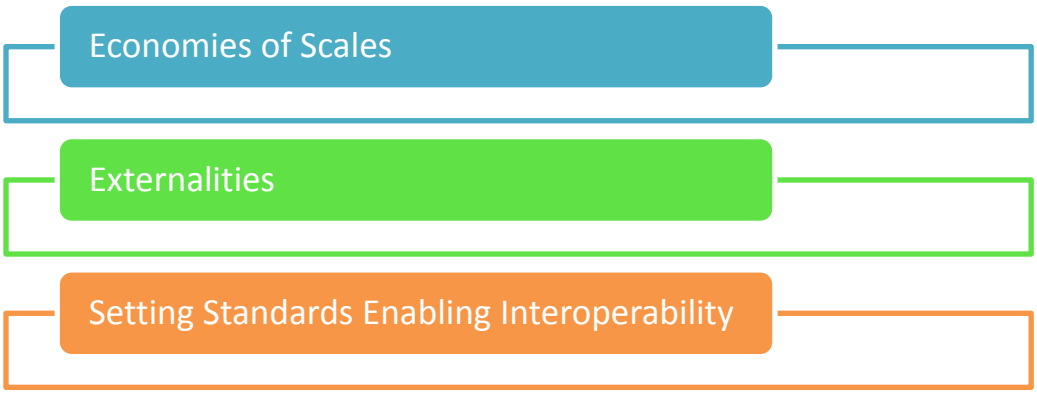
Figure 11: Smart grid investment ratio, 80% by the DSO



Source: *JRC 2011*

There are certain areas in which it is essential to define regulations in the process of incentivize SG deployment; Eurelectric has identified those areas for European smart grid. They are as follows: (Lorenz, 2009)

Figure 12: Areas where Regulations MUST be defined according to Eurelectric



4.2.1. Challenges Posed by Unbundling

Unbundling in electricity market can be described as the ubiquity of smart grid technologies affecting older, traditional technologies already in place for the purpose. There are new revolutionary concepts introduced for distribution and management of energy which eventually will replace the traditional practices. Instead of one entity responsible for all the activities involved, there will be several smaller units responsible for certain tasks included in the value chain. The whole electricity chain will be defined in a new way where smaller units will be responsible for individual tasks such as generation, management, transmission, distribution, billing etc. Instead of one service provider, there will be several. Unbundling poses great challenges for smart grid deployment. Smart grid deployment is more a case of upgrading then substituting the existing traditional practices with the new smart technologies. Where these upgrading activities will provide more effective and efficient management of the electricity value chain and the assets attached with it, it also poses a challenge when it

comes to unbundling. Regulations are needed to be defined to make sure that unbundling does not create barriers for the new network investments and for creating new services for consumers. Interoperability, in general, can be defined as the ability of a system to work with or use the parts or equipment of another system. When it comes to smart grids, interoperability is an important issue. In order to avoid unbundling of existing infrastructure and practices in use, interoperability is a must factor to be taken into account. It will not only help avoid the revamping of the whole existing electricity infrastructure but in turn will also reduce the initial investment required. Interoperability standards should be defined in such a way that same equipment can be used for all attached activities. Electric vehicle charging infrastructure is an example in this case. Tesla motors have different fast charging equipment then the other electric vehicles, their investment on charging infrastructure is focused on its own customers. Consumers are bound to utilize the services from the same company once they are part of the customer base. Just like Apple, where all future purchases are to be made from Apple. This is something which is hampering the way for it to become the economy of scale and incentives provided for the mass roll out. The need is to create the right environment so that the upgrading activities can be carried out without causing any confusion to the consumer. In case of electric vehicles, there should be one standard type of charger for fast charging globally. Policy makers need to work together to handle this challenge in a way that investors does not get insecure of their returns and the consumers doesn't get confused either. This is the only way to develop the market positively.

4.2.2. The Need of Stable and Predictable Regulatory Framework

A stable and predictable regulatory framework is essential to ensure positive market development. It will provide certain benefits for the process, some of them include, the getting rid of the danger of stranded investment. Smart meters were

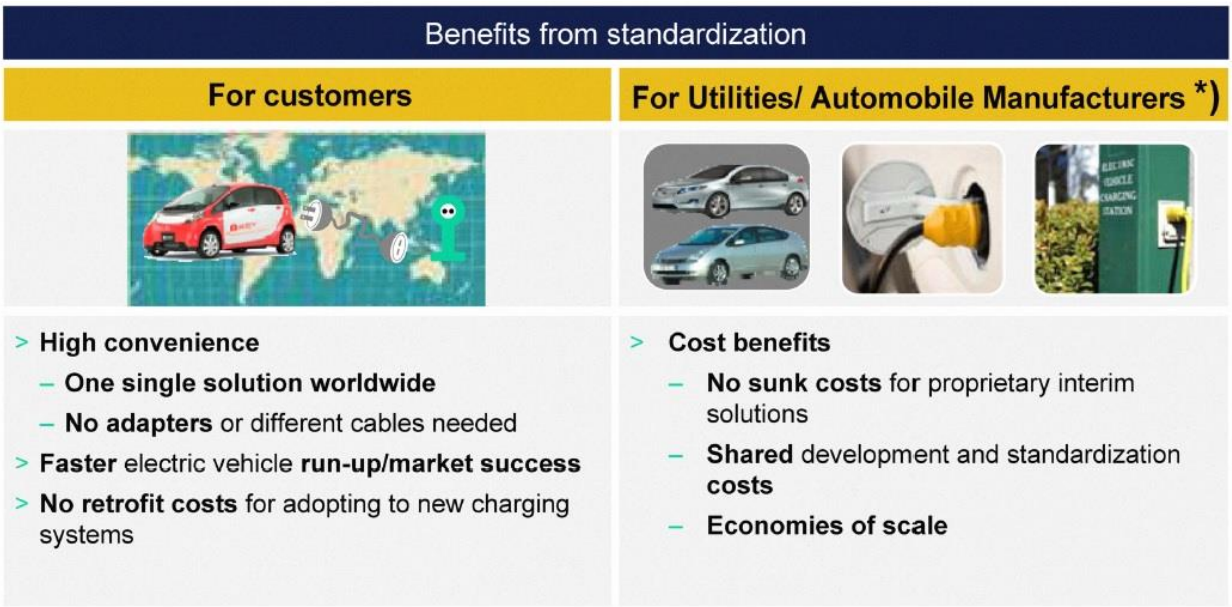
started being rolled out some time ago and standards and regulatory framework should protect that investment. Technology is evolving every day and there are new things being added providing increased benefits and advantages. Regulations should be predictable in order to determine the direction of technological development and innovation. Apart from this, customer's data protection issue has to be addressed on immediate basis to stop the negative perception about smart grid technology. This is particularly important to increase the customer base that accepts and agrees with the deployment of information sharing technologies. Moreover, to avoid the exploitation of monopoly position and create opportunities for new players and entrepreneurs, it is important to address the interoperability issues of technology, this will not only serve as the driver for SG technology roll out but can also be regarded as the key to success. In this way, several stakeholders can work together, being complimented and supplemented by each other's products and services. This will eventually create a positive and welcoming environment for the smart grid deployment.

4.2.3. *Example of Electric Vehicles* (Lorenz, 2009)

Stable and predictable regulations and standardization initiatives will benefit customers, utilities and car manufacturers like wise. For customers it comes with the high convenience and a broader range to make their choices with increased options, where they can have one single solution globally, unlike the above mentioned Tesla Motor example, where similar charging systems for all electric vehicles irrespective of the manufacturer and the brands can be made possible. This way the customer doesn't have to pay extra costs for adopting a new charging system. Likewise, in the case of utilities and car manufacturers, there are several factors which provide them with benefits as well. They will have cost benefits; same standards all over the world will create a positive environment for collaborative development activities and it will eventually lead to the electric vehicles becoming the economy of scale. New services and products will sprout

for the customers and the market can experience a revolutionary upscale eventually.

Figure 13: EV Example - Benefits from Standardization



Source: *Regulatory framework to incentivize Smart Grids deployment – EUROELECTRIC views, June 2009, Gunnar Lorenze*

The main constituent regulations of electric vehicle example can be transferred to smart grid components as well, e.g. to create the open communication standards, like TCP/IP protocols, all stakeholders can use the same protocol for communication purposes. This communication can be between the consumer and distribution grid and similarly between all the other stakeholders involved that need the data for energy management purposes. This way, instead of relying on just one communication tool, several software providers can be involved. New players in the field can come up with innovative solutions which in turn will guarantee competitive pricing which will eventually reflect on the cost of electricity and will benefit the consumer. This will be a key driver to increase the consumer engagement in the deployment of SG technologies on the greater

scale. Developing standards, which are stable and predictable for future up grading, will not only create a positive environment for technological growth but will also ensure the investment security. It will be a huge facilitator in providing a dynamic and productive environment for new product and service innovations and would serve as an invitation for the new players to step in and contribute for the greater cause.

4.2.4. Defining Roles for Stakeholders

Standardization activities will help defining the role of stakeholders involved in the value chain. They will be clearer in pursuit of their objectives and will determine the direction for the development in their own expertise. There are several components of smart grid value chain; all these components need to be treated individually to ensure the quality and efficiency of the process. Meter operations should be handled separately along with the metering services since the role of metering is not just to bill the consumer but also to share the information necessary to keep the energy balance and ensure the energy efficiency. The information collected through smart meters should be used not only for the sole purpose of management but also for creating new services and products. That information is gigantic and will offer promising opportunities for revenue generation. Regulations should define, that who is going to pay for that information and to what extent that information can be sold, in a way that it does not compromise the security of the consumer. Once the roles are defined and incentives are created, the market should let work, this is the only way to ensure promising growth, recover cost and investments and create the right environment which is needed for the revamping of whole electricity sector infrastructure.

4.2.5. The main goal of defining Regulations

The primary goal of defining regulations should be incentivizing the deployment, creating positive and growing environment, facilitating new technological

innovation and adaption of the technology by the consumer and stakeholders through their increased involvement. Interoperability standards are the key to compensate for the unbundling disadvantages. The purpose of regulations is to create the right environment for the development of the market and standardizing core operations will do that, not everything needs to be regulated since it can pose barriers which in turn hamper the development of the market.

4.3. “Adding "smartness" to the regulatory framework” (Lorenz, 2009)

EURELCTRIC presents ideas for adding smartness to the regulatory framework in wake of European smart grid, these recommendations are particularly deemed important in generally as well, when it comes to smart grid deployment, development and eventually growth of the market. The externalities yielding positive outcomes, generating profits are considered necessary to be internalized, this strategy will obviously create more revenues for the DSOs and utilities and will help to recover the capital cost they have encountered being the most important and deriving stakeholder in the electricity value chain. Collaborations must be initiated between stakeholders to ensure growth and development activities. The rates of electricity provided to the consumer should be standardized based on the performance, those performance parameters can be guarantee of supply, efficiency, interruption levels of the supply etc. These initiatives will have a direct effect on the revenues attached with DSOs, and DSOs being the biggest investors in the process will be able to carry out their roles more affectively.

5. Electric Vehicles

Importance of electric vehicles in advent of modern smart grid is not a hidden fact. These electric vehicles will also serve as small energy storage devices when plugged in as well as the voltage stabilizers in case of blackouts. Electric vehicle adoption over the conventional fossil fuel based cars is essential for eliminating a considerable percentage of carbon footprint related to transportation and providing an efficient, green, cheaper (when it finally becomes an economy of scale) way of transportation. They are particularly important to decarbonize the transportation sector.

Electric vehicles represent a diversified fuel mix and by doing so, they reduce the dependence on fossil fuels and provide energy security, depending on electricity, provided the country is self-sufficient in its production, it comes with the energy security i.e. independence from depending on other countries to meet the energy needs.

These electric vehicles are in the market since 19th century but due to factors such as high cost, unavailability of supporting infrastructure and issues like range anxiety, they couldn't get the success status over the years. Now the question is, what makes us believe that in the near future, they will become the first choice of the consumer. One of the reasons is the relation of electric cars with smart grids. The nations investing on smart grid development are also concerned about legal framework to help build infrastructure for electric vehicles.

One of the issues which have been the major cause of consumer reluctance in going for electric vehicles instead of fossil fuel based cars, is the range anxiety. Under suitable weight and power parameters, the average range for an electric car per cycle of the battery is around 120km. In case you need to go farther than that distance; electric cars are definitely at the disadvantage.

Unlike the other components of smart grids, EV's are the only component which can be felt by the consumer physically. They can actually see, practice and live their day to day lives managing their electric vehicles and in order to do that, they have to become 'smart consumers' themselves, which in fact is the whole point of smart grids. The smart grids chain can also be narrated as the intelligent production of electricity, transmission, distribution and finally, consumption.

The charging infrastructure for electric vehicles can be categories into four major types; this classification is deemed important from commercial as well as technical point of view (EURELECTRIC, 2013).

1. Public charging station on public domain
2. Public charging station on private domain (e.g., commercial areas such as shopping malls)
3. Semi-public charging station on public or private domains (e.g. car sharing services, hotels or business parking for visitors and customers)
4. Privately accessible charging station (e.g. home or office locations)

All these electric vehicle charging infrastructure categories need investment. That investment can only be made possible from the private sector if there are enough incentives provided by the governments and most importantly the security of investment, the returns. Since electric vehicles are not only going to be another consumption unit of electricity but the batteries in these cars will also serve as the distributed electricity storage units and voltage stabilizers as well. Management of these batteries as electricity storage facilities is going to be a difficult task. Policy makers are still working on how to tackle the necessity of managing these energy storage units, especially when it comes to billing the consumer on usage as well as when they are going to use these batteries as energy storage, how will they benefit the car owner.

5.1. EV Charging Methods

There are three basic charging methods for electric vehicles, categorized into three levels, level 1, 2 and 3.

5.1.1. Level 1 Charging

Level 1 charging is done through a 120 volt alternating current plug and it can be done anywhere, all you need is access to a 120volt electric socket with no additional charging equipment required and it takes around 4 to 12 hours for the vehicle to fully charge. EV owners can do it at home and according to researches, more than 50% of home owners in United States have access to level 1 charging method for their electric cars. Depending on the type of car, level 1 charging adds about 2 to 5 miles of range to a plug-in electric vehicle per hour of charging time (U.S. Department of Energy).

Figure 14: Examples of Level 1 Charging Equipment

Source: *Electric Vehicle Charging Levels and Requirements Overview: December 2012, Jim Francfort, Idaho National Laboratory*

5.1.2. Level 2 Charging

Level 2 is also done through alternating current (AC). This method uses charging through a 240V or 208V electrical services instead of 120V which is used in level 1 charging method. In contrast to the level 1 charging, this method requires installation of home charging or public charging equipment and dedicated circuit of 20 to 80 amps, the current capacity of the circuit depends on the type of vehicle, different electric vehicles have different requirements (U.S. Department of Energy).

These charging equipment are normally dedicated to the electric vehicles and depending upon the specifications of the battery and the circuit type, it adds up to 10 to 20 miles of range per hour of charging time (U.S. Department of Energy).

Figure 15: Examples of Level 2 Charging Equipment

Source: *Electric Vehicle Charging Levels and Requirements Overview: December 2012, Jim Francfort, Idaho National Laboratory*

5.1.3. Level 3 Charging

Also known as DC quick charging, direct current fast charging equipment which charges through a 480V AC input provides fast charging. It is normally installed at areas of heavy electric vehicle traffic, especially where a large number of electric vehicles are concentrated, such as parking lots, shopping malls etc. Charging through DC fast charging can charge 80% of the battery in less than 30 minutes. It is the fastest charging method commercially available to date.

Figure 16: Examples of Level 3 Charging Equipment –

Source: *Electric Vehicle Charging Levels and Requirements Overview: December 2012, Jim Francfort, Idaho National Laboratory*

5.2. Business Opportunities in Electric Vehicle Charging Infrastructure

When it comes to business opportunities in infrastructure development for electric vehicle charging facilities, there are quite a few possibilities that can be exploited. Some of those opportunities are mentioned in this chapter. Some of them require big investments, some of them do not. These business opportunities can be directly or indirectly related to EV charging infrastructure, the bottom line is to identify opportunities through which revenues can be generated.

- Charging stations at Public Parking's
- Services available at charging stations while car owners wait for their cars to get charged
- Battery Swapping stations
- Mobile charging stations

5.2.1. Charging stations at Public Parking

Most of the EV owners charge their cars in their houses. People who are more concerned about the 'green electricity' even use the electricity produced by the solar panels installed on their roof tops. Despite of all these efforts, the fear of running out of the juice is always there. One of the top selling models of EV's, Nissan Leaf has the range of about 75km. Which in normal circumstances is not too less since at this point in time, when EV's are not as common as the other fossil fuel based cars, people normally treat their electric cars as the 'second car'. For travelling inside the city, commuting to their work which in most cases is not more than 60 km round trip, they prefer to use their electric cars. Despite of all these factors, there still is a chance of running out of juice. To counter this problem, public charging stations can be installed in the public parking lots.

These charging facilities shouldn't be less than Level 2, where the car owners can add 10 to 20 km of range per hour of charging. These public parking spaces can be dedicated just for electric car which will not only give the feeling of superiority to the customer but will also make them feel acknowledged for their efforts towards the green initiative.

Figure 17: Dedicated Parking for EV's

***Source**: Electric Vehicle Charging Levels and Requirements Overview: December 2012, Jim Francfort, Idaho National Laboratory, retrieved, August 2013*

5.2.2. Indirect revenues attached with charging facilities

There are externalities attached with almost every business. The most convenient charging method is to charge the vehicle at home, in the night but when that is not available, an alternative is to charge the vehicle on public charging stations. Since this process is time consuming and unlike the gas

station, you normally have to wait for at least 30 minutes (that also in case of fast charging station). The time these car owners spend on the charging station can be made worth wile by providing them with entertainment facilities. These facilities can be presented in an innovative style where the customers don't feel trapped. These charging stations can be installed at gyms. While people work out and get themselves energized, their car batteries can be juiced up at the same time. This is one example of the indirect revenues that can be generated through these charging stations. The offerings can have a wide range, including, spas, shopping centers, restaurants etc. Just like airports, when people are waiting for the check-in, they spend time by shopping at duty free shops which generates considerable revenues for the airports. The value proposition is that the customer is optimizing his time, the time which was otherwise spent on waiting.

5.2.3. Battery Swapping Stations

The idea of battery swapping is not a new one. An Israel based company; "Better Place" is the first one who came up with the concept of swapping dried up batteries with the fully charged ones. These battery swapping stations can be installed at convenient locations and can have a permanent subscription-based-customer base. Since different models of EV's come with different specification of batteries, these swapping facilities can have all the possible options available. One of the main requirements would be to keep track of data, how many cars in the area, how many cars passing through that way, what type, how many different kinds of batteries. Though easier said than done but the idea is already successfully in place in Israel and revenues have been generated. It is the fastest way to recharge electric cars, where the customers don't have to wait like they have to in case of charging the same battery. Even the level 3 fast charging takes minimum of 30 minutes to charge the battery to 80%. The installation can be like an automated car wash, where the car goes in and gets the battery removed automatically and swapped by a fully charged one. The value

proposition is the fact that it is the fastest way to get the car back on road, even faster than Level 3.

5.2.4. Mobile charging stations

This business opportunity is one of the most innovative solutions when it comes to electric car charging infrastructure. A quick charging station that can use a standard 120V plug, the idea is to charge a set of batteries through the regular charging method which takes its normal course of time, in case of level 1, up to 8 hours. These batteries when fully charged can be connected to the car with a level 3 interface and can charge the car in about half hour. These batteries when not in use can also serve the grid by providing an energy storage unit. A trailer or a truck, carrying these batteries can reach on call wherever needed and charge the dried up battery of the car and get that vehicle up and running in few minutes. This idea is particularly useful in remote areas where there is no charging infrastructure available. It can also be used as the emergency energy module, in case of emergency, such as catastrophic conditions, hurricanes etc. Since charging time is one of the most significant issues and is acting as a barrier in consumer's adaption of electric vehicles in place of fossil fuel based cars. This strategy can certainly give them enough confidence and can overcome the reluctance caused by range anxiety in the long run. This concept becomes practical only when the level 3 charging interface is available on the cars, and when the cost of the battery system is about 10-20% of the cost of the overall car (Innovations Commercialization).

This method is also particularly useful because of the fear of utilities caused by fast charging stations everywhere. Fast charging devices generally take around 440V, while most of the domestic appliances are around 110V. Having fast charging stations in abundance will overload the grid which definitely is an issue. Mobile fast charging strategy will not only take care of this problem for the utilities

and will avoid the over loading of the grid but will also provide the car owners with fast charging of their car batteries, whenever and wherever they need it.

Figure 18: Mobile Car Charging

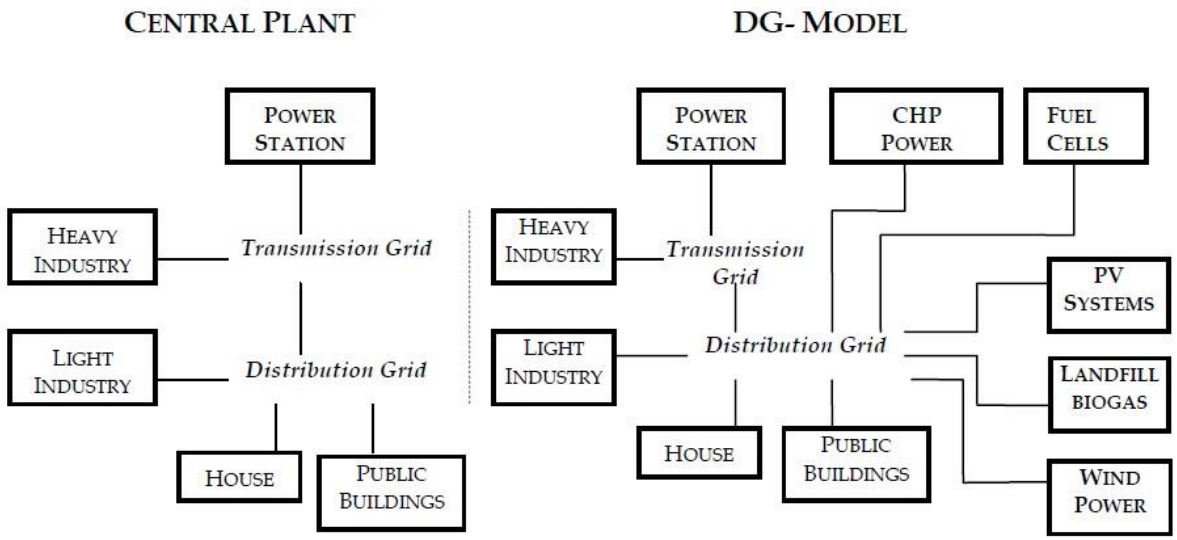
Source: *http://cleanfuelconnectionnews.com/electric-vehicles/electric-car-running-flat-the-aaa-has-you-covered/, Retrieved, August 2013*

6. Distributed Renewable Generation

Smart grids and distributed renewable generation go hand in hand. In fact one of the main advantages of smart grid is to be able to integrate several small electricity generation units to provide for the needs of electrification. Now this is something which is developing over the years with the spreading awareness about smart grids and in case of increase in the area of implementation and growth of smart grids, more distributed generation units will sprout. This growth will bring new business opportunities.

Central power plants are connected with transmission grid and that transmission grid is then connected to distribution grid and also provides for electrification needs of the heavy industry. Then the distribution grid is further connected with light industry and provides electricity for public building and houses. On the other hand, in DG model of electricity production, the distribution grid does not only take electricity from the transmission grid but also is connected to the several distributed generation units; these units can be of both types, renewable and nonrenewable generation plants. Renewable sources include combine heat and power plants, fuel cells, PV systems installed on public or private properties, wind power and landfill biogas etc. These DG sources are all connected to the distribution grid, smart grid technologies enables the distribution grid to manage all these sources, the two way information sharing mechanism enables smart girds to balance the electricity requirements, since there are troughs and peaks in the power generated through renewable sources. Sun never shines all the time; wind doesn’t blow all the times either.

Figure 19: Schematic diagram of traditional central-plant model and DG-model



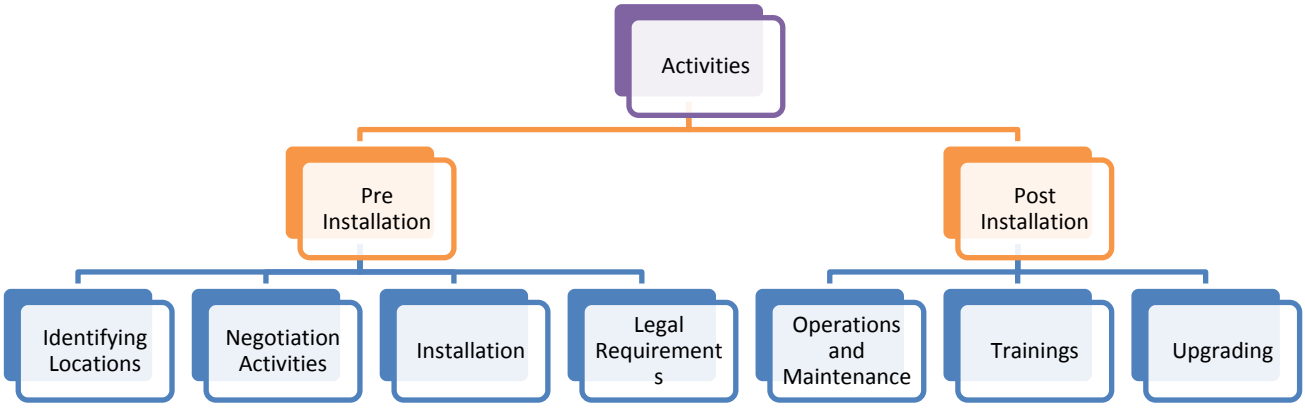
Source: *Leda-Ioanna Tegou, Heracles Polatidis, Dias A. Haralambopoulos, 2007, Distributed Generation with Renewable Energy Systems - The spatial dimension*

There are several opportunities connected to the advent of smart grid and distributed renewable generation, these opportunities can be exploited by not only the utilities but also by the entrepreneurs. Utilities will have to transform their role from commodity suppliers to energy solution providers (Frank Klose, 2010). There are several areas in which business opportunities can be identified and new revenue streams can be generated. One of the most common types of distributed renewable generation units will be solar PV power plants. The concept of 'rent a roof' is already in practice. In such cases, there will be an increased demand of solar PV panels manufacturing and other services related to that. Not only the sales of the equipment used in such installations will be boosted up but also the services sectors attached with such activities will face an increased business activity.

One of such business opportunity will be facilitating the process of making a distributed renewable generation unit operational. There will be opportunities for energy solution providers, energy consultancy firms and skilled professionals. In this thesis some of the activities related to setting up a distributed renewable generation unit are identified which can create opportunities for entrepreneurs and skilled professionals and in turn generate revenues.

These activities can be divided into two man categories:

Figure 20: RDG, Pre and Post installation revenue generating activities



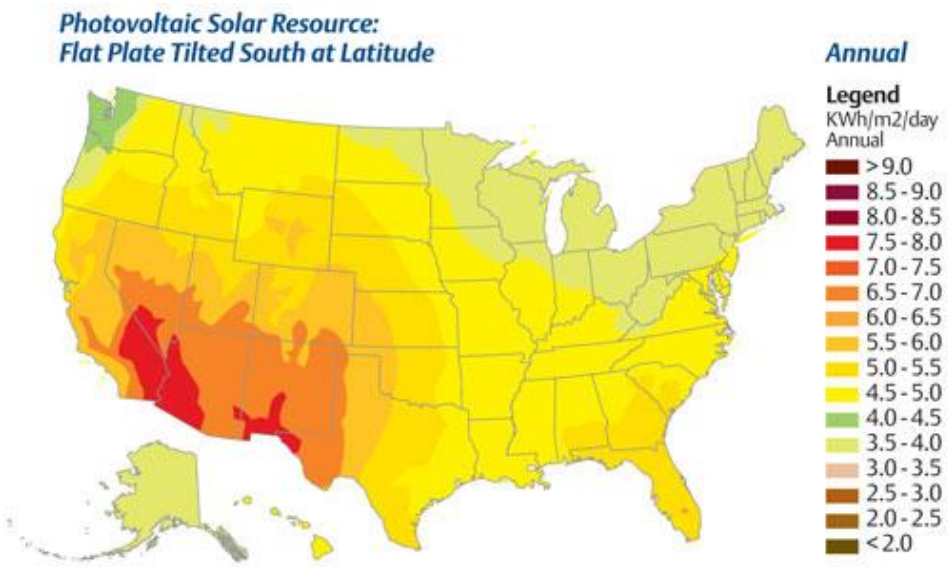
6.1. Pre Installation Activities

6.1.1. Identifying Suitable Locations for Renewable Distributed Generations Units

Identifying a suitable location for DG power plant is something which involves a lot of factors. Such as finding places where there are no natural constraints such as sun exposure for PV installations, wind speed for wind turbine installation etc. Geographic information system allows us to understand, analyze, interpret and visualize data in several ways, the relationship between different data sets,

pattern, trends etc. This technology can be particularly handy when identifying locations which are best suited for the installation of a DG power plant, especially when that power plant is dependent on the geographical traits of the locations and the decision has to be made based on the attributes mentioned earlier such as sun exposure, wind speed etc. Consultancies can be provided to the utilities for recommending them the most suitable sites, also to the property owners that what kind of DG plant would be most efficient in the given circumstances.

Figure 21: GIS representation of U.S. Solar Availability, Annual Summary, with Fixed Panel Tilt to Latitude



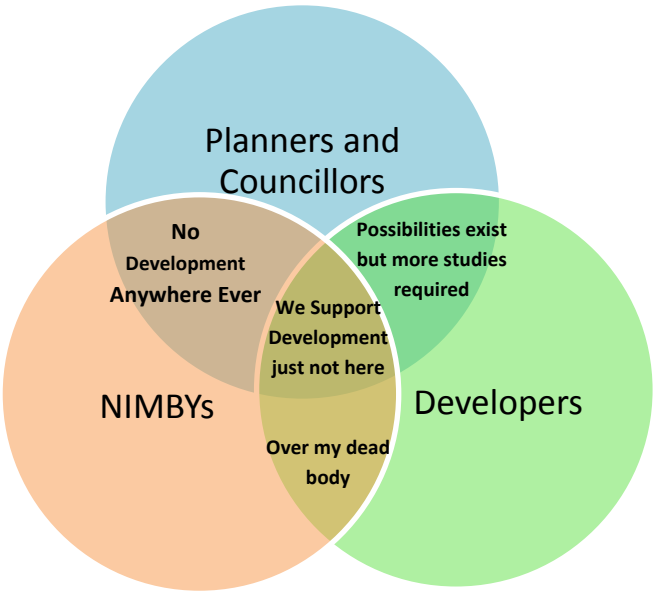
Source: *http://www.ospmag.com/issue/article/Understanding-Hybrid-Energy-Solutions-in-the-OSP, Retrieved August 2013*

6.1.2. Reaching the Property Owners and Proposing the Business Opportunity

Reaching the property owners and proposing them the business opportunity of installing DG plant on their property has to be done professionally and skillfully. People are not always very comfortable with the idea of letting anyone else use their property for their benefit even though they will be getting benefited too by

the collaborative venture. To deal with the public opposition which is now termed as NIMBY (Not in my backyard) approach, BANANA (Build absolutely nothing anywhere near anything) etc. professional approach is required. These issues are so well acknowledged globally that these acronyms have been added to the dictionaries. Dealing with all these issues is not an easy job. Apart from the temperament, it requires professional skills. And people can get paid for that. Every problem comes with opportunities and those opportunities can make money, revenue streams can be generated out of those. On the other hand, there are people who want their properties to be used and generate revenues from that, bringing those people and the investors together for the collaborative joint venture would require a lot of formalities. Facilitating such activities is also part of providing solutions and consultancy. There would definitely be a considerable potential of generating revenue streams out of such activities.

Figure 22: NIMBY Venn diagram



Source: *http://www.eqjournal.org/ : Professor Bruce M. Firestone*

6.1.3. Installation Activities

In order to make sure the most efficient generation possible from a particular power plant, it has to be installed according to the standards defined by the manufacturer, complying with the regulations defined by the regulatory authorities. It is very important that the installation is carried out without compromising the quality of engineering involved. Skilled workforce can be provided by energy solution providers and/or the consultancy involved. This is one of the most obvious revenue generating streams when it comes to distributed generation installations. A number of equipment are involved in just solar panel installations such as, solar panels Per se, invertors, wiring, connections to the grid, smart meters etc. All these components have to be installed according to the defined standards and professional care has to be taken while performing such activities. Flawless installation can only be ensured if it is done by professionals. These activities will not only provide revenues for the solution provider companies but will also create jobs for skilled workers.

Figure 23: Solar Panel Installation by Professionals

Source: http://solar.gridbid.com/, Retrieved, August 2013

6.1.4. Taking care of Legal Requirements

Governments are providing incentives, in terms of subsidies and feed-in-tariffs. Manufactures can provide financing options for their equipment. Properties can be leased to install DG power plants. All these activities involve several contractual requirements and it is not easy for everyone to understand all those legal requirements and making sure that they are not selling themselves out. People don't want to get trapped in pursuit of glittering incentives and benefits. They need someone to guide them through the process, to carry out all the legal framework of the process. Legal protection is required by not only the property owners but also for the developers. Energy solutions providers, consultancies and law firms can take care of such issues for the stakeholders involved. People like to get sureties, guarantees; they make them feel secure and comfortable when entering a business, that is why this is another potential revenue stream which can be utilized to make sure a successful venture for all the parties involved.

6.2. Post Installation Activities

Once the DG unit has been installed and is up and running, it has to be maintained and operated professionally to make sure it reaches the breakeven and then finally starts making money for the developers and the property owners likewise. Professional advice and services are required even at this stage. Following are some of the activities that need professional handling.

6.2.1. Operations and Maintenance and Upgrading Activities

To make sure the plant is running at its full capacity at all possible times, it has to be made sure that all the equipment installed are functioning properly, there is a constant need of regular inspections. Overhauling, replacing and fixing

components whenever required, without having the stakeholders face any loss which is caused by something that has to be taken care of by the professionals. Energy solution providers and consultancies can offer their services to handle day to day activities in the units. Everyone likes to maximize the profits and minimize the work load; these day to day activities if outsourced, can reduce the burden of their shoulders and can provide more people with job opportunities. Along with the day to day operations and regular maintenance inspections, there is also the need for regular up grading. Compliance with the changing standards, to keep up with the latest and more efficient technologies, professionals have to provide with their expert advice and services.

6.2.2. Trainings

There are a considerable percentage of people who would like to be self-sufficient when handling their own property, instead of running to the consultancies or solution providers every time something happens, they would like to take care of things on their own. Training sessions and short courses can be organized for such people. This in turn would not only generate profits but will also be a source of producing skilled workforce.

7. Implications of the Research

The implications have a very broad spectrum, ranging from aspects of energy policy related to smart grids, the social dimensions of smart grids, quest of finding opportunities for entrepreneurs to step-in and contribute for towards the development and applications of smart grids; to innovative business models in the industry.

7.1. Recommendations for Regulators and Policy Makers

Regulations have to be defined with the goal of creating the positive environment for the participation of new players. This study refers to entrepreneurs in particular as new players in the power sector. The path of smart grids should be incentivized in a way that it facilitates new products and services development. These products can be offered by the utilities, DSO's and small and medium enterprises likewise.

One of the most important factors is to induce public acceptance for the new concept of electricity landscape. The consumer should be able to overcome their major reluctances and hesitation in adopting the SG technologies. Electric vehicle infrastructure is an essential component of SG technologies, infrastructure has to be developed with redefined interoperability standards i.e. one solution for the same problem all over the globe and/or all the way through the power sector value chain.

7.2. Recommendations for Entrepreneurs and Academia

The idea of electricity generation for entrepreneurs has not been very effective since it requires massive financial resources, which of course are not possible for small and medium firms, hence the entrepreneurs have to adopt the pathway of

electricity conservation and management in order to fully utilize and unleash the potential of already existing sources. This study also aims to find out such opportunities for entrepreneurs and this is going to be one of the most important implications of the research.

Keeping in view the evolving landscape of the power sector, new opportunities should be identified to boost the economy. These opportunities can be found in connection with the regulatory framework which will be defined and have been defined by the regulatory authorities to incentivize smart grid deployment. There can be several direct and indirect revenue generation streams that can be exploited. The need is to come up with innovative solutions and products. Academia can play an important role by including smart grid technology related courses in the curriculum, since this is the future and without the qualified professional workforce, the process of SG deployment will not only be slow but can also face serious deteriorating consequences. Up grading the educational components is the key to spread awareness and SG literacy in the students. These curriculum updates does not necessarily has to be just scientific and technological based, in fact there is a huge potential for indirect revenue streams i.e. identifying research and business opportunities in terms of externalities attached with the SG.

Conclusion

The regulatory framework must open new market opportunities for the existing suppliers and should create opportunities for the new players by creating incentives and defining regulations to avoid monopoly position. The customer should get more control over their consumption and choice of supply options in order to ensure increased engagement and acceptance for the new technology; they should be able to overcome the fear of insecurity of data and information sharing with the distribution grid and the other stakeholders of the value chain. These regulations should contribute positively in order to define the right business model and to create the positive environment for development and growth. And most importantly, incentivizing investment through regulations should be the primary goal to initiate the process, once initiated and provided with the right environment; eventually the world will experience the revolutionary benefits of smart grid technologies. This will have great impacts on global economy and will provide with the security of the basic necessity of electrification of the population.

Creating right environment for SG deployment and development through regulatory incentives will create enormous business opportunities. These opportunities will allow new players, particularly entrepreneurs to contribute with innovative technological solutions. These solutions can then be transformed into revenue generating streams. Apart from the directly related technology innovations, there is a huge potential of revenue generation through activities that are not directly related to the smart grid development. These opportunities once exploited, will create a considerable impact on the deployment of SG to facilitate it, as well as to expedite the process. This will result in increased consumer engagement and overcoming the barriers and utilizing the true potential of drivers.

References

EURELECTRIC. (2013, July). Deploying publicly accessible charging infrastructure for electric vehicles: how to organise the market? Brussels, Belgium: Union of the Electricity Industry - EURELECTRIC aisbl.

EURELECTRIC. (n.d.). *About EURELECTRIC*. Retrieved August 2013, from http://www.eurelectric.org/: http://www.eurelectric.org/about-us/

Frank Klose, M. K. (2010). *Towards a Distributed-Power World.* BCG - The Boston Consulting Group.

Geert P.J. Verbong, S. B. (2012). Smart grids or smart users? Involving users in developing a low carbon. *Energy Policy*.

Innovations Commercialization. (n.d.). *Innovation Commercialization*. Retrieved August 203, from http://innovationscommercialization.com/: http://innovationscommercialization.com/business-concepts/electric-vehicle-quick-charge-stations/

Jan Van De Putte, R. S. (2011). *Battle of the Grids.* Amsterdam: Greenpeace International.

Lorenz, G. (2009, June 11). Regulatory framework to incentivese Smart Grid deployment . Prague, Czech Republic: EUROELECTRIC.

National Energy Technology Laboratory. (2008, February). Advanced Metering Infrastructure. *White Paper*. United States: U.S. Department of Energy.

National Energy Technology Laboratory. (2010, June 18). Understanding the Benefits of the Smart Grid. United States: U.S. Department of Energy.

Peter Vaessen, D. T. (2007). *Power Quality and Utilisation Guide: Policy and Incentives on Distributed Generation.* KEMA Consulting.

U.S. Department of Energy. (n.d.). *Developing Infrastructure to Charge Plug-In Electric Vehicles*. Retrieved August 2013, from afdc.energy: http://www.afdc.energy.gov/fuels/electricity_infrastructure.html

Verbong, G. &. (2010). Exploring sustainability transitions in the electricity sector with socio-technical pathways. *Energy Policy*.

Vincenzo Giordano, G. F. (2011). A business case for Smart Grid technologies: A systemic perspective. *Energy Policy*.

WEF. (2010). *Accelerating Successful Smart Grid Pilots.* Geneva: World Economic Forum.