Economic, Social and Environmental Benefits of Smart Grids

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Abstract

The development of new technologies is faster than ever before in the human history, and as such there is an increased need of adaptation. In this sense, the present paper argues that current electrical grids should be transformed into a more modern and sustainable grid – the smart grid. This article will review the current situation from three main perspectives: economic, social and environmental. Each of these dimensions is influenced by various factors and in this paper we will systematically evaluate them. Our analysis suggests that currently there is a series of benefits offered by smart grids attributable to each dimension. Still, the level to which consumers will enjoy them is also conditioned by their willingness to embrace this technical change and transition to a new way of engaging with energy consumption through a user mediated relationship.

Keywords: smart grids; infrastructure development; environmental benefits;

JEL Classification: A13; D61; F64;

1. Introduction

To understand the meaning of the benefits that smart grids can bring we must firstly establish our understanding of the concept. Therefore, we begin with the purpose for which smart grids are being installed in the first place. As technologies are progressing faster and faster, the national and global markets have a much higher demand for electricity. For this reason a technology development process is currently under way that would allow us to accomplish a higher performance and a more effective usage of electricity in the electrical grid. In this case the most popular upgrade for electrical grid is the installing of smart grids. A smart grid is an electrical grid, which is being modernized and renewed by installing new technologies, which would allow having a two-way communication between the consumer and supplier. Such smart grid installation of current electrical grid can increase the electricity distribution and reliability, but also save money to both consumer and supplier. For smart grids to meet the standards and to be effective, they have to be sustainable. Sustainable smart grids are those, that meet all three dimensions of sustainable development: (1) are able to work economically and are cost saving, (2) are environmentally friendly, connecting renewable energy sources, and (3) allow users and suppliers to have a two-way communication.

In order to simplify the information, electrical networks can be defined as a set of hardware and wiring machines, which connect the power source (e.g. power plant) with consumers and their many needs. Power plants transform the initial form of energy, such as chemical energy stored in coal, glowing solar energy, wind, pressure or energy stored in the nucleus of uranium, into electricity, which is no more than a temporary, flexible and portable form of energy. The most important thing is to remember that electricity is not fuel: it is an energy carrier. In the electricity network and in factories or homes, electricity is converted back into a useful form of energy or activity as heat, light, information processing or torque motors (Amin and Stringer, 2008).

The current problems of smart grids, mostly related to countries that have a lower standard of living and haven't developed their electrical grid system are as follows:

1) Old (most plants are 35 years old or more);

2) Contamination (more than half of the electricity is produced from coal burning);

3) Inefficiencies (supplied electrical efficiency is only 35%);

4) Instability.

This means that the countries that have old electrical grids have a high contamination from being unsustainable (e.g. coal burning), have low electricity efficiency, productivity and are technically unstable. We will further explore why they would have a various advantages from installing smart grids into their electrical grid system (Hicks, 2012).

In order to meet the electricity transmission and consumption needs, there has been a need to create and use smart grids. An intelligent network is a complex structural unit communicating with each other as a whole. The network key components are: energy production; transmission and distribution networks; active users; operations center; energy exchange; service, energy storage devices. (Galdikas *et al.*, 2014)

Smart networks produce and respond to information in order to create a better electrical system. Smart grid technologies include: switches, sensors, software, timers and many other components, which now allow two-way communication throughout the energy system. These technologies can be placed anywhere on your smart network, starting and ending with power transformer substations, as well as electricity supply lines into consumer homes. Using the information technologies, smart grids can help to save energy, to facilitate the integration of renewable energy and make the electricity grid more durable, more resistant and more reliable (Succar and Cavanagh, 2012).

Smart networks enable the development of renewable energy in the network, because it is volatile and can result in high energy imbalance, resulting in grid experiencing stressful modes that may cause accidents in networks. To solve this problem there must be used storage devices that accumulate the energy generated when the surplus of renewable energy sources, and automatic control system that regulates the flow of energy (Galdikas *et al.*, 2014).

The existing power system can be considered a major cause of the greenhouse effect and global warming that cause environmental impact due to the fact of using fossil fuels, especially coal. In contrast to fossil fuels, renewable energy sources offer alternative sources of energy that does not pollute the environment in general, are technologically efficient and harmonious with the environment. There is an unprecedented focus on renewable energy sources, especially solar and wind energy, which provides electricity without causing carbon dioxide release. However, most of the existing transmission and distribution networks in countries that have a lower standard of living and haven't developed their electrical grid system are considered to be "dumb" systems because the system cannot send back the information needed to manage a modern real-time network. Existing power grids are unable to offer adequate services to the energy efficiency, reliability and safety or the integration of renewable sources of scale needed for the future would be sufficient demand for renewable sources. Therefore, the introduction of smart grid technologies is an essential requirement in order to reduce overall greenhouse gas emissions to manage demand to promote energy efficiency, improve reliability, submitted manageability. Smart networks are a combination of centralized uncomfortable electricity and power manufacturing, which allows multi-directional power flow and exchange of information (Shafiullah *et al.*, 2013).

One of the main ways to determine the effect of this smart grid is to group them into three basic groups according to impacts - environmental, economic and social spheres. Each of these dimensions has a different type of impact, but is equally important to know and understand.

2. Economic Benefits

Intelligent networks offer a range of advantages: they improve both physical and economic electricity supply operations to make them more cohesive and robust, more cost effective by reducing losses and at the same time offering economic benefits for all interested parties. The electric system is a critical part of the infrastructure in today's society. Visions of the future smart grid are very different. Visions ranging from in order to develop a common European “super” network for small, local network design, unbound with common network (Verbong *et al.*, 2012).

Price incentive is also one of the arguments why users should change the approach to smart grids (Benders *et al.*, 2006). Currently, consumers pay a fee for the slab relative energy consumption. Be that as it may, the real price of electricity is higher than the peak during off-peak times. Smart grids would allow time to see the real price of electricity, which would allow the user to reduce their electricity price, if they are able to respond to changing prices. Energy companies and network operators are also convenient, since it would not be such a high peak and high demand for electricity that is distributed. Now, the current cost to the user is limited and may range less than 0.5%. Also, a large reduction of energy consumption can influence social and technological barriers and constraints (Larsen and Petersen, 2009; Huygens, 2011).

Large-scale power grids, such as North America, Asia and Europe, provide two key advantages: reliability and economy. Interconnected electricity network with thousands of generators means that even if the largest generator stops, the power supply remains. Seen from the economic side, it also means that the electricity network participants can exchange electricity, taking advantage of the fact that 1000 km. generated electricity is cheaper. As the network operates at high voltages the total loss of the transmission network system is quite large and is about 3% of the total generated electricity (Kezunovic *et al.*, 2012),

Electrical Power Research Institute (EPRI) is a major contributor to assessing what smart grids bring when they come along and especially the benefits also some of the costs are included in their framework. In the table below you can see the listed economic benefits within each sub-category.

Table 1. List of Economic Smart Grid Benefits: Based on EPRI/DOE[1] Framework (EPRI 1020342).

Benefit Sub-Category	Benefit
Improved Asset Utilization	Optimized Generator Operation
	Deferred Generation Capacity Investments
	Reduced Ancillary Service Cost
	Distributed Generation
	Storage
	PEVs[2] as Storage & Load Control
	Energy Efficiency
	Demand Response
	Enhanced Energy Efficiency*
	Reduced Ancillary Service Cost
	Reduced Congestion Cost
T&D[3] Capital Savings	Distributed Generation
	Storage
	Demand Response
	Energy Efficiency
	Enhanced Energy Efficiency*
	Deferred Transmission Capacity Investment
	Deferred Distribution Capacity Investment
	Reduced Equipment Failures
T&D O&M[4] Savings	More Effective Use of Personnel
	Economic Benefit of Added Personnel
	Operations Savings from AMI[5]
	T&D Efficiency
	Reduced Distribution Equipment Maintenance Cost
	Reduced Distribution Operations Cost
Theft Reduction	Reduced Electricity Theft
Energy Efficiency	Enhanced Energy Efficiency*
	Electrification (Net Reduced Energy Use)
	Reduced Electricity Losses
	Productivity Increase
Electricity Cost Savings	Reduced Electricity Cost
	Automatic Meter Reading
	Customer Service Costs (Call Centre)
	Storage
	Enhanced National Productivity
	Reduced Restoration Cost
	Speed of Restoration
	Reduced Sustained Outages
	Reduced Major Outages
	Accessibility
Power Quality	Reduced Momentary Outages
	Reduced Sags and Swells
	Storage

* Enhanced Energy Efficiency includes: continuous commissioning of large commercial buildings direct feedback on energy usage, energy savings corresponding to peak load management energy savings corresponding to the enhanced M&C capability.

Source: created by author based on EPRI (2011).

[1] EPRI – Electrical Power Research Institute, DOE – U.S. Department of Energy
[2] PEV - Plug-in Electric Vehicles
[3] T&D - Transmission and Distribution
[4] O&M - Operations and Maintenance
[5] AMI - Advanced Metering Infrastructure

Table 1 summarizes the economic benefits. From an economic perspective of view, all of the benefits are very important as they all together, with installing smart grids, bring a whole different way of smart grid management. It is crucial when installing smart grids to understand the meaning of the full economic benefit that smart grids can bring as it can be called as a „game changer“ in the whole electrical industry.

Economically speaking, if more normal electricity grids are upgraded to smart grids, this would mean that there would be less energy lost which costs money to make. The more energy you save, the more energy you can spend on using in a different industry or other specialized electricity-soft areas. The more energy you can sell and use, the bigger the money flow for companies and the more profit they can make a long with making electricity cheaper for the consumer also by saving it in the first place. The bigger the money flow, more money saved by distributors and consumers means there can be money spent on other things, whether they are associated with smart grids and electricity (upgrading other parts of electrical grids for distributors) or not (customers allocating their resources for a better personal and community well being).

3. Social Benefits

The social aspect in smart electricity networks typically includes a demand for the introduction of control (Demand Side Management, DSM). Mostly smart grids go hand in hand with DSM, that demand could follow supply. DSM is the old instrument designed to allow a re-peak loading at a time when demand is much lower. Of course, DSM domestic use is partly new. For the DSM function, it is necessary that a presentation to some form of flexibility to users. These settings change the washing and drying machines use and also freezers and refrigerators. These devices must also become excellent, being able to be operated remotely. The flexibility of these devices is limited (about 25% of maximum performance, including wet all devices, but without the cold appliances) (De Jonge, 2010).

There are several reasons why users might want to take smart grids and change their attitudes. One argument is for environmental reasons. This is the main argument to persuade consumers to make smart meters. The idea is that giving users (households) detailed feedback on their consumption costs will encourage them to reduce their energy consumption. It is argued that the potential for energy reduction can reach between 5% and 15% (Burgess and Nye, 2008; Darby, 2006; Van der Beek, 2010). Recent tests show very versatile results: tests gave the US demand for a reduction between 4% and 15%, but similar experiments in Ireland and the UK gave a reduction of energy consumption by only 4% (Hardy, 2012). For long-term lack of experience is not precisely say whether these changes are likely to be short-term or long-term, when customers later return to their old habits (Nyborg and Røpke, 2011).

Social sustainability, even if still a vague concept, but that can basically be linked to our quality of life in society (Ribeiro *et al.*, 2011). In order for smart grids become successful and sustainable they must include in the early stages of evaluation at public level the external factors and uncertainties that may cause future smart grids (Mengolini and Vasiljevska, 2013). Many articles and reports has been boosting the importance of smart grids on external factors such as the effect to work, not enough technical workforce (aging workforce), new skill requirements, safety and organization and management issue problems (Ribeiro *et al.*, 2009; Giordano *et al.*, 2011, KEMA, 2009).

Wustenhagen *et al.* (2007) identifies three main types of smart grids acceptance: socio - political, communal and market acceptance. According to Wolsink (2010) the socio - political and market acceptance is the most difficult in the smart grid. Institutional innovation adoption of renewable energy sources has been very challenging in the Netherlands. Market acceptance is associated with predictability and role assignment in new markets, as well as the degree of control and management, according to the energy companies. It is strongly linked to the question that who owns and manages the flow of information is who created the smart meters. In order to pursue the adoption of the consumer it is important to know what choices he has to be able to organize themselves and what kind of institutional adaptations needed to create new roles of individuals (Wolsink, 2010).

Public smart grid adoption and implementation as with any technology is very important at an early stage of the installation (Mengolini and Vasiljevska, 2013). Stern (2011) distinguishes several ways to increase consumer adoption of smart grids:

- Easy usage of new technologies;
- Transparency: information presentation as you can clearly benefit from the deployment of smart grids including the long-term benefits;
- Monitoring system: access to pilot projects to increase monitoring and reduce consumer concern.

Davis (1989) noted that there are two main social - psycho factors for the technology acceptance model which may affect the pro-environmental behaviour: perceived degree of convenience for the consumer, but also the ability to assess by how easy it is to use the technology and perceived usefulness is the degree in which the user evaluates whether the technology is beneficial and advantageous compared with the last previous technology.

For most people it is not important whether or not smart grids will be installed or not because the majority of society does not know what they are, what they do or what they would bring. It is important to understand that education has a very important role here too. If more and more people will be educated and will share the knowledge of the social benefits of smart grids, even if it will be in small scales via public announcements or word of mouth, this would significantly increase public awareness of modern day electrical grid changes. With more people acknowledging and accepting smart grids it would be easier for companies, electric power grid part manufacturers to sustain their businesses. The social acceptance of new smart grids would bring an economic wealth to both the distributor and consumer. Without the public acceptance, it is very difficult to lead new innovative ideas in any kind of industrial sector, and smart grids' sector is not an exception.

4. Environmental Benefits

Succar and Cavanagh (2012, p.4) mentioned in their work: "Smart grids can give us cleaner air, better health, lower electricity bills and reduced carbon dioxide (CO_2) emissions in the atmosphere." Smart grids, together with the generation facilities and end users help to reduce CO_2 emissions by 58% from the power sector as compared to 2005 CO_2 emission data (EPRI 2011).

Paget *et al.* (2011, p.3) claimed that "the policy centres and global forums formulated the concept that smart grids and their technologies provides an opportunity to promote economic growth, while emphasizing environmental sustainable methods for energy reception and transmission", as well as "renewable electricity generation should strengthen coherence (reducing the negative environmental factors), reducing greenhouse gas emissions by reducing reliance on local or imported fossil fuels and increase energy security by diversifying sources of energy benefits." A similar view is shared by Caló *et al.* (2014, p.81) "A common assumption about smart grids say that their design and implementation to power networks will bring great benefits, cleaner and sustainable energy system", and "... in the future in order to achieve a sustainable energy system will need to perform the analyzes, taking into account the multi-dimensional troubleshooting structure, including the integration of different sources of energy dynamics".

Table 2.List of Environmental Smart Grid Benefits: Based on EPRI/DOE Framework (EPRI 1020342).

Benefit Sub-Category	Benefit
Environmental	Electrification
	PEVs
	Enhanced Energy Efficiency*
	Storage
	Facilitate Renewables
	Reduced CO_2 Emissions
	Reduced SO_X, NO_X and PM-10 Emissions

*Enhanced Energy Efficiency includes: continuous commissioning of large commercial buildings direct feedback on energy usage energy savings corresponding to peak load management energy savings corresponding to the enhanced M&C capability.

Source: created by author based on EPRI (2011).

Table 2 summarizes the environmental benefits of smart grids. The main important goal of saving the environment is by reducing the CO_2 and other gas emissions. There is no way smart grids can harm the environment. It's purely a "green" system allowing cutting off the unnecessary pollution, gas emissions by allowing the use of renewable energy sources.

As in any industry, environmental issues follow small and big companies. Adding insecure consumers and NGOs[6] to the mix makes it even harder to pursue new innovative ideas, even in industries that have been there for very long, such as electrical grids. Installing smart grids is one way of turning the table around. It brings both economic and environmental benefits, thus meaning that it works for both sides of the giver and receiver, especially when the receiver gains an opportunity to become a giver too. Getting rid of unsustainable energy sources and starting using renewable energy sources has been talk for decades now and with the ability of installing smart grids, it's possible to achieve a large portion of the causes made by non-renewable energy sources.

[6] NGO – Non-Governmental Organization

5. Conclusions

To view the benefits of each dimension, it is viable to understand that there are a lot of different circumstances that can change and adjust the benefits, depending on how the work of installing the smart grid is being executed, from the top of managing perspective to the bottom of making technical installations.

The most important economic benefits are: enhanced energy efficiency, distributed generation and reduced minor and major outages. Enhanced energy efficiency lets us save a lot of energy by allowing electricity to disperse from peak times to non-peak times when demand of energy use is lower. The whole point of this is installing smart meters both in households and companies / productive facilities (e.g. factories), so that information that is being gathered can be collected and the flow of electricity adjusted in real time. This way there is much more possibilities for generation distribution. It is also one of the key factors why long and short term power outages happen and by allowing the installation of smart grids, the risk of a power outage would be minimized. In economical perspective, this means that for the initial cost of smart metering, in both short and long terms, the effects of installed smart grids would be beneficial to both the consumers and provider in lower costs of distributing and maintaining electricity grids.

Social life changing benefits would be demand side management and social sustainability along with social acceptance of smart grids. Demand side management means that both small homes (i.e. households) and big company (i.e. factories) users will be available to participate in the electricity buying/selling industry. This is achieved by everyone knowing what the price of electricity is right now at the moment when they need it meaning that every user will be able to choose when to use what electricity at what cost. This allows maintaining a healthy grid, rerouting high peaks to non-peak times by selling electricity for a higher price than usual during peak time and lower during non - peak times. For this to happen a very important factor is the user's social acceptance of smart grids entering their lives. Instead of simply paying monthly electricity bills, consumers will be able to be part of an empowered administrative community and will be able to decide on their own whether they want to buy higher or lower cost electricity from different providers available on the market.

Highest scoring environmental benefits are partial removal of old, or not sustainable electricity grids (i.e. upgrade to smart grids) which brings us down to reduce gas emissions and improved use of renewable energy sources. By installing smart grids, more renewable energy sources can be added to the grid by making more and more consumers part of the electricity industry. This means every house can have its own energy source and buy/sell electricity during their time of need and preference. By adding more renewable energy sources to the main power grid, will allow to reduce the need of energy gain methods that are polluting the earth. Many of these pollutions is power plants, coal burning, etc. It will also save and let generate more energy which can be distributed to other segment of economics that will use the energy for theirs and communities benefit.

To summarize, all of the three dimensions for assessing the benefits of installing smart grids demonstrate clear and tangible multilateral benefits to consumers and providers. In some cases, one dimension will outshine the other, depending on many factors and the different variables that add up in the whole smart grid installing process. All in all, the installing of smart grids, will bring a more sustainable power grid for future generations and will allow a faster economic growth for regions. It will educate distributors and customers to a new way of relating to market equilibriums, and most importantly it will be fully environmentally friendly. This shows how tied up all three dimensional factors are and by proceeding further it is necessary to analyze and understand all of them and not be misinformed in the future about the possibility of upgrading old electrical grids to smart grids.

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