Smart Grid Analytics for Sustainability and Urbanization

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Chapter 4
Smart Cities, Smart Grids, and Smart Grid Analytics:
How to Solve an Urban Problem

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ABSTRACT

The introduction of the 21st century has experienced a growing trend in the number of people who choose to live within a city. Rapid urbanisation however, comes a variety of issues which are technical, social, physical and organisational in nature because of the complex gathering of large population numbers in such a spatially limited area. This rapid growth in population presents new challenges for the already stretched city services and infrastructure as they are faced with the problems of finding smarter methods to deal with issues including: traffic congestion, waste management and increased energy usage. This chapter examines the phenomenon of smart cities, their many definitions, their ability to alleviate the discomforts cities suffer due to rapid urbanisation and ultimately offer an improved and more sustainable lives for the city's citizens. This chapter also highlights the benefits of smart grids, their bi-directional real-time communication ability, and their other qualities.

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INTRODUCTION

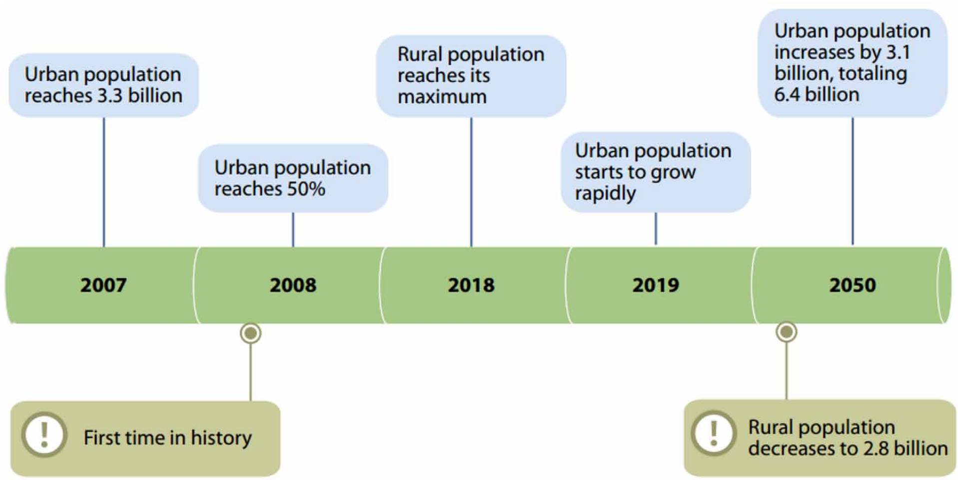
Urbanism has existed for more than 5,000 years witnessing cities being formed according to their landscape, their position from the sea, the ruling of rivers and the transportation networks that connect cities (Anthopoulos & Vakali, 2012).The period between 1950 and 2005 has witnessed a marked annual increase in urbanisation within the developing countries, with a reported growth rate of 3.6% compared to the 1.4% experienced in industrialised countries. By the year 2000 an estimated 45% of the population in developing countries (1.97 billion) and 75% (945 million) of developed countries were already living in cities (Khansari et al., 2014).

Between the years 2009 and 2050 it is predicted that the world's population will increase by 2.3 billion taking it to 9.1 billion people in total and over this same period the population within urban areas is predicted to grow by 2.9 billion to reach 6.3 billion people or 70% of the world's population by 2050. These figures hide a significant difference between the new and emerging markets with the least developed countries witnessing the most dramatic population growth and urbanisation (Bélissent, 2010).

The United Nations (UN) has predicted that by the year 2050 the rapid relocation to cities will have caused the world's urban population to increase by 75% and the result of this migration to the cities will be an increase in the number of densely populated areas (Barrionuevo et al., 2012). This figure differs as a 2007 to 2008 United Nations World Urbanisation Prospects study claims that the population within urban areas is to gain 3.1 billion surpassing the 3.3 billion in 2007 to a figure of 6.4 billion in the year 2050 as shown in Figure 1 (Washburn et al., 2009).

Cities were formed as a natural response to changed life circumstances and have also had a profound and lasting impact on the further development and progress of the human species (Schuurman et al., 2012). Cities are the future of humankind. The 18th century witnessed less than 5% of the World's population living in a city and a huge majority of these were simply engaged in generating enough food to live. The entry into the 21st century however, has been accompanied with a strong worldwide inclination to increase the concentration of the population within fairly few large cities. These large dense cities are attractive and appeal to their citizens as they have the potential to be both highly productive and pioneering and thus very attractive for our futures (Harrison & Donnelly, 2011). Despite only making up 2% of the world's surface cities house half of the world's population, consume 75% of our energy resources, and produce 80% of the carbon which is harming our environment (Aoun, 2013).

Figure 1. Urbanisation causing cities to outgrow rural areas (Washburn et al., 2009)



Urbanisation is driven by profound technological, social and economic changes which are incurred because of globalisation processes which in turn are forcing cities globally to adopt ground-breaking, competitive, sustainable and long-term policy strategies (Schuurman et al., 2012). Urban living is beginning to adopt a principal role in how humankind evolves as today there are reportedly more than 1 in 2 living in urban environments (Dohler et al., 2011).

As people worldwide continued to move into cities in greater numbers in a bid to improve their economic circumstances city populations continued to increase to the point where the period between 1990 and 2000 witnessed urbanisation in developing regions marked by the appearance of cities which prior to 1990 did not exist. However, along with this rapid growth and the increase in numbers migrating to the cities, the increased urbanisation is posing many major challenges to our societies including air pollution, overconsumption of resources, city congestion along with urban insecurity (Steinert et al.,2011; Hall, 1988). City governments are faced with these many challenges and others such as higher crime rates, difficulties in waste management, wasteful and increased energy consumption, the basic delivery of public services, and so on (Alawadhi et al., 2012; Steinert et al., 2011).

Rapid urbanisation increases the challenges within cities and the United Nations (UN) estimates that between 2008 and 2009 the population in both rural areas and urban areas became equal, while by the start of 2019 the number of people living in cities will exceed the numbers residing in rural areas. As the numbers residing in cities increases energy shortage presents itself as a major problem and the U.S. Energy Information Administration (EIA), an agency within the U.S. Department of Energy anticipates that the World marketed energy consumption will increase by 44% from 2006 to the 2030's. The EIA also anticipates that energy demand from emerging economies such as the BRIC countries (Brazil, Russia, India and China) will grow by 73% in this same time frame which far exceeds the 15% increase from developed countries such as the United Kingdom, the United States, Australia, France, Japan and Germany. Increases in price are common occurrences and caused by the high costs of developing new generation capabilities, the directives for more secure and renewable energy forms and the tendency for countries to import energy, particularly oil (Washburn et al., 2009).

The term 'city' and its definition are different in each country but the most common definition refers to a relatively large and permanent settlement. Cities have highly dense populations and their inhabitants mainly live because of work within industry, commerce and services. Cities are operationally based on several core structures including: energy, water, information and telecommunication, transport, business market, city services, citizens and sanitation (Morvaj et al., 2012).

In today's world where current resources are already threatened it is important to make cities greener and ultimately more sustainable as urban areas are consuming many of the resources which are currently available. Advanced systems that will enable processes to be both automated and improved inside a city will have a key function within smart cities. From the smart design of buildings which retain the rain water for later use to the intelligent control systems that monitor infrastructures autonomously, the potential improvements which are enabled by sensing technologies are immense. With predictions highlighting that the global economy will be considerably unbalanced due to the expected growth of cities, it is forecasted that by 2050 urban areas will exceed 6 billion people and such growth will further exacerbate the existing climate and energy challenges that urban areas already experience. In a bid to address these challenges cities which are more resource efficient and technology driven are required and the smart city promises to take advantage on its economic opportunities and social benefits as it alleviates the pains of urbanisation (Hancke & Hancke Jr, 2012; Washburn et al., 2009).

Several other concepts such as the smart city have all been developed and put in place such as the digital cities and ubiquitous cities in a bid to achieve both a competitive and a sustainable influence, as the cities themselves firmly believed that innovative uses of ICT would nurture sustainable city innovation which can improve the quality of life of its citizens (Schuurman et al., 2012).

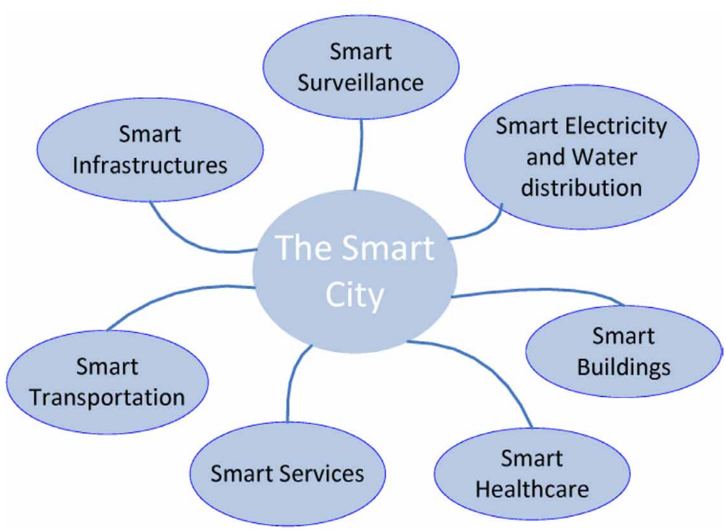
One approach adopted by several cities in a bid to curb the urban planning challenges was to transform the city into a smart city (Kuyper, 2016). As a result, momentum within the European Union (EU) continued to grow as almost every European city has witnessed various projects being started as attention to smart cities increases (Schuurman et al., 2012).

With the constant rise in world population causing an increased consumption of resources and leading to resource shortages and climate change the need for ground-breaking solutions is clear to see. Urban areas are mainly responsible for the shortage in resources thus prompting a growing need to create smart infrastructures in a search of more greener and energy efficient urban dynamics. Solutions to these problems involve improvements to most of the components of urban dynamics and ultimately the smart city itself as displayed in Figure 2.

The smart city concept can be viewed as a recognition of the increasing importance digital technologies for both achieving a competitive position and sustainable future however. The smart city-agenda grants ICTs the task of providing a vision of how to alleviate and resolve the challenges associated with rapid urbanisation through achieving many of the following goals: reduction in energy consumption, reduced carbon emissions, sustainable growth, improved quality of life for its citizens and ultimately a better urban life (Steinert et al., 2011; Schuurman et al., 2012).

For several years now cities have been incorporating the use of new technologies however, lately the rate at which technology is currently being implemented is on the increase. Cities have been making use of new technologies for several years now and as the degree of technology adoption increases cities around the world are ultimately becoming smarter. Newer technologies along with faster and easier connectivity enables cities to optimize resources, save money, and at the same time provide better services to its citizens (Cerrudo, 2015).

Figure 2. Sensing in Smart Cities (Hancke & Hancke Jr, 2012)



With recent years, having witnessed the number of world inhabitants residing in cities surpassing those residing in the countryside and the population of the Earth measuring 7170 million as of July 2014, there is a huge demand on the quantity of energy required for this number of individuals to carry out the tasks in their daily lives (Rodríguez-Molina et al., 2014).

There has however been no change to the basic structure of the electrical power grid for the last 100 years even though the average age of power grade transmission lines in the U.S. are exceeding 50-60 years. The U.S. Department of Energy (DOE) has stated that the past 20 years has experienced an increase in both demand and consumption of 2.5% annually. Experiences have shown that the hierarchical centrally controlled grid of the 20th Century is ill equipped to cater for the needs of the 21st Century as additional challenges and issues such as power-grid integration, system stability and energy storage also require addressing. Deficiencies and issues in the present system such as congestion, slow response times and safety related factors have all contributed to blackouts over the last 40 years (Gungor et al., 2010; Gungor et al., 2011). The fact that there has been a total of three major blackouts within the last ten years and it is the dependence upon on old technology which leads to uneconomical systems which are costing needless amounts of money to the utilities, consumers, and taxpayers (Metke & Ekl, 2010).

January 2009 witnessed the U.S. Department of Energy (U.S.DOE) release an assessment on the state of the U.S. electricity grid which was based on the work carried out by its Electricity Advisory Committee (EAC). The report which was officially titled "Keeping the Lights on in a New World". This report paints a very bleak picture of a Grid which is neither modern nor smart highlighting that much of the electricity supply and delivery infrastructure is approaching the end of its useful life (Collier, 2010).

With recent years has witnessed that the ageing U.S. power grids have become both underinvested, overburdened and subject to many new policies and challenges including uncertainty in schedules and transfers across regions along with the infiltration of renewable energy systems (RES). It is faced with the unpredictability of events due to limited knowledge and management of complex systems and the threat of terrorist attacks, either physical or cyber-attacks. The number of consumers has also increased as have their demands from the power system as they are expecting a better quality of service and a more reliable supply (Momoh, 2009).

Due to the many challenges, which, the existing power grid presents the new concept of the smart grid which is based on a more solid and modern communication infrastructure has emerged for enhanced efficiency and reliability (Gungor et al., 2011).

Electricity demands worldwide continue to rise with the ever-increasing population of the Earth and the smart grid presents itself as a very attractive and convincing system for the future of energy especially as the Earth has abundant, yet limited resources and it is important to justify the use of energy and allow the usage of renewable energies, thus providing electricity to use with a lower impact on the planet. The smart grid meets these needs as it not only combines efficient energy consumption with new and innovative technologies related to renewable energies, but it can also provide numerous valuable services including data provision and power monitoring (Rodríguez-Molina et al., 2014).

Both Smart Grids and Smart Cities involve the use of advanced electrical engineering and service technologies which are both assisted by ICT and additional solutions to efficiently manage complex infrastructure systems. Significant interactions exist between both Smart Grids and Smart Cities with the shared principles including intelligent interconnectivity, integration including the end user element of the Smart Grid which is also an important element of the Smart Cities (Forfás, 2013).

BACKGROUND

Smarter cities refer to those urban areas that utilise operational data such as that which arises from city traffic congestion, power consumption and public safety events to enhance the operational properties of city services (Harrison et al., 2010). With the world's urban population continuing to increase many governments are contemplating adopting the smart city concept within their cities. This involves the implementation of big data applications which will support smart city components enabling them to reach the required level of sustainability and thus improving living standards. Smart cities exploit multiple technologies to improve the performance of health, transportation, energy consumption, education, and water services leading to higher levels of comfort of their citizens. Achieving this involves cities reducing both costs and resource consumption as well as engaging with their citizens more effectively (Al Nuaimi et al., 2015).

Two of the many cities which have embraced this concept, tackling the challenges presented by urban planning and converting to smart cities are Barcelona and Amsterdam with both continuing to invest in smart city strategies to this day (Kuyper, 2016).

A recent technology which has an enormous potential in the enhancement of smart city services is big data analytics. Digitization has become an essential part of everyday life and the collection of data has resulted in the amassing of large amounts of data which can be used in many beneficial application areas. A crucial factor for success within many businesses and service domains which includes the smart city area is the effective analysis and utilisation of big data (Al Nuaimi et al., 2015).

The concept of the smart city encompasses and understands the growing importance of Information and Communication Technologies (ICT). It is vital that strategies are quickly identified and related actions performed to make cities smarter, i.e., more operationally effective, sustainable from an environmental perspective and performing in a cost-effective manner. To meet these goals smart cities, need to be managed, measured and monitored in an intelligent manner. The term "smart" is frequently replaced by other adjectives such as interconnected or intelligent. It is through the automation of services, buildings, traffic systems etc and the technological advancements in data collection that we can monitor, understand analyse and subsequently plan cities in such a way as to improve their efficiency and ultimately the quality of life for its citizens (Carli et al., 2013).

THE SMART GRID

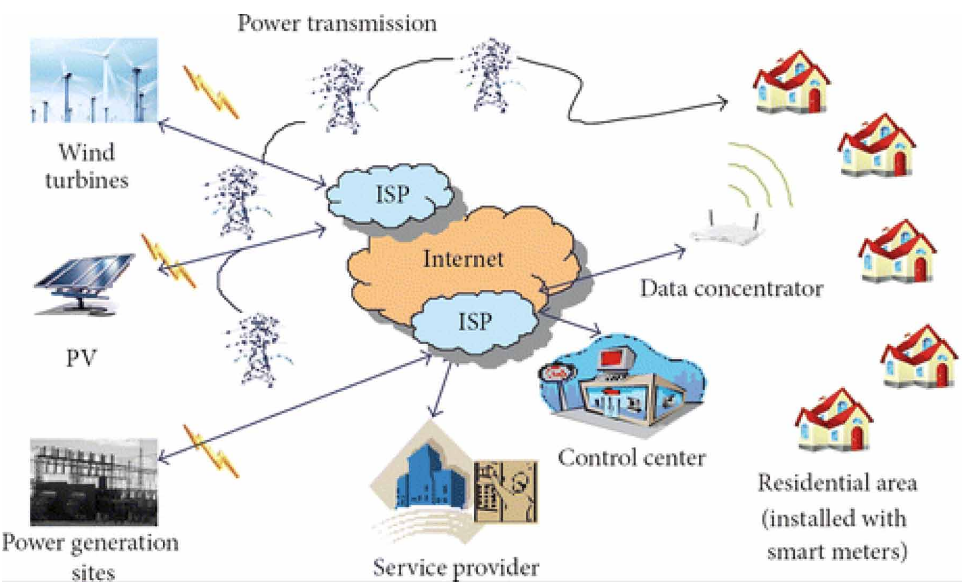
The term grid was traditionally used for an electricity system which would support all four or some of the following operations: electricity generation, electricity transmission, electricity distribution and finally electricity control (Fang et al., 2012). Smart grids comprise both hardware and software tools which allows electricity generators to transmit power more efficiently, decreasing peak capacity requirements and permitting real-time, interactive exchange of information with customers. Globally, smart grid technologies also display the potential to reduce carbon emissions (Steinert et al., 2011).

Electric systems worldwide however, have encountered many challenges including an ageing infrastructure, reliability of the electrical system, security issues which threaten the development of power systems, a continuing increase in energy demand, an increase in the number of renewable energy sources (RES) and the need to provide a secure supply of electricity to the consumer as the conventional electricity distribution systems that exist are primarily non-intelligent as these energy distribution structures only deliver a unidirectional flow from the generating station to the consumer with the supply of electricity either estimated or predicted using previous available data One improvement to the existing distribution scheme is to employ a bi-directional system which allows the flow of electricity to a client's premises and vice versa. This enables a more resourceful use of energy allowing electricity to flow back to the utility to be stored for later use in instances of low demand and such systems are collectively known as smart grids. While the traditional unidirectional power grid system has served well for the past century the modern society of today now requires a more reliable system which is more scalable, economical, manageable, cost effective and environmentally friendly. It is due to these challenges that the next generation electric power system was born. The concept of the Smart Grid has gained increased attention since its proposal by the U.S. Electric Power Research Institute in 2001 and has been propelled even further by the promotion of low carbon economies in developing countries (Yu et al., 2012; Hancke & Hancke Jr, 2012; Bari et al., 2014).

One of the critical features of the Smart Grid is use of both information and communication technologies to collect and act on information in an automated manner to increase the reliability, efficiency, sustainability and the cost effectiveness of the production, transmission and distribution of electricity. The standard Smart Grid comprises several power-generating entities and power consuming entities which are all connected through the means of a network Grid. Figure 3 displays an example of the communication architecture which exists within the Smart Grid as the generators feed energy into the grid and the consumers draw energy from the grid (Bari et al., 2014).

Using a two-way digital technology, the Smart Grid can deliver power to the consumer or end user enabling a more efficient management of the consumer's end uses of electricity and a more efficient use of the grid to correctly identify and adjust supply demand-imbalances promptly and detect faults through the self-healing process thus improving the quality of service provided, enhancing reliability of the grid and reducing costs. The Smart Grid involves more than simply installing smart

Figure 3. Example of communication architecture in the Smart Grid (Bari et al., 2014)



meters as the introduction of information technology to the electric grid develops various applications that use the devices networking and communications technology capabilities and control and data management systems (Bari et al., 2014).

One such application in Smart Grid communication and a key task in the Smart Grid is the Advanced Metering Infrastructure (AMI). Unlike the old-style method which involved technicians physically visited each consumer monthly to record the data manually the Smart Grid's two-way communication ability enables smart meters in AMI to provide real-time monitoring of power activities and consumer usage to be collected on a periodical basis (e.g. every 15 minutes) by a data concentrator using either wired or wireless communications and forwarded to a central location. Such real-time data is more efficient and precise and allows reports on power consumption to be created which enables (a) the achievement of balance of power demand and supply, (b) analysis of consumer energy usage, (c) historical data on energy consumption, (d) billing information, (e) pricing and (f) suggestions on reducing peak load (Bari et al., 2014; Li et al., 2012).

Electricity is currently the fastest-growing component of the total global energy demand. The requirement to meet this high demand for energy worldwide in a cost effective, secure and sustainable manner is motivation for investment in this area the further development of a high growth market for smart grids. One estimate places the total global investment in smart Grids between 2008 and 2015 at US$200 billion while a study for the EU Commission predicts that the total investment in the EU, U.S. and China will be a total of 365 billion euros by 2020. The market for Smart Grid technology infrastructure which includes smart meters, sensor networks, fibre optic and wireless networks, data analytics is also very lucrative and expected to rise to almost US$ 16 billion by 2020 (Forfás, 2013).

Within the electric utility industry, the Smart Grid is viewed as an up and coming business strategy as there is a need to reduce energy consumption through energy efficiency and demand response. To meet rising demands there is a need for utilities to increase generation capacity with generation coming from a mix of oil, gas, nuclear and green power and consumers are also asked to bear the burden by reducing their demand using new and efficient appliances or installing smart home controls (Roncero, 2008). As the demand for electricity as a global energy continues to grow there is in comparison to the conventional power grid, a growing demand for a sustainable, secure, clean and cost effective solution which offers a two-way flow of electricity and information between the supplier and the consumers of electric power and promotes the use of renewable energy sources (RES). Subsequently there is a growing market for the Smart Grid which involves a series of new technologies and offers these qualities in the future power grid development (Gharavi & Ghafurian, 2011; Saxena & Choi, 2015; Hancke & Hancke Jr, 2012; Yu et al., 2012; Hernández et al., 2012).

The Smart electricity Grid opens the door to many new and different applications with widespread impacts: providing the capability to incorporate more renewable energy sources (RES), electric vehicles and distributed generators into the network, ensuring the reliable and efficient delivery of power through demand response and thorough control and monitoring capabilities, the use of automatic grid reconfiguration to prevent or restore power outages (self-healing capabilities) allowing consumers to have better control over their electricity consumption and to enable them to actively participate in the electricity market (Giordano et al., 2011). A secure and reliable delivery of power around the country is achieved using a clever monitoring system which not only keeps track of energy coming in from various sources but the two-way bidirectional communication system collects data about how and when consumers are using power and can detect where energy is required surpassing the existing one directional system of power supply (Ling et al., 2012).

DEFINING THE SMART GRID

The term grid was traditionally used for an electricity system which would support all four or some of the following operations: electricity generation, electricity transmission, electricity distribution and finally electricity control (Fang et al., 2012).

Due to the complex nature, of power systems it is difficult to place a definitive definition or description on the Smart Grid as this differs depending upon location as does the vision of the stakeholders and the technological complexities involved. The European Regulators' Group for Electricity and Gas (ERGEG) defines the Smart Grid as an electricity network which efficiently incorporates the performance and activities of all the users which are connected to it such as the generators or the consumers and those that do both in a bid to ensure an economical and efficient power system which has low losses and high levels of quality and security of supply and safety (Yu et al., 2012; Bari et al.,2014).

The U.S. department of Energy (DOE) as highlighted by (Yu et al., 2012; Ardito et al., 2013) assigns a more detailed definition to the Smart Grid highlighting that the functions that the Grid must provide include the following:

- A self-healing quality from power disturbance events.
- Allow the active participation by consumers in demand response.
- Operate robustly against both physical and cyber-attacks.
- Provide high quality power suitable to meet the needs of the 21st century.
- Support for different types of storage and power generation.
- Enabling new products, services and markets.
- Enhancing assets and operating in an efficient manner.

The U.S. department of Energy (DOE) has also put forward the following definition for the Smart Grid:

An automated, widely distributed energy delivery network, the Smart Grid will be characterized by a two-way flow of electricity and information and will be capable of monitoring everything from power plants to customer preferences to individual appliances. It incorporates into the grid the benefits of distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand at the device level (Bari et al., 2014).

The definition of the Smart Grid in China differs again with the perception concentrating on all aspects of the power system to include smart power generation, transmission, distribution, storage and consumer usage. The Smart Grids in China are therefore subsequently defined as an integration of renewable energy, intelligent decision making, the adoption of new materials, energy storage technology, advanced equipment, information technology, control technology all of which can recognise digital management, intelligent decision making and interactive transactions in the generation of electricity, transmission, distribution, usage and storage (Yu et al.,2012).

KEY FEATURES AND REQUIREMENTS OF THE SMART GRID

The Smart Grid has several key requirements and characteristics and a list of the most relevant achievements and major functions include the following:

1. **Self-healing:** The Grid has a reduction in restoration time and maintenance due to predictive analytics and the self-healing attribute of the Grid which is aware of the status of every major component in real or near real time and has control equipment to provide optional routing paths which provides the capability for alternative flow of electricity throughout the system to maintain power to all customers (Gharavi & Ghafurian, 2011; Ardito et al., 2013; Roncero, 2008; Giordano et al., 2011).
2. **Secure Electricity Supply:** Due to the two- way end to end communication capability which the Smart Grid supplies there is the need for secure communications as the requirement of both physical and cyber security of all assets is critical (Gharavi & Ghafurian, 2011; Ardito et al., 2013; Saxena & Choi, 2015; Yu et al., 2012; Kim et al., 2015
3. **Interactive:** The Smart Grid integrates both electricity and communication in an electric network which supports a new generation of interactive energy, supplying the end consumer with digital quality electricity after making

intelligent decisions regarding the transactions of electricity, generation, transmission, deployment usage and storage (Gharavi & Ghafurian, 2011; Roncero, 2008; Yu et al., 2012).

4. **Predictive:** The Smart Grid uses machine learning, impact projections and analysis to make predictions of the next most likely events so that appropriate actions can be taken to reconfigure the system. Through the Smart Grid's exchange of information between different elements it can deliver predictive information and advice to utilities, their suppliers and their customers also on how to manage their power supply in a better manner. The self-healing and predictive qualities of the Grid also reduces restoration time (Roncero, 2008; Gharavi & Ghafurian, 2011; Kim et al., 2015).
5. **Renewable Energy:** The Smart Grid through two-way communication can increase the ability to deploy the addition of renewable energy sources (RES) to assist with addressing global climate change and the integration of distributed and renewable energy provides electric power to consumers in a more reliable and efficient manner (Saxena & Choi, 2015; Gharavi & Ghafurian, 2011; Yu et al., 2012; Giordano et al., 2011).
6. **Sustainable:** The Smart Grid enables better use of the assets, it should provide long term sustainable power system which is aware of all the actions of the users connected to it to enable it to efficiently provide a sustainable supply of electricity with low losses and high levels of quality and security for the safe supply of power (Ardito et al., 2013; Gharavi & Ghafurian, 2011; Yu et al., 2012).
7. **Economic:** In comparison to the traditional power grids the Smart Grids are both economically efficient and environmentally friendly (Yu et al., 2012).
8. **Cleaner Energy:** The introduction of the Smart Grid should allow for the use of electric vehicles thus reducing the need for hydrocarbon fuels resulting on a reduction of the carbon footprint of modern society and an increase in low carbon economies within developing countries (Yu et al., 2012; Gharavi & Ghafurian, 2011).

Development of the Smart Grid and the key features and requirements as categorised above does not involve replacement of the current existing electricity network as such a procedure would be impossible both from a technical and economical perspective. Development of the Smart Grid is however an enhancement of the existing network through the introduction of new features and services. The Smart Grid however continues to build on the available infrastructure increasing the employment of existing properties and empowers the application of the new functionality (Ardito et al., 2013; Gharavi & Ghafurian, 2011).

POLLUTION

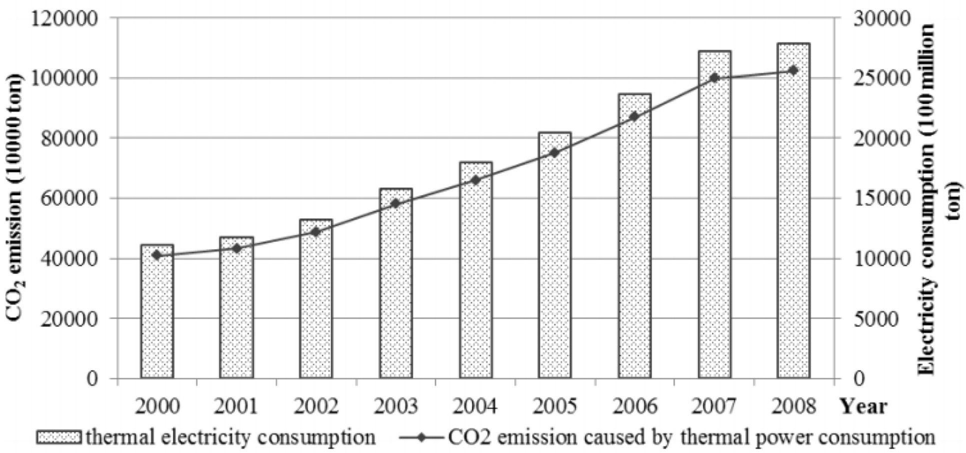
The current rates at which the resources of the Earth are being consumed are unsustainable and as such is creating a major environmental problem. Climate change, depletion of resources and air pollution have a major influence on both the Earth and its population resulting in a need to change our current behaviour (Boudreau et al., 2008). The rapid urbanisation which has been experienced has had an environmental impact even though cities only account for a mere 2% of the planet they are however, accountable for 60 to 80 percent of energy consumption and 75% of carbon dioxide emissions which contribute to global warming. (Boudreau et al., 2008; Barrionuevo et al., 2012; Albino et al., 2015; Aoun, 2013; Kennedy et al., 2009).

While current technology such as coal-fired power stations provides, the essential electricity required to support our comfortable lifestyles they also create carbon emissions and contribute to global warming at the same time (Boudreau et al., 2008). As electricity consumption leads to 40% of worldwide carbon dioxide emissions mainly since almost 70% of electricity is currently produced from fossil fuels there is a need for smart grid technologies to reduce these emissions through feedback on current energy usage, more efficient usage and improved peak load management (see (https://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf).

As public concern over environmental issues persists in growing, worldwide efforts for a greater environmental sustainability have not been able to stabilise or even decrease the atmospheric level of greenhouse gases (GHGs). The largest percentage (49%) of GHG emissions are produced by the energy supply sector and due to an increased energy demand and a larger share of coal in the global fuel mix, GHG emissions associated with the energy supply sector have increased more rapidly between 2000 and 2010 than in the previous three decades with the year 2013 witnessing the levels of carbon dioxide, the principal GHG produced due to the burning of fossil fuels such as coal and oil surged to its fastest rate in 30 years with a total of 50 billion tons of carbon dioxide being emitted annually (Kranz et al., 2015).

With the increasing demand for electricity there has also been a rapid rise in electricity consumption- related carbon dioxide emissions. In all areas concerning carbon dioxide emissions a total of 40% can be attributed to the electricity industry in China. As the demand for electricity has increased the electricity consumption related carbon dioxide emissions have also increased (Figure 4). With both economic output and energy consumption continuing to rise in the future there is a major need to develop a power system which has both high efficiency and low carbon emissions for the healthy development of the electricity industry (Yu et al.,2015).

Figure 4. Electricity related CO2 emissions in China from 2000 to 2008. (Yu et al., 2015)



One of the main goals of smart cities is ensuring that the level of pollution remains at an acceptable level by paying attention to carbon emissions which present a serious threat to both our planet and health. With rapid urbanisation comes increased traffic pollution, waste and energy costs all of which present as threats to human health and sustainability (Barrionuevo et al., 2012; Hancke & Hancke Jr, 2012).

TRANSPORTATION

Smart transport is focussed on the development of infrastructure, technologies and systems all of which are energy efficient, have low impact on the environment and provide the necessary mobility required by society in a cost-effective manner. Research into the area of intelligent transport systems is receiving much interest and investment from leaders in telecommunications and software and leading car manufacturers (Dohler et al., 2011). Urban planners can also use of big data to improve decisions made regarding both road and mass transit traffic patterns to better plan for future developments or improvements to the infrastructure (Hiller & Blanke, 2016).

Facilitating methods by which citizens can get around cities and access public services is a major challenge for urban planners especially since the increase in urban populations. However, many cities are already addressing this issue such as Curitiba, Brazil which has introduced a transportation system to improve mobility for which a fleet of 2,160 buses have already been designated providing the city with high capacity, high speed, high frequency buses complemented by other lines operating between neighbourhoods. The inclusion of an extra120 kilometres of bike lanes within the city also displays the city's movement towards tackling mobility for the city's citizens (Barrionuevo et al., 2012).

Work on the other side of the world in Singapore is being carried out on a pilot project to ascertain the most effective and beneficial technology for enabling urban mobility and the city has already installed a system of traffic sensors enabling authorities to predict traffic jams up to one hour in advance (Barrionuevo et al., 2012).

The transport sector however, is also the second leading source of worldwide GHG emissions after energy. ICT solutions have the ability to reduce transport needs by making it easier to mix methods of transportation and select the most energy-efficient type of transport. Such solutions can also help optimise routes and reduce inventory needs encouraging more efficient driving. With the increase in fuel prices many companies will adopt the use of the more energy efficient ICT solutions which in turn has a major influence on the reduction of emissions (Steinert et al., 2011).

Of all the energy, related activities which humans carry out in an urban environment traffic is one of the most energy expensive ones. In addition, it is also characterised by large waste as only 30% of the fuel potential is used to transfer kinetic energy to the actual vehicle with the majority of this energy is dissipated in decelerating phases by brakes and gases. Power bumps are however, pioneering energy harvesting devices which reduce the speed of vehicles through the conversion of kinetic energy which is otherwise wasted by brakes into electricity. For evident reasons of energy balance these devices should not be randomly placed on road networks but however positioned in decelerating sites only which includes urban road crossings, pedestrian crossings, main road exits and where standard passive speed bumps are installed (Pirisi et al., 2012).

The large increase in car ownership in recent years highlights the need for better traffic management top avoid the occurrence of traffic jams and improve the flow of traffic especially at intersections. A traditional way to regulate and monitor the flow of traffic involves using traffic lights. Typically, these have fixed switch interval times (*i.e.*, from red to green and to yellow), and this is not altered according to traffic conditions. Traffic jams have serious influences on fuel consumption due to the increased frequency in starts and stops and there is also increased carbon emissions as a result. Estimation of the number of cars approaching an intersection would generate useful information whereby switch interval times could be adjusted based on the volume of traffic. For such a system to be realised the detection of traffic and the counting of the number of cars is required. The removal of stop signs and traffic lights to tackle traffic conditions has also been proposed however, this requires vehicles which are connected wirelessly and able to communicate with each other to adopt the use of decision making for collision avoidance and using a time slot technique a vehicle would be able to negotiate intersections with wireless communication taking place through RFID (Hancke & Hancke Jr, 2012).

The ownership of electric vehicles is a growing concern and continues to be more popular as environmental concerns increase (Moslehi & Kumar, 2010). Electric vehicles are a means of reducing the reliance on fossil fuels which in today's world are the principal energy source in both the transport and power generation industry. Depletion of these resources which are unsustainable has led to the need for an alternative solution as the oil economy is both unsustainable and very limited. The burning of fossil fuels produces emissions of greenhouse gases (GHGs) which are highly influential in world climate change (Moslehi & Kumar, 2010; Mwasilu et al., 2014).

By 2050 due to the significant increase in electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) the transport sector will account for 10% of overall electricity consumption. If vehicle charging is not managed correctly it could increase the peak demands experienced in both residential and service sectors thus requiring infrastructure investment to avoid supply failure. Over the long term the smart grid technology could allow electric vehicles to feed electricity stored in their batteries back into the system when required. (see (https://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf).

RENEWABLE ENERGY SOURCES (RES)

Even though fossil fuels are the main source of energy worldwide today, the world is however considering the use of alternatives to energy generation systems which are more economical and environmentally friendly. There are several factors which influence this decision and they include: (a) an increased demand for electric power from both developing and developed countries, (b) the lack of resources within many developing countries to build power plants and distribution networks, (c) some industrialised countries facing insufficient power generation and (d) greenhouse gas emissions and concerns over climate change (Mohd et al., 2008).

The U.S. accounted for 95% of the installed wind energy worldwide in the early 1980's but recorded figures saw this figure drop to only 22% in 1998 as other nations adopted this practice of power generation. The past 30 years has witnessed the rapid growth in sales of both solar and wind power systems as the cost of the electricity generated have continued to improve while investment costs decline (Herzog et al., 2001).

The market for energy storage technologies has also witnessed a rapid growth and Ireland has significant advantages for research, development and the trialling of such technologies as Ireland's island status presents major early challenges for the grid system having limited interconnections with its neighbours and boasts a rich wind energy source with a target of 40% of electricity to come from renewable sources by the year 2020 which is the highest in the EU for variable renewables within a single system (Forfás, 2013).

The Smart Grid through its ability to allow a two-way flow of electricity and information is however expected to meet the required needs of the modern power system and revolutionise electricity generation, transmission and the distribution process. The Smart Grid also complements the current electric grid by the inclusion of renewable energy sources (RES) such as wind, solar and biomass which are more environmentally friendly and cleaner in comparison to the fossil fuels currently used in many bulk electric power generation facilities in the majority (Bari et al., 2014). While centralised sources of generation will continue to play a major role within the Smart Grid, large-scale wind and solar generation both however, also have a part to play in the generation of power while the cost is justified (Gharavi & Ghafurian, 2011).

The impact of human factors on climate change has forced the scientific community to focus on renewable energy systems as they represent a way of maintaining our current way of life and energy consumption levels without depleting our non-renewable sources such as carbon and fossils which are currently the primary cause of climate change (Pirisi et al., 2012).

Renewable energy sources have an enormous potential as they can in principle meet the world's energy demands many times over and the provision of sustainable energy services can be achieved using normal, accessible, renewable energy sources such as biomass power plants, fuel cells, wind turbines, solar-thermo power, hydropower turbines, photovoltaic solar systems, gas micro-turbines, combined heat and power (CHP), micro turbines, and hybrid power systems. Wind has enormous potential as it is a globally clean source of energy which is available worldwide and produces no pollution during power generation (Herzog et al., 2001; Mohd et al., 2008). With recent advances in the technology of power systems, the integration of wind energy into the Smart Grid has become a reality and has seen both on land and offshore wind energy becoming major workings of the energy systems worldwide. The Smart Grid enables the connectivity of wind turbines as occasional sources of energy while advanced turbines with power electronics and other devices are authorised to support the Grid with reactive power protecting equipment during severe Grid disturbances (Gharavi & Ghafurian, 2011).

Renewable energy sources including wind, biomass, solar geothermal and hydropower can all provide renewable energy sources based on the use of regular local resources which are all routinely available. Their transition into renewable based energy systems is becoming more attractive as their costs have dropped as the prices of both oil and gas continue to fluctuate. Fossil fuel and renewable energy prices, social and environmental costs are moving in opposite directions and it has become clear that future development in the energy sector will be predominantly in the new regime of renewable energy and to a certain degree natural gas-based systems and not the conventional oil and coal based sources (Herzog et al., 2001). The ability in producing smarter, lower-consumption energy based on renewable sources such as hydropower, solar, wind, biomass and biofuels, geothermal, and ocean and tides signifies an important step forward towards a sustainable energy future and creates new and exciting opportunities for cities (Khansari et al., 2014).

Despite the many benefits such as sustainability which alternative energy technologies such as wind and solar provide, renewable energy sources do however have negative consequences also (e.g. the energy and materials required for the construction of wind turbines or solar panels) (Boudreau et al., 2008).

THE SMART CITY

While the actual phrase Smart Cities is however not new itself as its actual origins may have originated from the Smart Growth movement of the late 1990s which promoted new policies for urban planning. Since 2005 several technology companies have adopted this phrase for the application of complex information systems to combine the operation of urban infrastructure and services including, buildings, water and electrical distribution, transportation and the provision of public safety. This phrase has since changed to include virtually any form of technology-based improvement in the planning, development and the operation of cities such as the deployment of services required for plug-in electric vehicles (Harrison & Donnelly, 2011). The general notion of the Smart City arose due to the utilisation of information technology for decision making by citizens, service providers and city government alike (Khansari et al., 2014).

With the current economic crisis which exists combined with the increasing expectations citizens have, cities experience increased pressure to behave in a smarter way providing both better and more efficient infrastructures and services, often at a reduced cost and it is this which has contributed to the term "Smart City" (Ballon et al., 2011).

The term or phrase "Smart City" is far-reaching and can incorporate a selection of different services which are offered to citizens and visitors alike and different ideas and objectives which vary from city to city despite being in the same country. However, the Smart City does offer one vision and that is resolving the troubling challenges by applying ICT to alleviate the impacts suffered due to rapid urbanisation and the associated follow- on effects (Steinert et al., 2011). The concept of the "Smart City" is relatively new in origin although it stems from or at least is a more advanced descendant of the older "information city", "digital city" and the "intelligent city" categories as recent years have witnessed the Smart City surpass its predecessors in popularity (De Jong, 2015). A controlled use of energy is a fundamental factor in the development of the Smart City concept as many of the ideas of the Smart City such as the charging of low polluting electric vehicles or the use of electric heat pumps as a different lower carbon dioxide emission central heating technology all require an energy source to function efficiently (https://www.gov.uk/government/publications/smart-cities-background-paper). Despite its new origin, the Smart City concept still covers a wide cross-section of approaches and procedures to enrich the quality of urban living, the provision and the management of public services and long-term sustainability. After all a city's strength and standing depend on multiple factors including communication technology, waste management, public transport, access to clean drinking water, education, health and public safety (Barrionuevo et al., 2012). In an approach for tackling the many challenges encountered in urban management the concept of the "smart", "intelligent" or "cognitive" cities have all gained increasing attention as a method for dealing and resolving these challenges (Khansari et al., 2014).

Technology, particularly the use of ICT in connecting people, political institutions and business led to the birth of the Smart City. The Smart City's development is also attributed to the application of technology and other hi-tech solutions to urban problems as other technologies also play important parts as they aim to improve issues such as mobility and the environmental sustainability within the city (Dameri, 2013).

Smart cities are looked upon as recognition of the increasing importance which digital technologies play in both a competitive and sustainable future. The Smart City has awarded ICTs with the ultimate task of achieving urban development goals such as improving the quality of life for its citizens and creating sustainable growth. There have been six main areas identified where digital innovations should make a difference and they include: smart living, smart governance, smart economy, smart environment, smart people and smart mobility (Schuurman et al., 2012; Vanolo, 2014; Steinert et al., 2011).

The term Smart City is distinguished using the six conceptually distinct characteristics (Vanolo, 2014; Steinert et al., 2011; Lombardi, 2011):

1. **Smart Economy:** This involves the creation of business opportunities, providing citizens and businesses with broadband access and enabling networks to expand outside city centres. It also involves using electronic means in business processes of all kinds such as e-banking, e-shopping and e-auction.
2. **Smart Mobility:** This refers to local accessibility, the availability of ICTs and transport systems which are safe, modern and sustainable and the promotion of more efficient and intelligent transportation systems.
3. **Smart People:** Linked to the level of human qualification and social capital, originality, flexibility, tolerance, cosmopolitanism and the participation in public life.
4. **Smart Living:** This involves the quality of life which is imagined and measured in terms of availability of both cultural and education services, tourist attractions, social cohesion healthy environment, personal safety housing, access to a high-quality healthcare service.
5. **Smart Environment:** This is understood in terms of attractiveness of natural conditions, lack of pollution and sustainable management of resources and reduction in energy consumption through the application of novel technology innovations while promoting energy conservation.
6. **Smart Governance:** This relates to the decision-making process, transparency of governance systems, the availability of public services and quality of political strategies.

A Smart City indicates the usage of all available technology and resources in both a coordinated and intelligent manner to develop urban centres that are integrated, habitable and sustainable (Barrionuevo et al., 2012) who identified that the five types of capital which contribute towards a city's intelligence include the following:

- Economic (foreign investment, international transactions, gross domestic product (GDP) and sector strength).
- Human (talent, education creativity, innovation).
- Social (traditions, habits, families, religions).
- Environmental (energy policies, water and waste management, landscape).
- Institutional (civic engagement, elections and administrative authority).

The assumption of a smart city is that by having the correct information at the correct time, citizens, service providers, and city governments will similarly be enabled to make better decisions resulting in a better quality of life for the city's inhabitants and the overall sustainability of the city. However, information resulting from a Smart City application has a two-fold impact as firstly it changes the social behaviour of citizens towards a more sustainable utilisation of city resources (bottom-up) and secondly it enables service providers including utilities, service providers and city governments to provide a more sustainable and efficient service (top-down). All of the important infrastructures within smart cities such as roads, bridges, tunnels, rails, subways, airports, seaports, communication infrastructures, water power and major buildings are all monitored to maximise the services that are available to citizens including security services while optimising the use of resources. Real-time information regarding the status of urban services is required by cities so that they can improve public safety and offer sufficient infrastructure-based services including reliable electricity, safe drinking water, reliable communication and dependable transportation (Khansari et al., 2014).

Traditional cities however, differ from the Smart City as they are not able to enhance this provision of services simply due to the constantly changing conditions. The Smart City provides the required infrastructure for both citizens and officials enabling them to make more intelligent and informed decisions which plays an important role in dealing with challenges which relate to ecological, social, cultural and economic sustainability (Khansari et al.,2014).

The Smart City architecture involves the following three layers (Khansari et al.,2014):

1. **Human/Institutional Layer:** This layer comprises all residents, non-governmental organisations (NGOs), regulators and actors within the private sector who are involved in the creation of market dynamics. The addition of profit maximisation goals into the financial utility function of these social agents defines strategies at both the data network and the physical network levels.
2. **Data Layer:** This layer includes all the data gathering devices, information sensors local wireless and cellular networks which monitor the standing of various systems within the city. This layer also combines subsystems to make the overarching system ultimately more "smart."
3. **Physical Layer:** This layer comprises all the physical objects and infrastructures and their associated physical properties providing connectivity for the city's subsystems. It enables wireless sensors to be installed in components of the physical layer to collect monitored parameters and transfer this data to the data network layer and data network agents can likewise use those sensors/ actuators within the physical layer to monitor the performance of city systems and start control actions based on the economic optimisation scheme employed within the social network layer.

Smart cities ultimately can alter the environmental and social behaviours of citizens whether this involves the provision of information about mechanisms for reduction in energy consumption or updating on travel routes. They also enable smart governance and political participation among citizens and officials using ICTs such as e-governance and e-democracy. They control urban infrastructures such as systems of water, energy and land use, transportation supporting the use of renewable energy sources as a path to sustainable development. However, in adopting these technologies cites must deal with the challenges of privacy, security and government surveillance (Khansari et al., 2014).

A city is a Smart city when it operates in a sustainable and intelligent manner through the integration of all it infrastructures and services into one cohesive unit adopting the use of intelligent devices for monitoring and control ensuring both sustainability and efficiency. Sensors are a crucial element of any intelligent control system and a process is enhanced according to its environment and for a control system to be conscious of its environment it is fitted with a collection of sensors which it uses to collect data and using this data it can adjust its operations accordingly. One such example in the Smart City is the use of meters in determining gas, electricity and water consumption which would have been traditionally mechanical however, as smart metering implies a new technology of electricity meters have evolved from the manual procedure to automatic meter reading (AMR) reducing costs, improving accuracy of readings and leading to an advanced metering infrastructure (AMI) which unlike the (AMR) allows two-way communication with the meter driven by a growing understanding of the benefits of the two-way interactions between system operators, consumers and their loads and resources (Hancke & Hancke Jr, 2012).

The ability for Smart Cities to offer broadband connectivity to all city resident is limited by several factors which include the cost of deployment, operation, maintenance of the network. In a bid to overcome these challenges several approaches are adopted as unsurprisingly the largest challenge encountered is the financial cost of the smart cities broadband network. Several different approaches have been proposed by both national and regional government bodies and various industry stakeholders. These involve the sharing of some resources in a type of public-private partnership arrangement with various service providers. One primary approach proposed involves smart buildings and technologies assist to make the design, construction and operation of buildings both new and existing more efficient. ICT technologies and solutions include the building of management systems which run both heating and cooling systems which run accordingly to the needs of the occupant of the building and software which switches off personal computers and monitors in buildings when everybody has returned home. The building of energy management systems can reduce energy consumption by 5 to 40% and globally smart building technologies could eliminate 216 billion euros worth of carbon dioxide emissions (Steinert et al., 2011).

Essentially the formation of a Smart City is dependent on ubiquitous connectivity. Individuals, companies, governmental and non-governmental organisations, educational and healthcare institutions, public safety providers, objects such as buildings, sensors, all types of fixed and mobile devices and utilities and all the processes connected to a city require the ability to interact with each other in real time to enable the sharing of data and other content in a safe and secure manner. Ultimately the brain of the Smart City is the Smart Cities broadband network (Steinert et al., 2011).

DATA IN THE SMART CITY

The Internet integrated Smart City is becoming a reality within urban centres worldwide as this data-driven city is dependent on data collected from several different areas including buildings, infrastructures, people and third party data brokers. Exploration into how big data can be used for the building of smart cities in the developing and emerging regions of the world. Large technology companies such as Microsoft and Cisco assist with the design and security of the Internet of Everything which is fundamental to Smart Cities. Data-driven analytics delivers a wealth of information including the understanding of citizen and environmental relationships driving sustainable decisions and building urban survivability. Big data which describes the storage, collection, use and reuse of huge amounts of data collected from smartphones, the Internet, publicly and privately and increasingly from sensor devices of all shapes and forms. Big data is created in Smart Cities due to the use of technology and applications to both collect and analyse personal information from citizens and residents which is shared across functional areas and used in the urban planning process (Hiller & Blanke, 2016).

Due to the large volumes of data collected within a fully smart city an individual's every movement can be tracked and the data will show where he/she works, the different modes of transport they take, their shopping habits, places they visit and their proximity to other individuals. Such data will be centralised and easily accessible. Private companies will know more about people than they know about themselves (Hiller & Blanke, 2016).

SECURITY ISSUES

The large volume and quality of data collected will increase as the Smart Cities develops and as personal data is collected from smartphones, smart meters, plug-in electric vehicles and sensors making personal privacy a matter for concern (Bartoli et al., 2011)

Despite the many advantages which come from the collection of vast amounts of data interest regarding the subject of personal information and its privacy has grown raising serious issues. The widespread use of sensors and surveillance within the Smart City creates a society which ignores the privacy of individuals although big data is created in Smart Cities because of the use of the technology and applications to collect personal information from the city's residents for use in the urban planning process. For cities to become smarter, in many cases they will often have no other option but to collect either identifiable or personal information from its citizens or residents. Precise laws and regulations may be required for the Smart City, data collection, and the preservation of individual privacy and some areas have already taken and addressed these concerns. It has been proposed that both communities and individuals should have the option of making informed decisions with a complete list of who, why and whether their data is to be used and for what length of time this should take place (Hiller & Blanke, 2016).

Smart grids lead to a whole new set of challenges and a major component of future smart grids relies on both cyber security and control as the two most important challenges faced by the future smart grid are security and privacy while the two different classes of attack on the smart grid are either cyber or physical (Hiller & Blanke, 2016; Ardito et al., 2013; Saxena & Choi, 2015). These two different classes can be differentiated as the cyber-attack may cause a misbehaviour of physical components managed by software routines whereas the physical attack might lead to AMI bypassing to falsify accounting values or cause instability due to physical destruction (Ardito et al., 2013). Cyber-attacks can be divided in the following four categories (Hiller & Blanke, 2016):

1. **Device Attacks:** This is usually the first step of a complicated attack and it involves compromising the control of a grid device.
2. **Data Attacks:** The goal of a data attack is inserting, deleting or altering the data flow to get misbehaviours.
3. **Privacy Attacks:** This tries to use electricity usage data with the aim of learning or inferring the user's personal details/information.
4. **Network Availability Attacks:** The purpose of this type of attack is to overpower the communication and computational resources of the grid thus resulting in delay or failure of communication.

While the issues of security and privacy are, important issues faced by the smart grid and authentication is a key challenge in smart grid communication the modern power grid employs the use of supervisory control and data acquisition (SCADA) systems with communication protocols. However, these protocols used in these systems are often vulnerable to man in the middle (MITM) attacks, replay attacks, impersonation attacks and the cryptographic keys used in various devices of the system may become compromised as a result. The process of authentication involves proving the identity of a given system, including users, applications and devices as the typical smart grid network involves millions of devices all interacting with each other. Information exchange in the smart grid network requires all involved entities to be bi-directionally authenticated (Saxena & Choi, 2015).

DEFINITION OF THE SMART CITY

Although no agreed definition exists regarding a Smart City several components can be identified including: smart economy; smart mobility; smart environment; smart people; smart living; and smart governance (Vanolo, 2014; Steinert et al., 2011; Lombardi, 2011). Cities can be defined as smart when investment in both human and social capital together with investment in traditional (transport) and modern information and telecommunication infrastructure generates sustainable economic development and a high quality of life while promoting prudent management of natural resources (De Jong et al., 2015). Despite the lack of a widely recognised and accepted definition it is now however, possible to try and write the following comprehensive definition of the Smart City:

A smart city is a well-defined geographical area, in which high technologies such as ICT, logistic, energy production, and so on, cooperate to create benefits for citizens in terms of well-being, inclusion and participation, environmental quality, intelligent development; it is governed by a well-defined pool of subjects, able to state the rules and policy for the city government and development (Dameri, 2013).

SMART CITY PROTOTYPE

An early example or prototype of the Smart City is Santander a small port city in Spain. The city includes the installation of approximately 12,000 sensors placed in many different locations including under the asphalt, attached to street lamps and affixed to the top of city buses as well as many other locations. The sensors are designed to measure air pollution, locate the availability of parking spaces, have the availability to dim street lighting and even go as far as telling the garbage collectors when public bins are full. Street signs are fitted out with digital panels which display real-time parking information which is relayed back to a central control centre. City residents can download a selection of smartphone applications to obtain city information such as information on parking spaces, road closures, bus delays and pollen counts. Using this prototype, the city has saved about 25% on its electricity costs and 20% on garbage collection alone (Hiller & Blanke, 2016).

Several triggers can put cities on the road to becoming smart as the city may play host to a demonstration project which enables one or a few different companies to test their most innovative solutions and one such city is Songdo in South Korea were digital innovation projects are being tested (Aoun, 2013). This half-finished South Korean city of Songdo is a mixture of empty plots and gleaming towers built on landfill which was dumped into the Yellow Sea and when the 607 hectare Songdo IBD (International Business District) which comprises the heart of the city is complete many developers believe it will be the greenest, most wired city in the world (Strickland, 2011).

Business hubs like Songdo in South Korea unlike conventional cities are newly built and created from scratch. The city of Songdo was a joint undertaking by Cisco and real estate developers. Currently twelve years and $40 billion later it has resulted in a so-called “City of the Future” or “The World’s Smartest City” and is home to roughly 70,000 people. The city of Songdo has completed roughly 60% of its proposed infrastructure and buildings with a current population of what is expected when the project is presumed to be completed in 2018. The city comprises numerous sensors monitoring everything from temperature to the flow of traffic. Environmental planning efforts consist of charging stations for electric cars and a water recycling system which will separate clean drinking water from water which is used to flush toilets. Household waste is disposed of directly from homes into underground tunnels where it is automatically treated and processed (Hiller & Blanke, 2016). The building of newly built hubs such as Songdo in South Korea and the design of such a compactly integrated system is moderately easy as there are fundamentally no limits outside of the usual financial constraints as to what urban planners can dream up and conversely the transforming of conventional cities presented much greater challenges (Barrionuevo et al., 2012).

These new cities have the distinct advantage of incorporating the vision of the Smart City from the outset and such cities are purposely placed or located in an area which is designed to attract businesses and residents which incorporates both ICT infrastructure and world class services. These cities often include broadband connectivity, renewable energy smart transportation and other smart city systems. Such cities are increasing in numbers worldwide especially in emerging markets including: Songdo IBD, South Korea; Meixi Lake, China; Masdar City, Abu Dhabi; King Abdullah Economic City, Saudi Arabia; Lavasa, India; and the newly announced Skolkovo, Russia. While some of these new cities have government sponsors others are however privately owned (Bélissent, 2010; Washburn et al., 2009).

THE FUTURE

The Global electrical grids are approaching the greatest technological transformation since electricity was introduced into the home. The Smart Grid is replacing the out-dated infrastructure which delivers power to both homes and businesses. The grid is a modernisation of the current electrical system and it enhances the ability of customers and utilities ability to monitor control and predict their energy usage (McDaniel & McLaughlin, 2009). Many benefits have already been derived from the use of analysing big data and they include areas such as healthcare where analysing huge datasets helped in determining drug interactions, negative side effects and the advantages certain drug therapies provide and in cities the big data within the smart grid enables electricity suppliers to have better control and monitor the usage of power within the city (Hiller & Blanke, 2016).

The smart electricity grid has also opened the doors to new applications with wide ranging influences which provides the ability to safely integrate more renewable energy sources (RES), electric vehicles and a more efficient and reliable delivery of power and the grid's ability for the prevention or restoration of outages (Giordano et al., 2011).

Smart cities are the future as both climate change and population movements demand them and 2015 saw the White House declare that $160 million in financial investment was set aside for further research in this area. India itself has a goal of developing a total of 100 smart cities as it anticipates that 50% of its citizens will reside in cities by 2050 in comparison to the 32% currently living there (Hiller & Blanke, 2016).

CONCLUSION

With the Global population continuing to increase and over half of the World's population selecting only urbanisation and residing in cities as opposed to rural areas, the resources of cities as a result are subsequently stretched due to the large numbers which select city life. With the growing numbers in cities there is consequently large volumes of data generated known as 'Big Data' which is created in large quantities, high velocity and in many different formats and stored for reuse. Many different forms of data are collected regarding citizens within cities including data concerning their use of electricity, gas and water usage of residents within a city are all collected.

Cities as a rule are becoming smarter and using smart grid analytics, the basic building block for the Smart City implementation they can deliver a vast amount of information about how citizens use the city's resources enabling the city government to make smart and more sustainable decisions ultimately leading to the city's sustainability. In the world's more developed countries the focus is more on the regeneration of urban areas as opposed to the development of new cities (Kuyper, 2016) and the smart city's popularity in Europe is based on several factors including the availability of sufficient funding (Vanolo, 2014).

The smart grid does not replace the existing electrical system as such a process would be impossible for both technical and economic reasons but it enables building on the current existing infrastructure while increasing the employment of existing assets and implementing both new services and features to permit the implementation of the new functionality (Gharavi & Ghafurian, 2011; Ardito et al., 2013).

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KEY TERMS AND DEFINITIONS

Biomass: Biomass is fuel developed from organic materials, a renewable and sustainable source of energy used to create electricity or other forms of power. It is renewable not only because the energy in it comes from the sun, but also because it can re-grow over a relatively short time period in comparison to fossil fuels which take hundreds of millions of years take to form.

Data: In the computing world data is information which is converted into a form which is usable or can be processed. In computing data takes the form of binary digital form whereas raw data is data in its most basic format.

Fossil Fuels: These take the form of coal, oil and natural gases which cause carbon dioxide emissions upon burning causing greenhouse gases (GHGs) and are the main cause of climate change.

Global Warming: This refers to a gradual increase in the temperature over the Earth's atmosphere usually caused by the greenhouse effect caused because of raised carbon dioxide levels and other pollutants.

Greenhouse Gases (GHGs): These include gases which add to the greenhouse effect by absorbing infrared radiation (IR). Carbon dioxide is just one such example of a greenhouse gas.

Information and Communication Technology (ICT): Information communication technology is information technology (IT) with the communication role added via telephones or wireless signals and computers also which allows for information and audio/visual signals to be transmitted, accessed, stored and used in some format.

Pollution: The introduction of a substance or solution into the environment which has either harmful or poisonous effects on the environment.

Sustainability: The environmental quality of not harming the environment or depleting natural resources to the point where they are no longer available thus still able to support the local community.

Urbanization: This refers to the percentage of people which live in urban areas compared to rural areas. Urban areas refer to built-up areas such as cities and towns whereas rural areas refer to areas which are not industrialized such as the countryside.

Utilities: This encompasses a broad range of services such as gas, water, electricity, waste removal, and sewage systems, and at times access to computing facilities such as the internet which are provided within households and businesses alike.