Smart Grid of the Future and Enabling a Climate Economy

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ABSTRACT

As we look to continue to grow the economy, we should consider the impact our choices will have on climate change. With all things considered, the Smart Grid is a highly effective climate conscious route in growing the economy which will pay big dividends in years to come. This route offers several benefits for all stakeholders in the process: electric utilities, businesses, consumers, and the environment. The integration of demand-side resources (energy equipment behind the meter) will play a significant and disruptive role in the smart grid of the future with consumers selling electricity at comparable or cheaper prices than utilities. Users of grid power and distributed generation will have the ability to generate value from otherwise stranded renewable energy and energy efficient assets, manage these energy portfolios in the palm of their hands utilizing Energy Resource Management Systems, thus making money whilst responding to the climate challenge. The COI solution will contribute to a $21 trillion climate economy that will reduce GHG (Greenhouse Gas) Emissions by 246 GTCO2e (a 23% reduction) by the year 2050 (Project Drawdown, 2017).

VALUE OF THE SMART GRID

The introduction of the automobile transformed the lives of individuals all over. It created an industry legendary for its reliability. During the late 1800s / early 1900s, the main way for most people to get around was by foot or carriage. Innovation allowed for the first automobile to be invented and allowed consumers to choose to travel further distances. Once automobiles were transformed significant changes occurred. Cars became manufactured on an assembly line, markets were created, innovation was encouraged, and a new era of customer choice inaugurated (Woodford, 2018). This same potential exists for similar transformations and opportunities for the Smart Grid.

The Smart Grid is an infrastructure that uses a digital technology that allows for two-way communication between the utility / supplier and its customers, and sensing along the transmission lines (DOE, 2019). Controls, computers, automation, equipment and new technologies work together within the electrical grid to respond digitally to our quickly changing electric demand (DOE, 2015). This two-way communication will enable consumers to save energy, reduce costs, and increase reliability and transparency (Al Abri et al, 2015). Like the automobile, technology holds the key to Smart Grids and their future. The grid was developed during a simpler time when power was localized, sourced from fossil fuels in a predictable manner, and businesses only needed enough electricity to power a few loads throughout the day. By 2017, the grid connected to 3,200 utilities and over 2.7 million miles of power lines (Brecheisen, 2017). The revolutionizing of technology over time is driving the need for a modernized grid with progressive capabilities. The growing demand society has imposed on the grid, combined with the maturing infrastructure, has resulted in the grid approaching capacity.

A VISION OF A SMART GRID FUTURE

In order to support its continual success, a new wave of grid technology is certainly needed. This entails the largest modification since the creation of the smart grid. A major driver of this grid is the evolution of dispersed and variable energy sources such as wind and solar (Brecheisen, 2017). The smart grid allows for an easier integration of renewable energy systems such as utility-scale solar farms and customer-owned flexible energy resources like behind the meter solar chiller plants, lighting, and battery storage.

Composed of advanced digital technology, the Smart Grid is the rapidly developing, modern and tech-savvy successor to the original grid. The world is constantly developing more complexity, and therefore advancing new grid technology is vital in allowing the energy industry to advance to new levels of efficiency and reliability. Since renewable energy sources are continuing to blossom and mature, a supportive grid with demand-response technology and a higher efficiency is necessary to improve the immense potential in today’s energy industry.
In addition, the Smart Grid will add an overall benefit to the environment and society, in the form of reducing the need for traditional transmission lines, power plants, and greenhouse gas emissions. A Smart Grid built and implemented successfully will also reduce usage during peak hours. This is already being demonstrated across the US. Research from the California Energy Commission shows that demand response works. They found that customers will reduce their

demand by 5.7%. The Federal Energy Regulatory Commission (FERC) estimates that demand response can reduce peak demand by 3-7%, depending on the region. Demand response (DR) to manage customer load has been done by Progress Energy Florida (now Duke Energy) and has managed to reduce demand by as much as 2,000 MW (Scott, 2008).

CRITICAL UNAVAILABLE TECHNOLOGIES ENABLED BY THIS VISION

COI Energy has identified four major critical challenges which can be overcome by Smart Grid technologies that are now available.

The first challenge concerns power outages. Power outages in 2016 resulted in losses of over $27 billion for US businesses across eight key market segments (Wootton, 2016). Reducing the likelihood of blackouts and power outages would result in savings of millions of dollars annually. Asset management technologies within the Smart Grid will allow for a better way to monitor major transmissions assets like circuit breakers and transformers, thus allowing the grid operators to better predict maintenance needs and avoid failures. A transformer that is 230kV or higher is an important multi-million-dollar asset with progressively long lead times for delivery.

The second challenge is lack of accuracy to predict and improve life expectancy. The average age of installed large power transformers (LPTs) in the United States is approximately 38 to 40 years, with 70 percent of LPTs being 25 years or older. While the life expectancy of a power transformer varies depending on how it is used, aging power transformers are potentially subject to an increased risk of failure (DOE, 2014). Consequently, asset management methodologies enabled by the Smart Grid offer life extension, since there will be more power generation and transmission options, and thus blackouts and cascading failures are greatly reduced or eliminated (Scott, 2008).

The third challenge is market inefficiency. Market efficiency and the economy are also important perspectives to consider when discussing the Smart Grid. Market inefficiencies are a result of a lack of information which affects all market domains including financial, commodity and energy. Improved methods of forecasting and managing demand and renewable production provided by the Smart Grid will help lead to improved market efficiencies.

The fourth challenge is keeping costs low whilst fulfilling the national obligations to modernize infrastructure and tackle climate change. In the United States there has always been a privilege to use energy at a low cost while having a reliable electricity supply for roughly a century, which is a major factor for economic growth, productivity, living standards, and environmental impacts. All these aspects are at risk due to aging infrastructure, changes in energy resources, and the need to alter the carbon footprint of the asset in response to global warming. Both the commercial and industrial sectors have benefited greatly from automation, embedded intelligence and incorporation into a broader field of electronic markets. Just like in the industrial and commercial sectors, electricity too will reap the same benefits from the Smart Grid. Marketplaces such as the COI Optimizer, that shall be described later in this white paper, will equally embed GHG emission data. Federal and state policies across the US are promoting and funding the integration of emissions intelligence as part of a modernization and climate change mitigation strategy whereby reported emissions are reduced over time towards internationally agreed targets.

WHAT MAKES UP A SELF-HEALING SMART GRID

For a Smart Grid to be considered fully functional, it must feature sensors throughout the transmission and distribution grid to collect data, real-time two-way communications to move that data and electricity between utilities and consumers, and the computing power necessary to make that intelligence actionable and transactive. Indeed, only by bringing the tools, techniques and technologies that enabled the Internet to the utility and the electric grid is any sort of transformation possible. A self-healing grid always encompasses digital components and real-time communications tools to monitor its own electrical features and can offer several benefits that support a more stable and efficient system. Three of the principal functions of a self-healing smart grid include real-time monitoring and reaction, anticipation, and rapid isolation. Real-time monitoring allows for the system to continuously adjust itself to an optimal state. With anticipation, this enables the system to automatically look for problems that could trigger larger disturbances in the system. Finally, rapid isolation allows the system to isolate parts of the network that experience failure from the rest of the system to avoid the spread of the failure and enables a more rapid restoration (Amin, 2012), thus addressing the second challenge of life expectancy of systems.

As a result of these parameters, a self-healing smart-grid can reduce power outages and minimize the duration when they do occur, thereby tackling the first challenge. Since the system is self-healing, it has an “end-to-end resilience” that senses and overrides human errors that consequently results in power outages. To this end, the power sector is among the leading industries in terms of research and development. Demand for electricity is rising fast. The system needed to operate the underlying communication networks, data centers, electric vehicle charging stations and storage facilities adds more than 2500 MW of global demand per year which was not in existence five years ago. The 2500 MW is roughly equivalent to approximately 825,000 homes use in one hour (Yogi Goswami et al, 2015). It is also worth considering that with the growing utilization of the Internet and the digitization of records, the world’s electric supply needs to triple by 2050 in order to keep up. In addition to managing power disturbances, a Smart Grid has the capability to measure how and when consumers utilize the most power. With this information it allows for utility providers to charge consumers adjustable rates for energy based on supply and demand, under a highly efficient market thus dealing with the third challenge. Eventually, this adjustable rate will provide consumers an incentive to shift their most demanding use of electricity to times of the day when need is the lowest. This will allow consumers to better manage and efficiently use energy while simultaneously contributing to a healthier environment by lowering GHG emissions, in effect overcoming the fourth challenge. In order to convert our current infrastructure into a self-healing smart grid, multiple technologies must be created and integrated. The ultimate smart-grid contains small self-sufficient power systems called microgrids, a smarter and stronger high-voltage power grid that serves as support to the overall system. For the grid to have self-healing capabilities it requires replacing traditional analog technologies that have digital components, software processors, and power electronic technologies. The key ingredient to the grid becoming self-monitoring and self-healing is by installing all these components throughout the system so that they can be digitally controlled.

WHAT IS SLOWING DOWN THE IMPLEMENTATION OF THIS VISION, AND WHAT CAN BE DONE

There are several issues that factor into the slow progressiveness of the Smart Grid. The first of many being the technological development. There have been substantial developments in communication and information technology in the past decades. But in order to make the grid smarter, it is necessary to develop a new communication system, integrated or separate from the existing Internet, which would be resilient from attack and extremely dependable. Advanced sensor systems are to be developed to implement in the smart premises and grid for phase measurement, to get consumer consumption information and to control automatic circuit breakers for minimum interruption of electrical appliances during peak shaving. Innovative components like smart meters, efficient energy storage, smart appliances, high voltage DC transmission devices, and flexible AC transmission systems (FACTS) devices are to be developed and implemented. Sophisticated software creation to protect and control the grid and appliances of consumers is also a key component to be included in technological development. This will allow for the smart grid to act on its own account by decision supports and advanced control.

To keep the vision of the smart grid, the quality of the supply must also be ensured. The current grid is to be recreated and extended to guarantee quality supply to all households. There also needs to be consideration for the integration of renewable energy. The ever-changing nature of renewable energy sources like wind and solar entail complex technologies that are integrated into the existing grid. They also require large amounts of land area. Shortage of technically skilled men and women and the wrong selection spot for implementation would also play a role in hampering the integration of renewable energy.

The interoperability and cyber security can be achieved only through rigorous implementation of various standards. The interoperability standards developed by the National Institute of Standards and Technology (NIST) in the United States include:

- advanced metering infrastructure (AMI) and smart grid end-to-end security,
- revenue metering information model,
- building automation,
- inter-control center communications,
- substation automation and protection,

- application level energy management system interfaces,
- information security for power system control operations,
- phasor measurement unit (PMU) communications,
- physical and electrical interconnections between utility and distributed generation (DG),
- security for intelligent electronic devices (IEDs),
- NERC CIP 002–009 cyber security standards for the bulk power system,
- cyber security standards and guidelines for federal information systems and bulk power systems,
- price responsive and reliability DR event information,
- home area network (HAN) device communication, measurement, and control,
- HAN device communications and information model,
- smart grid Interoperability Panel (SGIP) catalogue of standards.

In earlier stages each country must develop their own standards for the implementation of smart grids considering their existing standards and for easy implementation. Internationally accepted standards and security measures will have to be implemented by all countries involved in the smart grid adoption to make the power grid a global grid (NIST, 2016).

THE MARKET SIZE OF THE ENABLING TECHNOLOGIES FOR THE SMART GRID OF THE FUTURE AND THE IMPACT IT HAS ON THE CLIMATE ECONOMY

With technology evolving and implementations happening, the global smart grid market size is expected to grow from USD 23.8 billion in 2018 to USD 61.3 billion by 2023, at a Compound Annual Growth Rate (CAGR) of 20.9% during the forecast period. This predicted growth is illustrated in Graph M.1 (Markets and Markets, 2018). Policies from the government and legislative mandates, awareness of greenhouse gas emissions, innovate grid technology, grid reliability and efficiency are driving forces in the adoption of smart grid solutions. In the forecast period, the highest market share is expected to be held in the smart grid distribution management segment. Smart grid distribution management consists of a software platform that integrates Supervisory Control and Data Acquisition (SCADA), Energy Management System (EMS), Distribution Management System (DMS), Demand Response Management (DRM), and Distributed Energy Resource Management (DERM) for energy distribution management and optimization on a real-time basis. This software market segment is expected to grow at the highest CAGR during the forecast period. The parameters in the study of the market can be viewed in Table M.1 (Markets and Markets, 2018). This table categorizes the market of the smart grid to forecasted revenues and analyze trends in each of the submarkets.

Based on the parameters, the software segment is projected to be the largest contributor to the smart grid market during the forecasted period. The smart grid market has 3 segments: software, hardware, and services. Smart grid software helps to simplify the implementation and functionality of the smart grid. The smart grid software enables grid players to ensure effective management of smart grid operations, improve process efficiency, and reduce energy production costs. Hence, the software segment in the smart grid market would witness an increasing demand from utilities. Based on software, the smart grid market consists of smart grid distribution management, substation automation, smart grid network management, grid asset management, advanced metering infrastructure (AMI), smart grid security, and billing and customer information system segments. The smart grid distribution management helps utilities in providing consistent, safe, and proficient power by offering advanced analytics, monitoring, training, and optimization by integrating Outage Management Systems (OMS), EMS, DMS, DRM, and SCADA. The main growth drivers for the smart grid distribution management software market include the growing smart grid technology market, increased adoption of distributed renewable generation, and increased regulatory pressure to reducing carbon emissions (Markets and Markets, 2018).

Table M.1

Report Metrics	Details
Market size available for years	2016–2023
Base year considered	2017
Forecast period	2018–2023
Forecast units	Value(USD)
Segments covered	Software, Hardware, Service, and Region
Geographies covered	North America, Europe, APAC, MEA, and Latin America
Companies covered	It includes 26 major vendors, namely, General Electric (US), ABB (Switzerland), Siemens (Germany), Schneider Electric (France), Itron (US), Landis+Gyr (Switzerland), Aclara (US), Cisco (US), OSI (US), IBM (US), Wipro (India), Honeywell (US), Oracle (US), S&C Electric Company (US), Eaton (Ireland), Kamstrup (Denmark), Trilliant Holdings (US), Globema (Poland), Tech Mahindra (India), Enel X North America (US), eSmart Systems (Norway), Tanatalus (US), EsyaSoft (India), Grid4C (US), and C3 Energy (US)

Graph M.1

THE ROLE CUSTOMER ENGAGEMENT PLAYS IN ENABLING A CLIMATE ECONOMY

Both utility side and business platforms play large roles in enabling a climate economy. Customer support plays a huge role in enabling a climate economy. 30% of all energy consumed in commercial and industrial buildings is wasted in the US (EPA, 2011). Lack of prosumer (business customers) awareness is one of the main challenges to addressing this waste and in the implementation of the smart grid. In order to reduce peak load consumption and promote distributed renewable energy generation, customer support is a must. Implementation of the smart grid guarantees improved quality and reliability of power supply. It allows for a user friendly and transparent interface for consumers with utilities, increased choice for prosumers including green power and options to save money by shifting loads from peak periods to off-peak periods. However, prosumers should be conscious of new technologies and support utilities to get the benefits of smart grid both for the individual and the nation.

Table S.1

Table S.1. Potential Reductions in Electricity and CO_2 Emissions in 2030 Attributable to Smart Grid Technologies

Mechanism	Reductions in Electricity Sector Energy and CO_2 Emissions[(a)] Direct (%)	Indirect (%)
Conservation Effect of Consumer Information and Feedback Systems	3	-
Joint Marketing of Energy Efficiency and Demand Response Programs	-	0
Deployment of Diagnostics in Residential and Small/Medium Commercial Buildings	3	-
Measurement & Verification (M&V) for Energy Efficiency Programs	1	0.5
Shifting Load to More Efficient Generation	<0.1	-
Support Additional Electric Vehicles and Plug-In Hybrid Electric Vehicles	3	-
Conservation Voltage Reduction and Advanced Voltage Control	2	-
Support Penetration of Renewable Wind and Solar Generation (25% renewable portfolio standard [RPS])	<0.1	5
Total Reduction	**12**	**6**

(a) Assumes 100% penetration of the smart grid technologies.

The approximations in Table S.1 are created on the annual electricity supplied to the U.S. grid and the related CO_2 emissions in 2030, as estimated by the U.S. Energy Information Agency (Markets and Markets, 2018).They represent the percentage reduction in the annual U.S. electrical energy production and resulting CO_2 reductions, based on the emissions of the average U.S. generating power plant. This allows the percentage reductions to be placed in context with the renewable portfolio standard (RPS) for their electrical system that have been already adopted by many states, typically 20% or more over a period of one or two decades. The uncertainties in these estimates are relatively high, based on the range of estimates provided by the studies drawn upon for this report, and the judgment of the authors. While the individual reduction estimates are typically judged to be uncertain in a range of ±50%, and in some cases larger, the variety inherent in the mechanisms suggests a higher level of confidence when their combined effect is considered. The estimates assume full deployment (100% penetration) of smart grid technologies. Since the reductions are expected to be linear with respect to the penetration level, this assumption enables the estimates to be readily scaled to lower levels of assumed penetration. The importance of these reduction estimates is in their combined effect. While several of the mechanisms are estimated to have small or negligible impacts, five of the mechanisms could potentially provide reductions of over 1%. Moreover, the combined effect of the direct mechanisms is 12%, and the indirect mechanisms total 6% of energy and emissions for the U.S. electricity sector. These correspond to 5% and 2% of the U.S. ***total*** energy consumption and energy-related CO_2 emissions for all sectors (including electricity). The magnitude of these reductions suggests that, while a smart grid is not the primary mechanism for achieving aggressive national goals for energy and carbon savings, it can provide a very substantial contribution to the goals for the electricity sector. Further, a smart grid may help overcome barriers to deployment of distributed solar renewables at penetrations higher than 20% (Baldacci et al, 2010).

COI'S ENERGY DISRUPTIVE TECHNOLOGY

COI Energy is at the center of this Smart Grid vision and is focused on creating a climate friendly economy and world by eliminating energy waste in buildings to improve the performance of electric grids globally. COI Energy is achieving this by contributing to the Smart Grid technology markets through:

- a cloud-based software platform, the COI Optimizer Platform, that collects real-time energy and asset registry data to predict resources best suited to solve grid imbalances without disrupting business operations.
- user specific portfolio tracking and alerts from the resulting value generation from previously unused energy sources.

Users are notified of ways to save energy and make money, adding tangible value daily. This influences a climate-friendly approach by enabling low cost, clean and flexible energy resources for utilities and business customers. To borrow from the current trend in transportation technologies, the platform can be viewed like Lyft for the electricity sector — it is a platform that manages a fleet of renewable energy and energy efficiency assets, allowing for the monetization of each asset when called upon. It brings real-time visibility to a process where lack of visibility was the driver of costs. Electric utilities can now remove aggregators from the process thereby driving down cost to activate behind the meter resources.

COI Energy's primary customer is the investor owned utility (IOU), whereby they are offered a subscription-based business model that consists of a one-time activation fee and a monthly or annual subscription per meter. This unique business model enables the users of the platform to make as much money as possible from their energy assets without having to share the revenue with an aggregator. This contrasts strongly with COI Energy's top 3 competitors: EnerNOC (Enel), C Power and First Fuel. EnerNOC and CPower provide a shared savings business model but they do not provide a marketplace to buy, sell, trade and gift capacity. They sell DR solutions. First Fuel provides energy efficiency (EE) solutions to utilities, but no marketplace. COI Energy does not take a split of the customer's savings or revenue. The marketplace for Smart Grids is fragmented, with many competitors competing with one or two of COI Energy's offerings, but they do not offer the same integrated solutions.

The COI Optimizer Marketplace Platform is an integrated hardware-software solution that combines the following three modules: OptimizeDR™ (Demand Response), OptimizeEE™ (Energy Efficiency), and OptimizeRE™ (Renewable Energy). Together these three modules form a critical set of technologies that fulfill a Smart Grid vision by enabling clean, low cost and flexible energy resources to improve the performance of the electric grid. The hardware assembly provides two-way communication enabling real-time data collection with manual and automated control functionality. Its artificial intelligence and machine-learning algorithm offers usage insights and predictive analytics around the energy assets in the building and allows the monetization of those resources. The energy assets include renewable energy (such as solar coupled with battery storage), energy efficiency (such as LED lights) and demand response (such as production equipment).

COI Energy's solution enables better integration of renewable energy on the grid and more efficiency in the energy system; as such, it helps solve climate change. Buildings account for close to 40 percent of energy consumption in the U.S. and remain largely powered by fossil fuels. Customers could save on average 18 to 30 percent in energy consumption by fully engaging with the COI Energy platform. Once replicated across the US building stock, reductions in carbon footprint can be of even greater national and international proportions. Under a plausible scenario, representing incremental growth of renewable energy solutions in power generation using a high adoption trajectory to 2050, the global reductions would amount to 246 GTCO2e by 2050. That translates to $4.92 trillion net implementation cost and $20.96 trillion net operational savings in the grid around the world (Project Drawdown, 2017).

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