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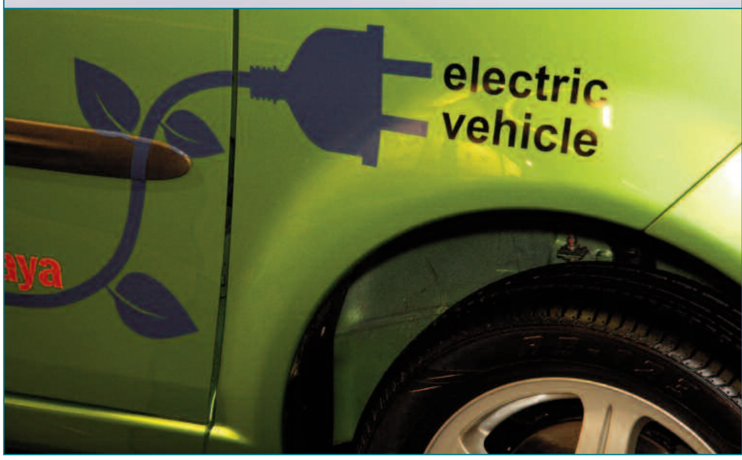

ACCELERATING SMART GRID INVESTMENTS

World Economic Forum
in partnership with
Accenture

This World Economic Forum report was developed by the Forum's Energy Industry Partnership in collaboration with Accenture and with the input from an Advisory Board of experts.

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Accelerating Smart Grid Investments – Executive Summary

The challenges of climate change and the continued growth of electricity demand are putting increasing stress on the world's electricity network infrastructure. The prevailing design philosophy for the existing electricity networks is a legacy from a period when energy was relatively cheap and plentiful and meeting rising demand was the dominant driver. The world is now at the point of transition to a new era where clean energy will be at a premium, networks will need to be flexible to the incorporation of new low-carbon technologies and customers will demand greater insight and control over their own consumption.
Smart grids are a necessary element to enable this transition:

- They deliver energy more efficiently and reliably
- They provide the capacity to integrate more renewable energy into existing networks
- They provide the ability to manage increasing numbers of electric vehicles
- They enable customers to have greater control of their energy
- They have considerable capacity to reduce global carbon emissions
- They stimulate an array of new business models in the energy sector

In addition to noting the benefits, it is worth recognizing the potential impact of inaction: without smart energy infrastructure, the integration of intermittent renewable energy supply and the charging requirements for electric vehicles have the potential to put the stability of the energy system at risk. Even at relatively low penetration levels, these technologies could cause instability and increased risk of outages. By acting now, decision-makers can avoid having the electricity infrastructure become a bottleneck to delivering a lower-carbon future.

"Smart grids are emerging as the next strategic challenge for the energy sector and as a key catalyst to achieve the vision of a low-carbon economy."

Ignacio S. Galán, Chairman and Chief Executive Officer, Iberdrola, Spain

Smart grid technology will bring together the advancements in the IT and Telecommunications sector – embedded sensing, computing and ubiquitous communications – to deliver a safer, more efficient and more resilient energy system. Not dissimilar to the Internet, this smart grid will act as a backbone infrastructure, enabling a suite of new business models, new energy management services and new energy tariff structures. The smart grid will enhance the way that utility companies manage assets and offer consumer-relevant products and services, how consumers interact with their energy supply, and how governments respond to the challenge of maintaining security of supply and reducing carbon levels while managing costs of energy delivery. However, a number of factors are holding back this transition and may ultimately act as a limiting factor to the broader drive to reduce greenhouse gas emissions. This paper seeks to define smart grids and present a recommended design philosophy, identify the barriers to adoption and, finally, suggest potential strategies to address the challenges.

One Size Does *Not* Fit All

The transition towards a smart grid can be driven by a number of factors, some or all of which may apply to varying degrees. However, the hierarchy of needs will vary from country to country, region to region and even circuit to circuit, based on the legacy network that exists and the ambitions of local policy-makers. In some cases, reliability may dominate the list of outcomes due to challenges faced by an ageing infrastructure; however, in another area, the drive to incorporate plug-in hybrid electric vehicles and distributed generation and storage may be dominant. In these instances, different physical architectures might evolve that are optimized to the local need. Over time, needs may change and therefore the design philosophy will need to embrace the concepts of flexibility, modularity, scalability and forward compatibility.

"Ultimately, smart grids empower consumers by providing unprecedented visibility and control over energy usage and will change the way we all think about and buy energy. This new system will also transform the relationship between the utility and consumer from a one-way transaction into a collaborative relationship that benefits both, as well as the environment."

Peter L. Corsell, Chief Executive Officer, GridPoint

To highlight the issue of variability in vision and design, a number of smart grid archetypes have been outlined to highlight how changes in the hierarchy of needs may lead to smart grids that are optimized to prioritize certain functionality. These are not intended as a menu of designs, but simply as a demonstration of their potential diversity. In each case, policy-makers and regulators will need to define their hierarchy of needs and then work with the incumbent utility to define the journey that takes them from where they currently are to where they want to be. In each case, the transition will need to be defined to allow a gradual layering of capabilities that will lower the impact on the incumbent utility and deliver the best value for the customer.

Policy and Framework Alignment

There are a number of factors that, in combination, act as a brake on smart grid investment, most of which are institutional and relate to the regulatory and policy frameworks that have evolved to support the existing power delivery system. The current frameworks often create reverse incentives or fail to create sufficient positive incentives for private sector investment. In the future, the regulatory model will have to adapt to balance a suite of outcomes in which carbon reduction and security of supply are rewarded in the same way that productivity and efficiency gains have been rewarded in the post-privatization era. As a consequence, difficult trade-offs may need to be made with the degree of market competition and cost to the consumer.

"Smart grids represent an evolution of the electricity network from generation to consumption in a way that is interactive, flexible and efficient. The challenges include integrating renewable but intermittent power from large-scale plants, often located far from consumers, and from small-scale installations. It will take several decades to apply the solutions to a mix of new and existing equipment. All stakeholders – policy-makers, regulators, utilities and vendors – must tackle this challenge together."

Joe Hogan, Chief Executive Officer, ABB

If policy-makers and regulators see long-term carbon reduction and security of supply as important outcomes, they will need to rebalance the regulatory incentives to encourage privately financed utilities to invest at rates of return that are commensurate with the risk that they are taking. The relative risk profile for smart grid investments, given the technology and delivery risks that come with relatively immature suite technologies, will require policy and regulatory frameworks that allocate risk to the parties that can diversify it most effectively. This may mean creating frameworks that allow risk to be shared between customers (either through their utility bills or taxes) and shareholders so that risks and rewards are balanced at the lowest total cost to the customer. As it stands, there are few examples of where this is being done effectively.

Moving from a Utility-centric Business Case to a Broader Societal Value Proposition

In those cases where more forward-thinking regulators and policy-makers have either commissioned business cases or progressive utilities have taken it upon themselves to push the issue, there have been mixed results. Typically, the smart grid business case is tackled as an add-on to the AMI business case and, as a stand-alone case, it is hard to justify the additional expenditure. In the majority of cases, there have been negative business cases driven by two fundamental challenges:

- **High capital and operating costs** – Capital and operating costs include large fixed costs attributable to the ubiquitous communications network; hardware costs do not factor in significant improvements in economies of scale and production innovation, and software integration assumes significant delivery and integration risks.

- **Benefits are constrained by regulatory rules** – When assessing the benefits business case, modellers are restricted in what they can realize as cash benefits to the shareholder. For example, in many cases, line losses are considered as a pass-through to the customer and, therefore, any reduction in losses would have no net impact on the utility shareholder.

There is a clear link between the business case and many of the barriers identified in this section. Regulatory and policy frameworks determine the economics of the business and therefore drive what can be accounted for in the benefits case. They determine what benefits can be monetized and which remain neutral to the utility shareholder despite being of potentially significant value to the consumer or society more broadly. Governments and industry need to jointly assess the value for smart grid investment and to develop either convincing rate cases that reflect the value of the positive externalities, or public-private partnership vehicles to share the investment burden between the public and private purse. By moving beyond the traditional utility-centric business case to a broader view of the societal value, it will make it easier for politicians and regulators to articulate the value to customers.

In the early years of smart grid investment, the costs will inevitably reflect the relatively high risk of cost overruns. By investing in a small number of high profile, large-scale, integrated pilots and sharing the learnings, the global smart grid community will be able to reduce the risk premium on the capital and operating costs to a level that makes the value case more viable. With US$ 461 million of total smart grid investment in 2008 and an expected significant increase in investment requirements over the coming decade,[1] even small percentage reductions have a large impact.

Cities as Catalysts

During the early stages of the transition towards smart grids, cities will play a critical role in demonstrating the art of the possible and consequently reducing the delivery risk for regional or national roll-outs. Cities such as Boulder, Colorado, and Austin, Texas, are already leading the way with large-scale pilots, and this trend can be expected to continue with a migration to larger and larger cities. However, not every city is suitable to be at the vanguard of this change. To identify those cities that are most likely to lead the change, a number of factors must be identified that, when they converge, will produce an environment that is primed for change. Key considerations include the market structure (i.e. regulated or liberalized), the degree of political alignment at the city level and the occurrence of municipal asset ownership.

Conclusion

Despite the clear benefits case for smarter electricity infrastructure, there are a number of factors, as defined within this report, which are acting as a brake on investment.

Two key themes sit at the heart of overcoming such challenges:

- **Regulatory refresh** – There is an urgent need to refresh the utility regulatory regimes that oversee the governance and economics of the power industry. No longer is it the sole purpose of this industry to provide energy to the masses at cost-competitive prices; there now exists a set of competing imperatives which centre on the provision of infrastructure to support a low-carbon economy while maintaining security of supply and quality of service to the end consumer. The regulatory regimes worldwide need to be restructured to reflect these new imperatives. Governments and regulators should provide clear profit motives to utilities to place value on energy efficiency, encouraging utilities to produce and deliver as efficiently and clean electricity as possible, without compromising security of supply. In both vertically integrated and competitive utility value chains, utilities should be rewarded for helping achieve this mission.

- **Public-private partnerships and societal value propositions** – The limitations need to be recognized of either the utility or the city/region acting in isolation. A wealth of smart grid benefits sit across the boundary between the utility and society as a whole. It is unrealistic to expect the utility shareholder to take on the full risk of investment in this instance. Public-private partnerships are required for this technology to reach its full potential. A new era of collaboration is essential.

It is necessary to move away from purely financial business cases to develop broader societal value propositions, which are reflective of more than financial benefits and consider positive effects on citizens and businesses from clean, reliable energy supply. They can then be used as a tool with which to appropriately allocate smart grid cost/benefit.

Smart Grids as an Enabler to the Low-Carbon Economy

The development of a fully fledged, low-carbon economy will require changes to the core electricity infrastructure. Smart technologies will be a necessary element of this transformation.

Over the next two decades, assuming a limited intervention scenario, the International Energy Agency (IEA) expects to see aggregate global energy demand to roughly double from current levels as the population increases, new consumers in the developing world acquire electronic products and the growth in computing consumption increases.[2] This growth in demand will coincide with a global drive towards lower carbon generation sources in the battle with climate change. It will also operate within the context of an ageing power grid transmission and distribution infrastructure which desperately requires investment.

To successfully transition to a fully fledged low-carbon economy, the core infrastructure for transmission and distribution of electricity needs to be addressed. Smart technologies will be a necessary part of this transformation, applying telecommunications and computing technologies developed over the last two decades to the current and future electricity infrastructure.

Cities will play an important role in managing this transition. At present, 71% of the world's carbon emissions are from urban centres[3] and, as such, cities are at the front line of the battle for a low-carbon economy. Cities are at the centre of global commerce, industry and finance, and are critical to the functioning of the global economy. If urban environments are to be sustainable in the long-term, it will be critical to develop scalable, secure and reliable communications and power grid networks that will become the backbone for a much broader suite of advanced and low-carbon technologies. Cities, as centres of consumption, will become the focus for energy conservation and efficiency, and smart technologies will enable new products and services to be offered to help consumers manage energy needs, whether at home, at work or in transit.

The US Department of Energy published their Grid 2030 vision in July 2003 in which they stated the intention to migrate towards smart grids. However, over the six years since its publication, progress towards the vision has been hampered by misalignment of incentives among customers, government, regulators, utilities and product suppliers. Standard business case methods often fail to represent the true cost/benefit of smart grid investments; costs are high, driven partially by a lack of awareness regarding the opportunities for realizing economies of scale and scope within infrastructure investments to deliver multiple outcomes, and do not represent the full spectrum of hard and soft benefits, many of which cannot be ascribed a specific monetary value. It is possible to move beyond this impasse by creating a suite of policy and economic frameworks that allow the alignment of incentives across stakeholders and define value cases that more fully describe the benefits case at a societal level.

The global and local response to the challenges of climate change will require an integrated supply- and demand-side response. On the supply side, there is a drive towards sustainable, low-carbon electricity generation (e.g. nuclear, wind power, solar, etc.) and hydrocarbon substitution (e.g. biofuels, biogas, electric vehicles, etc.). On the demand side, customers are increasingly seeking more information and control over their consumption and, as a consequence, there are new technologies that enable energy conservation and efficiency (e.g. smart buildings, smart meters, demand response, etc.). Without investment in the smart grid infrastructure to support these technologies, natural limits will be reached as to what can be achieved. The existing distribution grid infrastructure is primarily designed for one-way flow of electricity and limited consumption in the home. With the growing implementation of large-scale, intermittent renewable energy generation, distributed generation and electric vehicles, the operational limits of the network as it is currently designed will be reached. To avoid stalling progress towards a sustainable and low-carbon future, necessary investments must be made in power grid and urban infrastructures that will effectively (without significant operational constraints) accommodate these technologies at large-scale deployment.

1. What Defines a Smart Grid and Why Do We Need Them?

1.1 Introduction

In the following section we will describe the power grid, how it operates today and how a smarter grid will change the design and operations to lead to more efficient, effective power delivery in the future. There are several challenges which are leading decision-makers to consider this technology as an option and in some cases a requirement. This section will explore the different capabilities which sit within the smart grid construct and how they help respond to those challenges. Once it is recognized that smart grids are not a simplistic one-size-fits-all, it is possible to examine the geographic variances which occur and identify several smart grid archetypes which correspond to a location's specific starting point and implementation objectives.

1.2 How Does the Power Grid Operate Today?

Today's power grid is analogue and needs a great deal of investment. There is significant scope for operational improvements through smart grid technologies.

Today's power grid is composed of two networks. The first is an actively managed transmission network which supplies electricity over longer distances at a higher voltage; the other, the distribution network, operates at a lower voltage and takes electricity the last mile to individual homes and businesses. Combined, transmission and distribution networks represent a significant technical legacy, mirrored in its investment requirements; current estimates are US$ 13 trillion worldwide through to 2030.[4]

"He's been dead more than 75 years, but Thomas Edison – hailed as the father of the light bulb – probably could run the nation's modern-day electric grid. It just hasn't changed that much."[5]

Unlike other industries, telecommunications for example, power utility infrastructure is composed of many analogue/electromechanical legacy systems that are prone to failure and blackouts. It is dominated by centralized generation disseminated via a relatively passive (limited control), and one-way or limited two-way communication network between utilities and the end users. Residential energy consumption is often projected rather than measured. Grid maintenance is time-based and often reinforced when system components fail or reach their expected lifetime. Outage management practice relies on consumers notifying the utility that a power outage has occurred. A significant volume of the electricity which enters the network is lost either through technical inefficiencies or theft from 4-10% in Europe[6] to more than 50% in some developing city environments.[7]

Figure 1: Transition to a smart grid

Current State	Modern Utility
Analogue/electromechanical	Digital/microprocessor
Centralized (generators)	Decentralized (generation)
Reactive (prone to failures and blackouts)	Proactive
Manual (field restoration)	Semi-automated, automated (self-healing)
One price	Real time pricing
No/limited consumer choice	Multiple consumer products
One-way communication (if any)	Two-way/integrated communication
Few sensors	Ubiquitous monitors, sensors
Manual restoration	Condition-/performance-based maintenance
Limited transparency with customers and regulators	Transparency with customers and regulators
Limited control over power flows	Pervasive control systems
Estimated reliability	Predictive reliability

1.3 What Is a Smart Grid?

Smart grids incorporate embedded computer processing capability and two-way communications to the current electricity infrastructure. Smart grids operate across the utility value chain, and should not be confused with smart meters.

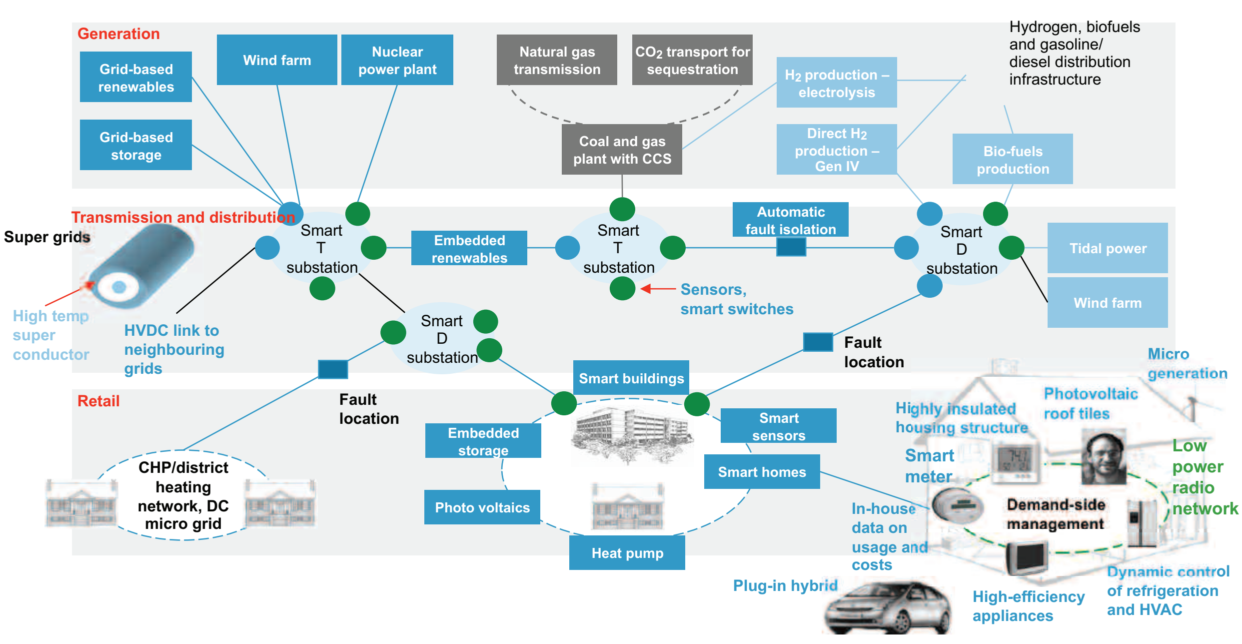
A smart grid uses sensing, embedded processing and digital communications to enable the electricity grid to be:

- *observable* (able to be measured and visualized)
- *controllable* (able to manipulated and optimized)
- *automated* (able to adapt and self-heal)
- fully *integrated* (fully interoperable with existing systems and with the capacity to incorporate a diverse set of energy sources).

A smart grid will create the platform for a wide range of advanced and low-carbon technologies.

The smart grid, as defined in Figure 2, encapsulates embedded intelligence and communications integrated at any stage from power generation to end point consumption. To date, the majority of the industry debate has centred on smart meters and advanced metering infrastructure – devices designed to accurately measure and communicate consumption data in the home or office environment. Confusion can arise if the term "smart meter" is used synonymously with "smart grid". One of the objectives of this paper is to provide some clarity regarding this misunderstanding. The reality is that, with the holistic smart grid, the smart meter becomes just one more node on the network, measuring and relaying flow and quality data.

Figure 2: Smart grids – A holistic definition



Today's Importance of Smart Grid

A confluence of factors is driving the need for investment. Smart grids have the ability to fundamentally change the way people interact with their electricity supply.

A number of factors are converging, driving the energy industry towards a smart grid (as outlined in Figure 3). These factors are bringing the agenda to the attention of politicians and regulators and driving a need for industry solutions. The requirement to act now is compounded by the non-insignificant lead time on these technologies. The opportunity cost of not investing at this stage firstly could create a rate-limiting step in the renewables and electric vehicle ramp-up, and secondly could result in mass investment in "dumb" infrastructure which later has to be upgraded at greater total cost to the customer.

A smart grid will exhibit seven key characteristics:

- **Self-healing and resilient**: A smart grid will perform real time self-assessments to detect, analyse and respond to subnormal grid conditions. Through integrated automation, it will self-heal, restoring grid components or entire sections of the network if they become damaged. It will remain resilient, minimizing the consequences and speeding up the time to service restoration. The modernized grid will increase the reliability, efficiency and security of the power grid and avoid the inconvenience and expense of interruptions – a growing problem in the context of ageing infrastructure. In the US alone, interruptions in the electricity supply cost consumers an estimated US$ 150 billion a year.[8] It will reduce vulnerability to the growing threats of natural disasters (hurricanes, ice storms) as well as cyber-attacks and terrorism.

- **Integration of advanced and low-carbon technologies**: A smart grid will exhibit "plug and play" scalable and interoperable capabilities. A smart grid will permit a higher transmission and distribution system

Figure 3: Factors driving smart grid

Regulatory Mandate

- EU and US climate change **legislation is forcing companies to implement smart technology**
- United Kingdom mandate for residential **national roll-out of smart metering** by 2020
- **US$ 4.5 billion US fiscal stimulus** allocated to smart grid – number of states now planning pilots
- Rapidly developing **EU policy** re. Smart Grid

Future Gen Mix

- Deployments of **renewables and distributed generation** technologies will affect the design and operation of the distribution network leading to increasing need for automation
- **Plug-in hybrid vehicles** are likely to further increase the stress on the distribution network
- **Low-carbon technologies** will mean the energy grid will need to be able to deal with **intermittent generation and drive need for demand management**

Ageing Grid and Reliability

- **Massive investment** will be needed to upgrade the transmission and distribution grid over the next 10 years to meet new low-carbon energy requirements
- All new network upgrades will include the introduction of **sensors and controls** to enable efficiency and improved management
- "The total estimated annual cost to the US economy from **power outages** and **power quality disturbances** is over US$ 100 billion…" which can be saved through smart technologies

Customer Needs

- Under **rising costs of energy**, customers are likely to demand a more granular level of information to **reduce their bills**
- Consumer energy awareness and demand for **sustainability** will require an enhanced ability to measure and **manage use**
- The use of more **flexible pricing mechanisms,** such as Time of Usage and Critical Peak Pricing, will **require automation**

Environmental Impact

- The enabling of energy demand management to reduce consumption – **peak shaving and load shifting** will require more control in the home
- **Carbon emissions reduction will** drive the need for more information to enable energy efficiency
- Government refunds will require more **monitoring of carbon emission** savings for auditing purposes

Technology Evolution

- Increased use of smart technology is increasing data volumes and driving the need for high-speed analytics
- Automated meter reading is quickly becoming **obsolete** as energy companies move to advanced metering infrastructures
- In the face of new capital investment, **smart grid components** are becoming **increasingly cost competitive**

penetration of renewable generation (e.g. wind and photovoltaic solar energy resources), distributed generation and energy storage (e.g. micro-generation). Case studies from Belgium demonstrate that as low as a 7% penetration of distributed wind turbines on the low voltage network can begin to cause major problems on the distribution network.[9] To mitigate the intermittent nature of renewable generation, the smarter grid can leverage embedded storage to smooth output levels. Without a smart grid, diurnal variations in generation output will typically require renewables to be backed with fast ramp-up fossil fuel based plants. Smart grids will also provide the necessary infrastructure for mass adoption of plug-in hybrid and electric vehicles, ultimately enabling both scheduled dispatch of recharge cycles and "vehicle-to-grid" capability. Such networks will allow society to optimize the use of low-carbon energy sources, support the efforts to reduce the carbon intensity of the transport sector and minimize the collective environmental footprint.

- **Enable demand response**: By extending the smart grid within the home (via a home area network), consumer appliances and devices can be controlled remotely, allowing for demand response. In the event of a peak in demand, a central system operator would potentially be able to control both the amount of power generation feeding into the system and the amount of demand drawing from the system. Rather than building an expensive and inefficient "peaking plant" to feed the spikes in demand, the system operator would be able to issue and demand response orders that would trigger a temporary interruption or cycling of non-critical consumption (air conditioners, pool pumps, refrigerators, etc.).

- **Asset optimization and operational efficiency**: A smart grid will enable better asset utilization from generation all the way to the consumer end points. It will enable condition- and performance-based maintenance. A smart grid will operate closer to its operational limits, freeing up additional capacity from the existing infrastructure; this remains an attractive proposition when a US study demonstrated that transmission congestion costs Eastern US consumers US$ 16.5 billion per year in higher electricity prices alone.[10] Smart grids will also drive efficiencies through reductions in technical and non-technical line losses – estimates are that 30% of distribution losses could be mitigated.[11]

- **Customer inclusion**: A smart grid will involve consumers, engaging them as active participants in the electricity market. It will help empower utilities to match evolving consumer expectation and deliver greater visibility and choice in energy purchasing. It will generate demand for cost-saving and energy-saving

Figure 4: Opportunities and benefits of a smart grid

Government and Regulators

- A highly effective carbon abatement investment option
- Opportunities for GDP uplift and green-collar job creation
- Opportunities to rationalize national infrastructure investments (telecommunications, energy)

Utilities

- Opportunity to transition from commodity provider to higher-value service provider
- Operational and maintenance savings from improved outage management, etc.
- Ability to take steps towards corporate sustainability and carbon goals

Vendors

- Opportunities to develop new products and services to take to market
- Ability to alter consumers' interaction with energy
- Opportunities to develop improved understanding of consumer behaviour

Consumers

- Energy bill and carbon savings
- Greater transparency, control and choice over energy consumption
- Increased availability of clean technologies, such as electric vehicles and micro-generation

products. In a world where consumer expectations and requirements are growing, smart grids will help educate the average consumer, foster innovation in new energy management services and reduce the costs and environmental impact of the delivery of electricity.

- **Power quality**: A smart grid will have heightened power quality and reductions in the occurrence of distortions of power supply. As the load demands increase on an exponential path, power quality degradation will manifest as more of an issue, in turn requiring distributed monitoring and proactive mediation. This will confluence with a decrease in tolerance for power quality variances from modern industry, particularly the hi-tech sector and the higher costs of such quality issues as economies grow.

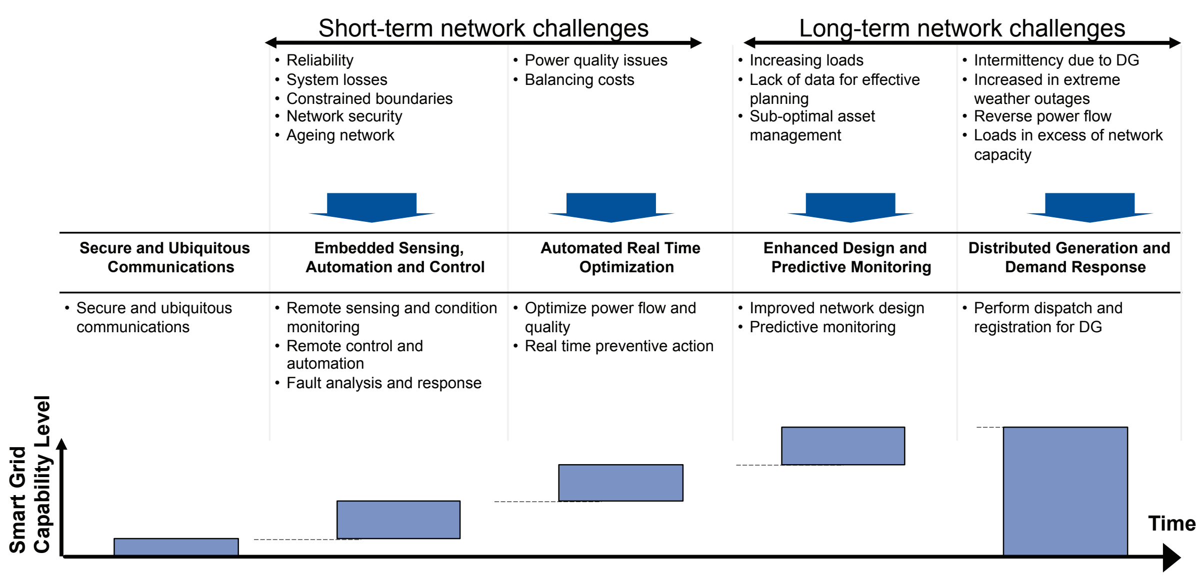
- **Market empowerment**: A smart grid will provide greater transparency and availability of energy market information. It will enable more efficient, automated management of market parameters, such as changes of capacity, and enable a plethora of new products and services. New sources of supply and enhanced control of demand will expand markets and bring together buyers and sellers and remove inefficiencies. It will shift the utility from a commodity provider to a service provider.

1.4 What are the Technical Capabilities that Deliver a Smart Grid?

Layers of technical capability will be applied to a power grid to deliver these smart grid characteristics:

- **Secure and ubiquitous communications**: resilient, two-way digital communication infrastructure exhibiting appropriate bandwidth and latency and enabling communications from generation source to consumer end point
- **Embedded sensing, automation and control**: monitoring and sensors (voltage, current, etc.), automated switches and controls and micro-processing capability to enable the electricity network to respond to real time conditions
- **Automated real time optimization**: advanced monitoring, sensing and controls, decision support algorithms, low latency communications to support active load balancing and self-correct for interruptions and power quality issues in real time
- **Enhanced design and predictive monitoring**: asset data collection, analytics and advanced visualization techniques integrated in to the utility enterprise systems to provide the tools to optimize network planning and predict and respond to anticipated equipment failure

Figure 5: Smart grids – Incremental layers of capability



- **Distributed generation and demand response**: simplified interconnection standards, two-way power flow capabilities and more effective load balancing techniques to allow distributed generation and energy storage to be incorporated seamlessly into the transmission and distribution network; energy management systems will track the balance of supply and demand on the network and control consumer devices to optimize 24-hour energy consumption

1.5 One Size Does *Not* Fit All

Implementation of a smart grid will be step-wise and tailored to fit, rather than one-size-fits-all. The architecture will be a product of the legacy infrastructure and "to-be" vision for a smarter grid.

When developing an understanding of smart grids, it is important to recognize both the common technical principals (embedded intelligence and ubiquitous communications) and the geographic variances which exist, and to move away from a one-size-fits-all definition.

Each smart grid implementation will have an architecture that will be a function of:

- **Legacy characteristics of the power grid**: the condition of the existing smart grid infrastructure will be an important determinant of the smart grid strategy. The degree of urgency for implementation will vary, depending on the relative state of repair and the remaining capacity. The current and future generation mix will also determine both the need and scope for the smart grid. In some instances, a smart grid could be a complete new build infrastructure, for example, to support greenfield sustainable cities, which will offer several more degrees of freedom for the strategy and implementation.

- **Primary drivers for implementation**: the specific tactical and strategic objectives which the smart grid is designed to achieve will also vary in each instance, reflective of the region's challenges and ambitions. The focus could be on either transmission or the distribution network, where separate suites of technologies might be required. The primary drivers could range from enabling a city environment to integrate low-carbon technologies to reducing the risk of outages from extreme weather events. These implementation drivers will define the "to-be" vision of capability for the smart grid implementation.

With both the legacy and the vision, the delta which the smart grid implementation is intended to close can be defined. Relating to the nature of this delta, the smart grid will be configured differently to prioritize the capabilities required to deliver specific business outcomes.

It is important to recognize that a smart grid implementation is unlikely to be a big bang. The complexity and scale will require an incremental approach with the marginal capabilities, packages of hardware, software and communication solution, phased over time. Staged releases of logical capabilities which gradually transform the grid's functionality would be expected.

One of the first decisions with the smart grid strategy will be which communications technology to adopt. Utilities will have to be forward-minded to ensure that the backbone they deploy has sufficient bandwidth and latency to support the end game functionality of the smart grid. Utilities should also be cognisant of the option for installing smart grid component technologies/solutions that can be "lit up" at a later stage as the communications infrastructure is rolled out and/or the enterprise systems are successfully integrated.

Below, some representative smart grid archetypes are identified, and the drivers and capabilities likely to be prioritized in initial releases are examined. None of the examples listed has a fully fledged smart grid today, but many have identified the need for change and have begun developing strategies for change. The archetypes are not intended to be exhaustive, but rather provide some examples and templates for what smart grids will look like in different regions. The archetypes help crystallize the differences in drivers; it is recognized that, within one geography, multiple priorities will be at play and, in this instance, multiple archetypes will apply. In each case, the legacy and hierarchy of outcomes will define the parameters of the journey towards a smart grid, and the transition will see multiple releases over time that will build layers of incremental capability that will ultimately deliver the desired outcomes. This staggered release strategy will allow the utility to manage the transition at a pace that does not compromise grid performance.

Seven key smart grid archetypes provide logical groupings for implementation architectures. They are intended to crystallize the differences in drivers; it is recognized that, within one geography, multiple priorities will be at play and, in this instance, multiple archetypes will apply.

Archetype	Description

1. Aging Infrastructure E.g. New York

Key drivers
- Preventing energy loss
- Reducing costs
- Increasing reliability and resilience to threats

Capabilities
- Secure and ubiquitous communications
- Remote sensing and condition monitoring
- Remote control and automation
- Fault analysis and response
- Optimize power flow and quality
- Real time preventive action
- Improved network design

Several major cities around the world are struggling with outdated energy grids that have outlived their useful life and failed to evolve with the demands of modern society. In the US, Canada and many parts of Europe, the grid is now 60+ years old and major infrastructure investment is overdue.

Reducing costs and preventing energy loss are key drivers of the business case in these cities, as opportunities for maintenance cost reduction and efficiency gains are significant.

Smart grid implementations in these cities are likely to focus on replacing distribution and transmission assets, as these are key drivers of costs. Furthermore, the ability to predict and avoid power failures through network intelligence will be important.

- A good example of this archetype is New York City. Reliability will be a key factor; the Northeast blackout of 2003 left 45 million people across eight US states without power, including all of New York City, resulting in huge economic losses and several fatalities. The US Electricity Advisory Committee estimates that a smart grid would enable a 90% reduction in the cost of disturbances to business.
- New York sources a significant portion of its electricity from Canada, meaning vast transmission networks are an important source of costs.

2. Island Networks E.g. Singapore

Key drivers
- Incorporating renewables
- Enabling substitution technologies
- Optimizing consumption

Capabilities
- Secure and ubiquitous communications
- Remote sensing and condition monitoring
- Remote control and automation
- Predictive monitoring
- Perform dispatch and registration for DG

Self-contained islands may be ideal environments for spearheading smart grid adoption, as small urban areas are conducive to electric vehicle use and relative simplicity of regulatory environments enables swift action. Furthermore, islands are often heavily dependent on external sources of energy and highly vulnerable to the effects of global warming, providing further incentive to diversify the energy mix towards micro-generation and renewables.

The key focus in this type of smart grid will be on the distribution grid, through enabling substitution technologies and distributed generation. Import/export interconnections and sub-sea transmission interconnections will also play a role.

continued from previous page

Archetype	Description
	A good example is Singapore, recently pegged by an international panel of experts as an ideal place to launch an EV network.[12] Key characteristics: • A contained urban area – (the longest east-west stretch is just over 40 km and north-south stretch about 20 km) • Top-down policy environment which will ensure rapid deployment of a complicated and ambitious system once there is buy-in from the top • Singapore has one of the most efficient and reliable electrical grids in the world and a sophisticated IT sector, a good platform for smart grid roll-out • Environmental concerns – key vulnerabilities to climate change include coastal land loss, increased flooding, impact on water resources and spread of disease • Energy security concerns – No indigenous oil and gas resources. Hydro, geothermal and wind power are not available in Singapore, while nuclear energy is not feasible due to population density and lack of scale. Plugging solar panels into the grid is a potential solution • Singapore believes the current liberalized market structure should provide a platform for innovation, while correcting market failures with market-based instruments or through imposing standards and regulations[13] • An ambition to develop leading-edge expertise that can be exported to larger markets will also drive the smart grid effort and boost the business case. However, a lack of economies of scale is one challenge that will need to be overcome

3. Concentrated Intermittent Renewables E.g. US Midwest

Key drivers
- Incorporating renewables
- Preventing energy loss
- Optimizing consumption

Capabilities
- Secure and ubiquitous communications
- Remote sensing and condition monitoring
- Remote control and automation
- Predictive monitoring
- Improved network design
- Optimize power flow and quality
- Perform dispatch and registration for DG

Renewable energy sources, such as wind farms, are more location-dependent than conventional power sources, contingent on where the natural resources are most abundant (wind/tides/sun) and where there is sufficient space and availability of planning permission.

Typically, these factors lead to geographic separation between concentrated renewables and centres of demand, often cities. This increases the need for efficient long-distance transmission networks.

Alternative energy sources also have a high level of variability in electricity output, causing variability of the power supply. This leads to intermittency issues as electricity transmission systems require a real time balance in supply and demand to maintain network stability and security of supply.

Such issues can be met in several ways, some of which involve a smart grid, including using demand-side management and use of e-vehicles and vehicle-to-grid storage capacity, and some probably do not, such as greater use of flexible generation like gas turbines, or incorporation of storage. The benefit of a smart grid solution is that it helps avoid intermittent renewables being backed-up with fast ramp-up fossil fuel generation.

The United States Midwest exemplifies this archetype:
- "To accelerate the creation of a clean energy economy, we will double the capacity to generate alternative sources of energy like wind, solar and biofuels over the next three years," said US President Obama in a February radio address. "We'll begin to build a new electricity grid that will lay down more than 3,000 miles of transmission lines to convey this new energy from coast to coast."[14]
- A key question is going to be how to get renewable power from the mountain states to the West coast, or to the centre of the country.[15]

Archetype	Description

4. Developing Economy
E.g. Mumbai, Rio de Janeiro

Key drivers

- Increasing reliability and resilience to threats
- Incorporating renewables
- Reducing costs
- Preventing energy loss
- Optimizing consumption

Capabilities

- Secure and ubiquitous communications
- Remote sensing and condition monitoring
- Remote control and automation
- Fault analysis and response
- Optimize power flow and quality
- Real time preventive action
- Improved network design
- Predictive monitoring
- Perform dispatch and registration for DG

As economic growth continues in emerging economies, millions of consumers in countries such China, Brazil and India are reaching levels of prosperity that will require substantially higher energy use. In many of these developing economies, energy theft is a growing problem and one of the biggest challenges that utilities are trying to address.

India's Ministry of Power estimates that about half of the electricity in the country is billed. The financial impact of technical and commercial losses has been estimated at 1.5% of GDP.

Brazil is another country with similar problems; the federal statistics institute, Instituto Brasileiro de Geografia e Pesquisa (IBGE), says that, by 2020, the number of residents living in slums could climb to 55 million, equivalent to 25% of the national population. Access to basic services like electricity in Brazil's low-income communities is limited, and slum residents in the country's south-east and north-east regions often resort to illegal power connections to meet basic needs such as refrigeration and lighting.[16]

Accommodating this demand growth and at the same time reducing non-technical losses will require significant new build of generation, transmission and distribution capacity. The case for smart will revolve around the grid's ability to reduce non-technical losses, integrate renewables and improve resilience to external threats.

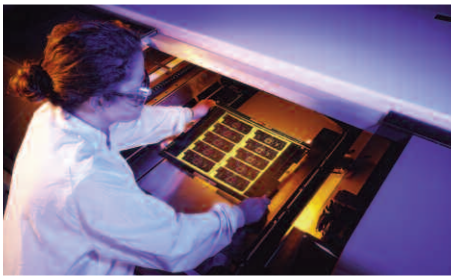
Rio de Janeiro provides a good demonstration of the challenges and potential solutions and has a small pilot project underway:

- One local energy-distribution company, Ampla, was losing revenue from more than 53% of all the energy it supplied. Through implementing smart grid technology, it has been able to reduce losses to 1.6% of energy supplied[17]
- The key components included remote monitoring technology, feeding data to an operations centre every 15 minutes. Software systems then analyse the data and generate web reports, pinpointing transformers with higher than acceptable losses
- Furthermore, the ability to remotely disconnect culprits has been especially important, as it saves the cost of having to send someone to do it manually and overcomes the previous inability of connecting/reconnecting clients in violent areas controlled by drug dealers

Archetype	Description

5. Hi-tech Manufacturing
E.g. Silicon Valley

Key drivers
- Improving power quality
- Preventing energy loss



In many of the existing hi-tech manufacturing clusters, a high degree of power quality and reliability is critical to complete the day-to-day activities. The equipment used is typically extremely sensitive to power fluctuations, and any voltage surge, sag and momentary outage on the supply cause several tools, equipment and even entire production lines to malfunction, resulting in significant business losses.

The application smart grids features in the network, such as sensoring, automated self healing and controlling mechanisms distributed throughout the network, can monitor power quality and in the majority of the cases trigger automatic responses ensuring a higher quality power in the network and less downtime.

Silicon Valley is a good example of this model:
- Silicon Valley is the leading hi-tech economic centre in the United States. The economy is highly dependent on the quality of the power supplied to many of the electronics manufacturers and IT houses spread around the region.

6. Distributed Generation and Storage
E.g. Flanders, Belgium

Key drivers
- Incorporating renewables
- Enabling substitution technologies
- Optimizing consumption

Capabilities
- Secure and ubiquitous communications
- Remote sensing and condition monitoring
- Remote control and automation
- Real time preventive action
- Improved network design
- Predictive monitoring
- Perform dispatch and registration for DG

In most parts of the world, environmental awareness, the rising cost of energy and the lowering cost of technology such as solar panels are driving governments and citizens alike to increase the number and diversity of micro-renewable energy sources. Financial incentives by governments can cause relatively rapid increases in the penetration of these technologies (there are examples of feed-in tariffs which offer 10-fold the value of the energy). On-site photovoltaic panels and small-scale wind turbines are present-day examples; emerging resources include geothermal, micro-combined heat and power boilers, biomass, hydrogen fuel cells, plug-in hybrid electric vehicles and batteries.

Today's distribution system is designed to deliver energy in a single direction from the substation to the home. The integration of micro-generation goes against this design assumption and can risk exposing system and customer equipment to potential damage, decrease in power quality, decrease in reliability and extended time to restoration after outage.[18]

Such considerations are important in countries such as Belgium:
- A Belgian utility is working to adapt fast to the increase in micro-generation.

Archetype	Description
	• Feed-in tariffs of 45 cents for electricity placed back on to the grid have meant that individuals investing in renewables can break even just two years.[19] Combined with fast turn-around planning permission, an average of 7% of KwH is now produced from decentralized power sources.[20]As a result, the utility is required to explore the use of smart technologies to support this new energy infrastructure.

7. Enhanced Resilience
E.g. New Orleans, North-east China

Key drivers
- Increasing reliability and resilience to threats
- Preventing energy loss
- Improving power quality

Capabilities
- Secure and ubiquitous communications
- Remote sensing and condition monitoring
- Remote control and automation
- Fault analysis and response
- Optimize power flow and quality
- Real time preventive action
- Predictive monitoring

A safer and more resilient network grid is essential to ensure progress and economic growth. Existing energy grids are vulnerable to external threats or attacks, such as natural disaster or cyber-attacks, putting at risk energy supply and availability.

"Implementing a next-generation electrical power grid is vital to strengthening … resilience and promoting energy efficiency, security and alternative sources of power. Our nation is at a crossroads as our energy dependence and vulnerable critical infrastructures become significant liabilities to our security and resilience. Our current grid is highly vulnerable to severe disruption in the case of a catastrophic event."[21]

The implementation of smart grids, using advanced communications and other electrical capabilities, can create a more dynamic and agile grid that enhances the resilience of the grid and ensures availability of energy supply.

Some regions have higher propensity to these situations, such as natural disasters, cyber-attacks or both, making them ideal for smart grid adoption.

Prime examples are New Orleans, with its high propensity for natural disasters, any major city vulnerable to cyber-threats and attacks, and the Harbin province within China, which has a susceptibility to outages due to ice storms.

Smart grid adoption would be able to avoid and prevent many of the problems resulted from these threats. Embedding smart technologies in smart grid functionalities such as early warning systems, self healing mechanisms and active temperature control can be on the front line to prevent outages and ensure energy supply.

2. Barriers to Implementation

Seven barriers are holding back the implementation of smart grids; none of which are insurmountable, as described in the next section. The paramount issue is a regulatory framework that is out of sync with today's industry needs and society's broader environmental objectives.

In the following section, the current challenges that are holding back investments in smart grids will be examined, before looking, in Section 3, at potential actions that could be taken to address them and accelerate the adoption of smart grid technologies. There are a number of factors that, in combination, are acting as a brake on smart grid investment, most of which are institutional and relate to the regulatory and policy frameworks that have evolved to support the existing power delivery system. Seven areas have been identified that will need to be addressed before smart grids become more widely adopted:

1. **Policy and regulation** – In many cases, utilities do not get as far as a business case for the smart grid as there are regulatory and policy barriers in place that either create reverse incentives or fail to create sufficient positive incentives for private sector investment.

2. **Business case** – Where policy-makers and utility executives are aware of the role that smart grids can play, they are often unable to make the business case for smart grid investments. Within the business case, two factors operate: first, the capital and operating costs are too high, as suppliers have not been able to achieve scale economies in production and delivery risk is priced in; and second, only those benefits that are economically tangible are factored in, while other ancillary and non-financial benefits are not included (e.g. the carbon benefits) or are aligned to the appropriate value-chain players.

3. **Technology maturity and delivery risk** – A smart grid brings together a number of technologies (communications, power electronics, software, etc.) at different stages of the technology maturity lifecycle. In some cases, these technologies have significant technology risks associated with them because de facto or agreed standards have not emerged. In addition, there are only a handful of examples of large-scale implementation of more than 50,000 premises and therefore there continues to be significant delivery risk priced in to the estimates.

4. **Lack of awareness** – Consumers and policy-makers are becoming increasingly aware of the challenges posed by climate change and the role of greenhouse gas emissions in creating the problem. In some cases, they are aware of the role of renewable generation and energy efficiency in combating climate change. It is much less common that they are also aware of the way that power is delivered to the home and the role of smart grids in enabling a low-carbon future.

5. **Access to affordable capital** – Utility companies are generally adept at tapping the capital markets; however, where delivery risks are high and economic frameworks are variable, the relative cost of capital may be higher than normal, which acts as a deterrent to investment. Stable frameworks and optimum allocation of risk between the customer, the utility and government will be the key to accessing the cheapest capital possible. In the case of municipalities and cooperatives, this challenge may become amplified as the ability to manage delivery risk is reduced.

6. **Skills and knowledge** – In the longer term, a shortfall is expected in critical skills that will be required to architect and build smart grids. As experienced power system engineers approach retirement, companies will need to transition the pool of engineering skills to include power electronics, communications and data management and mining. System operators will need to manage networks at different levels of transition and learn to operate using advanced visualization and decision support.

7. **Cybersecurity and data privacy –** Digital communication networks and more granular and frequent information on consumption patterns raise concerns in some quarters of cyber-insecurity and potential for misuse of private data. These issues are not unique to smart grids but are cause for concern on what is a critical network infrastructure.

Of the seven barriers outlined above, the first three pose the most significant hurdles, but, if addressed, will go a long way towards creating an environment that will encourage investment in smart grids. None of these barriers is insurmountable; however, it is important to understand the root cause of the issues before developing strategies to break them down. In the following sections, each area will be looked at in more detail with examples that highlight the challenge.

2.1 Policy and Regulation

Policy and regulatory frameworks need to adapt; today's frameworks evolved to encourage competition in generation and supply of power rather than to promote clean energy supply.

The current policy and regulatory frameworks were mostly designed to deal with standard networks and utility operating models; in effect, "an all-you-can-eat buffet of electrons". In some cases, this has evolved to encourage competition in generation and supply of power. With the move towards smart grids, the existing policy and regulatory frameworks will need to evolve to encourage the right behaviours and incentives for investment. The new frameworks will need to align the interests of consumers with utilities and suppliers to ensure that the societal goals are achieved at the lowest cost to the consumer (either through the utility or tax bill).

In most cases, governments set policy while regulators monitor the implementation, protect the consumer and seek to avoid market abuse. Over the last two decades, the trend towards liberalized markets in many parts of the world has focused the attention of policy-makers on enabling competition and consumer choice. In economic terms, the onus has been on the private sector to make capital investments and to earn regulated rates of return on those assets. In a mature market model, this is a relatively low risk, low reward endeavour. The regulatory models have evolved to become more and more effective at avoiding market abuse and regulating rates of return.

Moving forward, the regulatory model will have to adapt to balance a suite of outcomes in which carbon reduction and security of supply take a more prominent place in the defined outcomes. As a consequence, trade-offs may need to be made with the degree of market competition and cost to the consumer. If policy-makers and regulators see long-term carbon reduction and security of supply as important outcomes, they will need to rebalance the regulatory incentives to encourage privately financed utilities to invest at rates of return that are commensurate to the risk. The relative risk profile for smart grid investments, given the technology and delivery risks outlined above, will require policy and regulatory frameworks that allocate risk to the parties that can diversify it most effectively. This may mean creating frameworks that allow risk to be shared between customers (either through their utility bills or taxes), and shareholders, so that risks and rewards are balanced at least aggregate cost to the customer.

As it stands, there are few examples of where this is being done effectively. Section 3 will look at some of the mechanisms that are being used or suggested in countries that are wrestling with this challenge.

2.2 Business Case

By purely quantifying the utility's financial benefits which could be realized today, the smart grid business case fails to recognize the broader societal value proposition.

In those cases where more forward thinking regulators and policy-makers have commissioned business cases, or progressive utilities have taken it upon themselves to push the issue, there has been a mixed set of results The majority of examples results in negative business cases, undermined by two fundamental challenges:

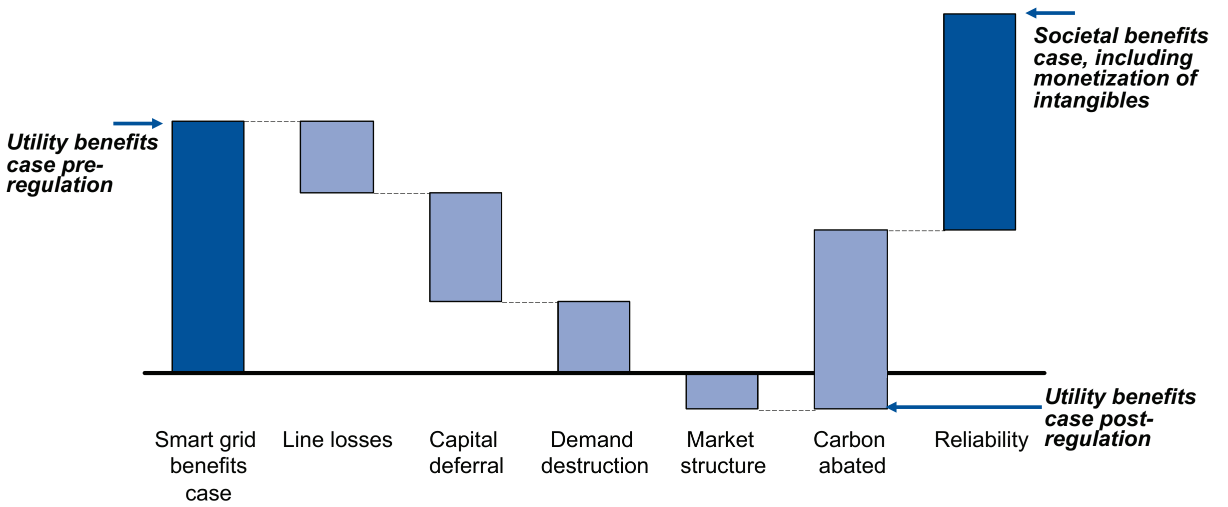
- **High capital and operating costs** – Capital and operating costs include large, fixed costs attributable to the ubiquitous communications network. Hardware costs do not factor in significant improvements in economies of scale and production innovation, and software integration assumes significant delivery and integration risks.

- **Benefits are constrained by the regulatory framework** – When assessing the benefits, business case modellers tend to be conservative in what they can realize as cash benefits to the shareholder. For example, in many cases, line losses are considered as a pass-through to the customer and, therefore, any reduction in losses would have no net impact on the utility shareholder.

There is a clear link between the business case and many of the barriers that have been identified in this section. Regulatory and policy frameworks determine the economics of the business and therefore drive what can be accounted for in the benefits case. The regulatory frameworks and accounting rules will determine what benefits can be monetized and which remain neutral to the utility.

As illustrated in Figure 6 (see next page), the smart grid benefits case may begin as positive but, as misaligned policy and regulatory incentives are factored in, the investment becomes less attractive. A broader societal benefits case which monetizes externalities is required.

Figure 6 – Illustrative graph of smart grid benefits case



The first consideration is the incentive to remove inefficiencies from the system. Utilities may be fully compensated for the line losses on their network; therefore, this common good fails to be monetized by the utility chief financial officer. Utilities also often recoup a return on their assets deployed; therefore, capital deferral (especially within generation) again is discouraged. The electricity demand destruction realized through empowered consumers will strip profits from the retail business, and finally the utility market structure may create a situation whereby those that are required to invest realize limited benefit. The end result is that, once the reverse incentives have been factored in, the utility's purely financial smart grid business case provides a mildly negative view. But this perspective fails to realize the value of externalities; it discounts the positive effects of reduction in greenhouse gases and improved network reliability. Section 3 will look at how the parameters of the business case can be broadened through changes to the regulatory accounting guidelines and innovative incentive structures.

On the cost side of the equation, there is no avoiding the fact that smart technologies are expensive to implement, and at the current level of maturity it is right to factor in the risk associated with delivery. However, there are ways in which policy-makers and regulators can help mitigate that risk and lower the fixed cost of communications by seeking economies of scale and scope with broader digital communications strategies (high speed wireless and/or fibre roll-out). Going forward, it can be expected that there is a move away from utility-specific business cases to broader societal value propositions that look across the entire value chain and seek to identify winners and losers. In this way, a framework is created to reallocate value accordingly to aligned incentives.

2.3 Technology Maturity and Delivery Risk

Smart technologies vary in technological maturity, with the challenges of data management and secure, ubiquitous communications proving to be key considerations.

Within the smart grid technology landscape, a broad range of hardware, software and communications technologies, at various levels of maturity, can be seen. In some cases, the technology is well established; however, in many areas the technologies are still at a very early stage of maturity and have yet to be trialled at significant scale. At a component level, this means that many of the core elements of the solution are not being produced at a significant enough scale to make them economically viable. With so few large-scale pilots under way, the industry is still at the earliest stages of understanding how to manage the explosion of data that comes from the embedded sensing on the network. As the technologies mature and standards (imposed or de facto) form, the delivery risk will decrease but, until that is the case, the risks will be factored into the business cases, making it harder to justify.

On the hardware side, rapid evolution of designs and functionality is seen from vendors all over the world. Over the last three years, this space was being led by new companies that were innovating rapidly and developing integrated product sets that operated within their own ecosystems, using proprietary data protocols and sometimes even their own communications solution. More recently, these companies have evolved to become more agnostic to the communications solutions and more focused on operating within a suite of hardware and software solutions. In addition to this trend, there is increasing interest from the more established hardware providers as policy-makers, regulators and utilities begin to make more significant commitments to smart grids. This trend is expected to continue with increasing competition from Asian manufacturers and, as a consequence, standards will naturally form and equipment costs will drop as economies of scale arise and competition increases.

On the software and data management side, the critical challenges to overcome relate to the integration of multiple products sets and the management of data proliferation. With multiple software providers come multiple data formats and the need for complex data models. In addition, the proliferation of data puts stresses on the data management architecture that are more akin to the telecommunications industry than the utilities industry. Many of these issues are currently being addressed in pilots such as SmartGridCity™ and, as a consequence, the delivery risk will reduce as standard architectures become established best practice. (SmartGridCity™ is a trademark of Xcel Energy.)

At present, communications are presenting a real challenge as utilities struggle to find a common architecture that provides the right balance of latency and bandwidth to satisfy their requirements. There are many options that exist, from mesh radio solutions through 2G and 3G to power line carrier (PLC) and broadband over power line (BPL) and optical fibre. Each option has different performance characteristics depending on where and how it is implemented. Given the relatively high fixed cost of a ubiquitous communications platform, it is essential that it is designed with future functionality in mind and with an ability to scale to fit over time as additional demands materialize. In many cases, there is a confluence of government digital broadband communications infrastructure roll-out and smart grid communications infrastructure roll-out.

2.4 Increasing Awareness

The profile of smart grids among industry and the public needs to grow.

Consumers' level of understanding and engagement in how power is delivered to their premises is often low. Within the policy-making and regulatory arena, smart grids have only recently begun to attract interest where renewable generation has dominated the share of mind for low-carbon strategies in the past. This is compounded by the relatively short tenure (3-4 years) of an average PUC member. Within the utility industry itself, only recently have smart grids reached the boardroom and, even then, there remains a lack of consensus over what it is and how it is best applied. If smart grids are to gain traction, it will need to be clear to all the stakeholder groups what smart grids are, how they are different to the status quo and why they will be a central enabler of a low-carbon future:

- Consumers will need to be educated on how their energy consumption patterns at home, at work and in transit drive cost and have value
- Policy-makers and regulators will need to work across government departments, to understand how smart grid technologies will transform the networks and allow for the integration of future low-carbon technologies
- Utility executives will need to take a more holistic view of smart grid technologies, looking beyond the smart meter to a broader set of smart grid capabilities that will fundamentally change the operating model of the business; barely a process or system will remain untouched

2.5 Access to Affordable Capital

Utilities are a relatively risk-adverse, heavily regulated industry; they will need to adapt towards investing in less mature product sets.

In an environment of stable, predictable economic regulation, access to capital is well understood by all parties in the transaction. As the traditional capital investment and replacement programmes are supplemented with smart grid investment programmes, the pricing of the additional risk will mean that the utility weighted average cost of capital (WACC) will increase. Unless this is reflected in higher allowed rates of return for smart investments, the utility is unlikely to sanction the expenditure; furthermore, the increased cost of capital will further degrade the business case. In the long run, it is expected that the risk profile return to something closer to the current state as new, stable economic frameworks come into play, delivery and technology risks unwind, and risk is equally and optimally shared across the value chain.

If long-run, marginal costs of hardware are to drop, the current low-volume vendors will need to scale up production by investing in manufacturing innovation and mass production facilities. To access the capital required for this transition at a reasonable cost, they will need to demonstrate that their risk of technology obsolescence is low and that their volume projections are stable and predictable. As it stands, there are many technologies vying for similar functionality and little in the way or firm commitments to volume purchases.

2.6 Skills and Knowledge

Smart technologies will require specialist skills to develop, implement and maintain the new energy system. New skills and knowledge need to be injected into an ageing industry workforce.

At this stage in the development of smart grids, there are such a limited number of large-scale pilots that getting access to leading industry architects is relatively easy. As the number of projects proliferates, the demands will grow for best practice documentation and information transfer from the original set of communications, data and system integration architects to the new projects. The existing population of utility engineers has developed deep skills in analogue electrical engineering; however, as the utilities drive towards smart grids, there will be a demand for a new skill set that bridges the analogue/digital divide and brings new skills in communications, data management, decision support and analytics.

Over the last two decades, the ageing workforce trend has largely gone unchecked and, as such, many utilities in the developed economies are destined to lose a generation of power system engineers at a time when they will be needed most to transition the existing networks to become smart grids. To address this challenge, a new cadre of engineers will need to be trained to manage the transition and to build an expanded set of skills that will help them design and build physical, communications and data architectures that will support the new grid. This transition will take investment of time and resources from government and the private sector to support education programmes that will create the engineers of tomorrow.

In the future, there will be a need for a broader knowledge base that can be tapped by entities choosing to transition towards smart grids. Much of the progress to date has been made by private companies developing and patenting new technologies, processes and architectures. Despite the current drive by the US administration to foster innovation in clean technologies in the US and the initiatives by FERC and DoE to drive standards, there is a risk that these technologies will become universally available but not royalty free. Those companies that are investing in intellectual capital will want reasonable returns on their investment. This issue will be addressed in the US through the NIST (National Institute of Standards and Technology) and may pave the way for a broader, global consensus on smart grid IP.[22]

Further to the challenge of developing enough skills and knowledge to design and build the smart grid, a new workforce of system operators, asset managers and field crews will need to be trained to operate, manage, install and maintain the network. This exercise will require developing new competencies and skills in areas such as advanced decision support, visualization and communications engineering. The scale of this change in skills and competencies will require utilities to think hard about how they manage the transition to avoid overburdening staff with change.

2.7 Cybersecurity and Data Integrity

With enhanced digitalization and the greater availability of data comes greater risk of data mismanagement or intentional cyber-attack; such risks should be effectively assessed and managed.

With the transition from an analogue to a digital electricity infrastructure comes the added complexity of having to manage the security of the communications infrastructure and data collected. Concerns are now being raised about the integrity and security of what will become a critical national infrastructure. Articles have been released that suggest that a digital network is more susceptible to malicious attacks from software hacks.[23]

In addition to these concerns over the vulnerability of the communications and control system, there are broader concerns over invasion of privacy and security of personal consumption data. The data and information collected on customer consumption (and potentially generation) could provide significant insight into customer behaviour and preferences. This information, while potentially valuable to the customer, service providers and system operators/planners, could be abused if the correct protocols and security measures are not adhered to.

In both of these cases, there are measures that can be put in place to mitigate these concerns. However, if not dealt with early in the process and in a transparent manner, the issue could shift public perception negatively and prove to be a barrier to adoption.

3. Solutions to the Barriers to Implementation

Despite the challenges laid out in Section 2, there are a number of concrete actions that can be taken to accelerate the adoption of smart grid technologies. At the root of the solution is a suite of systemic changes that need to be made to the way that policy-makers and regulators structure the economic incentives and align risk and reward across the value chain. By creating the right economic environment for private sector investment and thinking more broadly about the way that societal value cases are created and presented, the two most critical impediments will have to be overcome. Although national and transnational changes are required, there is a central role for cities to play in this process. Progressive and visionary cities will act as catalysts. By testing these solutions in increasingly larger environments, the entire industry will learn what it takes to implement smart grids successfully, and cities at the vanguard of the smart grid revolution will reap the rewards of developing an industry that is set to boom over the coming decade.

3.1 Creating Political and Economic Frameworks that Align the Stakeholders

Policy and regulatory frameworks will need to adapt to enable the low-carbon economy – aligning incentives for smart grid investment for both integrated and non-integrated utility value chains.

As it stands, the regulatory and policy frameworks in place in most locations are not designed to encourage the transition towards a smart network infrastructure, and in some cases the frameworks create negative incentives for investment. In a few cases, ambitious attempts have been seen to redress the balance and encourage investment in smart grid technologies. The final design of the regulatory framework will differ from location to location and will need to reflect the legacy environment (level of market liberalization, age and history of assets, ownership structures, etc.), desired outcomes and proposed strategy for transition. In each case, economists and lawyers will need to assess the frameworks and bring to bear a suite of potential mechanisms that create the right incentives across the entire value chain, allocate risks optimally, protect private investors against stranded asset risk and deliver the outcomes at the lowest cost to the consumer (through their bills and/or taxes). This section will tackle a number of critical policy issues and propose potential remedies (some of which are already being trialled). It has been deliberately chosen to stay at the level of basic principles, given that the details will differ from instance to instance; however, a number of universal principles should generally be applicable:

- **Decoupling** – In most cases around the world, utility revenues are a function of the commodity price and volume of that commodity sold. In these cases, there is a negative incentive to reduce consumption. In some cases, regulators have introduced specific energy efficiency incentives; however, in the US, some regulators have gone further and decoupled utility rates from the volume of the commodity that they are selling. By guaranteeing a rate of return on the installed asset base independent of the consumption levels, the incentive to drive sales is reduced. Decoupling does not, however, address the issue of "gold plating", as the utility is still remunerated on asset base installed. However, this is not a new issue and regulators have developed methods to address this. In some cases, regulators may also want to create stronger incentives for volume reduction in the domestic market or flattening of peak load. However, decoupling is only intended as a transitionary measure to manage the transition from a commodity-based business model to a service-based business model. In the long-run, regulators, policy-makers and utilities will need to transition towards a model that rewards efficiency, low-carbon generation and flexibility for the consumer.

- **Output-based regulation** – As regulators and policy-makers consider the best frameworks for smart grid investment, it is worth considering a greater level of output regulation. If it is assumed that similar regulated return models will be used in the future, it is worth considering linking bonus/penalty mechanisms to the rate of return to encourage delivery of the outcomes defined in the smart grid vision (those outcomes specified during the design and architecting phase). In principle, the utilities that are able to deliver the most efficient network per unit of electricity generated should get the highest rate of return.

- **Managing telecoms investments** – Telecoms infrastructure will form a significant proportion of the total investment in smart grids and has potential overlap with other aspects of the broader economy. In many developing and developed economies, the growth of a high-speed data and voice infrastructure (both wired and wireless) is a fundamental aspect of their future economic growth plans. The roll-out of these networks will cover similar footprints and may present opportunities to drive economies of scale and scope. Customers should not have to bear the burden of multiple coincident communications networks unless it is strictly necessary for reasons of security. Furthermore, by piggy-backing the existing communications infrastructure where possible, it will improve the business case for marginal improvements in smart grid functionality. In many cases, telecommunications and energy regulators have separate remits. Going forward, these regulators will have to work more closely together to agree on spectrum allocation, standards and cost/risk allocation. The same is true of policy-makers who will be responsible to consumers and taxpayers for delivering telecommunications and energy infrastructure at the lowest total cost of ownership.

- **Improved allocation of risk** – As mentioned in Section 2, the technological and delivery risk associated with smart grid implementation is significant, although it will decrease over time as more issues arise and are addressed. In the meantime, it is important that the regulatory frameworks are structured to allocate risk to the parties that are best able to manage it and diversify it. Every party in the value chain should shoulder some of the risk to align incentives, but some parties are more able than others to manage the risk. When designing the frameworks for delivery of the smart grid and awarding contracts, it should be clear that utility shareholders must hold some of the risk, but only sufficient risk to make them act in a way that aligns their interests to those of the consumer, and to a level that is material but not so severe that it is a disincentive to engaging in the project. By balancing bonus/penalty mechanisms at a material level, there will be improved alignment of incentives. In addition to creating the right incentives for the utility, there should be careful consideration of how much of that risk the utilities can pass on to the suppliers and contractors. If the risks are simply passed through to the suppliers and contractors but the benefits are kept by the utility, the alignment breaks down. All parties should have positive and negative incentives in the framework for delivery.

- **Migrating value across the value chain in a deregulated market** – Although the process of deregulation has delivered significant cost savings for the consumer in many deregulated markets, it does tend to make the process of transition to a smart grid more complex as there are multiple private sector parties involved with varying potential to win and lose. In each deregulated market, it is important to look at the entire length of the value chain and understand where investments will need to be made and where benefits will accrue. It will then be down to the economists to work out how best to migrate the cost and benefit across the value chain to make sure there is an equal alignment of incentives and delivery of benefits to the consumer. As with the private sector, if consumers are being asked to shoulder significant elements of the risk, they should also see the greatest percentage of the reward.

Figure 7 – US regulatory model examples

	1 Build with Supplier	2 Mandatory by Commission	3 "I will build if you approve"
	• Xcel Energy and Current Technologies; TXU and Current Technologies	• PG&E; San Diego Gas & Electric; Southern California Edison	• Exelon; Duke Energy
Strategy	• Proof of concept at technology level • Deployment to smart city. funding is designed as a shared-risk model with contributions from multiple partners. Total investment US$ 100 million, US$ 15 million from Xcel • If successful, the project will be put on rate base to be recovered • Decoupling of rates due to energy efficiency initiatives	• Investments are mandatory with directives approved by the public utility commission • Decoupling of rates allow for utilities to be kept whole and recoup investment • Energy efficiency programmes are in place to avoid new building and rate base increases	• Will only invest in upgrading the grid if public utility commission approves amount of capex prior to deployment • Energy efficiency programmes are being proposed but recovery of 90% of demand destruction
Consumer Cost Impact	• Minimal impact until rolled into consumer rates	• Consumer will bear the full cost of recovery of these investments • Benefits are yet to be proven to offset costs	• None at the moment, but likely to be minimized due to regulatory environment

Source: Company websites; State PUC; Accenture

- **Dealing with stranded assets** – In some cases, there will be a significant legacy of installed assets that may become stranded by the transition to a smarter grid. In deregulated markets, this may mean that some players in the value chain will lose out significantly from this technology. While this could be considered to be a natural risk of doing business, there will be calls for mechanisms to smooth the transition. If some stakeholders are set to lose significant sums from the process of modernization, there will be strong incentives for them to delay the transition. Whether this is dealt with through the regulatory mechanism or allowed to play out without interference will be a political decision, but it could put significant stress on the transition. This issue has been faced a number of times already in other areas, and the same mechanism would apply but should be considered on a case by case basis.

- **Funding of pilots** – If smart grids are to move forward at a rate that will help society deliver its ambitions to reduce greenhouse gas emissions, there will be a need for many, coordinated smart grid pilots, which then move quickly via effective dissemination of best practice to full-scale implementation. These pilots will need to vary in size and scope to ensure a broad spectrum of understanding of the risks and mitigations that need to be addressed to make smart grid value cases more attractive. At present, pilots such as that at SmartGridCity in Boulder have been reliant on the investment of private sector companies and have been conducted at significant risk. Since the announcement of the fiscal stimulus packages in the US and elsewhere, there has been a rapid increase in the level of interest in smart grids and potential trials. To get best value for money for the consumer and taxpayer, these pilots will need to coordinate scope and size. They will need to be funded or underwritten by either taxpayers or consumers with incentives placed on the parties engaged to share outputs and learnings so that consumers can mutually benefit from investments made elsewhere. Recently, a number of strategies have been adopted by utilities to encourage regulators and policy-makers to agree to pilots. A subset of US examples are outlined in Figure 7.

3.2 Moving Towards a Societal Value Proposition

A large proportion of the smart grid value proposition resides in its benefits to the public sector and to society as a whole. A more holistic perspective is required to capture and quantify externalities such as avoidance of power disturbances and carbon savings.

The business case for smart grids today is defined in a narrow context that prices risk in to the cost and underplays the potential benefit. The challenge will be to move from a utility-centric investment decision to a societal-level investment decision which recognizes the breadth of players and demonstrates the broader value of smart grids, which may or may not currently be rewarded within the confines of today's regulatory regime but remain valuable to both the consumer and society. Recognizing this value is the first step to appropriately rewarding it.

The business cases used for evaluating smart grids should be developed to encompass generation, transmission and distribution, retailers, customers and smart grid technology suppliers. Business cases should attempt to monetize appropriate externalities such as carbon. They should consider the gross impact at an economic level of building sustainable communications and energy infrastructure – GDP uplift, etc.

On the cost side of the equation, business cases should consider that both the price per unit and the assigned value for risk is expected to come down over the deployment lifetime of a smart grid programme. They should also consider whether costs can be shared through economies of scale and scope with other major infrastructure investments such as the national deployment of a broadband infrastructure. On the benefits case, they should recognize the potential of smart grids as an infrastructure provider to a low-carbon economy and attempt to monetize intangible benefits, such as carbon.

Achieving greater efficiency in energy delivery – Efficiency reduces the need to maintain expensive and potentially carbon-emitting generation assets and helps reduce overall energy consumption. Smart grid business cases should take account of building greater efficiency

into the energy network (reduction in losses on the network, peak load shifting) which today are ultimately picked up by the consumer. New regulatory frameworks which reward utilities for minimizing the technical losses on their network will drive different behaviours. Regulatory frameworks which are more innovative in how they provide regulated return on assets and how they incentivize demand destruction will lead the way to smart grid deployments. Some strong examples are already seen today where regulators' energy efficiency programmes compensate generators for 90% of the value of demand destruction.

Enabling distributed generation and storage combined with new business opportunities – Smart grids will change where, when and how energy is produced. Each home and business will be enabled to become a micro-generator. Onsite photovoltaic panels and small-scale wind turbines are present-day examples; emerging resources include geothermal, micro-combined heat and power boilers, biomass, hydrogen fuel cells, and plug-in hybrid electric vehicles and batteries. As the cost of traditional energy sources continues to rise and the cost of distributed generation technologies falls, the economic case for this transition will build. Assuming a 10% penetration of distributed generation, technologies' smart, interactive storage capacity for residential and small commercial applications has been estimated to add US$ 10 billion per year by 2020 to the US economy.

Facilitating electrification of vehicles – The ability to electrify the transport sector also hinges upon a smarter grid. Today's network is designed to provide approximately 1 KwH/home. The advent of electric vehicles and their charging requirements is likely to increase this dramatically. Early estimates are that the current distribution grid is not dimensioned for more than a 15-20% penetration of electric vehicles. The recent launches of e-vehicles by several major manufacturers – GE, Toyota, Nissan, etc. – represent the bottom of the S-curve on these technologies. If their uptake is to be supported, it is imperative to plan ahead to put the platform infrastructure in place.

Carbon abatement – An important element to the rationale of deploying smart grids is the ability to save carbon, both directly through more efficient transmission and distribution of electricity and more indirectly through the ability to change consumers' behaviour and as an enabler for a raft of low-carbon technologies. Worldwide, smart grid technologies can prevent about 2,000 MMT CO_2 of emissions, or about 4% of worldwide emissions in 2020,[24] according to a recent study by The Climate Group. This, together with other information and communication technologies (ICT) opportunities (in the key areas of travel/transport, buildings and industry systems), suggests a potential reduction of about 15% of total worldwide emissions in 2020. Moreover, considering even a relative conservative future price of carbon, for example US$ 20, would make the financial business case for smart grids immediately positive.

Some visionary utilities, such as Duke Energy, are beginning to quantify and assign monetary values to their smart grid value proposition. Duke's smart grid business case includes the avoided costs from improved reliability, the carbon savings from lowered maintenance truck rolls and the carbon and operational savings associated with the reduced need for peaking plants. The study demonstrates that 40% of the total value case for smart grids is societal.[25]

However, societal value propositions for smart grids do not necessarily need to be limited to purely monetary benefits. A number of externalities are likely to not be readily converted into dollar values and, yet, still reflect changes that are considered valuable to society more broadly. Rather than trying to convert these benefits to a monetary figure and having to make significant assumptions that could undermine their validity, regulators and policy-makers could take the benefits in their existing format and build them into the economic framework of incentives by creating rate of return multipliers (both positive and negative) to encourage the right behaviour from utilities.

3.3 The Role of Standards

Debate exists around the relative importance of standards; the key is getting the right type of standards at the appropriate level within the architecture.

At face value, the rapid migration towards a set of standards seems the logical and lowest risk solution to decreasing the implementation cost and risks for smart grids. However, there are inherent risks in setting de jure standards too early in the maturity cycle for a technology that will need to be borne in mind as the industry is driven headlong towards a set of standards. With most technologies, a progression of formalization is seen through coalescence around specifications and requirements; through the formation of de facto standards towards de jure national and ultimately international standards. With smart grid technologies it is possible to see a rapid acceleration of this process in some markets, especially in the US, where the American Recovery and Reinvestment act mandates the creation of national standards and the process is already under way to create them. A similar acceleration is seen in the European market and is expected also in Asia.

There are pros and cons to rapid adoption of de jure standards. On the positive side, there is likely to be a more rapid reduction in the hardware and integration costs for deployment of smart grids as suppliers and utilities gravitate towards agreed standards. However, on the negative side, there is a risk that the standards could act as a barrier to innovation and constrain the ultimate functionality of the system in an area where the technology is still relatively immature. One example of where the haste to develop standards ultimately hampered functional innovation is in the mobile telephony industry. In the drive to define the standards in the US, the industry created solutions that constrained the US networks' ability to deliver value-added services such as text and multimedia messaging. In Europe, the GSM standard allowed more flexibility to network operators and as a result there was a more rapid adoption of text messaging and the resultant revenue uplift.

Given the complexity of the power industry, the multiplicity of interfaces, the level of capital investment and the strategic importance of critical national infrastructure, the case for rapid adoption of standards is strong. However, in the absence of de facto standards, the stakeholders in the process will need to pre-empt the future functional requirements of utilities and create standards that are flexible enough to allow for innovation in the products and services that can be offered on the back of the standard infrastructure.

3.4 Increasing Awareness of Smart Grids

The dissemination of clear, consumer-relevant smart grid information to the public domain will be a key accelerator for education across the stakeholder groups.

There is an imminent need to increase the amount and the quality of available information regarding smart grids across the board, from senior policy-makers and the C-suite of the utilities to the electricity consumers. Each stakeholder group will have a different set of priorities and motivations for learning about smart grids, and the content and direction of the education will need to reflect that need and provide the appropriate details in given areas.

The first step is to establish a clear, universal definition on the common principles of a smart grid. Lack of a consensus clouds the industry today. Smart meters (with both one-way and two-way communications) are discussed synonymously with a smart grid which delivers quite a different set of capabilities. Beyond agreement on a definition, the topic also needs to be discussed more holistically as a true enabler to the low-carbon economy, rather than as an investment decision to be taken purely within the boardroom of individual utilities. The societal benefits case for such investments warrants discussion across the public/private sector boundary to develop workable industry solutions.

The role of consumer education is not to be underestimated. To maximize the benefits of smart technologies, significant behavioural change will be integral. The participatory nature of the new network and the advent of energy management tool and services will fundamentally shift the way people value and interact with their electricity supply. The creation of user-friendly and innovative products and services will play an important role in engaging the public and articulating the answer to the question, "What's in it for me?"

Policy-makers and regulators will require help in quickly getting up to speed on this relatively novel concept to ensure that they are setting in place economic regulatory and market constructs which address the true needs of the industry. They will also need to ensure that they are aligned across political parties to deliver consistent messaging to their citizens. Forums and open discussions with utilities and technology suppliers will be an important element of this process.

Relatively quickly, utilities also need to obtain a base understanding of the technology, business case and implementation challenges of smart grids. They need to leverage the learnings from the handful of smart grid pilots which are live today. Utility executives need to begin factoring smart technology into their asset management planning and anticipating the impacts on both their business models and operations.

3.5 Creating a New Pool of Skills and Knowledge

Addressing the skills shortages and providing the infrastructure to facilitate cross-industry knowledge exchange is fundamental to moving the technology forward.

The "greying workforce" and shortage of engineering talent are already concerns within the utility sector. Successful implementation of the smart grid will require a large number of highly skilled engineers, particularly those trained to work on transmission and distribution networks. As such, a dramatically increased commitment to on-the-job training and workforce development will be required across the industry. In parallel, there is a need for investment in the development-relevant undergraduate, postgraduate and vocational training to ensure the building of a sufficient pipeline of next generation, smart-grid-savvy electrical engineers. Mechanisms such as the Green Jobs Act and Workforce Investment Act in the US provide initial examples of formalizing this investment.

Smart grid investors should also look beyond their national borders and recognize the wealth of engineering talent that is available globally. Today, China is the largest producer of engineering graduates in the world, with some 600,000 passing out of its colleges and universities last year. India is not far behind, producing slightly more than 500,000 engineering graduates a year.[26] In comparison, the United States produces only 70,000 engineering graduates every year. All of Europe produces just 100,000.[27] The ability to sensitively leverage this abundance of talent will help alleviate short-term bottlenecks in supply.

The investment should not be limited to the T&D engineering workforce; research and development skills and knowledge will also be fundamental to accelerating this sector. Studies and papers released by the US National Energy Technology Laboratory and President Obama's recent pledge of US$ 1.2 billion to the Advanced Research Projects Agency-Energy marks good progress in this arena. The literature to date has been fairly US-centric, and there is a clear requirement/opportunity for countries outside the US to establish a stronger presence in this area.

The final key solution in this area is the efficient and effective dissemination of knowledge. The role of organizations such as the Institute of Electrical and Electronics Engineers will be integral to coordinating international smart grid efforts and helping share and establish best practices. The role of innovative professional networking sites which are dedicated to linking professionals within the cleantech sector should also not be underestimated as a forum for discussing and solving the key challenges facing the industry. Part of the solution will be effective impetus placed on those organizations which conduct pilots to contribute knowledge capital backs to the wider community. Levers such as fiscal stimulus conditions may be useful in this regard.

3.6 Addressing Cybersecurity Risks and Data Privacy Issues

Concerns over cybersecurity should be met with appropriate standards and legislation. Individuals should be satisfied that their personal data is protected and handled appropriately.

With increased computer and communications network interconnection comes the increased potential for cyber-attack. Information technology companies have been tackling similar security issues for more than 20 years, but the critical asset base in question makes this a considerable challenge. This is not a challenge limited to the larger utilities within an integrated system; all players must adhere to sufficiently high standards to withstand attack, as they all retain the potential of becoming a vector of vulnerability to the broader network.

NERC, with the support of NIST and EPRI, has been making some solid progress in the definition of cybersecurity standards. First and foremost, they are supporting utilities to identify critical assets and to apply risk-based assessments.[28] It is hoped that these standards will be rolled out industry-wide and provide a global benchmark. To date, the US has been most proactive in the creation of smart grid standards; it is imperative that Europe follow suit via the European Smart Networks programme to provide a unified international standard for Europe to serve what will potentially be a highly interconnected pan-European smart grid.

Standards will also need to be supported through new legislation; there are two US smart grid cybersecurity bills in the pipeline.[29] In alignment with this, utility executives will be expected to progressively establish expectations for cybersecurity performance and hold employees accountable. The systems will need to be rigorously tested on build and undergo continuous risk management. The challenges are not insurmountable and have been overcome with other critical systems – e.g. the global banking system – when treated with due care and attention.

There remains a valid concern regarding the way individuals' energy consumption data is used, both by the utility and by third parties. Such concerns recently held up a decision to mandate smart metering in the Netherlands.[30] The solution to such challenges will involve clear legislation around smart meter and smart grid data ownership and privacy, similar to how telecoms data is carefully managed and used today. Utilities, regulators and governments will need to give consumers confidence that

their usage data is being handled by authorized parties in an ethical manner. Such assurances will be the key when developing the public perception of these new technologies.

3.7 The Central Role of Cities in Catalysing Investment

Cities will play a pivotal role as catalysts for smart grid implementation, with some of the greatest needs and the greatest motivation. Several factors have been identified which highlight those cities likely to be early adopters.

Why Cities?

When looking at the global variation in smart grid drivers, it becomes apparent that cities will be integral in managing the transition to a smarter energy infrastructure and a functioning low-carbon economy. The city environment provides a prime location for smart grid investment. They are centres for electricity demand, investment and innovation; they are great starting points from which to pilot technologies in the move towards larger and larger scale roll-outs. Cities are looking for solutions; they have requirements to provide services which work towards national and internationally agreed targets on efficiency and carbon reduction goals (e.g. cities within the European Union striving towards a 20% reduction by 2020). Cities are also competing on a global stage for inward investment (to attract business and entrepreneurs), for public expenditure (for public funds to invest/create jobs, etc.), for residents (affluent, talented citizens) and for visitors (tourists and business travellers). Putting in place sustainable communications and electricity networks will be critical in maintaining a long-term competitive edge. Rather than a piecemeal infrastructure upgrade approach, smart grid investments offer cities an integrated infrastructure upgrade methodology: optimization of operations (transmission and distribution networks), a drive for behavioural change (using less, cleaner energy) and the introduction of new technologies (smart grids, combined with smart meter and home/office automation) simultaneously.

On a purely environmental basis, it is imperative that cities engage in smart grids – 71% of emissions are generated by urban environments. Moreover, people continue to coalesce in urban environments, driving load growth and increases in city infrastructure – 50% of the world's population lives in cities today, and 70% of the global population is expected to live in urban environments by 2050.[31]

Smart grids could reach their greatest potential in urban environments, providing the backbone for a series of low-carbon technologies in the city environment, including the integration of distributed micro-renewables; biomass-based generation (using anaerobic digestion of organic waste); dynamic transport solutions; distributed sensing and control environments; interconnected smart building environments; electric vehicles charging infrastructure, etc. The municipality political construct has a privileged position to act as an integrator to help realize sustainability across multiple areas, often grid assets owners, with links to waste management companies, and building companies, and a role in transportation politics to bring together the disparate stakeholders and align them towards common goals such as CO_2 reductions.

Which Cities?

Cities will not be equal in their immediate amenability to a smart grid deployment or their relative capability to execute a smart grid strategy, the primary variables being policy and regulatory constructs, economics and consumer appetite. To identify the cities that are most likely to lead the change, a number of factors have been identified that, when they converge, will produce an environment that is primed for change. Both national and local factors will be at play.

National factors

- **Market structure**: The electricity market structure will be the key. Within a regulated and vertically-integrated market (e.g. in the US), the relative ease of aligning the different parts of the value chain to drive a common outcome will be significantly less complex. The alternative, a deregulated, liberalized market (e.g. United Kingdom, Germany), will have an increased need to motivate multiple, competing parties to drive in a common direction and to develop economic regulation which successfully rebalance who invests and who benefits.
- **Federalization:** Those countries which favour dissemination of the decision-making power will empower the local decision-makers (governors, mayors, etc.) to promote smart grid investment within their domain and equip them with the autonomy to strive ahead of the curve.
- **National ambition:** Some countries will target smart grids as a technology to excel and develop relevant intellectual property and skills to export globally. One example is South Korea, whose government drive has seen over-allocation of fiscal stimulus funds to smart grids, and the recruitment of over 100 personnel to a dedicated government department.

Local factors

- **Visionary leadership**: To engage in a task of this magnitude, the city will require bold and visionary leadership.
- **Political alignment**: The alignment of the political and decision-making authorities at the municipality level will be the key – the local government, the mayor, incumbent utility and the city council will need to step through the smart grid transition together. This was a key success factor in Boulder, Colorado, for example.
- **Municipal asset ownership**: It is much easier for cities to make smart grid decisions if the city owns the distribution assets.
- **Consumer appetite**: The city's appetite for change will also be fundamental. Those cities with environmentally aware citizens, who are open to new technology, will be able to move at a faster pace.
- **Specific goals and timelines**: An impending event or set of challenges can act as a catalyst for the decision-making. This could be a major political or sporting event or an impending election or contract renewal for utility concessions.

It is important to recognize that, even if cities operate as an impetus for smart grid implementation, they cannot act as single point implementations; this approach will never allow smart grids to reach a meaningful scale. Rather, they must sit within an integrated regional/national approach and commitment to a smart electricity system. It is also noted that, in some instances, visionary utilities may lead the way, e.g. as in Palo Alto, California.

4. Summary Recommendations

The acceleration of smart grid investment is pivotal to the creation of a low-carbon economy. It will require timely and definitive action across a range of stakeholders.

To achieve the successful acceleration of smart grid investment, it is necessary to raise awareness and understanding across all industry stakeholders. In parallel, it is imperative to support a transition from planning to implementation, establishing pragmatic policy and regulatory structures which drive the right behaviours and long-term outcomes across the industry.

The successful global acceleration of smart grid investment will be a central tenet of the transition to a lower-carbon economy. The benefits of smart grids (as described throughout this paper and crystallized in Figure 4) are persuasive and resonate across the full spectrum of stakeholders. To access this wealth of value, it will be necessary to ensure that the systemic industry structure is correct. Central to the required changes are two themes:

- **Regulatory refresh** – adapting utility regulatory regimes worldwide to provide clear profit motives to utilities to place value on energy efficiency; encouraging utilities to produce and deliver as efficiently and clean electricity as possible, without compromising security of supply

- **Public-private partnerships and societal value propositions** – a new era of collaboration is required across the utility industry and among government/policy-makers, accompanied by a move away from purely financial business cases to broader societal value propositions that demonstrate the benefits of smart grids to the general public

Despite the stated benefits outlined above, some policy-makers may still be hesitant to make what is undeniably a significant and definitive investment. However, it should be stressed that the potential costs of procrastination in making this transition are equally significant. Failing to have the appropriate backbone infrastructure is likely to put a brake on the integration of alternative low-carbon technologies. Maturing, clean technologies will struggle to shift from small-scale implementations to mass roll-out, for example PHEVs, and microgeneration. Without smart grids and the regulatory structures that support a shift in the utility retail operating model, it will be more difficult to deliver energy efficiency measures. The opportunities for industry to create new products and services, to develop a better understanding of their customers and to provide more jobs and economic uplift will be considerably curtailed.

The time for this action is now. Recent economic modelling by the Stern Review estimates that if action is not taken now, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever, rising to 20% of GDP or more if a wider range of risks and impacts is taken into account. In contrast, the costs of action now – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year.[32]

To help progress the debate and to move towards this end goal, the section below provides a handful of key recommendations for each stakeholder group as a distillation of this paper's findings.

4.1 Government and Policy-makers

Policy-makers and governing bodies have a role to play at multiple levels to accelerate smart grid investment.

Trans-national

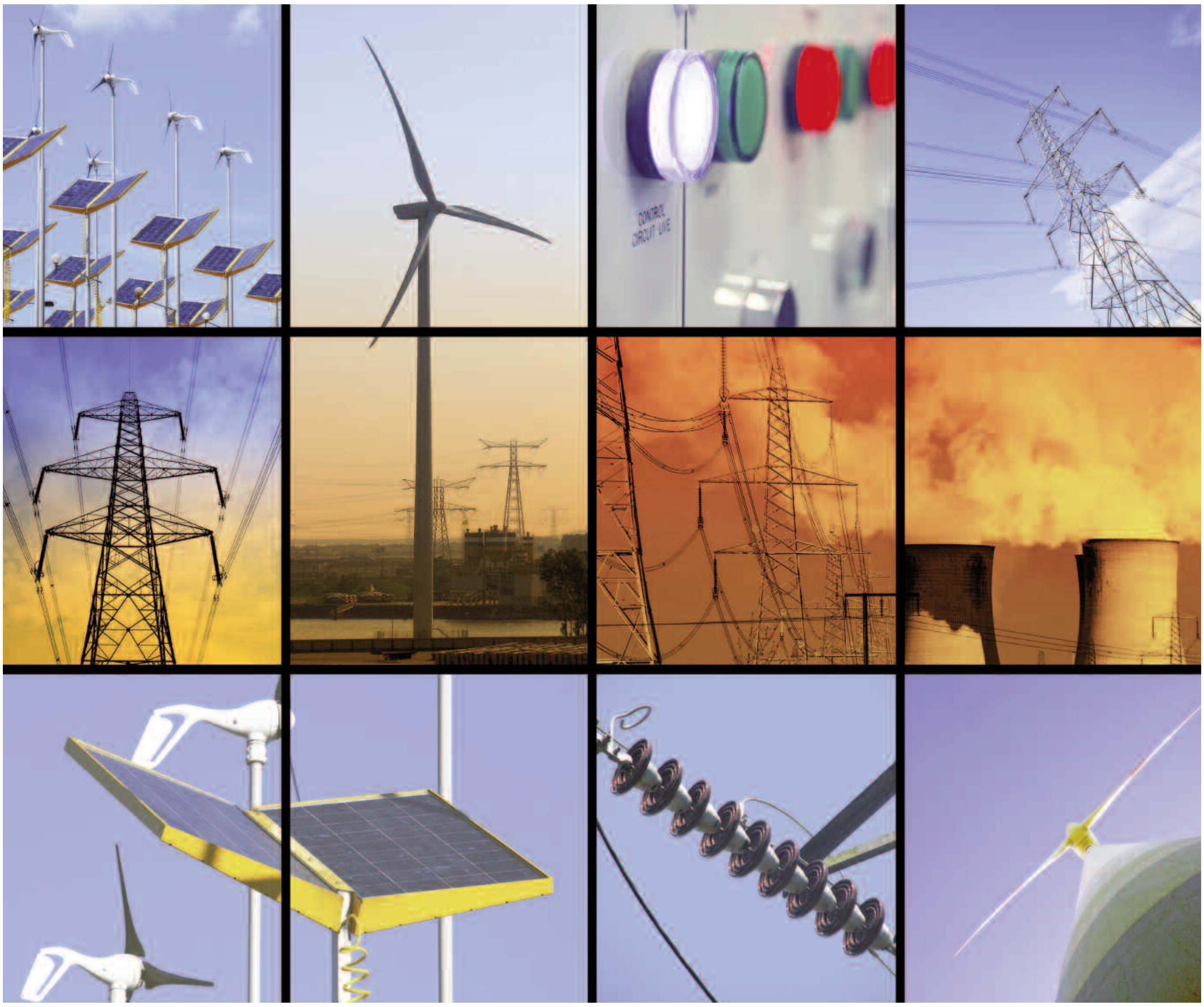
- Global policy forums will play a key role in establishing common smart grid standards and protocols that will remove industry uncertainty surrounding the risk of technology obsolescence and accelerate investment. A coordinated set of pilot projects with shared access to data and knowledge gained will help reduce delivery risk and therefore improve the value case for smart grids.

- Global climate change initiatives, such as the UN Climate Change Initiative (COP15), have an essential role to play in translating carbon reduction targets to action. Formalization of GHG reduction targets and liquid carbon markets will create a stronger platform for change and will help translate intangible carbon reduction externalities into financially quantifiable benefits.

National

- National policy-makers will need to rebalance the potentially competing objectives of climate change, security of supply, competitive markets and cost to the consumer. Clarity over these objectives and generation portfolio mix will help set the parameters for regulators and utilities to generate smart technology strategies.

- National statements of intent on the potential for this technology to achieve national carbon and security of supply objectives will help drive industry momentum and awareness. Statements of intent will allow vendors to invest in scaling up production which, in turn, will improve the value case for investment.



- Beyond statements of intent, national governments could potentially play an important role by developing regulatory frameworks and co-funding of pilot projects conducive to bringing down risks to investors.

- National governments are encouraged to look across their departmental portfolios to see the opportunity for economies of scale and scope regarding the deployment of smart technologies and national telecommunications infrastructure.

- National policy-makers can play a key role in encouraging utilities to stretch their thinking beyond standard smart metering deployments to consider smart grid and smart homes and offices.

Local

- Bold leadership by local government leaders can help catalyse the implementation of smart grids by drawing together critical stakeholders from utility companies and major industrial and commercial consumers.

- By setting a bold vision, strategy and roadmap for achieving energy efficiency and carbon substitution goals, local government can position cities at the forefront of the low-carbon economy, attracting high-value investment and boosting local GDP. The competition between major cities to house this next wave of clean technology companies is intense and will require integrated local strategies.

4.2 Regulators

Regulators will be responsible for designing and implementing relevant and workable regulatory frameworks and incentive structures that reflect the policy objectives set by politicians.

- Regulators will need to create regulatory frameworks that align the incentives of each participant in the energy value chain. In deregulated markets, this will require new economic frameworks that allocate risk and reward efficiently, create the right incentives and deal with asset stranding risk.

- In assessing the viability of utility investment plans, regulators should switch from a purely financial business case towards a broader set of measures that reflect the total societal value proposition.

- By shifting towards an output-based regulatory framework, regulators can translate the broader set of societal values into economic incentives and penalties that will encourage behaviour that aligns the needs of shareholders with societal needs.

4.3 Utilities

Utilities will be responsible for the majority of smart grid implementations and will need to reconcile the needs of society with shareholder needs.

- It is recommended that utilities adopt a more holistic approach to business case building. By widening this value proposition to a broader societal value proposition, they will build their regulatory case and demonstrate to their consumers the broader benefits case which will be realized over time.

- Utilities can reduce the risk of technology obsolescence by deploying smart technologies that are modular in design, forward compatible and interoperable.

- Conversations with government and regulators early in the process to identify potential for economies of scale and scope on multiple infrastructure investments (especially in telecommunications infrastructure) will deliver the greatest value to consumers.

- Utilities are recommended to undertake large-scale, broad capability pilots, and to measure the benefits as they are realized, adding concrete numbers and savings to what is to date a fairly difficult equation to quantify. They are encouraged to this knowledge to refine future business case development.

- Utilities should consider strategies for transitioning from commodity service provision to a broader set of consumer value-added services early in the planning process. Early definition of this long-term strategy will help build in smart grid infrastructure that enables this transition (e.g. Home Area Networks and EV charging infrastructure).

4.4 Vendors

Technology vendors for all aspects of smart grids should not underestimate their role and should ensure that they engage in the smart grid debate.

- Vendors are encouraged to bring the wealth of their experience to the policy table and ensure their requirements are reflected in new regulatory regimes and global standards.

- Modular design, forward compatibility and interoperability of smart grid equipment will be a key driver of how fast utilities and consumers adopt the technology. Vendors are encouraged to move rapidly towards de facto standards to help utilities re-risk investments.

- As the industry moves rapidly towards standards for critical smart grid infrastructure, it is important that vendors continue to innovate with the end consumer in mind. The most successful vendors will create blended product and service offerings that make it easy for consumers to change their behaviour. For smart grids to move towards mass adoption, consumers will need to embrace the technology.

4.5 Customers

Customers have a critical role to play in the development of smart grids. By demanding and paying for cleaner and more flexible services (and being willing to switch supplier – where possible – to a supplier that offers more innovative, focused and value-added products), the business model will change by default. New entrants will come into the market with more customer-centric offerings and incumbent utilities will innovate and become more focused on how to create more flexible, efficient and value-added products and services. By demanding these services, the utility companies, politicians and regulators will understand that there is mileage in pursuing policies and frameworks that consumers want, and awareness will grow.

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Glossary

- **de facto standards** – A de facto standard is a standard (formal or informal) that has achieved a dominant position by legal enforcement.

- **de jure standards** – De jure standards are standards that have been approved by standard bodies, professional organizations, industry groups, a government body or other groups.

- **Decoupling** – In public utility regulation, decoupling refers to the disassociation of a utility's profits from its sales of the energy commodity. Instead, a rate of return is aligned with meeting revenue targets, and rates are trued up or down to meet the target at the end of the adjustment period. This makes the utility indifferent to selling less product and improves the ability of energy efficiency and distributed generation to operate within the utility environment.

- **Demand response** – This term generally refers to mechanisms used to encourage consumers to reduce demand, thereby reducing the peak demand for electricity. Demand response mechanisms enable consumer appliances to be shut off or cycled in response to electricity supply conditions, enabling electricity customers to reduce their consumption at critical times. Under conditions of tight electricity supply, demand response can significantly reduce the peak price and, in general, electricity price volatility. Since electrical systems are generally sized to correspond to peak demand (plus margin for error and unforeseen events), lowering peak demand reduces overall plant and capital cost requirements.

- **Distribution network** – The wiring from substations to customers is referred to as electricity distribution, following the historic business model separating the wholesale electricity transmission business from distributors who deliver the electricity to the homes.[1]

- **Distributed generation** – generates electricity from many small energy sources. Currently, industrial countries generate most of their electricity in large centralized facilities, such as coal, nuclear, hydropower or gas powered plants. DG is another approach, using small-scale power generation technologies (typically in the range of 3 kW to 10,000 kW) to provide an alternative to or an enhancement of the traditional electric power system.

- **Output-based regulation** – regulation that rewards or penalizes specifically defined outcomes, such as carbon emissions, reliability improvements (in terms of customer minutes out), etc.

- **Plug-in hybrid electric vehicles** – a hybrid vehicle with batteries that can be recharged by connecting a plug to an electric power source. It shares the characteristics of both traditional hybrid electric vehicles (also called charge-maintaining hybrid electric vehicles[1]), having an electric motor and a internal combustion engine, and of battery electric vehicles, also having a plug to connect to the electric grid (a plug-in vehicle).

- **Predictive monitoring** – extracts sensor information from equipment, control systems and business systems, and then uses sophisticated analytic models to predict equipment faults and sub-optimal performance long before the equipment fails. The system uses both historical and real-time data to make predictions about the future.

- **Stranded assets** – An asset that is worth less on the market than it is on a balance sheet due to the fact that it has become obsolete in advance of complete depreciation.

- **Smart grids** – Sensing, embedded processing and digital communications to enable the electricity grid to be *observable* (able to measure the states of all grid elements), *controllable* (able to affect the state of any grid element), *automated* (able to adapt and self-heal) and fully *integrated* (fully interoperable with existing systems and have the capacity to incorporate a diversity of energy sources).

- **Transmission network** – the bulk transfer of electrical power (or more correctly, energy), a process in the delivery of electricity to consumers. A power transmission network typically connects power plants to multiple substations near a populated area.

- **Vehicle-to-grid** – a system in which power can be sold to the electrical power grid by an electric-drive motor of a hybrid vehicle that is connected to the grid when it is not in use for transportation.[1] Alternatively, when the car batteries need to be fully charged, the flow can be reversed and electricity can be drawn from the electrical power grid to charge the battery. Vehicle-to-grid can be used with such gridable vehicles – that is, plug-in vehicles (electric vehicles as battery electric vehicles or plug-in hybrid electric vehicles) with grid capacity.

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