AN AUSTRALIAN SMART ELECTRIC GRID – CRITICAL INFRASTRUCTURE FOR ADDRESSING GLOBAL WARMING

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Smart Grid systems (high performance communications and distributed intelligence overlaid on the 100+ year old electric grid) have the potential to be the single largest contributor to a solution for global warming available today. Electric power produces 35% of Australia's greenhouse gases and studies indicate that a Smart Grid could reduce total greenhouse gases by nearly 9%. Unfortunately, the focus of some utilities and regulators on installing so called "Smart Meters" (at an estimated cost of $2.7 to $4.3 billion for 100% rollout in Australia) may result in an increase in greenhouse gases rather a reduction.

OVERVIEW

Smart Grid systems (high performance communications and distributed intelligence overlaid on the 100+ year old electric grid) have the potential to be the single largest contributor to a solution for global warming available today. Electric power produces 35% of all greenhouse gases in Australia (Garnaut 2008, 468). The Electric Power Research Institute estimates that overlaying a Smart Grid on portions of the U.S. electric transmission and distribution networks could reduce carbon dioxide emissions from electric power by up to 25% while reducing the estimated economic impact of electric outages by over 80% (EPRI 2003, 42). Using an equivalent estimate of the CO2 reduction in Australia would equate to a nearly 9% reduction in overall greenhouse gases.

The Garnaut Climate Change Review highlights the potential damage that climate change would play in Australia due to its hot and dry climate indicating that 'small variations in climate are more damaging to us than to other developed countries'. It identifies Australia's per capita emissions as among the highest in the world with emissions from the energy sector expected to quadruple by 2100 unless mitigation is initiated. This high level is primarily attributed to the heavy reliance on coal to produce electricity. The report concludes that

> 'The electricity sector is projected to play a central role in the way in which the Australian economy achieves an abatement commitment within a global agreement. The role emerges from the 35 per cent contribution that electricity makes to greenhouse gas emissions today. It is magnified by the capacity for other sectors, notably other stationary energy and transport, to achieve lower emissions by changing from high-emissions fossil fuels to lower-emissions electricity' (Garnaut 2008, xix, 153, 468).

As it plays such a key role in the climate change, it is important to examine the existing electric system and identify potential efficiencies to reduce the usage of electricity as well as the carbon impact of the remaining electric generation. Carbon capture and widespread renewables receive a large amount of attention; however, little attention is being placed on the grid itself. The grid represents an area of huge opportunity as the electric utility has limited information regarding the performance or efficiency of the electric grid beyond the substation which connects to the electric transmission system. In fact, utilities often do not know the power is out unless a customer reports it.

A 'Smart Grid' is an intelligent, managed, controlled and ultimately self-healing electric distribution network capable of closely matching supply with demand while improving efficiency and reliability. Sensors and control devices on the grid, combined with integrated high-speed communications and advanced analytic software, provide utilities with actionable intelligence reports and information. Such tools make the electric utility more efficient and reliable, and in turn reduce the need for coal burning power plants that generate high levels of greenhouse gases. A Smart Electric Grid can identify where electricity is lost or where the system is not in balance or optimised. Such optimisation can save 3% or more of overall electric demand without requiring any change in consumer behaviour.

While the existing electric system was designed for one way power flows from continuously monitored centralised generation and transmission, the electric grid of the future will consist of two way power flows through the use of wide spread renewables and even plug-in hybrid electric vehicles (PHEV's) which act as large batteries when not being used. This changing nature of the grid is changing the requirement of communication from low latency always-on communication at the power plant to low latency always-on communication throughout the entire grid, including to these distributed renewable resources or even the PHEV's as they are introduced in 2010.

There is no silver bullet for reducing greenhouse gases from electricity. Various solutions are required, including improved energy efficiency. Adding renewables increases the production cost of electricity and requires additional transmission. Carbon capture systems, when available, will add additional costs as will the introduction of a carbon cap and trade or carbon tax system. As a result, Australian retail electricity prices are projected to increase between 40 and 70% by 2020 in real dollar terms (Garnaut, 2008, 575).

Despite the pressure on rates and the critical role of electric utilities in global warming, the focus of many of the utilities and regulators in Australia is on installing Automatic Meter Reading ('AMI'), which is also referred to as 'Smart Meters'. Supporters of these systems advocate a capital investment of $2.7 billion to $4.3 billion for a national rollout of residential and small commercial meters in Australia. They claim that the systems will help manage demand growth, provide operational savings and reduce greenhouse gases. While the NERA cost benefit analysis prepared for the Australian Ministerial Council on Energy shows these systems provide some operational cost savings, they have a limited impact on a net present value (NPV) basis on reducing demand and provide little to no reduction in greenhouse gases. The operational savings are primarily from the reduction of meter reading costs and are not enough to justify the system on its own accord (NERA Economic Consulting 2008, xi, 7, 8).

The anticipated future capital requirements for renewables and carbon capture and the resulting impact on rates requires that Australia invest in solutions that minimise the carbon footprint of electric utilities, solutions such as the Smart Grid. By focusing on the Smart Grid, greenhouse gases can be reduced without a requirement for consumer change in behaviour. Smart Meters should only be targeted where there is a high cost to read meters, large customer turnover, or where customers agree to participate in demand reduction programs.

Unfortunately, in many parts of the world including Australia, the regulatory framework disaggregates generation from long haul transmission from last mile distribution from the retailing of electricity. While such a system promotes competition in pricing of electricity generation and retail sales, there is no one organisation that benefits from the overall system-wide view or optimisation of the electric network that a Smart Grid provides. In fact, where a company owns more than one component, they often benefit from the inefficiencies of the electric system as the amount of electricity sold is higher than what would optimally be necessary. In addition, distribution companies' revenues and thus profits are often influenced by the amount of capital deployed or the power distributed, not by the efficiency of the system. While this may have been acceptable in the past, in a carbon-constrained world, it is necessary to focus on the overall efficiency of the system.

Xcel Energy in the United States is viewing the Smart Grid from such an end-to-end solution. In a white paper on Smart Grid City, their Smart Grid project in Boulder, Colorado, they state:

> 'We are looking at the integration of the fuel source to the end-use consumer and all touch points in between. We believe that everything from a piece of coal or a breeze of wind to the thermostat has to be part of the smart grid and that it must include integration among all of the components.'

However, they also caution:

> 'the real risk in a true coal-to-cool-air, wind-to-light implementation of the smart grid is that these technologies that transform conservation and efficiency efforts can lead to degradation of the regulated return and uncompensated demand destruction' (Xcel Energy 2008).

The disaggregated nature and the misaligned incentives must be addressed by the Australian Energy Regulatory to assure overall efficiency solutions, like a Smart Grid, are deployed.

Perhaps the European Commission sponsored Smart Grid Deployment study summarises the critical nature of a Smart Grid the best:

> 'Without effective deployment of the SmartGrids concepts, European security of electricity supply in general, and the operational security of the European electricity grids in particular, may not be maintained. This is crucial not just for the large scale development of renewables, but also because of the steady demand growth and more onerous environmental requirements which conventional grids and methodologies will increasingly find difficult to meet' (European SmartGrids Technology Platform 2008, 21).

The remainder of this article provides more details on what a Smart Grid is, the benefits of real time communication and why a Smart Metering System is not the solution to the challenges of the electric utility and Australia.

WHAT IS A SMART GRID AND WHY IS IT NEEDED?

The Electric Power Research Institute ('EPRI') has defined a Smart Grid as:

> '… a power system that can incorporate millions of <u>sensors</u> all connected through an <u>advanced communication</u> and data acquisition system. This system

will provide real-time analysis by a distributed computing system that will enable predictive rather than reactive responses to blink-of-the-eye disruptions' (Howard 2007).

Unlike AMI systems, a Smart Grid solution will allow Australia to reduce its carbon impact, improve its electric reliability and increase its energy efficiency by implementing:

- Real time system optimisation to minimise the power needed to run the grid, reducing both cost and environmental impact;
- The real time bandwidth necessary to aggregate and manage Renewables, Distributed Generation and Plug-In Hybrid vehicles, allowing these alternatives to replace conventional coal fired power plants.
- Advanced distribution asset monitoring to accurately identify potential asset failures prior to an outage; and
- Automated fault analysis from across the distribution grid to accurately identify where and in many cases why, an outage has occurred.

The utility industry is facing significant issues due to rising demand combined with the increasing difficulty of developing new generation and transmission facilities. This is linked, in part, to a concern about the environmental impact of traditional generation sources. As a result, there is increased interest in the use of renewable energy sources as a solution to a part of this problem. The combination of an aging distribution infrastructure and workforces in addition to the rising cost to society of outages render the problems increasingly acute.

A Smart Grid focuses first on the grid itself, by combining advanced power quality sensors, distributed analytic software and low latency communications to create Smart Grid applications focused on improving the efficiency of the distribution grid itself. A Smart Grid provides the electric distribution organisation with unprecedented visibility and real time analytics of the condition and status of the electric distribution system. Smart Grid solutions include system optimisation, underground fault detection, substation and distribution asset condition based maintenance as well as a number of planning applications. Furthermore, a Smart Grid can incorporate distributed generation alternative energy sources by managing the real time power flows and by balancing the varying availability of those resources with varying demand. The result is a reduction in carbon emissions through a reduction in the amount of electricity needed and through the enhanced productivity of intermittent distributed renewables.

While the grid itself is the focus, the communications network in a Smart Grid can also be used to notify users about their consumption and provide information about the present supply, including the real-time price, allowing customers who want to participate in energy savings programs to more intelligently determine the amount and timing of their electric usage. This is shown diagrammatically in Figure 1.

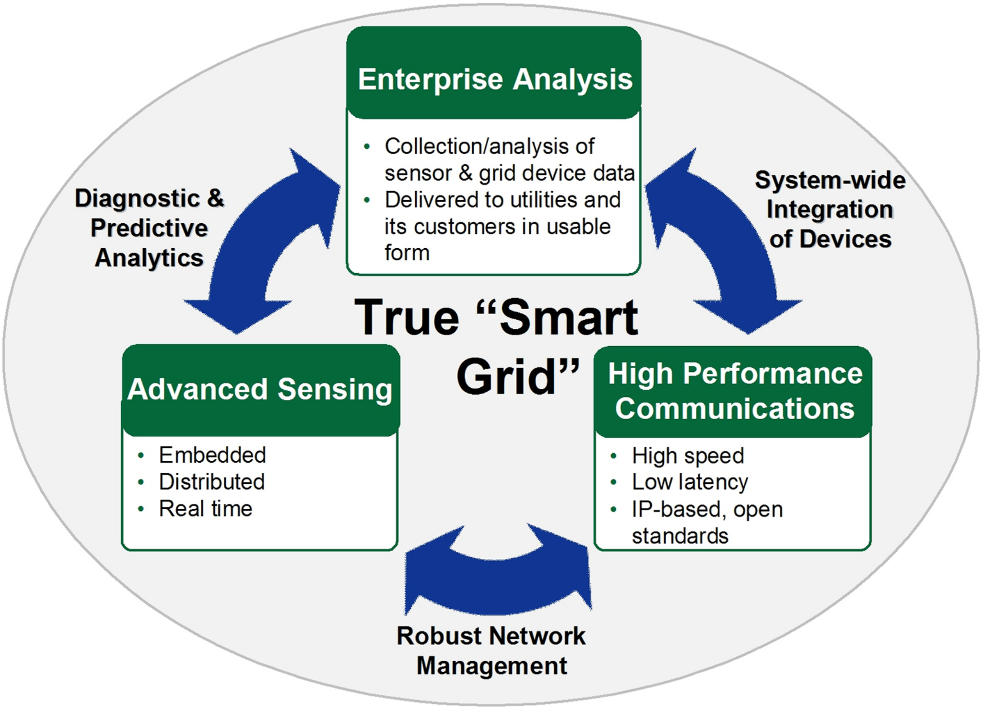

Figure 1 The true "Smart Grid"

High speed communications, embedded sensing and actionable intelligence are the keys to enabling a Smart Grid. The Energy and Environmental Economics, Inc. (E3), and EPRI Solutions, Inc. report prepared for the California Energy Commission (CEC) on the Value of Distribution Automation (CEC Report) emphasised 'communications is a foundation for virtually all the applications and consists of high speed two-way communications throughout the distribution system and to individual customers' (Price et al. 2006, 51). The report also stated that sensors are the next basic requirement for virtually all Distribution Automation applications. High-speed communications and embedded sensing are a fundamental differentiation of a Smart Grid versus narrowband AMI systems.

HIGH PERFORMANCE COMMUNICATION AND SENSING NETWORK

The need for real time, high-speed communications is changing the way all industries do business. Like many other industries, as communications capabilities are added to business processes, high performance communications will likely become a strategic business requirement for electric utilities. Managing the distribution grid in the 21st century – in a world increasingly focused on improving the efficiency and reliability while reducing the environmental impact of electric consumption – will necessitate monitoring electricity as it passes millions of discrete points (zone substation elements, high, medium and low voltage power lines, capacitor banks, distribution substations, meters, communicating thermostats, load control devices, etc.). Over the projected lifetime of the system, it is likely that a requirement for the real time optimisation of the grid based on millions of data points will emerge similar to the way that telecommunication systems operate.

In the electric grid, there are two key communications requirements for a Smart Grid; that the high performance communications network is linked to distributed sensors to detect the status of the electrical grid in the real time and the use of an open IP based architecture.

HIGH SPEED, LOW LATENCY TWO-WAY COMMUNICATIONS WITH EMBEDDED SENSING

An IP-based, open standard, two-way high-speed network that operates with low latency to facilitate multiple real time applications will become increasingly necessary in the electric grid. Such an architecture is the only network that can support the variety of consumer-initiated and utility-initiated services presently contemplated or that will emerge over the next 10 to 20 years. Significant events, such as a major fault in the electric grid, occur in sub second time periods. A 21st-century Smart Grid network must have the bandwidth, embedded sensing and software to collect, organise, analyse and report huge volumes of information. It needs the two-way bandwidth necessary to link the real time events being measured (such as load and congestion, system stability and equipment health or outages) with the appropriate grid responses necessary to improve efficiency and reliability. Moreover, the complexity of managing distributed endpoints significantly increases when the potential for widespread residential and commercial solar panels, plug-in hybrid vehicles and other distributed energy sources is considered.

The CEC report estimates system optimisation could reduce distribution grid line losses by 15% or more and reduce overall electric demand by approximately 3%. Similarly, a study at Hydro Quebec quantified those savings at two billion kWh. In a large scale outage, if multiple devices are capable of communicating simultaneously to take corrective distribution automation actions, the CEC report estimates such corrective action could reduce the impact of the outage by 30% to 50% depending on the number of switches involved (Price et al. 2006, 75, 89, 111). At the same time, distributed generation such as residential solar panels and plug-in vehicles will greatly increase the need for communications between the utility, the distribution grid and the consumer. In these examples, high speed real-time communications between millions of data points, including but not limited to meters and advanced analytic software will be necessary as fundamental requirements to monitor and control these distributed resources.

Widespread distributed renewables highlight the need for real time communications. Electricity cannot be stored or buffered and events on one part of the grid can impact other parts of the grid. One of the issues with renewables is that they are intermittent. The wind doesn't blow when it is hot but thunderstorms do occur, both of which often happen when electric demand is at its highest, thus reducing the output of renewables such as wind or solar at a critical time. A recent example in Texas gives some insight into the potential problem. One afternoon when wind represented 5% of the supply and demand was increasing, in the course of three hours, the wind declined by 80%. At a critical point in those three hours, the wind output was approximately 70% below the forecast made an hour prior. As a result, Texas was forced to use an emergency load reduction program to reduce 3% of its total electric usage within ten minutes to keep the grid from collapsing (Electric Reliability Council of Texas 2008). That was a centralised wind farm connected to the grid with high-speed communications. The amount of power being generated by the wind farm at the critical time that day was roughly equivalent to approximately 300,000 residential solar panels which represents a 10% penetration in a city like Dallas. If a thunderstorm rolls in and the output of all these distributed solar panels is not being monitored in real time, a similar risk could emerge.

OPEN STANDARD IP BASED COMMUNICATIONS ARCHITECTURE

As Smart Grid systems evolve to achieve society's clear interest in increasing efficiency, conservation and reliability, innovation will occur to promote the achievement of these goals – but only if new ideas can be enabled by an open platform operating within the grid. Thus, more and more devices in the distribution grid will need access to high-speed communications. Smart Grid systems utilising standard IP based communications will allow various pieces of equipment touching the distribution grid to be able to communicate with and be integrated into the system. History has shown that in any network environment, true innovation occurs when critical elements of the system are opened up to other developers and applications providers.

An emerging concern is the issue of security. By using standard IP based systems instead of proprietary systems, utilities are able to take advantage of the billions of dollars that has been invested in improving security for industries such as banking.

Based on the experience of other industries, it is clear that the requirements for communications and sensing will expand rapidly as new technology is introduced. It is important that utilities should invest in a robust communications capability for the 21st century, not in proprietary and limited bandwidth technology that is already outdated for most industries. This is especially important as the communication solution and elements Australia chooses today will largely determine how much network control, reliability enhancement and consumer empowerment it will enjoy for many years.

INTEGRATED UTILITY GRADE SMART GRID APPLICATIONS

Simply providing sensor data from millions of points can overwhelm any utility's ability to process and make sense of the information. True situational awareness comes not from simply collecting sensor data, but by analysing the data to extract meaningful information. This analysis must utilise data from across the utility, not just from any single silo within the utility. This enterprise analysis requires automated analysis to deal with the scale of the task and to stretch critical knowledge bases within the utility workforce. Additionally, the analysis must be located at the point of the sensing to allow distributed control and automation of present and future network activity such as recloser operation, distributed generation control, and demand response. This analysis platform must provide linkages to every other system within the utility, through APIs and with information flow that ensures that existing systems benefit from the enhanced view into the state of the network.

A Smart Grid system utilises operational and non-operational data from transmission, substation, and distribution systems to provide an unprecedented view of utility operation. The end result is the provision of Actionable Intelligence – identification of specific and definable actions that respond to live problems, improve operating efficiency, help mitigate aging workforce issues, lower energy losses, and even avoid failures before they occur. Actionable Intelligence defines the time, place, and specific action that should occur, allowing dispatch of crews directly to specific problems without lengthy search and ensuring a speedy response directed at the problem. This approach can even identify problems before a customer may notice the issue.

The following example illustrates this point: The voltage sensing present at each transformer detected an asymmetry in the voltage on the two legs of a single phase distribution transformer. An algorithm running against this data identified the characteristics of a neutral failure, and located the failure down to the exact pole, as shown in Figure 2. A crew was dispatched to the site and found a loose split bolt connection. The connection was repaired and the system was also able to confirm the repair. This is shown in Figure 3. In this case, the Smart Grid solution identified a problem before it led to an outage or resulted in a safety issue.

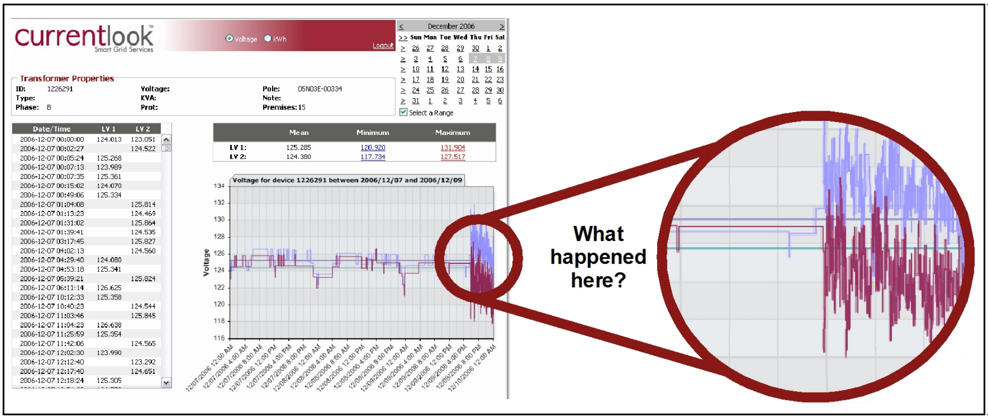

Figure 2 Voltage sensor identifies failure and location

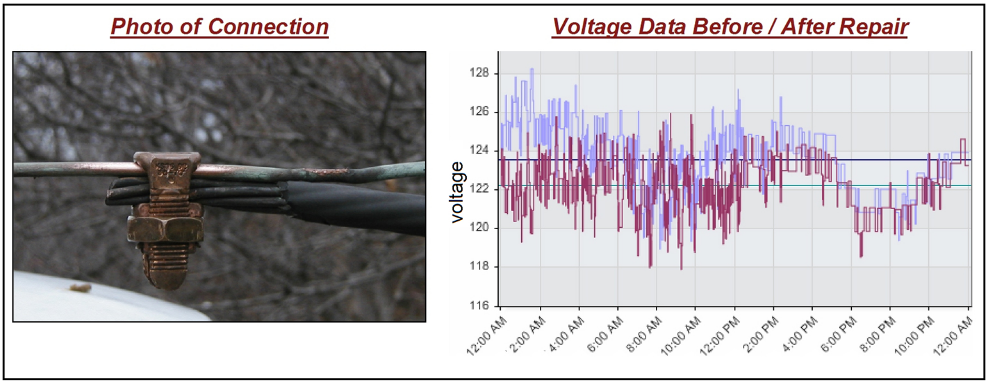

Figure 3 The fault and the system response to the repair

A Smart Grid provides a number of distributed software systems to collect, analyse, and distribute operational information on distribution network performance and provide Actionable Intelligence to the utility.

SMART METERS ARE NOT THE SOLUTION TO THE CHALLENGES OF THE ELECTRIC UTILITY OR AUSTRALIA

There are several significant challenges to Smart Meters cost-effectively achieving the goals of the electric utility to improve energy efficiency, reliability and the environmental impact. These challenges include the fact that the Smart Meter systems have limited communications capabilities and thus will not be able to meet the emerging communications needs over the 15 to 20 years period often used in a Smart Meter business case to justify the benefits. The second is that any energy savings or carbon impact depends almost entirely on the consumer choosing to participate and any benefits are limited to the participate rate achieved.

LIMITED COMMUNICATIONS CAPABILITIES

Many AMI systems are designed for once-a-day communication, and thus have very limited communications bandwidth. The best-in-class AMI focused system (typically wireless mesh) operates at approximately 28.8 to 56 kbps (the equivalent of dial-up modem speeds that were outdated 10 years ago). In Australia, the cost analysis indicates that nearly 80% of the overall project cost is for the purchase and installation of the meter while only 4% is for the communications network (NERA Economic Consulting 2008, 34). Further more, since the communications network is integrated into the meter, it is assumed that the 28.8 kbps capability would remain adequate for the 20 year business case as upgrading the network would require replacing the meter (NERA Economic Consulting 2008, 39). This clearly represents an underinvestment in communications and a potentially unrealistic assumption on the useful life.

In addition, NERA expressed concern that the metering systems are proprietary.

> 'In our view, the potential benefits from further pursuing interoperability may outweigh the likely costs… In our view, it is critical that the party responsible for the smart metering rollout is faced with competition both for the supply of meters as part of the initial rollout and when smart meters will need to be replaced in the future' (NERA Economic Consulting 2008, 183).

Wireless AMI solutions are appropriate for what they were designed for, replacing meter readers with a once a day meter reading solution and providing limited, additional insight into customer outages. As discussed earlier, a self sensing and self healing two-way power grid requires high speed low latency communications and an open IP based network.

CONSUMER PARTICIPATION IS REQUIRED TO ACHIEVE ENVIRONMENTAL BENEFITS

The lack of Smart Metering demand reduction and environmental benefits is due in large part to the fact that the Smart Meters program is predominately targeted at residential consumers who account for only 28% of Australian electric consumption (ESSA 2008) versus the entire distribution network. A Smart Meter, in and of itself, does not reduce electricity consumption but allows a consumer who is interested and who typically has air conditioning (approximately 60% of Australian households according to the Australian Bureau of Statistics 2006a) to either shift their load to off peak times or to permanently curtailing use.

The value of any demand response and environmental benefit is highly dependent on the number of customers choosing to change their behaviour. The Cost-Benefit analysis assumes that approximately 45% of consumers will voluntarily participate in a time-of-use rate or will allow the utility to control their energy usage (NERA Economic Consulting 2008, 50). This estimate seems very high as the average residential electric bill is approximately $2.38 a day (Australian Bureau of Statistics 2006b). Thus a consumer who can save 15% of electricity is saving less than $0.40 a day. It should be noted that the 45% participation rate is significantly higher than the assumed participation rates in other parts of the world and that the actual savings realised by the customer will be less since a significant portion of most electric bills represents fixed charges for the core infrastructure that will have to be paid regardless of the amount of usage.

Even when customers participate, shifting loads does not reduce the environmental impact of electric power. NERA reports

> 'Shifts in the load profile … where peak load is reduced but off-peak load is increased will impact on greenhouse gas emissions. This impact, considered on its own, could result in either an increase or a decrease in emissions, depending on the type of generation plant that is the marginal generator during each period' (NERA Economic Consulting 2008, 205).

Thus, in the parts of Australia that rely on baseline coal, emissions could actually be increased. It is only when the participating customers permanently reduce load that there is any environmental benefit. While Smart Meters business cases often claim a reduction in overall load, the same report acknowledges that much of the projected curtailment of load from a Smart Meter program could be achieved by education alone without requiring an investment in Smart Meters (NERA Economic Consulting 2008, 206).

SUMMARY

Smart Grid Systems and high performance communications are a key foundation to addressing global warming. Unfortunately, utilities today are focused on implementing proprietary limited bandwidth Smart Metering solutions based on business cases that require consumer participation and contain potential unrealistic useful lives assumptions. Like in many other industries, high-speed communications will eventually change the way the utilities operate. It is important for both utilities and regulators to realise an investment in a Smart Grid and in high performance communications will provide a greater value to society and bring the same kind of innovation to electricity that the Internet has brought to many other facets of our lives.

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