ENABLING THE DISTRIBUTION NETWORK ELECTRICITY MARKET WITH BROADBAND

Dean Spaccavento

Distributed electricity generation has the potential to deliver sustainability benefits through dramatically increasing energy efficiency, as well as through encouraging the adoption of renewables. It is not without its problems however: two of the largest are the limited utility of the small amounts of power generated, and the lack of economic incentive to invest in small generators.

This work discusses an electricity market, using broadband communications as its information infrastructure, specifically designed to make electricity generated by households and offices an attractive source of revenue and a viable source of power.

MAYBE A LITTLE TOO SMART

There has been increasing discussion of late concerning smart grid technology. At the most basic level, a smart grid is an electricity grid that uses vast amounts of data to increase grid service quality and lower cost. Or, a more cynical person may choose to view smart grids as simply electricity providers' efforts to catch up with those industries that have used information technology to streamline, measure and enable their core business processes for many years now.

This definition allows one to comprehend the broad scope of what could be considered smart grid technology. Smart grid technology enables more intelligent planning, design, build, operation, maintenance and decommissioning processes. Improving how these processes operate is valuable, but simply implementing smart grid technology does not necessarily yield greater environmental sustainability in electricity provision.

Instead, sustainability wins come from the new processes that are able to be implemented on top of an information rich, open and accessible electricity grid. Business processes like these are often game changing, requiring organisations with significant investments in traditional infrastructure to re-invest in new technology to support these business processes. More fundamental than that, these processes will often threaten the business models of traditional organisations. So, why would a utility or an established market invest large amounts of resources into supporting processes that threaten the way they do business?

The answer is, they won't.

They will invest in improving the quality of those processes that they already have. And they will invest in technology that stabilises their customer, regulatory and revenue bases. These investments will see some small increases in environmental sustainability as they improve efficiency. But investment will not occur in the infrastructure required to create significant sustainability gains.

In particular, they will not build the infrastructure to allow energy consumers to buy and sell power from one another. Despite the energy efficiencies available via cogeneration, and the potential to harness a range of renewables over a broad geographical area, energy providers don't like the idea of distributed generation. It threatens their business models, and it uses their own electricity network infrastructure to do so. Electricity retailers, and distribution network operators will not actively invest in distributed generation.

But inertia from these organisations will not stop it from occurring. It might not even slow it down. This is because the key piece of infrastructure required for distributed generation, which is not easily implemented by an individual, is an always-on, low-latency, high-speed, ubiquitous communications network. A network like this is what is required to enable an energy market at the heart of the distributed generation paradigm. And fortunately in broadband Internet, one of them is already available to the vast majority of premises in Australia.

The aim of this work is to show that by leveraging existing broadband infrastructure, large-scale distributed generation is realistic in the short term, and will yield significant environmental sustainability benefits.

It discusses the sustainability gains to be made from distributed generation, and proceeds to discuss the structural, as opposed to regulatory, inhibitors to distributed generation, focussing on the economics of distributed generation. To vastly improve these economics, a Distribution Network Energy Market (DNEM) is then proposed and discussed, paying particular attention to the properties of broadband that make it an ideal communications medium for such a market.

DISTRIBUTED GENERATION AND ENVIRONMENTAL SUSTAINABILITY

It would be remiss to not provide a rationale for the environmental sustainability benefits of distributed generation before launching into a discussion of how broadband is pivotal in bringing distributed generation to fruition.

Distributed Generation, hereafter DG, provides the following significant sustainability benefits:

1. Increases in the efficiency of energy use;
2. Encouragement of the adoption of new sources of energy.

DG is, at least in the short to mid term, an energy and infrastructure efficiency measure. But in the longer term, with the right supporting technology, DG has the potential to completely remodel electricity grids across the world, enabling the widespread use of renewables and ushering in an age of individual energy use awareness and responsibility.

ENERGY EFFICIENCY

Whilst energy use is correlated with economic growth, the amount of energy used per unit of GDP, otherwise known as energy intensity, has been falling for some time in developed economies. This is due to efficiency gains made through better technology and more intelligent energy use (International Energy Agency 1997). It is comforting to recognise that these efficiency gains have occurred against a background of low energy costs, and without a strong push to increase energy efficiency. This leaves fertile ground for significant energy efficiency gains in the short-term.

One of the most effective ways of boosting energy efficiency is to harness the waste heat created when generating electricity. Converting energy from one form to another always creates energy losses, the majority of which are heat. As we cannot gain electricity directly from nature with our present technology, we convert primary energy sources such as fossil fuels, uranium and sunlight into electricity, and this creates heat. This waste heat is low quality energy, but it is still able to do work, particularly in space heating or cooling applications. Conversely, primary energy is often converted directly into heat via combustion. In this case it makes sense to use a prime mover to create mechanical energy and waste heat, using the mechanical energy to do useful work, and the heat to meet the original heat requirement. When more than one useful form of energy is derived from a single energy conversion process, it is called cogeneration. As will be discussed below, cogeneration in residential and commercial premises is able to yield significant energy efficiency gains.

Australian residences are the third largest users of final energy, consuming 11% of total final energy demanded. Of total residential energy use, 38% is used for space heating, 23% for water heating and 32% for appliances. To meet these demands, 35% of the final energy used in residences is in the form of gas, and 50% is in the form of electricity (Department of the Environment, Water, Heritage and the Arts 2008). Table 1 provides a detailed breakdown:

	Wood (%)	LPG (%)	Gas (%)	Electricity (%)	Total % Used
Space Heating	13	1	21	3	38%
Cooking	0	0	2	2	4%
Water Heating	0	1	11	11	23%
Appliances	0	0	1	31	32%
Space Cooling	0	0	0	3	3%
Total % Provided	13%	2%	35%	50%	100%

Table 1 Residential energy use by fuel and end use

From this data, it is clear that Australian residences need heat and electricity – heat to warm their homes, cook their food, and create hot water, and electricity to power their appliances.

Similar numbers reflect Australian commercial energy usage. The Australian commercial sector uses 7% of total final energy demanded. Its final energy fuel profile, end uses and electricity consumption load profiles are relatively similar to those of the residential sector. Electricity and gas account for 65% and 25% of final energy use respectively and are used for heating (33%), cooling (21%), ventilation (16%), lighting (15%), office equipment (9%) and cooking/hot water (6%) (Australian Greenhouse Office 1999). Again, heat and electricity dominate the energy balance, however the amount of energy used for cooling is much higher than in the residential sector and much more electricity is used in ventilation and space conditioning.

At this point it is worth noting that the efficiency of electricity generation from natural gas, in the most efficient gas generators (CCGT – Closed Cycle Gas Turbines) is approximately 50%. That is, of the total energy available in the natural gas, half is converted into electricity and half into other energy forms, almost all of it heat. This number is significantly lower for coal power stations, especially older, pulverised coal generators which dominate Australia's electricity production. Without cogeneration, this waste heat is simply vented to the atmosphere in flue gases.

To provide some understanding of how much energy this is, consider Table 2.

	Energy Use (PJ)	Heat (%)	Heat (PJ)	Electricity (%)	Electricity (PJ)
Residential	440	63%	**277.2**	36%	158.4
Commercial	280	35%	**98**	65%	182

Table 2 Energy use by dominant energy forms in the residential and commercial sectors

Australia's total final energy use is approximately 4000PJ (Syed et al. 2007), which means that the total amount of heat required in the residential and commercial sectors is equivalent to 277 PJ and 98 PJ respectively. In comparison, Australia generates a little more than 50 TWh of electricity from gas, contributing 21% to Australia's total electricity generation (Syed et al. 2007). At an optimistic efficiency of 50%, 50 TWh is equivalent to 98 PJ of gas, which means 98 PJ of heat is simply wasted. This is equivalent to the total amount of heat required by the commercial sector and 35% of the energy used in residential heating.

Electricity generation from gas is predicted to grow at 4% annually over the next twenty years (Syed et al. 2007), as the waste products from burning gas are significantly less damaging than those of coal, as shown in Table 3 (Energy Information Administration 1999). This means that by 2030, gas fired generation will have doubled, resulting in almost 200 PJ of heat being vented to the atmosphere.

	Natural Gas	Oil	Coal
	(kg per Billion Btu of Energy Input)		
Carbon Dioxide	53,182	74,545	94,545
Carbon Monoxide	18	15	95
Nitrogen Oxides	42	204	208
Sulphur Dioxide	0	510	1178
Particulates	3	38	1247
Mercury	0	0	0

Table 3 Combustion emissions by fuel and pollutant

But what if instead of venting that heat, we were to use it to meet space and water heating requirements? It would mean a significant decrease in the energy and hence carbon intensity of the Australian residential and commercial sectors. Instead of reaping 50% of the energy stored in gas, conservatively, 80% of it could be retrieved, resulting in a 30% efficiency gain.

For this to occur in Australia, electricity generation would need to be decentralised to the point where waste heat could be captured. A trade-off exists here between investment in infrastructure to transport waste heat, and cogeneration infrastructure. More generators means less investment in heat transport infrastructure, and *vice versa*. This balance will vary based upon population density with higher densities favouring heat transport, and lower densities favouring discrete cogeneration plants.

Still further efficiencies are possible. Our current electricity grid has on average 10% energy loss between the point of generation and the point of consumption (Australian Uranium Association 2007). By bringing electricity generation close to electricity consumption, this loss can be eradicated, yielding a 10% decrease in the amount of fuel burnt to generate the same amount electricity.

The numbers speak for themselves. By distributing electricity generation and applying the waste heat from this process to residential and commercial space and water heating, approximately 35% efficiency gains are attainable. With Australia's gas network reaching 3.7 million domestic premises and 100,000 commercial premises (Australian Bureau of Statistics 2008), it makes increasing sense to distribute electricity generation to gain these efficiencies.

On a 'softer' note, bringing electricity generation closer to the people who consume power is likely to encourage people to think more about their electricity consumption. In a centralised generation grid, the equipment used to generate electricity is well out of sight for most people. The closest most people get to understanding where their power comes from is from noticing the steam clouds and cooling towers of a thermal power station on a trip to the countryside, of which neither are particularly attractive. And whilst this does have an impact on people, it seems to be often forgotten by the time they return home – a case of “out of sight, out of mind”.

Whilst distributed generation equipment does not create the eyesores of centralised thermal plants, its proximity to electricity consumers will make it much harder to forget about. And whilst there seem to be no formal studies to support the anecdotal evidence, awareness of where their power comes from should lead people to be more mindful of their electricity use.

NEW SOURCES OF ENERGY

Distributing electricity generation creates a larger number of smaller generators. This provides an opportunity for new sources of electricity to be deployed as the capital expenditure on an embedded generator is much less than that on a centralised generator. This is simply because an embedded generator's economics allow for a much smaller plant. By reducing the size of the expenditure required, the risk of implementing a new technology to provide electrical energy is lowered, and this increases the likelihood of that technology entering the market.

This is critical if new technologies are to be improved. If a market for a product exists, organisations developing and marketing it are provided with a revenue stream to supplement grant money or venture capital. More importantly, they are able to gain real world usage data from which they can improve their product. Creating a market for electrical generators with reduced size, complexity, cost and lifespan allows iterative product development cycles to bring new technologies to maturity faster.

Further to this, if a large enough market for these generators can be created, the economies of scale available to domestic electrical goods can apply to electricity generation. There is little reason why embedded electricity generators could not be manufactured at a cost similar to that of a refrigerator or a hot water heater. This would considerably lower the price of installing embedded generation, increasing the size of the market for many years to come. At present, embedded generation equipment is not only expensive to purchase, it is often costly to install. But the same could be said of household air conditioners fifty years ago, which when initially introduced could cost up to a fifth of the total price of the home! (Cooper 2002).

From a sustainability perspective, creating the opportunity for new electricity generation technology to operate in the market, means that the opportunity to obtain electricity from sources other than the coal and gas-fired grid will be created. DG creates a bias towards renewables and low-emission fuels, as the externalities from generating electricity are not as easily ignored when you live next to the generator. Nobody wants a coal-fired power station in their backyard, but people have shown enthusiasm for solar and wind technologies to be deployed on or near their homes and offices. This bias towards renewables and low-emission fuels for DG means that not only does the market for these technologies promote their development, but also that every watt generated by these technologies, is more than 1 watt less (due to the elimination of transmission losses) that needs to come from coal fired generation.

Embedded generation also increases the geographical footprint of renewable generators, decreasing the risk inherent in harnessing intermittent energy sources such as solar and wind. One of the problems of renewables is that local weather conditions affect electricity generation. This makes centralising renewable generation risky as a single unfortunately positioned cloud, or pressure system will dramatically reduce the ability to provide power. The cost of real estate however, requires that centralised renewable generators be as densely packed as possible, increasing their susceptibility to local weather conditions. To counter this, renewables should be widely geographically spread, but able to feed into a single grid, in exactly the way DG would see them deployed. Adding renewable generation throughout a region, in a piecemeal fashion, reduces the risk posed by local weather conditions to generation, increasing the total system availability, decreasing the risks of renewable generation, and increasing the adoption of renewables.

Further sustainability gains come from a more indirect consequence of DG – vehicle-to-grid (V2G) electricity supply. Passenger vehicles comprise 79% of total road vehicles in Australia (Australian Bureau of Statistics 2007). The inevitable electrification of passenger transport will see each of these vehicles add their ability to store and supply electricity to the grid. If people participating in V2G can be compensated for providing their electricity, in the same way that owners of embedded generation are compensated, V2G could play some role in promoting the adoption of electric vehicles.

What's more, because electric passenger vehicles will be attached to the grid wherever people are consuming electricity – due to that vehicle having gotten them there – that electricity storage is likely to be close to where electricity is being used. If the batteries in these vehicles are intelligently charged and discharged when attached to the grid, these vehicles can be used to meet peak grid loads. Batteries are able to provide large amounts of power without notice, and as they will be attached to the electricity distribution networks, they are able to alleviate the stress on transmission networks on hot days, and reduce the need for inefficient and dirty peaking generators, and increased land use for higher capacity transmission networks.

Whilst there are problems with renewable and low-emissions embedded generation and V2G, creating the environment for these technologies to be improved, yields significant sustainability benefits. The core of this argument is that the decentralisation of electricity supply creates opportunities to evolve our electricity supply towards more sustainable technologies.

NOT WITHOUT ITS PROBLEMS

Despite the sustainability benefits of making electrical distribution networks a two-way street, it is not without its difficulties. Whilst an in-depth discussion of the these difficulties is a work all of its own, at the broadest level, the problems are concentrated in three areas:

1. Physical electricity network limitations;
2. Regulation;
3. Economics.

Evolving electricity distribution networks to accommodate large amounts of power being generated by traditional consumers challenges the fundamental design assumptions of these networks. Because of the way these networks are designed, small amounts of DG will have little impact, but larger amounts will result in voltage control problems, network instability and protection issues, power quality reductions and a decreased ability to control the network using traditional network control techniques. More fundamental than that, is that the vast majority of electricity meters are unable to measure exported power, so even if the ability to safely contribute large amounts of electricity to the network existed, it would not be provable and hence billable.

These problems are alleviated by smart grid technology, as one of the functions it provides is fine-grained and dynamic network management. Utilities will implement this technology without prompting, as it allows them to increase the capacity of their networks without additional conductor infrastructure. Likewise, advanced metering will be implemented to allow energy retailers to increase their margins on electricity supply. Both of these initiatives will serve to enable DG without necessarily intending to do so.

The rules governing electrical distribution networks are set by government, electricity market operators and utilities. They are primarily designed to ensure energy security, and also make the assumption of a small number of large, centralised generators. To make DG a reality, a significant proportion of these rules will need to be reconsidered to take into account a large number of smaller generators. Without these changes, DG will be inhibited in scaling past the early adoption stage, and will not be able to support commercial providers of goods and services enabling DG.

There is already some momentum towards modifying this regulation as various state and federal government programmes encourage embedded generation as a way to increase the sustainability of electricity provision. This will continue as DG become mainstream and grows in scale.

If DG is to be adopted by more than the very wealthy, enthusiasts and governments, its economics must be compelling. To become an energy supplier, a household or business must make a significant expenditure on some form of electricity generation. Be it a cogeneration plant, solar cells, a wind turbine or an electric vehicle, there must be a return on investment if DG is to be sustainable. If the economics of DG are unattractive, it will fail to gain widespread acceptance.

Centralised generators gain returns from their investment in generation equipment by participating in wholesale electricity markets. These are generally complex, expensive to participate in, and geared towards large generators, making them unsuitable for selling electricity generated from DG.

Returns from DG come in two forms: the first being in replacing electricity that would have otherwise been purchased from the electricity retailer, and the second being income derived from selling exported power. With the majority of NSW households spending in the order of $800/annum on electricity (Independent Pricing and Regulatory Tribunal 2007), the annual limit from the first form of returns is set. This number is set to grow steadily, but this is still a relatively low return, especially when the fuel costs for cogeneration are taken into account. This is also the upper bound, relying heavily on a strong coincidence of power generation and power use within the premises. In reality, returns from import replacement alone will not make DG economical.

Exporting generated electricity to others however, does not rely upon a coincidence of premises electricity production and use, but instead looks to provide electricity to other premises. This dramatically increases the chance of coincidence in demand and supply, resulting in the consumption of exported electricity. But how is an exporter to be compensated for this?

Feed-in tariffs have been implemented in some Australian states, and are being proposed in others, at quite attractive rates for electricity generated from photovoltaics. For example, for a nominal 1kW solar installation in Adelaide, the South Australian feed-in tariff will provide a householder around $900 per annum if all of the solar generated power were exported to the grid. These tariffs presently don't cover cogeneration, wind, solar thermal, V2G or other electricity sources, so whilst they are a good start, they suffer from being inflexible at a time when DG is young and evolving quickly.

INTRODUCING THE DISTRIBUTION NETWORK ELECTRICITY MARKET (DNEM)

An alternative solution for generating a return from an investment in DG assets is an electricity market specifically designed for trading small amounts of electricity on distribution networks. Such a market would endeavour to be free of government regulation, provide choice for electricity consumers, and allow electricity exporters to sell electrical energy from whatever source they wish, at a rate set by the market. But most importantly, a DNEM would allow small and currently low utility supplies of electricity to be synthesised into a stable, economical source of power for residential and commercial customers.

As with any market, the quality of the information available in the market has a significant bearing on how efficient the market is. Increasing the amount of information in a market reduces market friction and encourages a more efficient allocation of resources. In electricity markets this is especially true as the assets being traded are an abstraction of a physical phenomenon, the assets are commodities (one watt looks like any other watt) and because trading in electricity is instantaneous due to the inability to store market-influencing amounts of power.

In a market with a large number of relatively small transactions, large numbers of participants and very low lead times, such as the DNEM being proposed in this work, high-fidelity market information is essential to the efficient operation of the market. Hence, the DNEM requires a communication medium with the ability to move large amounts of timely data, amongst a large number of participants, with low-latency and without interruption.

And it is here that broadband can make a contribution to environmental sustainability. By becoming the communications medium for a highly efficient DNEM, broadband is able to improve the economics and utility of DG, encouraging its adoption and allowing society to access the environmental sustainability benefits that DG can bring. The remainder of this work will examine the key components of a DNEM, and the key roles that broadband plays in these components.

POWER TO THE PEOPLE

The DNEM is place where electricity consumers connected to electricity distribution networks are able buy and sell power. The market is intended to provide much greater choice in electricity supply, as well as to encourage investment in DG.

Unfortunately, the implementation of the market does come with significant complexity. Currently, electricity is purchased from one electricity retailer at a time, with a large amount of friction in selecting an alternative. This keeps things very simple from a purchasing and settlement perspective however. Significantly more complex search, purchase and settlement processes are required if electricity is to be bought and sold without friction, across a large number market participants.

Take, for example, the simple act of switching on a light. As things stand today, this closes a circuit causing current to flow from the distribution network, through the premises' power meter, to the light. The power meter sees a slightly higher power consumption and increments its counters a little faster. Come billing time, the electricity retailer considers the change in the power meter's counter over the billing period and charges for the total electricity used over the period, including the energy used by the light. A single supplier, selling a single product, at a fixed price over the billing period keeps this process simple.

But what happens when there are multiple sellers, selling differentiated product, at different prices? In this case, power users need to be able to make a choice of where the power to illuminate their lights will come from before the lights can be illuminated. And once that power has been used, the supplier of that power needs to be compensated. These are the facilities that the DNEM provides.

That is, the DNEM is a market where sellers of power advertise the power they are able to provide. This advertisement includes the amount of power that can be provided, how long it can be provided for, the location of the generation source, the technology used to provide the power and the terms of the power use. Under this arrangement a traditional power retailer, purchasing power from the wholesale market is able to participate in the DNEM. This retailer would have the most available power supply, at a very competitive price, but would be disadvantaged by procuring most of their power from distant, high emissions power. They would play an important role however in making up DG supply shortfalls, for bootstrapping the system, and to ensure that the inevitable market glitches do not result in blackouts.

When a consumer requires power from the distribution network, they must make a decision to as to where to get that power from, and how much they are willing to pay for that power. This is accomplished via a bidding process, where power consumers have a fixed period of time in which to bid for a provider's power. Higher bids could be expected for larger amounts, of higher availability, renewable power, generated close to the consumer, at times of peak power use. Or a consumer may choose to contract with a supplier to purchase their power during certain times as part of a commercial agreement.

For this arrangement to work, a premises must be able to execute multiple buys simultaneously, so that it is able to aggregate a large number of small, short-lived power offerings to meet the premises' demand for power. This is key to achieving the environmental sustainability goals of

DG. If small, short-lived and otherwise useless pieces of power can be made useful, and providers of that power can be compensated for that power, DG will become mainstream.

Once the consumer has finished drawing power from the supplier, the consumer must pay the supplier for their power. The amount paid will depend on the amount of power drawn, the terms of use for the power and the successful bid price for that power. It is part of the function of the market to enable this settlement, as the market is the independent party in the transaction and is privy to all of the information behind the transaction. Also, it is imagined that there will be many transactions made by a premises throughout the day, far too many to be manually settled.

The very broad description above hints at the complexity of such a market, and at the sophistication and speed a market participant must have to be able to meet their power needs as a consumer. This market is no place for humans, for only computers are able to process the vast amounts of data, make the bidding decisions and understand the power use of the premises with enough speed to keep the lights on. This means that each premises participating in a DNEM must have an intelligent agent representing them.

This agent would be responsible for making all of the purchasing and supply decisions for a premises. Naturally, this agent would be an integral part of the premises' power management infrastructure, with a deep understanding of the power use of the premises, and of the generating assets available to the premises. Additionally, this agent would look to utilise weather, DNEM, appliance ratings and other data to try to optimise purchasing and supply decisions, with more intelligent and better-informed agents reducing power costs or increasing generation revenues. Those agents able to purchase smaller and shorter lived, and export larger and longer-lived sources of power, will do better in the market. This sort of optimisation is achieved through being able to access and process large amounts of information.

BROADBAND IS THE ENABLER

High-speed, low-latency, high availability, ubiquitous computer network communications is foundational to the DNEM. Broadband enables a high-speed and highly parallel bidding process, which is the essential component of the DNEM. Without the ability communicate at high speeds, with a large number of market participants, the DNEM would be unable to clear the relatively small and short-lived pieces of power created by DG.

If small and variable amounts of power are to be aggregated into usable amounts, a DNEM agent must be able to continuously participate in the market. If, for example, a residence has a relatively constant 3kW load between 4pm and 8pm on a summer's day in Sydney, a DNEM agent will need to make multiple purchases on the DNEM. Towards the beginning of the period, large amounts of electricity generated from photovoltaics will be available, some of this perhaps from the premises' own generation capacity. But given that solar generates small amounts of power, the agent will have had to make several purchases to meet the 3kW load. Even during the beginning of this period, cloud cover may have reduced the output of one of the suppliers, leading the agent to have to replace them.

As the evening wears on, the amount of solar radiation decreases and large numbers of electric vehicles return home and are connected to the grid. In addition, gas fired evaporative chillers are activated to cool family homes. The DNEM agent is forced to maintain a 3kW supply and begins to bid for the residual power stored in the batteries of the electric vehicles, and the cogenerated chiller electricity to make up for the solar shortfalls. Even then, as chillers are turned on and off to regulate temperature, and vehicle batteries become depleted, the agent must continue to bid for and purchase power to maintain a 3kW load.

In reality, a constant 3kW load for four hours is unlikely, and so the agent must not only manage fluctuating electricity sources, but also fluctuating load. Provided that the agent is able to bid for and purchase small amounts of power from the market at high speeds, these fluctuations can be accommodated.

In this way, a supply of power that exactly matches a premises' demand can be synthesised from small amounts of power available on the DNEM, and any DG capacity they themselves possess. The smaller the amounts and faster the purchasing, the higher the fidelity of the synthesis, resulting in a higher quality electricity supply at a lower cost. This synthesis is key to the success of the DNEM as it allows small and intermittent generators to collaborate to meet large and relatively stable loads.

Whilst this proposal is nascent enough to not have any quantitative analysis completed on the rate of market operations required to attain this synthesis, it is certain that a narrowband network connection would not provide the information transfer capability required to create a synthesis of sufficiently high fidelity.

Although a fast and fluid purchasing regime will be able to mitigate unfulfilled supply commitments, the market will still punish those suppliers that promise an amount, or duration of supply and are not able to keep that commitment. This will come in the form of lower bids for that supplier's power. Hence, it is in the supplier's interests to ensure that they are able to fulfil their supply commitments.

This is relatively easy for cogeneration as the control logic of a heating or cooling appliance should be able to provide an indicator of how long fuel will need to be burnt to reach a target temperature. Even if this is not possible, because cogeneration is a fuel-based technology, fuel can simply be burnt until the commitment is met. For V2G, things are similar. Batteries are able to provide an indicator of how much capacity they have left and this can be communicated to the agent for trading purposes.

Renewables pose a problem however, as a power supplier is subject to the weather. One approach would be to make such small power amounts available on the DNEM that a supplier's exposure to an inability to meet a commitment is very small. This strategy means a supplier will receive lower bids than necessary as consumers will prefer longer durations of power. A better strategy is to access as much weather and market data as possible to understand the optimal amount, duration and timing of renewable power to supply throughout the day, for maximum possible returns.

In fact, this strategy is applicable to all market participants and will lead to a more efficient market. Participants with market, weather, traffic and other information will make purchasing and supply decisions that lower their energy costs and increase their supply revenues. They will import power when power is cheap and plentiful, and export power when it is expensive and in high demand, thus stabilising the market. Further to this, market participants will actively seek to take advantage of these scenarios before they occur, by using data to make educated predictions of market conditions, further increasing the robustness of the market. For example, electric vehicle owners may charge their vehicles more than required overnight, so that they may export the excess power during the hot parts of the next day when power prices are higher than the price they charged at. This adds capacity to the distribution network that would have otherwise not been available.

Obtaining enough detailed data to be able to do this effectively requires a high capacity network connection, particularly for market data. However, the ability to move large amounts of data is not the only property of broadband required for the DNEM to work efficiently.

For the DNEM to work correctly, information flow needs to be as continuous as current flow. This is due to the high transaction frequency required, and the fact that a modern premises is a non-stop consumer of power. The always-on nature of broadband accommodates this requirement. An on-demand connection would be driven by DNEM participation to be continuously connected, and a timer-driven connection would be unable to support participation in the DNEM as it could not be synchronised to an asynchronous market.

Likewise, the low latency of broadband is required if the bid, rebid cycle is to operate to find optimal pricing for power advertised on the DNEM. High-latency connections throughout the market would reduce efficiency by introducing market friction, and consumers being serviced by a high-latency connection in an otherwise low-latency market would be at a significant disadvantage during the high-speed bidding process.

MAKING ENVIRONMENTAL SUSTAINABILITY SUSTAINABLE

Broadband enables previously centralised processes to be distributed. From journalism to software development, providing people with the ability to move large amounts of data, in real-time, very quickly and without overhead, empowers people to collaborate to solve problems much larger than themselves.

Distributed electricity generation is an example of this. Whilst embedded generation is only able to generate relatively small amounts of power, when aggregated intelligently, a significant portion of real demand can be satisfied. And because distributed generation only makes sense when it is capturing energy that would have otherwise been lost, or by using renewables, its encouragement will yield environmental sustainability benefits.

By using broadband to bring together buyers and sellers of power generated by distributed generation, small amounts of power are aggregated intelligently to meet loads that would otherwise be met by centralised, coal-fired power stations. But more valuable than this small replacement of power, is the incentive that financial returns enabled by the market, will have on increasing the adoption of distributed generation.

REFERENCES

Australian Bureau of Statistics. 2007. Motor Vehicle Census. Australian Govt., November.

Australian Bureau of Statistics. 2008. 2008 Year Book Australia. Australian Govt.

Australian Greenhouse Office. 1999. Australian Commercial Building Sector Greenhouse Gas Emissions 1990–2010. Australian Greenhouse Office.

Australian Uranium Association. 2007. Australia's Electricity. September. http://www.uic.com.au/nip37.htm.

Cooper, Gail. 2002. *Air-conditioning America*. 1st ed. JHU Press.

Department of the Environment, Water, Heritage and the Arts. 2008. Energy Use in the Australian Residential Sector 1986–2020. Australian Govt.

Energy Information Administration. 1999. Natural Gas Issues and Trends 1998. U.S. Government.

Independent Pricing and Regulatory Tribunal. 2007. Overview of final report and determination on electricity retail prices in NSW.
International Energy Agency. 1997. *The Link Between Energy and Human Activity*. 1997 edn.
Syed, Arif; Wilson, Ryan; Sandu, Suwin; Cuevas-cubria, Clara; Clarke, Antony. 2007. Australian Energy. National and State Projections to 2029–30. ABARE, December.

Cite this article as: Spaccavento, Dean. 2009. 'Enabling the distribution network electricity market with broadband'. *Telecommunications Journal of Australia*. 59 (1): pp. 8.1 to 8.13. DOI: 10.2104/tja09008.