THE FUTURE OF THE SMART GRID: THE ICT AND DATA MANAGEMENT PERSPECTIVE

STRATEGIES AND CRITICAL REQUIREMENTS FOR SUCCESS

Authors: Jane Fae and Professor Merlin Stone
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INTRODUCTION

There are a lot of research reports in the market competing for your attention, so why should you consider reading this one ASAP, what will you get out of it, why should you trust what you are told?

Why should you consider reading: the quickest way to reassure you is by sharing feedback from a peer of yours who says …

‘The content is excellent and contains precise insights’
Bram Reinders, Alliander

What you will get out of it: the independent findings reveal solutions to problems that matter, approaches that are working for others, and highlights “bumps in the road” to be avoided.

The “strategic business review” presents you with a concise view of the smart grid market that challenges the status quo, presenting a new commercial model to help piece the jigsaw together, highlighting paths to ensure sustainable growth for all – now and in the future - from consumer to government, regulators, utilities, ICT and niche supporting technology players.

The accompanying “big report” provides supporting analysis to the business review.

Both reports can help bridge the knowledge gap between the industry, investors, customers, partners, regulators, and governments.

Why you can trust what you are told: created by independent experts, cross checked with VIPs from your industry, and based on our expert in-depth research and analysis to ensure that the report is of use to many different teams in your organisation, ranging from those seeking an eagle eye view (see the “strategic business review”), to those working on the ground seeking case studies, technical information and the best solutions to the most pressing problems (see the “big report”).

What makes us different: The special source in our reports is added from the platform that the conference organisers have built up in this sector for a decade, thus ensuring we are up to speed with high level industry thinking before we deep dive into the topics.

“Free range” thinking: Our independent expert analysts produce the best research because they appreciate, “writing ethical reports to truly support industry growth” (Prof. Merlin Stone), and as Jane Fae – the researcher for the smart grid reports – says, ‘no other publisher is pushing the envelope like this.’

how to keep in touch: if you are not yet subscribed to engerati.com, the digital platform that draws together conference content and research reports and real time news, then I kindly suggest you do so to ensure you and your organisation are highly visible and connected and engaged with your peers in the energy community. Engerati enables you to share opinion, review video presentations, and access premium business reports at reduced levels of investment.

Many thanks,
The editor
Engerati research by experts for experts

ABOUT THE EDITOR

Andrew Burden has worked in business information for 15 years at leading publishers including Informa, Datamonitor, Ovum, and eMap.

Andrew focuses on creating synergy between business information providers and customers, to craft insights that truly enhance decision making.

Contact Andrew through Linkedin www.linkedin.com/pub/andrew-burden/4/940/8a

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**SCOPE**

A strategic management report ("Strategic Business Review"), backed up by in-depth research into the smart grid ("Big Report"), setting out a roadmap to the development of smart networking in the electricity industry, considering how the future evolution of smart grid is both dependent upon, and influenced by, emerging trends in Information and Communications Technology (ICT) and data management and analysis.

The reports:
- highlight the path to sustainable growth for all players
- present a commercial model of the smart grid
- map the emerging smart network and confronts the conventional vision behind it
- outline the key challenge in ICT and data management that needs to be resolved
- examine the way that the smart grid is catalysing the entry of new players into the utility marketplace
- look at how grid evolution is leading to the emergence of 3 new business models
- highlight strategic issues and critical success requirements for different players in the market including locked-in markets and format wars
- recommend strategies for success in the smart grid revolution for each player

The Strategic Business Review delivers insight for companies, investors and nations looking for growth opportunities in this fast developing and widely hyped market, together with actionable recommendations that will help to minimise risk and at the same time avoid the danger of failure to act in a timely enough fashion.

The companion “Big Report” is an in-depth technical look at the market, used to inform the strategic business review, containing case studies, stats, trends and meaningful analysis about the likely future of the smart grid.

**ABOUT THE AUTHORS**

The report is written by Jane Fae and Professor Merlin Stone who have worked together over the last two decades to bring fresh insights to business in the areas of ICT and data management and, more recently, looking at how the latter areas are impacted by - and impact upon - the development of the smart grid.

To create this report, they have reviewed information from proprietary sources, paid subscriptions and the worldwide web and cut through the noise to provide an expert point of view on strategic issues and recommendations that will grow your business and your industry.

Jane Fae is a journalist and expert in the field of smart grid, with a track record that has included work for respected national newspapers, political magazines such as the New Statesman, as well as editorship of the Journal of Database Marketing, and writing of a series of major reports for a truly global audience covering smart grid technology, the legal and regulatory framework within which it has grown, and corporate social responsibility.

Professor Merlin Stone is an economist and renowned expert on marketing and CRM, with many years experience of managing, consulting, research and analysis, particularly in hi-tech markets, financial services markets, mobile telephony and media.

**Engerati research by experts for experts**

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THE BIG REPORT

The “big report” is in-depth analysis of the smart grid market, see the companion “strategic business review” for an overview of the conclusions and recommendations for each player.

FROM OLD TO NEW: THE SHIFTING LANDSCAPE OF ENERGY MANAGEMENT

The historic reality of energy transmission and distribution is hierarchic, uni-directional and relatively simple in outline, that is, electricity is generated in central, usually large-scale, power stations as illustrated in Figure 1.

**Historic conceptualisations of electricity transmission and distribution**

![Diagram of Traditional Transmissions and Distribution Architecture](source: NIST engerati)

**BR figure 1:**

Traditional transmissions and distribution architecture
The range of generating technologies used in stations has been limited, primarily fossil fuel based - according to local politics and national geographical circumstance - a greater or lesser degree of nuclear and hydroelectric generating capacity involved. For the most part these have been of minor significance with a few significant exceptions e.g. France (nuclear) or Norway (hydro). Electricity is transmitted from point of generation to point of use over heavy duty high voltage power lines, first to transmission substations where it is picked up by distribution companies, and then transmitted downstream to commercial and residential end users over the distribution network. Information & Communications Technology (ICT) has played a role, though this has largely been restricted by the nature of this network.

**Electricity generation and transmission is a problem of matching supply to demand:**

- **over supply** – running costly and resource intensive plant to produce energy that cannot be used or stored is highly wasteful and an outcome that electricity generation companies aim to avoid at all costs
- **under supply** - leads to power outages and/or reduced power availability, tending to incur consumer backlash, leading to higher levels of dissatisfaction, and possibly requiring monetary compensation

The situation is compounded by the fact that in the historic model, there is little scope for storage, electricity, once generated, must be used or wasted. Until recently, the only significant technologies for storing electricity, or energy, was to convert electrical energy into some form of potential kinetic energy, most usually by pumping water uphill, or into a pressurised environment, and then turning it back into electric energy (by allowing it to run downhill or to release the pressure) at some later point in time. Battery technologies for the storage of significant amounts of electricity have either been non-existent or prohibitively expensive. In addition, many types of plant require significant time to come on-stream. Their energy is not available the moment they are started up. This, in turn, creates a need to predict both system state and likely demand at any given moment in time several hours – or even days – in advance.

Within the grid, the focus has been on gathering information about grid and user operating characteristics and seeking to extract from this data patterns that will enable electricity generators to forecast with increasing degrees of accuracy:

**Points of potential failure within the grid**

**Likely consumer demand** at specific points in time

This has been aided significantly by some of the earliest manifestations of smart technology, measuring and monitoring devices that are capable of extracting and feeding back information on grid operating characteristics in ever greater degrees of accuracy and closer to – or in – real time mode.

**THE NEW “SMARTER” GRID: CONCEPTUAL FRAMEWORK**

This model has largely been over taken in recent years by a new vision of the grid. Widely hailed as “the smart grid”, not all aspects of this “re-visioning” are intrinsically smart. Rather, they rely on smart technology and approaches to enable them to work.

**Vision**

In broad terms, the vision of the new smart grid is of a future where the one way grid is turned inside out in order to become two way. Energy may be generated and stored locally by end users, and surplus energy may be fed back into the grid as required, in order to reduce significantly the need for additional generating capacity. Almost all elements within the grid, from electricity substations to the individual appliances employed by consumers will be increasingly “smart” in their design, capable of being controlled remotely and making decisions on how to function based either on their evaluation of local circumstances, or through an increasingly sophisticated “dialogue” with other components of the grid, machine-to-machine (M2M).
The key features of the model reflecting this vision are set out in Table 1.

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<th>Additional features of new energy grid</th>
<th>Consequences</th>
<th>Requirement</th>
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<td>Greater range of energy sources, especially renewable, used for central generation</td>
<td>Renewables vary in their reliability and are difficult to predict with any precision in terms of energy yield e.g. wind or solar may be highly intermittent and variable in intensity</td>
<td>Greater flexibility to enable energy suppliers to smooth over variation in energy supply</td>
</tr>
<tr>
<td>Availability of new energy sources at household and commercial level</td>
<td>Microgeneration is the production of energy from local, frequently renewable power sources and will become more widespread, accompanied by an increasing tendency for small generators (even individual domestic consumers) to seek to feed their energy output back into the power grid, and to be rewarded for doing so</td>
<td>Greater flexibility to smooth over energy supply variation Accurate recording of energy transfers in and out of the grid, matched by verifiable accounting of monetary obligations.</td>
</tr>
<tr>
<td>Addition of an Electric Vehicle (EV) pool to national grids: new storage technologies</td>
<td>This will have a dual consequence. 1. addition of large numbers of EVs will represent a significant step change in the power supply requirement: a major drain on energy resource as recharging takes place overnight 2. EVs are a potentially massive reservoir of stored energy, and along with other stored energy sources, may be called back into service utilizing the new two way features of the national grid</td>
<td>Sophisticated software to manage energy transfer up and down the grid hierarchy. Control systems must take account of consumer permissions given for energy “reclaim” – as well as accounting accurately and appropriately for such activity</td>
</tr>
<tr>
<td>Addition of “intelligence” at every level within the grid – from substation to individual appliance</td>
<td>Significantly enhanced ability to control and intervene in the operation of devices remotely. Ability to use information to shape the functioning of the grid.</td>
<td>Intelligent software that can negotiate the communication and interaction between increasingly critical, increasingly sophisticated items of equipment. Processing and storage capacity to handle the significant increase, by several orders of magnitude, of data storage and interrogation.</td>
</tr>
</tbody>
</table>
Central to this vision is that it is seen as the “solution” for several issues, including:

- **shifting from reliance on fossil fuels** to more environmentally friendly alternatives and simultaneously, a means to cope with the fact that some fossil fuels are already at a point where supply is diminishing (“peak oil”)
- **energy security** in a world where energy supplies to developed nations often come from or must travel through regions that are politically hostile to them
- **reduced infrastructure investment**, from more efficient use of existing infrastructure and power generation capabilities enabling utilities to defer investments in a range of major capital items, from new plant to transmission and distribution network
- **rising energy prices**, where more widespread use of information will enable a much more cost-effective energy supply for end users

Equally important is the fact that this vision is seen as something safeguarded and even promoted by the utilities: it is in many ways seen as a solution to “their” problems and will be enacted through their actions.

**Architecture**

The key difference brought about by the new grid architecture is highlighted in Figure 2, the Smart Grid Conceptual Model envisioned by the US National Institute of Standards and Technology (NIST).

The full model shows all communications and energy/electricity flows connecting each domain and how they are interrelated. Each individual domain is further made up of key smart grid elements that are interconnected by means of two way communications and energy/electricity paths. It is these connections that are considered to form the basis of the future, intelligent and dynamic power electricity grid.

The NIST Smart Grid Conceptual Model identifies and illustrates the building blocks that make up an end to end smart grid system, from Generation to (and eventually from) Customers. It is a tool that helps explore the interrelation between different smart grid segments. In practice, the neat division into discrete blocks cannot be wholly maintained, however, unlike many conceptual models, it is a relatively accurate representation of the key operational areas if only because there are certain discrete physical elements that an electricity generation process and associated grid must contain.

![New (smart) grid architecture](source: NIST)
Key operational areas in electricity generation and associated grid:
- Power must be generated
- Power must be transmitted and distributed
- Power will be consumed

These are all relatively independent functions within any grid system and it makes sense to examine these, initially, in isolation.
The Institute of Electrical and Electronics Engineers (IEEE) have taken this conceptualisation further, deconstructing the smart grid as a large scale “System of Systems” where each NIST smart grid domain can be expanded into three smart grid foundational layers:
- Power and Energy Layer
- Communication Layer
- IT/Computer Layers

In this view, the second and third layers represent enabling technologies and implementations and it is their combined operation that makes the grid “smarter”. For the purposes of this report, the focus will be on these two layers – the ICT and data management side of the equation – with domains grouped into three:
- Transmission and distribution
- Customer/end user
- Operations/Markets/Service Providers

While smart principles are equally being introduced into the generation area of the grid, these are out of scope for this report.

New smart technologies: their role in increasing energy information

The smart grid is not one single thing, it is the aggregation of a range of applications and technologies that have arrived at approximately the same time. Although different technologies are uniquely relevant to specific segments of the grid, the principal changes are broadly similar in scope at every level and taken together have the effect of increasing available information about the state of the grid at any moment in time.

The increase of available information about the state of the grid:
- **Data gathering** through the use of intelligent sensors, relaying information to control centres (both supplier and user) where key decisions on how to respond to that information may be taken in a timely and effective manner
- **Communications** translating information into an accessible and easy to use format
- **Enablement** developing predictive algorithms in order to manage elements of the grid more effectively through to **Analysis**

This same essential model of improved sensing technology providing more timely and critical information to central control points (either human or computer), in time to make significant changes to the moment to moment operation of the grid, cuts across each domain. While the precise technologies may vary, the same new and smart approach is being applied to every level within the system.

The development of sensing technology has been accompanied by two further technological shifts:
- **Significant increase in the use of ICT** to enable remote control and automation of key systems, including “demand side management”
- **Creation of metasystems and metadata** not directly associated with the management of the energy network, but with managing the data and systems that are now used to manage the network, for instance, security protocols and cost optimisation algorithms or the provision of information as part of a customer relationship management model
The Internet of Things

Deployment of smart grid techniques is situated within an emerging theory known as the “Internet of Things” (IoT). According to the Smart Grid Dictionary, the IoT is defined as a “conceptual description of the ability to connect any objects with an IP address and some level of embedded intelligence to the communications network. Embedded intelligence can include localization, sensing, identification, security, networking, processing, and control.”

More practically, the application of IoT is central to the work of the EU funded CASAGRAS (‘Coordination and support action for global RFID related activities and standardisation’) project, funded under the EU’s Seventh Framework Program. According to CASAGRAS, the IoT refers to the wireless self configuring network between objects, and they suggest that “in the future, ‘things’ as boring as household appliances could be networked to the Internet. Hypothetically speaking, a fridge could be aware of what is stored inside and order another litre of milk when it runs out or even make people aware that it is close to its expiry date.”

At present, the IoT exists only in embryonic form, a few best practice models have been constructed mostly in terms of stand alone bundles of applications relating to objects identified and included in networked systems, some industrial processes, cutting edge “smart buildings” where even individual light fixtures may be IP addressable.

Viewed from this perspective, the smart grid – and individual components of the smart grid – is but a specialized instance of the IoT. Within the smart grid, a variety of networks connect devices and use embedded intelligence in the forms of sensing and control to deliver and manage electricity. Within the earliest manifestations of the smart grid, it is clear that the devices involved were physical, essentially boxes that carried out a specific function and defined by that function. Increasingly, as for other technologies, the distinction between physical and real and functional and virtual is breaking down, with many key smart functions being delivered by virtual applications made available within and through the cloud. Therefore, in understanding how data and systems contribute to function within the smart grid, it is important to get beyond the relatively traditional view of seeing function as tied to individual devices. There is, and will remain for the foreseeable future, a great deal of function specificity to individual devices, however, the boundaries between physical and programmed delivery are blurring. It is important to recognise that in discussing individual components of the smart grid function is increasingly the focus.

Within the smart grid, the IoT may be viewed as a collection of nested or overlapping networks. A Home Area Network (HAN) sits within a Neighborhood Area Network (NAN), a NAN may be located within a Field Area Network (FAN), and that, in turn, forms part of the distribution grid of a utility.

A further defining characteristic of the smart grid/IoT is how both have as implicit goals the reduction or minimisation of human involvement and, conversely, the replacement of human intervention by machine-to-machine (M2M) activity. This, it may be argued, is mostly a matter of perspective, M2M interactions will continue to be governed by processes that are in turn informed by data that has been converted to information and insight through the application of advanced analytics solutions.

There will, for the foreseeable future, continue to be human intervention in some shape or form, although the degree of automation, and hence the distance between human and machine action, may grow greater. In time, systems may self regulate on the basis of heuristic (experience based) algorithms that they have initiated in order to meet system goals. Still, it is unlikely those goals will be set by anyone other than a human being.
Commentators writing on developments in the smart grid talk about whether issues and developments are up or downstream. In general, the reference is to whether a particular development falls on the utility side of the smart meter, and is therefore largely to do with managing the traditional Transmission and Distribution (T&D) system, or whether it falls on the home side and deals with a range of issues that may affect the individual homeowner and have impact within the home.

The issues involved are, as already outlined, broadly similar because they are in all cases about collecting data on grid status and electricity usage, collating that data and then using it to make key operational decisions about the management of the domain on a second by second basis. What changes, according to domain, is who is “in charge” of the data, of the software, of the overall system and the precise technical architecture that is best suited to the domain itself. Thus, the communications infrastructure needed to take several thousand synchrophasor readings per second from the main grid and the data analytic algorithms required to support that process are wholly different from the communications and analytical requirements for collating data on level of energy use by resident, and modelling customer types on the back of that data.

The T&D objective

The primary focus for the introduction of smart technologies at the Transmission and Distribution level is on enhanced fault detection and self healing of the network without the need for intervention by technical support. To a degree this occurs already, as the basic hierarchic model used to illustrate the traditional electricity grid has been superseded in recent years by radial networks and networks where some degree of re-routing is possible. Thus, in a conventional network, where the flow of current across the network as a whole or some part of it reached critical levels, it was possible to re-route flows through less stressed parts of the grid. The danger of re-routing was that it merely shifts the problem
to another part of the network, stressing that element. A
domino effect may follow, with unplanned power outages,
to the detriment of all network customers. Alternative
techniques for dealing with such situations include a
controlled “rolling blackout” whereby specific regions
covered by a network are subject to power cuts for a pre-
determined period of time, or voltage reduction across the
entire network.

Smart technology does not change the essential nature
of the problem. It does make information on the current
state of the network significantly more available to those
charged with maintaining it. That is reflected both in the
amount of information available and the timeliness, with
more frequent readouts on the state of critical network
components and more up to date provision of that
information (often in real time, as opposed to historic).
In addition, smart technology will assist in managing
a bi-directional energy grid. Historically, grids were
designed with energy flowing out from the centre to point
of use, however, local generation raises the prospect
of a subnetwork generating more power than it uses,
where in a conventional network this is both destabilising
and dangerous. This now changes, as the smart grid is
essentially a “distributed network” with energy flows both
out from and in to the centre or, increasingly, from one
part of the periphery to another without ever touching the
central generating facility.
The principal functions of the smart T&D grid are:

- Automation (substation and power systems)
- Diagnostics (load measurement, voltage stability monitoring, outage detection)
- Automated crisis management (dealing with outages, system instabilities, critical overload)

These principal functions are, in turn, supported by a number of key components within the architecture illustrated in Figure 3.

The goals for these components are supported by:

- Widespread adoption of system standards (e.g. IEC61850)
- Wide area management systems (WAMS) that provide real time monitoring via Phasor Measurement Units (PMUs)
- Fast and robust communications (e.g. IP routers and Ethernet communications)
- Advanced M2M control and communication supported by Intelligent Electronic Devices (IEDs)
The present supervisory control and data acquisition (SCADA) remote terminal unit (RTU) systems that are situated within the transmission substation are not able to scale up in order to support next generation smart intelligence. Many are still based on technology that makes use of telephony modems, rather than IP networks, and serial bus technology to communicate with their substations.

**IEC 61850** is a part of the International Electrotechnical Commission’s (IEC) reference architecture for electric power systems and plays a significant role in substation automation. Its data models can be mapped to a number of protocols (including MMS, GOOSE and SMV), these are capable of being run over TCP/IP networks or substation LANs. Used in conjunction with high speed switched Ethernet, IEC61850 has revolutionised the speed of communications within the electricity grid (e.g. utilities can now obtain response times of less than 4 milliseconds for protective relaying). Over the last decade, the increased availability of flexible IEC 61850 compliant intelligent electronic devices (IEDs) and utility grade IP routers and Ethernet switches has been transformative, either because it provides a standard within which utilities can upgrade or by setting a benchmark that other standards may be measured against.

**Phasor Measurement Units (PMUs)** are devices that produce time stamped phasor measurements of the voltage and current on a grid by carrying out synchronized real time measurements (enabled via GPS) of sine wave magnitude and phase angle at multiple remote measurement points on the grid. Also known as synchrophasors, their importance lies in the fact that they are genuinely synchronized, so enabling synchronized comparison of two quantities in real time, allowing operators to assess system conditions more accurately. Synchrophasor technology is therefore a tool that allows system operators and planners to measure the state of the electrical system and manage power quality. In practical terms, PMU technology is central to the new intelligent grid. Synchrophasor data may prove a “game changer” because in theory they allow increased power flow over existing lines, up to a line’s dynamic limit as opposed to its worst case limit. A PMU may be a dedicated device or the PMU function may be incorporated into a protective relay or other grid component.

**Intelligent Electronic Devices (IEDs)** enable local and/or remote sensing and control of substation equipment at what is typically a M2M level, meaning that they fit very closely with the concept of the Internet of Things. A typical mid-sized US utility will have between 2,000 to 5,000 devices online at any one time (2012) providing SCADA communications, condition based monitoring, and regular checking for event related data in their substations. The increasing proliferation of IEDs is significant, as it embeds communications and intelligence within the distribution network, thereby providing utilities with new opportunities to monitor and manage their networks. The result, in theory, should be greater overall reliability, represented by fewer outages together with lower operational costs due to a reduction in the need for expensive repairs.
Areas of smart enablement

In addition to these broad components - substation automation, IEDs and PMUs - adding smart components to a network is likely to cover some or all of the areas set out in Table 2.

<table>
<thead>
<tr>
<th>Smart focus</th>
<th>Outline</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Switch Automation</td>
<td>The electrical connection between substation and distribution grid is managed by means of line switches that physically connect or disconnect power lines. This function is required in order to permit safe maintenance and repair. At present, line switches tend to be thrown manually, requiring a technician to visit the relevant site to carry out this task.</td>
<td>Utilities are able to monitor and control the state of these components centrally without manual on site intervention. Video monitoring further allows remote operators to check the status of switches visually before starting work on a circuit. Typical functionality includes: • remotely sensing and reporting back on line switch position (open, closed) • with video: confirmation of line switch state • remote activation of switching</td>
</tr>
<tr>
<td>Voltage regulation</td>
<td>The use of voltage regulators helps stabilize voltage at constant levels within the distribution grid. The majority of regulators now also allow for the monitoring of line voltage though usually by attendance of a technician on site to read levels directly from the voltage regulator.</td>
<td>“Always-on” communication with remote voltage regulators allows utilities to carry out monitoring remotely without the need to send out technicians to carry out this function. Key features of smart voltage regulation include: • regular and ad hoc voltage level reports • remote control of voltage level settings • event based reporting of problems with individual voltage regulators</td>
</tr>
<tr>
<td>Transformer Status monitoring</td>
<td>Transformers are a critical component, allowing voltages to be stepped down throughout the grid. This function is carried out at several levels in transmission and distribution substations and as the final voltage step-down into homes and businesses. At present, the main way utilities learn that a transformer has blown is when customers call to inform them of power outages. The search for the cause of the outage and its resolution begins only at that point.</td>
<td>Smart grid enables utilities to monitor transformers remotely, including central monitoring of: • transformer voltages and currents • transformer oil levels and temperatures</td>
</tr>
<tr>
<td>Volt/VAR Control</td>
<td>Capacitor banks control the level of voltage supplied by minimizing voltage drops and absorbing energy from line spikes. The same banks also provide Volt / VAR Control by switching in capacitor banks to compensate for VAR losses when large inductive loads are set off, such as when air conditioners, furnaces, dryers, and/or industrial equipment start.</td>
<td>Enables automation of the process of switching in capacitor banks to maintain voltage levels and minimize VAR losses. Key features include: • centralized ability to switch banks in and out of operation • centralized monitoring and reporting</td>
</tr>
<tr>
<td>Reclosers &amp; Circuit Breaker Automation</td>
<td>Reclosers and circuit breakers are a means to protect overhead power lines by opening a breaker when a fault occurs. Unlike conventional circuit breakers and fuses, requiring a technician to visit the site of an open breaker or blown fuse to restore service caused by to the fault, a smart recloser can automatically attempt to close the circuit. The majority of overhead power line faults are transient (i.e. caused by events such as a lightning strike) reclosers can usually restore power. However, non-transient and a small number of transient faults require a technician to clear the line and/or manually control the recloser to close the circuit.</td>
<td>Permits utilities to monitor and control reclosers centrally without the need to send out a technician. In addition, smart grid provides a number of functions over and above those that a normal recloser can achieve: • central monitoring and reporting on circuit status (i.e. either open or closed), actions carried out on the recloser and performance statistics • direct transmission of commands to the recloser</td>
</tr>
</tbody>
</table>
A range of issues besets migration from an existing non-smart architecture to a smart one where Intelligent Electronic Devices (IED) and data are fully integrated. These include:

- Legacy systems
- Varying and incompatible proprietary IEDs and IED data formats
- Insufficient bandwidth to handle the volume of data and control instructions within an acceptable timeframe
- Inaccessible/hard to access data
- Excessive resource overhead required for maintenance of IEDs and associated software
- Security concerns

At the core of these issues lies a much smaller issue set that may be summed up by questions around interconnectivity and interoperability, both within the grid and onward to enterprise systems and applications. The process of migration is not, in principle, different from any major IT migration process, it is made more complex by the fact that migration is taking place within a network where, as already highlighted, overload or failure of a small number of critical components is capable of bringing down the whole. Migration cannot, therefore, be done in a random or unstructured fashion. New elements of the smart grid and new technologies should only be introduced when it is clear that they can be integrated fully into the network as a whole and that their introduction is not creating temporary weakness within the system.

Examples of new data flow for improved grid management are:

- **New Partial Discharge detection (PD) technologies** permit measurement of PD online and in noisy environments. PD information is one source of early warning when electrical insulation begins to degrade.

- **Dissolved gas analysis (DGA)** carried out on operating power transformers. The key change here is that historically, these tests have been carried out manually and at lengthy intervals (e.g. once a year) and smart technology enables these to be carried out remotely, in real time – and with significantly increased frequency.

- **Thermal Profile** modelling and analysis against actual transformer performance

Major suppliers, including Cisco, Siemens and ABB provide equipment and solutions for substation control and telecontrol technology that allow the acquisition and transmission of relevant data and information from the power grid to the control center. Upgrading of function – and many of the issues around dealing with legacy systems - is simplified, since new applications such as online monitoring can be integrated directly into existing system architectures.

**Smart data within the transmission and distribution network: acquisition and use**

The implementation of smart grid is not just an opportunity to do the same things more efficiently, it is also an opportunity to do new things, to monitor and manage existing assets to a degree and standard that utilities have not hitherto considered possible or worthwhile. In many instances, generators may be deterred from taking full advantage of new technologies because of entrenched thinking in respect of what is or is not worthwhile to do.

A key goal of grid management is to minimise power outages and to reduce the need for load shedding of one form or another to take place. New sensor technologies are being developed with increasing rapidity, enabling new types of data to be captured at a faster rate than ever before.

In managing migration, system operators need to be asking questions about whether change is contributing to the working of the smart grid. These include:

- Does the new system incorporate a significant level of intelligence in system operation and maintenance?
- Is it based within an IP communication network and open standard technologies?
- Has substation information and data been unified?
- Is the system supported through role based information distribution and visualization?
- Does the system include asset management within its scope?

Is security – both from physical and cyber attack - embedded within the system?
Each of these tests represents a significant advance in the monitoring of specific items of equipment. When combined with advanced data processing techniques, including AI, neural net algorithms and a full battery of data mining capabilities, it becomes possible to convert test outcomes into a simple predictive alert presented to human operators within a SCADA center. At the same time, while individual tests may highlight specific diagnostic issues, more sophisticated correlation analysis of data taken from diagnostic systems monitoring different elements in the system should combine to produce significantly more powerful predictive tools in respect of individual components in the system.

The combination of data derived from PD, DGA and thermal profiling should be capable of producing a far more accurate diagnosis of the current state of individual transformers, enabling failures to be identified and avoided far earlier than they are within the current non-smart grid. Such systems may be collectively referred to as Smart Grid Global Monitoring Systems (SGGMS). A range of Smart Grid Global Monitoring Systems (SGGMS) already exist on the market, though their deployment has to date been slower than might appear justified by the benefit they can bring to a utility operator.

There are a number of reasons for slow deployment of SGGMS:

- **Wide variety of SGGMS models and systems available.** This section outlines one possible implementation of a monitoring system, pulling together three separate types of data in order to evaluate the likely future performance of one system element (the transformer). The rapid explosion in sensing technologies means that new potential predictors are appearing in rapid succession and their track record as predictors, either individually or in combination with other data items remains not fully tested. Given that there is cost associated with any new implementation, it is easier to delay implementation than to push ahead.

- **Little experience** of developing business cases to quantifying the benefits of such approaches thus, even in situations where the positive from avoiding outages seem massively to outweigh the cost, because this has not been formally demonstrated, the technology has not been implemented.

- **Existing culture** sees system and component checking as a process that is carried out intermittently and by “experts”. If utilities are to benefit fully from SGGMS, they need to undergo a cultural shift toward understanding that monitoring can be carried out continually and the assessment and decision making process can safely be transferred to automated systems.
T&D SMART CASE STUDIES

Averting power outages in advance

Energy transfer across AC networks is hampered by thermal, voltage and stability limits. The maximum loadability within a transmission system is the state where voltages collapse and units become unsynchronized. This point is a severe/serious system constraint.

The distance from a given operating point to the state of maximum loadability is known as the "stability reserve". It changes value as the system state changes and may differ significantly from values calculated offline. It needs to be recalculated after each state estimate and load flow because operating the system at, or near, its stability limit can result in blackouts.

**Case study: Siemens QuickStab solution averting power outages**

<table>
<thead>
<tr>
<th>Averting power outages in advance is addressed by Siemens’ proprietary QuickStab solution, declared as a system wide voltage and steady state stability index calculation. Given a load flow solution or state estimate of a multi-area power system, QuickStab:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Computes</strong> for each area the maximum loadability and the safe system loading for a user-defined security margin</td>
</tr>
<tr>
<td><strong>Performs</strong> the full range of voltage and steady-state stability computations for contingency scenarios</td>
</tr>
<tr>
<td><strong>Identifies</strong> generators that may cause instability and ranks the machines and tie-line injections in order of their impact on system’s stability</td>
</tr>
<tr>
<td>The application can be used as a stand-alone offline application, invoked from, or used in conjunction with, load-flow programs such as Siemens PSS/E, and seamlessly or loosely integrated with real time network analysis applications of SCADA/EMS such as Siemens Spectrum Power</td>
</tr>
<tr>
<td>Benefits of this solution are derived both from the task it undertakes, and the fact that it is able to deliver information fast, often in real time relative to grid stability. The Transmission System Operator (TSO) is able to understand instantly the systems distance to instability, thereby:</td>
</tr>
<tr>
<td><strong>Enhancing</strong> the system’s operating reliability</td>
</tr>
<tr>
<td><strong>Facilitating</strong> the implementation of market-based operating decisions, such as energy and demand transactions across large interconnected networks, without risk of outage</td>
</tr>
<tr>
<td><strong>Supplying</strong> more load, selling more energy and/or deploying more power without having to add new transmission facilities</td>
</tr>
<tr>
<td><strong>Improving</strong> congestion management procedures and developing remedial action strategies</td>
</tr>
<tr>
<td>Active operation of the system is also supported by Quickstab's ability to setup and assess multi-area what-if scenarios.</td>
</tr>
</tbody>
</table>

source: Engerati
Case study: GridEye protecting the power grid

GridEye is a complex grid monitoring technology developed by the US Department of Energy’s Oak Ridge National Laboratory (ORNL) designed to predict – and therefore avert – major outages. It achieves this by producing high volume real-time granular data flows about the state of the power grid, this in turn is dependent on a distributed network of low-cost sensors called frequency disturbance recorders (FDR) that are plugged directly into standard 110-volt outlets and deployed at offices, school buildings and residences.

Plugging into 110-volt outlets makes FDRs far cheaper to install than other devices with comparable capabilities. Each individual FDR feeds GPS tracked synchrophasor data - synchronized to within one microsecond - into the GridEye system at a rate of 1,440 times every second.

By monitoring phase angle differences, GridEye is able to determine the degree of stress on the system and this in turn highlights when the grid is moving toward instability. The degree of granularity of the picture obtained depends on the extent of deployment of the technology. It is possible to deploy GridEye across an entire region or interconnection, allowing grid operators to evaluate the current state of the grid (allowing for more cost-effective running) as well as to forecast and so avoid disruptions and disturbances.

In addition to providing insight into adverse events, such as generator and line trips, early plans for deployment of GridEye sensors will focus on areas of greater instability in the grid, specifically, those portions where renewables such as wind or solar power are being integrated into the grid.

This approach, it is hoped, will both provide fresh insights into the way these sources impact on the grid, as well as providing the necessary tighter control relative to a significantly more unpredictable and intermittent energy source.
Customer Focus within T&D automation

While much of the focus within smart transmission and distribution systems has been operational – the creation of software and systems that will support the task of maintaining the network and reduce actual outages – some utilities have understood that the information generated by a smart network can also be useful in managing customer expectations.

Case study: Siemens QuickStab solution averting power outages

ComEd is an energy delivery company providing electricity services to approximately 3.8 million customers across Northern Illinois. ComEd is an energy delivery company and does not run power plants or generate electricity. It delivers electricity over a network of more than 90,000 miles of power lines in an 11,400-square-mile territory. Since 2001, it has invested more than $5 billion in their transmission and distributions system, a small part of this has gone to providing customers with an online guide to outages.

This is implemented by means of an online mapping facility providing details of outages by location and numbers affected, plus more detailed information available by means of a drill down to individual address level. It is not clear whether this system is currently maintained manually or is automated, however, future development of smart systems make it likely that automated will, in time, be the preferred means of delivery for this service.

BR Table 3:

Suppliers with IT solutions to support smart networks

<table>
<thead>
<tr>
<th>solution / supplier</th>
<th>Cap Gemini</th>
<th>Cisco</th>
<th>HP</th>
<th>IBM</th>
<th>Oracle</th>
<th>Siemens</th>
<th>GE</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Technology vendors</td>
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<td></td>
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</tr>
<tr>
<td>Wireless technology vendors (including chip, antennae and transceiver)</td>
<td>Qualcomm (CDMA), Full Spectrum GridNet (WiMAX) GainSpan (WiFi).</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Specialist smart grid solution vendors (deploying RF mesh networks)</td>
<td>Silver Spring Trilliant Verizon Qualcomm Sprint Nextel</td>
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<tr>
<td>Mobile Telecomms operators</td>
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</tr>
</tbody>
</table>

source: Innovation Observatory

Providers of T&D automation and intelligence services

According to Innovation Observatory’s 2010 report, ‘Assessing the smart grid opportunity’, a long list of companies have already identified the opportunity to provide ICT support to the rapidly expanding smart grid market and are either creating their own dedicated offerings, or positioning themselves to do so.
MARKET SIZE AND TRENDS

The market is still in its very early stages and as such it is too early to be precise about the shape that it will eventually take. Heavyweight technology players clearly see it as a source of opportunity though at the same time, as they are unable to supply all elements of a smart grid network, are still testing the water, deciding particular areas they are best able to supply, and in what combination (as stand alone supplier, in partnership with utilities, or in partnership with smaller niche enterprises offering particular services or products).

Opportunity

What is clear is that the size of the opportunity is enormous, with forecast cumulative global spend on smart grids over the next decade easily counted in terms of hundreds of billions of dollars. Estimates vary enormously. Pike Research forecast global spending on smart grid projects to approach US$36 billion by 2013, with worldwide investment reaching a cumulative total of US$600 billion by 2020. According to the International Energy Agency, China alone is planning to spend US$96 billion in the next decade, while the United States has recently committed US$4.5 billion. This makes the value of even modest market share significant.

Such estimates should be treated with extreme caution because they are attempts to pin down significant international spending against a background of highly uncertain macro-economic conditions, and a slowdown in a major economy, such as China, or hesitation around smart investment by US utilities could result in massive deviation from the above.

At the same time, arguably, investment in T&D smart infrastructure is much more immune from fluctuation than “downstream” investment in smart home technology. This is because these are infrastructure projects and for a variety of reasons a number of major nations need to renew or create major T&D grid elements afresh:

• The US, one of the first nations to industrialise and therefore create an energy infrastructure, is also first to suffer from obsolescence of existing grid. Aging infrastructure and a declining workforce in respect of traditional T&D skills makes grid replacement a necessity over the next decade. Upgrading to smart grid is thought both to add effectiveness and efficiency and circumvent the skills gap
• Major developing nations, including China, Brazil and India need to establish T&D infrastructure in order to fulfil promises of connecting every citizen, even those in remote rural locations.
• Countries such as Japan, where electricity tends to be transmitted over regional subgrids, need to create a single national grid to avert future energy crises.

In addition, cross-border cooperation between nations is creating ever greater need for smart T&D grids to handle cross-border energy flows. In North America, there is an ongoing energy transfer between the US and Canada. In Eastern Europe, Germany, Austria, Poland and the Czech Republic have a growing interdependence when it comes to energy.

At the same time, organisations such as Grenatech (who have a vested interest in promoting super grids) have been arguing the merits of a pan-Asian smart T&D grid, bundling electricity, natural gas and telecommunications infrastructure, and stretching from China to Australia, by 2050.

Risk for investors

While opportunities are large, investors in it must steer a course between two parallel risks.

On the one hand, the market is changing very quickly and there is, at this stage of technology development, the possibility of making large losses by investing over heavily in a solution or strategic direction that subsequently proves to be a dead end.

On the other hand, movers in this market cannot afford to wait too long, as doing so could lead to them being locked out by competitors more prepared to take risks and to identify as early movers, but immersing themselves too quickly, too soon in a particular approach runs the risk of their making significant strategic mistakes.

Would be players in the smart grid marketplace need to balance these two contrary tendencies and, wherever possible, leverage their offering on proven expertise and technology robustness. They must not delay but they should not leap too recklessly either.
SMART TECHNOLOGY FOR THE END USER, SMART HOMES, SMART COMMERCE

The Customer domain of the NIST smart grid, illustrated in Figure 4, begins at the point where the end users of electricity (domestic, commercial/building and industrial) connect to the electric distribution network by means of smart meters.
This “downstream” part of the smart network is composed of in home sensors, communications technology and control devices, both automated and control. However, it is important to understand that this physical grid is also embedded within a theoretical framework (automated metering and demand response) to be discussed separately.

The customer subnetwork does not exist in isolation, as highlighted in Figure 5. If the smart meter is the main gateway into the home, the exit point from the utility or distribution company is the Head End Server, acting as interface between a number of homes, grouped together by means of a concentrator and wide area network (WAN) and linking these elements to a range of back office applications, such as billing or customer service.

From the perspective of the domestic customer, each end user has a discrete domain made up of electricity premise and two way communications networks. The traditional view of this domain is that the end user is mostly a passive consumer of energy provided by the utility supplier, where energy is used to power a range of domestic appliances, ranging from electric lighting and heating, through to entertainment systems, washing machines and cookers amongst others.
Two key changes are forecast for the near future, and these changes are both enabled by the smart grid and also drivers of development of the smart grid (they would be difficult or impossible to implement without the smart grid), while the smart grid is in part a response to the working out of these trends. They are:

- **Local (micro) generation**, often using renewable, enabling end users to supply some of their own energy as well as, at times of peak generation, actually feed energy into the national grid.
- **Local storage**, this may be through the development of new stand alone battery technology, or through the addition of an Electric Vehicle (EV) to the domain.

EVs will add significantly to energy requirements and it is likely that they will need to be charged for several hours at a time and this charging will need to be managed both by the EV owner and by the utility, as a tendency for ALL EV owners to recharge at around the same time (i.e. overnight) is likely to create a massive fluctuation and corresponding instability in the grid. At the same time, once charged, so long as it remains linked to the grid, an unused EV is also a major source of potential energy that it is believed utilities would like to be able to call upon in future.

While this broadly describes the energy use and network structure within a domestic end user setting, the same outline applies in principle to non-domestic end users, the building/commercial sector, and the industrial sector. The main differences lie in the type of application for energy that is likely to be required, and this is much more specific to dedicated industrial processes, and the scale of any element within the system.

Thus, a home user may require electricity for cooking or heating, an industrial user might require electricity for smelting metals or maintaining a furnace. A domestic customer might generate a relatively small amount of power through a few solar panels or a single turbine wind generator, and need to charge one, at most two EVs whereas an industrial customer might run their own dedicated power park capable of generating megawatts of power, as well as a fleet of EVs representing both a significant call on grid output as well as a major energy storage facility when not in use.

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**Theoretical rationale of the “smart home”**

The basic business case for creating smart homes is that, through providing more and more detailed information about energy use in the home, coupled with automation and load control, a win-win situation is created for both utility and consumer. The former is able to implement finer and finer degrees of load management, with generation more closely matched to energy requirement. At the same time, the consumer is able to benefit from this in terms of greater personal control of their energy use and spend, leading to lower overall bills.

**The language of smart home control**

A number of terms are used in respect of the smart home and smart home architecture. These include:

- Automatic Meter Reading (AMR)
- Advanced Metering Infrastructure (AMI)
- Demand response (DR)

**Automatic Meter Reading (AMR)**

AMR is not genuinely smart but is a first step on the way to the creation of a smart system. It is primarily a system making use of one way communications to carry out remote interrogation of meters and as such, to eliminate a large proportion of the labour-intensive processes inherent in manual meter reading. Initially, AMR has led to lower operational costs however, one result of introducing the capability to read meters remotely and at any time is that some companies have dramatically increased the frequency of meter readings in order to create models of how energy is used throughout a period of time. This, in turn, has wiped out many of the cost savings put in place by AMR.
Advanced Metering Infrastructure (AMI)
The second stage toward development of a smart grid is the putting in place of a more fully interactive control infrastructure – AMI – based on two-way communications. The basic AMI system includes a data concentrator and energy meters linked into the network by means of the latest communication technologies, again reducing operational costs and, in this case, enabling a much broader range of business processes, including remote connect/disconnect capabilities, on-demand meter readings, tamper and fraud detection, outage detection, and even more important from the point of view of information gathering and analytics, energy readings taken at even shorter time intervals for demand response programs.

Demand response (DR)
The holy grail of AMI is a DR program. In principle, there are just two ways that utilities may cope with peak demand in the current system. These are:
- increase supply (by bringing additional plant on-line)
- reduce demand
A third option that may in time be available via the smart grid is the drawing off of surplus energy from Microgeneration sites or reclaiming energy stored either locally (by end users) or centrally.

Demand reduction in practice
Utilities have many techniques for reducing demand. These range from dynamic pricing, tending to focus on encouraging shifts in consumer behaviour over time through moving the price goal posts, through to direct load control, a more direct real-time intervention in the level of energy used.

The first step on the road to smart energy management is dynamic pricing and Time of Use (TOU) billing models. These are an attempt to influence the way consumers make use of energy by varying the costs of energy supply according to use profile. It is more finely tuned than simply billing for a total energy use but rather less flexible than more advanced smart capabilities.

Options likely to be offered by utilities in this respect include:
- **Time of Use (TOU) pricing** – pricing tiers, such as peak or off-peak (or in one EU state “valley”) are set up relative to specific times of day. These are then publicized to consumers, thereby providing a financial incentive to shift demand to off-peak hours and/or to reduce overall consumption.
- **Critical Peak Pricing (CPP)** – a variant on TOU pricing, where consumers are alerted to price changes applicable during spikes in peak electricity demand, so providing financial incentive for them to shift their energy demand instantly.
- **Real time Pricing (RTP)** – a broader approach more closely related to demand response, where utilities may both flex energy prices according to fluctuations in the cost of generation and at the same time send out signals to consumers (and appliances) in order to integrate demand side applications in taking decisions about load shifting.

The final stage in smart home energy management is for utilities to take on direct load control of appliances and to adjust the settings on appliances or even to turn them on or off during peak demand periods. Typically, consumers are inefficient in the way they manage systems such as HVAC, pool pumps, thermostats, air conditioners, cooking and washing devices.

Remote Appliance Controllers (RACs) allow utilities to manage such appliances, thereby introducing a win-win situation of lower cost for utility and customer. RACs can be programmed to intervene in response to a range of situations, including time of use, critical peak pricing events, and direct load control events, as well as in response to a manual intervention by the system/network operators.

Such interventions may be ad hoc or, as envisaged for the future, put in place as part of a package. A critical feature of such package deals is that the consumer is effectively being rewarded for their “responsible” energy use by means of lower tariffs. This approach is in practice the corollary of the market approach to energy management where end users bid energy reductions (“negawatts”) into
a market in the hope that a utility is prepared to regard their foregoing of electricity use/benefit with a direct financial reward.

Implicit in such schemes, therefore, is an opt out capability. This would permit a consumer to opt out from a specific Direct Load Control (DLC) or Critical Peak Pricing (CPP) event, either on an ongoing basis (the end user may permit intervention in Heating Ventilation Air Conditioning (HVAC) systems, but not other appliances) or on an ad hoc basis (e.g. through manual override of a DLC instruction by the consumer). So, in terms of DLC, a user might allow an energy company the right to turn their HVAC on and off remotely - but refuse to allow that facility in respect of their oven and they might agree to pay a premium for running certain services at certain times - or not. This tends to reinforce the idea that DLC is a financial benefit to the utility and in exchange for this they will, in time, need to reward the end user financially.

Demand response is not a simple fix to be applied at one end of the generation journey, DR should be used intelligently as a tool that can influence every level of the electricity supply chain, illustrated in Figure 6. It can be used in a long term strategic way, as a means to affect the overall efficiency of a system by feeding in to planning or it may be used in real or near real time contexts to manage the grid on a moment to moment basis.
Deep demand response

In addition to the simple conceptualisation of demand response as a means to reduce energy use, some analysts are starting to talk about “deep demand response”, this occurs when a fully integrated smart network is used to match supply and demand dynamically, down to the appliance level, in real time.

Deep demand response relies on two independent but intrinsically allied factors:

An ability to predict the output of all energy sources, including renewable, within an actionable time period

The ability to control and modify load demand within that time period

By linking both of the above pieces of information to energy markets, it becomes possible to factor in the possibility of plugging shortfalls in energy supply by purchasing it wholesale on the open market. Managing of an electricity grid then becomes the aggregate task formed by balancing, on a moment to moment basis, three separate pieces of information:

- likely energy available
- scope for reducing load
- cost of purchasing energy

In order to make decisions in sculpting energy loads in this way, the operator needs metrics that express ability to change the load. Finely tuned alignment of supply and consumption requires controllers that make continuous decisions based on information about load schedule as well as energy availability.

Factors required to sculpt a load:

- **variable scheduling of operations**, the consumption schedule must permit choices on when energy is consumed
- **presence of “slack”**, where there is capacity, however negligible, to store energy in the system (in the case of a fridge, pre-cooling is a mechanism that introduces slack into the physical system)
- **presence of “slide”** an ability to schedule a device’s energy consumption (e.g. running a washing machine at an off peak time. Less conventionally, slack can enable slide, for example, by deferring a cooling cycle in the refrigerator).
The customer domain physical architecture

The main components that make up the end user smart network are listed in Table 4, in respect of a domestic setup this may also be referred to as a Home Area Network (HAN)

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart meter</td>
<td>The gateway from the distribution grid to the home</td>
</tr>
<tr>
<td>Home Box</td>
<td>In home distribution center for communications and control of gadgets (the bridge between the smart meter and the rest of the house)</td>
</tr>
<tr>
<td>Smart appliances</td>
<td>Smart enabled appliances</td>
</tr>
<tr>
<td>In home displays (IHDs)</td>
<td>Dedicated in home component designed to provide end user with insightful reporting of information about energy usage</td>
</tr>
<tr>
<td>Sensors</td>
<td>Monitor within the HAN for discrete significant events</td>
</tr>
<tr>
<td>Renewable generation facilities</td>
<td>The capability for carrying out local microgeneration of energy that may be fed back into the main grid</td>
</tr>
<tr>
<td>Local storage facilities</td>
<td>Dedicated batteries and/or electric vehicles</td>
</tr>
</tbody>
</table>

Smart meters perform a dual function, acting both as clearing house for information about energy use and patterns within the end user domain, as well as the ability to control and manage the flow of electricity to and from the customer. Some of the main functions of the smart meter are listed in Table 5

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic Voltage Monitoring &amp; Reporting</td>
<td>Basic residential meters are capable of capturing instantaneous voltage values, and providing either on demand or scheduled reporting of the measured voltage</td>
</tr>
<tr>
<td>Load profiling and Time of Use Billing</td>
<td>The ability to determine precise customer load usage at a given point of time and to relate billing and tariffs directly to load profile</td>
</tr>
<tr>
<td>Remote connect/ disconnect</td>
<td>Provides the ability to disconnect a customer from the grid or to reconnect either from a central control facility or in accordance with pre-set automated criteria. This function may also be used to impose load limitations on individual customers</td>
</tr>
<tr>
<td>Outage and restoration reporting</td>
<td>Smart meters may report directly to the network operator the point at which an individual user or, acting as a Neighbourhood Area Network, the point when a small area becomes disconnected from the grid or unstable. Such systems are also capable of providing near real time notification of the moment that power is restored to a circuit</td>
</tr>
</tbody>
</table>

source: Analyst Overview

source: Analyst Overview
**HomeBox**
Within the home, appliances and other household applications will be under the control of a HomeBox providing decentralized data storage, embedded functionality and connectivity, while the smart meter will act as the main gateway into a home.

Core functions may include security (camera, door/window opening sensor, motion sensor, remote control or smoke detector) domotics (power plug relay, window shutter control and heating control), energy management accessories (monitoring of electricity, water and gas usage) and healthcare (vital sign monitoring).

The HomeBox system is then backed up by a range of features:

- real time alerts across all media (SMS, MMS, email, voice call or fax)
- remote control from any IP addressable device (mobile, pc, etc.)
- visualization of the home via a camera

A key issue in the implementation of the smart end user domain is in selecting the communications standard that will operate between the home box and the rest of the domain.

**Smart appliances**
Smart appliances are everyday household objects, but with embedded intelligence. In future these can be controlled remotely or can adjust their operation to specific external stimuli. Such devices may also, in time, be able to communicate on a M2M basis.

**Sensors**
Sensors may be used in quite different ways within a smart building. In the first case, they exist to monitor the physical attributes of a particular network, from tracing electrical wiring, plumbing, and gas lines back to specific devices or fixtures, through to monitoring the actual power usage of individual appliances. Householders will be able to determine the level of energy use within a household by device.

Further sophistication may be added in future, possibly through the addition of RFID technology, allowing a building to determine either the presence or absence of inhabitants, or even the presence of particular inhabitants, and to adjust devices accordingly. Turning appliances on and off when individuals leave or come home, adjusting ambient room temperature to suit the preferences of particular individuals.

**In home Displays**
In Home Displays (IHD) are devices created with the intention of providing consumers with actionable information on in home energy performance and their objective is to transform technical data into easy to understand customer information.

**Data availability**
Data available on the home and distribution side of the smart meter are differentiated by cost. That is, information and data may be sent “upward” toward the Head End System (HES) but this data transfer is limited by the cost of the WAN connection, with WAN suppliers usually imposing a limit both on the cumulative daily amount of data transferred and the frequency/timing of that transfer (usually limited to once per day). For this reason, most HES only capture half hourly cumulative readings from the meters. This is a factor that needs to be taken into account in future iterations of the smart grid, as the fine tuned control of home appliances will potentially require far more data to be made available at far more frequent intervals.

On the consumer side of the meter, this limit does not apply, the consumer is able to obtain data that is both more timely and far more frequent. For instance, an IHD may update the view of current power consumption or the cost of that power every ten seconds.
Customer Relationship Management

The new data availability meshes easily with a business and marketing model that has been widely adopted across a range of sectors – from financial services to telecoms to retail – over the last couple of decades. This is Customer Relationship Management (CRM). There are many definitions of CRM, but core elements of this approach include the fact that it is a company wide business strategy, encompassing not simply departments traditionally thought of as customer facing, such as sales, service and billing but all corporate activities. Information about customers is used to measure and value customer relationships, as a result of this, customers are managed relative to their value to a company.

The most obvious place where such measurement finds expression is in the marketing area and externally directed communications. Thus, an individual customer may be allocated a notional value in respect of their anticipated future business, they may also be allocated to one or more segmentation systems, adding yet further detail to how the individual is deemed likely to respond and react to promotions.

In general, it makes sense to spend more on high value customers, promoting to them more frequently, attempting to sell more expensive product to them, with the proviso that concepts such as the customer journey, or customer lifecycle also acknowledge that the most valuable customers at a given point in time may be those who have just reached their peak spend with an organisation and that thereafter the core marketing task is to mitigate a likely downward turn in their spending.

In other words, the key to CRM is not simply to reward or direct the maximum marketing effort towards the currently most valuable customers, so much as to take into account customer characteristics, including personal preferences, current value and likely future value in managing the customer. That shapes both the tone and content of promotional messages, it determines not only what is said to an individual, but when and how, and it may also be used to determine the way that a customer is treated when they initiate contact with a company.

Whether they have preferential channels of access, service levels that may be defined, in some instances even in terms of how much time they will be allocated on an average call. CRM in theory is all encompassing, determining the way that customers are treated at any and every interaction they may have. Those interactions may, in turn, be part of the everyday run of business where calls, promotions, and follow ups originate with a conscious decision to communicate on the part of a member of staff. Or they may be automated and event driven such as a letter dispatched automatically on non-payment of an account, or a follow up triggered if an individual has failed to book a required service appointment.

In practice, CRM is only as good – or as deep – as the information available to business managers. That, in turn, is a function of the data physically present within a system and the ability of the system to unlock that information for use in everyday transactions and transactional analysis. A major barrier to the implementation of CRM within some businesses is that key data exists within legacy systems, but cannot be easily transferred into operational environments where it can be used to inform or initiate everyday processes.

The promise of smart grid networks is that they will make available to utilities – and other operators in the energy mix – total information in respect of how a customer is behaving. In theory, over time, not only a customer’s aggregate home energy usage at 15 minute intervals during the day, but also energy use by appliance and even, forecast energy use. Where appliances are controlled by timers, it should be possible for the smart grid operator to access timer information, so having a good idea of the point at which particular units will spring into action and this is particularly important, since it allows a segmentation based not simply on when a customer is at home, but on when a customer is likely to be home. That, in turn, allows for a theoretical future in which call centre resource planning is interfaced with smart appliance information, allowing companies to plan their call activity around when individuals are most likely to be present to answer.
Central issues in implementing CRM

A number of the issues likely to affect corporate implementation of CRM are identical to the issues likely to affect other aspects of smart grid networking. These focus around the ability of organisations to handle the massive increase of data volumes generated, their ability to extract meaning from that data, and their ability to do so in real time.

Certain tasks, such as customer segmentation using available data drawn from a number of different systems are relatively straightforward as far as existing data analysis providers are concerned, providing the end result required is a relatively static outcome, and the business is prepared to take the time, sometimes several weeks, to amass personal and use data from a range of sources, including operational and legacy systems, match these together, and then to come up with conclusions about the end user.

This is a wholly different proposition from extracting data in real time, combining it with a range of other data that is available only in widely dispersed silos within the overall system, and then feeding the results of that analysis back into operations in order to influence CRM decisions on an ongoing and dynamic basis. That remains the holy grail as far as many utilities are concerned and its resolution in other areas, such as the Transmission and Distribution networks, is likely to impact on its resolution at customer level too.

Smart home case studies

Case study: Siemens QuickStab solution averting power outages

A key issue for utilities is how they can obtain a better understanding of consumer energy usage patterns, while simultaneously enlisting consumers as their allies in reducing excessive energy use.

One solution to this issue may be provided by ORNL's CoNNECT platform, providing two views of energy use for a utility and a customer's use. The utility view provides insights about customer energy use profiles, both individually and in aggregate, and may contribute toward a fine tuning of rebate/incentive programs for conserving energy.

The public view, based around user friendly analytic tools, provides customers with geovisual analytic capabilities that deliver greater information and insight into their own energy consumption patterns, correlating their consumption to changing weather conditions, and comparing their consumption to that of their peers in the same geographic areas. The view further provides them with the capability to evaluate future energy technologies, including renewables.

The hope, expressed by ORNL, is that the function delivered by the CoNNECT framework will:

- accelerate adoption and market penetration of Energy Efficient and Renewable Energy technologies
- promote a community engagement through user generated content
- provide maximum flexibility and transparency to the data owners
- overcome pervasive institutional, market, and financial barriers to energy efficiency by increased consumer awareness, education, and outreach
CRM CASE STUDIES

Motivators

Early visions of the smart grid included, often, the ideal view that simply providing customers with information would assist them in reducing energy usage. In fact, this view appears to be too simplistic and has been widely refuted by two findings, from research and from practice, over the last few years.

CRM findings from research and practice:

- Customer savings from smart technology need to be substantial (of the order of 30% or greater) before customers are prepared to take notice and this is key, since some smart programs put in place in recent years are achieving single digit savings only.
- Customers wish to be hand held through the savings process with research suggesting that rather than being presented with rich (and often complex) data, the majority of consumers want applications to deliver them simple actionable choices e.g. if you switch to supplier X, you will save $y per year. This is endorsed by a recent J D Power survey, looking at what works when it comes to energy service planning, and simply providing information was ranked 5th out of 15 approaches.

Another approach that has been put forward by some companies is social comparison, applications and products that provide consumers with comparisons of how they are performing against other consumers of energy product. This was ranked overall 10th in the same survey.

The reason for the apparently negative outcome for social comparison:

- Customers who are already energy savers like this approach, since it delivers praise for their “good behaviour” but they are a minority.
- Laggards and “average” customers, likely to make up half or more of the customer base according to self perception, will often feel snubbed or dissatisfied with this approach. Some may be inspired to make temporary changes, but others will react with anger or excuses for having been shown to be “below par”. The net result is damaging to customer relationships.

Comparisons, unless controlled for a host of factors including age and number of occupants in a household, property features, and so on, are likely to be superficial, thereby providing yet more justification for consumers to ignore them.
Case study: C3, combining information with incentives, recruiting customers to your cause

According to energy management solutions provider, C3, the optimum solutions combines online applications, tailored customer information, and rewards. C3 have found that this approach is preferred by utilities and customers alike, since it increases customer satisfaction, provides customers with immediate gratification for taking positive action, and helps utilities to achieve their goals.

C3’s mission is to assist customers (utilities and other businesses involved in the energy generation transmission and distribution sectors) increase profitability and cash flow by optimizing their enterprise energy management strategy. Their family of software solutions are designed to help companies understand, optimize, and report on their energy use and greenhouse gas emissions, in order to reduce cost, risk, and environmental impact.

Their approach incorporates the top three customer preferences outlined in the J.D. Power survey already cited:

- provide points for reducing energy use,
- show how much energy can be saved by taking a particular action, and
- show the impact of completed actions on energy savings.

The C3 online portal provides households with actionable, tailored recommendations for saving money. It shows the impact of those changes, and rewards customers for reducing their energy consumption, by providing rewards points redeemable for goods and services from well-known vendors. The net result is savings of up to 6% from households enrolled in the online program.

Energy savings combined with schools initiative

A similar approach has been piloted by New York-based Efficiency 2.0, whose rewards program is being spread and supported by word of mouth through schools where the program operates.

Case study: Efficiency Personal Energy Efficiency Rewards

Efficiency has piloted a Personal Energy Efficiency Rewards program (PEER) in about half a dozen pilots locations, of these the largest is with Commonwealth Edison in Chicago. A two pronged approach includes mailings with advice about how individuals compare to their neighbors and simple ways to cut energy use, as well as a more complex website proposition where people can opt in to earn coupons. Printed reports go out to more than 300,000 people. Once they have received their hard copy report, customers can sign up for a website providing even more tailored data and allowing them to earn rewards. This is similar to an initiative, by RecycleBank, that offers reward points when users save a certain amount of kilowatt hours (currently in 2012, 50 kWh = one $10 coupon).

Average energy savings for the customers opted in to the web program averages about 6.1 percent compared to about 2.5 percent for those on the mail only program, and more than 12,000 people are signed up in the Chicago area.

A further lift occurred when incentives were used to bring schools into the process and school children began to support the program by encouraging parents to purchase energy saving devices in order to maximise the reward to their school. As of March 2012, schools in both Illinois and Massachusetts had opted in to the program.

While many of the customer actions people are simple, and low or no cost, Efficiency 2.0 have also used available data (more than 500 million data points) to come up with tailored suggestions for individual households. On the surface this is a success story, however, compared to typical High St discounts of 30% to 50% on many products, an energy saving of 6% is not impressive. Research suggests that a good target for such savings, if they are to maintain customer interest, is 30% meaning programs such as this will need to evolve in order to maintain momentum when the novelty wears off and reward schemes cease to be so attractive.

Efficiency 2.0’s immediate short term goal is for it to lift its base to five million online customers by 2014.
KEY PLAYERS IN THE SMART HOMES DOMAIN

Many smart meter producers and vendors tend to be home grown.

**Key players: Smart Meters**

US - major players include Echelon, Elster Group, Holley Metering Ltd, Iskraemeco, Itron, Landis+Gyr, PRI Ltd, Sensus and SmartSynch.

China - key players identified are Ningbo Sanxing Electric, Wason, Hi Sun Technology, Linyang Electronics and Holley Metering

Supporting infrastructure

Many of the other elements found inside the smart home, including the Homebox, Sensors, Smart appliances and In Home Displays (IHDs) are produced by an increasingly diverse range of manufacturers, both globally and local.

**Key players: smart appliances**

Smart appliances is dominated by existing appliance manufacturers such as Whirlpool and Phillips, who are simply looking to add smartness to an existing range of products and probably hoping that integration with Home Automation systems, independent of smart grid, will create a market for their product.

Communication standards

A major debate is currently engaged in respect of the right communications standard(s) to implement within the HAN. This sector remains an area with many competitors active, though there are signs that the ZigBee standard is beginning to edge ahead of others.

MARKET SIZE AND TRENDS

**Smart Meters**

China is planning to spend about $2.5 billion to $3 billion per year on a smart meter rollout over the next several years, with much of the benefit being felt by Chinese meter makers.

In respect of sensors, one report forecasts that by 2017, about $2.3bn will be spent on HAN sensors, with the biggest opportunity being for appliances. Deploying sensors that link home appliances with smart meters will significantly increase overall energy efficiency and reduce peak demand generation requirements.

The size of the smart appliance market remains subject to some disagreement, with Zpryme forecasting it as set to reach $15.1bn in 2015 and Pike Research outlookng a fraction of this at US$6.3bn in the same year.

**Consumer power**

One of the key issues in respect of developing the smart home domain is the extent to which any given market supports “consumer power”. That is, whether consumers are entitled, or even encouraged, to purchase key parts of their home network or whether they are dissuaded from so doing. This discussion, in turn, reflects two quite separate but interlocking issues. On the one hand is governmental or regulatory pressure for consumers to act in a certain way. In general, the prevailing view in much of the OECD area is that smart meters should be delivered through the power companies at some level, although a key debate remains whether and if so, how much, consumers should contribute towards paying for them.

This, in turn, is influenced by the pure economic value to consumers of a smart meter and in the US, there has been pressure from power companies for consumers to pay for their smart meters. Despite consumer resistance to this move, it is arguable that US citizens, with amongst the highest energy consumption levels in the world, can best afford this expense, since it would quickly be repaid from savings on energy bills. By contrast, consumers in Brazil, who on average consume 10% as much electricity as those in the US, would need smart meters to be considerably
cheaper (c.$20 according to one estimate) before they could justify their purchase. The debate over IHD’s is even more fraught. A selection of research suggests that consumers need easy to understand information if they are to change their energy consumption behaviour – and that, in turn, is provided by a user-friendly IHD. However, apart from the UK, where the government has mandated energy companies to provide IHD’s to their customers, obtaining an IHD is largely left to the consumer, who may purchase one independently or, more likely, obtain one as an incentive. While one side of this debate focuses on the economic question of who should pay, there is also a major concern over standards and interoperability, with many fearing that, left to the free market, the developing smart home could initially face major difficulties as consumers load it with a plethora of non-interoperable or even mutually interfering devices. This, in turn, increases pressure for suppliers to guide or even economically influence consumers in their choice of In Home Devices.

**Emergence of stand alone applications**

**Caution! apps do not need to be linked to utility objectives.**

While much of the focus is on how utilities may supply dedicated In Home Devices to support consumers in managing their energy supply, evidence is emerging that what consumers are looking for is “ubiquity” in the ability to access home information wherever they happen to be via smart phone or tablet, rather than “dedication”. The result is a rapid growth in application development. Many apps, at present, are closely tied to utility and energy issues but the alarm bells ringing here should be against the realisation that such apps do not need to be linked to utility objectives at all.

Examples of how independent development of apps is now beginning to impact on the smart grid includes:

- A Popular Choice competition “Apps for Energy” sponsored by the US DoE, received more than 50 innovative mobile and web applications designed to help utility consumers save money by making the most of their “Green Button” electricity usage data
- VELObill, an app allowing users to track their utility bills, then compares their energy use to peers and neighbours through Facebook or by entering their postal code, created by Zero Footprint, a software company based in Toronto and New York that specializes in programs to help people cut energy costs
- Xenergy, developed independently and using the Tendril Connect platform APIs, won the title of SDG&E’s (San Diego Gas & Electric) Best Energy App and also received an Honorable Mention for Best Overall App, also linking up to the Green Button program

**Subcomponent supply**

Even where the focus on supply of major components within the smart market is directed toward local companies there are still opportunities in respect of subcomponents within the better known building blocks.

**Case study: STMicroelectronics subcomponents**

Swiss based semiconductor manufacturer, STMicroelectronics, has been making a big push into chipsets for smart meters and the communications systems that serve them. ST has long been been the strongest in European smart meter markets, but according to an announcement by their CEO in June 2012, they have recently “won China”. This highlights a trend across all of the smart sector where big names may be closely identified with providing identified components of the network but inside each component is a range of subcomponents, from chips to sensor cells, whose value in terms of business margin, may often be as great or greater than the finished item.

_source: Engerati_
ADDITIONAL SERVICE ORIENTED DOMAINS

There are three additional domains identified by NIST as being crucial to the efficient working of a smart grid:

- Operations
- Service Provider
- Market

In the case of the Service Provider and Market domains, both existed previously but the smart grid represents a major expansion on what went before, an “epiphenomenon of the smart grid with services added, or created services that were wholly absent from, or unnecessary in, the traditional grid.”

Operations Domain

The Operations domain is broadly equivalent to the same function as has been historically carried out within a single utility network – but now enhanced and expanded by the fact that managing energy flows within the smart grid of the future is intrinsically more complex, requiring a greater balancing of disparate factors than current grid management.

source: NIST
The Operations section manage and control the electricity flow of all other domains in the smart grid, using two way communications networks to connect to substations, customer premises networks and other intelligent field devices. It carries out monitoring, reports on grid events and issues, and also controls and supervises grid status as well as significant process information and decisions. Within the operations domain, business intelligence processes collate data from the customer and the various networks, and feed this back as intelligence to support the decision making. Some of these functions existed previously while some are new. Across the board the newest aspect of grid operations is the complexity. Computing within the grid is expected to be significantly more complex, requiring grid operators to put in place systems and processes that are more closely akin to cutting edge artificial intelligence technologies than the simple binary monitoring of grid states that has hitherto been the norm.

**Typical areas covered by the Operations domain include:**

- Supply chain issues
- Network management
- Finance (billing, accounting, etc.)
- Security
- Planning
- Meter reading
Service Provider

The Service Provider domain of the smart grid takes care of all third party operations among, and between, the domains. This responsibility might extend to cover web portals providing energy efficiency management services to end customers, or data exchange between the customer and the utilities regarding energy management, and the electricity supplied to homes and buildings.

BR figure 8:
NIST schematic for Service Provider domain

source: NIST
The Service Provider domain is closely related to that of Operations and in some conceptualisations of the grid, the two tend to be merged. The distinction that appears to be being drawn, broadly, by NIST, is between Operations that are retained in house, and Service Providers who are, by definition, external to utilities, but may be carrying out many of the same functions managed in house. The service providers may also manage other processes for the utilities, such as individual demand response programs, including billing and customer/account management, outage management and field services.

It is important to note that while service providers "provide" and carry out many of the core services currently carried out within utilities, and as such are likely to be viewed, initially, as little more than a (formalised) outsourcing capability, the emergence of separate networks and the move away from the hierarchic provision of energy will in time see service providers moving to a position of neutrality between networks. In other words, acting as go betweens and providing services that provide a bridge between groups and entities that otherwise might be considered to be competing. Thus, in a fully smart grid, the interests of the end user and those of the energy supplier do not always fully align. Given that progress towards full implementation of smart grid is predicated on a growing consumer trust in smart function suppliers and a belief that energy suppliers will not "rip them off", the role of the service provider is likely, in time, to evolve to far more than that of outsourced supplier. Rather, they are likely to gain most if they can be seen as "honest brokers", managing and in some cases enforcing contractual relationships between energy provider and user, or even, as the importance of inter utility transfers grows, between utilities or utilities and other energy suppliers, in such a way that neither party is unfairly disadvantaged or obtains an unfair advantage.

The case for using a service provider may, in time, go beyond the question of what services they provide and whether they can do so more cost-effectively than in house staff, to a wider usp, that by using a known independent service provider, utilities may be able to take their relationship with end users to a level not possible where a direct relationship exists.
MARKETS

The newest domain within the smart grid model and the one that is still under development both actually, and conceptually, is the Markets domain. This operates and coordinates all the participants in the various electricity markets operating within and under the smart grid.

Technically, the Markets domain is an extension of service provision however the likely importance to the future evolution of the smart grid and, more importantly, to the smart grid economy is the reason why it is identified separately, as here. The Market domain interfaces with all other domains and makes sure they are coordinated in a competitive market environment, achieving this by providing the market management, wholesaling, retailing and trading of energy services, also handling energy information clearing house operations and information exchange with third party service providers. Thus, for instance, as the EV network matures, roaming billing information for interutility plug in vehicles will eventually link to the Markets Domain.
Market operation

The complexity of the task that this segment of the smart grid is likely to have to take on is highlighted by the underlying shift toward bi-directionality and an increasing degree of competition within the market place for energy. There is already an established market in energy in some parts of Europe, with suppliers generating at or slightly below capacity, and making up any shortfall in provision by bidding for surplus energy on the electricity spot market. This approach is central to the smart grid vision of a more effective, more efficient energy industry, with utilities as a whole being that much more likely to defer, or put off entirely, building of new plants so long as they can meet their contractual energy supply commitments by buying energy more economically for on-supply to customers.

The market of the future, however, is likely to contain more than just utilities and end users, or rather, more than simply utilities as suppliers, end users as consumers. Bi-directionality and local (renewable) generation of energy within the smart grid is likely to make it increasingly interesting to end users to sell their own surplus energy back into the market, where it can be bought up by utilities as part of their supply obligation. One approach is for end user supply to be available subject to contract, utilities either contract to buy a certain amount of energy from end users and/or to do so at a fixed price. In a situation where the two parties to a bargain are a massive utility company and an individual consumer, and also where managing thousands – millions even – of microcontracts, this might appear to be the obvious way to go.

Benefits of ongoing dynamic negotiation: it is likely that both sides to such future bargains – both utilities and end users – may be able to benefit from the ongoing dynamic negotiation that is, in effect, a smart electricity market.

On the end user side, it protects individuals from negotiating contracts that are, on the surface, advantageous, but give little benefit because their own energy output is too expensive for utilities to purchase.

On the utility side, it provides flexibility and, as more and more energy generators enter the market, so the Markets domain will enable them to purchase surplus energy cost-effectively.

The Markets domain is likely to have to deal with a number of additional scenarios. First, market providers may act as energy aggregators, or alternatively act on behalf of groups of end users who are already co-ordinating their efforts in some fashion. Clearly, the larger the amount of energy that a particular end user can bring to the market, the greater the bargaining power they have. Thus, the common assumption is that large industrial enterprises will be most capable of taking advantage of the smart grid, since at various times during the day, they are likely to have the largest amount of surplus energy, often co-generated as a result of their standard processing. Large quantities of heat, for instance, output as a result of running a furnace, which in the current grid system may simply go to waste.

There are various ways in which businesses and individuals can come together to generate energy:

Industrial estates may run small to medium sized power parks that power businesses on the estate during the week – and have relatively large surplus generating capacity available at the weekend.

Multi occupier residences are also capable of instituting collective solutions to their local power generating requirements that will, at times, have relatively large surpluses.

Neighbourhood Area Networks could well reach such levels of surplus, even though individual consumers are unlikely to. This could be formally agreed – across a modern housing estate, for instance, that was created with in built generating capacity – or it could be an informal arrangement created on an ad hoc basis by a market maker.

Two counter factors suggest that the market of the future might be more complex:

The existence of market-makers in the mix: as software becomes better able to handle large volumes of individual bargains, in a manner analogous to the way in which conventional stock markets work, the ability for even small power generators to enter the market becomes that much easier.
Two further aspects of future supply and generation within the smart grid are likely to be subject to the operation of the Markets domain.

**Energy storage:** EVs will be both a major drain on the grid, requiring significant energy for recharging at different times in their operating cycle, and a major opportunity, forming an increasingly significant pool of stored energy that can be “reclaimed” as needed. There is little difference, in practice, between reclaiming stored energy and pulling off energy surplus, although the price anticipated by the EV owner for the first may be that much greater, since energy reclaim may represent a degree of inconvenience to the individual.

**Negawatt:** a new term entering the energy lexicon is that of the “negawatt” this is energy NOT drawn down from the grid, and is a measure of appliances not used. The precise working of “negawatt” markets is still subject to extensive debate but the principle is relatively clear. Given that energy use within a particular premises is baselined at x, then any percentage reduction on x may be treated as “negawattage”. This calculation may be easier to perform on large industrial concerns or buildings where negawatts may simply be represented by an agreement to turn HVAC off for a proportion of the day and therefore to use less electricity maintaining a particular ambient temperature e.g. a 20% reduction in HVAC use is equivalent to cycling HVAC off for 12 minutes in every one hour time interval.

The Market conundrum

Although development of the Markets domain may be viewed as helpful, in principle, to energy efficiency and reducing energy use, it may also prove to be a major challenge to utilities in countries and regions where market principles become entrenched in the operation of a smart grid.

One of the explicit principles underlying early conceptualisations of the demand response model is the idea that when utilities are under supply pressure, they would, by means of the smart grid, be able to reach out and adjust the amount of energy being consumed by end users (load shedding).

While this idea has not been tested greatly, the underlying presumption is that in matters relating to energy and energy generation, it is for utilities to determine how best to manage all energy flows within the grid.

The emergence of the Markets domain fundamentally alters this because it suggests that there is both a value to utilities from end users agreeing to this practice, as well as a potential “dis-benefit” to end users from agreeing to allow utilities to intervene in their local energy use.

This argument has already shown some signs of causing difficulty for utilities in the US, where consumer groups have lobbied against the introduction of smart metering – and succeeded in delaying its introduction - on the basis that since utilities will gain economic benefit from fitting smart meters in individual homes, the cost of this exercise should be picked up by the utilities themselves and NOT passed on to consumers.

The development of the Markets domain will, in the end, fundamentally influence how smart grid develops. One view of the smart grid is that energy is a common good and that it therefore makes sense for central energy providers (utilities) to continue to manage energy supply much as now, taking decisions on behalf of the general public as to what makes most sense at a given point in time.

An alternative view, emerging in the US, but quite possibly exportable to other markets, is that end users should have some say in the economics of their energy consumption either because they are, simply, entitled to or – the free market view – because in the long term, the evolution of a truly free market in energy supply will encourage overall greater efficiency and effectiveness in this arena.

A basic issue, highlighted by developments in market models, is how to value either energy supplied back to utilities or deferred energy use. This has already been subject to some degree of controversy in Germany, and elsewhere in Europe, where utilities have been unhappy with government decisions to support consumer supplied energy by means of a feed-in tariff.
In June 2012, US utilities moved on from attempts to persuade the Federal Energy Regulatory Commission that new “demand response” policies would skew electricity markets across the country (they failed) to the courts. An alliance that includes the American Public Power Association, Electric Power Supply Association and Edison Electric Institute have asked a federal appeals court to reject a new nationwide policy that pays the same amount for demand response as it pays utilities to send more megawatts onto the grid.

The issue behind this outwardly technical debate is that evidence is increasingly emerging that as the renewable sector grows and the consumer role in energy supply grows with it, so wholesale energy prices are reduced (according to Australian energy analyst Giles Parkinson, German rates have fallen by 20% since 2008). While this may outwardly appear to be good for the consumer, in the long run, it calls into question current business models for energy supply and requires those at the top of the supply chain to rethink how they will do business in future.

EXAMPLES OF SERVICE PROVISION TO THE SMART GRID

Market developments

A new proposition that is wholly dependent on introduction of a smart home energy management system is the creation of “negawatts” and their valuation in virtual energy markets. This approach has been christened DR2.0 by some analysts, to highlight differences against DR1.0, which is simply about lowering (peak) power use in response to utility requests.

DR2.0 occurs when energy users bid an anticipated power reduction into energy markets, this is wholly new, both as concept and execution. A major initiative in this area was launched in February 2012, with the support of ConEd Solutions, a major player in the energy market, and input from energy data infrastructure experts, Viridity, who have previously been involved in ground breaking technological initiatives for storing energy offline to feed back to utilities. Take-up has been slow but in concept at least, negawatts and the associated negawatt market are a sign of things to come. Further evidence of how this field is evolving is a paper published by the IEEE in 2011 regarding, “an intelligent auction scheme for smart grid market using a hybrid immune algorithm.” While largely mathematic-technical in approach and content, the important outtake from this and other similar initiatives is how software providers and players in established fields – in this instance, the spot market - are swiftly adapting their own business model in respect of a whole series of technologies and product not previously covered.

Key players in smart grid support

AMR market leaders include Itron (public), Landis-Gyr, ESCO (public), Elster, Sensus, Neptune, GE Energy, Badger, MasterMeter. Itron has a significantly dominant position by virtue of a 46% market share in the US (2009).

Key Systems Integrators include companies such as ABB and Cap Gemini however, many suppliers in this area, including IBM, Toshiba, Siemens and HP are able to support a multitude of different roles.

Smart grid support: market size and trends

The market itself is difficult to quantify, as many aspects of service provision are already quantified under other domains and it is hard, at the extreme, to determine where the boundaries for service provision lie.

The two trends worth noting in smart grid support:

Major ICT players pursuing a dual track approach, spending on their own in house product development, while continuing to gobble up a series of smaller niche players providing dedicated solutions.

Shift toward smaller niche enterprises building a business around single apps, as smart concepts enter the home independently of utilities, there is a shift toward smaller niche enterprises building a business around single apps – or a suite of apps – directly designed to meet consumer demand for information and control at a distance, as opposed to supplying the utility side of the industry.
THE COMMUNICATIONS LAYER

Communications is one of the three key layers identified within the NIST smart grid model and it is all pervasive, both within and across domains. At base, a smart grid cannot exist without the efficient, prompt (real time or near real time) transfer of data between processes and components e.g. for some market transactions involving supply of energy back to utilities, the interval in which an offer-bid combination may be made and closed is critical, with Viridity and Enbala recently making a breakthrough in this area when they were able to reduce that interval from 10 seconds to under 4 seconds.

It is an area awash with conflicting jargon, and this in part reflects the fact that no single communications solution would be appropriate across the grid, and at various points of function, different competing solutions are still being tested. A key issue is how far the lowest level elements in a system should be grouped together for processing purposes, how far they should be disaggregated, this, in turn, is dependent to a degree on the technology being trialled and its range, leading to a plethora of acronyms simply around level of aggregation.

Thus, literature refers to Wide Area Networks (WANs) and their corresponding Wide Area Management Systems (WAMS), contrasted with Home Area Networks (HANs), Local Area Networks (LANs) or Neighbourhood Area Networks (NANs). Other networks that appear in the literature include CANs (campus), MANs (metropolitan) and VANs (vehicle or virtual, according to context). There are more.

Principles for selecting communications technology

According to the IEEE, seven factors are key:

- **High reliability and availability** a basic requirement for almost all communication systems, the nodes in the system must be reachable under all circumstances. Issues arise in respect of wireless solutions due to issues over signal reception and with power line solutions because communication channels are dynamic and may be switched by network operators balancing the power consumption load. The fact that switching can take place at different levels within the network means the communications network must be robust enough to cope

- **Automatic management of redundancy** linked to the switching issue, since the network must remain robust even through topology changes, it must be able to re-route comms traffic automatically and on its own.

- **High coverage** the proportion of the service territory the network reaches across distances is a basic operational requirement of power networks, relatively easily satisfied by the use of telecommunication systems or power lines

- **Large number of communication nodes**, even the simplest network (one smart meter per customer) will rapidly give rise to tens of thousands of nodes and while the data content per node is usually not great, the total data volume needed to be transmitted within a network is often significant creating a major communications overhead

- **Appropriate communication delay and system responsiveness**, Quality of Service (QoS) management must ensure that communication speed and other features is adapted to the data class involved (e.g. metering, control, or alarm data), while also taking into account the need for exceptional events such as alarms from meter to control room

- **Communication security data** involved in energy distribution represents a security issue, both in respect of personal issues such as data privacy, and also more serious issues such as energy security. According to utility surveys the two most important aspects of maintaining a secure system are integrity (no malicious modification) and authenticity (origin and access rights are guaranteed). Security within a system may be evaluated in terms of documented standards such as NIST IR 7628

- **Ease of deployment and maintenance** communications systems need to be easy to instal initially and also relatively easy to maintain and update as key changes come into being
Other factors raised by analysts and utility operators include:

- competitive and cost effective, both at set-up (capital expenditure) and in respect of update and maintenance
- good transmittable range one that is appropriate to the task
- ability to handle enormous data demands, especially during times of emergency or natural disaster
- can be scaled up the ability of the system to grow in response both to corporate expansion and technological improvement (particularly the upgrade to 4G or 5G)

At a more technical level, analysts cite

- capacity/bandwidth how many messages the network can accommodate
- latency how long it takes for messages to arrive
- number of repetitions required (lower is preferable)
- reliability how often messages fail to make it through

The two key areas for communication that are considered in this section are T&D and within and around the Home Area Network. That does not mean that there are no communications issues for services, but these – with the exception of AMI, which is covered separately - reflect less time critical more developed management focus.

Matching technology and platform to use

The key question is,

‘Which communications technology is optimal for a given objective within the network?’

It is highly unlikely that a single communication solution will cover all of the various needs of smart grid operators – even within one domain, such as Transmission or Distribution. The issue is highlighted in Table 6, this demonstrates that although the broad requirements for operating different components within the T&D network are not widely different, they do vary and therefore the optimal solution for one function is not quite the same as the optimum for another.

<table>
<thead>
<tr>
<th>BR Table 6: Key requirements for T&amp;D functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
</tr>
<tr>
<td>Line Switch Automation</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Voltage regulation</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Transformer monitoring</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td>Volt/Var Control</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Reclosers &amp; Circuit Breaker Automation</td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Even if the industry had reached broad agreement on the optimum communications platforms and protocols for every part of the grid, there would still be an array of systems in use, and we are still very far from having reached any sort of conclusion as to what constitutes best of breed.

Solutions such as wireless versus wired versus mobile interfacing and fibre optics versus broadband versus power line are all under consideration. Yet even within solutions, individual technology variants and standards may differ. For instance, Silver Spring and Trilliant are both deploying RF mesh networks however, Silver Spring makes use of technology that operates in the 900 MHz frequency band, while Trilliant uses the IEEE standard 802.15.4 this provides compatibility with a number of frequency ranges.
There is the question of interfacing with legacy systems, other suppliers and energy companies, and the legacy systems of other suppliers and energy companies, as existing communication networks are made up of a varied mix of wired and wireless communications channels according to application or operational need and this is unlikely to change drastically in smart networks.

**Cutting through the jargon**

Discussion of communications issues tends to be obscured by the fact that they raise questions that are highly technical in nature and that solutions may be considered at several different levels. Thus, a major issue within the communications debate is whether utilities are better using wired or non-wired technologies.

This is a high level general question, to which the answer is that it depends on the precise use to which the technology is being put, the implementation of these technologies (may vary according to particular technology e.g. does “wired” mean using public networks, or power line?), the subtechnology being used (ISDN, POTS, GSM), the set of standards (WiMAX, IEEE 802.22) and even the topology used in implementing a particular technology (mesh versus node to node).

All of this makes it very difficult for the lay person to reach a conclusion in respect of a particular communications option, other than summarising as, “it depends” i.e. whether wired is “better than” wireless will depend on the particular use to which the technology is being put and whether range, reliability or cost is the key determining factor. At the same time, wireless may be inferior if implemented in one topology (node-to-node), but prove more reliable if implemented as RF mesh.

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**COMMUNICATIONS WITHIN THE TRANSMISSION AND DISTRIBUTION DOMAIN**

**Architectures**

Ideally a distribution network communications system will have a two tier architecture, as set out in Figure 10.

---

**BR figure 10:**

Outline two-level communications architecture for energy distribution networks

> Metering, billing, SCADA, third-party services

<table>
<thead>
<tr>
<th>Ownership possibilities</th>
<th>Utility company</th>
<th>Grid operator</th>
<th>Third style service provider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intranet</td>
<td>Public network provider</td>
<td>Grid operator</td>
<td>Network provider</td>
</tr>
<tr>
<td>Field Devices (Meters, control equipment)</td>
<td>Utility company</td>
<td>Grid operator</td>
<td>Third-party service provider</td>
</tr>
</tbody>
</table>

Field Devices (Meters, control equipment)

Source: IEEE, Transactions on Industrial Electronics

The two levels may be divided into a centralised environment supporting back office application servers used for metering and billing as well as a range of other add-on services, and a distributed communication environment supporting lower level devices, such as energy meters, switch gears, or control equipment. The former will tend to be located within an IP based environment such as a company intranet or a wide area network, while the latter may be drawn from a somewhat wider range of field level networks, of which the principal types are summarised further within this section. The two domains are then linked via Access Points (APs).
High level technologies

At the highest level, communications may be:
- Wired
- Wireless

The wired class includes technologies such as:
- conventional phoneline or Plain Old Telephone Service (POTS), also known as the public switched telephone network (PSTN), is the standard telephone service that most homes use
- high-speed, digital communications lines, such as ISDN and FDDI, distinguished from POTS primarily by the fact that they are much faster and have greater bandwidth
- (broadband) Power line, in which communications are carried by the grid itself

Wireless includes:
- conventional wireless communications, which may be run as GPRS (General Packet Radio Service), which is a high speed wireless standard running at up to 115 kilobits per second and particularly effective for sending and receiving small bursts of data, such as e-mail and Web browsing, as well as large volumes of data
- Wi-Fi, covering wireless LAN's run under the IEEE’s 802.11 standards
- ordinary mobile communications, run under GSM (Global System for Mobile communications) systems at 9.6 kilobits.
- private/professional mobile radio (PMR) or public access mobile radio (PAMR) technology, primarily used by public safety groups such as police and fire departments and governed by standards such as TETRA (Terrestrial Trunked Radio), developed by the European Telecommunications Standardisation Institute (ETSI) that describes a common mobile radio communications infrastructure throughout Europe
- WiMAX, which uses microwave technology and is governed by IEEE 802.16 standards, similar in principle to Wi-Fi, but with range up to 30 miles as opposed to a few hundred feet
Detailed consideration

A more detailed set of considerations that may be taken into account in respect of specific technologies are listed out in Table 7.

<table>
<thead>
<tr>
<th>Broad class</th>
<th>Communications mechanism</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wired</td>
<td>Dedicated Line</td>
<td>Independent</td>
<td>Permanently on Large bandwidth</td>
</tr>
<tr>
<td>Wired</td>
<td>POTS</td>
<td>Easy to handle</td>
<td>Low modem costs 64 Kbit/s (ISDN) 9.6 Kbit/s (GSM)</td>
</tr>
<tr>
<td>Wireless</td>
<td>GPRS</td>
<td>Easy to handle</td>
<td>Low modem costs Permanent connection Cost-effective tariffs 56 - 114 Kbit/s</td>
</tr>
<tr>
<td>Wireless</td>
<td>Tetra</td>
<td>Independent</td>
<td>High availability High Reachability</td>
</tr>
<tr>
<td>Wireless</td>
<td>WLAN (WiFi) WPAN</td>
<td>Independent</td>
<td>Permanent connection Low component costs</td>
</tr>
<tr>
<td>Wireless</td>
<td>WiMax</td>
<td>Easy to install</td>
<td>Supports either point-to-multipoint or mesh topologies</td>
</tr>
<tr>
<td>Wired</td>
<td>Power line</td>
<td>Independent</td>
<td>High Reachability Permanent connection</td>
</tr>
</tbody>
</table>

Table 7: Advantages and disadvantages of field-level network technologies for smart grids

source: IEEE and Analyst Overview
The simplest, most basic networking solution is through the application of traditional wired communication with dedicated data networks connecting the field devices. Typically, the wired section of communication would be implemented as a “final mile” solution, connecting the last transformer station to the central network. Such a solution is robust but possibly limited by the fact that the costs may be prohibitive.

Wireless local area networks such as IEEE 802.15.4 replace the cost issue with one of range, and tend only to be suitable where the final components are physically close to the Access Point (AP). Wireless options that may prove more effective are cellular networks such as GSM, GPRS or WiMAX. These have the advantage of high coverage and low installation costs where infrastructure is already in place however these also create a dependency on the network provider and the AP would be located near to the application servers.

A third and increasingly attractive option, known as Power Line Communication systems (PLC) makes use of existing power cabling. These require moderate additional network elements but rely on a more complex technology to overcome poor communication channel characteristics. In this scenario, the location of the AP is no longer a major issue although it is likely that it will be situated reasonably close, perhaps in the primary substation.

Finally, considerable debate is currently under way as to whether utilities should be making use of open-standard protocols in the development of communications, or creating dedicated ones. Thus, in line with the theory of the smart grid as an “internet of things”, it is highly likely that sections of the smart grid will be run using internet protocols and therefore gain the benefits (easier to address objects and to develop code) as well as the disadvantages (higher security risk).

One proposal that would address this is for a communications architecture that would use DNP3 (q.v.) in relation to Transmission functions, such as SCADA, while relying on TCP/IP devices for smart load and demand management. This divergence in protocol would help to reduce the number of vulnerability exploits and attacks from other TCP/IP devices.

It has also been suggested that Peer-to-Peer (P2P) networking for smart meters would help increase security and allow meters to implement a range of value added services.

### Standards versus product and technology

One source of potential confusion in discussion of communications options is that many products are based around standards and protocols developed by national and international regulatory bodies, and these standards may, in turn, be picked up and promoted under the banner of some umbrella group. It is therefore important to know whether a particular debate is in respect of a standard, a technology or a brand.

#### Examples of terms of communications across technologies include:

- **DNP3** (Distributed Network Protocol), also known as IEEE Std 1815-2010, is a set of communications protocols used between components in process automation systems. It has a significant role in many SCADA systems, where it is primarily used for communication between SCADA Master Stations/Control Centers, Remote Terminal Units (RTUs), and Intelligent Electronic Devices (IEDs).
- **WiMAX** (Worldwide Interoperability for Microwave Access) is a brand based around the IEEE 802.16 set of standards for wireless wideband access and promoted by the WiMax forum. It is widely used for metropolitan area networks.
- **IEEE 802.22** references a standard for Wireless Regional Area Network (WRAN) communications, which uses existing gaps (“white spaces”) in the TV frequency spectrum between 54 and 862 MHz. This standard is designed to support broadband access in areas that have low population and are difficult to reach.
- **ZigBee** is a specification for wireless personal area networks (WPANs) operating at 868 MHz, 902-928 MHz, and 2.4 GHz, based on the IEEE 802.15 class of standards. It is promoted by the ZigBee Alliance.
- **Wi-Fi** is a wireless networking technology providing wireless high-speed internet and network connections. It is based around the IEEE 802.11 set of standards and takes its name from the Wi-Fi Alliance, the organization that owns the Wi-Fi (registered trademark) term.
Topologies

Most wireless traditional systems use point to point or point-to-multipoint technologies, in which a permanent link exists between two or more endpoints in the system. Mesh networks are an alternative to these topologies.

Wireless/RF mesh networks are based on what are known as multihop systems where devices support one another in the transmission of information packets across the network. In such a network, each individual node can send and receive messages, with the result that a node also functions as a router and can relay messages for its neighbors. Through the relaying process, a packet of wireless data will find its way to its destination, passing through intermediate nodes with reliable communication links.

A mesh network closely resembles the internet and other peer to peer router-based networks, in that it provides multiple redundant paths through the network, such that the failure of one link (or several) does not automatically lead to systems failure, as the network automatically re-routes messages through alternate paths.

Further advantages of a mesh network are that they are:
- capable of self-configuration and self-organisation
- relatively quick to instal (taking hours, as opposed to days or weeks to put in place)
- robust because there will almost always be an alternative path to the destination
- especially applicable to difficult terrain and conditions

In addition, transmission range and quality can simply be increased by the addition of extra nodes, reducing average node distance by a factor of two leads to an output signal that is at least four times more powerful at the receiver, without the need to boost the signal in any given node by adding more power.

Practical selection criteria

The smart grid is likely, in the fullness of time, to make use of multiple different communications technologies. Debates such as whether to use wired or wireless technology, particularly as it plays out in respect of power line, is typical of wider debate in this area.

Technological considerations: Power Line Carrier (PLC) versus wireless

PLC is viewed as an increasingly suitable candidate technology for specific parts of the smart grid, in particular, the sensor and access elements of the T&D sections of the grid. It also has wide penetration as a support for AMR and AMI operations.

**PLC technology uses the power grid itself as a means to transmit data and can be further divided into:**

**Broadband (BPL)** permits communication at higher bit rates (at present, 10 to 300 Mb/s) and may be in HANs and access networks [7]. A project to adopt Broadband PLC for internet access applications was initially piloted in the 1990s in the UK, but abandoned in 1999, mainly due to higher than anticipated costs and growing electromagnetic compatibility issues.

**Narrowband (NBPLC)** primarily used for electric company communications, tending to make use of frequencies up to 150 kHz in Europe and 450 kHz in the US, with delivered bit rates from 2 to 128 kb/s. There is also an ultra narrowband form of PLC.

Meter reading

Home automation
PLC has its strong advocates, as well as its critics. Historically, criticism of PLC has raised issues with:

- no clear standardization pathway
- data rates are too low
- PLC modems, too expensive and present electromagnetic compatibility (EMC) issues

Additional issues that have emerged in relation to PLC include:

- **Mismatch of PLC technology to smart grid applications**: especially the case in the US where many operators are using BB-PLC modems originally designed to support Home/Building Area Networks (HAN/BAN) or Internet access. These have limited range and are often over designed for Smart Grid applications. Their over use also means promoting a single PLC technology across a range of applications rather than matching PLC technology to application.

- **Over-standardisation**: in recent years, the PLC industry has moved from a complete lack of BB-PLC standards to the opposite extreme of having multiple non-interoperable technologies ratified by several Standards Developing Organizations (SDOs), such as TIA-1113, ITU-T G.hn, and IEEE 1901 FFT-OFDM. Implementing BB-PLC modems within the smart grid now requires selecting the appropriate standard and dealing with the fact of their incompatibility.

- **Lack of guaranteed QoS**: PLC suffers unpredictable frequency and time dependence of impedance, attenuation and transmission characteristics, impulse and background noise as well as wide variability, limited bandwidth, and harmonic interference. The channel may also suffer from sudden and unexpected downward fluctuations in bandwidth.

Despite all of the above, PLC remains an attractive option for specific uses, such as long distance communication, as well as AMR, AMI and in home applications. BB PLC remains highly attractive as a home networking technology for complementing WiFi. A number of the technical concerns have been reduced by recent technological advances, while an IEEE standardization process is at work standardizing both in home and access networks for seamless interaction with smart grid applications.

PLC lines are already present, leaving it as the only serious wire line contender in terms of deployment cost and PLC is also relatively easy to maintain. In fact, given that much grid – and hence smart – infrastructure is located underground or in places not otherwise accessible, PLC may often be the only feasible technology available to support the smart communications infrastructure.

In metropolitan/wide area networks, for instance, wireless wideband technology has been proposed for low populated areas due to its easy deployment. A technology such as WIMAX will work from the core to the high/medium voltage substations, with PLC then taking over from substations up to the homes.

**Geographic/demographic factors**

Other factors that will influence the choice of technology include issues such as distance relative to population and the terrain over which communications must take place. Several wireless technologies require line of sight between nodes or repeater stations, making them far less suitable for areas highly cluttered by obstacles.

In much of North America, PLC based AMI systems are generally not preferred because there are only one to three customers per transformer, rendering most PLC technologies too costly. This is very different from the situation in much of Europe, where there are around 100–300 customers per transformer.
The role of 3G/4G technology and the move to small cells

An alternative approach to supporting the smart grid is point to point 3G or in the future 4G, the fourth generation of cell phone mobile communications standards, capable of providing mobile ultra broadband internet access. The key point made by providers of mobile technology is that grids built around mobile technology are built around pre-existing networks. There is no need to put in place the various towers, collectors, transmitters that are likely to be associated with other manifestations of network technology.

Benefits claimed for this approach are:
- improved speed of deployment over traditional meshed networks
- provides speedy access to an open standard, IP based network
- allows direct communication with each meter

An important feature of the mobile solution is LTE (Long Term Evolution), also referred to as 4G LTE, a standard for high speed wireless communication of data via mobile phones and data terminals. Delivery of the increasingly ubiquitous broadband mobile network traffic requires deployment of many more base stations, closer to the user. This is accomplished within the LTE standard by means of a multi radio access technology heterogeneous network (multi-RAT HetNet), combining big, traditional base stations with small inexpensive cells.

This move to small cells, combined with standardized reference designs is changing the economics of 3G with typically a halving of the traditional per-node opex and capex costs. At the same time, a requirement that LTE integrate dual-mode, multicore system on chip permits support for both 3G and LTE to take place within in a single unit, resulting in higher 3G network quality and increased subscriber capacity without the need for additional investment.

Most of the components identified here will be supported by a mesh network and need to be integrated within the smart grid by means of wireless connectors and gateways.

Public versus private network usage

A key decision for utilities is whether to make use of public or private networks, and here the control issue is key, particularly the ability to intervene in emergencies. In addition, the decision may hinge on whether a utility is content to use existing software that can be implemented immediately, or if it requires a more tailored solution possibly taking longer to implement. Utility companies are likely to choose an option that provides high profitability, while fulfilling the other goals for the firm. In the US within the wireless sector, private networks currently have a significantly higher market share (US$193m is over three times the size of that for public networks on $64m). A higher CAGR for public networks (39% for public versus 21% for private) means this gap will narrow but will not reverse over the next 3 to 4 years.
A comparison of the features of public and private networks is set out in Table 8.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Public</th>
<th>Private</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security</td>
<td>a focus for public networks since their inception, and currently provide much more robust security measures than available via any private network.</td>
<td>custom building a comms platform for a specific utility may lead to the inclusion of security features specifically adapted to the needs of that business. Future developments of the system will also build on what has gone before and can be targeted to meet immediate needs.</td>
</tr>
<tr>
<td>Reliability</td>
<td>broadly excellent, with wide coverage. On the down side, there remain some lapses in coverage between carriers and some areas have higher latencies than others.</td>
<td>network infrastructure can potentially ensure coverage at times of extreme stress, e.g. even during natural disasters. A mesh framework creates multiple communication pathways that will automatically re-route information if an outage is experienced. Dedicated back-up systems are also likely to be in place. A private network operator is more likely to be amenable to extending cover (at a price) to areas where no public coverage currently exists.</td>
</tr>
<tr>
<td>Size and future development</td>
<td>public networks are already more advanced in respect of many aspects of development than private networks: most are also committed to a continuing roll-out of new and useful features and functions.</td>
<td>possibly the main advantage of a private network is that it provides massive potential for future growth and this growth, both in scale and functionality, is determined by the utility. The utility can dictate the degree of customization required to the nth degree and providing it is technologically feasible – and affordable – it should be delivered, in accordance with utility priorities. Private networks are already noted as having a decreased latency of 10-100 milliseconds, possibly proving significant in some executions.</td>
</tr>
<tr>
<td>Cost</td>
<td>The set up (capital) cost of a public network is significantly less than that of creating a private network, coupled with a much faster return on investment. The cost of using public networks has decreased in recent years and is likely to decrease further in future. Maintenance costs may also be favourable for public networks.</td>
<td>A possible benefit of private networks is that setting up such a network may attract some form of government subsidy, either in the form of direct capital assistance or tax incentive/capital offset and this might significantly change the economics of the underlying decision. Going forward, the main costs of a private network are in the upgrade and maintenance areas. This would be the responsibility of utility staff (or suppliers), and is likely to be an on going responsibility and could prove a heavy future expenditure.</td>
</tr>
</tbody>
</table>
The costs and reliability of public networks have long been concerns for utilities when considering use of public networks for their communications. Issues of reliability may best be dealt with by operators setting up their own (private) cellular network infrastructure, using technologies such as GSM/GPRS, WiMAX or terrestrial trunked radio or even making use of available infrastructure and opting for PLC systems.

This approach was the one adopted in the communication network architecture developed as part of the European research project REMPLI that had as its main goal the interconnection of application servers and field-level equipment within the constraint of supporting already existing standardized SCADA or metering protocols.

A further non-technical issue that may affect choice in deregulated markets is the ownership of equipment, infrastructure, and services. Within the transmission and distribution networks, the end points of channels are usually owned and maintained by one company. The communication channel may be provided by a third party, this could be a telecommunication provider (for various mobile systems) or the grid operator for PLC, with add-on services provided by yet other suppliers. This argues strongly toward a clear separation of communication channels within the system architecture, so enabling utilities to leverage public or private partnerships as most appropriate.

HOME AREA NETWORKS

Basic architecture for AMR and In Home devices

In dealing with in home functionality and home energy management systems (HEMS), the issue of what is “upstream” of the smart meter, what “downstream” comes into play.

“Downstream” within the home are the various devices outlined, including HomeBox, In Home Displays, and home appliances. Appliances are the principal power consumption devices in the smart grid, home appliances in a house are connected to a smart meter measuring and collecting their power consumption. Advanced home appliances can proactively send reports to the smart meter (e.g. future power consumption demand).

“Upstream” is essentially the communications infrastructure and architecture required to support AMR and, where relevant, AMI, consisting of the following components:

- **Smart meter**: collects the power consumption demand data from home appliances.
- **Concentrator**: a neighborhood area network (NAN) is created by linking to smart meters belonging to houses in an area. A NAN has a concentrator (i.e. gateway) that collects data packets (HEMS traffic) from smart meters using short-range communication technologies (e.g. WiFi). Received packets are stored in the buffer of the concentrator. The concentrator’s WAN transceiver retrieves a head of queue packet from the buffer and transmits it to a WAN base station.
- **WAN base station**: manages bandwidth allocation for the data transmission of each concentrator. Data packets received by the WAN base station are forwarded over the wired network (e.g. Internet backhaul) to the control center.
- **Control center**: receives HEMS data for processing and storage. This data is used to optimize the electrical power generation and/or distribution.
Home Area Network

On the home side of the smart meter, a home area network (HAN) can be established among home appliances and a smart meter. This ensures that data on the use or expected use of energy by each appliance is passed back up to the energy provider. It also allows appliances to communicate with one another, so as to coordinate their actions where appropriate to do so. This is known as Machine to Machine or M2M communication.

M2M communication standards

M2M components vary in types and sizes, and may be located in remote areas with limited accessibility making wireless access more cost effective as well as more and flexible when it comes to deployment with the result that M2M communications are rapidly shifting from traditional wired Ethernet toward wireless environments.

M2M networks have to bridge seamlessly with a plethora of communication systems by supporting multiple communication technologies, including mobile broadband communications such as WiMAX and Long Term Evolution (LTE) and local area networking (e.g. WiFi). They must also provide connectivities between multiple decentralized nodes without a pre-existing infrastructure, achieved rapidly and at low cost by means of ad hoc networking.

Communications among the smart electronic devices generally feature low data rate, low mobility, and low power consumption, and this is a factor in determining the range of communications solutions available. In order to meet these requirements, a number of short and medium range wireless technologies have emerged, including Bluetooth, IEEE 802.11 (WiFi), ultra wideband (UWB), IEEE 802.15.4 ZigBee, and 6LoWPAN.

The key to smart HAN enablement lies in low power and low cost technologies.

Major network technologies that can be used in HAN communications are:

- **IEEE 802.15.3a (UWB)** may be used to communicate with sensors. Issues with this technology lie in its high power requirements. The IEEE 802.15.3a task group providing support for this technology was wound up in 2006.

- **IEEE 802.11 (WiFi)** suits higher data rate applications over larger areas and is currently the most accepted protocol for wireless in home communications. However, like UWB, WiFi has a high power requirement.

- **IEEE 802.15.1 (Bluetooth)** has become popular for wireless connections for voice, data, and audio applications over short ranges, and is well suited for low power/low data rate applications. Tends to be range limited and at present, Bluetooth networks or “piconets” support up to only eight devices communicating simultaneously, so creating a need for multiple Bluetooth networks as the number of In Home Devices multiplies.

- **IEEE 802.15.4 (ZigBee)** employed in many home networking solutions including HANs and was developed particularly for wireless devices, ensuring low power and long life time. The ZigBee network layer allows for a range of topologies, allowing flexible configuration of the HAN GW and takes only milliseconds to emerge from its sleep state (significantly less than Bluetooth or WiFi devices).

Also put forward as candidates are power line communication (PLC) and 6LoWPAN.
Of all the various options, ZigBee is the most currently extended and mature technology, providing simple network configuration and management, a good communication range (10–100 m) while maintaining significantly low power (1–100 mW) and lower cost. It has also presented the most smart grid related applications to date.

Finally, the combination of PLC and ZigBee/IEEE 802.15.4g provides a new concept of home and substation automation with outside interaction. While not all these elements will be present in the network all of the time, they need all to be integrated into the policy base management.

**M2M technical issues**

As reliance on M2M technologies increases, a number of key issues are increasingly in need of resolution and these are:

- **Standardization**: M2M communication requires integration and convergence between various different communications systems (e.g. local and wide area networks). However, very few standardizations yet exist.

- **Traffic Characterization**: the characteristics of traffic exchanged between M2M components have not been well studied so far. M2M traffic differs from that in human based networks by virtue of the fact that it performs specific dedicated functions, such as data collection and monitoring and requirements. Traffic characterization is essential to the design and optimization of network infrastructures, as well as development of (QoS) support for M2M applications.

- **Protocol Re-design**: the leading transmission protocols of the Internet (TCP/IP) are inefficient for M2M traffic and therefore need to be redesigned with M2M requirements in mind

- **Spectrum Management**: limited spectrum resource means wireless M2M technologies need to efficiently transmit signals over frequency channels. Secondary spectrum markets provide use of the spectrum to entities other than the original license holders and need to be well formed and functioning optimally to ensure that available spectrum will migrate to more efficient usage.

- **Optimal Network Design**: optimal design of M2M communications networks should minimize costs while simultaneously meeting QoS requirements in respect of traffic and applications.

**The emergence of cognitive radio**

A number of consequences of the size and complexity of the proposed smart grids is leading some analysts to contemplate the need for more intelligent communications channels.

**Data impacts on communications technology**

It is likely that the data itself will:

- be significantly greater in volume than anything that utilities have dealt with to date
- vary considerably in volume and kind across the day
- require very different handling and QoS priorities in terms of transmission latency, bandwidth, reliability, and security according to type of data, thus information on devices’ state, load, and power pricing should flow over the communications network accurately, effectively, and reliably. Different priorities can be set for meter data and power price data

**Communications architecture impacts on communications technology**

The communications architecture itself may bring about a need to change the way it functions according to prevailing conditions. Factors that contribute to this are:

- clustering of increasingly intensive radio systems in near proximity to one another, which could lead to interference
- the need for interoperability between grid elements
- the heterogenous nature of subnetworks within the smart grid (LAN, NAN, WAN, etc.) that requires different components to interface smoothly to one another
Cognitive radio

A proposed solution is for the development of cognitive radio, this is defined in terms of the potentiality for wireless systems to be aware of context and capable of reconfiguration based on the surrounding environments and their own properties. In other words, communications devices may in future be able to amend the way they operate and the channels and standards that they access, in response to prevailing conditions and the requirements of tasks that they are set.

Development of the smart grid has clear parallels with telecommunications networks, in which carriers and communications service providers have already put in place tested strategies for generation, collection and processing of performance data. This is then supported by advanced analytics grounded in a well understood model of network topology to determine how network traffic can be prioritized, route optimized and dynamically managed to ensure timely delivery of critical data and improved, low cost bandwidth management for latency-tolerant critical data.

Metadata about the performance of the communications network is critical to ensure that the network overall is working according to desired specifications.

COMMUNICATIONS TECHNOLOGY IN PRACTICE

Case study: New 4G solution from SmartSynch

A recently launched solution, claimed by its providers to be state of the art is the SmartSynch next-generation platform for smart meters, supporting 3G wireless technology for use on all of their cellular partners’ networks. The platform is based on Qualcomm’s 3G technology and is intended to provide the world’s first integrated, over the air application portfolio for the smart grid. The system is designed to provide utilities with function now, as well as the ability to upgrade their capability by remotely downloading new smart grid applications as they become available.

According to SmartSynch, this is the first time that an integrated Application Management Platform (AMP), optimized for the smart grid and M2M space, is to be used for wide scale, full system smart grid deployments. Situated within an open development environment, this platform makes it that much easier to design and create new applications in a secure environment before transferring them to the live network.

This approach highlights two key trends within the smart communications market, and is also relevant to the development of solutions for the connected home.

First is the bid being made for 3G and LTE as a mode of communications on a par with other technologies. As noted, mobile technology shares some of the advantages of PLC in being a medium that can be installed relatively easily without major additional infrastructure upgrades to a network.

Second, there is widespread forecast of a merger in the home between small cell technology and the wire line hubs, routers and gateways already providing security, home automation, energy management and other services. These programmable platforms will allow the concept of software defined networking (SDN) to be extended to gateways and low cost routers in the home. More importantly, they reduce the hardware overhead that comes with the installation of any new equipment and may go some way towards dealing with issues, highlighted elsewhere, of standardisation and interoperability.
Identifying best communications solution

In late 2011, Qualcomm set out to measure those parameters for three different communications technologies: PLC, RF mesh and 3G cellular. We believe that the results should be treated as a baseline and a comparator for additional evaluation, as opposed to the last word in this area.

Their results were based on a study of over 1,500 use cases from OpenSmartGrid (a subset of the UCA International Users Group), and they used this to derive specific metrics for eight important smart grid applications:

- Interval meter reading
- On demand meter reading
- Remote connect/disconnect
- Demand response
- Real time pricing
- Outage management
- Distribution automation
- Firmware updates

Results, which appear to be positive for cellular, should be treated with caution because Qualcomm is a major player in telecommunications technology and the provision of 3G to smart grid, and as such can hardly be considered disinterested in the outcome.

There are two out takes that those planning to implement smart grid might wish to take on board. First, that the approach and methodology is sensible, in assessing a technology it is important to drive that assessment back to measurable (SMART) criteria and then stick to them. The list here may not be identical to the list that everyone would choose, but it is a good start.

Second is the unreliability of generic measures of technological “goodness”. The message from much of this debate is first that local circumstances, including economics, geography and precise objectives for any smart grid initiative are paramount – and therefore all technologies need to be assessed a) relative to those and b) in relation to the portfolio of technologies likely to be selected.

The public/private/hybrid decision

Pacific Gas & Electric (PG&E) and Southern California Edison (SCE) have opted for private networking of their communication needs, with a shortlist of Itron, Trilliant, and Sensus.

Consumers’ Energy in Michigan opted for a public network through the cellular carrier, SmartSynch, to provide the communications platform for its Smart Grid. CE were able to agree modifications that SmartSynch would make to its existing service offering in order to meet the specific needs of the utility, thereby gaining some of the advantages of a private deal, as well as the robustness of a public supplier.

In the United Kingdom, Silver Spring Networks and Cable & Wireless Worldwide are developing a comprehensive hybrid solution that would prevent any lapses in communication coverage. The goal is a low risk platform that provides increased security, reliability, and dependability within a network infrastructure. The service is also intended to offer a managed data center and managed data services, thereby contributing to the integration of the communications platform and the IT function.

The hybrid model, while being developed in the UK, provides a third option to public and private, which is potentially applicable far more widely.

Key players in the communications market

The overall market for smart communications is wide, since, as highlighted throughout this report, the communications solution as a whole is currently “up for grabs” in many areas. There is either no agreed single technological solution, or there is agreement on a particular technology for one sub segment of the grid but not for all.

This means that the market is open to conventional players in all of the key areas enumerated in this report, including wireless, wireless/mobile telephony, cable, conventional telecommunications, etc.

Given the dangers of even attempting to rely on a single communications platform to drive smart grid initiatives,
a number of trends are emerging. The best practice in all of these is a multi-level/mixed strategy. Where utilities are taking the lead, they will specify and decide on the right mix of communications support, cherry picking suppliers according to specification. In other areas, major suppliers to the smart grid are acquiring companies they believe will support them in providing that in-depth support: an example of this is Itron’s purchase of SmartSynch in May 2012 for c.$100m.
Market size & trends

According to Zpryme, reporting in 2012, the total Smart Grid Communications market in the US is forecast to experience tremendous market growth with a projected CAGR of 17% through 2015. The market as a whole is expected to grow to $1.593bn in 2015, when the wireless segment, currently just over half the size of the wired segment, is expected to overtake wired and this is the result of widely different growth rates of 26% for wireless but just 10% for wired.

A 2012 report by Pike Research forecasts spend on communications devices worldwide in support to plateau at c. US$3.1bn in 2012 for the next four years at least. In the same period, additional spend with public service providers is expected to rise from slightly over US$3bn to just under US$5bn.
DATA, DATA ANALYTICS AND PROCESSING

The superficial view of the data and processing side of smart grid is that it is simply “bigger”. There will be more data needing to be processed faster and this will allow utilities and others involved in the smart grid to provide better, more efficient service all round for customers. The situation is far more complex than this, with significant interaction between data, communications and processing where, in some cases, it is far more difficult to treat these areas as wholly separate. In order to take full advantage of these trends, utility companies will need to make step changes in the ways they deal with the data, analytics and processing issue.

Types of data

The smart grid is likely to generate a wide variety of data needing to be dealt with in different ways and according to different time scales and priorities. A selection of these data types is set out in Table 9.
<table>
<thead>
<tr>
<th>Domain</th>
<th>Focus</th>
<th>Type of data</th>
<th>Use</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home / Distribution</td>
<td>Energy Use</td>
<td>• aggregate energy use</td>
<td>recording and analysis of energy use data within the home allows utilities to create a better picture of customer habits and thereby pitch more effective energy solutions to them either in terms of ongoing price plans or minute to minute</td>
<td>a mix of relatively infrequent for billing and analysis purposes and real time for In Home Display and potentially also relevant to DR interventions by utilities</td>
</tr>
<tr>
<td>Home</td>
<td>Financial</td>
<td>• bills</td>
<td>a profile of how customers are using energy enables utilities to price energy more competitively, as well as helping customers to manage their own energy use more effectively</td>
<td>tends to be relatively lengthy interval related to billing frequency, but some real time data may be needed for In Home Display</td>
</tr>
<tr>
<td>Home</td>
<td>Customer / Personal</td>
<td>• demographic, behavioural, attitudinal</td>
<td>a profile and typology of the customer, enabling marketing and behavioural change programs to be targeted appropriately</td>
<td>relatively static, needs update as required and possibly annually to conform to various data protection requirements</td>
</tr>
<tr>
<td>T&amp;D</td>
<td>Operational / component performance</td>
<td>• voltage readings (synchrophasor measurements), fluctuations in flow</td>
<td>used for a variety of operational needs, including: • outage management • distribution optimization • energy management systems</td>
<td>Mostly needs to be in real time or near real time</td>
</tr>
<tr>
<td>Markets</td>
<td>Managing energy spot markets</td>
<td>• supply availability and demand, bid / offer pricing information</td>
<td>currently used to balance energy supply and demand by managing the buy-sell process for surplus energy on an open market. Likely to become significantly more complex with the introduction of new home suppliers of small energy sources and the concept of “negawatts” (energy consumption forestalled)</td>
<td>In or near real time. Forward markets may have the luxury of minutes or hours of notice, markets dealing with current energy requirements may need to be able to access data and process a buy decision within 4 seconds.</td>
</tr>
<tr>
<td>Services / Operations</td>
<td>Managing key system issues</td>
<td>• metadata about system and component state</td>
<td>permits management of the system: • identification of at-risk components • asset Management • security breaches</td>
<td>Some data (security) may need to be at or near real time. Other data, such as inventory, may be pulled together on a more intermittent basis. Failure management may not need to be quite as timely – but cannot be too infrequent</td>
</tr>
</tbody>
</table>

**Engerati**
The overall issue here is that data may reside in dozens of different systems, linked and accessed through many different communications channels and may need to be available at a variety of latencies, from real time, to within a day to intermittent for non critical applications.

One key issues is the overwhelming amount of data now likely to be in a system at any given moment in time and the fact that operators need to be able to combine massive amounts of data in new and innovative fashions in ways that they have not been combined before.

Inputs from the T&D parts of the smart network are unlikely to be the simple on/off binary that might be envisaged by the general public. Where a major grid element such as a substation fails catastrophically, perhaps due to lightening strike or vandalism, then that gross level of failure within the system will be noted and will trigger appropriate remedial action.

Increasingly, however, system management involves identifying components that may be working at substandard levels or are in a pre-fail stage. Raw data includes quantities such as voltage measurements from different parts of the grid, or impedance rate of change. Phasor measurements, of paramount importance, are made up of a complex number representing both the magnitude and phase angle of the sine waves in electricity transmission.

As noted elsewhere, these need to be taken with a significant degree of accuracy up to 1,440 times per second and while accurate timing is managed by means of global positioning systems (GPS), operators need also to deal with the possibility that any given set of measures may itself be subject to significant noise within the data collection system.

In addition all readings (whether in full, or sampled from the field equipment) need to be able to be brought together and processed in real time so as to have an effect on electricity generation. These raw data components – voltage, impedance, phasor measurements, etc. – need to be aggregated up into management information about key operating characteristics of the grid itself, such as energy generation, load, demand or network capacity.

On the consumer side, a range of important measures relate to current usage. For instance, current load, appliances in use, appliance operating characteristics (energy usage, slack capability, slide capability) and timer information (when is new load due to be added/removed).

Equally important is payment and pricing information, this may include actual information in respect of the amounts that a given consumer is paying for their energy at a given point in time or is likely to end up owing.
Data rich, information poor smart grid data management issues

The underlying challenge to smart grid operators is that they are about to find themselves in a situation familiar during the early adopter phase of almost all major new systems, that is “Data Rich and Information Poor” underscored by a number of issues that new operators in this area need to tackle and representing a step change in scale of task:

- data volumes (“big data”)
- real time processing
- multiple data types: dealing with complexity
- data integration (or the impact of the lack of integration): ownership and compatibility issues
- transformation issues: legacy systems
- data quality: structured and unstructured, new and old
- acquiring skills: aging/retiring workforce potentially leads to shortage of skills

The alternative view of the new data and data analytics market place

An alternative and insightful view of the new data and data analytics market place is provided by the Versant “Magic Cube”, illustrated in Figure 13

![Figure 12: Schematic for Data and analytics “magic cube”](image)

The three dimensions to the cube are:

- **DATA VOLUME**: the volume of data that needs to be managed is a moving target. Exponential growth of datasets means that whatever is “big” today will be average tomorrow, making the future proofing of solutions both central and difficult to achieve

- **DATA/MODEL COMPLEXITY**: data complexity embodied in the relationships as well as the relationships between data objects continues to grow. Quoting IBM, Versant highlight that the majority of CEOs see complexity as their organization’s greatest challenge

- **CONCURRENT DATA**: The amount of concurrent data transactions (the number of users and the level of concurrent access to the database, and in particular, instances of conflict resolution) is growing exponentially. Latency is directly related to a system’s ability to handle this issue and governed by whatever is defined as the critical limit for concurrency.
Versant further position existing systems within this cube, highlighting two facts:

- No systems alternative presently deals optimally with massive concurrency
- Older systems (file based or RDBMS) are not suited to complexity

Versant conclude that the future lies in ODBMS/NoSQL systems.

**The Big Data issue**

The amount of data generated by smart meters and intelligent sensors in the grid is set for explosive growth over the next few years. A report by SBI Research (Rockville, Maryland) suggests that the volume of smart grid data that utilities will need to manage is likely to surge from 10,780 Tbytes of new data created in 2010 to over 75,200 Tbytes in 2015. This places considerable pressure on both the communications and processing infrastructures of the smart grid.

**Impact of real time processing**

Data needs to be dealt with adequately and in a timely fashion. This is system critical, and inadequate support at the point of data collection and analysis is a potential point of failure for information systems and, ultimately, the networks relying on those systems. The issue is part cultural, part historic.

At present:

- total data is assumed to be available at a single location
- all data is assumed to be available for analysis, though not necessarily in real time
- analytical techniques in current use are primarily based on time series anomaly detection and change detection methods and either ignore the spatial element of that analysis, or are not easily able to scale up to dealing with massive data sets

The underlying issue is that commonly used database management tools are not capable of detecting critical changes in network function that could lead to cascading power system failure. Utilities need to be able to analyse streaming data from sensors and measuring devices linked to inline operating components that are themselves often system critical, sometimes within a time frame of 2000 milliseconds. Transmitting this data to a single central location for analysis would be counter-productive, as this merely adds a further time interval into a time critical process.

Similar issues in respect of analysis of streaming data have been resolved, to a degree, on the internet but nothing directly comparable to the needs of utilities has yet been found.

Very similar issues arise in respect of analysis of streaming data from smart meters and Home Networks, where, out of the three levels of demand response available (manual, auto, optimized and adaptive), utilities have only really begun to shift slowly from the first to the second of these and each level brings with it a step change in the amount and criticality of data involved, requiring that utilities now begin to develop new and more effective distributed infrastructure to help them tackle the problem.

**Uncertain data and interaction with communications**

The general public is used to a view of the electricity grid where the majority of measurements are simple quantities (so many volts of electricity consumed over a given power interval, or a binary view that a component has failed or not failed). In practice, however, systems collecting data such as synchrophasor measurements are subject to all manner of “noise”. There is the datum itself, fluctuating rapidly across a very short time interval, and so may require statistical estimation as opposed to direct measurement to pin down. There are “noise” effects from the communications network itself, both in terms of incomplete or inexact transmission of data, as well as latency effects arising from the way in which the communications channel works. Too, there is random “noise” within a system as complex as the smart grid.

Even a task as outwardly simple as the identification of failure of a component within a smart network is complex, and in many circumstances is no longer resolvable by
a simple binary issue reporting approach. For instance, where a line linking substation A to neighbourhood B comes down in a simple transmission grid with low levels of inbuilt redundancy, the effect – and diagnosis – is relatively swift and straightforward because individuals in area B will report that they are no longer receiving power.

In a distributed smart grid, a signal may be received in a control center to the effect that a particular network component has failed/is failing, but this may not be accompanied by any observable system outcome i.e. power may continue to reach end users because the net is self-healing and may automatically flow power around any minor disruption within the net.

**Real states associated with a failure message include:**
- A component has failed
- A component is failing intermittently
- Error detection software has wrongly detected and reported a failure
- ICT systems and software transmitting the failure message are in error

Similarly, at any moment when a system is NOT showing error, it remains possible that one or more system components are failing.

**Data Ownership & Control issues**

The key issue that may, in time, serve to disrupt visions of demand response and customer relationship management lies in issues around data ownership and use.

On the marketing front, a number of initiatives (mostly in the US), have led to consumers demanding and in some instances obtaining the right to be rewarded by companies wishing to make use of their data. This is a large issue worldwide and is still in its infancy, and consumers are waking up to an awareness that there is (economic) benefit to organisations from use of their personal data. The primary concern has tended to be around privacy, with consumers in many jurisdictions simply resisting commercial use of their details, opting out of particular programs or refusing consent to be contacted for various purposes. This makes the marketing arena that much more difficult to police, for instance, best practice around customer data requires that for each individual “permissions data” is also held, indicating the purposes the customer has given permission for the data to be used, with potentially quite extensive variance by channel. This is endorsed by law and across the EU tends to permit an opt-out regime to exist for hard copy direct mail, while requiring an opt-in regime for electronic and telecommunications.

In respect of smart networks, the objections have widened out. In some areas, consumer groups have understood the messages about how smart grid can enable remote control of their home appliances, and at the same time have become fearful about the threat from hacking. Cyber security, while a minor threat in the context of an individual home user, has now been elevated to the status of major obstacle for some consumers. This objection has slightly more purchase in the US, where implementation of smart metering itself is subject to ongoing debate. In many parts of Europe, the view from the government is that smart grids, backed by AMI and smart metering, is a strategic necessity and that their introduction should be given state and legislative backing. In parts of the US, by contrast, concerns over privacy and security have been joined by concerns over questions of who should pay for the introduction of smart metering. Some consumer groups and state legislatures have asked, with justification, why consumers should be asked to pay for an enhancement to the electricity network that will, in time, result in significantly lower costs to the utilities themselves.

Playing lastly into this mix of counter-factors are questions around who should control the use of electricity. At base, demand response solutions presume a world in which the grid is decentralised, but utilities continue to play a lead role in determining how electricity should be managed “for the common good”. DR assumes that at times of peak demand, utilities will be able to intervene at some level within individual consumer households to reduce energy use or to disconnect specific individual appliances. Consumers, according to this view of the future, should welcome that vision because of the community benefits it brings.
The two main counter-factors are a growing alternate vision in which market forces are brought into play. Consumer use of energy is viewed as an economic good with costs and benefits associated: in this scenario, consumer non-use, the generation of “negawatts,” also has associated costs and benefits and if utilities wish to benefit from a consumer decision to reduce usage, they should pay for it. Also injurious to the grand vision of the smart grid is the possibility that many of the benefits ascribed to the smart energy grid may be delivered sooner by various home automation implementations. These include smart appliances controlled remotely via mobile apps in order to satisfy a range of customer objectives that may include, but not be limited to, energy efficiency. From the energy provider point of view, the difficulty is that each of these factors is tending to push consumers in the same direction, towards viewing their personal data and their private consumption of energy as generating economic goods in the market place and that those organizations wishing to obtain the benefit should be prepared to pay in some form.

It is possible that the current push towards compensating consumers will be a passing fad but equally, it may become ingrained, leaving utilities with just two alternatives if they wish fully to implement smart grid to pay consumers for the right to use their data and control their energy use, thereby reducing the aggregate benefits available to utilities from smart grid to seek legislative backing, effectively state endorsed implementation of smart grid systems retire – but the necessary numbers with digital and ICT skills have yet to materialise. This makes working in the smart grid an area of opportunity.

According to a survey by Zpryme on Hiring Trends in the US smart industry, published in summer 2012, the average annual compensation for experienced management professionals is $136,000. They comment: “The rapid digitization of the U.S. electric grid has created a lucrative job market for energy industry professionals; the future workforce will be especially impacted by the Smart Grid.”
SQUARING THE DATA, ANALYTICS AND PROCESSING CIRCLE: THE ELEMENTS OF A SOLUTION

The bottom line is that traditional enterprise database technologies will no longer suffice. The volume and complexity of data when coupled with the levels of performance demanded from systems that use such data have reached a point where simply spending more

• doing the same things better, faster, in greater volume
• has only marginal return. That is in part because of the step change nature of the various issues outlined but also because of the interaction effects.

Data, communications technology and analysis are no longer separate projects. Rather, data is modified by the communications medium by which it is supported: and analytical and control software is as much about determining what data is being observed as in processing discrete certain units of data.

First generation big data technologies have been created by companies needing a quick fix provision of enterprise data management solutions at web scale. Examples of these technologies include the Facebook/Cassandra database or Four Square/Mongo database. However, there is concern that these solutions, as not core to the business of the inventor, may be sub-optimal. A number of open source projects have taken up these data technologies, but lacking enterprise infrastructure standards there is a risk that these solutions will turn out to be relatively immature, special purpose products.

Stochastic and statistical methods of data analysis

Fault diagnosis methods have tended not to consider either the significant influence of ICT in power systems, or to actively seek to detect and distinguish between faults in distribution networks and failures in communication systems. The complexity of the underlying systems is leading utilities to rely increasingly on a range of techniques specifically adapted for dealing with uncertainty, of the kind highlighted in Figure 14

The search for techniques to deal with uncertainty has led to the development of fuzzy logic approaches to power system fault diagnosis, enabling operators to model inexactness and uncertainties created by protection device operations and incorrect data. One instance of fuzzy set theory being used derives from a case study looking at a method for fault section estimation that considers the network topology under the influence of a circuit breaker tripped by a preceding fault.

The application of fuzzy set theory to the network matrix was central to dealing with uncertainties created due to protection devices, and allowed an examination of the relationship between the operated protective devices and the fault section candidates. A further approach that has been evaluated at least theoretically, because it is helpful at separating out causation where multiple events are taking place at the same time, is the application of Petri Nets: one study made use of the underlying network topology to design a PN, in order to detect failures in data transmission and to identify faults in the distribution network.

In classical set theory, the membership of elements in a set is assessed in binary fashion where an element either belongs or does not belong to the set. Fuzzy set theory...
permits a degree of indeterminancy, with elements allocated to a set according to some known or estimated probability function and are widely used in areas where information is incomplete or imprecise, such as bioinformatics.

A further technique that has been explored in dealing with smart grids is the Petri Net (PN). This is a mathematical model that allows not only the representation and description of an overall process but also the modelling of the process evolution in terms of its new state after each event has taken place.

Stochastic control is a form of control theory that may be applied under conditions of uncertainty in the data. It is assumed some random noise - with known probability distribution - is affecting both the state evolution and the observation of the controllers and the aim of stochastic control is therefore to design an optimal controller that achieves the control objective at minimum average cost despite the fundamentally “noisy” operating environment.

Adaptive Stochastic Control

Management of a smart grid is constantly subject to a wide range of variables and its control, computationally, is characterised as a multistage, time variable, stochastic optimization problem. One solution is to make use of complex, computationally driven, command and control systems such as Adaptive Stochastic Control (ASC). ASC systems are at present only found in nuclear power plant management, but even these would be insufficient, since while they are good at identifying the “next worst” condition that a plant can take at any given time, they are less good for determining “next most likely”.

The ASC for the Smart Grid must identify the next worst AND the next most likely condition and will employ algorithms that perform complex mathematics using model simulations of the future in near real time. Such solvers are more common in military, petrochemical and transportation industries.

By contrast, in the utility industry, only Independent System Operators use such complex algorithms, and then only for economic dispatch of power. This means that in order to manage the smart grid – and avoid catastrophic failure - these advanced ADP control algorithms will need to be modified and significantly enhanced.

**Computational intelligence**

Smart grids will need to be supported by means of a combination of capabilities for system state prediction, dynamic stochastic power flow, system optimization, and solution checking.

One proposed solution is that of multi-agent systems, where each individual component of the system is some kind of intelligent agent. Alternatively, different systems or agents can be allocated to the solution of specific problems. However, various disciplines, including game theory and economics, have shown that this approach is likely to converge, at best, to something called a Nash equilibrium where no player is incentivized to change their strategy provided no other player changes strategy, and this in general will be far inferior to any of the best possible Pareto optima outcomes where no player becomes better off without another player suffering. This outcome can be avoided only if some special effort is made to design the overall system to achieve some kind of collective optimality. That effort is one of the key defining elements of the fourth generation vision, embodied in the concepts of computational systems thinking and computational intelligence.

**Computational systems rely on three strands of thinking and three agents (known as C3) to deal with an evolving, uncertain, variable and complex environment such as the smart grid. These are:**

- sense making, communication agents
- decision making, computation agents
- adaptation, control agents

At the heart of this lies a real time wealth of knowledge that continuously evolves and refines itself as the system undergoes changes, learning and unlearning facts and insights over time. The typical paradigms for this Computational Intelligence are, independently, the same as the core techniques set out in Figure 14:

- neural networks
- immune systems
- swarm intelligence,
- evolutionary computation systems
- fuzzy systems
These paradigms can also be combined or “hybridized” to form neuro-fuzzy systems, neuro-swarm systems, fuzzy PSO systems, fuzzy-GA systems, neuro-genetic systems, etc. and these are generally superior to any one of the stand alone variants.

**Processing in the cloud**

Cloud computing involves the delivery of two key components of long term utility requirements - massive data volume storage and real time processing - in the form of a service to end user over a network.

**There are three types of cloud computing:**

- Infrastructure as a Service (IaaS)
- Platform as a Service (PaaS)
- Software as a Service (SaaS)

The most relevant type of cloud computing for utilities is likely to be the Software as a Service model, where users rent application software and databases while cloud providers manage the infrastructure and platforms that the applications run on.

At present, utilities are a long way from being able to take advantage of cloud approaches, since in order to do so, they would need to undertake a radical redesign of the architecture underpinning most grid data collection and analysis applications. Such a solution would need to be scaleable, adding significant extra applications in respect of control function or modeling and analysis, without the need to change radically each time.

**Case studies**

**Case study: Versant, experience with complexity**

A good example of the sort of business that is now stepping up to meet the challenges implicit in the support of smart grids is Versant Corporation, who have a reputation as a global leader in developing data management software infrastructure for complex, mission critical applications.

In February 2012, Versant joined EPRI’s smart grid research program, known as IntelliGrid (qv.) as the only NoSQL, object oriented data management solution provider in the program. This, it is claimed gives them the ability to handle structured, semi-structured, unstructured and transactional aspects of Big Data requirements. Their database engine, illustrated in Figure 15, is claimed to facilitate large enterprise data ingestion, distribution, and complex event processing in a partitioned enterprise data set capable of scaling out over time. It is also designed to allow efficient coupling to the “soft real time” analytical systems driving business.

**BR figure 14:**

**Schematic for Versant database engine:** partitioned database model

- Streaming Data Ingestion: CEP events, CDRs, ...
- Extreme Scale Partioned Key Values MapReduce
- Large Scale Complex Data Management
- Business Rules, Domain Models, Aggregation
- Workflow
- Algorithmic Processing
- Real time analytics

Source: Versant

**source:** Engerati
Versant’s approach is designed to permit the seamless coupling of raw unstructured enterprise data, mined for interesting aggregations (possibly through integration with software such as MapReduce / Hadoop), based on a distributed, scale out, enterprise database management system that is not constrained by the need to constantly move enterprise data between systems.

More critically, they bring to the task strong expertise across fields such as energy, telecommunications, geospatial information systems (GIS), and financial services.

Versant solutions are already in use managing many of the global data infrastructures that will help make power grids more intelligent, including several of the largest telecommunications networks around the world and more recently they have begun to expand their activities into the transmission system sector in the EMEA region.

**What makes Versant’s approach relevant is their experience in two areas.**

**Climate change research:** a GIS-based application powered by Versant’s technology at the National Snow and Ice Data Center enabling a “time centric” change analysis of data on the Greenland ice sheet. A relational database was ruled out as completely impractical due to the large size of the data sets and required response time. In this case, the Versant system may be processing billions of time series items of information in real time.

**Stock exchange, supporting trading processes:** considerable experience handling complex and time critical data to support trading processes at the world’s largest stock exchange, giving them an early edge in the development of dynamic pricing systems.

The characteristics of these solutions closely fit to the problems that energy companies are likely to have to deal with once smart grid is fully implemented, that is: the inclusion of more remote, more intermittent energy sources within the network mix, including renewables such as wind, solar and tidal; massive data volumes; and a need to deal with this data in real time.

**Separation of component function**

Smart meters are far more than simple local information exchange devices, transmitting information about in home use up and down stream from home to utility and back again. Smart meters are increasingly supported by a range of (in-built) sensors, allowing them to feed back a much broader range of data, including voltage, frequency and power factor. This information is highly useful in the management of a smart grid, but most utilities are not yet in a position to cope with “big data”. Some are already struggling to manage the shift from monthly billing to providing customers with usage and cost data at hourly, or even quarter-hourly intervals. The task of managing yet more in respect of data voltage fluctuations or appliance use is then the final straw at this time.

That is one reason why Echelon introduced, in June 2012, new functionality into its power sensing for smart meter, including a new software suite for its smart grid platform that permits grid power quality data to be separated out from billing data, and to limit its availability to an as needed basis only.

Going forward, this may be the only way for utilities to survive the onslaught that is popularly referred to as a “data tsunami”. They must remain highly focused on what tasks are essential and which merely “nice to do”, and concentrate resources on the former. The ability to split these tasks by channel will help significantly.

**Is upgrading on a piecemeal basis a more realistic approach?**

A common assumption in respect of the new smart infrastructure is that the best way to implement new services such as prepay would involve buying a new Customer Information Software (CIS) system, despite the fact that many utilities have likely spent $100 million or more in their CIS systems (according to GTM Research).

Arizona Public Service (APS) initially took that view but on finding they could engage greater functionality through add ons (and were concerned at the length of time proposed for the replacement) they decided instead to go for an upgrade program. Working with Arora on the transformation project, APS focussed on creating a
foundation where exchange between new and legacy programs was able to take place with a standards-based approach. The approach of creating standards and building out from legacy systems on the basis of those standards allowed functions that could be built in house to remain there, while specialist function such as the provision of visualization of data to the utility's backend and to customers, were delivered through applications that APS purchased.

The upgraded CIS has given APS significantly enhanced customer support, including facilities for customers to:

- choose prepay
- track their usage via an online web portal or text or email
- pick their billing date, improving customer relations and reducing the incidence of late payment

Lastly, by combining CIS and AMI, APS has cut down the time between meter reads and processing in the CIS, leading to a saving of c. $7 million per year.

The app-based approach is likely to continue to benefit moving forward, as can piggybacking on apps based in cloud computing. Incremental enhancements – as opposed to “big bang” change - are now possible, resulting both in much swifter delivery improvement at lower cost and creating a framework for future enhancements.

Providers of data analytics and control software

Data analytics is an area likely to be dominated by IT and Internet companies that have a track record of mining data and creating smart algorithms over several years, and in the case of non-internet applications, decades, according to Pike Research.

Major data analytics players – IT giants – identified are:

- Accenture
- Capgemini
- HP
- IBM
- Microsoft
- Oracle
- SAIC
- SAP
- Siemens

Smaller, newer data analytics entrants include

- OPOWER
- OSIsoft
- Telvent
- Ecologic Analytics
- eMeter

Itron is market leader in respect of software that manages data from “interval” meters i.e. meters that provide utilities with readings at “intervals” as opposed to old style meters reading once a month or even less frequently.
Strategic alliances/mergers

A number of alliance and mergers have been taking place in recent years designed to graft strong data analytic capabilities on to utilities:

- **Smart Meter Data Management (MDM)** In late 2011/early 2012, the two largest standalone vendors of smart meter data management (MDM) were purchased by corporate giants: in December 2011, Siemens purchased eMeter, while shortly afterward, Landis+Gyr bought Ecologic Analytics, before themselves being purchased by Toshiba for $2.3 billion.

- **MDM and Demand Response** January 2012, MDM-smart meter vendor Aclara and smart grid integration start up CalicoEnergy partnered over a platform promising to link MDM to demand response.

- **Smart Metering and Critical Infrastructure Monitoring** January 2012, municipal and cooperative utility MDM specialist ElectSolve joined grid networking start up On-Ramp Wireless for a “pre-integrated smart metering and critical infrastructure monitoring solution.”

- **Smart Grid Analytics** January 2012 Itron announced the launch of its new smart grid analytics platform: February 2012 announced intention to double its Raleigh, N.C. software workforce to more than 400 people.

- **Real time monitoring** Spring 2012, Schneider Electric, a French global company focussed on the electrical and controls industry, bought real time monitoring services specialist Telvent for $2bn. This gave them entry to a significant number of smart meter and smart grid deployments in Europe and North America, plus in-depth MDM expertise.

SAP is also leveraging partnerships extensively. This is being managed through their Lighthouse Council initiative, they have been recruiting a number of partners including OSIsoft, who describe themselves as the leader in real time data infrastructure solutions.

Companies from outside the traditional MDM area have also become involved. Data storage giant EMC has invested $24m in smart metering start up Silver Spring Network, and has pledged to work with the latter on “analyzing smart grid data to make it actionable and valuable to utilities and their customers.”

Another start up Verdeeco is promising tools to pull together existing under used smart grid data, and turn it into insight via “apps” built to suit the small municipal and cooperative utility market.

Market size and trends

The market for smart grid data analytics including all software and services capable of mining data and providing intelligence for smart grid stakeholders could reach a cumulative $11.3 billion between 2011 to 2015 according to a report by Pike Research, Smart Grid Data Analytics, published in late 2010.

Industry highlights and issues include:

- Development of a new suite of smart grid products and services with a new grid as platform architecture reference design likely to influence further developments in the industry (Cisco)

- Sorting out massive data volumes at the smart meter level (Oracle)

- Dealing with legacy back office systems (Oracle and IBM)

- Provision of meter data management products that integrate to grid network management software suites, pulling together functions such as business intelligence, customer service, asset management, outage detection and distribution grid management (many players, but including Oracle, Trilliant and IBM)

- Encouraging utilities to integrate all their smart grid system data into a single platform to enable master management. Addition of dedicated data analytics functions, including outage detection, power load monitoring and meter health (eMeter)
OPERATIONAL ISSUES WITHIN THE SMART GRID

The new smart systems are highly dependent on their ability to communicate with utilities, customers and one another. Key operational issues that are largely independent of communications and data issues are:

- interoperability
- standards
- security

Definitions of interoperability

On the one hand, across several key areas of the grid the market is moving toward open standards and open applications, enabling consumers to access function irrespective of supplier or technology involved. On the other, some service providers have locked into dedicated standards, either for historic reasons, or because they believe that such an exclusive approach has strategic merit.

Locking into dedicated standards is clearly a high risk strategy, because where a supplier is successful in achieving pole position for their standard(s) they will have a clear commercial advantage and even if not capable of becoming monopoly suppliers for that service will nonetheless reap significant rewards for their achievement. However, attempting to develop an exclusive standard for any part of the grid – and failing – is likely to prove both expensive and competitively disadvantageous.

The role of interoperability and interchangeability is discussed at length in a paper by Paul Kominers of Harvard University’s Berkman Center for Internet & Society. This cites the NIST definitions of these two qualities, these are broadly:

**Interoperability:** the capability of two or more networks, systems, devices, applications, or components to exchange and readily use information. . . . That is, different systems will be able to exchange meaningful, actionable information.” Communications interoperability on the smart grid is about the capability of two components to communicate to each other the data necessary to function. In general, interoperability may be measured on a spectrum that reflects degrees of openness.

**Interchangeability:** “an extreme degree of interoperability” characterized by a similarity sometimes termed ‘plug and play.’ Interchangeable components can be freely substituted without loss of function and requiring minimum to no additional configuration.”

Other organisations have brought forward a range of different definitions of interoperability. ETSI issued a paper in 2008 looking at how different levels of interoperability may exist relative to specific systems and that while one level may suffice for one purpose, this may not be sufficient for another purpose. The four categories of interoperability that they enumerate are technical, syntactical, semantic and organizational interoperability.
A number of examples are cited where interoperability between different levels within the smart grid is beneficial or even crucial to the grid’s smooth working:

**Dynamic pricing** depends on utilities obtaining accurate consumption data from household AMI meters in real time. A series of interoperability requirements follow from this, AMIs must be capable of communicating their data to utilities in a form that the utility providers’ system is capable of understanding. AMI manufacturers and utility providers therefore need to coordinate how their respective devices and systems compile, transfer and receive information.

**Integration of current power sources** with the new intermittent sources of energy that may be located at widely dispersed locations peripheral to the grid requires the capability for smart grid systems a) to determine quickly when intermittent sources have stopped generating power and b) to offset the loss in generation without any serious deterioration to grid performance. This requires seamless communication, coordination, and response to such events across systems in use at the power generation stations and the grid architecture (e.g. substation, transmission lines).

**Consumer ability to adjust energy use** according to price, energy type, time of day, etc. requires the Energy Services Interface (ESI) – the HomeBox – to receive and interpret local information from the utility and also to appropriately adjust the consumers’ appliances.

Two counter trends have been identified that could prove harmful to the effective development of the grid. These are:

- **“lock in”:** the development of standards that are over rigid and can lead to technology that is not fit for purpose being preferred to more agile new technologies

- **Local standards:** the opposite to lock in; an over reliance on local initiatives to provide solutions to local problems, leading to a lack of common standards and in the end little or no interoperability between systems set up in different geographic locations.
INTEROPERABILITY BY GEOGRAPHY

US

The issue of interoperability appears to have entered the debate with the Energy Independence and Security Act of 2007, this gave NIST the lead role in creating a smart grid. This was followed by the American Reinvestment and Recovery Act (ARRA) mandating a subsidy of $10m in addition to $5m already committed by NIST. NIST has set up a series of working panels to assist in achieving this, the principle body is the Smart Grid Interoperability Panel (SGIP) aiming to provide overall research and advice. SGIP is further sub divided into some seven Domain Expert Working Groups (DEWGs), these are groups containing experts relevant to specific technical issues in each domain:

- Transmission and distribution (TnD)
- Home to grid (h2g)
- Building to grid (b2g)
- Industry to grid (i2g)
- Vehicle to grid (v2g)
- Business and policy (BnP)
- Distribution, renewable, generation and storage (DRGS)

Three other significant groups within the NIST family are the Smart Grid Architecture Committee (SGAC), Smart Grid Testing and Certification Committee and the Cyber Security Working Group (CSWG). The entirety of this enterprise is supported by a major wiki giving details of all significant discussions and meetings at the SGIP site at collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/WebHome (this link may not open directly in your browser, follow the match in your search engine). Membership of these groups is drawn widely from experts and stakeholders in both industry and academia. For instance, the SGAC has members from IBM, Électricité de France, the Massachusetts Institute of Technology, PG&E, EnerNex and Boeing.

Development of smart grid standards is a mixture of market forces and evolution, combined with a sense that it would be helpful if standards were set from the centre and therefore fairly massive intervention on the part of government and large enterprises. This reflects an acknowledgment by the center that the smart grid is far more than just a set of new technologies that in isolation would do little more than provide a series of increments to the performance of individual utility grids. Rather, the smart grid is seen as the entirety, the sum of the interactions between smart technologies at different levels within the network, where failure is likely to lead, eventually, to the failure of the entire grid enterprise.

Significant initiatives

A significant initiative in getting to grips with implementation issues is the Electric Power Research Institute’s (EPRI) IntelliGridSM program which is intended to create the technical foundation for a smart power grid, linking electricity with communications and computer control. A major early product release is the IntelliGrid Architecture, an open standards, requirements based approach for integrating data networks and equipment enabling interoperability between products and systems. This program provides utilities with the methodology, tools and recommendations for standards and technologies when implementing all aspects of smart network systems. A further benefit of this program is that it provides utilities with independent, unbiased testing of technologies and vendor products. This approach is helpful to industry in that it provides guidance on all aspects of deployment of smart infrastructure technology (monitoring, communications, computing, and information management) both to support current needs and ready for future applications. A framework of this kind provides the methodology, tools and recommendations for standards and technologies as well as independent, unbiased testing of technologies and vendor products. IntelliGrid also provides and supports ongoing development of communications architecture in order to facilitate interoperability between products and systems.

The IntelliGrid architecture is already being used by several utilities including Southern California Edison, Long Island Power Authority, Salt River Project, and TXU Electric Delivery. EPRI have also set up a “living laboratory” in order to assess devices, systems and technologies.
Europe

Progress within the EU closely mirrors that in the US to date. The European counterpart to the NIST initiative is a report – Standards for Smart Grids – compiled by the three pivotal European Standards Organisations (ESO's) and approved in June 2011:

**CEN:** European Committee for Standardisation, a major provider of European Standards and technical specifications and the only recognized European organization (according to Directive 98/34/EC) for the planning, drafting and adoption of European Standards in all areas of economic activity with the exception of electrotechnology (CENELEC) and telecommunication (ETSI).

**CENELEC:** European Committee for Electrotechnical Standardization, responsible for standardization in the electrotechnical engineering field.

**ETSI:** The European Telecommunications Standards Institute (ETSI), produces globally applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies.

The scope of this work included:

- Devices
- Interfaces
- Communication
- Cyber security and system integrity
- System model(s)
- Network and system management
- Grid codes and Industry rules

The scope also had as a requirement, an acknowledgment of existing market rules.

The high level recommendations to emerge from the Standards for Smart Grids report:

**Use a top down approach:** ensure that the different applications to be deployed over time will fit together

**Build up a flexible framework of standards:** almost all aspects of market business models, players and technical solutions are still in flux and a flexible model or architecture must be available to map services and use cases

**Agree on a European set of use cases:** establish a single repository of use cases to systematically identify existing and future standardization needs

**Align with international standards:** cooperate with international and relevant national smart grid standardization activities. European standards should be based on existing international standards and European results should be promoted to the international level.

**Don’t reinvent the wheel:** reuse existing mature standards whenever appropriate.

**Adapt the organization and processes for standardization:** smart grids are seen as a system issue rather than a product issue.

It also made seven general recommendations, these were:

- **G-1** Continue with further development of the report
- **G-2** Use international standards as a basis for promoting EU industry
- **G-3** Go for speed of implementation by reusing existing systems
- **G-4** Concentrate on future proofing of standardization
- **G-5** Build up a SINGLE repository for smart grid use cases
- **G-6** Adapt standardization processes (i.e. define the processes needed to match the lack of maturity of many smart grid applications)
- **G-7** Put in place a clear relationship between legislative requirements and standardization
The report provides a strategic overview, outlining the standardization requirements for implementing the European vision of smart grids, especially taking into account the initiatives by the Smart Grids Task Force of the European Commission, it provides an overview of standards, current activities, fields of action, international cooperation and strategic recommendations.

In one sense, its most important recommendation is that the report be developed further, since this is, the European equivalent of the US NIST’s wiki but in print format: a framework onto which standards, architectures and data models will in time be grafted. Thus, it is the process of developing and updating the report that is key, as opposed to the state of the report at any given point in time.

In April 2012, the European Commission reiterated a commitment to developing the smart grid, smart metering and electric vehicles with a focus on standardization of interfaces, the implementation of security by design and data privacy principles in relevant devices. A reference architecture for smart grids in Europe and a set of key standards is expected to be issued by the end of 2012. Also of note here is the way that the European approach is pragmatic, in effect, getting on with developing their own renewable and smart technology, while leaving the major debates over standards to other regions.

A possible sign of things to come was flagged up in September 2011, with the joint announcement by NIST and the European Union’s (EU) Smart Grid Coordination Group (SG-CG) that they intended to work together on Smart Grid standards development. The announcement placed some emphasis on common goals and areas of focus. The collaboration aims to harmonize the conceptual frameworks according to which the two groups are already working, and will seek to promote regular exchange of information on issues including:

- Legislation, regulation and other policies underpinning NIST and SG-CG work
- Respective work methods, work programs and time lines
- Standardization deliverables
- Testing and certification frameworks

- Cyber security requirements and technologies

Within Europe itself, there are also a number of initiatives emerging that may in time contribute to standardisation. This reflects the fact that unlike other major players in the emerging smart grid marketplace, Europe is still the least homogenous, politically, made up of a loose alliance of independent states, as opposed to the Federal System in place in the US or the much stronger central control of China or Japan (or even India or Brazil, although still well behind the developed world in terms of smart grid development these are able to build their own grids with independent standards for some processes possible simply by virtue of the size of market that they are creating them for).

The most significant contribution to the standards debate outside of the major political blocs was the German Standardization Roadmap E-Energy / Smart Grid, released in 2010, a position paper providing recommendations for necessary fields of action, international cooperation and strategy. The main result of this exercise was the discovery that many standards already exist in spite of some public perception of a lack of standards.

The UK’s Centre for the Protection of National Infrastructure (CPNI) provides integrated security advice, combining information, personnel and physical aspects of the same, to organisations that make up the national infrastructure. Recently acknowledging the challenges posed by smart grid, it reported that, “until recently the terms ‘process control’ and ‘SCADA’ were unknown outside a niche area in industry. Today it is one of the key issues for national infrastructure protection.” It is likely that the CPNI’s work in this area is likely to prove a significant part of international security solutions to help prevent smart grids succumbing to cyber attacks.

Other European countries, including Austria, the Netherlands and France, have been developing their own roadmaps towards smart grid. One initiative of particular relevance is discussion of a joint project in Eastern Europe possibly bringing together countries that would include Germany, Austria, Poland and the Czech Republic in harmonising their transmission grids. The reason for this lies in the characteristics of the German energy network, this has been increasingly reliant on intermittent renewable energy for some while, as well as, since 2011,
committed to going non-nuclear in as short a time frame as possible.

These twin goals are only possible through the purchase of electricity at peak demand times to smooth out fluctuations, from its nearest neighbours and this in turn places significant strain on the transmission grids in those countries. Two issues are implicated here: first, there is a need to modernise parts of the transmission grid in those countries in order to cope with the massive power flows that are increasingly demanded. Second, in addition to modernisation the system is likely to function significantly more effectively if the systems are standardised so as to work interoperably.

In April 2011, ETSI and the European Association of the Electricity Transmission and Distribution Equipment and Services Industry (T&D Europe) signed a Memorandum of Understanding in order to work together on developing ETSI standards for smart grid. This collaboration between the telecoms standards body and that organisation affirms that T&D Europe will provide input and requirements from the electricity transmission and distribution industry to ETSI’s smart grid standardization activities.

See our T&D report for more information.

China

In China, the fact that all grid development is effectively centralised through the State Grid Corporation of China makes it relatively easy to identify where standards are coming from and the rationale behind them. The SGCC Framework, otherwise widely known as a three stage drive toward implementation of a smart network, is embodied in its Strong Smart Grid Plan. This is a smart grid standardization roadmap based mainly on open standards, and this cannot help but influence strategic decisions taken by vendors operating in Chinese markets since China will be one of the largest markets worldwide for new smart product and services.

The first iteration of the SGCC framework defined eight domains, 26 technical fields and 92 series of standards and took into account several existing standardization roadmaps. It is explicit in stating that an age of information will be followed by an age of intelligence where the integration of clean energy requires a strong and smart grid as a means to tackle climate change and to optimize the allocation of energy resources.

The strong smart grid is defined as an intelligent power system encompassing power generation, transmission, transformation, distribution, consumption and dispatching. Under this definition, the grid will cease to be a simple carrier of transmission and distribution of electricity, but will evolve instead towards an integrated and intelligent platform for the Internet of Things, internet network, communication network, radio and TV networks. The present sharp line between generation and demand will blur.

For the first batch of smart grid standards, SGCC has identified 22 relevant standards: 10 domestic and 12 international. These have also been in the scope of IEC SG3, and include their 5 core standards.

Japan

The Japanese approach to standard setting contains many elements that closely reflect the approach adopted by the US, with a series of industry working groups led by a government research initiative in NIST. However, the model appears, for now, to be more heavily rooted in promotion of Japanese industry, a means of exporting Japanese business to the rest of the world, as much as developing smart grid at home.

The start point was an initiative by the Ministry of Economy, Trade and Industry (METI), who set up a strategy group in August 2009 – the Japanese Industrial Standards Committee (JISC) - with the aim of promoting Japanese activities in international standardization in the smart grids field. Standards are viewed as being essential to achieving the necessary level of interoperability, a key ingredient in establishing flexibility and expandability of the future smart grid.

A first report delivered in January 2010 set out the need and general outline of a roadmap to be established in close cooperation with other standardization organizations and countries. Seven main fields of business were identified, together with core aspects for the Japanese economy:

- Wide Area Awareness in Transmission
Supply Side Energy Storage  
Distribution Grid Management  
Demand Response  
Demand Side Energy Storage  
Electric Vehicles  
AMI Systems

26 Priority Action Areas were assigned across these fields. Japanese work is being carried out in close cooperation with the IEEE, the IEC and CEN/CENELEC, with the result that recommendations also fit with previous recommendations made by those organizations.

The government has invested significantly ($1.1bn) in smart grid technology trials. It has also put together the Smart Community Alliance, made up of approximately 75 corporations and other organizations in order to extend the concept of smart grids to bring the energy efficiency and efficient management of other resources such as water, gas, and transportation into the mix. A further focus is the overlap between smart grid and home automation.

Non-national initiatives towards standardisation

Two key initiatives in the creation of smart grid standards are:

IEC Strategic Group 3 “Smart Grid Report”: this is a roadmap plus high level recommendations compiled by the Standardization Management Board (SMB) of IEC in February 2010 and officially available on the IEC webpage since June 2010. This work, a total of over 100 IEC standards and 44 standardisation recommendations, has been widely used in the development of EU standards to date. The IEC group is now focusing on use cases and general requirements for a smart grid reference architecture, as well as developing a Mapping Tool to support smart grid project managers (www.iec.ch/smartgrid).

ITU-T Smart Grid Focus Group: in February 2010, the Telecommunication standardization sector of the International Telecommunication Union (ITU-T) set up a Focus Group on Smart Grids (FG Smart). This Group, while limited to the telecommunication/ICT aspects of smart grid, aims to collect and document ideas helpful in developing recommendations to support the smart grid from a telecommunication/ICT perspective. A focus for this work is on standards development.

Security

The electricity grid is an increasingly vulnerable target for a wide range of attacks in future. This arises from a number of features that are peculiar to the grid itself.

First, there is a dependence on ICT to a far greater degree than perhaps in respect of any other energy format. Because electricity travels across the grid at near light speeds, the management of specific issues of component failure or over/under supply in respect of particular regions of the grid are beyond the capability of human operators to maintain. This issue is not entirely absent in respect of other networks, such as gas or water but the speed of required decision making is unique to electricity.

Factors giving rise to anxiety are:

The possibility of new personalised forms of cyber attack, the new smart grid will permit for the first time the theoretical possibility of cyber attacks being directed against specific individuals. Initially, these are more likely to be large businesses than private individuals, but the possibility exists. The damage that could be achieved where control of significant electrically operated plant is available remotely could be considerable.

The proliferation of Intelligent Electronic Devices in controlling the grid: this may be more of a theoretical issue than real, since control will continue to reside in a relatively small number of SCADA centres.

Increased physical access to the grid: the proliferation of IED’s and related devices is seen as increasing the number of potential access points to the grid as a whole.

The use of Internet Protocol (IP) and commercial off the shelf (hard/soft)ware: while there are good reasons for deploying IP technology as a means to speed up development of the smart grid, a significant drawback is that IP is a common network standard with numerous, widely known vulnerabilities. For example, attackers can exploit packet hopping within a network to mask the origin of a hostile packet or series of packets introduced into the network.
Increased number of stakeholders: according to M. Masera writing on the issue of governance (2010), “The current decentralized nature of liberalized electricity infrastructure has as a consequence that individual operators cannot be held responsible for the way the system as a whole functions… Nobody owns, designs, or operates the infrastructure. The state of the infrastructure is the result of many independent decisions taking by all participant actors, not just at the technical level but also at the market level.”

In other words: the degree of actual threat to electricity supply potentially involved by failures in cyber security is major, but the ability of governments and the public to hold individual organisations to account for those failures is comparatively reduced.

Threat awareness

Broadly speaking, any point in the grid that is addressable intelligently is vulnerable to attack. That means attacks on smart grids could be as significant as attempts to bring down power stations, through to the “mischievous” hacker attempting to switch on all washing machines in a neighbourhood on a Sunday afternoon. Also in play are the commercial hackers, looking to scoop up personal data for financial gain as demonstrated by Tony Flick and Justin Morehouse in a presentation at Defcon 18 (available on YouTube), who gave the audience an insight into the threat to personal data from hacked smart meters.

The degree of seriousness that US power companies are starting to take security is highlighted by the fact that some are now disclosing these threats in SEC filings, while energy giant Con Edison is possibly the first company to describe cyber attacks as a stand alone risk category. Such disclosure is motivated in part by self interest, since failure to do so or to follow North American Electric Reliability Corp. (NERC) compliance can cost power companies as much as US$1 million per day in mandated penalties.

A turning point in utility assessment of threat was the Stuxnet virus. This is the first known malware to spy on and take down industrial systems – including a nuclear power plant in Iran - as well as the first to include a programmable logic controller (PLC) root kit. While the worm spreads indiscriminately at first, it includes a highly specialized malware payload designed to target only Siemens Supervisory Control and Data Acquisition (SCADA) systems configured to control and monitor specific industrial processes.

The broad industry view is that utilities and smart grid, in terms of security, are roughly where the telecommunications grid was a decade ago. Organisations such as the Department of Homeland Security and McAfee anti-virus specialist have warned of a dramatic increase in attacks on utilities over the last two years, with the latter frequently only able to play catch up, closing security exploits after the event.

Still, the utilities are not yet ready to deal with such threats, alongside analysts warning that threats to personal security and the national power grid are reaching critical mass is the latest Pike Research report on grid security that judges Utility cyber security to be “in a state of near chaos”. This is reflected in concerns that in the US, many utilities are taking a tick box approach to security, spending billions of dollars on meeting federally mandated security compliance, as opposed to investing in the development and testing of real security solutions.

In terms of consumer response, security is an issue that is cited in surveys regarding reasons to be resistant to smart grid. In most cases, consumers appear unaware of the detail beyond either a generalised science fictional doomsday scenario where cyber terrorists bring down the national power grid, or simply see their home data as “one more thing to hack” and therefore something else to worry about. Despite this, concerns about cyber security remain significant for a small proportion of consumers, making it an issue that smart grid operators need to address as part of the general PR approach to ensuring confidence in the grid.

Principal areas covered by smart grid security include a range of issues, including identity management and access controls, defence against threat and theft, industrial control system security, smart grid cellular communications, physical safety and security.
National approaches

The Roadmap for Smart Grid Interoperability Standards, published by NIST directly, explicitly raised key cyber security challenges to be addressed by US authorities. These included:

- Assuring cyber security using IP
- Ensuring secure information and control flows through the multiple overlapping networks of the grid
- Safeguards to prevent access to utility control systems
- The dangers of the introduction of malicious software
- The conceptual challenge of adapting a traditional IT focused understanding of cyber security for the power sector

Further consideration was given to these issues in a separate 150 page report produced by a NIST led Cyber Security Group, bringing together over 350 participants from the private sector, academia, regulatory bodies and federal agencies. This report set out an overall smart grid cyber security strategy, including the definition of a cyber security risk assessment process that is intended to be a start point for the creation of a comprehensive set of US cyber security deliverables.

The situation in the EU is very different, with concerns over security and initiatives in that sphere largely delegated to national governments. However, two issues seem likely to increase pressure for that to change. First is the increasing number of cross-border and cooperative projects being implemented by European states.

Where the transmission and distribution grid in one country is directly linked to the T&D grid in another, it is clear that the security threat to both countries is as dangerous (or the security is only as good as) the lowest level of security offered across all participants in the joint project. This was recognised by the European Council (2008), stating: “There are a certain number of critical infrastructures in the Community, the disruption or destruction of which would have significant cross-border impacts”.

Second, there is a growing acknowledgment that it makes sense to include security standards in the growing body of regulation and standards already being developed in Europe, a framework and forum exists within which security standards may be developed, and it seems likely that they will.

Security market

The spend on smart grid security technologies is already big and will increase significantly. According to a report from ABI Research published in November 2011, the spend on smart grid security technologies in 2010 was estimated at $590 million, with annual spend projected to surpass $2 billion in 2016.

The Transmission upgrade area accounted for the largest proportion of this spend, making up approximately 54% of the total in 2011. This segment is forecast to remain the largest for the next five years. Additionally, security spending on substation and distribution automation is forecast to be significant over the next few years as well.

A report from Pike Research in May 2012 - Smart Grid Cyber Security – estimates cumulative spending for securing the US smart grid deployment will reach $14 billion by the year 2018. The report further estimates that as much as 63% of the expenditures for smart grid network security will be concentrated on the control systems governing the power grids operations.

Global estimates suggest that eventually the cumulative spend on smart grid security over this period could be as high as US$40 billion.

The focus for security may be on specific devices or specific processes, operating either within a traditional data processing centre or within the cloud.

Security solutions

Security may be reduced to two basic functions of prevention and detection:

- Intrusion Prevention Systems (IPS)
- Intrusion Detection Systems (IDS)

Both have difficulty coping with the volumes of data in the system. Elements of a solution have been identified as operating in real time and making use of a new category of technologies called “cyber forensics” where instead of
waiting for a virus to be recognised by a massive central database of viruses, systems should be actively looking for real-time data anomalies. Still at the mostly theory stage, this is believed to be “the way forward” by many security experts.

Security suppliers

Large companies like IBM, Lockheed Martin and Accenture are clear leaders in the field, spending millions on development as well as looking for partners and acquisitions to provide niche solutions to add support to their solution product portfolios. Niche security players include companies such as TLC Secure Inc., InGuardian and IOActive.

One of the lead solutions in this area is Lockheed’s “Palisade”, this claims advanced threat detection and forensic tools that provide utility security analysts the functional intelligence they need to maintain and protect electricity networks. Palisade also goes one step beyond conventional monitoring applications and services, thereby giving to analysts an enterprise wide visibility, awareness and alerts to identify and mitigate threats.

In the US, there are signs of public/private collaborations in developing methodologies to support grid security. A new demonstration project, the Automated Vulnerability Detection (AVUD) system is to be run by three partners: Sensus, EnerNex and the Department of Energy’s Oak Ridge National Laboratory.

Their system makes use of function extraction (FX) to detect and fix software-hardware issues before they become big problems, in effect, staying one step ahead of security problems.

In addition to direct security solutions, a number of players are now providing audit facility. As long ago as 2009, HP launched a security audit for smart grid services, based on existing security audit methodology that has been used internally for over six years to test its own software and hardware in sectors such as defence. This, according to HP, makes the methodology both mature and sophisticated.

CASE STUDIES

Non-interoperability delays PLC deployment

The effects of the proliferation of multiple non-interoperable technologies can be seen very clearly in the BB-PLC standards arena, where lack of common standards has led to confusion in the market and delay in deployment. Non-interoperability brings with it the risk that devices will generate interference with one another.

Some analysts have either assumed – optimistically – that this issue will be minimal or if it does occur that interference can be managed. There is some validity to this, as there now exist standardized mechanisms that limit the harmful interference caused by non-interoperable neighboring devices, commonly referred to as “coexistence mechanisms”. Even here, argument continues, it is certainly the case that some ground breaking and innovative measures have been devised to deal with co-existence and non-interoperability issues. However, there is no guarantee that this will always be the case or that mechanisms in place now will continue to function as traffic on one or other standard increases. At the same time, there is concern that the mere fact that co-existence CAN be created will lead device manufacturers to be less concerned about standardisation, thereby pushing systems to their limits.

The issue of co-existence in respect of PLC based Smart Grid applications has been addressed in detail in NIST’s Priority Action Plan 15 (PAP 15), issuing a set of recommendations that require, among other things, to mandate the support of coexistence in all BB-PLC implementations.

Free markets, interoperability and upgrades

Most current energy displays that work with clip on sensors do not use a wireless standard but rely on proprietary protocols designed by each manufacturer. This solution reduces cost and time to market but means that there is no interoperability, it has application in regulated markets, or markets with a monopoly energy provider, but has serious drawbacks in deregulated markets where switching suppliers can lead to customers
being in possession of items of expensive, now unusable “stranded” equipment.

Given, too, that the average expected lifetime of a smart meter may be 15 to 20 years, it is essential that smart meters are able to communicate with each other and with other essential items of smart equipment within the HAN. This in turn requires interoperability based around standards defining how smart meters communicate, what data will be shared and how it will be communicated. A wireless standard is also needed to enable displays to be located at the optimal point within the home environment without need for extensive and costly cabling, though this in turn introduces issues such as range, throughput, security and power consumption.

In respect of smart metering, there are a number of wireless standards available, of which one of the most developed is the ZigBee PRO protocol stack, known as the Smart Energy Profile (SEP). In the UK, six standards are still under consideration:

- Wireless M-Bus at 868 MHz
- Wavenisat at 868 MHz
- Z-Wave at 868 MHz
- ZigBee at 868 MHz
- ZigBee at 2.4 GHz
- Bluetooth Low Energy at 2.4 GHz

WiFi has been ruled out in many areas as its power consumption is too high.

The Smart Energy Profile is based on the 802.15.4 radio standard and contains around 1,500 pages of specification and is still growing. To date, three versions of the Smart Energy Profile have been released and a further three are under development. These versions are described in table 10.

<table>
<thead>
<tr>
<th>Version</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Initial Release, deployed in Texas.</td>
</tr>
<tr>
<td>1.1</td>
<td>Update with enhanced features: used as the starting point for UK trials</td>
</tr>
<tr>
<td>1.1.1</td>
<td>Bugs fixed bugs and more robust testing added</td>
</tr>
<tr>
<td>1.1.2</td>
<td>Includes Support for Rising Block Tariffs: driven by BC Hydro, Canada</td>
</tr>
<tr>
<td>1.2</td>
<td>Incorporates SSWG features for the main UK deployment</td>
</tr>
<tr>
<td>2.0</td>
<td>A future IP based version, being supported by some US utilities, capable of running over different wireless standards.</td>
</tr>
</tbody>
</table>

In theory, versions are backwards compatible, so the initial deployments of SEP 1.0 meters will work with a future 1.n display. However, this is not straightforward, for instance a SEP 1.2 display may provide a richer more consumer friendly display when combined with a SEP 1.2 meter than with a SEP 1.0 meter, leading to questions being asked by users and possible service calls. In general, mixing of versions is always likely to lead to the end product not working precisely as intended.

Upgrades and compatibility is possible, in theory, by means of an Over The Air (OTA) firmware upgrade. This is not, however, always as straightforward as it sounds.
Utilities demand the ability to upgrade IHDs for two reasons:

- To ensure continuing compatibility with new releases of ZigBee SEP
- To “future proof” installations

Unfortunately, this approach adds cost and complexity, possibly leading to further issues. The central issue here is that OTA is only part of a much more complex device management solution, needing to be implemented at the Head End System (HES).

The HES needs to be part of an end to end upgrade process, aligning upgrades to critical information about the devices to be upgraded, including:

- Hardware version of the device
- Current firmware version
- Current operating state

However, the average HES does not possess such features, so they would need to be written. Also required would be an ability by the meter to transmit this information back to the HES, and this in turn is likely to require new registers within the meter and additions to its communications protocol.

Most serious of all is that firmware upgrades can be fatal to the system, in the sense that if they fail there is no way for the customer to recover, as there is no recovery disk. They therefore have to be very robust. At the same time, where utilities adopt an upgrade approach the optimum process, other than for minor bug fixing, is for all devices in the home to be upgraded simultaneously. This will always carry some risk, since the worst case scenario when upgrading a meter is that not only will a utility be unable to bill a customer, they may also disconnect them - necessitating a home visit to put matters right. In the worst case scenario, a utility could unwittingly disconnect a large proportion of its customer base in the course of a single system upgrade.

Issues associated with interoperability do not get easier as the communications protocol gets “smarter”. As noted above, upgrade to the firmware needs to happen across the board at one time, else utilities risk leaving individual parts of the HAN outside the smart network. SEP 2.0 provides more function and involves far more devices inside the home within its scope but this may be its undoing, since the very complexity associated with SEP 2.0 may make it impossible (or too risky) to carry out an upgrade.

That is leading to two separate solutions that may be deployed at the same time.

Many countries are opting for SEP1.x as a solution that is less likely to incur risk than the more function rich but higher risk SEP2.0.

At the same time, those countries that are staying with SEP 1.x are increasingly separating the smart metering network (SMHAN) within the home and the customer owned home area network. This simplifies the domain considerably, allowing more complex solutions to be implemented.

A further issue is a difference of perspective between the technical and commercial view of electricity supply, summarised as:

- Engineers (meter manufacturers) want standardisation and high volume
- Economists (marketers) want competition at every level in the commercial model

This has been exacerbated by the shift towards deregulated markets and the introduction of competition between various players within the supply chain. The main – often the only - form of differentiation that utilities have available to them is tariffs and customer service.

This is problematic where it begins to affect standards – as it has. For in order to support a range of pricing options, metering, and the communication standards that underpin metering, it has been required to include a wide range of alternative methods of tariffing, as well as allow for future options.

This creates another difficult choice: incorporate ALL the options specified and the product and standard becomes unwieldy, either becoming difficult to create or very expensive.
The alternative is creating a product that includes basic function only and leaving utilities to add their own more specific functions, solves these issues, but at the price of introducing new difficulties: now two different products working to the same basic specification may not work with one another. Again, the problem is manageable within a system that includes a high degree of central purchase and control but allowing for free market principles and permitting various parties along the energy chain to purchase their own preferred options for IHD’s, the problem returns.

The issue can be reduced in terms of impact by:

- Specifying ONLY those precise features that are needed
- Not specifying “nice to have” features
- Avoid non-standard solutions
- Carry out end to end testing of all components in an implementation in all possible combinations involve all key market players.

The last of these approaches is one that has been put into action by Texas who put into effect a series of end to end testing workshops known as ZigFests, as a means to bottom out all potential issues with implementations before going live.

The key learning from this discussion is the over-riding importance of standards within a deregulated market as, often, the only means of maintaining interoperability.

Divergent specifications

A further risk identified by Onzo is that the various bodies, including government, industry and consumer specification groups and regulatory bodies may tend to go in different directions. The end result of this is that the overall system may fail to deliver or even be capable of delivering as intended. Thus, according to Onzo, the UK and Australian national requirements both currently call for IHDs to display data that is not available on the meter, a requirement that is simply not deliverable.

Work is currently ongoing with members of the Consumer Energy Display Industry Group (CEDIG) in the UK to highlight these issues and bring the appropriate parties together to resolve them. The danger here is twofold, first is the obvious deployment of an impossible requirement: the second is that some suppliers and manufacturers might attempt to “fix” the problem by means of proprietary work arounds, destroying any hope of interoperability and defeating the overall objective of comprehensive end to end device management.

Cyber security, an expert view from Professor Peter Cochrane

“Cyber security is always about people rather than the actual technology. Either people are the threat themselves and those around them, or they constitute a covert insider or outsider threat. On another level some people other are dumb enough to design hardware and software that poses a risk.

Stuxnet and Flame are possibly the most sophisticated virus yet to appear on the net. Stuxnet was designed to target Iranian uranium enrichment facilities in that country. This virus targeted one specific set of controllers and contained inside knowledge about operating system. It not only got past a firewall: it actually got into centres disconnected from the network. The suspicion is therefore that it was introduced either maliciously or through carelessness: the use of a shared memory stick or printer allowed it in.

In the long run, the smart grid should be relatively more secure, since the cloud, where much of the processing will take place, is made up of different sized dynamic networks: there is no single operating system or dominant set of protocols, which makes it harder for the “bad boys" to get in and do serious damage. As analogy: a burglar breaks into a house expecting to have instant access to the homeowner’s valuables. Instead, on coming through the front door, he finds himself in a room with ten identical doors. Going through one of those, he finds another room with ten doors, and so on. The burglar is quickly lost – and isolated. The “internet of things” has much in common with this architecture: it will be an absolute maze, within which it will be easy to isolate perpetrators and slam the door behind them. In theory, it is not difficult.
to quarantine attacker software. Despite this, the rush to get into smart grid is seeing products that are weak, and known to be security weak, on the premise that they will be fixed later. Threats to individual privacy or even the threat from “kiddyhackers” are irritants. However the big threat is terror group wishing to switch off a nation’s power grid.

**The real threat** is the infiltration of power stations and vital infrastructures. If you wish to attack a country, one of the first tasks must be to bring down the power grid, leading to no transportation, logistics or banking, waste, waste disposal and food – and within a month serious widespread illness. The worry should be that in any cyber war, there would be a takedown of power stations, and this should be recognised as a national security issue. Despite this, much of the technology that supports telecoms and smart grids alike are made in China. A strategic threat analysis would suggest that this is a bad scenario. In the short to medium term, it is a safe bet to assume that viruses will enter the smart grid and propagate. Our best hope is that we will reach a point where we consider security seriously before one of these threats manifests itself in the form of serious damage.

**The real solution** is that we need to pay much more attention to the security aspects of the smart grid: real attention as opposed to lip service. It is not beyond the wit of human beings to build highly secure networks and devices. In the longer term, a solution is likely to be found in an approach that mimics human white cell protectors. We could develop intelligent agents that roam the net looking for bad pieces of software (malware) to be isolated and destroyed. Effectively, a real-time anomaly detection and immune system. That – and the decision to take security seriously – should be capable of securing the smart grid.

**Professor Peter Cochrane, entrepreneur and futurologist**
STRATEGIC ISSUES OF GRID DEVELOPMENT

In addition to the general technical issues associated with the operational aspects of building and running a smart grid are broader commercial and economic factors, issues associated with questions such as: whether the project is worth pursuing; who is most likely to benefit from the transition to smart grid; and whether the principal players in smart grid development are well suited to delivering the project.

National and Cultural differences

As background, it is worth looking at what smart grid represents and the cultural backdrop it must develop against in different parts of the world. For it is not being implemented uniformly across the globe. Differences in implementation tend to reflect economic, cultural and political preferences at the national and, in some cases (particularly within the US), state level. They also reflect difference in the current development of national grid systems and this is reflected in divergences in smart implementation.

A comparison of the features of public and private networks is set out in Table 8

<table>
<thead>
<tr>
<th>Country</th>
<th>Key Drivers</th>
<th>Smart focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>Aging T&amp;D infrastructure</td>
<td>Renewal of T&amp;D infrastructure</td>
</tr>
<tr>
<td></td>
<td>Major recent stimulus spending in response to kick start economy through recession</td>
<td>Primary focus for smart grid is on introduction of smart metering</td>
</tr>
<tr>
<td></td>
<td>Highly free market / consumer driven culture: introduction of smart grid predicated on consumer buy-in via sharing benefits of smart meter information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resistance to introduction of smart metering systems and major delays to smart programs in some states due to consumer skepticism around smart technology (security, privacy, cost-sharing)</td>
<td></td>
</tr>
<tr>
<td>China, India, Brazil</td>
<td>Rapidly developing nations</td>
<td>Creation of modern grid infrastructure</td>
</tr>
<tr>
<td></td>
<td>Infrastructure insufficient to meet requirements of current growth and industrialization programs</td>
<td>Unified “blue skies” vision of roll out of smart grid, with consumer benefits increasingly available later in the process: end user broadly viewed as passive / grateful recipient of central largesse</td>
</tr>
<tr>
<td></td>
<td>Nascent consumerism: demand for new energy products and services taking off, but consumers still relatively under-empowered versus central planning and generation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Need to link up remote rural communities to national grid</td>
<td></td>
</tr>
<tr>
<td>EU, Canada</td>
<td>Within the EU, the 20-20-20 targets: by 2020, EU countries must cut emissions of CO2 and greenhouse gases by 20 percent compared with 1990 levels, increase renewables by 20 percent and cut energy consumption by 20 percent. Renewables seen as playing a major part in this shift: significant levels of renewable generation already achieved within some countries (e.g. Germany, Spain, Ireland) Smart metering viewed as beneficial: not primary focus, as per US; but not consumer choice, either</td>
<td>Roll-out of smart metering continues on a state wide basis: consumer choice largely irrelevant Significant issues over integration of renewable and fluctuations in power supply Use of cross-border transfers to balance out highs and lows: requires cross-border grid development and control technology</td>
</tr>
<tr>
<td>Japan</td>
<td>Major shift in energy strategy post 2011 tsunami (away from nuclear, towards renewable and energy efficiency) Grid infrastructure developed in fragmented fashion by private sector: issues around transfer / balance of energy between regions Energy policy regarded as strategic adjunct to national export and world trade Focus on the automated / integrated smart house, as opposed to individual smart technologies</td>
<td>Recalibrating of energy policy towards energy efficiency and effectiveness; greater role to be played by smart technology and renewables Government / enterprise partnerships to promote Japanese standards globally in respect of smart technology</td>
</tr>
</tbody>
</table>

Source: Analyst overview
The factors identified in Table 11 are not mutually exclusive. Development of renewable energy sources is an issue within the US, with some of the world’s largest renewable generation resources for wind and solar power being situated in Texas and California respectively. At the same time, Europe’s grid infrastructure has been historically regarded as more robust than other infrastructures elsewhere in the world. However, increasing reliance on renewable and a decommissioning of nuclear reactors, particularly in Germany following the devastation of Japan’s Fukushima nuclear power plant, has led in turn to increased cross-border flows of energy as a means to balance energy supply to requirements. This, in turn, has exposed trans-European grid weaknesses and is leading to calls for upgrading of infrastructure to enable it to support a very different future energy landscape. The European focus has also been on increasing the level of renewable within the energy mix but not altogether at the expense of smart metering. Italy has led the way as an early adopter of smart metering and almost all EU nations now have in place specific targets for the implementation of smart metering.

In general terms, one view of the evolution of smart grids across the world is framed in terms of the difference between the imposition of a single, centrally inspired vision, often safeguarded or promoted by government, and a more hands off approach where the development of smart systems is left to the market. Proponents of the first approach argue that the transition to smart grid is so massive that it cannot be left to market forces to implement, while proponents of the market vision make the opposite argument, that precisely because the project is so massive, attempting to implement a single monolithic vision without consumer feedback within the loop is likely to be ineffective and inefficient.

This may be in part a false dichotomy, with central planning more appropriate to implementation of the large infrastructure projects now underway in China and other developing nations and a market led approach more appropriate to the development of consumer friendly appliances.
Utility culture and the dangers of being “first mover”

Several smart grid initiatives are currently on hold or being pushed out some way into the future. This reflects three separate but interacting factors:

Risk aversion utilities are widely recognised to be seriously conservative organisations so while there is a popular vision in circulation that sees smart grid as being a major benefit to utilities, they are also risk averse, and do not wish to commit themselves to a series of key strategic decisions unless they feel that they have some guaranteed return in respect of that decision. While this is often put forward as a criticism of the utilities, it should be born in mind that many of the risks identified are real and that the sort of investment being asked of utilities is by no means trivial. A shift to smart grid technology is likely to involve major investment in infrastructure that will need to persist for years, possibly even decades.

Uncertainty There is a large degree of uncertainty around smart grid, at every level. From straightforward questions about the optimal technology, through to the model likely to be put in place by legislators and regulatory authorities, as well as standards bodies, this in turn may affect key issues such as how utilities will be remunerated for their efforts and who owns some aspects of the infrastructure such as data. Given the size of the investment involved, it is relatively easy to be critical of utilities in these circumstances but in many instances the uncertainty is a key factor in decision making. If it is possible that legislators will enact a legal structure that makes certain smart grid technologies unfit for purpose, utilities would be very unwise to be investing before the nature of those decisions was known.

The dynamic of delay Unfortunately for operators in this area, delay itself is a decision, of sorts. Early entrants may have a head start on utilities that take their time but they pay a price for being first into the fray, they become test beds for others to take decisions after them. Developing a smart grid too early in the cycle of technological development runs the risk of embedding old and potentially obsolete technology before the major benefits begin to come on stream and this may yet turn out to be the case for Italy, one of the first - possibly even the only - country in the world to have smart enabled the majority of its energy network by 2012. While gaining much international approval for this achievement, it may yet turn out that this was a strategic error since changes to smart metering and the growing role of 4G and 5G technologies over the next few years may be less available to Italian operators. This is the counter issue, that being late into the field allows other players time to establish themselves. This is especially true around the implementation of the smart home, where a massive overlap exists between the smart home linked to a smart network and a very similar enterprise linked to home automation. The difference between the two is that while home automation projects may use much of the same equipment (smart appliances) to achieve many of the same objectives (energy cost savings, remote control of home equipment), the former relates directly to the role of the utilities and can be expected to link directly to utility objectives, while the latter has no such link and may well result in consumers putting in place technologies that deliver many of the benefits claimed by utilities for smart grids but outside the utility envelope.

Home Area Network versus Automated Home

A significant issue for utilities is how the HAN is increasingly overlapping with home and building automation systems – and what this means for the future of the integrated smart grid concept.

A HAN is an automated home system, but one that is primarily dedicated to the control of energy supply and use. At the same time, the average HAN possesses far more bandwidth than is necessary simply for that role, and so is able to take on secondary functions such as maintaining in home event detectors alarms that are able to monitor and
react to security issues (burglary, fire, etc.), medical crises and environmental emergency. A HAN is also capable of integrating to and managing other functions such as CCTV monitoring (for security of child-minding purposes), access control, cooking, heating, air conditioning and entertainment systems. A home automation system is likely to display much of the same or similar functionality. It may also be the case that a home automation system will carry out some degree of energy monitoring and control. The key difference lies not in what the two systems do, but in where they originate.

A HAN, insofar as it is used to support smart grid functionality, is either initiated by an energy provider or constructed in collaboration with one. By contrast, a home automation system may be installed by a dedicated provider possibly even at the point when a building was first constructed. Certainly, one view is that home automation functions optimally when a building was designed with that purpose in mind, as opposed to having the service grafted on afterward. In one sense, it makes little difference to the physical implementation of these systems and this is underlined by current initiatives in Japan around devising the smart home, supported by government and a range of major industrial partners. The same technology will broadly support either vision, and the Japanese “smart home” is also an intelligent or automated home. Issues arise in two respects.

**System control**

The ultimate smart grid is one in which it is envisaged that utilities will have the capacity to manage energy use within an end user domain to a greater or lesser degree. It seems inevitable that some degree of conflict will arise in this respect, for instance where a utility needs to reduce power consumption across the grid and wishes to reach out and turn off or delay operation of critical appliances within the end user setting.

This decision may be of little consequence to the end user or may be critically important and be a “choice” the end user makes and would expect some degree of compensation in return. Distinguishing between the two, particularly in a smart future where both an energy provider and an end user may exercise some degree of remote control over the appliances in a home is likely to require the establishment of an entirely new set of protocols and agreements over use.

**Consumers in the cloud**

A significant issue for utilities is that many of the key apps, in terms of control of home appliances, are already being provided to consumers either for free, or at nominal cost by a range of suppliers who are doing so because the app in some way supports their own activity. Thus, they may be appliance manufacturers seeking to upgrade consumers to smarter appliances, telecommunications companies interested in providing greater functionality for their customers, or simply companies that see developing a clever app as helping to incentivise their customer base and increase loyalty. In every case, the development and dispersal of such apps is a blow to the utility vision of supplying and controlling such function itself.

**Data ownership**

As the NIST model implies, the smart grid is itself a network of networks, each network can function adequately on its own. However, maximum benefit to the central energy provider is likely to result where that entity has access to data from all of the subsidiary domains and is able to make use of that data to manage energy use throughout the network. Where an end user has implemented an intelligent or automated home independently of the energy provider, significant information about energy use may form part of the sub-system “owned” by the end user, as opposed to a sub-system provided by the utility. Ownership of usage data is already proving a major issue in some parts of the world (particularly in some US states) it seems likely that an arrangement of this sort would make data ownership (and therefore its use for analysis and insight) subject to greater dissent.
The merger of utilities and telecoms?

A development that appears to have gone down well with consumers over the last decade or more, since the advent of more sophisticated communications options, is the “triple bundle” where telecommunications companies bundle together phone, cable and internet, allowing consumers to leverage what were once wholly independent services against each other, both for their own financial benefit (a triple package is usually more cost effective than buying the three services separately) and in order to gain added function through services that mesh neatly together.

Telecoms companies have shown considerable interest in becoming players in the smart grid, and several have been quick to put themselves forward as strategic partners to utilities seeking to develop their own smart networks. Examples of this trend include:

- AT&T providing wireless network facilities to carry smart grid traffic with SmartSynch
- Investment of $23M in Home Security, Home Energy Management start up iControl by a consortium including telecoms provider, Comcast

According to many analysts, quadruple, quintuple or even wider bundling of services makes consumer sense. These are all services containing a large commodity element to them, provided to the consumer by a remote supplier over a distribution network. Billing is related directly to quantity consumed and the same back end billing and accounting software can, with relatively minor modification, as easily be used for KWh as phone minutes.

The consumer view is favourable. A survey released in 2011 by Accenture found:

- 73% of consumers would consider buying electricity from companies other than traditional energy providers
- 22% were willing to buy from their cable or phone company
- 90% of consumers in China, South Korea and Singapore would buy from non traditional sources

Despite this, the evidence to date is that telecoms providers and utilities have been less eager to bundle their services together in any more extreme fashion though there have been a few notable exceptions.

Utility/Telecoms alliance in Australia

ActewAGL is a utility operating in the Australian Capital Territory (ACT), offering its customers up to seven services, including electricity and natural gas. The main incentive for customers is a reduction in their bills. The utility was deregulated and became subject to wider competition in 2003, although the rates it may charge for electricity remain heavily influenced by government tariffs.

Against this background, and in an effort to remain competitive, that ActewAGL in partnership with Telecom provider TransACT began to bundle the electricity, natural gas and phone services that most of their customers already had. The range of bundling options has grown steadily since 2003, with the fairly straightforward proposition that the more services consumers include in their bundle, the more money they will save.

The basic bundle that customers MUST take is three basic services, reducing bills by 3%. However, add a further four (green energy, cable, cell phone and internet) the saving rises to 25% on either their phone or electricity bill, up to a maximum of AU$500 in any one year.

Issues that ActewAGL had to deal with included:

Customer perception: a key objective of bundling was to make the customer service experience as seamless as possible, this was achieved through major investment in systems and processes

Price shock: the risk when services are bundled is that the monthly or quarterly bill will look significantly higher than customers are used to. Bills are therefore broken out by service to minimise the effect of shock

By 2010, the proportion of ActewAGL’s 135,000 customers involved in some degree of bundling had risen to c. 25%
Factors that possibly contribute to the success of this model are:

- **It is small/localised**: a larger initiative might be harder to communicate and manage, and the scope of the initiative is largely restricted to the Canberra area.

- **Consumer attitude**: Australian consumers are significantly more “green-minded” than those in the US or many parts of the rest of the world.

- **Incremental growth and “baby steps”**: the companies involved in this project did not dazzle their customers with high-level visions. Rather, they built on areas that consumers were familiar with and, as confidence grew, so they were able to expand the bundles on offer.

**Case Study: Small local initiative in the US**

NineStarConnect is a US-based bundling service formed from an alliance between Central Indiana Power, a small cooperative operating in the suburbs of Indianapolis, and a local telecom, Hancock. As can be seen from its home page, illustrated above, NineStar offers its customers a range of services including broadband/internet, video and HTV, phone and home security as well as acting as an electricity provider differentiated according to the typical profile of electricity use (Home, farm, business).

The idea began when CIP was investigating a smart meter project, Hancock was already connected via fibre to many of the 12,500 homes served by the electric utility. It occurred to senior executives at CIP that there were opportunities for further synergies. The two companies merged in early 2011, along the way having to deal with the first of many challenges, the need for the state legislature to overturn an existing law forbidding the merger of telecoms and electricity providers and questions asked about whether there was a danger, once this principle was accepted, of other alliances being agreed between much bigger players, leading to the creation of mega-corporations in the combined sectors.

NineStar had then to deal with a merger of two hitherto very different corporate cultures. A quick win was the simple merging of the separate call centre operations. In other areas, more work was needed, with cross-functional teams put together to supervise the transition process. For instance, utility managers are less likely to need to be concerned with access to a household and therefore with needing to make sure the homeowner is at home to grant access, whereas work in the cable area is more likely to require that the homeowner be present and therefore that they take time out from work in order to ensure that they are to hand.

One of the principal drivers to this merger was for both companies to grow their respective customer bases. Hancock, especially, aims to expand its fibre network by recruiting from CIP’s rapidly expanding customer base. At present, however, NineStar has yet to offer the price savings that are on offer from bundling of the kind provided by ActewAGL and despite the unified home page there is still a strong feel to the rest of the website of two disparate service providers working together but not in an altogether unified fashion.

While the partnership currently is restricted to service bundling, it is clear that it also provides a useful springboard for future strategic working by ActewAGL and TransACT on areas such as the smart grid.
One obstacle to the short term bundling of electricity and telecoms is that this takes both sides of the bargain outside their comfort zone. There is growth potential here for major players, however, there is also significant growth still to be had within their home areas where they are already familiar with the rules of the game. Thus, in March 2012, national provider of integrated telecoms solutions, Bullseye Telecom, launches one of the industry’s first business communications and network security bundles. This brought together a range of services, including Digital Voice, high definition IP phones, internet access, 3G wireless fail over, plus managed VPN, firewall, data security and PCI Assurance and several other features that have historically been put together from a range of separate providers for telephone, Internet, security and network services. That, in turn, has imposed a significant overhead, in terms of research, sourcing and selection for small to medium sized companies, so Bullseye’s solution is both broadly welcome within the market and provides Bullseye with a competitive advantage as they are providing a new service not currently available through other suppliers.

Given the size of the gap and the closeness of fit with existing Bullseye offerings, it is relatively easy for them to initiate a new bundle in this area without the risk of moving into areas such as electricity supply that they know far less about and which are likely to prove a more difficult sell to their customer base.

Case Study: Customer failure to engage

A paper by smart data specialist, Onzo, looks in some detail at the failure of many smart initiatives even to achieve limited objectives. Sweden, for instance, despite being an early adopter of smart metering and AMI has seen customer usage rise, rather than fall. In other countries and regions, the reduction in customer energy use has been marginal at best.

The key to changing customer behaviour is through customer engagement, this in turn means providing useful feedback about their energy use: experience from the UK where installation of IHD's has been widespread shows it is possible, without additional financial incentive, to achieve:

- Sustained reduction in overall energy of 8%
- Sustained shift in usage off the peak of a further 5%

A key element to this success lies in the provision of In Home Displays (IHDs) providing real time information rich feedback on customer electricity use. This, in turn, requires wireless communication between the Head End System and the IHD.

A number of issues arise here from utility culture – their “comfort zone” - and the degree to which this is at variance with what is needed to engage with customers.

Initially, the business case for a shift to AMI and smart metering was couched in terms of automated billing, theft and fraud prevention, and demand response, only more recently has this shifted towards changing consumer behaviour through customer engagement.

Different approaches have been tested by industry. The simplest and least engaging has been to use the raw consumption information (half hourly or daily reads) obtained at the Head End System (HES) to provide users with an overall daily understanding of their usage. The best known example of this is possibly the Green Button initiative in the US.

An alternative approach is to send this data to In Home Displays (IHD’s) using wireless communications technology. Historically, utilities have tried three approaches to this spreading of IHD’s:

-deploy smart meters and require/expect customers to buy their own IHDs
-
-Offer IHDs as upgrade/anti-switching incentive not to switch
-
-Provide IHD's free to all customers

The last approach has, to date, been pioneered by and largely restricted to the UK, where this step was mandated by government and over 2 millions IHD’s are now in situ. Difficulties with any of the above solutions focus on compatibility and interoperability, with consumer led solutions being most risky, in the sense that they are most likely to lead to the adoption of non-standard, non-interoperable devices.

The major issue here derives from the original and continuing conceptualisation of smart meters as revenue engine, so while much of the utility rhetoric is couched in terms of customer benefit, the implementation is very different. Customer interface, where it is considered at all, tends to be utility and retailer centric, with a focus on supporting complex time of use and block tariffs, applying financial incentives (and disincentives) in respect of certain behaviours, but does not obviously appear to change behaviours in respect of energy use.
Onzo highlight this in respect of ZigBee’s Smart Energy Profile 1.2, despite this profile running to approximately 25,000 words it does not once refer to “engagement”, while the only references to “consumer” are in respect of Critical Peak Pricing and Prepay. This reflects a major disconnect. Research suggests consumers respond well in terms of changing their energy use behaviours to well designed displays and feedback mechanisms. “Well-designed” in this context relates to maximising information provided and providing information that customers consider compelling.

In contrast, the displays being specified by most of the smart metering deployments focus on displaying complex tariffs, as opposed to attempting to engage consumers. The end result — consumers not engaged and savings not achieved — are predictable and likely to be detrimental to the roll out of smart technology as a whole.

Major customer disconnect

A key issue, highlighted in a study by Lineweber (2011) is illustrated in Figure 16. While a near majority of customers are positive about installing a smart meter, hearing about benefits from doing so only increases the favourable margin slightly. In other words, those who are convinced are convinced while those who are unconvinced now are likely to remain so until significant work has been undertaken to convince them otherwise.

![BR figure 15: Customer perceptions of the importance of potential benefits from smart meters](image-url)

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Important Benefit</th>
<th>Likely to occur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in electricity costs over the long term</td>
<td>75%</td>
<td>26%</td>
</tr>
<tr>
<td>More accurate meter reads</td>
<td>71%</td>
<td>42%</td>
</tr>
<tr>
<td>Having fewer/shorter power outages</td>
<td>65%</td>
<td>17%</td>
</tr>
<tr>
<td>Auto notification of outages that do occur</td>
<td>52%</td>
<td>33%</td>
</tr>
<tr>
<td>Access to detailed info about household energy use</td>
<td>46%</td>
<td>35%</td>
</tr>
<tr>
<td>Access to real-time info about household energy use</td>
<td>41%</td>
<td>41%</td>
</tr>
<tr>
<td>Ability to track energy use by day, week, month</td>
<td>41%</td>
<td>41%</td>
</tr>
<tr>
<td>Enable net metering</td>
<td>37%</td>
<td>23%</td>
</tr>
<tr>
<td>Easier/faster customer service</td>
<td>37%</td>
<td>32%</td>
</tr>
<tr>
<td>Info about availability of renewable generation sources</td>
<td>28%</td>
<td>23%</td>
</tr>
<tr>
<td>Ensure ability to recharge electric vehicles</td>
<td>27%</td>
<td>19%</td>
</tr>
</tbody>
</table>

Source: Versant Engerati
In addition, a growing resistance to the introduction of smart meters is manifesting itself in a number of western nations on the basis that customers are distrustful that utilities will introduce smart networks in a fashion that is genuinely for their benefit. Concerns expressed relate to issues such as security and privacy, as well as the vexed question of how economic benefits of the project will be distributed between consumers and utility companies.

Key to acceptance of the introduction of smart grid technology into the home is a requirement that consumers actually understand what is on offer. An interview based survey carried out in early 2011 and reported in Energy Policy demonstrates the gulf that currently exists between consumer understanding and reality. One finding of possible concern was that although consumers were general favourable to the concept of smart metering, no individual participating in the survey was able to describe accurately the purpose or function of a smart meter.

The Energy Policy survey highlighted a number of significant misconceptions, including:

- **Widespread confusion** of smart meters with enabling technologies such as IHD’s or smart thermostats, this is an over estimate of the benefits to be delivered by smart meters and could lead to disappointment and reaction against smart meters

- **The “big brother” concern** expressed by several interviewees was that smart meters were designed and introduced specifically to enable direct load control (shutting off appliances at peak times) or even to cut a home off altogether. This was accompanied by widespread fears expressed around loss of control

- **“Benefits now”** there was a further widespread view that the smart meter was being introduced to provide benefits for consumers “instantly” again, this suggests an over estimation of the capabilities of the smart meter and also a degree of wishful thinking. There will be benefits associated with smart technology, but the allocation of those benefits between consumer and energy suppliers has yet to be established

Underlining the lack of detailed understanding was that no participants in the survey mentioned benefits that are intended to follow from the introduction of smart metering, including a reduced risk of outages.

Also problematic was possible over optimism about what the smart grid would deliver. A number of interviewees suggested that more accurate billing, a realistic outcome from smart metering, would help utilities build trust with customers. However, this feature is not directly planned for by utilities – and more accurate billing could as easily lead to higher bills – an outcome mentioned by none of the participants.

This was a small scale survey, and therefore may not be representative of wider public opinion. It is also possible that the responses were highly influenced by a “halo view” in respect of smart technology as a whole. At the same time, Utilities and advocates of the smart grid need to beware of this gap in consumer attitudes where ignorance will lead to uninformed conclusions that may, in some circumstances, be unnecessarily opposed to smart grid expansion.
**Case study Off:Grid:Electric Integration of renewable electricity supply**

A key element of the coming smart grid is the integration of locally generated renewable energy into the electricity supply mix. However, this has not been happening in those parts of the developing world where renewable have been considered to have the greatest potential.

Off.Grid:Electric has examined the issue in depth, with particular attention paid to questions such as:

- why has local renewable generation not taken off with the 1.4 billion people who live off the grid?
- why has it not been taken up by businesses such as the mobile phone industry that operate in remote places?

Despite the fact that falling costs of renewable equipment made that option increasingly attractive to end users in both the consumer and business sector, there existed four significant barriers still to its widespread implementation and adoption:

**High Upfront Cost** the costs of renewable energy systems are almost always frontloaded into the energy cost

**Risk of Poor Quality** with few savings available, developing world customers tend to be highly risk averse when it comes to spending them. Bad experiences with, for instance, poor quality Chinese solar systems, can have a hugely negative impact on the market and willingness to buy

**Lack of Distribution** it is very difficult for energy innovations to reach the communities where they are most needed. Very few organizations operate distribution channels into these communities, while distribution costs can add dramatically to the price of items

**Lack of Service** When a renewable energy system fails, there are often no local experts able to repair the systems, making even minor problems serious.

The conclusion from this work was finding and implementing the right business model, capable both of overcoming these barriers and maximising the benefits accruing from these new energy sources, would be hugely positive for supplier and end user alike. They further concluded that the business model with the best fit would be based around “power as a service”, where customers pay for power instead of renewable energy systems.

The Off.Grid: Electric team are now working on a pilot for this approach in Tanzania.

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**Ready to go smart?**

The combination of the “size of the prize”, together with the enormity of change that is required by utilities has led to the emergence of a variety of audit tools that are designed to determine whether utilities are ready for change, or how far they have progressed.

One example of this is the Smart Grid Maturity Model (SGMM), a management tool that is claimed to help utilities

- plan their smart grid journeys
- prioritize their options
- measure their progress on the journey toward realization of a smart grid

The tool can be used to assess current state of smart grid implementation, define goals, and generate inputs into their planning and implementation processes. The SGMM comes as a product suite including:

- SGMM Model Definition
- SGMM Matrix
- SGMM Compass Assessment Survey
- SGMM Navigator Process

While it is clear that such a tool may be helpful, there is also a danger that it could lead to a false sense of re-assurance, particularly given the critique, set out in this report, that future smart grid progress is unlikely to follow the top down vision already set out by utilities and government.
The SGMM is developed “by utilities for utilities”: the model also has an excellent establishment pedigree, in the sense that it is hosted by the US Software Engineering Institute with the support of the US Department of Energy and “input from a broad array of stakeholders”. The clear danger is that this measures utility progress relative to the somewhat conservative smart vision 1.0 and fails to take account of disruptive changes elsewhere in the arena.

Economic benefits on hold

Returning to the high level case that is put by many blue skies thinkers in respect of smart grid, there are some serious issues around the level of economic benefits on offer and, in the long run, who would gain most from them.

The high level vision appears to be based on a utopian future where utilities have already implemented a single all encompassing smart grid, and this is then able to deliver electricity massively more effectively and, therefore, at rates that are sufficiently reduced so that the benefit of those reduced rates can be shared out between utilities and consumers.

Already, the reality is a little different. Starting simply with smart meters, there are questions being asked in the US (where the return for householders from AMI and smart metering ought to be the greatest) about who should pay for the equipment. In the long run, it looks likely that utilities will have to carry a large chunk of the cost of smart metering, eating into any putative profits in future.

This cost/profit issue is likely to be compounded significantly in any free market economy by a number of factors:

The cost of interoperability: as highlighted in respect of interoperability debates, there is a significant cost in terms of function where non-interoperability occurs. Yet, at the downstream end of the grid, on the consumer side of the smart meter, free market principles make it almost inevitable that in the early days, this will happen, making it harder to manage a truly smart grid – and harder to take economic benefit from it.

Active players seeking returns: the tendency, already displayed in some areas, for energy end users to identify that they are no longer passive recipients of utility company largesse but active players in a market in where energy supply and even energy pricing is increasingly up for debate. Straws in the wind here are demands by US consumers that they share in the benefits of smart grid, the infant energy markets, possibly allowing, in time, consumers to “bid” their energy savings to the optimum utility buyer, and the effect of introducing local generation that is already having an effect in terms of depressing wholesale energy prices.

DIY consumers: there is a growing tendency for consumers to do their own thing in terms of home automation, potentially leading to conflict in future over issues such as data ownership. In other words, free market principles look likely to make it harder to achieve economies through standardisation and at the same time, see a reduction in the available benefit to utilities, as consumers flex their muscle and take their own share of the economic benefits.

The issue here for western utilities is that though they may have understood that the smart grid of the future is conceptually composed of a series of independent subnetworks, they have yet to adapt to the psychological reality of that state of affairs and understand that a subnetwork controlled by players who are not utilities is just that: a subnetwork that they no longer control.

Whether a centrally controlled grid system would fare better is an altogether different question. It is unlikely to suffer quite as badly in terms of standardisation or demands to share out economic benefits. Nonetheless it may be less flexible, less adaptable, and therefore less ultimately smart than its free market counterpart.
SOURCES

This report was compiled from a range of sources including online research, an extensive search of core journals for related articles, plus interviews with key players and experts involved in the issues covered. Set out below is a list of some of the principal sources accessed in compiling this report. It is not an exhaustive list.

Academic journals

Applied energy (Elsevier)
Civil engineering
Commodities and industrials
Computer networks (Elsevier)
Electric Power systems research (Elsevier)
Electrical Power and Energy Systems (Elsevier)
Energy policy (Elsevier)
IEEE Communications magazine
IEEE Computational intelligence magazine
IEEE Consumer Electronics magazine
IEEE Industry Applications magazine
IEEE Network
IEEE Transactions on applied superconductivity
IEEE Transactions on consumer electronics
IEEE Transactions on industrial electronics
IEEE Transactions on industry applications
IEEE Transactions on instrumentation and measurement
IEEE Transactions on power delivery
IEEE Transactions on smart grid
Issues in Science and Technology
Journal of process control (Elsevier)
Proceedings of the IEEE
Renewable and Sustainable energy reviews (Elsevier)
Renewable and sustainable energy reviews (Elsevier)
Renewable energy (Elsevier)
Renewable energy focus
Science Direct (Elsevier)
SciVerse Science Direct (Elsevier)
Sustainable computing: informatics and systems (Elsevier)
Technology review
The electricity journal(Elsevier)
Utilities Policy (Elsevier)
William and Mary Law Review

General Sources

ABB research
ABI Research
www.abiresearch.com
ASAT solutions
AT&T research
Black & Veatch
Business Green
www.businessgreen.com
China Decision Makers Consultancy
www.cdmc.org.cn
Connectivity Week
www.connectivityweek.com
Electronics Weekly
www.electronicsweekly.com
Energy ICT
www.energyict.com
Forbes
Greentech Media
www.Greentechmedia.com
Grenatech
Gridtalk
Innovation Observatory
www.innovationobservatory.com
Onzo
Pike Research
www.pikersearch.com
Renewable energy
www.renewableenergymagazine.com
Scientific.net
www.scientific.net
Smart 2020
www.smart2020.org
Smart Grid Library
www.smartgridlibrary.com
Smart grid news
www.smartgridnews.com
Social science research network
www.ssrn.com
Solar Feedswww.solarfeeds.com
T&D World
www.tdworld.com
Zpryme

Plus various blogs by Christine Hertzog, independent expert, author and MD, Smart Grid Library

Government

Reports and statements by various government agencies, including US DOE, UK DECC, EU Energy Commission, plus counterparts in Germany, France, Japan, China

Oak Ridge National Laboratory
Green Button
www.greenbuttondata.org

Standards organisations

CEN
www.cen.eu/
CENELEC
www.cenelec.eu
CPNI
www.cpni.gov.uk
EPRI/Intelligrid
intelligrid.epri.com
ETSI
www.etsi.org
NIST
www.nist.gov

Suppliers

Cap Gemini
Commonwealth Edison
GE
HP
IBM
Itron
Nuri Telecom
Oracle
Qualcomm
Siemens
Silver Spring
Smart Energy Illinois
Smartsynch
Trilliant
Versant
Zigbee Alliance