# A PHASED CITY ENERGY PLATFORM FOR NETWORKED PRECINCT BUILDINGS IN THE CONTEXT OF MANAGEMENT INFORMATION SYSTEMS AND SMART GRIDS

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## Abstract

*This research investigates the context and advantages of energy sharing between networked precinct buildings in the context of pre-existing urban stock. The paper considers whether the sharing of patterns of use and knowledge of buildings' spatial, architectural and energy-related components can act as a phased prequel to energy sharing and provide a 'knowledge pool' to facilitate changes to the technological mix in a building, as well as modes of usage. In the context of energy use and conservation it is well understood that resource sharing can be advantageous across multiple buildings, but less is known about the potential benefits of energy knowledge sharing across buildings. The sharing of energy data across buildings with different owners/operators but offers the advantages of balancing demand across facilities, right-sizing technology components, intelligent planning and future usage pooling – particularly for smart buildings with energy storage and generation capacity. With a focus on the Australian context, this research investigation examines how an initial energy information platform phase could benefit a range of building stakeholders and be lead to a subsequent energy sharing phase. The author argues that there is value in a city energy information platform as a prequel to smart grids and subsequently as a complement to smart grids.*

**Keywords:** building energy management; building information management; information aesthetics; green buildings; urban sustainability

## INTRODUCTION

This research investigates the advantages of energy knowledge sharing between public, institutional and commercial buildings in the context of pre-existing urban stock. The purpose is to mitigate the energy-related environmental impact through the 3 primary areas noted in International Energy Agency Annex 31 (IEA, 2001) for Life Cycle Analysis (LCA), namely: energy and ventilation, and passive systems. There is significant demand: for example 75% of firms in the US consider that the driver for 'green building' is increased energy cost and view sustainability as consistent with their profit mission (McGraw-Hill, 2009).

The hypothesis of the research is that the sharing of patterns of use and knowledge of buildings' spatial, architectural and energy-related components could act as a phased prequel to energy sharing and provide a 'knowledge pool' to facilitate changes to the technological mix in a building, as well as modes of usage. The argument for phasing the energy platform in two stages is that a precinct of smart buildings can initially be established prior to a smart grid. When smart grids are available, the platform can then take advantage of the energy sharing options.

With a focus on the Australian context, this research investigation examines how an energy information platform tool could leverage real-time 'information aesthetics' techniques in visual interfaces for use by a range of building stakeholders.

Several contextual and developmental aspects are critical to the described energy phasing options for a precinct. These are: 1) the future direction of infrastructure, 2) smart buildings and energy efficiency, and 3) management information systems. Each of these is discussed in the paper. Following the consideration of an energy platform, the author concludes that there is value in a city energy information platform as a prequel to smart grids, and subsequently for the platform to become a core building feature.

***Energy use in the Australian context***

Australia has the highest per capita level of greenhouse gas emissions in the world (Turton, 2004). In the context of this situation, three objectives of this investigation were to explore unique ways of using city buildings to provide: (1) a better stakeholder understanding of energy use in a city and a sense of the scale of this energy use, (2) actionable advice to allow building stakeholders to reduce their energy use, and (3) a digital enterprise platform for Australian energy saving and alternative energy companies to get better reach.

There is a pressing need to achieve better energy management in Australia. Better energy management is a key component offered by the energy saving industry. Because of Australia's heavy reliance on coal-based energy which in 2001 contributed to 72% of $CO_2$ emissions (Saddler et al, 2004), the only short term approach to $CO_2$ reduction is to encourage conservation, which is typically driven by economic benefits and/or legislation – there may also be an element of corporate social responsibility and customer pressure. The researcher argues that making the energy reduction issue visible and actionable by stakeholders will get a much broader engagement across the city of Sydney. Building owners and operators will also see how their own energy use relates to other buildings, and finally there is evidence that social networking can encourage positive peer behaviour through example and information exchange.

Although there have been efforts to establish new sustainable cities globally, no such project has reached fruition. For example, the planned sustainable city Dongtan in China has been a notable failure that lacked an execution (Larson, 2009) despite a strong consulting team that included Arup. Sustainability work on new cities is important; however the vast majority of urban buildings is composed of existing historical stock. This puts the emphasis on ways of improving current cities.

In Australia, energy use per capita continues to increase. Between 1990-91 and 1998-99 Australia's total energy consumption increased by 23% (ABS, 2002). Over the same period, population increased by just under 10%. Recent figures show that an increase trend is still underway (DEWHA, 2004). This is not inevitable and good environmental policy and legislation can make a big difference: since 1974 California has held its energy use per capita constant, while the USA as a whole has leapt 50% (Mufson, 2007).

## FUTURE OF INFRASTRUCTURE

The services infrastructure of a city comprises power and water distribution, gas, telecommunications and the internet, along with waste management. There are two main challenges in the case of power management: firstly ensuring that the supply is closely matched to demand and secondly to make sure that the distribution supply allows power to be rerouted when parts of the network fail. In practice, to avoid power outages traditional power distribution requires power stations to generate excess electricity and this can rarely be stored. The inefficiencies of power distribution in the route from a power station via grid and substations to the customer due to losses are significant at 6.9% in the USA during 2008 (EIA, 2009). Traditionally, power management is based on analysing historical data to predict demand. The result is a supply-driven system. The concept of a smart grid is to create a demand-response system, effectively making the power supplied demand-driven. Through this approach, it is estimated that smart grid technologies in the USA can reduce peak demand by 5% in 2030 (EPRI, 2008). Additionally, smart meters allow other savings to be made by shifting customer usage with pricing patterns that are both responsive and clearly communicated.

The Economist Magazine's special report on smart systems (Economist, 2010) writes that:

*'The physical and the virtual worlds are converging, thanks to the proliferation of sensors, ubiquitous wireless networks and clever analytics software. Increasingly there will be two interconnected worlds: the real one and the digital reflection.. and "Smart cities", in which more and more systems are connected, are multiplying.. the number of [smart] applications is vast. Yet the most promising field for now may be physical infrastructures.'*

In terms of operation, smart grids use digital technology to achieve a two-way communication to control appliances at the user end of the distribution. The digital technology is an overlay to the existing power distribution that is interfaced into it with smart meters, also know as net meters, at the customer end. Smart grids allow consumers and other users to respond to changes in grid conditions in a way that has previously been the preserve of very large users or utilities. Smart grids also facilitate economically-intelligent generation and supply of power back into the grid from users that can create excess power from their own generating facilities such as renewables, cogen or trigen. Customers in 57 countries (Global Feed in Tariffs, 2010) are able to supply back into the grid – some for a number of years. This feed-in system predominantly pioneered by Germany in 1991 with the Electricity Feed Law (Federal Law Gazette, 1990). A more recent example is the UK's Renewable Obligation Certificates or ROC's, available since 2002 (Ofgem, 2011) for renewable customer generation of over 500kWh annually. This requires three devices: a generation meter to measure system output, an export meter to register the amount of electricity fed into the grid, and an inverter to synchronise voltage variations with the grid. With a smart grid and varying pricing schedules, these customers can benefit economically by fine-tuning when to use power, when to provide it to the grid and when to draw it from the grid. The ROC system incentivises providers to buy back renewable power from customers by setting a percentage of renewable power that the provider must source, currently 11.1% for 2010/11, with the penalty of paying proportionally into a fund when obligations are not met.

The dominant interest in smart grids is for power distribution, but they are also suited to water and gas supply. Although these utilities can get less value from a real-time demand-response because they don't suffer from supply-driven losses, they can benefit from demand-response control in the context of pricing and user control based on availability and demand. In advance of smart grids many governments have introduced legislation to incentivise renewables, along with retrofit programmes for insulation in buildings.

Smart grid development is gaining momentum. The American Recovery and Reinvestment Act provides $4.5 billion for smart grid demonstration projects (ARRA, 2009). In Australia, the government is providing $100M for a demonstration project called Smart Grid, Smart City (Smart Grid Australia, 2010). Based in the city of Newcastle, New South Wales, this will be the first commercial smart grid in Australia and covers power and water. The consortium comprises EnergyAustralia, IBM Australia, GE Energy Australia, AGL Energy, Sydney Water, Hunter Water Australia, and Newcastle City Council.

Better distribution and smart grids do not overcome legislative issues that can remove incentives for users to return power to a distribution system. Good energy tariffs in Germany have resulted in 200 time the solar production of Australia even though as a country it has half the amount of sunshine.

Australia does have a Renewable Energy Certificate or REC scheme that is not unlike the UK's ROC. However, the underlying feed-in tariff system is problematic. There is no national Australian feed-in tariff programme (Energy Matters, 2010) and although there are feed-in tariffs for a number of grid-connected renewable electricity generation sources, the rules vary between states and there are significant limits on the amount of power that will be bought back into the grid: at renewable premium tariff rates for photovoltaic solar only up to 5kW in Victoria, 10kW in New South Wales, and limited to solar panels in South Australia. Standard tariff rates are available for increased power feed-in in Victoria for up to 100kW from a range of renewables (State Government Victoria, 2010).

There is an issue for commercial building operators in Australia who wish to supply significant power back into the utility distribution system either to sell, for subsequent later use, or for use in another city precinct where a customer may have other buildings that can use the power at that time. This is because in many cases the energy utility company only has to buy a small amount of power at a premium tariff, some more at a standard tariff, but most power at wholesale prices. The utility provider is then able to sell it back to the customer at retail prices, representing a loss for the customer. Hence, there is a significant financial loss involved even if the power is moving only 100 metres between buildings.

It is worth noting that smart meters are required in Australia for feed-in of renewable power. Although these are installed on an ad hoc basis for domestic renewable suppliers, the aim is that the full roll out of smart meters will have been completed by the state of Victoria in 2012 and by New South Wales in 2017. The smart meters provide time based metering with 30 minutes update intervals.

***Advanced power distribution and transmission***

A promising area that relates to energy saving with smart grids is technologies for advanced power distribution and transmission. Power transmission from power stations to cities normally use three-phase alternating current (AC) at 110kV, but can run over long distances or underwater with high-voltage direct current (HVDC). The choice of system is based on keeping energy losses to a minimum. The original city-based power distribution used direct current (DC), and was set up by Thomas Edison in New York in the 1880's. AC replaced DC soon afterwards because it offered reduced energy losses. More recently, the development of high temperature superconductors may make DC distribution in cities viable once more for high load areas and can halve losses, even though the cables need cooling with liquid nitrogen or hydrogen. Hydra, a pilot project by Consolidated Edison and American Superconductor was recently launched in New York to connect two substations together

(New Scientist Tech & Reuters, 2007). Although this technology is not yet developed for low-load areas, the use of DC could result in 30% savings by eliminating losses that are caused by the mismatch between AC supply and electrical devices which are generally DC (EPRI, 2011).

## SMART BUILDINGS AND ENERGY EFFICIENCY

The Lawrence Berkeley National Laboratory (LBNL, 2009) has created a smart building model for the US Government. In this, there are three strategies: enterprise operations, systems integration, and a high performance building core. The strategies give rise to enhanced operational effectiveness, enhanced productivity and improved tenant satisfaction, and energy efficiency.

Siemens is one of the world's leading integrated building services solutions providers of energy controls for buildings (Economist, 2010). The company bundles products and services together and offers guaranteed 'energy performance contracts' . Siemens defines smart buildings as:

*'A safe, secure, reliable building, campus, manufacturing, or production facility that efficiently and productively consumes purchased or created onsite, electricity, natural gas, renewable, other fuels, and water, in a integrated, holistically planned and day-to-day executed, environmentally friendly strategy, from its initial green field design, through construction, migration, modernization, until retirement/demolition, that provides a acceptable return-on-investment.'* (sugay, 2010).

How do these definitions of smart buildings compare with sustainable buildings? The International Energy Agency defines sustainable buildings as:

'*Those buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings and the broader regional and global setting.*' (IAE, 2001).

The definitions of a smart building and a sustainable building have significant overlap when it comes to energy efficiency. Furthermore, given that 40% of the world's energy is consumed by buildings (IEA, 2002), smart buildings have the capacity to contribute significantly to sustainability.

## MANAGEMENT INFORMATION SYSTEMS

The collection of information technologies that the construction industry can now take advantage of for building design and operation come under the umbrella of Management Information Systems (MIS). Recently a top-level, human-collaborative component of MIS has been identified as Integrated Project Delivery (IPD). IPD can be used for new build but it can also be used for retrofitting and refurbishment projects. IPD is defined by the American Institute of Architects as:

'*A collaborative alliance of people, systems, business structures and practices into a process that harnesses the talents and insights of all participants to optimize project results, increase* *value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction.*' (AIA, 2007).

IPD typically uses collaborative software and internet-based software on demand, avoiding firewall issues between users. The value of collaborative working through web methods for improved efficiency and innovative working is highlighted by Taspscott and Williams in MacroWikinomics (Taspscott & Williams, 2010), and they quote Google CEO Eric Schmidt:

*'Organisations that learn how to participate in (networks) can access a greater diversity of thought and talent than they could ever hope to marshall internally. Collaborative innovation is now an essential skill, as important as budgeting, R&D, and planning.'*

Building Information Modelling (BIM) can be used in conjunction with IPD to offer increased communication and team efficiencies. For an advanced smart building project execution, the 3D model and building component data held in a BIM system can be used in conjunction with a Building Management System (BMS) or a Building Energy Management system (BEM) to operate the building. These systems can in turn integrate with Distribution Management Systems (DMS) for greater running efficiencies at a precinct or citywide scale.

### *Information aesthetics*

The information technologies that comprise MIS have numerous human-computer interfaces (HCI – also known as human-computer interaction). Information aesthetics is an important dimension of HCI and hence MIS. Information aesthetics relates to the visualization and communication of information numerically, visually or symbolically for a computer system or application user.

Tractinsky, N. (2004) sets out three reasons why information aesthetics is relevant to information technology: 1) for many users, it is the critical aspect of interaction; 2) our evaluations of the environment are primarily visual, and the environment becomes increasingly replete with information technology; 3) aesthetics satisfies basic human needs which are increasingly supplied by information technology. Tractinsky also describes five categories of variable that exist within an information aesthetic framework: design characteristics, aesthetic processes, aesthetic evaluations of IT, outcome variables, and moderating variables. These variables collectively define the impact that information aesthetics has on user behaviour.

The positive benefits on decision making through affect – which is an aesthetic response type – in complex situations has been demonstrated (Isen, 2001). There is also research that highlights the significance of graphics in managerial decision making (Jarvenpaa & Dickson, 1988), as well as the user's acceptance and intention to use information technology (Davis, 1989).

## ENERGY PLATFORM FOR A NETWORKED PRECINCT

In the context of energy use and conservation it is well understood that resource sharing can be advantageous across multiple buildings, but less is known about the potential benefits of *energy knowledge sharing* across buildings. Such knowledge relates to patterns of energy use based on: core 24/7 activities, seasonal cycles, and irregular events, the physical characteristics of a given building, along with the mechanical, lighting and services systems, and external environmental data such as location and orientation. Effective decision-making environmental tools should allow a user of such a system to evolve solutions as well as understanding the problems (Williamson, 2003), and users should be able to explore 'what if' scenarios to investigate the impact of changes, and where those changes offer the best return when compared with a range of metrics.

Under the umbrella of MIS, retrofittable Energy Management Control and Information Systems (EMCIS) running applications such as the Siemens InfoCentre Suite® effectively inform where efficiencies can be made (Yee, 2004). Consequent upgrade options for individual buildings can follow, for example in terms of financial and/or $CO_2$ cost-benefit analyses. Upgrades of existing buildings can take place in many ways. These include: insulation, more efficient HVAC, heat-recovery, natural ventilation, building-integrated renewable energy devices, architectural components, passive solar architecture and spatial design. Additionally, a building or group of buildings within a single organisation can be improved in a site-wide context by systems such as trigeneration combined cooling, heating and power generation. These approaches offer significant improvements in energy use; the question is whether knowledge sharing can extract further notable savings. The sharing of energy data across buildings with different owners/operators is atypical, but offers the advantages of balancing demand across facilities, right-sizing technology components, intelligent planning and device usage pooling – particularly for smart buildings with energy storage and generation capacity.

The first phase of a planned city energy information platform for networked precinct buildings for Sydney, Australia, would be a process tool to facilitate such efficiencies. The visualisation components of the tool will be user-centered, but could also include a real-time public viewing system for energy awareness that can be used in building lobbies and public places.

The choice of a precinct is to allow several buildings to be part of the investigation, thereby differentiating from a MIS for a single building. Furthermore, the precinct can then be upgraded to be part of a smart grid within the confines of the precinct, or as part of a city-wide smart grid. This again offers a phasing route, on the basis that fully functional citywide smart grids are a number of year away. The city infrastructure has been discussed and this has a critical impact on the extent to which precinct-wide energy management is possible, as well as integration into a city's energy management.

For the phases of the energy platform to be successful, the measurement of where energy losses occur within the precinct buildings is vital, as opposed to simply the energy use. This requires extensive use of sensors and monitoring at a very granular level. This is where the EMCIS technology comes into play. The energy platform MIS should also permit the iterative development of the best possible associated information aesthetics through a user-centred design method (ISO 13407: Human-centered design process).

Six important considerations relating to the energy platform development are:

*Stakeholder engagement*: the demand-side stakeholders in a proposed energy platform would be developers, operators, tenants, city-wide authorities. The supply-side stakeholders would be systems suppliers and integrators, consultants, energy companies.

*System and service design*: energy use, energy prediction, energy efficiency, environmental responsiveness to location, knowledge sharing, information aesthetics, public visualization, internet technology.

*Understanding retrofit hierarchy (listed as easy to hard)*: awareness, training, retrofit, smart grid, urban rebuild, new build (the typical focus on new build makes the least contribution).

*Facilitation*: visualising and communicating to stakeholders, modeling, integrated energy technologies, knowledge bank, new power management methods.

*Economic benefits*: Australia's National Objectives, competitive advantage for industry partners, understanding of 3, 5, 10+ years on financing and environmental benefit.

*Strategic questions*: what components are missing or needed to achieve it? What are the benefits of products, systems, services? What is the sensitivity of the options - value and effort assessment? Where are the technology gaps, ie: where is there is demand? What are the barriers to demand?

Stakeholder participants need to supply data from themselves and their energy providers, to allow the platform to model and visualize existing energy flows and usage in their buildings at a macro scale and relate this data to environmental climatic change and time cycles. A user platform and information architecture must be established, running the system using live data with real time stakeholder control. Data visualization nodes would be established in buildings and possibly for a public smart phone 'app'. A prototype platform comprises hardware, network and software for user testing and revisions to interface and functionality with prototypes located in each participant's building. During the location of the device, as well as measuring energy use, it would record data such as on energy information download use, collaborative aspects, and frequency of use of the device.

## CONCLUSION

Over the last 20 years, major efficiency improvements in manufacture and supply among businesses in developed countries has come from computerised supply chain management – accelerated by uptake of web-based processes and Systems, Applications and Products (SAP). These effectively relate to efficient and effective use of information to streamline and re-organise functional physical processes that are already in place. In other words, the improvements are knowledge-based.

Networking now provides an opportunity for building efficiency: much of the physical infrastructure of existing building stock has to remain for economic reasons, and the vast majority of Australia's major city buildings are more than 5 years old. However, the continuous use of usage information to extract efficiencies, coupled with retrofitting, can produce energy improvements for existing buildings along with new build.

By setting out the context and future developments in the built environment, the paper has shown that there is value in a city energy information platform for networked public and commercial buildings as a process tool to facilitate energy efficiencies. The paper has set out the scoping for a program that would include site experiments and prototype evaluation in Sydney, Australia, planned during 2012-14 in collaboration with [name] corporation. The energy information platform tool envisaged would utilise the latest real-time information aesthetics techniques in visual interfaces for use by the range of building stakeholders, as well providing a web-based viewing system for energy awareness that can be used in building lobbies, public places, or on the web.

Smart cities can be constructed from scratch and these are now emerging. The most notable examples under construction listed by the Economist (Economist, 2010) are: Masdar in Abu Dhabi using Siemens technology for 40,000 people and built on a raised platform with all services below; Songdo City near Seoul for 65,000 people with fully wired building devices by Cisco; PlanIT Valley near Porto in Portugal for 150,000 people using prefabricated parts with built-in urban IT infrastructure. While these new smart cities may point the way to the future of construction, with the bulk of cities already built the emphasis for many generations will be on retrofitting or replacing existing infrastructure.

Ultimately, smart buildings are needed to provide all the data for effective use of a smart grid. But as a prequel to the smart grid, smart buildings can provide energy savings now and also share information to help owners, occupants and operators to improve energy efficiency. As such, there is value in developing such a phased energy platform. The long term goal would be to provide energy saving across the city, encouraging businesses and raising the 'digital hub' profile of Sydney. The project could be scaled to other cities in Australia with an end goal to help meet Australia's national $CO_2$ targets over time.

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## REFERENCES

ABS. (2002). *Year Book*, Australian Bureau of Statistics, Australian Government; Australia.

AIA. (2007). Integrated Project Delivery - A Working Definition. *American Institute of Architects California Council May 15, 2007*; USA.

ARRA. (2009). *American Recovery and Reinvestment Act of 2009*, Senate and House of Representatives of the United States of America in Congress; USA.

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use and User Acceptance of Information Technology. *MIS Quarterly* (13), September 1989, pp. 319-339.

DEWHA. (2004). *Data* for 1997-2004. Department of Environment, Water Heritage and the Arts, Australian Government; Australia

Economist Magazine. (2010). *A giant awakens*. September 9th 2010.

Economist Magazine. (2010). It's a smart world. *Special report on smart systems*. November 4th 2010.

Economist Magazine. (2010). Living on a platform. *Special report on smart systems*. November 4th 2010.

Energy Matters. (2010). www.energymatters.com.au/government-rebates/feedintariff.php ; last accessed 20th February 2011; Australia.

EPRI. (2008). *The Green Grid, Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid*, 1016905, June 2008. Electric Power Research Institute, Palo Alto, California.

EPRI. (2011). *E-Merge Alliance*, Electrical Power Research Institute; http://my.epri.com ; last accessed 22nd February 2011. Palo Alto, California.

Federal Law Gazette. (1990). Electricity Feed Law; Act on Feeding Renewable Energies into the Grid of 7 December 1990; *Federal Law Gazette I p. 2663*, last amended by article 3 of the Act of 24 April 1998 (Federal Law Gazette I p. 730, 734); Germany.

Global Feed in Tariffs. (2010). www.globalfeedintariffs.com/global-feed-in-tariffs ; last accessed 20th February 2011; UK.

IEA. (2001). Sustainable Buildings: A Summary of Policy in 16 OECD Member Countries and the European Commission, *Energy Conservation in Buildings & Community Systems Programme* (ECBCS); International Energy Agency.

IEA. (2001). Energy-Related Environmental Impact of Buildings, IEA, *Energy Conservation in Buildings & Community Systems Programme* (ECBCS); Annex 31, International Energy Agency.

IEA. (2002). *Building energy consumption on a worldwide Basis*. International Energy Association.

EIA. (2009). *An Updated Annual Energy Outlook 2009 Reference Case Reflecting Provisions of the American Recovery and Reinvestment Act and Recent Changes in the Economic Outlook*; Report #: SR-OIAF/2009-03; US Energy Information Administration.

Isen, A. M. (2001) An Influence of Positive Affect on Decision Making in Complex Situations: Theoretical Issues with Practical Implications, *Journal of Consumer Psychology* (11:2), 2001, pp. 75-85.

Jarvenpaa, S. L., and Dickson, G. W. (1988). Graphics and Managerial Decision Making: Research Based Guidelines. *Communications of the ACM* (31:6), June 1988, 764-774.

Larson, C. (2009). China's Grand Plans for Eco-Cities Now Lie Abandoned. Environment 360. *Publication of the Yale School of Forrestry & Environmental studies*; http://e360.yale.edu/content/feature.msp?id=2138 ; last access 14th April 2011; USA.

LBNL. (2009). *Smart Buildings: Business Case and Action Plan*. Lawrence Berkeley National Laboratory for the Government Service Agency of the US Federal Government; USA.

McGraw-Hill. (2009). *Greening of Corporate America, the pathway to sustainability – from strategy to action*, McGraw-Hill Construction for Siemens Industry Inc.

Mufson, S. (2007). In Energy Conservation, California see the light. *Washington Post*, February 17 2007; USA.

New Scientist Tech and Reuters. (2007). *Superconducting power line to shore up New York grid*; http://www.newscientist.com/article/dn11907-superconducting-power-line-to-shore-up-new-york-grid.html ; last accessed 22nd February 2011.

Ofgem. (2011). *Renewables Obligation*. www.ofgem.gov.uk/Sustainability/Environment/RenewablObl/Pages/RenewablObl.aspx ; last accessed 20th February 2011; Office of the Gas and Electricity Markets; UK.

Saddler, H., Diesendorf, M. and Denniss, R. (2004). *A Clean Energy Future for Australia*, a study by Energy Strategies for the Clean Energy Group, WWF Australia.

Smart Grid Australia. (2010). www.smartgridaustralia.com.au ; last accessed 20th February 2011.

State Government Victoria. (2010). *DPI criteria for the assessment of fair and reasonable feed-in tariff offers / DPI criteria for the assessment of premium solar feed-in tariff offers*; Department of Primary Industries, Victoria, Australia.

Sugay, E. (2010). Greening the Building, Current Practice and Trends. *Siemens Energy Efficiency Workshop*; conference presentation at the University of Technology; Sydney, Australia.

Taspscott, D. and Williams, A.D. (2010). *Macrowikinomics: rebooting business and the world*. Portfolio, Penguin USA.

Tractinsky, N. (2004). Toward the study of aesthetics in information technology. *Twenty-Fifth International Conference on Information Systems*; Washington DC; USA.

Turton, H. (2004). Greenhouse gas emissions in industrialised countries – where does Australia stand? *Discussion Paper Number 66*, The Australia Institute; ISSN 1322-5421. Australia

Williamson, T., Radford, A. and Bennetts, H. (2003). *Understanding sustainable architecture*, Spon Press; London, New York.

Yee, G. Webster, T. (2004). Trends in Energy Management Technology - Part 3: *State of Practice of Energy Management, Control, and Information Systems*, Lawrence Berkeley National Laboratory.