Review of Storage Options for Grid Connected PV within Australia

Authors

Craig Froome[1], Paul Meredith[2]

[1] School of Chemical Engineering, The University of Queensland, Brisbane 4072, Australia

Email: c.froome@uq.edu.au Phone +61 7 3346 8735

[2] Centre for Organic Photonics and Electronics, School of Physics and Mathematics, The University of Queensland, Brisbane, 4072, Australia

ABSTRACT

This paper reviews the options available and recent progress within Australia's energy storage industry and the role they will play within the solar sector. It will also outline the research proposed and benefits to the solar sector as a whole.

As part of The University of Queensland's 1.2 MW PV Array Project, storage options are now being considered to model peak load shifting and matching demand vs. Production from the solar array. Part of this array is being constructed on two identical car park structures located adjacent to each other. It is proposed that storage be added to one array whilst the other will feed directly back into the grid. Various studies will then be undertaken to determine how this storage can be best utilised in conjunction with the PV generation.

Preliminary studies have indicated that storage will help overcome the current barriers relating to intermittency and that further cost savings through reduced distribution charges will further accelerate the deployment of solar technologies. A review of technologies available, particularly those on the Australian market has been undertaken to determine the best option for this project. Whilst decisions have been reached in relation to appropriate technologies, further research needs to be undertaken to quantify cost savings and deployment rates.

Keywords – Renewable Energy, Energy Storage, Solar Energy, Energy Policy

INTRODUCTION

Australia is an energy resource rich country, with our solar resources being greater than those in countries with high rates of PV deployment. Recent Government policy, both at State and Federal level is aimed at resolving questions as to how these resources can effectively be exploited and help meet the existing renewable energy portfolio standard of 20% by 2020.

Solar, like wind, is an intermittent resource which is further complicated by the fact that different areas within the Australian distribution network have different peak demand periods. In some locations, such as Townsville's Magnetic Island, the peak demand may not arise until 6:00pm, being outside the generating period for PV technologies. Historically most renewable energy research relating to networks has focussed on generation and integration issues but as deployment rates increase we are seeing a shift to researching the benefits of embedded energy storage systems as a means to creating 'dispatchable solar power'.

The energy storage industry within Australia is still fairly immature with only a small number of distributors and even smaller number of manufacturers or those looking at ongoing research and development activities. Many of the larger international companies have shown little interest due to the current size of the market within Australia.

The distribution network providers are now starting to show some interest as through both the Renewable Energy target and state based feed-in tariffs for PV, deployment rates are increasing at a steady rate. The questions now arising are centred around how to best use the energy generated.

Many countries are establishing ambitious renewable energy portfolio targets similar to Australia's *Renewable Energy Target* (RET), requiring a portfolio target of 20% by 2020. With the most mature technologies being intermittent in nature, reaching a target in excess of 15% will not be possible without storage (Hall, 2008), however storage options are limited, particularly in Australia where the market is relatively small.

The University of Queensland (UQ) is deploying a 1.2 MW Photovoltaic (PV) array at the St Lucia Campus looking at not only energy generation and reduction of its carbon footprint, but also looking at building on research and teaching opportunities within the renewable energy sector. The ability to model the advantages of energy storage under a range of scenarios within this array provides a number of opportunities.

Energy storage options exist, however determining what is the best option is dependent upon the stored energy use. With government policy requiring 20% renewable energy within our electricity generation portfolio by 2020 and the majority of commercially viable renewable technologies all having an intermittent nature, energy storage issues will receive greater attention in the immediate future. Whilst the grid has been able to absorb the level of renewable technologies deployed to date, grid instability would require storage once those levels approach the 20% target currently legislated (Lee and Gushee, 2010). Distribution companies, have indicated that they believe research is needed in relation to storage, particularly in peak load shifting and matching demand vs. Production from solar. These areas provide the greatest opportunities from a demand management point of view and research in this area is lacking on an international basis.

Although only briefly considered as part of the current research, there has been some studies undertaken that indicate that shifting any part of a load from peak to off-peak has significant network benefits by way of reduced transmission and distribution losses (Nourai et al., 2008).

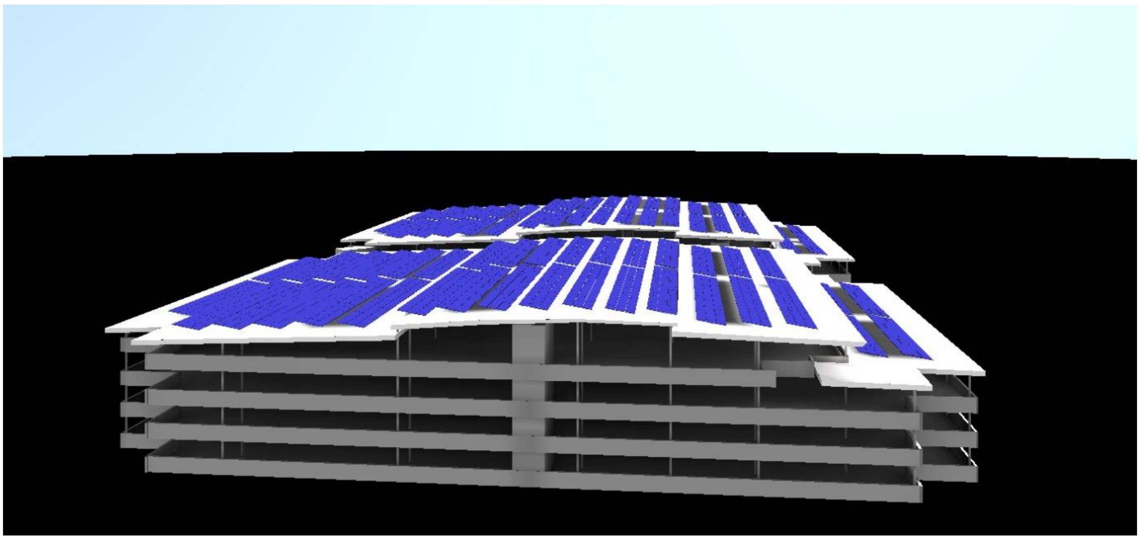
This paper focuses on the current technologies available and the options for deployment in a large-scale PV research array, such as that being deployed at UQ.

PROJECT

The technologies that are currently being deployed on the UQ PV array are focussing on electricity generation from renewable resources, initially with 1.2 MW of photovoltaic flat panel modules supplied by Trina Solar and installed by Ingenero. With the introduction of battery storage during phase two of the project we will be able to model the effect that storage has on both the reduction on intermittency factors and reduction on peak demand through load shifting. Agreement has been reached with RedFlow Batteries to install a 200kW zinc-bromine battery system (RedFlow 200 Model) which can deliver 400kWh of energy.

The two multi-level car park buildings are identical in size and construction and will both have identical arrays in size and layout as shown in Figure 1. When the project progresses to phase 2 in the second quarter of 2011, battery storage will be added to the western array only and a number of scenarios will be modelled looking at various load shifting options and the effect that this may have on the peak load and overall efficiency of the system. The ability to model two identical large-scale arrays under identical climatic conditions, one with storage and the other without, will provide considerable research data that is not currently available.

Figure 1 - Car Park Array Layout



Source: The University of Queensland

Given the size of the array it will contribute to approximately 6% of the St Lucia Campus peak power demand. This will provide a good base to model the effects of the introduction of a large-scale renewable energy generator within a distribution network. Whilst the technology itself is not new or innovative, the manner of deployment within a micro-grid and the benefits that may be obtained on the larger distribution network are still to be quantified. The fact that being on a car-park structure, with the majority of generation being exported back into the micro-grid will also provide relevant data.

Significant penetration of solar and other renewable energy sources into the national grid will highlight a number of operational concerns over maintaining system power balance. With the proliferation of large scale solar penetration into the grid, electricity networks will become two-way power flow systems. Sudden changes in weather conditions can cause a big power fluctuation within several seconds. Because the conventional generation has to be uncommitted to allow usage of solar and other energy sources, the sudden power deficit may not be easy to compensate quickly. This may result in power system instability and poor power quality problems having an impact on operating reserve, imbalance in energy, and voltage and frequency regulation of the grid. Therefore, these technical issues need to be addressed within the existing distribution network systems. Research in this area focuses on comprehensive power system stability issues that will arise due to massive solar and other renewable energy source integration (micro-grid level also). This includes the study of voltage regulation and development of control methods and compensation techniques to overcome any instability issues. Analysis of frequency regulation, spinning reserve and investigation of advanced islanding monitoring and control schemes due to faults in the existing protection systems is also under investigation. Existing and planned UQ research projects will help the distribution utilities to redesign the existing distribution network and provide timely solutions to customers and also help maintain the security of the grid. These issues are uppermost in many utility-scale and network providers' minds and this extensive power system engineering program has immediate and clear synergies with implementing solar research projects.

AVAILABLE TECHNOLOGIES

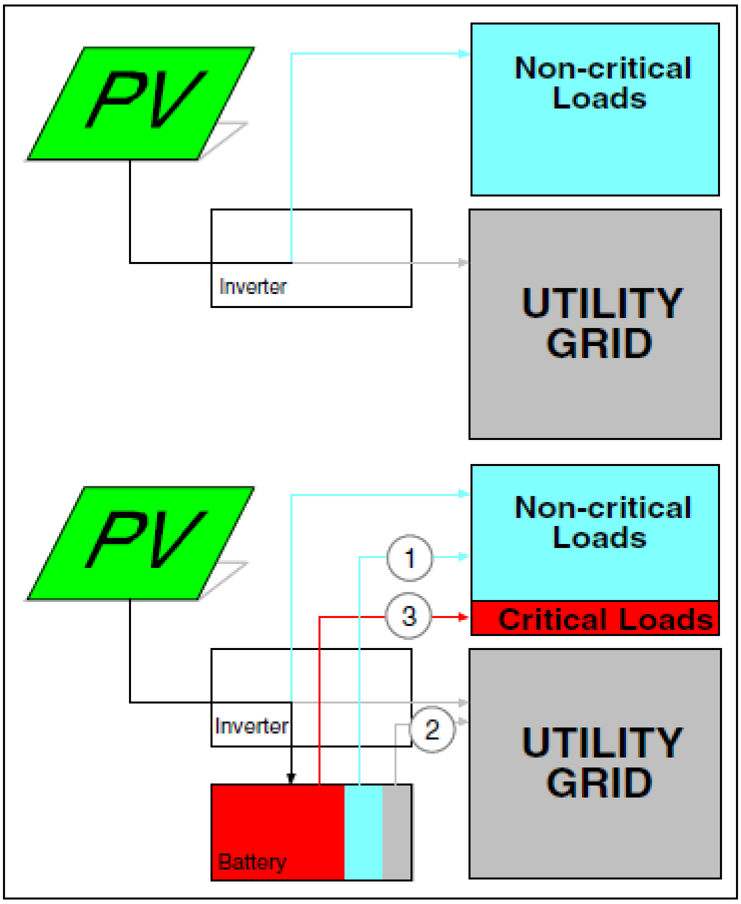
It is possible for energy storage to be used to improve system responsiveness, reliability and flexibility or for load levelling and peak shaving (Schaber et al., 2004). It is these issues which are of greatest interest to the distribution companies, with one local company currently assisting in the formulation of our research activities. Whilst there are various storage options, this paper will also focus on those technologies that can be best utilised by solar energy rather than renewable energy systems as a whole.

Figure 1 highlights the advantages of being able to deploy stored energy during periods of peak demand or critical load. Research undertaken by Hoff et al. (2007) indicated that there was a 40% probability of a summer peak load reduction with commercial customer storage deployment. This research also highlighted the possible uses of stored energy being ① local load management, ② utility load management and ③ emergency critical load storage.

Those looking for systems concentrating on responsiveness and reliability will focus on supercapacitors and flywheels which are able to provide reliable standby power but are not suitable for long-term energy storage (Hadjipaschalis et al., 2009). In comparison those seeking load levelling and peak shaving capabilities will focus on battery storage, with sodium-sulphur (NaS) considered the best option (Toledo et al., 2010). Traditional lead batteries cannot store the large amounts of energy required within a small volume (Ibrahim et al., 2008).

Although many researchers believe that the answer to energy storage is with hydrogen (which can be utilised with a range of solar options), it also has not been considered within this paper. A number of safety concerns have been raised in the past making large-scale deployment within a university environment unsuitable, particularly given that a high pressure tank would be required due to space constraints.

Figure 2 - Grid connected PV with and without storage



Source: (Hoff et al., 2007)

The available storage options considered suitable for deployment are included in Table 1, together with a non-exhaustive range of suppliers of commercially available products (Australian Institute for Commercialisation, 2010, Hall and Bain, 2008).

In addition those companies with a representation within Australia have been bolded, with many of the international companies contacted not willing to supply to the Australian market at this stage due to the small size of the market.

Apart from considering the above, Schaber et al. (2004) also stated that when choosing a storage technology you must also consider: -

1. Energy efficiency
2. Environmental impact
3. Location dependence
4. Lifetime
5. Economics
6. Space and weight requirements

Looking initially at the battery storage option, both the lead-acid and nickel-cadmium batteries are made from toxic substances, so if considering from a life-cycle viewpoint, these would cause some degree of concern with disposal and recycling (Schaber et al., 2004). Both the sodium and lithium batteries would be suitable for large-scale projects. It will also be important to consider the ability of the technology to "scale-up" based on the demand needs of where the storage is being deployed. The economics and lifetime of competing technologies has been highlighted as an area for future research, with deployment of flow batteries considered the preferred option.

Table 1 - Energy Storage Technologies and Suppliers

Option	Technology	Supplier
A. Batteries		
	Lead-Acid	**RedFlow**
		Ecoult
	Nickel-Cadmium	
	Sodium based	NGK Insulators
		GE
		MES DEA
	Lithium based	**SAFT**
		Li-Tec
		BYD Company
		EnerSys
		OxisEnergy
B. Flow Batteries		
	Zinc-Bromide	**RedFlow**
		ZBB Corporation
		Premium Power
	Vanadium Redox	Prudent Energy
	Organic Acid	Plurion
	Other	Enstorage Inc.
		Extreme Power
		Deeya Power
C. Supercapacitors		
		SAFT
		Li-Tec
		BYD Company
		EnerSys
		OxisEnergy

In the context of this study, flywheel technologies and supercapacitors have also not been considered as the current technology, whilst being able to meet capacity, will only store energy for periods up to one hour, therefore discussion in this paper will focus on batteries and flow batteries.

Batteries

Whilst there are a number of options as set out in Table 1, the better options for this particular project appear to be lithium-ion (Li-ion), sodium sulphur (NaS) and zebra ($Na\text{-}NiCl_2$) batteries. However, scale and the ability to scale-up to utility level is questionable locally.

Whilst some of the companies such as NGK have produced batteries that would be suitable to the project under consideration, they have indicated that the minimum supply order is 2 MW, which is outside of the current scope and available market within Australia.

Flow Batteries

There are a number of flow-battery designs utilising different chemical compositions including polysulphide bromide (PSB), zinc bromide (ZnBr), cerium zinc (CeZn) and vanadium redox (VRB) (Hall and Bain, 2008). The major disadvantage of flow battery systems is the additional capital and running costs associated with the operation of what is basically a small chemical plant (Hall and Bain, 2008).

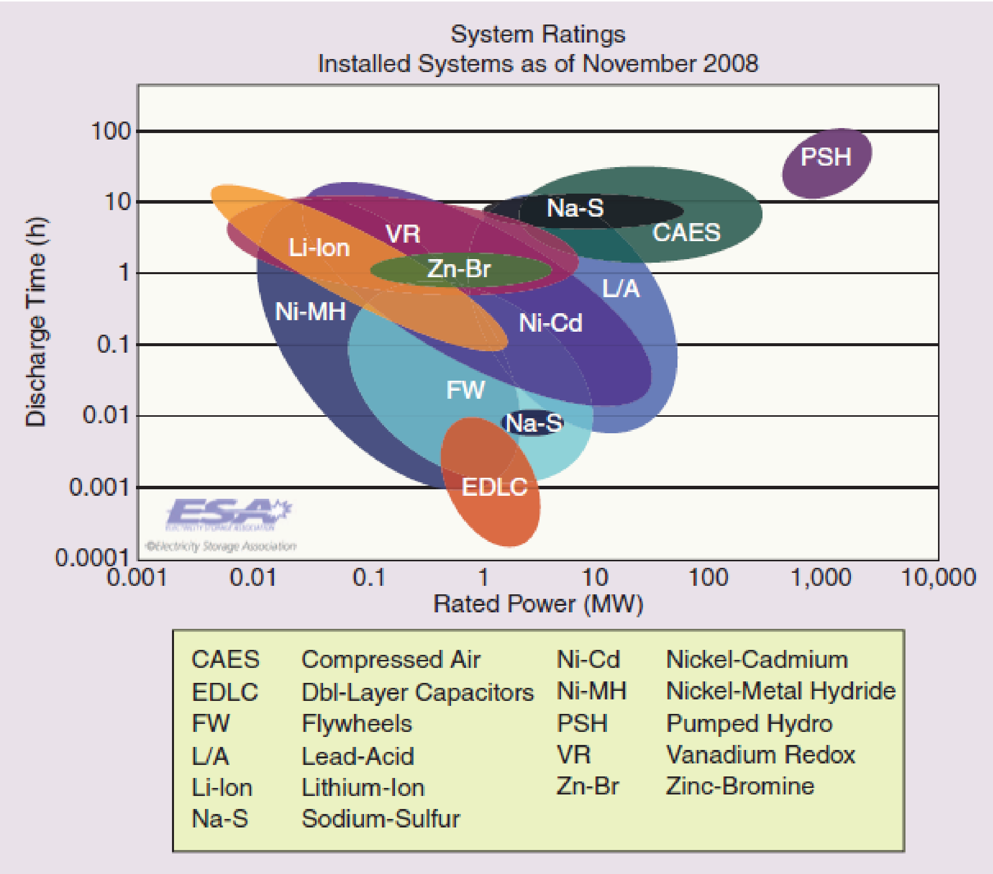
A number of technologies for energy storage have already been deployed internationally, with Figure 3 showing deployment as at the end of 2008. For the purpose being reviewed in this paper, it indicates that current technologies support the use of lead-acid, sodium-sulphur, nickel-metal-hydride, zinc bromide, lithium-ion and vanadium redox storage systems.

The zinc-bromide and lithium based batteries are both locally available and would meet the project design requirements.

Research by the US Electric Power Research Institute shown in Figures 4 and 5 further highlight the options referred to above with the sodium-sulphate and flow batteries being those most applicable to the research applications proposed.

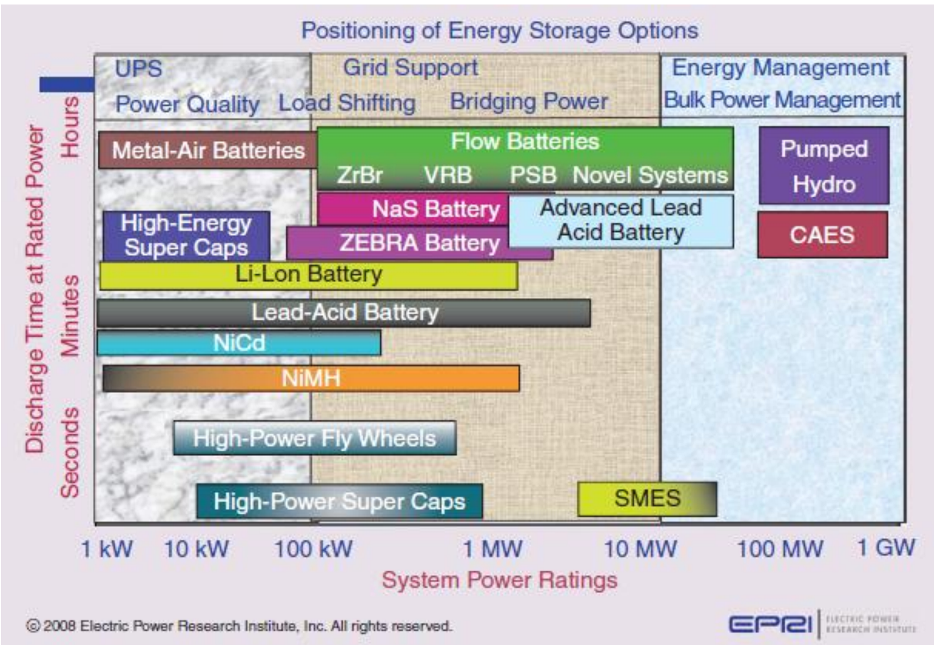
A review of local suppliers, together with consideration of research potential to scale a prototype to utility scale has resulted in the zinc bromide battery being selected for this project.

Figure 3 - Storage by Technology



Source: (Roberts, 2009)

Figure 4 - Technology by Application

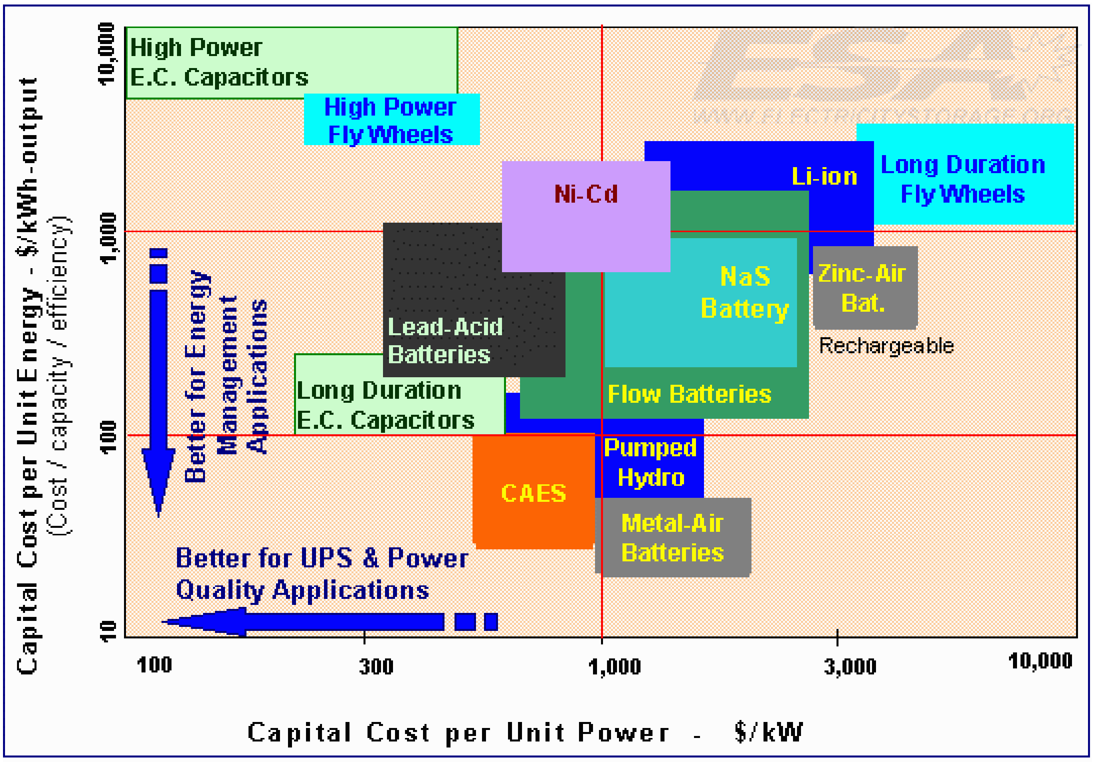


Source: (Roberts, 2009)

ECONOMICS

Whilst the research benefits of testing various systems generally outweigh economic decisions, the same rules do not apply to large-scale deployment by utilities. Therefore it is important to consider both the life and cost of the competing technologies.

Figure 5 - Technology Capital Cost Comparison



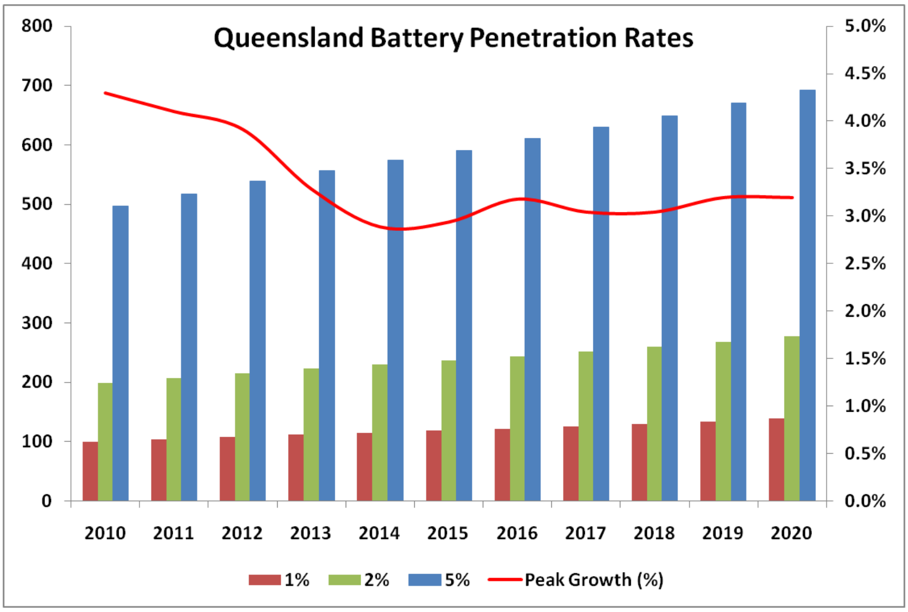
Source: (Energy Storage Association, 2009)

The most recent information prepared by the US Energy Storage Association (2009) as shown in Figure 5 was based on capital costs in 2002 and the anticipated reduction of those costs as technology matured. It indicates that both sodium-sulphate and flow batteries will have a similar cost structure. This also highlights how little research has been done in this area over recent years.

Whilst the lead-acid and sodium based batteries are relatively inexpensive they only have a life expectancy of 10 years compared to flow batteries which have a life of 30 years (Energy Storage Association, 2009), resulting in the cost per kilowatt being similar over the life of the battery. Further, the market anticipates that these costs will come down even further as the technology matures. (This can lead to decision makers looking at the least-cost technology in the short-term, whilst waiting for economies of scale in emerging technologies).

Relying on the market operator, AEMO, we have modelled the medium growth scenario for battery deployment (Figure 6), which indicates that based on anything less than five percent, infrastructure requirements will continue to grow. Preliminary indications show that the cost of battery storage, which is dependent on the technology choice, is approximately $1 million/MWh, making large-scale deployment in the near future unlikely.

Figure 6 - Battery Penetration Rates



An extension of the current research will be to review current actual costs of the competing technologies based on a typical installation within Australia, commencing with the UQ flow battery study. However, as noted earlier, this will be limited due to the number of active participants within the Australian market and the diverse range of technology options.

CONCLUSION

As Hall (2008) stated, "renewables can do for energy what micro-chip driven computers have done for information and what genetic manipulation will do for medicine". However it is unlikely that this will occur without efficient storage options to remove the intermittency of those renewable energy resources that are so freely available and demonstration sites made available so that the network companies can model the implications to both new and existing infrastructure.

This current research will provide the opportunity to assess the ability of storage to remove much of the criticism directed to intermittent renewable technologies, whilst also determining how storage can be best utilised within a distributed energy system.

BRIEF BIOGRAPHY OF PRESENTER

Craig Froome has extensive consulting experience and has undertaken a number of projects looking at renewable energy scenarios including the preparation of a discussion papers for both Government and industry. He is a member of The University of Queensland's *Renewable Energy Technical Advisory Committee*, which is looking at renewable energy projects that may be implemented within the University's campuses for the purposes of not only energy generation and impacts on distribution, but also looking at research and teaching opportunities.

Mr Froome is also a member of The University of Queensland's School of Economics *Energy Economics and Management Research Group (EEMRG)* which is focusing on recent and ongoing technological change and technological diffusion that is making key technologies, such as battery storage, solar PV and thermal more affordable. The broad aim is to identify how the costs of generation and network expenditure, due to the imperative for climate change mitigation, aging infrastructure and peak demand growth, can be addressed by distributed energy systems.

In conjunction with the EEMRG he is also currently working on the *I-Grid linkage* with the *CSIRO Distributed Energy Flagship* with the project's goal being to rigorously model and quantify the benefits of distributed energy systems while, at the same time, taking into account the costs of deploying and integrating them into the Australian electricity system.

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