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Moving your campus Smartly to 100% renewable energy

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Moving your campus Smartly to 100% renewable energy

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Abstract

Renewable energy use on campus is increasing across Australia; however the approaches being used are in general unsystematic and driven by financial cost savings through picking low hanging fruit and result in minimal swings away from non-renewable energy use. Here we offer a step-by step process to arrive at a campus that uses only renewable energy.

Achievement of this goal of 100% renewable energy use can be cost neutral with cost savings through the reduction of grid energy use to repay the loan giving reasonable pay-back periods of around ten years. The solar installations would also create an income stream from the Large Renewable Energy Certificates generated, reduce the need for internal and external grid upgrades, and have the added benefits of offering the campus as a living laboratory for teaching and research in renewables.

We show that this target can be achieved by reducing the energy usage on campus by efficiency upgrades; installation of solar photovoltaic panels with associated battery storage systems; and purchase of green power for the remaining unfulfilled energy requirements.

These implementations would result in a lowering of overall energy use, create energy security for the University through minimising energy purchased externally and also place it as a leader in Sustainability and Energy Management across the Australian tertiary sector and would drive new student enrolments across all Faculties with young people attracted to learn at the greenest and most innovative University in Australia.

Keywords: Renewable energy, sustainability strategy, Sunulator, tertiary sector, living laboratory

Introduction

Many of the Australian universities which are taking the greatest steps towards sustainability are signatories or members of either The Talloires Declaration (a ten-point sustainability action plan composed in 1990 at an international conference in Talloires, France (ULSF, 2001)) or The International Sustainable Campus Network (ISCN) (A non-profit association of colleges and universities (ISCN, 2016)). Both The Talloires Declaration and the ISCN promote a combination of education of sustainability, interdisciplinary research in sustainability, and the practice of on-campus sustainability. Although all three of these agendas are equally important to the overall goal of creating a sustainable future, the focus of this study will be on the actual implementation and practice of campus sustainability specifically on greenhouse gas emission reduction through 100% renewable electrical energy use.

The majority (37/41) of Australian universities have made moves to improving the sustainability of their energy consumption, some through stated aspirations, increasing the star rating of buildings, or through the setting of targets on the reduction of greenhouse gas emissions (unpublished internal study). As demonstrated in Figure 1, the targets, timeframes, baseline and method of calculation of these differ between universities. Furthermore, the methods employed in achieving these goals differed markedly, for example, one key example of an Australian university transitioning to renewable energy is The University of Melbourne. The University of Melbourne must be commended for their commitments to converting to renewable energy, both in terms of what they have already achieved, but also what they have committed to for the future. They have already established plans of being carbon neutral by 2030, and have started converting their energy from non-renewable to renewable. They are well on the path to 100% carbon neutrality having already spent over nine million dollars on energy reductions and renewable energy generation. Their estimated annual carbon savings is currently up to 33,175 tonnes CO2e, which is an accumulated savings of over 200,000 tonnes of carbon emissions since 2008 (University of Melbourne, 2016a).

An alternative method has been undertaken by Charles Sturt University (CSU). CSU has been declared Australia's first official carbon neutral university. To become carbon neutral and offset the carbon produced, CSU has purchased carbon offset credits from projects located in Australia and overseas. The University will continue its commitment to reducing its current emissions, particularly by reducing energy use using more efficient lighting and air conditioning, and generate more energy on its campuses using solar energy systems (Charles Sturt University, 2016).

Figure 1 below represents a comparison of the renewable targets of selected Universities around Australia as well as marking the proposed project (UoX proposed). Note that the figures are indicative only due to the differing carbon reduction reporting methodologies used between Universities. The graph shows that the University of Melbourne (Melb) aims to achieve 100% reduction in fossil derived electricity by 2030, University of New England (UNE) aims to achieve a 50% reduction by 2018, The Australian National University (ANU) aimed to achieve a 20% reduction by 2015 and currently aims to achieve a 35% reduction by 2020, Monash University and University of Technology Sydney (UTS) aim to achieve a 30% reduction by 2020, Queensland University of Technology (QUT) aimed to achieve 25% reduction by 2012, University of Newcastle (UoN) aim to achieve a 20% reduction by 2020 and 40% by 2030 per m2 gross floor area, University of Western Australian (UWA) aims to achieve a 20% reduction by 2020, University of South Australia (UniSA) aims to achieve a 15% reduction per m2 gross floor area by 2020, and University of New South Wales (UNSW) aimed to achieve 7.5% reduction by 2010.

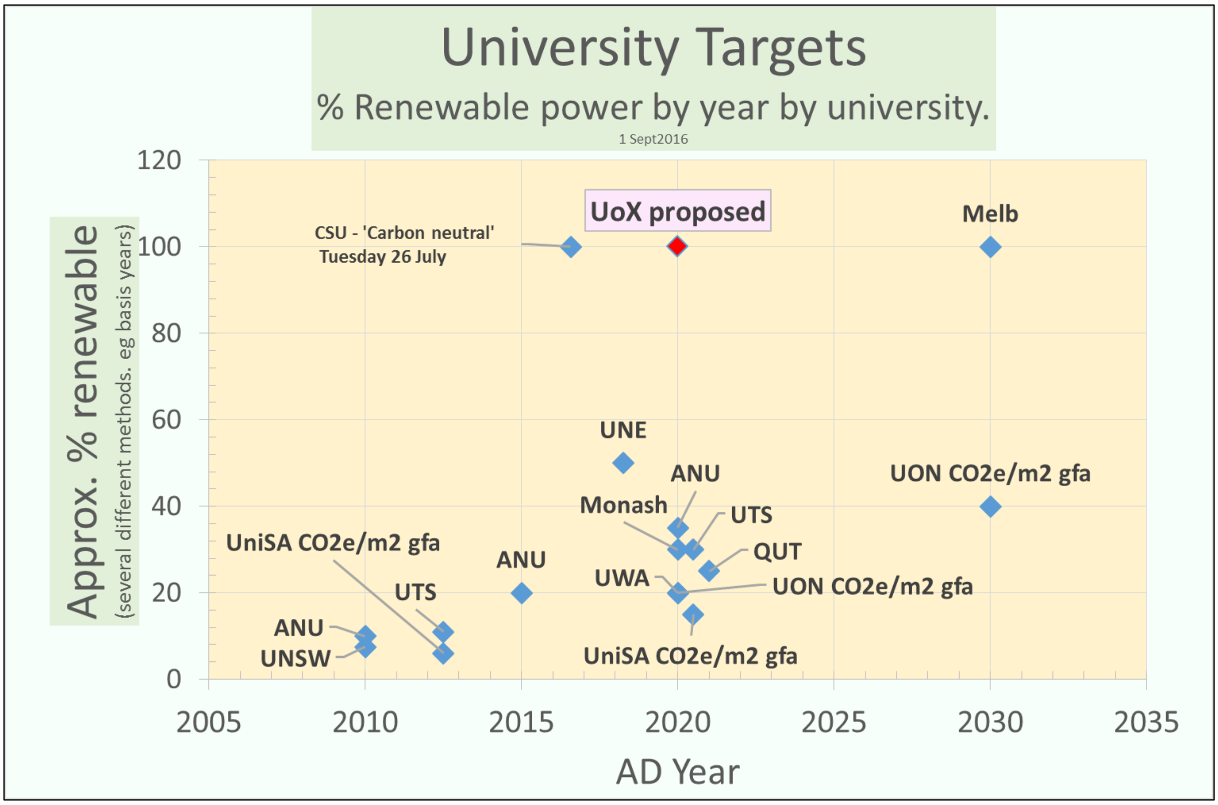

Figure 1. Selected Australian university's renewable electricity targets. Derived from: Australian National University (2009), Australian National University (2016), Boshoff (2016), Charles Sturt University (2016), University of Melbourne (2016b), Monash University (2015), Queensland University of Technology (2011), University of South Australia (2014), University of New South Wales (2005), University of Newcastle (2015), Institute for Sustainable Futures (2011) and University of Western Australia (2011).

Other drivers for creating a 100% renewable energy campus is to enhance the University's opportunities to create a living laboratory where the physical fabric of the campus can be incorporated and integrated with the University's teaching and research. Treating the University as a living laboratory includes utilising the University's research competencies to solve sustainability issues relating to its facilities and practices (Graczyk, 2015). The collaboration of facilities services with teaching and research can further understanding of the challenges posed in implementing sustainability within the University (Orr, 2004). A living laboratory provides a systematic approach to engagement of students and academics with applied sustainability issues and enhances the ability of the university to contribute to sustainability challenges (Evans, et al., 2015). Furthermore, investigating campus sustainability may encourage students to critically evaluate their own views on sustainability (Plymouth University, 2016). An example of the use of the campus as a living teaching laboratory can be found at Yale University in the USA. "Yale University has launched a first-of-its-kind pilot program to put a price tag on the use of carbon — with some of the most prominent campus buildings playing a role in the experiment" (Shelton, 2015).

A university campus offers an opportunity to allow energy locally generated on a number of locations to be collectively utilised across the campus through a micro-grid. This allows economies of scale to benefit the generation and use of renewable energy. Energy generated on one end of the campus can be used at little or no extra cost at the other end of campus. For example buildings with large roof space but low power requirements can provide their excess power generated by solar PV to other buildings with high power needs. Planning of onsite generation and use can be simplified as the campus can be thought of as one virtual generator and one virtual user. Furthermore, the implementation of onsite generation can be a campus wide rollout, rather than through individual projects.

Implementation of this innovative project could be a strong marketing and recruitment tool for prospective students and staff domestically and internationally. It would not only give a strong point of difference but would also align with the role of the University in transforming the region and becoming a truly global player. The campus as a Living Laboratory would be distinct amongst Australian Universities and would also be a fertile space for industry-university engagement on Work Integrated Learning and research.

Materials and Methods

To assess the Solar PV potential of the main campus the following tools were utilised:

- The university's energy management software provided the electrical interval data for the campus; and
- LG Solar Calculator "Solar System based on roof size" utilising satellite imagery was used to estimate the number of solar panels and capacity on available roof-space, car parks, vacant land (LG Electronics, 2016).
- Sunulator is a simulation tool developed by The Alternative Technology Association (ATA) that can be used to plan a grid-connected solar/battery project (ATA, 2015a; 2015b). Sunulator uses half-hourly consumption and generation data over a whole year to estimate how much solar generation will be consumed on-site versus exported. Based on electricity tariff information, it then calculates the impact on electricity costs and projects the savings over a 30-year time frame. Financial results include payback period, net present value (NPV) and return on investment (ROI)
    - NPV is the difference between the present value of cash inflows and the present value of cash outflows and is used to analyse project profitability
    - ROI measures the amount of return on an investment relative to the cost of that investment.

Half-hourly consumption data for the main campus was imported from the university's energy management software for the year 2015 into Sunulator. A number of scenarios were run, based on solar PV estimates from the LG Solar Calculator. The 6.5 Mega Watt Peak (MWp) simulation was for Solar PV rooftop alone, 10MWp also included car parks, 12MWp included vacant land together with a back Oval which is used as a temporary overflow carpark. Finally 12MWp + Batteries also included battery storage to utilise some of the electricity exported to the grid when supply exceeds demand on campus. Whereas the size of the solar installations is limited by space availability, with the larger the system the greater the NPV.

The following inputs were used in the simulation:

- Sunulator utilised Sydney solar radiance data from the Australian Bureau of Metrology to simulate solar generation, included annual costs of maintenance and panel cleaning (1% of capital cost), and a 0.5% solar panel annual degradation rate (ATA 2015b);
- NPV and ROI were calculated over a 20 year horizon;
- Current estimates of Solar PV and Battery costs together with average daily production (Sydney) were from Solar Choice (Solar Choice, 2016a, 2016b; Rodriguez, 2016);
- Sunulator supports both lithium ion and lead-acid chemistry batteries, however lithium ion was selected for simulation due to their advantages over lead-acid including higher efficiency at fast rates of charge or discharge (ATA 2015b);
- The size of the battery installation was optimised to the greatest NPV;
- The cost of money estimate was calculated based on CEFC co-financing loans (CEFC, 2014);
- An estimated Large Scale Generation Certificates (LGC) price of $75/tonne was conservatively based on market prices (Green Energy Markets, 2016);
- For carbon dioxide offset calculations, the NSW, Scope 2 emissions factor of 0.84 kg CO2e / kWh was used (Department of the Environment, 2016); and
- The university campus utilises a micro-grid and therefore it is assumed that renewable energy can be generated and utilised at numerous different campus locations. For the feasibility planning, onsite generation and use was treated as one virtual generator and one virtual user. University substation equipment upgrades to enable bi-directional flow of electricity if required were not considered in the feasibility study and would be the subject of a detailed implementation design.

Results

Modelling of generation capacity for number of permutations of solar PV is illustrated in Figure 2. The 6.5 MW model had the highest level of self-consumption, with consequently only 18% of generation exported to the grid (see Figure 3). However, it represented only 30% of electricity consumption at campus. The 10 MW model had lower level of self-consumption (with 30% exported to the grid) but represented 40% of total electricity requirements. The 12 MW model represented the practical limit on space available for Solar at the campus. This scenario had a lower level of self-consumption than previous scenarios (with 36% exported) and represented 44% of total electricity needs. To overcome this, taking the 12 MW model and introducing battery storage (5 MWh) dramatically improved the potential outcomes with 75% consumed on-site (only 25% exported) and represents 51% of current electricity consumption at the campus. At the current prices of batteries, larger battery arrays attracted diminishing returns for these scenarios. However, as with all rapidly developing technologies, battery capabilities will improve and costs will decrease over time. Thus the value proposition will change with additional storage providing even greater outcomes for combined solar PV and battery storage solutions. All scenarios had payback periods of 9-10 years, with the larger the system the higher the NPV. The 12MWp Solar PV + Batteries had the highest NPV.

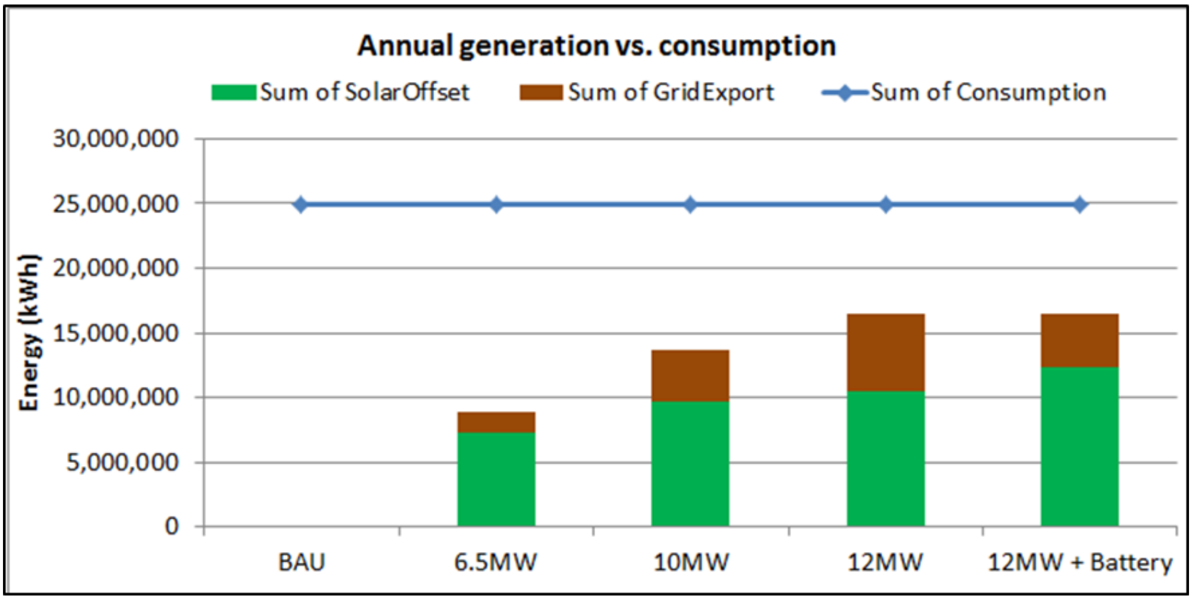

Figure 2: Annual Solar PV Generation vs Electricity Consumption

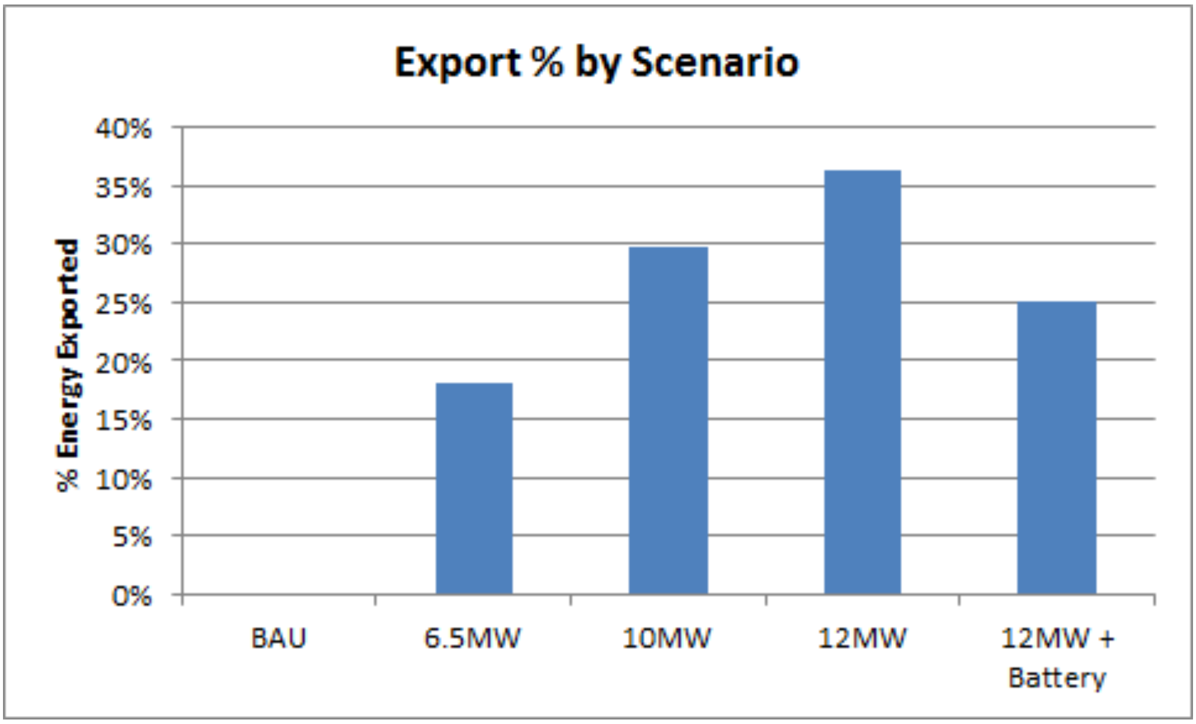

Figure 3: Percentage Electricity Exported for the various solar solutions proposed

In summary, a maximum of 43,500 solar panels of 12MW capacity plus batteries with an estimated capital cost of $18 million could be installed on the main campus to give 16.4GWh of electricity per annum and reducing electricity grid costs by 51%. This would include:

- 6.5MW Rooftop Solar
- 5.5MW On-Ground Solar
- A 5MWh Lithium ion battery storage array, to provide green power at peak consumption times when the sun is not shining and at night.

It is expected that the financing of the capital costs (such as through CEFC) would be covered by the reduced electricity charges together with income from Large Scale Generation Certificates (LGC) for the length of the loan. Income from LGC together with the reduction in grid costs would wholly finance a loan with a payback period of 10 years. Note that the income from the LGC assists the financial viability of the project and ensures an acceptable payback period. Once implemented, the local renewable energy generation gives the University the option of contributing to the national reduction targets through the voluntary surrender of the LGC.

Figure 4 details a simulation of the average daily generation of 12MWp solar PV together with 5MWh of Li ion batteries in half hour intervals. A proportion of the Solar PV generation electricity normally exported to the grid (when generation exceeds consumption) is stored in the batteries for use later when generation is less than consumption. This can be seen in the decreased grid imports in the afternoon and early evening in the 12MW + batteries scenario in Figure 5.

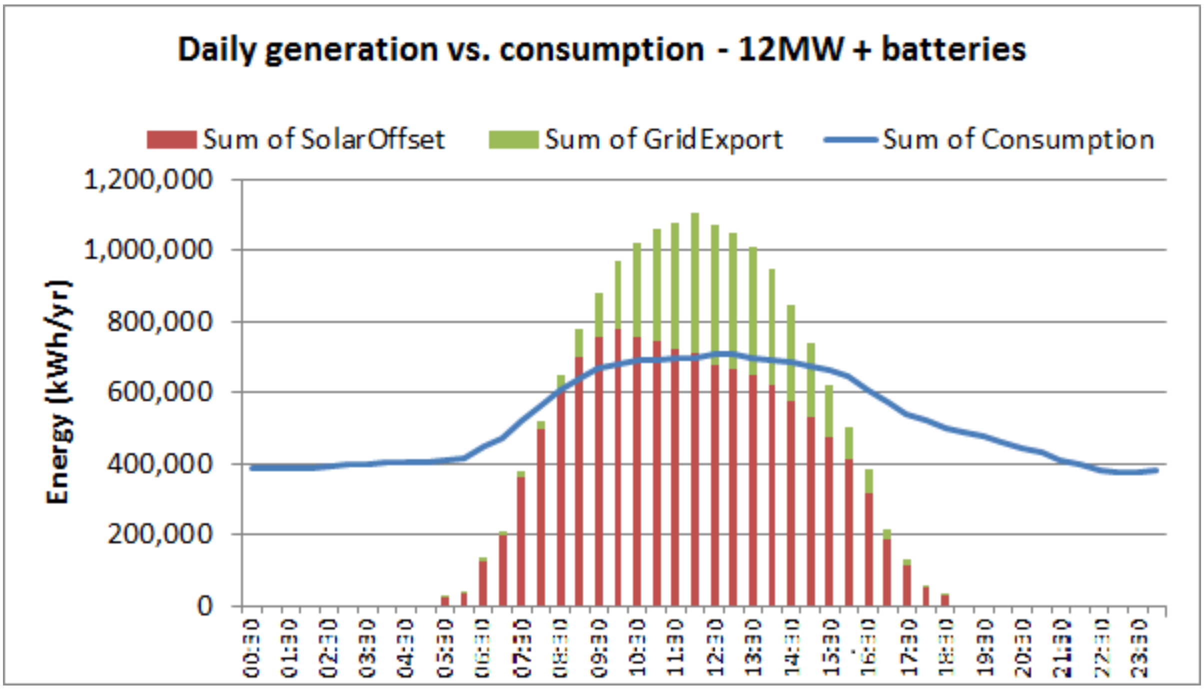

Figure 4: Daily Generation vs Consumption for 12MW Solar PV + Batteries

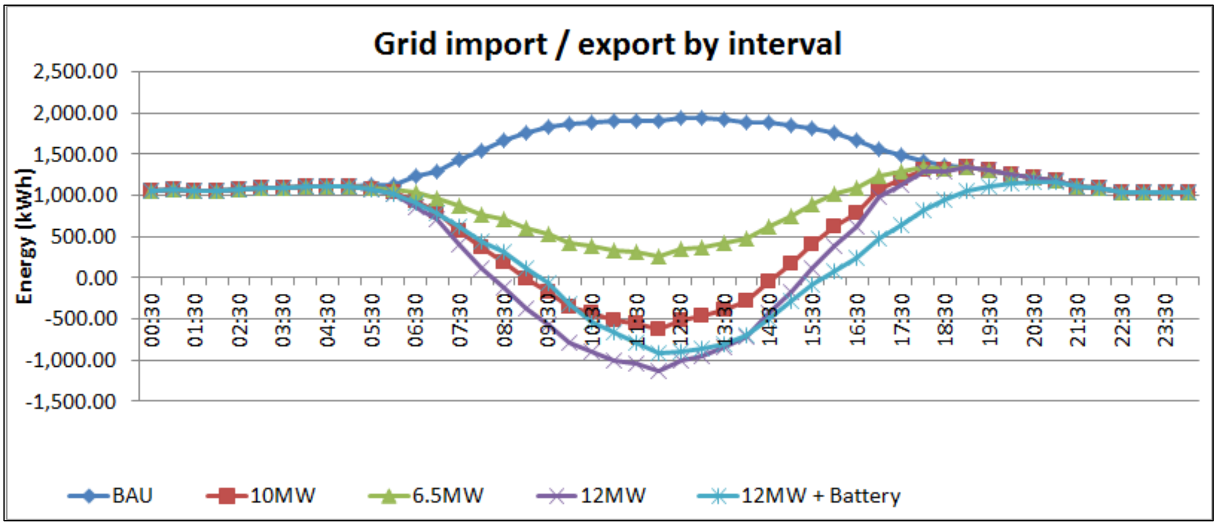

Figure 5: Grid import / export by time of day for the various solar solutions proposed

Purchase of supplementary green energy produced off site

As can be seen in Figure 4 the solar power generated on site does not fully supply the campus needs and it is recommended that green energy be purchased from generation sites off campus through a power purchase agreement with a solar farm or wind farm or through Green Power (GreenPower, 2011).

Power purchase agreement (PPA)
In the case of the university the type of Power Purchase Agreement established would likely be an Energy offtake agreement (an agreement between a producer and a buyer to sell/purchase portions of the producer's future production). UTS recently did this with Singleton Solar Farm (Parkinson, 2015).

Local Electricity Trading
An Australian Renewable Energy Agency (ARENA) funded investigation (ARENA, 2015a, 2015b; Institute for Sustainable Futures, 2015) is ‘conduct[ing] studies, consultations and virtual trials to

inform potential rule changes in the National Electricity Market (NEM).' Such rule changes would allow reduced network charges from only 'using only the local network'. "This project aims to facilitate the introduction of reduced local network charges for partial use of the electricity network, and the introduction of Local Electricity Trading (LET) between associated customers and generators in the same local distribution area" These rule changes are still in consideration. Such changes would potentially allow physically close generators and consumers to transfer electricity across their property boundaries, without incurring the existing (high) grid charges.

Green Power
The GreenPower Program is a government managed scheme that enables Australian households and businesses to displace their electricity usage with certified renewable energy, which is added to the grid on their behalf (GreenPower, 2011).

Other green technologies

It is recommended that green technologies such as Biogas generators, Micro-turbines, Geothermal, Waste Heat Engines and Concentrated Solar Thermal be included in the renewable energy generation on campus, to not only significantly assist in reaching the target of 100% but also as invaluable concrete exemplars for research and teaching. Funding could possibly come from ARENA. The key purpose of ARENA is to improve the competitiveness of renewable energy technologies, and to increase the Australian supply of renewable energy by advancing renewable energy technologies towards commercial readiness, improving business models, and reducing overall industry costs (ARENA, 2016c).

Financial considerations

With the implementation of efficiency measures such as Voltage Optimisation, Peak Demand Management and Energy Efficiency, significant savings in electricity costs may be realised (Czyczelis, 2014). This taken together with implementation of a 12MW Solar PV onsite with 5MWh battery storage would substantially decrease the reliance on power generated off-site. To achieve the goal of 100% renewable energy usage on campus, supplementary renewable electricity produced off-site could be purchased such as Green power to augment the onsite generation. The amount of offsite renewable energy required would depend on the level of efficiency measures implemented together with the Solar PV and Battery installation.

To install the necessary 12MW solar PV and battery system, and efficiency upgrades we estimate a loan of the order of $18,000,000 would be necessary with a payback of 10 years. A Superannuation Fund and CEFC have expressed interest in our proposal.

The Clean Energy Finance Corporation (CEFC) updated investment mandate requires a focus on innovative technologies and energy efficiency in the built environment. The CEFC is particularly focusing on University campuses and has a consultancy team specifically set up for clean energy investments at universities. The CEFC's finance can be structured over a longer term than traditionally offered by banks, tailored to match the cost savings delivered through the reduction in grid energy usage. In the University of Melbourne case the loan repayments were equivalent to the reduction of grid energy usage charges (CEFC, 2016).

It appears feasible that the University might undertake a loan from CEFC to implement the options proposed below. The loan package from CEFC would include purchase of capital items to allow solar PV generation, and efficiency upgrades.

Financial benefits - Solar PV

The annual electricity costs for main campus are significant, including a substantial peak capacity charge. The implementation of 12 MWp Solar PV together with 5 MWh Lithium ion batteries will result in a 50% reduction in electricity grid costs (see Figure 6 and Figure 7).

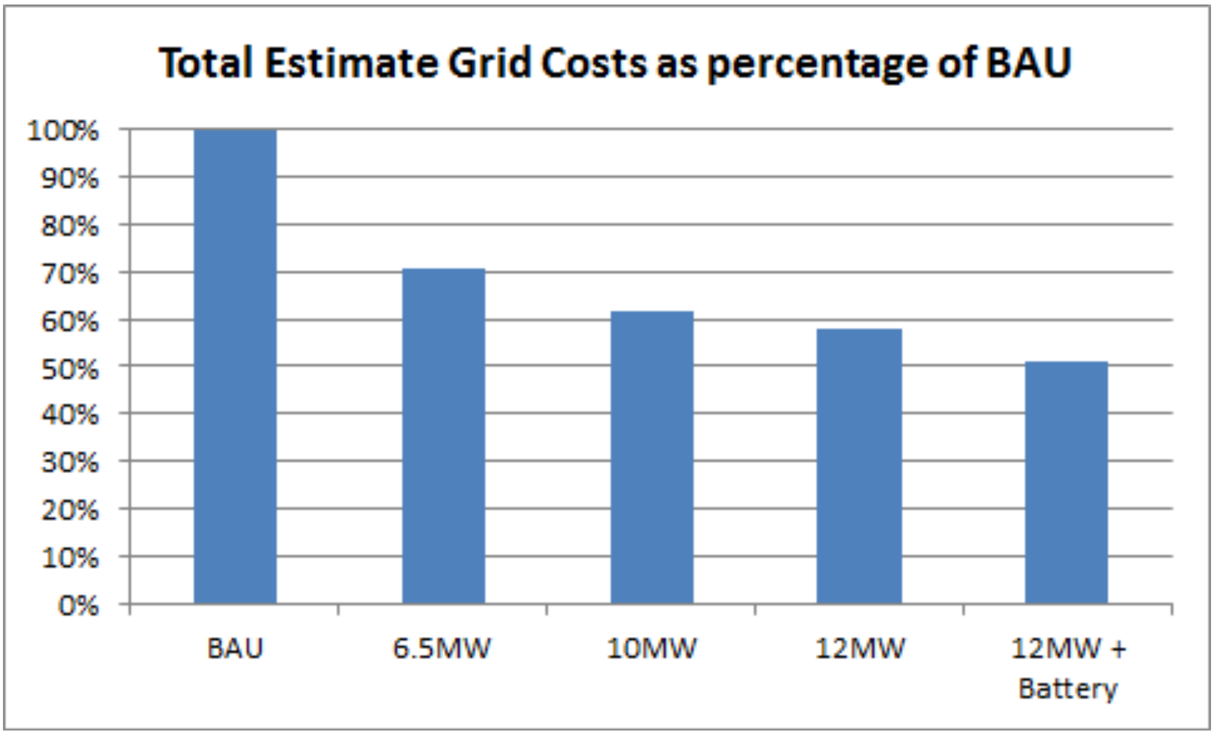

Figure 6: The estimated total grid bill cost per annum as a percentage of BAU of the various solar solutions proposed

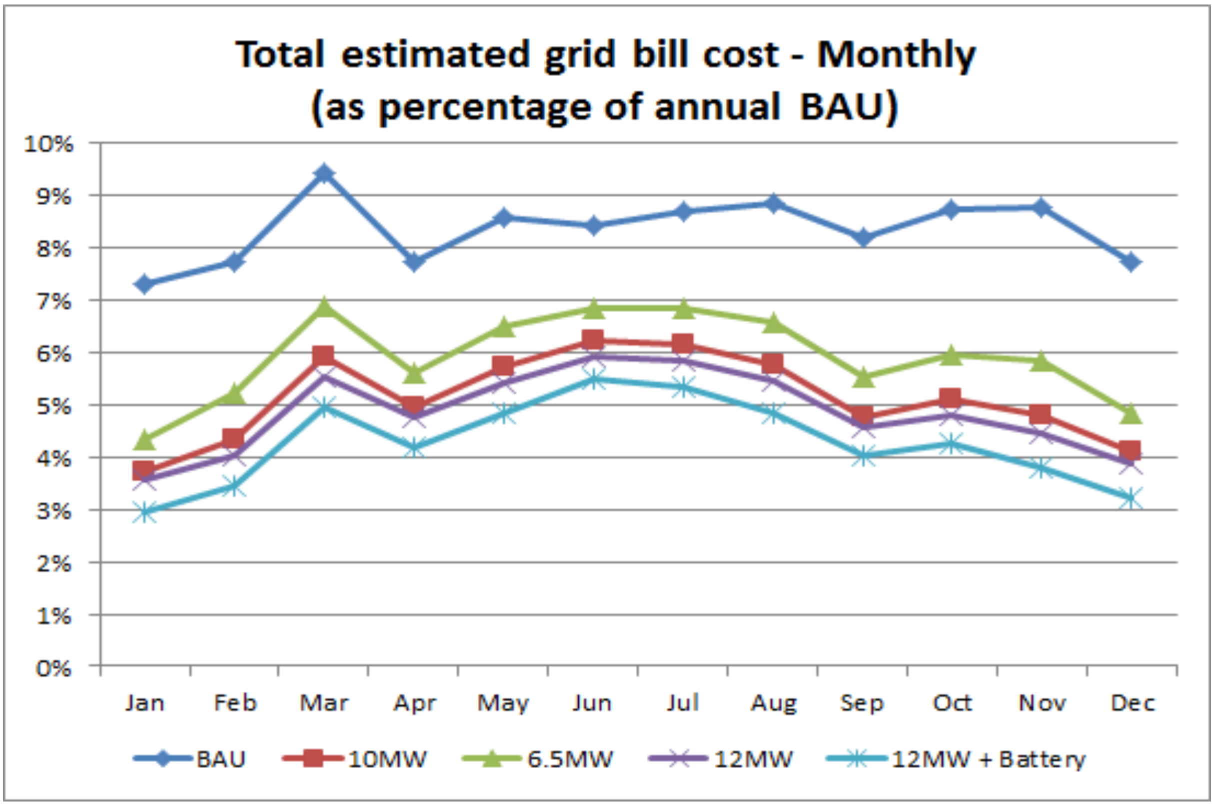

Figure 7: Total estimated grid bill cost - monthly (as a percentage of the total grid costs for BAU) of the various solar solutions proposed

The solar PV generation of 17 GWh electricity from this system would also result in the generation of approximately 16,500 Large Scale Generation Certificates (LGC) valued at approximately $1.3 million per annum. Income from LGC to be claimed annually would significantly influence the financial viability of this proposal.

Net Present Value (NPV)
The reduced electricity costs, together with the LGC revenue less maintenance costs would result in a significant annual cost saving. The NPV shows the sum of the cash flow over a 20 year financial horizon, including the initial investment as a negative impact. The 12MWp Solar PV + Batteries had the highest NPV (see Figure 8), and a discounted payback period of 10 years.

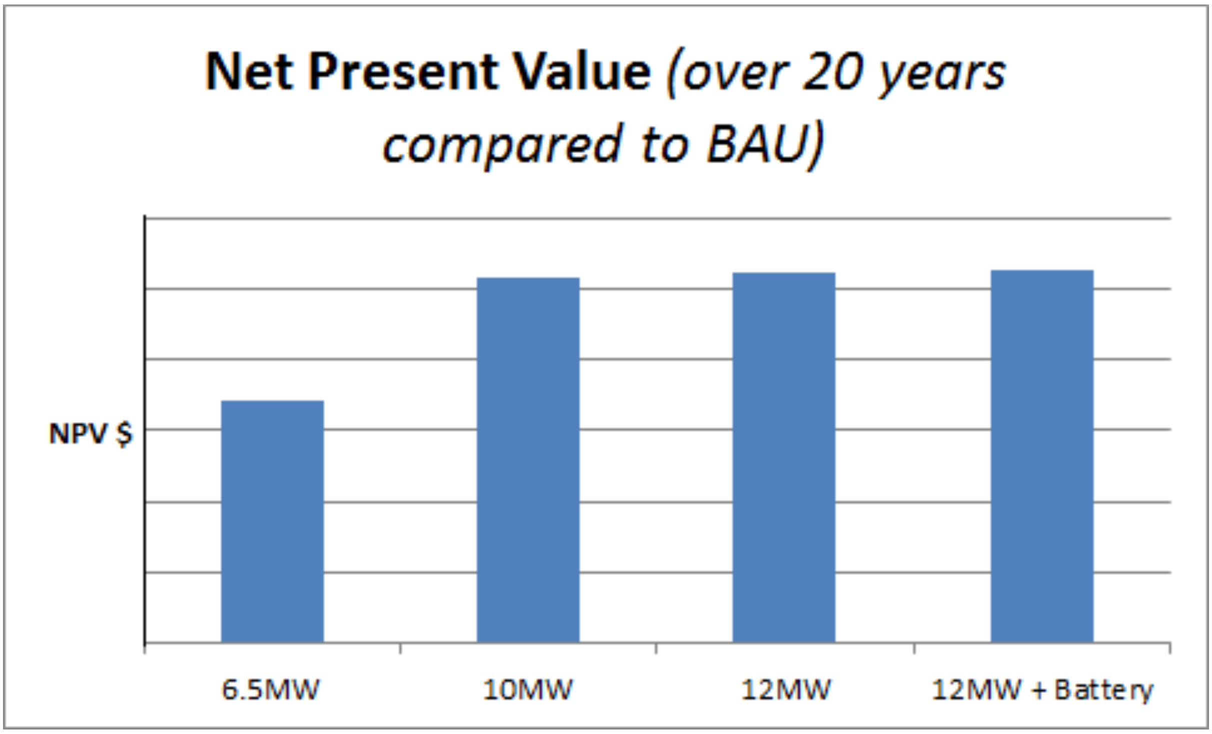

Figure 8: represents the Net Present Value of investing in a range of solar solutions

Return on Investment
The overall percentage return for each of the various solutions proposed is provided by the Return on Investment in the form of the Internal Rate of Return (IRR). The IRR is the interest rate at which the net present value of all the cash flows (both positive and negative) from a project equal zero. The ROI (IRR) is 8.1% for 12MWp Solar PV + Batteries (see Figure 9).

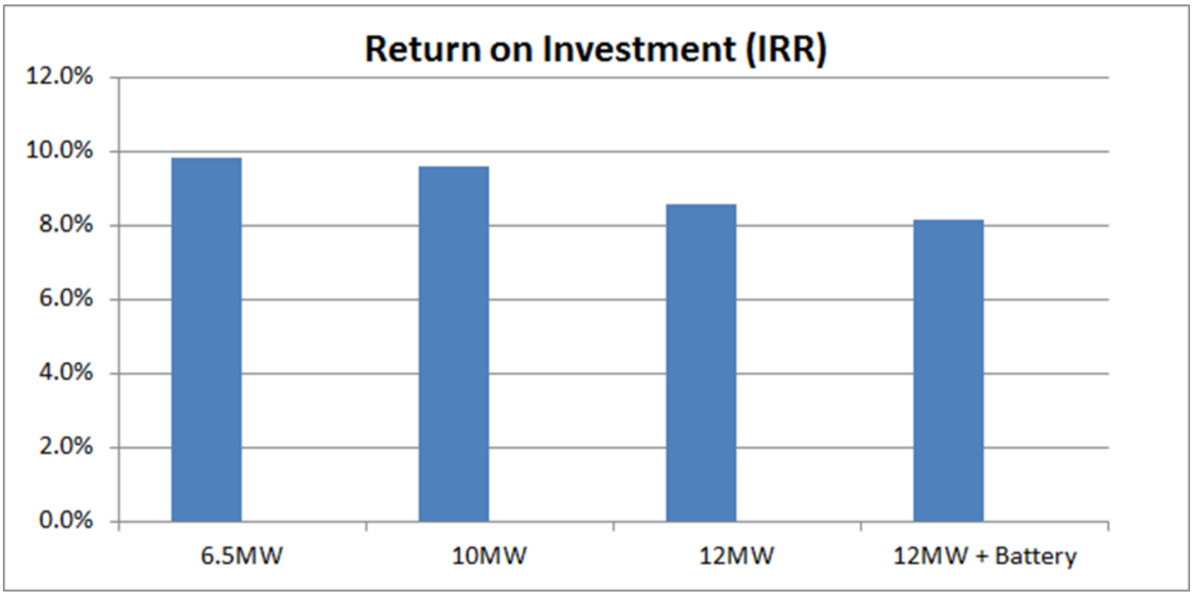

Figure 9: The Return on Investment of investing in a number of solar solutions

Payback Period

The Cash flow is initially negative due to the up-front investment. The year in which the cumulative cash flow turns positive is the payback period. All scenarios had payback periods of 9-10 years (see Figure 10), with a larger the system the higher the NPV. Note that the dip in year 10 and year 20 accounts for the replacement of solar inverters that have an expected 10 year life span.

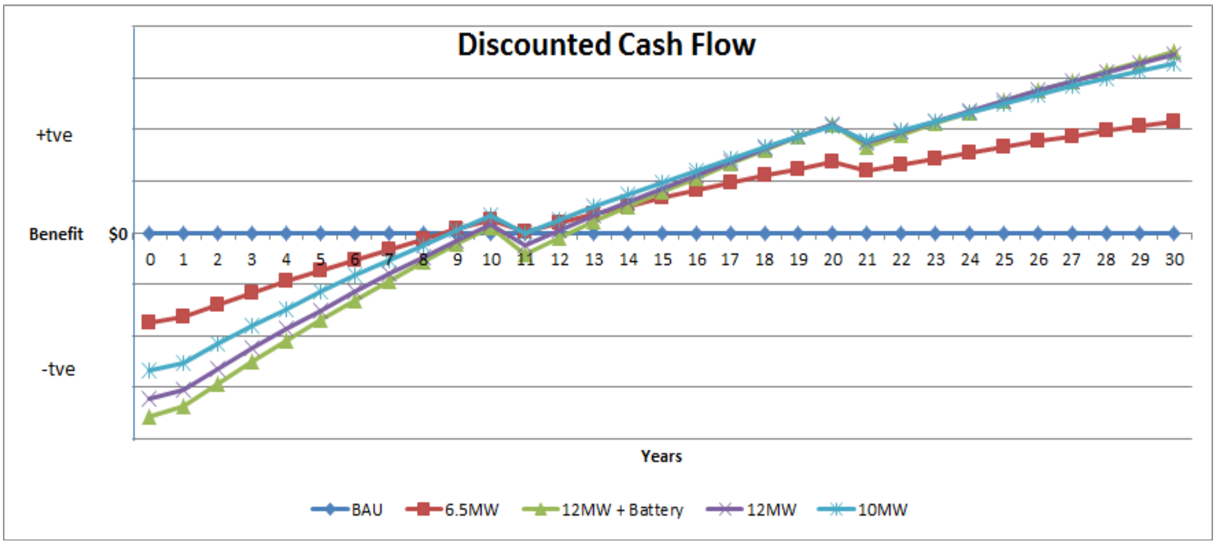

Figure 10: Discounted cash flow/payback period for a number of solar solutions

Financial benefits – Energy Efficiency

The payback period for energy efficiency implementations is usually less than 3 years, making them an attractive way of reducing electricity costs (NSW Office of Environment and Heritage, 2014). Energy audits of a number of buildings have recently been completed. These audits have identified what energy efficiency opportunities can be implemented and what savings can be achieved in reduced electricity consumption for those buildings on campus. These varied between buildings but included LED lighting retrofits, air-conditioning and building management controls upgrades, refrigeration consolidation, sensors, timers and behavioural opportunities. For example, University of Wollongong is expected to achieve 5% energy reductions annually (University of Wollongong Facilities Management, 2014). For the main campus a saving of 20% in energy efficiency over a period of 4-5 years would not be an unreasonable expectation.

Financial benefits – Peak Demand Management

At the main campus, Rolling Capacity charges can be in the order of 20% of the total bill. They arise where the maximum metered demand, or peak, - for a given period such as a month, is measured in kVA, and is recorded and an equivalent charge, is then levied for the whole billing period such as 12 months, is based on this maximum kVA demand.

Simulation studies using Sunulator have indicated that the implementation of 12MW Solar PV + Battery is expected to reduce peak demand by approximately 8%, with the implementation of peak demand management it would be expected to reduce this peak by a further 8%. As rolling capacity charges equate to approximately 20% of grid costs, this equates to approximately 3% savings.

Financial benefits – Reduced capital upgrade requirements flowing from having local 'behind the meter' generation.

'Behind the meter' generation may, in particular situations, reduce the need to upgrade expensive distribution systems and equipment. Due to projected increased grid electricity demand on campus under BAU, significant (multi-million dollar) capital expense would be warranted to upgrade the high voltage equipment (HV feeders into the campus). With on-campus generation and reduced demand through energy efficiency, this planned expense would be mitigated.

Other benefits: carbon offset, electric vehicle charging stations

The 12MWp Solar PV would result in 13,800 Tonnes of carbon dioxide being offset annually, equivalent to taking approximately 4000 cars off the road.

Approximately 25% of electricity generated would be exported to the grid. The installation of EV charging stations throughout the University could utilise this resource, charging vehicles when electricity generation exceeded consumption on campus. This would promote the use of electric vehicles within the region. Furthermore, the expected reduction in the cost of batteries in the near future would make it economic to install additional battery storage arrays making use of this resource and further decrease the University's reliance on other forms of electricity generation such as green power.

Projected Changes to University Energy Charges with 100% Renewable Energy

It is expected that the financing of the capital costs (such as through CEFC) would be covered by the reduced electricity charges for the length of the loan. For example, the implementation of 12MW Solar PV is expected to halve the electricity costs. Savings from other measures, such as energy efficiency, may be accurately estimated following a more detailed study (and activities such as further energy audits) being undertaken. This was out of the scope of the initial feasibility study. Similarly to Solar PV, the savings could plausibly also service a loan for these measures from CEFC.

To achieve the goal of 100% renewable energy usage on campus, supplementary renewable electricity produced off-site could be purchased such as Green power, Local Energy Trading or through a power purchase agreement to augment the onsite generation. The amount of offsite renewable energy required would depend on the level of efficiency measures implemented in concert with the Solar PV and Battery installation. For example, a 20% saving in energy efficiency, taken together with 50% expected savings from solar PV and battery storage would leave 30% to be purchased from off-site.

Benefits Management

Metrics need to be established on what the implementation project is measuring to determine success, such as reduction in electricity costs, electricity usage, and carbon emissions. These then need to be baselined at commencement and then measured at determined intervals on an ongoing basis to show progress. Energy Efficiency gains should be included in these measures not just on-site generation.

Discussion

The majority of Australian universities have made pledges to improving the sustainability of their energy consumption through setting targets on the reduction of greenhouse emissions. These targets vary in size and form as do the methods employed in achieving these goals.

A university campus utilising a micro-grid can utilise renewable energy generated at numerous campus locations across the campus. Onsite generation and use can be thought of as one virtual generator and one virtual user, simplifying the feasibility planning.

The process for achieving 100% renewable energy at a campus can be summarised in determining:

- What energy use can be reduced through various energy efficiency measures?
- What renewable energy can be generated on-site (referred to as behind-the-meter)? And
- What renewable energy can be generated offsite or purchased?

The order of these three points is important as energy efficiency generally has the best financial payback period, followed by on-site generation. Offsite renewable energy generation or purchase at this time is generally more expensive than onsite generation due to the cost of the electricity network grid.

Energy efficiency measures would be expected to be cost neutral from savings in electricity usage funding the repayment of capital loans. It is expected that approximately 20% of electricity usage could be reduced through energy efficiency.

Behind the meter Solar PV is currently the most cost effective form of electricity use. To determine the solar PV potential, available rooftops, carparks, and vacant land were mapped. Electrical interval data for the campus and current electricity tariff information were obtained. The Solar PV estimates, interval data and tariffs were utilised as input to a simulation tool to conduct various scenarios of grid connected solar PV and battery implementations. From various scenarios the maximum possible solar PV size of 12 MWp plus some battery storage was found to be the most effective from both a financial and emission reduction potential, with a halving of electricity grid use. These cost savings, combined with the revenue generated from the sale of LGCs would be sufficient to pay back a loan over 10 years such as through the CEFC.

The remaining renewable energy generated electricity could be either generated or purchased from offsite through mechanisms such as a PPA, local electricity trading (once implemented), or through the GreenPower program.

The achievement of 100% renewable energy as a cost neutral proposition is appealing to the University but also allows it to be achieved in a reasonable timeframe being somewhat separated from the asset management and financial constraints of the University.

Further, consideration must also be given to the multi-million dollar projected costs of external and internal grid upgrades that a University would have to incur under business-as-usual growth projections.

By being a leader in sustainability and energy management, 100% renewable energy is not only a drawcard attracting students and staff, but also provides the impetus to create a living laboratory for teaching and research in renewable energy.

Conclusion

To ascertain the feasibility of 100% renewable energy for electricity consumption on a University campus, a systematic process is employed of identifying and evaluating energy efficiency, onsite generation, and offsite generation. The implementation of energy efficiency measures and onsite generation such solar PV can be cost neutral with cost savings through the reduction of grid energy used to repay the financing within a reasonable pay-back period. Solar PV and other onsite generation would also create an income stream from the LGC generated, possibly reduce the need for internal and external grid upgrades, and enable the campus as a living laboratory for teaching and research in sustainability.

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