NTU Sustainable Energy

-USP Group 6
Global Green - How SmartGrid Technology Will Help Save $$$ and the Environment
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Smart Energy – Singapore and NTU have a stake

The Energy Market Authority (EMA) is primarily engaged in research into alternative energy sources and energy management to improve energy security in Singapore. In 2009, the Intelligent Energy System (IES) pilot project was implemented, marking Singapore’s inaugural move towards an integrated smart grid system. In 2011, “policy makers, industry leaders and academics” met to discuss the prospects and challenges of a sustainable, smart energy economy. (EMA, 2010) These landmark events highlight Singapore’s venture into sustainable energy production and consumption.

Moreover, Singapore is not exempted from the global endeavour to seek out alternative sources of renewable energy to provide for sustainable increased energy consumption. Just recently, the government contemplated building a nuclear reactor to provide massive amounts of energy in an efficient manner. While the idea was eventually abolished because Singapore is too small to allow for an adequate safety radius around the nuclear plant, this incident demonstrates the government’s vested interests in alternative sources of energy. (Chua, 2012)
Nanyang Technological University (NTU) is involved in the aforementioned IES pilot project as a test-bed, due to its “research and technological capabilities to facilitate the testing of the various smart grid applications and solutions”. (NTU, 2010). The smart grid represents a breakthrough in the research into sustainable energy management due to its ability to integrate multiple energy sources (including solar energy), enable energy providers to determine how much power to feed into the grid to ensure maximum compatibility with consumption trends and encourage consumers to make informed decisions about their energy usage.

**Students as stakeholders**

The purpose of our paper is to analyse the success of the Perth Solar City (PSC), an initiative in Western Australia to improve energy efficiency, and to apply the lessons learned in Singapore by leveraging on existing research and projects pertaining to sustainable energy. We seek to align ourselves with this growing awareness of the need for sustainable energy management and to achieve this outcome, in this paper, we will make recommendations of how students can be part of this ground-breaking movement.

In essence, student residential quarters (halls) will serve as platforms for technology and behavioural test-bedding with the implementation of smart meters, pay-as-you-use arrangements and time-of-use tariffs in the preliminary phase of development. We believe that NTU is well-placed to further the reach of this project with its commitment to energy management and capacity for technological development as demonstrated through the establishment of the Energy Research Institution @ NTU (ERI@N). Following, we will perform a cost benefit analysis of the tasks and procedures we have recommended to meaningful evaluate the challenges of implementing the project as well as consider how we may circumvent these foreseeable obstacles.

In the likely event that the smart grid technology is successfully integrated into the halls, we will also consider the potential leverages that the system can offer, namely through the integration of numerous energy sources. In particular, we will look at solar energy
generated using solar photovoltaic panels. Also, we will look into independent micro-grid development, as a follow-up to the existing system in Pulau Ubin.

In this paper, we will also refer to the notion of human security, which is defined as “security from the perspective of individuals and communities within the state” (Mely Caballero-Anthony, 2012). Human security comprises 3 aspects, viz. freedom from want, freedom from fear and freedom to live in dignity. In the sections to follow in this paper, we shall relate these aspects to energy security. The 1st aspect of human security, freedom from want, shall refer to the right of electricity consumers to an adequate standard of living, which is achieved by providing affordable electricity. The 2nd aspect, freedom from fear, shall refer to protecting consumers from sudden disruptions in daily life, which is achieved by ensuring a stable and reliable source of electricity. The recently added 3rd aspect, freedom to live in dignity (UN, 2010), shall refer to realizing human security via consumer-centered and participatory approaches. In other words, empowering consumers should form the basis of energy security.
2.0 CURRENT DEVELOPMENTS
2.1 Developments in Singapore

The "Intelligent Energy System" (IES) pilot is an initiative launched by the Energy Market Authority (EMA) in partnership with Singapore Power. This pilot aims to improve the capabilities of our power grid to the next level and to ensure that our electricity infrastructure is sustainable and secure enough to last us into the future. The IES Pilot seeks to test out and evaluate new applications and technologies around a smart grid. The results of this pilot will allow EMA to adopt and roll out workable solutions for Singapore's power system, resulting in reducing energy wastage and shaving peak loads to optimize system efficiency. This will ultimately lead to a reduction in energy costs and a drop in carbon emissions (Gross, 2010).

The IES Pilot will be rolled out in two phases, the first phase involving the laying out of infrastructure elements to allow the deployment of a two-way data communications infrastructure using smart metering technology, as well as to enable demand response and outage management. The second phase of the project will ride on the IES infrastructure to test different applications for consumers and household (EMA, 2007).

**Pulau Ubin Micro-grid Test-bed**

EMA aims to test the reliability of electricity supply within a micro-grid infrastructure using intermittent renewable energy sources via this micro-grid test-bed on Pulau Ubin, an island north-east of Singapore. This will build local capabilities in the area of smart grid design, systems integration and energy management. Previously, residents and businesses had to rely solely on their own diesel generators for electricity and do not have a reliable and secure electricity grid that is both cleaner and cost-competitive.

The micro-grid test-bed is powered by clean energy sources, including biodiesel and solar photovoltaic panels and this provides a continuous and reliable supply of electricity to end-users without any instance of any power failures. With this micro-grid test-bed, electricity is provided at a competitive price that is cheaper than the price that end-users used to pay
for diesel generated electricity. This price is also legislated by the EMA and requires its approval before any changes to the pricing can be made. As a result of this test-bed, end-users can now use higher load electrical appliances such as refrigerators and air-conditioners, allowing businesses to expand operations and extend operating hours. (EMA)

IES at Punggol Estate

The IES Pilot was conducted for households at selected residential estates in Punggol in mid-2012. These trials will evaluate the effectiveness of smart meters, in-home display units, and other related applications with regards to electricity monitoring and reduction in energy consumption. Effort has been made to contact with EMA for the results of these trials, however EMA has replied that they are still processing the results and thus unavailable as to date.

IES at Marine Parade

The Electricity Vending System (EVS) is a pilot project that aims to re-engineer the retail process of smart meters by making use of their capabilities. This scheme is an innovative concept that integrates the state-of-the-art smart metering technologies and the existing e-Payment infrastructure to allow small electricity consumers to purchase electricity. Through the EVS, consumers will be able to choose between different electricity supply packages offered by electricity retailers that best suit their lifestyle. Consumers will be able to purchase their electricity packages at various e-Payment channels such as through internet banking, payment kiosks and convenience stores.

EVS would enable us to reap efficiency gains and potentially reduce the cost of retailing of electricity. EMA conducted trial runs involving 1,000 volunteer households over a 6-month period in November 2008, which involved certain areas of the Marine Parade Group Representation Constituency.
These trial runs will test various aspects of consumer participation. The first aspect would be Demand management where the EVS enables a consumer to choose an electricity package that best suits his lifestyle, to know the cost of the electricity being consumed when he switches on appliances in his home and to manage the electricity consumed in his home. The second aspect would be the user friendliness of options to help consumers buy electricity. The EVS will thus provide information and tools to help a consumer decide on the electricity package which best suit his lifestyle, different ways to pay for electricity and also additional information that a consumer may want as value-added services. The last aspect would be consumer feedback in which the trials seek to test the efficacy of these various options enabled by the EVS and to gather feedback from consumers on how the EVS can be further improved (EMA, 2008).

This scheme shows us how we can incorporate technology (such as e-Payment) and the use of smart meters to come up with a system that allows end-users to better manage their demand of electricity and thus do their in conserving electricity.

### 2.2 Developments in NTU

NTU is also the place for an "Intelligent Energy System" (IES) that is launched by the Energy Market Authority (EMA). The Yunnan Campus of NTU is selected because NTU has the technological capabilities to test out the Smart Grid and its various components. This initiative represents Singapore’s effort to develop a more capable and intelligent electrical grid based on new technologies to increase our energy capabilities and ensuring sustainable usage. The IES initiative comprises 3 main components - the "Advanced Metering and Communications Infrastructure" (which allows a two way information flow between providers and consumers), "Demand Response Management Systems" (enable users to manage their consumption according to price changes) and "Management Systems for Distributed Energy Sources" (control system which assimilates different sources of power from solar PV systems to generation plants). When these 3 components are
successfully tested, they will lay the foundation for the future of Singapore's energy system. (EMA, 2009)

2.3 Situation in NTU Hostels

NTU's residential halls are powered by Senoko Energy, Singapore's largest power generation and retail company, using a low-tension system. In the context of electrical power distribution, low voltage is defined at 230V. (SP Power grid, 2013) For the purpose of this report, we have chosen to look into the electricity consumption of Halls 13-15 because USP students are currently housed within these 3 halls. Being in the same program and student community, recruiting USP students for any form of trials would facilitate marketing efforts, communication, as well as consumer feedback. Thus, not only would it be easier to obtain data, it would also be a meaningful start to implement a pilot study by the USP students, for the USP students. In addition, we believe that the 3 halls sampled are representative of the general electricity consumption patterns in NTU's residential halls.

The objective of identifying the current situation in the residential halls is to make a more informed comparison between what we have and what more that could be improved, with lessons gleamed from the Perth Solar City initiative.

Ultimately, we aim to illustrate the relevance of using smart meter displays to monitor personal electricity consumption behaviour, work towards levelling peak demand and eventually carry out peak shaving through solar panel installations.

The general consumer behavioural patterns are that of higher electricity usage during the academic terms from August to December and January to May. Although one may be inclined to think that Singapore’s climate will influence electricity consumption patterns, surprisingly, it does not. This is because the inter-monsoon periods, May to July, where Singapore experiences its hottest and driest months coincide with the school’s vacation period, resulting in the lowest energy consumed during that period. Thus, this reinforces
the need for a paradigm shift in the consumption attitudes of our students today as high electricity consumption cannot merely be attributed to the hot weather.

**Figure 1: Units consumed (MWh)**

**Figure 2: Cost of Electricity**
Figure 1 shows the number of electricity units consumed across Halls 13-15. The general annual trend for electrical consumption follows an M shaped curve with 2 peaks in May and September, where energy usage is highest during the school terms and sharply drops during the semester vacation periods. However, the graph in 2013 fluctuated less sharply than 2012. Despite a high average of 76.2 MWh being consumed monthly in each hall, we observed that the number of electricity units consumed in 2013 was actually lower than 2012. The total number of energy units consumed in 2012 was 2809 MWh for the 3 halls. In comparison, the total number of energy units consumed in 2013 was 2679 MWH, a drop of 129 MWH or approximately 4.7%. This may have been indirectly attributed to an increase in routine checks and announced penalties for unattended appliances in 2013, though the exact reason for the drop in usage is unclear.

However, as the average electricity bill per month per hall is still a substantial $22,000 as seen in Figure 2, electricity still takes up more than one-fifth of the operating budget of the hall management (Shang, 2013). Thus, there remains an impetus to further reduce electrical consumption and encourage green practices.

Currently, Senoko charges are based on the usage estimates for a month ($/kW) and the pricing tariffs set by the Energy Market Authority. Students pay a flat rate of $320 per month or $1600 per semester (NTU, 2013) and this often results in an overexploitation of resources since the rationale of most students would be to use more electricity since they have already paid for it or to be unconcerned with electricity wastage since they would not be charged extra for consuming more electricity.

However, such a systemic flaw would ultimately be disadvantageous to students in the long run as the hall management’s budget is self-financed without any subsidies. The implications of a self-financed budget are that if the exploitation of electricity becomes excessively high, it will result in higher rental fees, where students will definitely feel the pinch. This is because the rental fees that students pay goes towards more than merely
rent, it covers electricity and water usage as well. It goes towards and the electricity used for sensor technology in the common rooms and corridors which add on to the costs as well.

In relation to a self-financed budget, this may cause fluctuating expenses. The base line as seen in both Figure 1 and 2 can be estimated to be the minimum amount of energy units consumed each month and its’ corresponding cost. It was derived from taking the month with the lowest amount of energy units consumed across the 3 halls and then averaging it out to obtain the minimum inevitable cost incurred by the halls as a result of electricity being needed to power common spaces. It would be useful for hall management to take into consideration the base consumption when budgeting in order to better fiscal marksmanship.

Given this context, we propose the use of smart meters as a solution to reduce electrical consumption as phase 1 of our project to encourage energy conservation. A smart meter records electricity consumption at 30 – minute intervals and automatically sends this information to the grid operator. Conventional meters only record cumulative electricity consumption and have to be manually read (EMA, 2010). We believe that using a pay-as-you-use (PAYU) arrangement for electricity will be feasible as such a system has already been implemented for air conditioning within the hostels. The use of air conditioning is charged at $0.01 per 2 minute block and students are required to purchase an air-con card in order to operate the air-con. Likewise, electricity could be charged in a similar manner to encourage students to become more conscious and responsible for their usage. By being consciously aware of the cost of electricity, it will help students better manage their energy consumption and lower their energy costs. It can be argued to be more equitable as students pay for only what they use and the monthly rental fees can be lowered since electricity costs are taken out of the equation. In addition, allowing students to be responsible for the variable portion of their electricity consumption—via the PAYU arrangement—means that the Office of Housing & Auxiliary Services can have a better forecast of their revenue-expense margin, given that fluctuating electrical expense is taken out of their purview.
Our group recognizes that the smart grid business case assumes significant changes in consumer behaviour. There are of course, uncertainties associated with the proposed solution. Such uncertainties are mainly due to the inability to obtain accurate results on the success of the implementation. While smart meters can be effective tools to aid consumers to be more electrically efficient, we cannot say for certain that they will definitely help NTU halls decrease their electricity consumption as it is difficult to show a relationship between smart meters and electricity consumption at this point of the project.

A challenge to consider would be the constantly changing student body in the residential halls as room occupants often reside on a temporal semester basis, making it difficult to monitor a particular group of students because of their temporal nature. This is due to the fact that hall residents change at least once a year. In NTU, only the year ones are guaranteed accommodation while other students have to earn sufficient points to extend their stay. This causes a lot of movement in the type and number of students in and out of halls. This makes it difficult to analyse a relationship between the two accurately as the number of hours spent in hall, the types of activities that use electricity, the mindset of the person towards saving water etc all differ from person to person.

In addition, it is difficult to obtain accurate averages of electricity consumption due to the presence of illegal squatters and some occupants leaving the room vacant most of the time. Thus, it is difficult to monitor whether smart meters have effectively altered human behaviour to save electricity as such behavioural changes are usually more accurately observed in the long run.

Despite such uncertainties, it is a project that clearly shows much potential as it is highly similar to the electronic vending system that is used for the air-conditioning currently, where it has been successful in making students mindful of their consumption habits. Secondly, enabling the tracking of data in 30-minute intervals, and displaying them through
an in-house-display (IHD) interface also provides the necessary information for consumer studies, which can be used to decide on the relevance of time-of-use electricity pricing in the future. Lastly, the smart meter also acts as a net-metering system which enables the easy integration of renewable energy sources (e.g., solar photovoltaic), as opposed to a conventional mechanical energy meter (Sunteedy, 2014).

Currently, Senoko monitors energy usage through centralised meters in each block at the end of the month, and not individually in each room. For example, the electrical bill for Block 13 of Hall 1 amounts to about $69,000 a month (Shang, 2013). However, the objective of our group is to actually raise awareness about the electricity each individual consumes. By implementing smart meters in each room, students will be able to monitor their usage more effectively.

To balance the energy supply and pioneer the move towards a future with sustainable energy, we ultimately hope to create a micro-grid cluster incorporating solar photovoltaics (PV) and time of use pricing within the hall compounds. However, the lump sum billing system that is currently in place prevents us from identifying the daily peak demand period patterns. This is because with smart-metering infrastructure, we aim to implement time of use pricing to encourage students to shift their consumption in line to the time-related tariffs. A reduction in consumer electricity consumption during peak periods brings about two-fold benefits. Not only will students save on their electricity bills, the lower peak demand will also ease the pressure on generation plants– resulting in savings in terms of energy infrastructure spending (Gross, 2010). Thus, this reinforces the need for smart meters as they will provide data in the form of 30-minute intervals. Hall management would then be able to identify behavioural patterns such as peak consumption periods, and charge accordingly.

While the effect of installing a smart meter may be marginally small, smart meters have the potential to act as a stepping stone for further developments towards a micro grid with a distributed generation model. Thus, it will enhance the efficiency of energy consumption, and create a more sustainable green environment for the students to live, work and play in. This will be developed more under section 4 on future developments.
3.0 INSIGHTS FROM PERTH SOLAR CITY
3.1 Transferrable Lessons and Recommendations

NTU halls currently have no equipment that would allow individual units to receive accurate and useful information regarding their electricity consumption patterns and behaviours, as there is only a single point meter available for recording and measurement of total electricity consumption. Similarly, Perth Solar City (PSC) recognised the same problem, and in response called for an In-Home Display (IHD) trial. These installed IHDs were able to educate users on their electricity usage and provide them with real time information on their expenses in units (kWh) and in cost ($). The trial proved to be relatively successful, with participants reducing their electricity use by 5% during super peak periods. The table below seeks to highlight certain transferable lessons from the IHD trial to NTU halls to allow for more comprehensive proposed solutions seeking to tackle high and unnecessary electricity consumption.

Table 1: IHD Trial- Lessons learnt from Perth Solar City and Application to Singapore

<table>
<thead>
<tr>
<th>Lessons Learnt from Perth Solar City</th>
<th>Application to Singapore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most of the IHDs were sent to households on an involuntary basis. 44% did not make use of the IHD and the smart meter. There was a waste of resources. Unused IHDs could have been better allocated to other interested consumers. This could have led to further insights on the maximized benefits of the IHD. Need to target an engaged and motivated audience.</td>
<td>1) <strong>Pre-program communication and education.</strong></td>
</tr>
<tr>
<td>IHD used as a single tool alone. Full potential benefits of IHD not enjoyed and observed. Results show that electricity consumption and deferment was improved more when the IHD was used in conjunction with other tools and services. Should approach the issue of</td>
<td>Information sessions will be held before the actual program commences. Knowledgeable and engaging speakers will be invited for this session to introduce to the students the importance of environmental sustainability. The session would also aim for students to be aware of the vision and direction of our initiative, and to allow for a greater transparency between the users and the team. A greater transparency and faithful representation of our initiative would then translate to a greater trust for our team as students</td>
</tr>
<tr>
<td>high demand of electricity holistically, by employing various solutions that work hand in hand and complement each other.</td>
<td>understand and increase their receptivity to our cause. This would enable students to make informed decisions and to allow them to know that they are important stakeholders who deserve to know what they can and should do. Students will then be given the opportunity to be a part of the initiative and sign up for the IHD trial after the information session. In this way, we only recruit people who are interested in our electricity saving program and avoid wastage of resources.</td>
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<tr>
<td>Limited technical support. Technical problems that arose with the IHD were not settled as quickly as it could and should be. This led to some consumers disusing it. Should ensure that technical support is conveniently available. Instructional programmes to teach users how to resolve minor technical issues could also be implemented.</td>
<td>Limited information made known to users about the IHD and its benefits. Consumers were not engaged and motivated to take part in the trial. Should be transparent about the IHD in order to build trust with users. Provide them with comprehensive information on IHD (Users have the right to know what they are getting themselves into before they agree)</td>
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<tr>
<td>2) IHDs and smart meters should be installed.</td>
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</table>
IHDs and smart meters will be installed in each room in a designated block, to facilitate their easy monitoring. Smart meters are similar to conventional meters, except that they provide a more accurate reading of energy usage and total cost of electricity in real time. IHDs will subsequently be paired with the smart meter via sensors and transmitters, and will allow for users to compare their current electricity consumption with their past usage. Having such information readily available and accessible will aid users in making informed decisions regarding their electricity consumption patterns. Technical issues will arise indefinitely, and technicians will have to be trained and |
Another measure taken in the Perth Solar City project is the Living Smart Program. The Living Smart Program is a comprehensive and intensive behavior change program which aims to encourage households in Perth’s Eastern region to reduce their demand for water, conveniently ready on standby. Our initiative would entail sending our own USP students pioneering this trial to attend workshops on basic smart meter and IHD maintenance, to ensure fast responses should any issue arise. To add on, these basic skills picked up may be transferred to users to equip them to handle minor issues. This would reduce the dependence on professional technicians, thus saving both time and money, and inculcate a sense of ownership over their personal tools.

To complement the IHDs and smart meters, a pay-as-you-use scheme will also be implemented. Similar to the air con card already in place, students will be required to top up their card at designated machines and slot them in before they are allowed to turn on their the lights and fans in the room. This would raise the student's awareness to their use of electricity, and in turn prompt them to take notice of their unhealthy and unnecessary consumption patterns and to use electricity in a more conservative manner. Over time, such intentional actions taken by the students will translate into habitual actions, ultimately leading to a behavioural change.
electricity, waste services and car based travel. Under the electricity-saving program, customized letters and pamphlets were sent to every household, providing energy-saving information for them. The program is very successful as an average reduction in electricity use of 8.5% per household was evident (Perth Solar City 2012 Annual Report, 2012). The table below seeks to highlight certain transferable lessons from the Living Smart Program to NTU halls to achieve behavioural change and encourage participation in energy efficiency products.

Table 2: Living Smart Program- Lessons learnt from Perth Solar City and Application to Singapore

<table>
<thead>
<tr>
<th>Lessons Learnt from Perth Solar City</th>
<th>Application to Singapore</th>
</tr>
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<tbody>
<tr>
<td>Eco-coaching was free provided to every household. Over 90% of households initially recruited to the program were interested in participating further in the meter reading and eco-coaching aspect of the program. One-to-one eco-coaching makes households feel more comfortable in accepting suggestions.</td>
<td><strong>Allow for follow ups to be done by students (Eco-coaching)</strong></td>
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<td></td>
<td>During the trial, USP students in charge of the initiative will be tasked to carry out follow up roles, mimicking the Home Eco-Consultations provided free of charge in Perth Solar City. This would encourage the students themselves to take ownership of their block’s electricity consumption and remind them that they themselves are the stakeholders and have the authority to be the change makers.</td>
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<td></td>
<td>Having student-to-student interactions instead of requesting for the hall administrators to take on this role also allows for a more comfortable and non-threatening setting. These interactions will be held at regular intervals, during which feedback regarding the analyzing of the observed consumption patterns and of the trial itself will be exchanged. Such activity would encourage accountability between users and eventually propel behaviour change after the good habits have been adopted.</td>
</tr>
<tr>
<td>Summary of personal and collective community achievement on electricity saving was given to all households. People become aware that there are others who are also saving electricity and they are making a difference to the society. Some households even form groups and continue to meet regularly to share ideas, stories, and tools and motivate one another to take sustainability action locally. People will feel more encouraged to continue with green practices when they can see the collective result.</td>
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<tr>
<td><strong>Organize competitions on saving electricity</strong> Competitions can be organized in order to motivate people to save electricity.</td>
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<tr>
<td>Printed flyers and pamphlets were sent to households regularly. These materials were useful in raising awareness and teaching people to save electricity. However, some people suggested that there should be online materials as well so as to save paper. Online pages can be created to provide more information for the participants.</td>
<td></td>
</tr>
<tr>
<td><strong>Provide continual education on environmental responsibility through the use of flyers or online page</strong> Our initiative seeks to also leverage on the power of social media and its reach to millions. A Facebook page where all students can easily access information such as the progress of the initiative will be created. In this page, students will also be provided with a myriad of electricity saving tips and of recent news refined to topics regarding environmental sustainability news. This updated news will grant students a better overview of current environmental issues, and encourage them to continue with the green practices.</td>
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Lastly, we look at the Solar Photovoltaic systems tested in the Perth Solar City Initiative. Under the Perth Solar City Initiative, solar Photovoltaic (PV) panels are introduced and having them installed on the roofs of houses and businesses building to generate renewable electricity at virtually zero cost. (Perth Solar City 2012 Annual Report, 2012) Such technology is especially useful for countries that receive lots of sunlight. With government subsidies and the introduction of feed-in tariffs\textsuperscript{1}, the cost of having the outlay of a smart grid with solar PV panels can be recouped within a short amount of time, thus making solar energy a very viable option for a sustainable lifestyle. The table below highlights transferrable lessons from Solar Photovoltaic trial to NTU halls, which can be undertaken in the future.

Table 3: Solar Photovoltaic Trial- Lessons learnt from Perth Solar City and Application to Singapore

<table>
<thead>
<tr>
<th>Lessons Learnt from Perth Solar City</th>
<th>Application to Singapore</th>
</tr>
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<tbody>
<tr>
<td>Perth receives 7.9 hours of sunlight per day and this allows households to capitalise on the amount of time for generation of solar power.</td>
<td>Similarly, Singapore receives an average of 5.39 hours of sunlight per day and has the right conditions for the generation of solar power.</td>
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<tr>
<td>Installing large scale solar PV systems at iconic locations to promote uptake.</td>
<td>Have solar PV systems installed into tourist locations such as Gardens by the Bay which allows both Singaporeans and tourists to be exposed to the technology behind solar energy. Can start small by powering a certain operation process with the use of PV systems.</td>
</tr>
<tr>
<td>Households with solar PV systems showed a reduction in electricity consumption from the electricity grid. This is most prevalent amongst the middle income group, and consumers surveyed are mostly satisfied with the use of solar PV systems at home.</td>
<td>Most importantly, the conversion to solar PV systems would be warmly welcomed by residents as long as there are substantial savings and a reduction in electricity consumption. If we are able to show and present the opportunity for cost savings to residents, Singaporeans might be more than willing to try out solar PV systems in their own homes.</td>
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</tbody>
</table>

\textsuperscript{1} A payment made to households or businesses generating their own electricity through the use of methods that do not contribute to the depletion of natural resources, proportional to the amount of power generated.
A feed-in tariff is integral to the uptake of solar PV systems among residential and corporate consumers. It allows them to save up on cost and makes the technology available to them at a much cheaper price. However, the exact amount to subsidise and to price for electricity back to the grid is hard to determine and once introduced, hard to retract without the displeasure of citizens. It might even bring about an unwanted consequence where citizens export energy from their own solar system to earn money, which is what happened in Perth.

Alternatively, Singapore can adopt solar investment subsidies schemes e.g., a dollar for dollar, such that the payback period for the investment into the solar capability scheme would be lower.

The idea of using battery banks in line with the solar PV systems has been explored in many businesses as it allows excess solar energy to be stored and to be drawn upon when needed. This also allows the system to be more flexible to meet the difference in varying demands for electricity during different times of the day.

Using battery banks in hand with solar PV systems would bring about more efficient usage of the renewable energy and allow energy demands to be met.
3.2 Cost Benefit Analysis

The table below highlights some of the advantages and disadvantages of our proposed solutions. In addition, some of the limitations of a solar PV system and smart metering system are also further discussed.

Table 4: Cost Benefit Analysis

<table>
<thead>
<tr>
<th>Suggested solution</th>
<th>Cost</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar PV system with battery banks and feed-in tariffs</td>
<td>Relatively expensive technology that needs to be subsidised by the government. Comparatively more expensive to drawing power from the grid.</td>
<td>Able to meet some of the electricity demands during non-peak periods. Renewable energy is free, only the initial outlay cost has to be recouped.</td>
</tr>
<tr>
<td>Pre-program communication and education</td>
<td>-inviting appealing speakers who are well versed in environmental sustainability -miscellaneous cost for the running of the program (information booklet, refreshments, etc.)</td>
<td>-we are able to filter out an engaged and motivated audience for our trial. -Students are more willing to sign up in groups as opposed to door-to-door invitation. -Adequate information (eg. About our aims and directions, IHD) about our program will encourage students to get more involved in the program.</td>
</tr>
<tr>
<td>Installation of IHDs and smart meters</td>
<td>-cost of the installation of IHDs and smart meters -cost of training technicians to be able to handle the technical issues that may arise</td>
<td>- Users will be able to monitor their real-time electricity consumption and cost and can make informed decisions about electricity usage. -It paves the way for more engaging activities such as competitions.</td>
</tr>
<tr>
<td>Event Description</td>
<td>Additional Costs</td>
<td>Benefits</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Organise competitions on saving electricity</td>
<td>- manpower and time&lt;br&gt;- miscellaneous cost (e.g., publicity, prizes)</td>
<td>- to keep the trial engaging for the students&lt;br&gt;- allow students to witness and contribute to collective effort to save electricity.</td>
</tr>
<tr>
<td>Eco-coaching by USP students</td>
<td>- cost of sending students for training</td>
<td>- save the cost of hiring professional consultants&lt;br&gt;- Create a more comfortable and friendly setting for the exchange of feedback</td>
</tr>
<tr>
<td>Provide continual education on environmental responsibility through flyers or online page</td>
<td>- miscellaneous cost (e.g flyers and pamphlets)&lt;br&gt;- time spent to manage the online pages</td>
<td>- continue to motivate students to do their part&lt;br&gt;- more convenient avenue for people to access information&lt;br&gt;- Online page can generate more awareness and publicity about our initiative</td>
</tr>
</tbody>
</table>

Limitations of Solar PV:

1) Solar PV systems are unable to produce enough electricity to meet the peak demand of consumers and thus for certain periods of the day, consumers must draw power from the grid.

2) Drawing power from the grid is still relatively cheaper than the layout cost of using a solar PV system.

3) Singapore has space limitations and installing solar PV panels on HDB flats can be useful but certainly not enough to power the entire block. However, we can look into private housing (bungalows etc) to have them install solar PV panels to power up certain household processes such as water heating.

4) Due to high electricity usage, solar PV panels have to produce enough electricity during the day and Singaporeans having a lifestyle which is more connected and
uses more electrical appliances and technological gadgets, requires more electricity as compared to the more laid-back Australian lifestyle.

5) Feed-in tariffs have to be introduced for a definite amount of time and have to be fixed at the right amount. It cannot be too expensive for the government to sustain over a long period of time.

Limitations of smart metering:

1) One difficulty that will arise if smart meters were implemented would be the splitting of costs between tenants residing in twin sharing rooms. If only one card per room was used, disputes between tenants may arise as it will be a tedious process to periodically calculate individual usage.

2) The effects of educational and informational efforts taken may not reap the desired effects due to the student’s resistance. Such uncertainty questions if the resources used for it can justify for the benefits that arose from the effort.
4.0 FUTURE DEVELOPMENTS AND CONCLUSION
4.1 Future Developments

Recommendations – Phase 2

After Phase 1 of the recommendations (Section 3.1) has been implemented, Phase 2 involves installing Solar Photovoltaic (PV) systems in the abovementioned halls, by drawing on lessons learnt from the PSC project.

The feasibility of this phase is supported by groundwork which has already been laid out in NTU. Since 2010, NTU’s Yunnan Campus (Chew-Sim, 2010) has served as the main test bed for the IES pilot to trial new technologies, administered by the Energy Market Authority (EMA). In addition, the setting up of the Energy Research Institute @ NTU (ERI@N) has reinforced the university’s commitment to energy research (NTU, n.d.). Just recently, NTU scientists at ERI@N have studied the mechanism of harvesting energy via solar cells made using perovskite materials. Current thin-film solar cells have can convert close to 20% of sunlight to electricity. However, these perovskite solar cells have an efficiency of 15% and are approximately 5 times cheaper than current thin-film solar cells (NTU, 2013). This means that installing Solar PV technology can potentially be cheaper in the future.

Nevertheless, it’s important to recognize the challenges in implementing Solar PV systems. However, by drawing on the lessons learnt from PSC, it seems possible to at least mitigate some of these challenges.

The first challenge is that Solar PV technology is currently still very expensive. In Perth, the success of PSC can be mainly attributed to government policies in the form of subsidies and other incentives. These helped to reduce the financial burden on households and businesses. In Singapore, as of 1st Jan 2014 to 31st Jan 2014, the electricity tariff is 25.65 cents per kilowatt-hour (kWh) (CNA, 2013). By comparison, the cost of producing PV electricity in Singapore is between 12 and 18 cents per kWh (Kan, 2012). Although electricity generated via Solar PV technology is evidently cheaper, the capital cost of
installing the technology still remains high. Therefore, as compared to electricity supplied by SP (Singapore Power) Services, Solar PV technology is still unable to compete cost-wise. This problem is of particular concern to NTU, whose 5 peaks of excellence (NTU, 2010) include Sustainable Earth. Although students are reasonably expected to be educated on the environmental benefits of renewable energy, they might be resistant to the idea of making the switch to use Solar PV technology. In the short term, the cost of installing this technology may increase hall rental fees. Many students would not find it economical to fork out this extra money, because they tend to operate on a budget. Therefore, it’s important that their concerns are looked into. Drawing on the success of PSC, it appears that the school, USP and hall management must be very supportive. For example, they can help defray some of the initial capital outlay for Solar PV technology.

However, it is re-assuring that the capital cost of Solar PV technology has been falling steadily over the past few years, as illustrated in Figure 3 below. In fact, it now only takes 8 years to payback investment into this technology (Kan, 2012). In addition, grid parity\(^2\) has already occurred in several countries such as Australia (Parkinson, 2013) and is similarly expected in Singapore between 2014 and 2016 (Joachim Luther, 2011). This means that very soon, the cost of rooftop Solar PV Technology\(^3\) will become cheaper than the cost of electricity sourced from the grid.

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\(^2\) This refers to the point at which the cost of solar power matches that of electricity from the grid.

\(^3\) This should not be confused with the cost of electricity generated via Solar PV technology, which only constitutes a small part of the total cost of Solar PV technology as a whole.
Figure 3: Price experience curve for silicon wafer based photovoltaic modules. World market prices are shown as a function of global cumulative shipment (logarithmic scales). The red line represents price reductions according to a learning factor of 0.8, in other words a price reduction of 20% for each doubling of the shipment. (Joachim Luther, 2011)

The second challenge is the effectiveness of solar technology as an intermittent source of energy, especially during cloudy conditions or at night. To address this issue, the Solar PV systems can be supplemented with battery banks, as shown in Figure 4. This is particularly relevant to NTU because during sunlight hours, many students would be likely to have lessons so electricity consumption in the halls is expected to be rather low. Instead of feeding this excess electricity to the grid, it would be wise to store the electricity for use during non-sunlight hours or bad meteorological conditions. In any case, should the energy in the battery banks be depleted, consumers can tap on the grid for electricity instead.
Nevertheless, it’s important to note that battery banks are currently very expensive. Just to set up the battery bank system in his business cost Mr. Dave Thompson, the owner of the Cervantes Lobster Shed Factory in Western Australia, “about 100000 Australian Dollars” (Thompson, 2014).

This concern is also voiced by Professor Syed Islam from the Department of Electrical and Computer Engineering in Curtin University, who shared that

“You have lithium-ion (batteries), which are now being very competitive and the cost is coming down... But the cost of it, I mean a few kilowatt-hour battery energy storage is tens of thousand dollars and it is not still commercially viable. But, we hope that with advancement in battery technology, they (prices) will come down rapidly and then it will provide a solution, but it is still a big challenge.”

However, with vested interest and support from potential stakeholders such as EMA, start-up costs could possibly be substantially lowered. Furthermore, it is also possible to draw on the success of Phase 1 to show that students are willing to put in effort into saving energy (in order to lower their hostel electricity expenditure), to justify the additional costs
which will be incurred in purchasing battery banks. Otherwise, if battery banks still prove to be too expensive to purchase, then perhaps electricity can be supplied from the grid when electricity production from the Solar PV systems is unable to meet consumer demand.

Furthermore, it is possible to tap on ERI@N’s expertise in this field. For example, it has acquired valuable experience in the use of Vanadium Redox batteries. As mentioned by Vincent Sutedy, a research staff (Sustainable Building Technologies) at ERI@N,

“Maybe after some time, you feel the (lithium-ion) battery is no longer good (and) you need to throw it away. This one (Vanadium Redox battery) is perfectly no memory effect\(^4\), at least for 10 years. And the battery in terms of liquid can be easily expendable.”

**Recommendations – Phase 3**

When Phase 2 is successfully implemented, the project can then proceed to Phase 3, in which the abovementioned halls operate using a Micro-grid system similar to that of Pulau Ubin\(^5\). This is because the Micro-grid system synergizes very well with Solar PV technology.

This idea is supported by Professor Peter Newman, the Professor of Sustainability at Curtin University, who mentioned that

“*a lot of the new clean tech, green tech stuff is small-scale, works best on small-scale... and micro-grids work best for water if you’re asking that, and for power. They work quite well, because they’re supported by smart technologies, control systems that can help you...*”

\(^4\)Memory effect refers to the condition of rechargeable batteries holding less charge over time, if not completely drained. Vanadium redox batteries do not experience this condition and have a long operating lifetime due to the all-liquid active materials. [http://www.pcmag.com/encyclopedia/term/46771/memory-effect](http://www.pcmag.com/encyclopedia/term/46771/memory-effect)

\(^5\) The Micro-grid Test-Bed in Pulau Ubin will be further elaborated in the next section.
It is also hoped that other Halls of Residence can learn from this project to consider adopting Solar PV technology and the Micro-grid system as well. Beyond that, residential apartments in Singapore should also look into adopting such a similar system to fulfil energy requirements. This is because the price of electricity directly affects all consumers nationwide, households and businesses alike.

Although Singapore’s supply of electricity is mainly generated from imported natural gas, the prices of natural gas are indexed to fuel oil prices, in accordance with the market practice in Asia for natural gas contracts (EMA, 2014). Hence, the fuel cost component of the electricity tariff largely depends on fuel oil prices. The problem is that fuel oil prices are extremely volatile and have caused several hikes in power costs throughout the years (Sim, 2012). This has made it difficult to ensure a constant supply of affordable electricity for consumers.

Therefore, there is a need to find cheaper and reliable sources of energy. In this regard, Solar PV technology has proven to be the most promising candidate for Singapore. Being strategically situated in the equator, Singapore typically receives about 50% more sunlight irradiation than temperate regions (IEA, 2014). With that much sunlight readily available for Singapore, it is well-placed to fully exploit Solar PV technology as an alternative renewable energy source.

To encourage households to adopt Solar PV technology, it’s important to note that the approach needs to be quite different for private and public housing.

For private housing, the government will play an important role in incentivizing households to install Solar PV technology. Government grants such as “dollar-for-dollar” funding (Thompson, 2014) can be administered, similar to that of the Cervantes Lobster Shed Factory in Western Australia, which has proven to be very successful. Although the policy of Feed-in Tariffs might have backfired during the Solar PV saturation trial in PSC (Islam, 2014), it could be introduced in Singapore provided the government finds it economically viable to increase penetration level among private houses.
For public housing, solar system developers hoping to install Solar PV systems on top of HDB flats must be prepared to respond appropriately to possible challenges.

As highlighted by Professor Syed Islam of Curtin University,

“If you have high-rise building, in terms of the solar insulation and in terms of generation, you have better opportunities. But... in high-rise building there are lots of people living and you won’t be able to generate sufficient amount of energy. But it is going to complement the conventional energy in that regard.

The other aspect of high-rise building is that you could also look at not just solar energy, but energy as efficiency as a whole... In that regard, you could also look at probably very innovative things... the building could have storage system that it could store energy at times where enough electrical energy is available, whether it is from renewable or other sources. All of these can come into play.”

In fact, the commercial use of Solar PV Technology has already been administered by the Housing & Development Board (HDB) and tested out in Punggol Eco-Town. (SPH, 2013) Furthermore, HDB recently announced a “$31 million, five-year scheme to test solar energy in 30 precincts around the island (which) has been able to take advantage of the plummeting prices of solar panels. These have come down in the last few years from more than $5.17 per watt installed to about $2.10 today” (Chua, 2013). Hence, future solar system developers can learn not only from the smart grid system in NTU, but also these ongoing initiatives by HDB, in order to further the commercialization of Solar PV Technology.

In addition, the commercialization of Solar PV technology will help to mitigate the problem of spinning reserve with regards to power generation. Spinning reserve is defined as “the unused capacity which can be activated on decision of the system operator and which is provided by devices which are synchronized to the network and able to affect the active
power” (Yann Rebours, 2005). In the context of power generation, generators must match electricity generation and consumption at every moment in time (Wogan, 2013), in order to stabilize the frequency of the electricity transmission network. To keep the grid in balance, reserve capacity from all the generators is needed as a buffer, so they have to operate below their rated value. By deviating from their most efficient operational capacity, considerable undesirable effects result, such as additional use of fuel, wastage of water, excess CO\textsubscript{2} (carbon dioxide) emissions and lower efficiency of the power grid (ESA, 2014). Ultimately, the environment is adversely affected. Furthermore, additional costs are passed onto the consumers, making it difficult to lowering the price of electricity substantially.

By contrast, Solar PV technology does not operate on the principle of spinning reserve. Instead, when coupled with the use of battery banks, it enables just-in-time power generation (Chiu, 2013) in order to cater to changes in electricity consumption patterns. Excess unused power generated by Solar PV systems can be stored in these battery banks and released when needed, without releasing emissions or suffering major efficiency losses (Wogan, 2013). Although bulk electricity storage in the form of battery banks is currently very expensive and energy storage technology is still in its infancy, research has been underway to develop low-cost energy storage (Peltier, 2011) that could possibly shape the future of the energy industry. Once commercialized, energy storage systems can then be combined with Solar PV systems to enable just-in-time power generation. Hence, the abovementioned problems associated with spinning reserve can possibly be mitigated.

With regards to the test-bedding of the Micro-grid system in Singapore, if proven successful, perhaps the idea could be sold to other countries. In fact, the Energy Policy Group, through the state’s 2007 National Energy Policy Report (NEPR), mentioned that Singapore is well-placed to develop PV capabilities for export to the region (Mely Caballero-Anthony, 2012). Therefore, both Solar PV technology and the Micro-grid system have great potential not only for implementation within the NTU campus, but for Singapore’s economy as well.
This idea is also supported by Professor Peter Newman of Curtin University, who mentioned that

“I think the city of the future will have hundreds of Micro-grids, connected, and the connections will be important... If you can do it well in Singapore, that technology will export to every neighbour city in Asia, because all of them are series of little kampongs... So you make an infrastructure suitable for that scale, join it together, and you’ve got a solution that works.”

**Micro-grid Systems: The Future**

This section gives an overview of the capabilities of the Micro-grid system, which could be implemented in the future as mentioned in the previous section.

Pulau Ubin, one of the largest offshore islands of Singapore, is being used as a Micro-grid Test-Bed (EMA, 2010) for intermittent renewable energy sources by the EMA. The Test-Bed is currently testing Solar PV systems and biofuel generators, as shown in Figures 5.1 and 5.2 respectively. These renewable energy sources have been installed as replacements in place of traditional diesel generators to power households and businesses on the island.

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6 A kampong is a small village or community of houses.
7 However, some businesses such as restaurants still keep their diesel generators as a source of backup power.
Apart from being used as a Test-Bed for renewable energy sources, power boxes as shown in Figure 5.3 are distributed around the island. These enable households, businesses and engineers to monitor electricity usage. These power boxes parallel the use of smart meters under the Intelligent Energy System (IES) pilot (Chiu, 2013). Notably, the information provided has been useful for the EMA as well as larger businesses such as restaurants. For the EMA, it can monitor electricity usage trends and advise consumers to cut down on their consumption when usage becomes too high. For restaurants, their electricity bills are in thousands of dollars and therefore, they have the incentive to use the information to cut down on their electricity consumption in order to reduce their operating costs.

The Test-Bed has been very successful to-date as consumers on the island have been enjoying cheaper and more reliable electricity, as compared to previously when they had to use traditional diesel generators to generate electricity. Firstly, each household spends only about $50 per month on electricity, leading to cheaper electricity. Had they continued to
use diesel generators, they would have to spend about $200 per month on electricity due to additional maintenance and diesel costs (Chiu, 2013). In addition, a supply of reliable electricity has contributed to the absence of substantial blackouts and power disruptions\(^8\). Hence, the issues of cost and intermittency have been well-managed in Pulau Ubin. Therefore, Micro-grid systems have the ability to shape the future landscape of electrical consumption.

### 4.2 Conclusion

With the success of the first phase, NTU can then consider installing solar panels in the second phase. The installation of solar panels will allow NTU to utilize a more sustainable and green form of energy. This will also be in line with NTU’s goals in the NTU 2015 blueprint, where NTU plans to build on its current strengths and heritage to make its mark globally in several areas including sustainability. We can even source for donations from a few prominent NTU alumni to fund the initial outlay cost for the solar PV panels and have the panels named after them. This will also recognize their stake in helping NTU in its effort to create a legacy in its sustainability efforts. The third and final phase will be the usage of micro grids in different hall and building clusters. Expertise can be drawn from the current Pulau Ubin Micro-grid Test-Bed which is being overseen by the EMA. As such, they will be able to transfer the lessons learnt and the initial outlay in a similar scale to the different clusters. With the adoption of NTU Sustainable Energy, NTU will definitely be well on its way to becoming a global leader in sustainable energy.

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\(^8\) The absence of substantial blackouts and power disruptions have been due to both the Solar PV systems and biofuel generators working in tandem to ensure a continuous and stable supply of electricity.
5.0 REFERENCES
5.1 Appendix

Payback for Smart Meter

As the Office for Housing & Auxiliary Services is self-financed with a non-subsidised budget, they assume the role of a customer from the perspective of a smart meter installer. As such, it makes sense to calculate the pay-back period and the corresponding electrical percentage savings required for an investment made on the smart meter.

The following data has been collected and tabulated to enable the calculation for the payback period and corresponding percentage savings:

| Average Monthly Consumption Per Hostel during semester schooling months\(^9\) (kWh) | 87,314 |
| Number of Residents Per Block\(^10\) | 510 |
| Estimated Baseline Consumption in Common Areas (kWh) | 46,086 |
| Estimated Personal Monthly Consumption—Variable Component (kWh) | 80.839 |
| Average Electric Tariff in 2013 ($) | 0.2632 |
| Estimated Personal Monthly Electric Tariff ($) incl. 6.5% GST\(^11\) | 22.66 |
| Cost of Installing 1 Smart Meter ($)\(^12\) | 240 |

The following table shows the payback periods and their corresponding percentage savings required in the variable component of the electricity billing to each hall resident\(^13\):

<table>
<thead>
<tr>
<th>Payback Period (In Semesters) <em>Presume one semester to have 4 months</em></th>
<th>% of electrical savings per resident required (excluding electricity usage for common areas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 (7 years)</td>
<td>18.91</td>
</tr>
<tr>
<td>13</td>
<td>20.37</td>
</tr>
<tr>
<td>12 (6 years)</td>
<td>22.06</td>
</tr>
<tr>
<td>11</td>
<td>24.07</td>
</tr>
<tr>
<td>10 (5 years)</td>
<td>26.48</td>
</tr>
</tbody>
</table>

\(^9\) Calculated by averaging across 16 months across halls 13, 14, and 15; Schooling Period: Feb, Mar, Apr, May, Sep, Oct, Nov, Dec

\(^10\) Figures obtained from Office of Housing and Auxiliary Services.

\(^11\) Assuming that electric tariff is pegged at 26.32 cents per kWh

\(^12\) Installation of 1 smart meter requires 1 hour of work, 2 contractors priced at $20 per hour, Single Phase Smart Meter at $200

\(^13\) Disregarding inflation and fluctuations in electric tariff rates
<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>9</td>
<td>29.42</td>
</tr>
<tr>
<td>8</td>
<td>33.10</td>
</tr>
<tr>
<td>7</td>
<td>37.82</td>
</tr>
<tr>
<td>6</td>
<td>44.12</td>
</tr>
</tbody>
</table>

**Lack of incentive for investment**

Nonetheless, the implementation of a Pay-As-You-Use (PAYU) system will act as a disincentive for the Office of Housing & Auxiliary Services (HAS) to fund the initial capital outlay required for installation. This is because the PAYU puts the burden of paying for any fluctuations in variable electricity demand on the resident. The smart meter also benefits the hall resident more directly as it helps him to better monitor variable usage, and does not help to reduce electricity usage in common areas much. As such, other than helping to mitigate fluctuating expenses, smart meter may not result in definite operating cost savings for HAS, as electricity usage in common areas (the only electricity usage portion to be covered by hall rental fees in a Smart Metering Scheme) is unlikely to be reduced.

However, it is also unlikely that students will be willing to pay for the upfront capital cost of using a smart meter. This is mainly due to the fact that most students living in hostels do not reside permanently in the same room for 4 years. Hence, a simple cost benefit analysis would show that initial monetary cost and effort needed to learn how to use the smart meter usage easily overwhelms potential monetary savings. Thus, having students to finance the project may not be a clear cut option.

**Alternate incentive motivations**

Nonetheless, the investment can still be pitched as one that serves to inculcate energy management values in several batches of young adults, in preparation for family building in our soon to be Smart Grid City. The positive externalities of the investment can also be identified by creating an energy conservation culture in the hostels through marketing and publicity.

Alternatively, initial capital outlay can be funded by a variety of creative options. For example, USP scholars can be grouped into a single block, where 40 of such rooms where the scholars are staying in will be installed with smart meters. A certain office (e.g., USP office) could fund the initial capital required, and the students will pay back the office monthly the cost savings they have attained against the original electric bill they are supposed to pay. This can be done in a monthly instalment fashion and can extend beyond a single USP resident’s 4 years of residency as long as the next occupant is a USP scholar as well.
5.2 Glossary

Battery bank: The battery bank stores electricity generated from solar energy for use at nights or times of increased demand. It consists of large format multiple individual battery cells which when connected together then form either a 12V, 24V or 48V battery bank depending on how large the system is.

Feed-in tariff: The Western Australian residential net feed-in tariff scheme provides a premium subsidy payment for the energy these systems export to the electricity grid and customers accepted onto the WA scheme receive payments for a period of 10 years.

Micro-grid: Micro-grids are modern, small-scale versions of the centralized electricity system. They generate, distribute, and regulate the flow of electricity to consumers on a small community scale.

Smart Grid: A smart grid is a modernized electrical grid that uses analogue or digital information and communications technology to integrate the actions of all users connected to it – generators, consumers and those that do both to improve the efficiency of the network.

Smart meter: Smart meter is an electronic device which enables users to know the real-time electricity consumption rate and cost so that they can better monitor their electricity usage.

Solar PV system: Solar PV system utilizes photovoltaic panels to capture solar energy and then turns sunlight into electricity which can be used to run electrical appliances and lighting.

The Intelligent Energy System (IES) pilot: This pilot project was launched by Singapore Energy Market Authority (EMA) test a range of smart grid technologies to enhance the capabilities of Singapore’s power grid infrastructure. The IES pilot project will be implemented on multiple sites. The focal point of the project will be at the Nanyang Technological University (NTU).
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