Feasibility of Individual Household Power Generation in Victoria

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ABSTRACT

Two systems for individual household power generation have been designed and costed to supply the average Melbourne household's electricity needs. These systems are powered by a 'BlueGen' micro-Combined Heat and Power module (using a Solid Oxide Fuel Cell - SOFC) designed by Ceramic Fuel Cells Limited (CFCL), capable of 2 kW and six monocrystalline solar panels of 1050 W. For both an Off-Grid system and a Grid-Connected System, the costs to the household are estimated and the greenhouse emissions are compared to current Victorian power generation techniques.

The Off-Grid system is estimated to cost $46,533 based on a 30 year loan. The technology required for off-grid fuel cells using natural gas is not currently in production, but could be available in three to five years time. A concept SOFC based on the current BlueGen module, capable of grid independence, is used.

A Grid-Connected System based on the same design was devised, only needing slight modification in terms of components and connection to the distribution network (the Grid). This system would be available for construction in early 2010, with CFCL's BlueGen module to become available for purchase at this time. This system is estimated to cost $33,017 based on a 30 year loan.

Both systems are estimated to save up to 77 percent of carbon dioxide emissions (kg $CO_{2\text{-}e}$/year) when compared to the standard composition of Victorian power generation (consisting of brown coal, natural gas and hydro).

1. Introduction

Household power generation is a concept dating back to the early 20th Century. One of the first known theories for this system was made by Thomas Edison, whose dream was to see every household become environmentally sustainable by their own capacity (Black 2006, pp 6-7). In fact, the first known household power generation system was built for Thomas Edison's own grand mansion (Black 2006, pp 6-7). His vision was to bring power to the people through individual household power generation, using renewable technologies and storing electricity in battery banks. By using Thomas Edison's idea for household power generation, two designs for such a system have been created. A range of technologies, including wind, solar, biogas and fuel cells were investigated for application in the system. The current design incorporates fuel cell and solar technologies to provide a possible solution to reducing Australia's reliance on coal and other fossil fuel burning technologies. Two different system will be investigated; an Off-Grid System and a Grid-Connected System.

The Off-Grid System is conceptually Edison's vision, but using a fuel cell and solar panels to produce electricity for use in the household. The demand for the household would be met by electricity stored in a battery bank, allowing the system to regenerate the batteries whilst the household draws power from them. Overnight, when the demand is low, the battery bank would be recharged to full capacity (by the fuel cell), allowing the system to cope with the diurnal nature of household power usage. Inverters and battery chargers have been incorporated to allow conversion from AC to DC and DC to AC voltages. This system however is more of a future concept using a Solid Oxide Fuel Cell (SOFC), as the technology does not exist; the current BlueGen module requires a grid connection to operate. Ceramic Fuel Cells Limited (CFCL), currently producing the BlueGen module, have plans to produce an SOFC module in the future that is capable of standalone generation, but this is still three to five years away (CFCL 2009). Hence, a Grid-Connected System was also designed.

The Grid-Connected System is similar in design to the Off-Grid System, except for a few components only required for the Off-Grid System. The connection to Australia's distribution network also removes the need for a battery. This system will use the BlueGen module being developed for sale in early 2010 (CFCL 2009). This also brings about the possibility of using the current Victorian Feed-in-Tariff system, whereby a rate is paid to the household for selling excess electricity to the Grid (DPI 2009a).

In this report, the designs for both systems will be explained and the components of each system described. Additionally, the feasibility of constructing and operating an individual household power generation system is investigated. The costs associated with each system for a 30 year payback period are considered and the greenhouse gas emissions are compared to current Victorian power generation techniques.

2. System Design

2.1. Off-Grid System

A wide range of renewable technologies are available for designing an off-grid electricity system. Solar panels, wind turbines, fuel cells and biogas were explored for the initial design. However, each technology depends on natural resources that are more or less available depending on the system's location. Our system, located in an urban area of Melbourne, fixes boundaries in the use of the different sources of energy. In an Off-Grid System, wind turbines are often combined with solar panels to produce the household electricity. Nonetheless, in urban Melbourne, sites suitable for turbines are rare because of turbulence and a lack of wind that can decrease the efficiency and the life of the wind turbine (Bagot 2009). Also, potential noise issues in built-up areas were a reason to stay away from adding wind turbines to the system design. Biogas was another option, but it is difficult to implement at a household level due to the amount of waste and its high septicity. Hydrogen fuel cells were considered for an alternative technology to SOFC units, as they can be readily bought for use in off-grid systems. This alternative was not pursued because pure hydrogen gas is expensive and would need to be bottled and transported to the household regularly. Natural gas, however, is more accessible than hydrogen due to the infrastructure in place throughout Victoria. For these reasons, our design focused on implementing photovoltaic solar panels and a SOFC.

Although off-grid systems are usually conceived for use in remote areas, the purpose of this system is to propose an alternative way of producing electricity in order to decrease a household's overall contribution to climate change. Based on Melbourne data from an Essential Services Commission Draft Report (2002, p75), the average electricity consumption of a Melbourne household is assumed to be 4000 kWh/year. The diurnal demand curve for Victorian demand is shown in Figure 1; daily household demand can be assumed to have this same pattern.

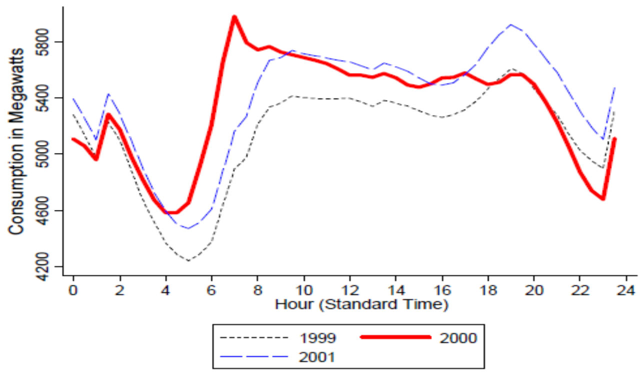

Figure 1: Average daily electricity consumption of Melbourne over 24 hours. This graph shows the diurnal nature of Melbourne's electricity consumption (Kellogg and Wolff 2007).

The Off-Grid System comprises six monocrystalline solar panels and a fuel cell that will possibly be developed by CFCL in three to five years time. The Off-Grid System (Figure 2) integrates a battery bank to store the electrical energy produced by the fuel cell and solar panels. The battery bank is made from six deep-cycle, lead-acid batteries in order to provide the immediate demand for the household, whilst the fuel cell and solar panels would charge the battery bank to prevent the batteries from fading. Additional components such as the regulator and battery charger are required for managing the electricity delivered to the battery bank. An inverter is also required to supply the household with 240 V AC power from the battery bank, which is stored at 24 V DC. The combined power produced at optimum performance for the fuel cell and solar panels is 2.5 kW, whereas at maximum performance a total of 3 kW is possible. In order to gain this maximum power output, it is crucial the solar panels should be angled 15 degrees steeper than the common roof pitch (Stapleton and Milne 2008). The details of each component are described in the following section. The maximum power that can be drawn through the system at any time (from the batteries) is 4 kW, limited only by the inverter.

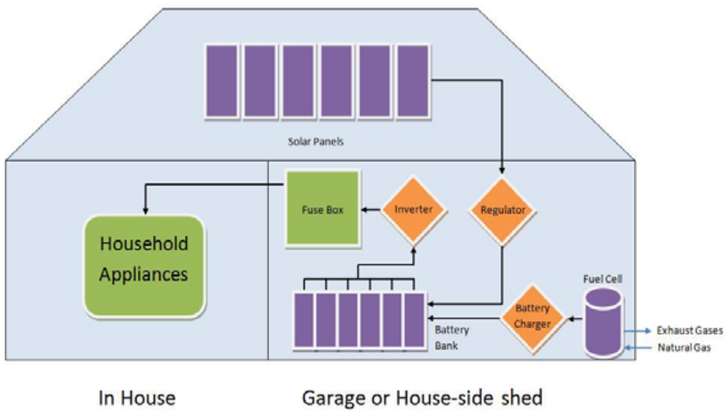

Figure 2: Layout of Off-Grid System for household power generation in the average Melbourne household. Solar panels supply power controlled by a regulator to the battery bank. A Fuel Cell provides DC power to the battery bank via a battery charger, which converts the AC output to DC output. The household then draws power from the battery bank through an inverter, which is connected up to the fuse box.

2.2. Grid-Connected System

As mentioned in section 2.1, the Off-Grid System is currently unable to be constructed, as the fuel cell technology required is not in production. However, the BlueGen module, currently developed for household application only operates with a grid connection. For this reason a system with the same components (CFCL fuel cell and six monocrystalline solar panels) as the Off-grid system has been designed for grid connection. Because the CFCL fuel cell will be available by early 2010, our Grid-Connected System will be feasible for construction from this date.

Changes to the system include removing the battery bank, as the storage of electricity is no longer required due to having a Grid connection. The Grid will receive the energy produced by the CFCL fuel cell and the solar panels, and the household demand will be supplied by the grid. Also, the electricity produced by the solar panels and BlueGen module in the Grid-Connected System will be greater than in the Off-Grid System. An example of this is shown in Table 1 where the regulator efficiency reduces the power produced by the solar panels. This is due to the efficiencies of components in each system.

Table 1: Difference of electricity production between an off-grid solar panel and a grid connected (Stapleton and Milne 2008). Connection efficiency of 0.85 is for regulator in Off-Grid System. Connection efficiency of 0.94 is for Grid-Connected Inverter. Correction factor of 0.18 explained in section 2.3.3.

Connection type	Output (W)	Connection efficiency	Correction Factor	Actual output (W)	kWh/year
Off-grid	1050	0.85	0.18	161	1407
Grid	1050	0.94	0.18	178	1556

The battery charger for the BlueGen module will not be needed, as conversion to DC power was only necessary for storage of electricity in the battery bank. However, the Grid-Connected System requires an inverter to convert the 24 V DC produced by the solar panels, to 240 V AC before going to the household or the Grid. The inverter will be different than the one used in the Off-Grid System because it needs to be specific for solar panel and grid connected use (see section 2.3).

Also, in our Grid-Connected System, the optimal angle for the solar panels will be different than for the Off-Grid System. In order to increase the annual amount of sunlight, the solar panels should have an angle of latitude minus 10 degrees (Stapleton and Milne 2008).

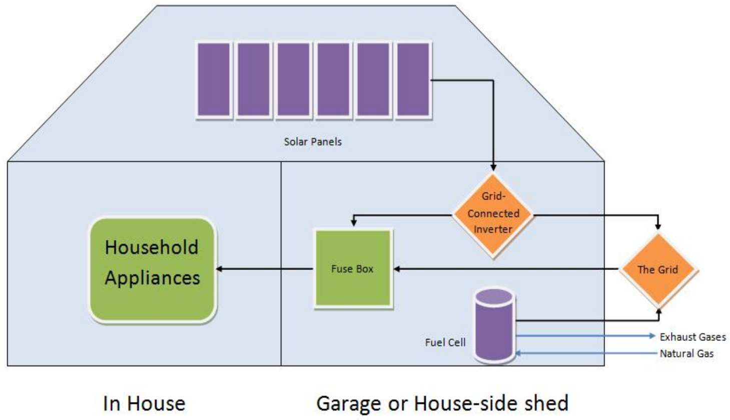

Figure 3: Layout of Grid-Connected System for household power generation in the average Melbourne household. This system has fewer components than the Off-Grid System requires. Solar panels supply the house or the grid according to the household demand. The fuel cell (BlueGen module) always outputs power to the Grid. The household demand is covered firstly by the solar panels and then by the Grid via the fuse box.

2.3. System Components

Both designs for Off-Grid and Grid-Connection Systems include components from Australian manufacturers or retailers. A list of components for each system is shown in Table 2. Component specifications are explained in the following sections.

Table 2: List of components used in both system designs, showing the allocation to each system. (An 'x' represents the presence of that component in the system).

	System Components and their allocation in the systems						
System	Fuel Cell	Solar Panels	Battery Charger	Regulator	Battery Bank	Inverter	Grid-Connected Inverter
Off-Grid	x	x	x	x	x	x	
Grid-Connected	x	x					x

2.3.1. Solid Oxide Fuel Cell

The CFCL fuel cell currently being produced requires a grid connection to power auxiliary components within the module (about 280 W) and also for exporting power to the grid (CFCL 2009). Therefore this BlueGen module can only be connected up to the Grid-Connected System. A concept fuel cell with possibilities of production in three to five years will be used instead. This fuel cell is essentially a BlueGen module that would be designed for compatibility with off-grid battery storage devices, such as a bank of batteries. All characteristics of this concept fuel cell are assumed to be similar to the current BlueGen module (CFCL 2009).

The BlueGen module (Figure 4) is the main source of power generation within the system, producing up to 2 kW of electricity for charging the battery bank (Figure 5). As the module is a micro-CHP unit (micro-Combined Heat and Power), this output produces 1 kW of waste heat, which can be utilised if connected up to the household's hot water service. When the BlueGen module is operating at optimum efficiency, 1.5 kW of electrical power are produced and 0.54 kW of waste heat energy produced (CFCL 2009).

Figure 4: BlueGen Module incorporating an Solid Oxide Fuel Cell (1), water treatment system (2), gas cleaning system (3) and power management system [including grid connected inverter] (4) (CFCL 2009)

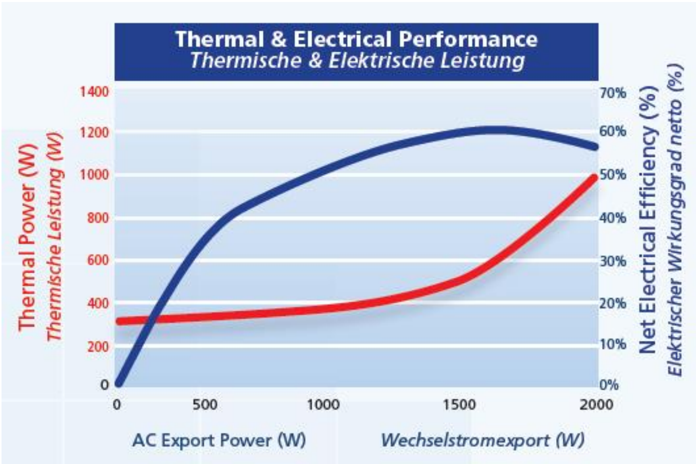

Figure 5: Electrical efficiency and thermal output curves for the BlueGen Module. Optimum operating conditions are at 1500 W AC power output and maximum operating conditions at 2000 W AC power output (CFCL 2009). The lower curve represents the Thermal Power potential against Power Output. The upper curve shows Net Electrical Efficiency against Power Output

The BlueGen module is a Solid Oxide Fuel Cell (SOFC) unit that uses natural gas to produce electricity. It also incorporates a water treatment and gas reforming stage within the unit that is needed for the fuel cell to work with natural gas as a fuel source (Figure 4). This is done in a few steps; firstly the sulphur in the natural gas is removed preventing SOx and NOx emissions from forming. The gas is then stripped of other gases to leave mainly methane (CH_4) of which is then reformed with steam at high temperatures (800-1000°C) to produce hydrogen gas (H_2) and carbon dioxide (CO_2). The hydrogen is then used in an electrochemical reaction with the oxygen ions (O^{2-}) to produce an electric current and water vapour (CFCL 2009; Tu and Stimming 2004). Therefore, according to CFCL (2009), a BlueGen module with gas cleaning and internal steam reforming processes would only produce CO_2 emissions and negligible amounts of other greenhouse gases.

2.3.2. Battery Charger

As the BlueGen module internally inverts the DC voltage to an AC output, a battery charger needs to be installed to integrate the CFCL fuel cell into the Off-Grid system. The battery charger would convert the 240 V AC output from the module to a DC voltage, required to charge the battery bank. This device is usually used in charging car and truck batteries, but can be used similarly to charge the designed battery bank.

In our system, the battery charger is a Sinergex 24 V 20 A PureCharge (Energy Matter 2009). This charger can supply 20 A at 82 percent efficiency and therefore would provide up to 200 Ah of current to the battery bank over night. Therefore, the battery charger would ensure that the batteries are fully charged before the morning period of household usage.

2.3.3. Solar Panels

Solar Panels are the other technology chosen in the design to provide electricity to the systems. There is a large choice of photovoltaic solar panels on the market, including monocrystalline, polycrystalline and amorphous solar panels (Energy Matters 2009). Six 175 Watt, monocrystalline Suntech panels rated at 24 V were selected for both systems. Monocrystalline panels were chosen because of their higher efficiency of converting sunlight into electricity than polycrystalline and amorphous solar technologies.

Like others solar panels, the output efficiency of monocrystalline cells decrease when the temperature exceeds 25°C. In fact, they lose 0.5% efficiency for every 1°C above 25°C (Stapleton and Milne 2008). Therefore, it is important to install the panel in a ventilated location on the roof, ensuring there is room for air circulation to flow around the solar panels. From the average maximum temperature in Melbourne (BOM 2009), the solar panel efficiency will not be greatly affected as maximum temperatures on average are only up to 1.5°C more than 25°C during January and February (Table 3).

Table 3: Average monthly maximum temperatures for Melbourne (BOM 2009).

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Max. Temp. (°C)	25.9	25.8	23.9	20.3	16.7	14.0	13.4	15.0	17.2	19.6	21.9	24.2

Solar panels produce more output energy when they are directly facing the sun. Ideally, they should be in full sun from 9am to 3pm in mid winter. The energy produced by a solar panel can be estimated from the Peak Sun Hours (PSH), which represents the solar energy available during a day.

The PSH of Melbourne for typical solar installations are shown in Table 4, indicating that the solar panels would work better with the system in the warmer periods of the year.

Table 4: Daily peak sun-hours (PSH) in Melbourne per month in Kilowatt Peak (Stapleton and Milne 2008).

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
PSH (kWp)	6.9	6.4	5.2	3.8	2.8	2.4	2.7	3.3	4.3	5.3	6.1	6.6

Based upon this data and a study done by McLennan Magasanik Associates (2008), for the Department of Primary Industries on the Feed-in-Tariff system, a correction factor of 0.18 for the Solar Panels was chosen. A correction factor is the efficiency of the solar panel at converting energy from the sun to electrical energy. A 24 V solar panel system was chosen on the basis for connection with the designed battery bank as explained in section 2.3.5.

2.3.4. Regulator

In the Off-Grid System, the regulator is located between the solar panel and the battery bank, to control the amount of charge coming from the solar panel before entering the battery bank. It disconnects the solar panel in case of overcharge. The Steca PR1515 solar charge controller 12/24 V 15 A with LCD display (Energy Matters 2009) is the model implemented in our system. It is especially designed to be use with a battery bank and it shows the state of charge of the battery bank. The efficiency of the regulator is assumed to be 90 percent.

2.3.5. Battery Bank

A battery bank is essential in an Off-Grid System to store the electricity produced by the different sources of energy. In a sense it plays the role of the Grid, as it supplies the load demand of the household and stores electrical energy for use at any time. It will receive the electricity produced by the solar panels which are controlled by the regulator and the electricity produced by the fuel cell that has been converted by the battery charger.

For the battery bank, dry cell lead-acid batteries produced by Ultimate were used. These batteries are a deep-cycled battery, designed for long-term current draw and recharging; commonly used as truck or motor-home batteries. In sizing the battery rack, the average daily Melbourne electricity demand was used. Hence, a bank of six 12 V batteries was selected, each capable of 135 Ah. By placing these in three groups of two, combining the groups of two in series to form 24 V and the three groups of two in parallel, a battery bank capable of 405 Ah at 24 V DC would be produced. This battery bank has been sized to store enough electrical energy to be drawn at full capacity for 24 hours.

The life of a battery bank is affected by its use and especially how often it is completely discharged. In our case, the fuel cells will provide a quite constant source of electricity; consequently, the batteries would not be completely discharged in this system as constant charging of the batteries would take place. Therefore the life expectancy of the batteries will be maximised.

2.3.6. Inverter

As 240 V AC is required for appliances throughout the household, an inverter is needed for the Off-Grid System, as the electricity used in the house would need to be converted from the stored 24 V in the battery bank. It needs to be placed between the battery bank and the fuse box connection to the household in order to provide AC power to the home. A 4000 Watt Latronics Sinewave Inverter has been chosen to produce this input for household use, as it is recommended as the most powerful and reliable inverter on the market (Energy Matters 2009). It also means that the average household would only be capable of drawing a maximum of 4 kW from the system. Larger Inverters are available on the market, but it is assumed that the average household would not need more than this at any point.

2.3.7. Grid-Connected Inverter

A Grid-Connected Inverter is required for connection of a solar installation to the Grid, as the frequency of the AC power produced by the solar panels must be fitted to the frequency of the Grid. An 1100 W SunnyBoy Grid-Connected Inverter (Energy Matters 2009), capable of regulating the DC output of the solar panels and supplying either the household or the Grid with 240 V AC power, has been chosen. Sizing of this inverter is based on the 1050 W of solar panels included within each design.

2.3.8. Connection via Fuse Box

Finally, both systems are to be connected to the household's fuse box, allowing distribution of the electricity throughout the household on demand. Therefore, the system incorporates the safety kill switches into both systems, which are compulsory throughout Melbourne homes.

2.4. Safety of the system

In terms of safety, the Off-Grid System requires a high level of vigilance. Lead-acid batteries emit a corrosive and explosive mixture of hydrogen and oxygen gas during the final stages of charging (Stapleton and Milne 2008). For this reason dry-cell batteries that are completely sealed were chosen, removing the need for topping up electrolyte levels and avoiding the production of explosive gases. Inverters are complicated electronic devices and so need to be installed in a dust free environment. Finally, the system is proposed to be constructed for installation in a ventilated section of a household's garage, or in a specially built shed by the side of the house.

Safety measures for the Grid-Connected System are similar to the Off-Grid System. Even though batteries are not needed in the system, a well-ventilated area should be created for housing the system to ensure the life of the system is maximised.

2.5. Feed-in-Tariff system

The Grid-Connected System is designed so that the household always draws from the grid and that the fuel cell and solar panels supply power to the grid. This allows the household to take advantage of the Victorian Feed-in-Tariff system (DPI 2009a), whereby a rate is paid back to the household depending on the size and amount of electricity put back into the grid. Through Origin Energy (2009) it is estimated for a house with capacity less than 160 MWh/year and systems smaller than 8 kW, a rate of 23.5c/kWh would be paid.

It is important to note that under the Feed-in-Tariff system currently proposed by the Government, fuel cells are not listed to receive the rebate (DPI 2009b). But since our system contains solar panels, which are entitled to receive the tariff, the system would be entitled for a Feed-in-Tariff such as that proposed by Origin Energy above. Therefore, since electricity produced by the solar panels cannot be distinguish from the electricity produced by the BlueGen module, it is assumed a Feed-in-Tariff is entitled for all electricity exported to the Grid from this system.

3. System Costs

The price of the system will have a large influence on how economically feasible it would be to construct. This section provides estimates for capital and operation costs of the two designed systems. Maintenance and installation costs for the system are not estimated for two reasons. Firstly, capital costs for building the system in the home are much greater than any of the maintenance costs. This is assumed because most of the components have warranty for the majority of their life expectancy, reducing the costs associated with replacement of faulty parts. Secondly, installation costs are hard to estimate, as installation of this type of system would need to be done by trained electricians who know how the system operates.

All processes regarding calculations for system costs are found in Appendix 2. (These calculations are based upon emissions costs in Appendix 1 – see section 4 for results).

3.1. Capital Costs

The capital costs associated with the two systems were found to be very expensive, shown in Tables 4 and 5. A single BlueGen module is estimated by CFCL to cost $10,000 at first release, and a 1 kW solar system to cost almost $12,000 (Table 4). It should be noted that the initial release price for the BlueGen module would be higher than future prices for further fuel cell products, given the technology is new and quite unique. Also, prices used for all components were those listed for sale to the general public or as quoted.

An important factor in calculating the capital cost is the life expectancy of each item. A solar panel's life expectancy is assumed to be 30 years (Sherwani et al 2009), whereas a SOFC's life expectancy is about 40,000 to 80,000 hours (Tu and Stimming 2004; Laukaitis and Dudonis 2005). The remaining components are assumed to have a life expectancy of 10 years. These assumptions are based upon manufacture warranties and the information of each component.

Table 4: Cost and Estimated Life Expectancy values for Off-Grid System components.

Components for Off Grid System	Cost ($)	Number of units	Total cost ($)	Estimated Life Expectancy (years)
Fuel cell	10 000	1	10 000	9
Solar cell	1 936	6	11 616	30
Batteries	4 000	1	4 000	10
Battery charger	800	1	800	10
Regulator	415	1	415	30
Inverter (24V)	3 900	1	3 900	10

Table 5: Cost and Estimated Life Expectancy values for Grid-Connected System components.

Components for Grid Connected System	Cost ($)	Number of units	Total cost ($)	Estimated Life expectancy (years)
Fuel cell	10 000	1	10 000	9
Solar cell	1 936	6	11 616	30
Grid-Connected Inverter	2 360	1	2 360	30

As seen in Tables 4 and 5, the main capital costs for Off-Grid and Grid-Connected systems are due to capital costs for solar panels and the BlueGen module. Over a longer period of time, though, the solar panels are relatively economical compared to the fuel cell, due to their longer life expectancy.

In order to calculate the annual capital cost of the systems, an annuity loan model has been used. A payback period of 30 years and interest rate of 7 percent (IR 2009) were used with the model to form the Annual Payment (Table 6) required to pay off the system in 30 years. The results can be seen in the Table 6. The Grid Connected System is cheaper with a yearly capital cost of $2,668 compared to $3,750 for the Off-Grid System. This is due to the number of components required for the Off-Grid System.

Table 6: Total Cost for the Off-Grid and Grid Connected Systems.

Connection type	Total Capital costs over 30 years ($)	Payment plan (years)	Interest rate (%)	**Annual Payment ($)**
Off-grid	46,533	30	7	**3,750**
Grid-connected	33,107	30	7	**2,668**

3.2. Operation Costs

The only operating costs attached with both systems are the natural gas consumed by the fuel cells. The solar panels are assumed to have no operation costs, although they need to be cleaned regularly to operate at optimum efficiency. The cost to run both systems in the household (excluding installation costs) is shown in Table 7.

Table 7: Total cost for running the Off-grid and Grid-Connected Systems.

Connection type	Annual Capital cost ($)	Annual Natural Gas cost ($)	**Total cost per annum ($)**
Off-Grid System	3,750	150	**3,900**
Grid-Connected	2,668	110	**2,778**

It should be noted that for the natural gas, a supply charge of $90/year (SEAV 2002) will be added to the total natural gas cost. However, as most Victorian homes already have a natural gas supply for heating and the stove, this supply charge can be shared with the existing one; no extra cost is added.

Assuming an average household's annual electricity bill is generally less than $1,000, the cost of operating either the Off-Grid or Grid-Connected System is currently not economically feasible. Even if the household became a net producer to the Grid and receiving a Feed-in-Tariff for a Grid-Connected System, which would reduce the average electricity bill by more than half, the cost of the system would still be larger than continuing to draw from the Grid alone. For this reason, a household would only operate such a system in the near future on moral grounds towards the environment.

4. Emission Comparison

The main reason for designing both an Off-Grid and Grid-Connected System for household power generation is to show an alternative to reliance on Coal-Fired Power Generation currently dominating the Australian electricity market. As the only greenhouse gas (GHG) emission produced by both systems is carbon dioxide (CO_2), the savings in CO_2 emissions can be considered as the total GHG emissions saving (CFCL 2009).

In order to compare GHG emission savings, a CO_2-equivalent ($CO_{2\text{-}e}$) must be used for Victorian power generation techniques as other GHG emissions besides CO_2 are produced (such as methane, SO_x and NO_x). As solar panels do not emit GHG's during operating and the BlueGen module only produces CO_2 emissions (see section 2.3.1), both systems produces much less CO_2 emissions than current generation techniques. A $CO_{2\text{-}e}$ emissions factor of 0.20 kg/kWh is used for both systems (CFCL 2009), as natural gas in the fuel cell is the only source of CO_2 emissions. Using figures from the Department of Climate Change (2009), a $CO_{2\text{-}e}$ value for Victorian electricity generation of 1.22 kg $CO_{2\text{-}e}$/kWh is used. From these factors, the $CO_{2\text{-}e}$ emission savings in kg $CO_{2\text{-}e}$/year for both systems are compared to current power generation techniques in Victoria (Table 8).

The natural gas consumption of the Off-Grid System differs to the Grid connected consumption as seen in Table 8. This is due to the total efficiency of the system. The Off-Grid System requires a battery charger to convert the AC output to DC for storage in a battery bank. The Grid-Connected System doesn't require a component between the fuel cell and the household, increasing the efficiency of the system and hence lowering the gas consumption needed to provide the required power supply.

Table 8: Comparison of $CO_{2\text{-}e}$ emissions between Off-Grid System, Grid-Connected System and current Victorian power generation techniques.

Connection	$CO_{2\text{-}e}$ emissions (kg $CO_{2\text{-}e}$ /kWh)	Consumption (kWh/year)	$CO_{2\text{-}e}$ emissions (kg $CO_{2\text{-}e}$ /year)	**$CO_{2\text{-}e}$ emission savings (kg $CO_{2\text{-}e}$ /year)**	**$CO_{2\text{-}e}$ emission savings (%)**
Off-grid	0.20	5,606	1,121	**3,759**	**77%**
Grid Connected	0.20	4,073	815	**4,065**	**83%**
Victorian power generation	1.22	4,000	4,880	-	-

From calculations, the Off-Grid System can reduce the total GHG emissions by 77%, whilst the Grid-Connected System reduces GHG emissions by 83% (Table 8). In total, both systems abate approximately four tonnes of CO_2/year. Therefore, using total cost per annum (Table 7) it is found to cost $975 and $695 to abate one tonne of CO_2 emissions by operating an Off-Grid System and a Grid-Connected System respectively. Again, compared to other measures presented by Government for abating CO_2 emissions (Elkvist et al 2007, p38), these systems are currently not feasible in an economic sense.

5. Conclusion

Two different systems have been designed using a concept conceived by Thomas Edison; an Off-Grid System which is independent from Australia's Distribution Network and a Grid-Connected System for connection to the Grid. These systems comprised a CFCL BlueGen module, using SOFC technology, and six monocrystalline solar panels to produce a maximum system capacity of 3 kW. The Off-Grid System is unable to be constructed at present due to grid-independent SOFC technologies do not exist, but the Grid-Connected System has the possibility of construction in early 2010 with the release of CFCL's BlueGen module.

Costs for both systems were calculated using Capital Costs and Operation Costs. Both the Off-Grid System and the Grid-Connected System were shown to be economically unviable at present due to emerging technology and a small market for renewable technologies. An Off-Grid System was estimated to cost the household $3,900/year over 30 years, whilst a Grid-Connected System would be more economical at $2,778/year over 30 years (not including a tariff rebate).

Both systems were calculated to produce up to 77 percent less CO_2 emissions than current Victorian power generation techniques; 83 percent for Grid-Connected System. Although, when it comes to the cost associated with abating a tonne of CO_2, it was shown once again that economically both systems are not currently feasible.

In order to make the world a better place, recommendations are advised into more research on fuel cell and solar technologies for individual household power generations systems. Although these systems are presently uneconomical to the average Melbourne household, only future developments through research and study of built systems will help drive the possibility of Thomas Edison vision towards reality.

6. References

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