Economics Of Residential Solar Hot Water Heating Systems In Malaysia

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Abstract:- Malaysia has favorable climatic conditions for the development of solar energy due to the abundant sunshine and is considered good for harnessing energy from the sun. This is because solar hot water can represent the large energy consumer in Malaysian households but, because of the high initial cost of Solar Water Heating Systems (SWHSs) and easily to install and relatively inexpensive to purchase electric water heaters, many Malaysian families are still using Electric Water Heaters to hot their water needs. This paper is presented the comparing of techno-economic feasibility of some models of SWHS from Malaysian's market with the Electric Water Heaters (EWH) by study the annual cost of operation for both systems. The result shows that the annual cost of the electrical water heater becomes greater than the annual cost of the SWHS for all models in long-term run so it is advantageous for the family to use the solar water heater, at least after 4 years. In addition with installation SWHS the families can get long-term economical benefits, environment friendly and also can doing its part to reduce this country's dependence on foreign oil that its price increase day after day.

Key-words:- Solar energy, solar water heating system, techno-economic evaluation, Annual cost method.

1 Introduction

Using the sun's energy to heat water is not a new idea. More than one hundred years ago, black painted water tanks were used as simple solar water heaters in a number of countries. Solar water heating (SWH) technology has greatly improved during the past century. Today there are more than 30 million m^2 of solar collectors installed around the globe.

One of economic reasons to install solar energy components is to available of amount site of sun radiation can be gets. Malaysia has a high solar energy potential; the monthly average daily solar radiation is 4000 - 5000 Whr/m^2, with the monthly average daily sunshine duration ranging from 4 hr to 8 hr (Sopian and Othman, 1992). So Malaysia has favorable climatic conditions for the development of solar energy and solar water heaters households used but, because of lack of public understanding and awareness of the working and potential benefits of Solar water heaters (SWH), the high initial cost of solar water heating systems (SWHSs) and easily to install and relatively inexpensive to purchase electric water heaters, many Malaysian families are still using Electric Water Heaters to hot their water needs.

This paper presents economic evaluation of some solar water heating systems models uses in Malaysia marketing with different purchase price such as Aztec, Solarmate, Solarpollo, Edwards, Summer, , and Microsolar M80VTHE Indirect Vacum comparing with electric water heaters. The comparison between these systems is based on the direct monetary outlay of the user by calculate the annual cost method.

The objective of this paper is to study the annual cost of operating a SWHS and to compare it to the annual cost of the operation of an Electric Water Heating system. In addition, we want to find out which of each the systems is more economical than the other in operation time (*N*).

2 Techno-Economics Analysis

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Solar system are generally characterized by high initial cost and low operational costs as compared with the relatively low initial costs and high operating costs of conventional (Electric Water Heater) systems. In additional heating water with the sun also means long-term benefits, such as being cushioned from future fuel shortages and price increases, and environmental benefits. The comparison between these systems is based on the direct monetary outlay of the end users. To study the economic feasibility of a system, different methods could be used to evaluate different figures of merit of the systems. In this study Annual Cost Method (AC) is used to comparing the relative costs of the SWHS with Electric Water Heater.

2.1 Annual Cost Method (AC)

It is intended in this study to let the operation time (*N*) of a system be variable because the wanted is to find the optimal operation life of both systems. ***The Annual Cost Method*** will be adapted in this study because it allows the comparison between the two systems that have different life times.

In general, taking the concept of time value of money in consideration, then the annual cost (AC) of a system can be expressed as the following equation:

$$AC = IC + AFC + AMC \quad (2.1)$$

Where:

- **IC,** initial cost of the system,[RM];
- **AFC,** annual fuel cost,[RM];
- **AMC,** annual maintenance cost,[RM / year].

2.1.1 Annual fuel cost (AFC)

The annual fuel cost for the Electric water heating systems are the electric bill cost over the year to provide hot water needs of an average family. The annual fuel cost for the SWHS is yearly electrical bill cost for the system which is built in coil electric heater used. Whoever; the SWHS without electric heater no has yearly electricity cost (RM 0.00 per year).

$$AFC_{EH} = 365 * NOH * P_{el} \quad (2.2)$$

Where, *NOH* daily number of hour's electricity is used to provide hot water needs of a family [H]; P_{el} is a price of electricity [RM/KWh].

$$AFC_{SWHS} = 12 * NOCD * NOH_s * P_{el} \quad (2.3)$$

Where, *NOCD* number of cloudy day per month, [day/month]; NOH_s number of hours switched thermostat [H]; P_{el} price of electricity [RM/KWh].
For SWHS without electric heater: The AFC_{SWHS} = RM 00.0, (no electricity cost).

2.1.2 Annual maintenance cost (AMC)

To simplify analysis, it will be assumed that the annual maintenance cost of the SWHS is directly proportional to its operation time so:

$$AMC_{SWHS} = \alpha_{SWHS} * N \quad (2.4)$$

Where α_{SWHS}, proportionality constant, [RM/year].

2.2 Computer Implementation

The previous economic analysis of the two systems resulted in the following two final equations:

$$AC_{SWHS} = IC_{SWHS} + 12 * NOCD * NOH_s * P_{el} + \alpha_{SWHS} * N \quad (2.5)$$

$$AC_{EH} = IC_{EH} + 365 * NOH + P_{el} \quad (2.6)$$

To evaluate the annual cost for both systems the calculation prepared a spreadsheet on Excel that incorporated the above variables and parameters as Table 2.1. AC_{SWHS} and AC_{EH} are plotted against the variable *N*.

Table 2.1 Summery of the Values of the Parameters

SWHS	EWH
IC_{SWHS} = as the model use	IC_{EWH} = 450 ×2
NOH_s =5[H]	NOH = 2 hour/day for 4 px and 3 hour/day for 6 px
NOCD =8[day/month]	P_{el} = 3kw × 0.25 RM
P_{el} = 3kw × 0.25 RM	
N = 10 [year]	

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3. Results And Discussion

Using simple formulations presented in the number (2.5) and 2.6), some exemplifying calculations have been done on Excel. The use of Excel was extremely powerful because any change in any parameter was linked directly to a change in the graphs which was very useful for purposes of the sensitivity analysis of the parameters.

Firstly, for the electric water heater considered that the family installs 2 units and the rate of hot water needs for persons is 10 gallons per day. So as the Fig. 3.1 the AC_{EH} is different by different of family size.

Secondly, for Solar water heating systems, Malaysia market expanded significantly from many years ago and as a result there are some popular models which are chosen to make this comparison of economic evaluation to find out which and when each of the systems is more economical than the other comparing with Electric water heater such as, Aztec, Solarmate, Solarpollo, Edwards, Microsolar M80VTHE Indirect Vacum, and Summer system.

3.1 Discussion

Close inspection of Eqs. (2.5), (2.6), and from the figures above reveals that:

- It would seem reasonable that energy consumption increases as the number of residents in the dwelling increases. This is clearly the case for the consumption of electricity by water heaters. With increasing family size, water heating appliance consumption increases more rapidly. This is because hot water is used on an individual basis as Fig. 3.1.
- The annual cost of the Electrical water heater EWH becomes greater than the annual cost of the SWHS. In the early years, it is advantageous to use the electrical water heater, but as time progresses, however, the cost of using the electrical water heater increases with increasing electricity bill. This narrows the difference between the electrical and solar water heaters, until it crosses the benefit point. Fig. 3.2, 3.3, 3.4, 3.5, 3.6 and 3.7
- The benefit point is different from model to others, is depend on the capital costs of the models and the capacity of system's tank.
- The cost of a SWHS varies considerably with the quality of construction, but in general costs of solar water heating technologies are available depending on design, materials, system efficiency, expected life time, capacity of their tanks and total collector panel area.
- With more number of valves and larger glass area lead to faster reheat time (no need of backup electric heater) and higher overall temperature such as models Microsolar M80VTHE and they are more economical that others model as Fig. 3.6
- The above result shows also that, in the long-run, it is advantageous for the family to use the solar water heater, at least after 5 years, when compared to the electrical water heater.

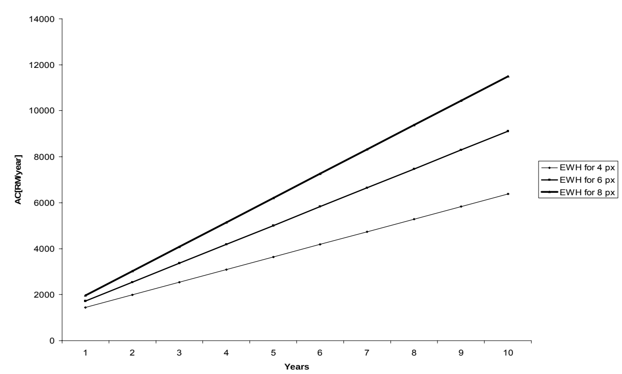

Fig. 3.1 AC_{EH} for Different Size of Families

1) Aztec - with:

- Price inclusive installation RM 4,250
- Total capacity is (56 gallons, 255 ltrs)

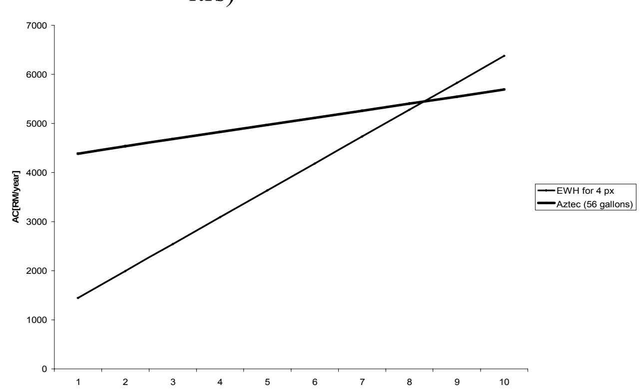

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Fig. 3.2 Comparison of Annual Cost of EWH of 4 Persons To Aztec System

2) *Solarmate* - with:

- Price inclusive installation RM 3,950
- Total capacity is (60 gallons, 270 ltrs)

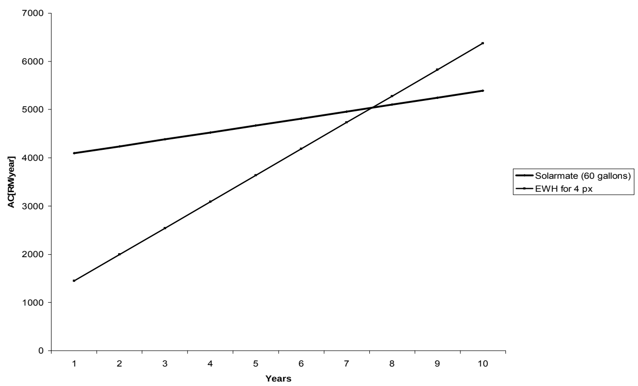

Fig. 3.3 comparison of cost of EWH of 4 persons to Solarmate system

3) *Solarpollo* -- with:

- Price inclusive installation RM 4,200
- Total capacity is (60 gallons, 270 ltrs)

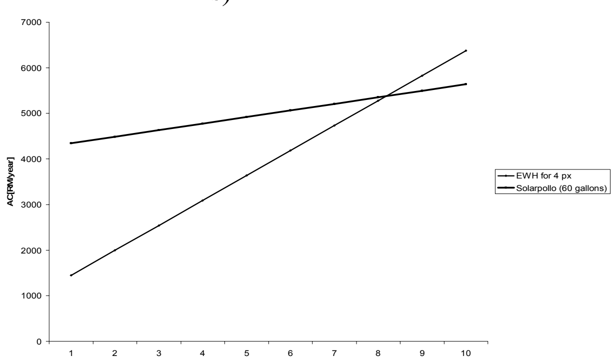

Fig. 3.4 comparison of cost of EWH of 4 persons to Solarpollo system

4) *Edwards* - with:

- Price inclusive installation RM 5,950
- Total capacity is (66 gallons, 300 ltrs)

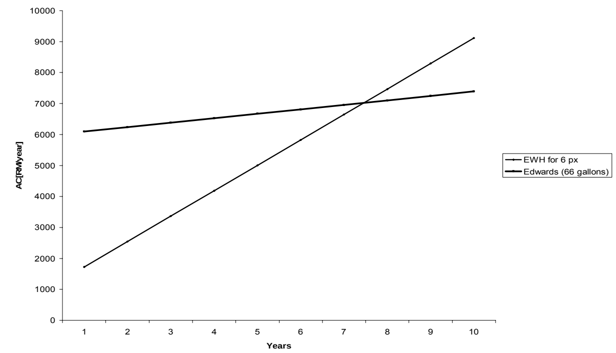

Fig. 3.5 comparison of cost of EWH of 6 persons to Edwards system

5) *Microsolar M80VTHE Indirect Vacuum* - with:

- Price inclusive installation RM 6,190
- Total capacity is (78 gallons, 356 ltrs)

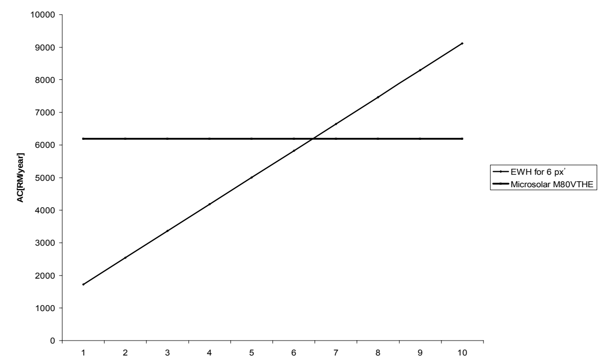

Fig. 3.6 comparison of cost of EWH of 6 persons to Microsolar M80VTHE System

6) *Summer* - general descriptions:

- Price inclusive installation RM 5,950
- Total capacity is (66 gallons, 300 ltrs)

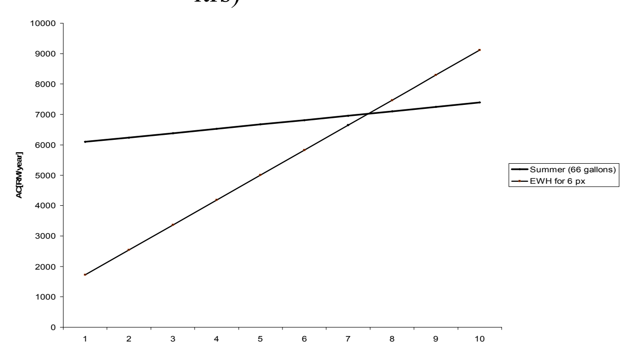

Fig. 3.7 comparison of cost of EWH of 6 persons to Summer system

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4 Conclusions

The argument for the family about using electric water heaters (EWH) or installing a solar water heating system (SWHS), leads to make comparisons of financial economic evaluation to decide which systems is more economical than the other.

By study the annual cost of operation of the some models of SWHS which are used in Malaysia and to compare it to the annual cost of the operation of a EWH the results show that the initial cost of a SWHS and the electricity price are the two most important parameters that determine the choice. As a rule of thumb, the cost of using the electrical water heater increases with increasing electricity bill and with increasing family size.

With using some calculations on Excel the result show that the SWHS is more economical and becomes more attractive than the EWH in long term-run, so it is advantageous for the family to use the solar water heater, at least after 4 years, when compared to the electrical water heater and for an option which has a renewable nature and environmental soundness, the SWHS seems to be a better proposition. Finally, more attention should be given to the families to install SWHS to get long-term economical benefits, environment friendly and also can doing its part to reduce this country's dependence on foreign oil that its price increase day after day.

NOTATIONS

SWHS	Solar Water Heating System
EWHS	Electric Water Heating System
RM	Malaysian Ringgit
AC	Annual cost of the system, [RM]
IC	Initial cost of the system, [RM]
AFC	Annual fuel cost of the system, [RM]
AMC	Annual maintenance cost of the system, [RM/year]
α	Proportionality constant, [RM/year]
N	operation time of the system, [year]
P_{el}	Price of electricity is used, [RM/kwh]
NOH	Number of hours electricity is used per day, [hour/day]
$NOCD$	Number of cloudy day per month, [day/month]
NOH_s	Number of hours switched thermostat, [hour/day]
AC_{EH}	Annual cost of electric water heater, [RM]
AC_{SWHS}	Annual cost of solar water heating system, [RM]

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Managing Intermittent Renewable Energy Sources

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Abstract: - With the rising price of wholesale electricity, renewable energy sources are becoming increasingly competitive. However the intermittent nature of the supply is considered a serious problem that requires to be addressed. We describe a dual electricity distribution system comprising a reliable supply with guaranteed voltage and capacity levels for use by appliances and lighting, and a second supply with variable output derived from renewable energy generation and typically used for heating. Loading is managed through economic means by manipulating the cost of units drawn from each stream.

Keywords: - Load balancing, renewable energy, intermittency.

1 Introduction

Implementation of measures needed to combat climate change suggests an increasing fraction of grid electricity in the UK should be generated from renewable sources [1]. Electricity generation from wind power is becoming extremely competitive because of government subsidies, the rising price of wholesale electricity (£55 MWh^{-1} in 2008), and growing turbine size. However, when the fraction of energy produced nationally from wind exceeds 20%, balancing power generation with consumer demand may become a problem [2], [3]. Some balancing already takes place with conventional power generation through the alteration of tariffs to skew the daily consumption curve towards a manageable generation regimen. This approach is not feasible with wind power because the output from minute to minute is unpredictable, hence conventional generation would need to be kept on standby for times of energy drought or imbalance. Energy could of course be stored during renewable energy production excess for later use when there is insufficient generation capacity, but a central storage repository capable of holding hundreds of terajoules of energy is needed. Pumped-storage is a very efficient mass storage mechanism, but there is insufficient reservoir capacity in the UK for effective implementation [4]. Conversion of surplus energy to hydrogen by electrolysis is a real possibility (and the basis of the 'hydrogen economy'), but at least 30 years away. There is no obvious solution to the problem of energy balancing and perhaps a different more radical approach is needed.

The reason the problem exists at all rests on the assumption that a continuous supply of electricity is required. Certainly a reliable supply is convenient, but is it actually necessary? Electric heating systems, particularly storage heaters, are largely indifferent to supply variation, and can use energy as it becomes available; LED-based lighting can be buffered through Lithium-Ion rechargeable batteries, and even some appliances such as electric kettles do not need a stable supply. In the future if the supply of oil declines as anticipated, personal transportation may require the overnight charging of an electric car, which again not necessarily reliant on a stable supply. However there are some appliances (including TVs, cookers, computers, vacuum cleaners etc) that as currently designed do need a stable regular supply. Referring to Table 1, one can estimate that as little as 10% of the energy used in the home needs to be reliable.

There is a case for running two separate power supplies into the home, one low capacity system offering a reliable service with a little of the energy provided by wind turbines and topped up by conventional fossil fuel and nuclear power plants, and a second high capacity system delivering the remainder of the energy produced by wind farms. In the second delivery channel, the available energy will depend directly on the mean wind strength across the region. To ensure the capacity of the primary system is not exceeded, units drawn from the stable supply should cost more to the consumer than units from the variable supply, and the price disparity can naturally or artificially increase over time to wean consumers off energy generated from fossil fuels, encouraging a change in energy-use habits or the adoption of new methods of using the lower-cost electricity. The onus of storage is then decentralized to the consumer, and removes one of the main drivers for the transition to a hydrogen economy.

Table 1 Domestic energy use in the UK. DTI data from 2005 showing how much of the energy used needs to be reliable, perhaps as little as 10 % (http://www.berr.gov.uk/files/file11250.pdf)

Category	*Percentage*
Space Heating	60.2
Water	22.6
Cooking	2.6
Lighting	3.4
Cooling	3.5
Consumer Electronics	3.1
ICT	1.9
Washing	2.7

The separation of the two supplies can be virtual rather than real for most of the transmission path from generator to end user, but the wiring cannot be the same for both systems at the point of use because the voltage must be stable in one case but allowed to vary in the other as a natural method of limiting current drain. Separation into two physical supplies can be at the consumer connection point, but this would require active control of at a household level on the part of the utility company. A preferred point of separation is at the LV distribution system.

As fossil fuel becomes too expensive to make direct combustion of oil, gas and coal in the home economic, more of the energy required for domestic heating will be taken from the grid. The national grid is currently working near capacity and an expansion is required to cope with renewable energy generation [5]. It would be desirable to upgrade in a way that separates fixed capacity and variable capacity streams to provide a level of security that is missing when there is but a single channel. In the short term, wiring used to deliver three-phase supplies can be reallocated as necessary and create a physical separation at the transmission level if this is thought necessary.

Peak and off-peak tariffs currently implement two virtual supplies, and separate metering within the home; what is proposed here is a logical extension where a physical separation is created that recognizes off-peak electricity is used in a different way and does not require the same degree of reliability.

In this paper we will begin to look at whether wind turbines distributed across a UK have a guaranteed minimum output over the year that could then contribute to the reliable supply and therefore reduce the level of conventional generation necessary. The suggestion has been made that lack of wind in one place is always made up for in another part of the UK. Perhaps of equal importance is the accuracy to which the generation level can be predicted ahead of time so that effective switching of conventional power plant becomes possible.

We will also consider if the householder is better off installing their own small wind generator instead using an unreliable secondary grid supply, the ‘home brew’ approach where the lower cost associated with large scale production is sacrificed to escape from externally imposed taxation and price control.

2 Wind variations across a region

The argument has been presented that there is no time in the UK when no wind energy is available, and by thoughtful and varied distribution and placement, wind turbines can provide a regular stable supply [6], [7], [8], [9]. In fact, this cannot be true because there will always be variation and the problem of balancing will persist, regardless of whether there is a guaranteed minimum level; any variation potentially poses a problem and installing a deliberate over capacity though undoubtedly effective, is wasteful and incompatible with the idea of sustainability.

For the purpose of this analysis, variation is not particularly important as it is the base level of guaranteed generation over the year that is important. We will begin this analysis by looking at two locations 114 km apart to determine if there is the required relationship that will ensure a continuous supply if extrapolated over the entire length and breadth of the country. We can show the results are consistent with other analyses of wind speed correlations in the UK.

Figure 1 The wind strength at two locations in the Outer Hebrides is compared.

We would expect there to be a non-zero minimum because of the UK climate pattern with prevailing south-westerly weather flow and the large size of the region in relation to that of a weather system – equal pressure and therefore no wind over the whole of the UK would be extremely unusual.

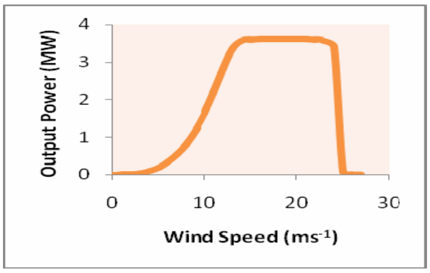

Figure 2 power curve of the Siemens 3.6 MW SWT-3.6-107 wind turbine.

Hourly Met Office data from the years 2000 – 2005 for the Stornoway and Uist monitoring stations in the Outer Hebrides of Scotland are available (Fig. 1). We will build up an electricity generation profile at each site based on the assumption that the turbines used for generation will follow the general power curve shown in Fig. 2 (which is in fact that of the Siemens 3.6 MW SWT-3.6-107 wind turbine). For the two sites to operate in a completely complementary fashion, there should a correlation of -1 in the data when the wind strength at one location is plotted against the other (Fig. 3). An anti-correlation means that when one turbine is inactive, the other is producing peak power.

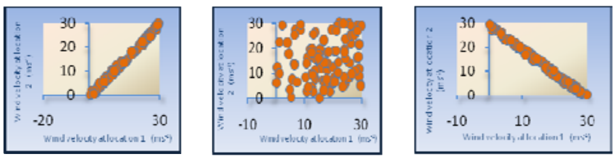

Figure 3 The correlations between the winds speeds at two different sites are +1 in the left-most graph, 0 in the middle graph (a random distribution) and -1 on the right. We would expect two sites near one another to have a correlation near to +1.

For the Stornoway and South Uist locations, the wind strength correlation is calculated to be 0.754, hence there is a small difference between the two sites (Fig. 4).

Though a two point correlation is a legitimate method of determining the variation, it is not that useful in terms of telling us how much more secure the supply is if one is able to draw energy from either site. This is because the response of the turbines is intrinsically nonlinear. A better approach would be to determine the number of hours at each site when the energy output is above a threshold value. As the threshold is raised, the number of hours will naturally decrease. We can then see how the curve changes when one uses the greater of the two hourly outputs. Fig. 5 shows that there is a significant difference. The improvement varies with demand (the threshold), but it is possible to get 6% more hours with adequate power output in South Uist once the Stornoway output is included. This is a significant improvement over what is a short distance compared to the length and breadth of the United Kingdom.

These findings are largely consistent with a similar analysis reported by [10]. The correlation coefficient was found to lie on a smooth curve with a value of 0.65 at 100 km and dropping to 0.15 at 800 km.

It is therefore probable that distributing turbines

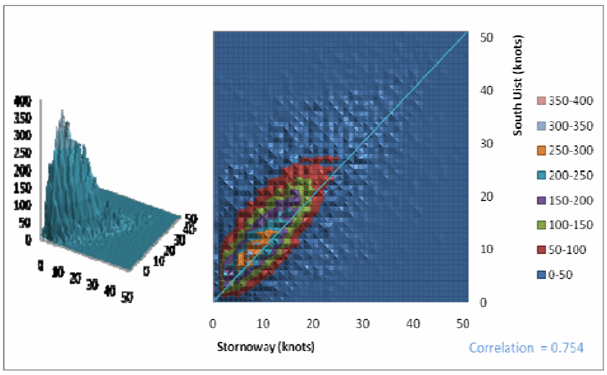

Figure 4 The correlation between the hourly wind speed in Stornoway and South Uist The inset shows the 3-D profile. As expected the correlation is high.

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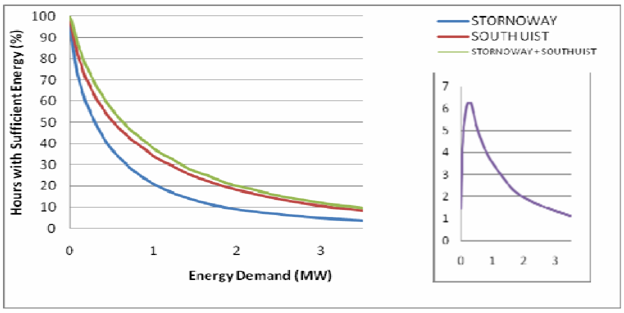

Figure 5 The number of hours in Stornoway and South Uist when the local wind strength is sufficient that the turbines generate at or above energy demand. The green line shows the performance improvement when both locales are included together. The inset shows that the improvement over South Uist on its own is as much as 6%.

across the country can ensure a reasonable output level is available most of the time. On the occasions when the energy is not available, hydroelectric pump storage can be used for load balancing, particularly as the response time of a hydro plant is around 30 seconds, faster than the natural variation of a large wind turbine where the system inertia smoothes more rapid wind changes. This would mean that some of the secure supply could be from renewable sources and further reduce dependence on fossil fuels.

It should be noted that for the Outer Hebrides, because of the Atlantic air flow, the correlation between the wind strength and the air temperature is generally the opposite of what might be expected. In other word, the stronger the wind the higher the

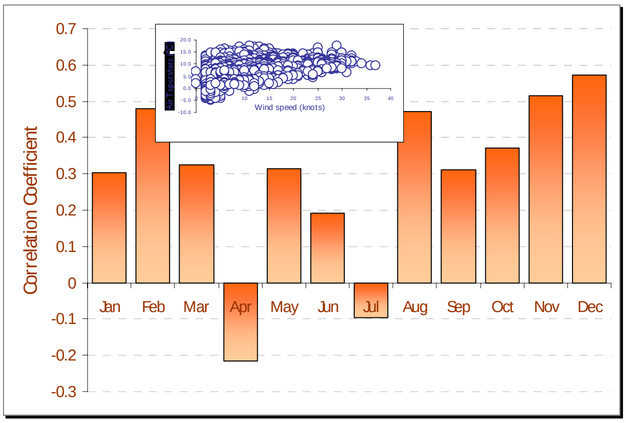

Figure 6 The correlation between wind strength and air temperature for Stornoway in 2005. The result is in disagreement with the common sense notion that the air is colder when the wind is strongest. This negative correlation only holds in April and July. Of course wind chill means that is not easy to relate to heat demand.

temperature, a positive correlation. Fig. 6 shows the correlation for Stornoway in 2005, and a calculation of the correlation coefficient by month.

The basic analysis here only infers that there is a reliable base from wind power and a more comprehensive analysis taking in sites from Scotland then across the UK looking at how real wind turbines will perform is merited. Also important is offshore generation that further secures the supply.

3 Small Scale Generation

It is possible for consumers to install private renewable energy capacity, and one serious possibility is the use of a small wind turbine driving a ground source heat pump. The issue here is the capital cost of the system. Small turbines are very expensive and produce less energy because optimal site selection is rarely possible and wind speed at ground level is much reduced because of friction with vegetation and water.

Local generation will therefore be subject to unusual facets of the microclimate, an effect that would be lessened by contry-wide generation.

The energy is more expensive and the turbine loading factor will drop from typically 40% in the Outer Hebrides for large turbines to about 20% for small turbines. Only if there are grants or tax breaks is this a better option, but individual generation should be supported to to reduce the current on the grid distribution network.

4 A Fossil Fuel Free Energy Economy in Scotland

It is possible to envisage an energy economy in Scotland for 2050 that will depend on little or no fossil fuel. Presently, the primary energy consumption in the UK is 3.8 toe *per capita* . We can anticipate in 2050 a population of 6 million consuming just 1.5 toe *per capita*. The reduction is achieved by relying almost completely on marine and wind renewable energy. Cars will have to be battery powered, charged overnight from the mains supply. This will reduce to at least a third the energy used by transportation because of the inherent inefficiency of the ineternal combustion

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engine compared to an electric motor (primary energy to useful work). Space heating costs will also fall to a third if it should become a requirement that ground or air source heat pumps are routinely installed;. The energy wasted as heat in power generation (up to 60%) can also be discounted as renewable generation increases, though the installed capacity of renewable plant must be greater than demand by a factor of three because the loading will be of the oder of 30-35 % . Finally there can be further reductions in energy use through conservation measures and change of habit. The total mean energy demand in Scotland in 2050 is therefore calculated to be 12 GW, of which 10% would have to be in the form a reliable supply. Fig. 7 indicates how this might be achieved.

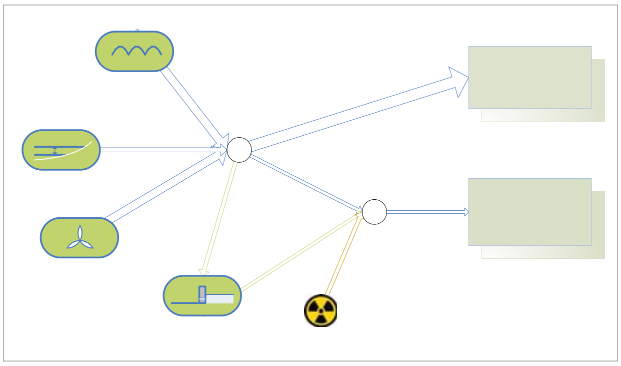

Figure 7 A model of energy fossil fuel-free energy deliver in Scotland in 2050. A 36 GW installed capacity of renewables will generate a steady 1.5GW for most of the time. When it does not, hydro or pump storage is used as backup. Or nuclear may be part of the mix.

With 36 MW installed renewable capacity, 1.5 GW steady supply is guaranteed most of the time. On the rare occasions it is not available, hydro can be utilised. Hydro is kept at full capacity. Nuclear can also be used to maintain the base load. Note that the demand on the steady supply will vary through the day and night and this must also be managed. The price differential should be such that onsumers are discouraged from swithcing to more expensive units when there is little energy on the variable line.

Of the remainder, between 0 and 34.5 GW will be available on the variable supply, an average of 10.5 GW assuming a loading of about 35%. We will look at how this can be managed in the next section, but note the implications of this quantity of renewable energy capacity. 20 GW of wind would require 4,000 turbines at a density of about 4 per square kilometer. An area of approximately 30 km x 30 km to be taken up with turbines. This is not too much and would be less if micrgeneration made a significant contribution. There is also the possibility of exporting energy.

5 Managing a Variable Supply

A **distribution** system is being proposed where the available power will vary and may even approach zero. It is essential that energy can be put onto the **transmission** system is a controlled fashion. The voltage and phase on the transmission grid must remain stable to permit invertors and transformers to function correctly. However taking energy off the grid is the problem. If the demand from connected equipment is higher than generation capacity, the voltage and frequency cannot be maintained. A safeguard must be incorporated into the distribution system that will ensure that as consumers try to take more off the supply than is available, the transmission system will not collapse. It is not sufficient to rely on consumer equipment to alter energy demand, perhaps by tracking the supply voltage or control signals; there will always be opportunistic units that will not conform, and the transmission network cannot control everything drawing power. It is suggested instead that power out at the low level transformers that regulate the nominal 240 VAC consumer supply is actively regulated. This is nothing new - there are already systems on the grid that monitor generation and demand and have the ability to shed load to protect system integrity [11], [12]. However, this requires decision making on the part of the utility or grid management. We propose here that the low voltage line be allowed to fluctuate at the transformer to control demand. Consumers may then compete for the available energy , it is not possible to ensure 'fair' distribution at a consumer level. While passive elements would maintain the same share of the available energy as the voltage fluctuates, active elements will not.

Each transformer is on a signalling network and is informed periodically of the maximim power it can deliver P_T. Through active load sensing the current equivalent real load L is determined. The equivalent voltage is calculated $V = \sqrt{(P_T L)}$. If $V \geq 240$ V, no action is taken. If less, the voltage is dropped to match the limit. This very simple system transfers

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the responsibility of managing variable supply to the consumer. If the consumer is not able to manage, they may purchase much more expensve units from the reliable supply.

This is in contrast with the proposal by Ruth Kemsley of Econnect [13] who worked with the Findhorn Foundation Community in Scotland to encourage consumers to surrender control over their household equipment and install 'load controllers' to enable remote switching to permit supply to match demand. This puts great pressure and responsibility on the energy provider and is not workable for large systems – the concept is just not scaleable. A similar switching scheme was proposed by Lasseter *et al.*, [14].

Another idea is the concept of the microgrid. This is a highly controlled system that can use battery storage and hydrogen production to balance supply variation and divert excess generation to and from the grid. This is described by Kueck *et al.* [15], but again is not scaleable. The grid is always assumed to be there as a buffer, or backup. The issue of energy storage on large networks is critical when most energy generation is from intermittent renewables sources and the problem of storage or 100% conventional generation backup will always exist whilst there is a demand for completely reliable power delivery.

Implementation of capacity limiting at transformer level can use existing distribution automation systems that monitor, coordinate and operate distribution components. A reliable highly integrated communications network infrastructure is needed, with fail safes to isolate sections of the system in the event of communication failures.

6 Conclusion

A new approach to load balancing when the generation sources are mostly intermittent renewable energy has been proposed which recognised that the apparent demand for a reliable stable supply only arises because some equipment requires this type of supply, and because there is only one physical supply, the requirement is universally imposed. But by separating devices that do need a regular supply from those that do not and providing two separate physical supplies, we can see that the base reliable load is drastically reduced and can be supplied by a variety of means, none of which need significant energy storage and permit a large fraction of energy to be from intermittent renewable energy sources such as wind farms.

We will consider in detail how a LV transformer can limit the output power in the most effective way.

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