Project Acronym: SERVE
REF EC: (Project Number) TREN07/FP6EN/S.07.71106/038382
REF (project coordinator org.):
DOCUMENT: Medium Wind and Load Control in Utilities Area of Eco-Village
REF.: Deliverable 7.2c

Project Coordinator: Seamus Hoyne
Project coordination org.: Tipperary Rural and Business Development Institute
Date: 3 December 2009
Revision: 2.0

Deliverable Report
Deliverable No.: 7.2c
Work Package No: 7

CONCERTO INITIATIVE
SERVE

Sustainable Energy for the Rural Village Environment

Report Title:

Medium Wind and Load Control in Utilities Area of Eco-Village

Date: 3 December 2009

Author: Christine Barbier, Senergy Econnect

Version: 2.0

CONCERTO is co-funded by the European Commission

Table of contents

1 Introduction

Work package 7 within the SERVE Project focuses on specific research related to sustainable electricity supply. The main objective of this research is to investigate and make recommendations which will lead to the implementation of methods and technologies to achieve sustainable electricity supplies within the Eco-village, in particular, and also in the wider SERVE Region. The activities include:

a) Community Purchasing of Energy (SERVE Region)
b) Local grid development and control (Eco-Village)
c) Future on-site renewable electricity supply options (Eco-Village)

Further work has been completed on the last two objectives with the development of an assessment of the options for medium sized wind energy to provide green electricity to the utilities area of the Eco-Village. This report has been produced by Senergy Econnect. The report outlines the key issues that require consideration in order to progress the development of a wind energy scheme at the site. The assessment has identified a potential load management solution to enable maximum use of the wind generated within the site as well as investigating the practicalities of assessing and installing a 50kW wind turbine near the utilities area. The report has assumed generic data for the electricity consumption of the utility area and the wind resources available on the site and this will need verifying against actual measured data before a final recommendation can be made.

The report on Medium Wind and Load Control for the Utility Area of Eco-Village is provided in Appendix 1 and forms part of Deliverable 7.2c. This report is in initial state and will be further developed as the work continues within the WP, particularly when actual site data from the Eco-Village becomes available.

2 Appendix 1: Medium Wind and Load Control in Utilities Area of Eco Village

senergy
alternative energy
econnect

Tipperary Institute – SERVE

Draft D7.2c Medium Wind and Load Control in Utilities Area of Eco-Village

Senergy Econnect project number: 2061

Prepared for	Seamus Hoyne Serve Project Coordinator Tipperary Institute Nenagh Road Thurles Co. Tipperary Ireland

	Name	Date	Signature
Prepared By	Francis Shillitoe	3 September 2009	[signature]
Checked By	Christine Barbier	3 September 2009	[signature]
Approved By	Ruth Kemsley	4 September 2009	Ruth Kemsley

SENERGY ECONNECT LIMITED
STOCKBRIDGE HOUSE, QUAYSIDE, NEWCASTLE UPON TYNE NE1 2HJ, UNITED KINGDOM
T: +44 191 2387300 F: +44 191 2387399 E: econnect@senergyworld.com
REGISTERED IN SCOTLAND SC347794 REGISTERED OFFICE: 15 BON ACCORD CRESCENT, ABERDEEN, AB11 6DE
www.senergyworld.com/econnect

Document History		
Issue No	**Description**	**Date**
01	Original Document Issue	4 Sept 09
02	Reissued with new Deliverable number and name	3 Dec 09

Executive Summary

This report investigates the feasibility of implementing load control to better utilise on-site generation from a proposed 50kW wind turbine in the Utilities Area of the Eco Village at Cloughjordan. This follows on from work carried out by Sustainable Projects Ireland Ltd ('SPIL') which indicated clear savings available from installing a 50kW wind turbine to offset the energy demand of the loads in the Utilities Area. Installing additional load control equipment could help to match energy demand with wind turbine output, reducing the amount (and hence cost) of energy purchased from the grid.

A methodology is described here for assessing the benefits of implementing a load control scheme, and modelling results are presented. At the time this report was written, only limited data regarding the demand profiles of the loads and predicted output of the proposed 50kW turbine were available. However, modelling carried out for 21 June and 21 December, using assumed demand profiles and wind turbine output, suggests the following conclusions.

- Installing a wind turbine could provide significant savings in energy imported from the grid.
- Even basic load management, such as having the boiler and district heating pumps on at different times, can smooth demand and reduce the energy imported from the grid.
- Using estimated data, the model indicated that installing additional load control might only provide modest further savings (in addition to those generated by installing the wind turbine). However when the overall wind input was reduced for each of the days modelled, the load control benefits increased.
- The results from this work are not extensive or accurate enough to draw a clear conclusion regarding the value of load control in the Utilities Area.

Measuring the Utilities Area power and energy consumption would provide better information for system modelling, both to inform the selection of the optimum wind turbine rating, and to inform the decision as to whether a load control system will provide sufficient value for money to justify its investment costs. However detailed measurements could prove costly. A judgement needs to be made as to the level of detail which is necessary. At present, the OWL power measurement system seems to be able to provide the required data at a modest price, however further investigation should allow the best option to be identified.

The following further actions are recommended.

- Identify and purchase suitable power monitoring equipment for the Utilities Area.
- Collect measured data for the Utilities Area demand profile over a period of weeks/months.
- Install an anemometer on site if possible, and collect measured data for local windspeeds.
- Monitor Utilities Area operation in detail over a short period (e.g. observations over a day, for a number of days with different weather and system operating conditions).
- Identify Utilities Area loads which would be suitable for being controlled to make best use of wind turbine output.
- Develop an outline design and costing for an automated load control system suitable for the Utilities Area.
- Establish what export tariff and grants would be available for all proposed wind installation options.
- Carry out a more detailed and extensive analysis of the energy balance, costs and benefits of different wind turbine types, including evaluation of a costed load control installation.

Senergy Econnect can support or carry out these tasks as part of the SERVE project, subject to equipment being provided to make necessary measurements and/or data being made available.

Table of Contents

1 Introduction

1.1 Background

The “Village” is a new eco-village development currently under construction adjacent to the existing village of Cloughjordan. Cloughjordan is located in the county of Tipperary in Southern Ireland, approximately 10 km north east of Nenagh and 10 km west of Roscrea. The Village is designed to have a low environmental impact. Its heating needs will be met by a district heating scheme powered by a biomass / solar thermal boiler system. Other energy needs are likely to be met using electricity. The SERVE (Sustainable Energy for the Renewable Village Environment) project has specific targets for energy use within the Village. Many relate to heat demand and supply for the planned 132 dwellings and 3 community buildings, but the electricity-related objectives are as follows:

5. Using RES (renewable energy system) heat supply via district heating and RES electricity purchase (initially) from a green supplier to approach 100% RES Supply in the Eco-village
6. To monitor and publish energy use and demand in all buildings to allow for demonstration of the cost-effectiveness of a holistic design approach and provide feedback to energy users
8. To investigate the potential for future polygeneration, by monitoring the actual electrical load of the Eco-Village and the scope for load management. Based on this data a RES electricity production facility will be developed to match Eco-Village demand by 2010, but funded outside of CONCERTO (EU funding mechanism).
9. Establishment of Energy Supply Company (ESCO) to operate and develop the energy supply systems in the Eco-Village by Month 12.

Senergy Econnect previously carried out studies [1], [2] to inform objective 8. above, considering options for on-site and off-site renewable electrical generation. The main technologies under consideration were wind turbines and PV generation. The pros and cons of installing large off-site wind turbines, medium-sized on-site wind turbines, domestic-scale wind turbines and PV arrays were discussed. Possibilities for incorporating load management into the Eco-Village to optimise use of renewable electricity were also presented, along with the practical implications and associated issues.

SPIL have also investigated installing a small wind turbine on-site, to help supply the energy requirements of the Utilities Area directly. The Utilities Area contains a diverse set of electrical loads, from the district heating scheme boiler and pumps, through to the public lighting supply and sewage systems. A RETscreen analysis was carried out on a nominal 50kW wind turbine. This size of turbine would not exceed the 50kW rating of the Utilities Area ESB connection; it would be able to qualify for 40% grant funding under the Sustainable Energy Ireland ‘Micro-Generation Pilot Programme’[1] and is approximately suited to the Utilities Area energy demand. ESB Customer Supply offers a micro-generation tariff of 9 cents per kWh for domestic customers, which applies to a rated maximum output of 11kW for a three phase connection. It is not clear what payment could be received for exported energy from a 50kW wind turbine in the Utilities Area (see Appendix B).

The loads in the Utilities Area are supplied from a single electricity meter and the wind turbine would be installed on the customer side of the meter. As the import price of electricity is greater than the export price there is a financial incentive to use more of the power generated from the wind turbine within the Utilities Area itself. A load control scheme would reschedule loads to coincide better with times of higher generation, to reducing the total amount of electricity imported from or exported to the grid. Some of the Utilities Area loads are more amenable than others to being rescheduled.

[1] http://www.sei.ie/Grants/Microgenpilot/

1.2 This document

This document takes the previous work on wind generation in the Utilities Area further than the previous studies. It describes a methodology for assessing the financial benefits from a medium sized wind turbine in the Utilities Area operated in conjunction with a load control scheme to maximise the returns from wind generation.

The analysis considers detailed predicted demand profiles, wind generation profiles and possible load management strategies. At the time of writing this report, little data had been gathered regarding the demand profiles of loads in the Utilities Area or the nature of the wind resource at Cloughjordan. However, simple estimated models have been constructed based on typical data from other sites, and an initial assessment has been carried out. This initial assessment can be refined as actual data becomes available. Further issues of this report are likely to provide a more reliable conclusion based on such updates.

All prices quoted in this report are exclusive of VAT unless otherwise stated. A Pound Sterling to Euro conversion rate of 1.2 has been used when required.

1.3 Selecting wind turbine size

For a site which has a wind turbine installed and also uses electricity from the grid to power its loads, the value of each unit (kWh) of wind energy varies, depending on whether it is used on site or exported to the grid. If it is used on site, then each kWh is worth the amount that would otherwise be paid to the electricity supplier (approximately 15-6 c/kWh, or the import price). If it is exported onto the grid then it is worth the value that a supplier will pay for it (9c/kWh for micro-generation, under the new Feed-In Tariff rules). Previously this tariff was not available, making it important for small generators to make sure they used as much as possible of the energy they generated.

Calculating whether a wind turbine provides value for money depends on the effective income it produces, either in savings in energy costs or in revenue from exporting power. This must be weighed up against the installation and operating costs. In general, the best return rate is obtained if a reasonable proportion of the wind energy produced can be used on site, i.e. the size of the wind turbine is matched to the site load. However the overall return also depends on the cost of the turbine to the installer (which could depend on whether grant funds are available) and also on the export tariff, which may depend on wind turbine rating as well. It may be more cost effective to install a smaller machine if it means that a grant becomes available, grid connection costs can be reduced, or a more advantageous tariff can be obtained.

At Cloughjordan, the Utilities Area loads in theory could reach 49kW (Table 1). However it is highly probable that not all loads are operating at the same time, and that not all loads will run at 100% power all the time. So the average load is likely to be significantly less than 49kW. Conversely, a 50kW wind turbine will only produce 50kW some of the time - its average output over the course of a year is likely to be nearer 10-15kW. Therefore an initial indication is that a 50kW wind turbine might be an appropriate size for the Utilities Area.

When more operating experience has been gained with the equipment in the Utilities Area, the average load will be better understood and the demand profile (how it varies through the day and through the year) will become clearer. This will help in evaluating the best size of wind turbine to install.

1.4 Applying load control to better utilise on-site generation

Load control can help to match wind power output with load demand, improving the balance between the energy used on site and exported energy, and increasing the return from the wind turbine. However it does require an additional investment in equipment, which may not be justified by the increased return from the wind turbine.

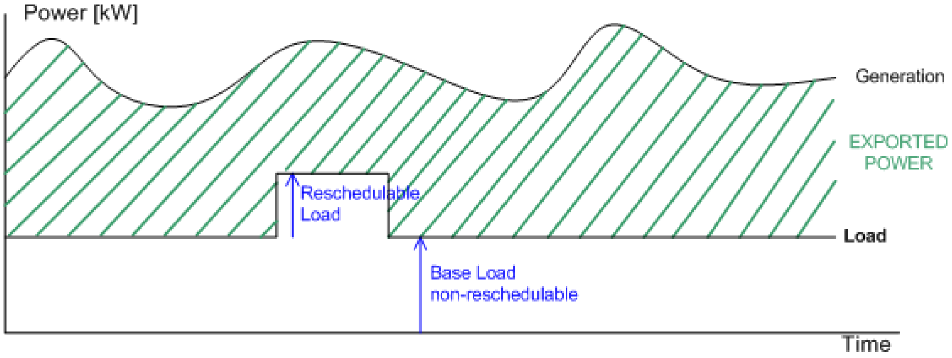
There are general principles that are applied to establish the benefits of any load management for a given sized generation plant. These are:

- There is a financial benefit in load control if the energy export price is less than the energy import price.
- If on-site generation is much greater than on-site load, then the site will nearly always be exporting power and there is no benefit in load control. This is illustrated in Figure 1(a).
- If the generation is much smaller than the load, then the site will nearly always be importing power and there is no benefit in load control. This is illustrated in Figure 1(b).
- Load control becomes beneficial when at some periods the site is importing and at other times exporting power. This is illustrated in Figure 1(c).
- The aim of a load control scheme is to reschedule some electrical loads from the periods when the site is importing electricity to the times when it is exporting, thus to better utilise the on-site generation and reduce the total energy imported and exported. This is illustrated in Figure 1(d).

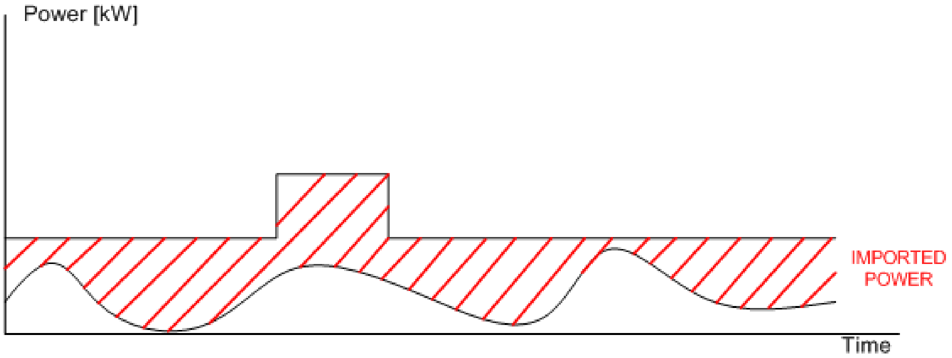
By assessing the power consumption of the non-reschedulable and reschedulable loads we can quickly decide if we are in scenario (a), (b) or (c). If we are in scenario (c) we need to determine if the benefit of applying a load control scheme to allow us to reschedule loads, scenario (d), is greater than the cost of implementing the scheme.

Wind energy is extremely variable with power outputs varying greatly on a minute by minute basis. An example of where load control for wind generation can be extremely effective is in the case of hot water heating. An immersion heater can be rapidly switched on and off to coincide with periods of high and low generation respectively. As the hot water is stored it does not need to be used immediately.

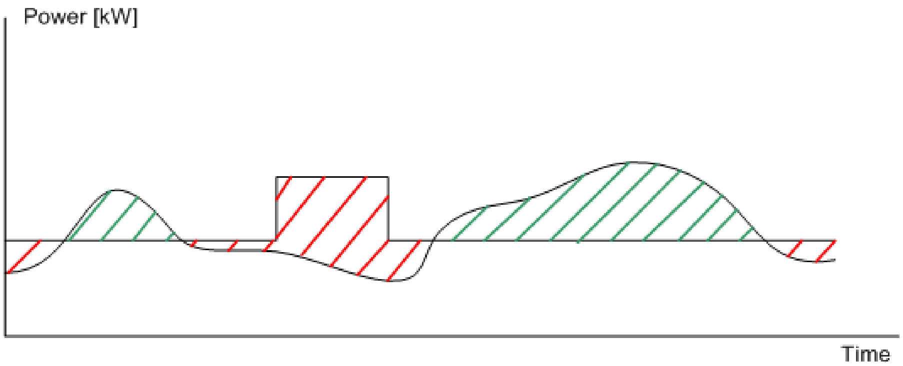
However in the case of the Cloughjordan Eco Village Utilities Area there is not a requirement for electrical water heating. The Utilities Area loads need to be continually operating for minutes or hours at a time. Therefore in this situation what happens to the wind power generated over longer periods is more important than the short term minute by minute variations. Wind speed does vary over longer time scales depending upon longer term weather patterns. What happens to wind speeds over a 24 hour period is of most interest to the Eco Village as it is patterns over this time period that can be best utilised for load rescheduling in the Utilities Area.



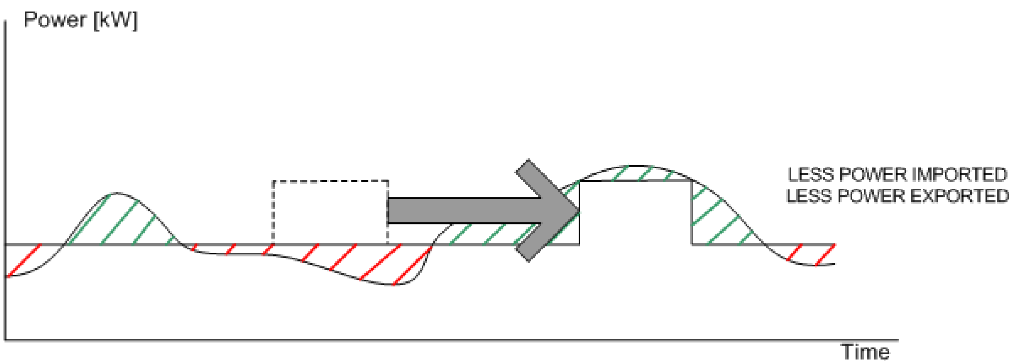
(a) Generation is always greater than load => no benefit in load control



(b) Generation is always less than load => no benefit in load control



(c) Generation is approximately the same as load



(d) Applying load control to better utilise generation

Figure 1 – On-site load/generation scenarios

1.5 References

[1] Deliverable 7.2a, Large Wind Option for Eco-Village, Pre-Planning Feasibility Study and Business Case for On-Site Wind Generation at the Cloghjordan Site, Senergy Econnect Ltd, Issue 2, December 2009

[2] Deliverable 7.2b, On-site generation, load management and local grid for Eco-Village, Senergy Econnect Ltd, Issue 2, December 2009

[3] Burton T. Sharpe D., Jenkins N., Bossanyi E., 2001. Wind Energy Handbook, John Wiley & Sons Ltd

[4] Van der Hoven, L, 1957. 'Power spectrum of horizontal wind speed in the frequency range from 0.0007 to 900 cycles per hour' *J. Met.,* 14,160-4.

[5] Buttimer, T. (trevor@rems.ie), 14 July 2009. RE: [planning] RE: Progress with Carey Solar. E-mail to Barbier, C., (christine.barbier@senergyworld.com)

[6] University Of Oxford Environmental Change Institute, 2005. Wind Power and the UK Wind Resource, http://www.eci.ox.ac.uk/publications/downloads/sinden05-dtiwindreport.pdf [Last accessed 29 July 2009]

2 A methodology for assessing the benefits of load control

In this section a methodology is described for assessing the benefits of controlling reschedulable loads in the Utilities Area of Cloughjordan Eco Village to better utilise the on-site generation from a 50kW turbine. A 50kW turbine was used as an example, as this was the rating considered by SPIL, although further investigation of the small wind turbine market may reveal that one or more smaller machines may be more easily available or more suitable. The process is illustrated in Figure 2. The process is divided into a number of stages with check points at each stage.

The first stage is to assess the financial benefit that can be gained from rescheduling loads in the Utilities Area using simplistic models of the loads and the wind generation. If the savings are significant, then it is worth carrying out further analysis. If the savings are found to be negligible then it is probably not worth continuing the study, as the potential savings would not cover the costs of installing the power monitoring equipment required for the next stage and analysing their output.

The second stage involves the actual purchase and installation of power monitoring equipment. It is assumed that data from a wind anemometer will also be available and that the cost of installing this is not part of the load control work. Data needs to be logged at an interval of five minutes or less, preferably for up to one year. The assessment can then be re-run with this actual data. If the savings are still found to be worthwhile, an analysis of the costs of various load control schemes can then be carried out.

The third stage is to decide on the most cost effective load control scheme and to design, develop and implement it. Three types of load control scheme are considered:

- Manual - where an operator may check weather forecasts and set timers on reschedulable loads on a daily basis. This would incur little capital cost although the operational man hour cost would be greatest.
- Advisory – where an operator may be advised by a load control system whether to change timer settings or to manually turn loads on or off. The load control system may take historic and forecasted data as inputs. This would incur a medium capital cost and some operational man hour cost.
- Automated – where a load control system decides when to initiate switching loads on and off. This would incur the greatest capital cost but have minimal operational man hour cost.

At the time of writing this report, very little data has been collected regarding the demand profiles of the loads in the Utilities Area or the nature of the wind resource. Where data is missing, assumptions and estimates have been made. Therefore the assessment results presented in this report are only a very early indication as to the benefits or otherwise of installing a load control scheme.

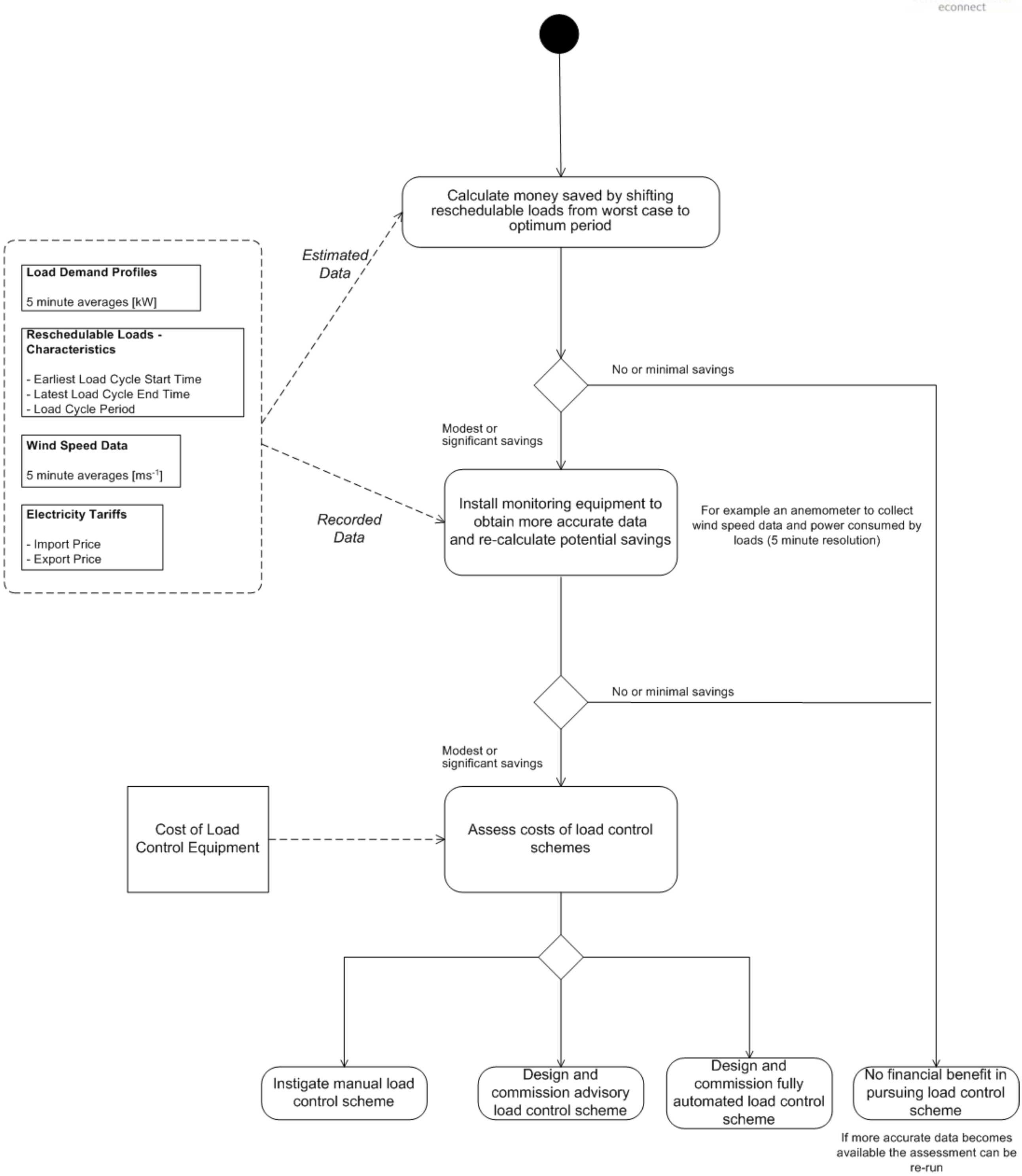


Figure 2 – Assessment methodology for load control

3 Wind resource and generation

For load management we are particularly interested in how wind speed varies over time. This is so we can reschedule electrical loads into periods of high generation.

The Van der Hoven spectrum [3], Figure 3, shows a frequency domain representation of wind speeds. The Van der Hoven spectrum is built up from data taken from a number of sites and over a long period of time. Although, each individual site will have its own characteristic, the Van der Hoven spectrum is useful in describing trends that are seen in wind data. Larger scale atmospheric circulation leads to rises and falls of wind speed which occur over periods of days. This is characterised by the Synoptic peak in Figure 3. On top of this longer term cycling, a daily cycle can be identified (Diurnal peak) due to the warming and cooling of the air due to the passage of the sun. This may be seen as a 24 hour peak in the daytime where intense heating causes large convection cells in the atmosphere, which dissipate at night, or a 12 hour peak where differential heating and cooling of land and sea cause a reversal of winds twice a day [3]. Wind speeds varying over time scales of less than ten minutes are considered to be caused by turbulence (Turbulent peak). Turbulence causes the actual wind speed measured on a second by second basis to vary greatly.

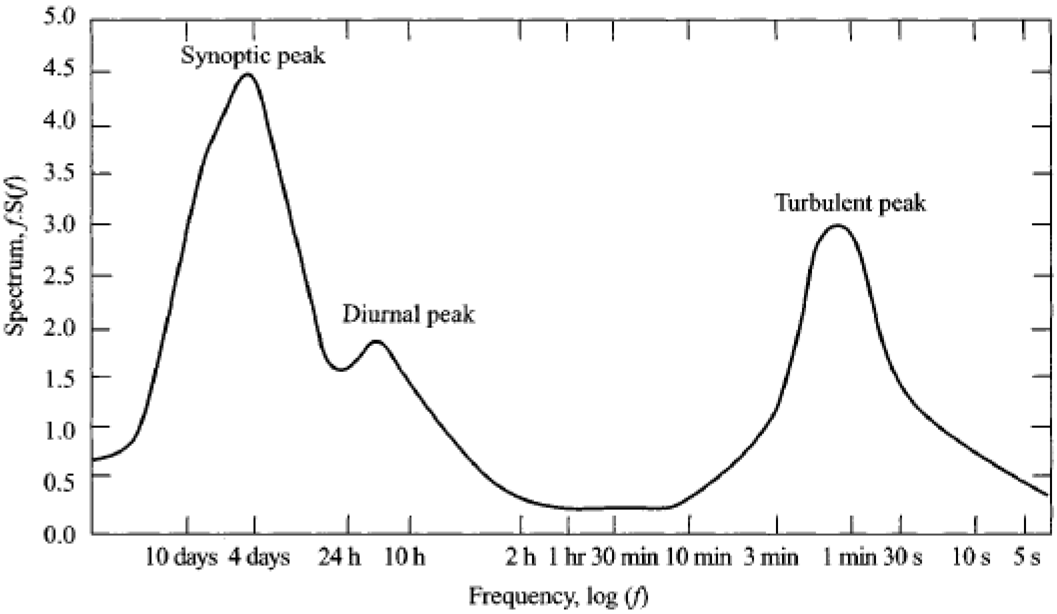
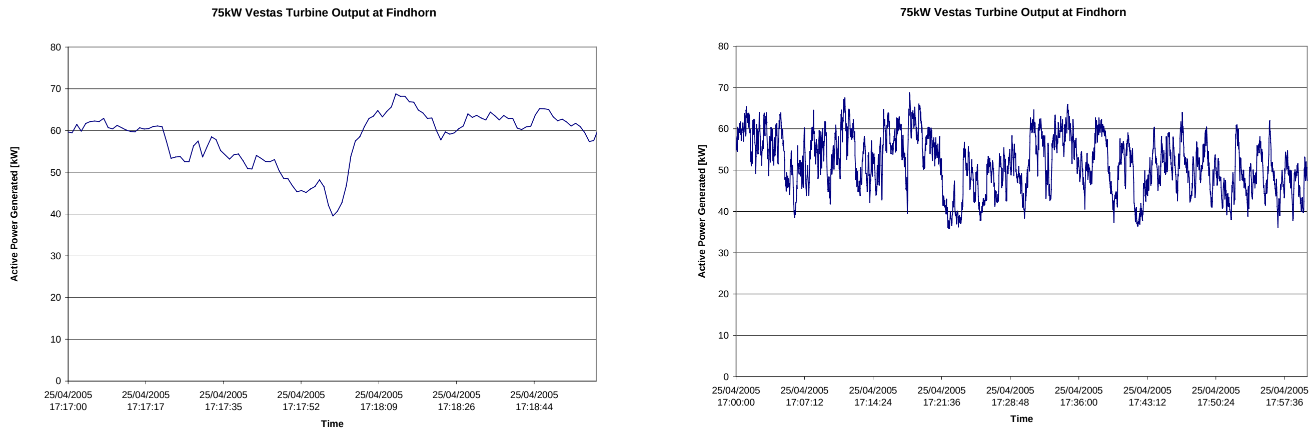


Figure 3 - Van der Hoven Spectrum [3]

Senergy Econnect carried out a piece of research for the UK Department of Trade and Industry in 2005. As part of this work, detailed measurements of the output of a Vestas 75kW turbine at Findhorn in Scotland were taken.

Figure 4 demonstrates how the power generated over the course of seconds and minutes can vary greatly, confirming the significant input that turbulence has on turbine output. Over longer timescales, as shown in Figure 6, a correlation with the Synoptic peak can be seen with a period of very low wind on 27 April followed by two days of high wind, 28-29 April. During the period of high wind the turbine reaches its maximum output but the effect of turbulence is still visible with the power output dipping below the maximum output on a minute by minute basis.



(a) Two minutes

(b) One Hour

Figure 4 – Variation of the power output of a 75kW wind turbine over short time scales

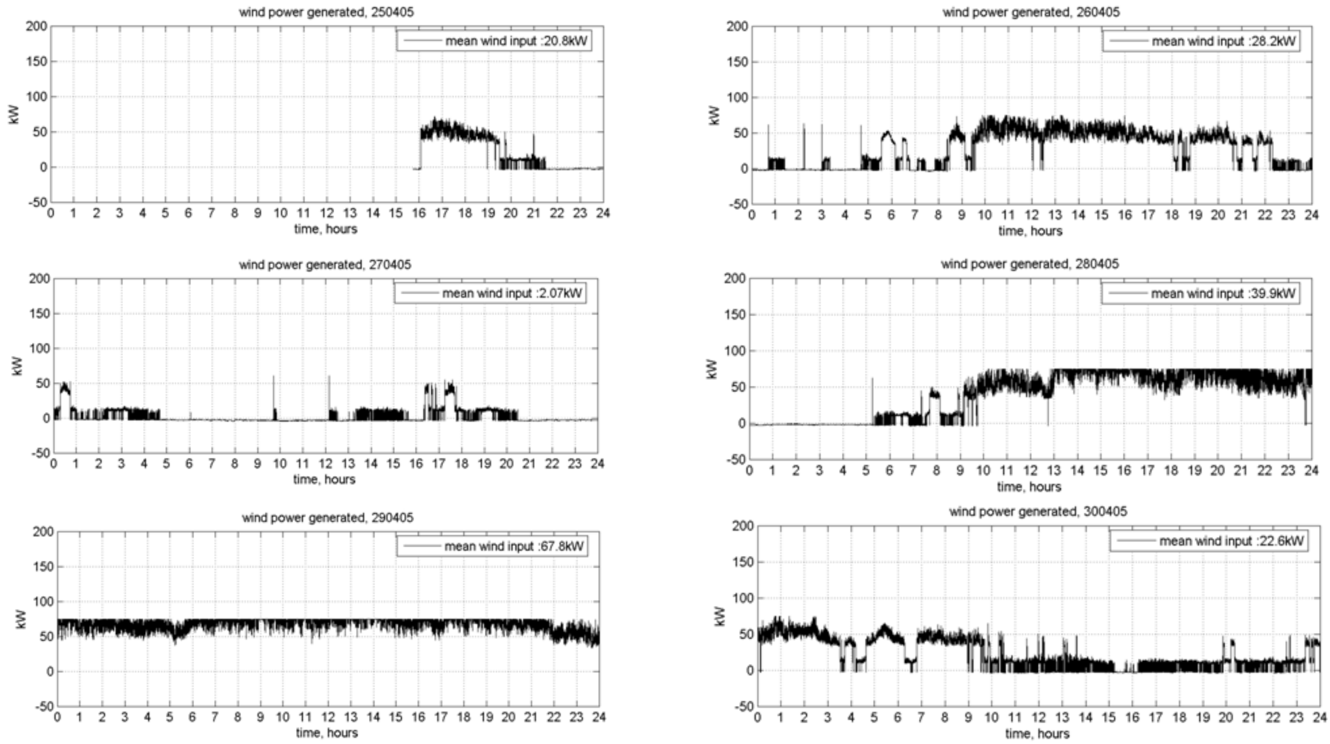


Figure 5 – Variation of the power output of a 75kW wind turbine over six days

No diurnal variation can be discerned from Figure 5 although a longer study period would be required due to the Diurnal peak being much less pronounced than either the Synoptic or Turbulent peak.

The University Of Oxford Environmental Change Institute carried out a report which showed a distinct seasonal and diurnal variation in the total wind farm output across the UK. This has been applied to the 50kW turbine assuming a 30% capacity factor, to give an initial daily wind profile for the months of June and December, as illustrated in Figure 6.

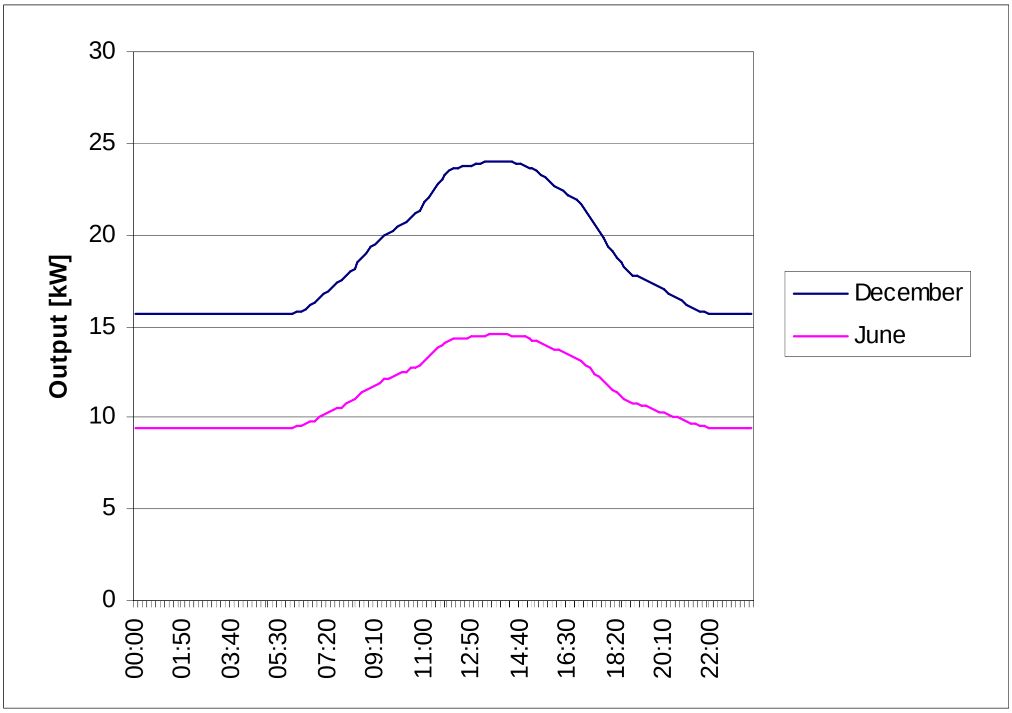


Figure 6- Models for wind power output of a 50kW turbine operating at a 30% capacity factor

Although the actual turbine output will vary greatly on a daily basis, this is a useful starting point, as we do not currently have any recorded data for the site. Figure 6 will be used as our model of wind turbine output at Cloughjordan Eco Village until more accurate data becomes available such as from anemometer readings.

4 Utilities Area demand

4.1 Load shifting definitions

Before describing the loads in the Utilities Area a number of definitions need to be introduced. The example of a washing machine shall be used to define the key terms, as illustrated in Figure 7.

On a particular programme it takes one hour to wash one load of clothes. This length of time is known as the Load Cycle Period. It should be noted that most of the energy consumed occurs during a 15 minute period where the power consumption exceeds 2kW due to cold water being heated. Now, the householder may want the clothes to be washed by 08:30, the Latest Load Cycle End Time, so that he or she can hang the clothes on the washing line before going to work. However, he or she does not want the clothes to sit in the washing machine for more than two hours as they get creased. As he or she isn't ready to hang the clothes on the line until 08:30, the earliest time the washing can be finished is 06:30, the Earliest Load Cycle End Time. Therefore, the load management system is only able to vary the time the washing machine can start washing clothes within a two hour window, the Maximum Load Shift Period, which means the earliest it can start is 05:30, the Earliest Load Cycle Start Time, and the latest it can start is 07:30, the Latest Load Cycle Start Time. The actual time the load cycle begins and ends, as determined by the load management system and the Load Cycle Period are called the Load Cycle Start Time and the Load Cycle End Time.

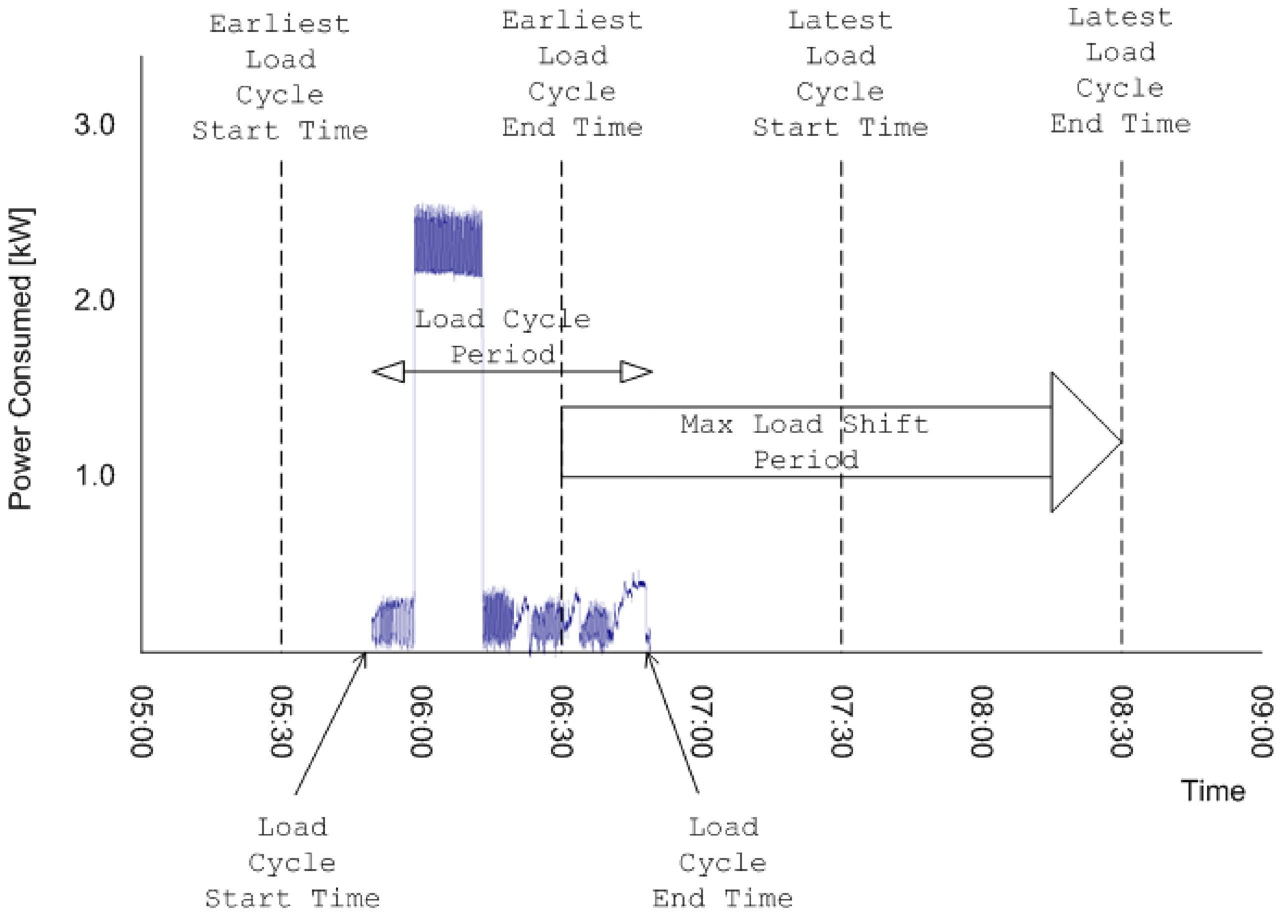


Figure 7 – Washing machine demand profile used to explain load shifting terms and definitions

4.2 Utilities Area loads

A list of the significant loads in the Utilities Area is provided in Table 1. Further work is required to determine whether the boilers, district heating pumps, discharge pump, water aeration pump and loads in the Enterprise Centre can be rescheduled. For the time being it shall be assumed that only the boilers can be rescheduled due to the fact that they heat large tanks of water used by the district heating scheme. It is assumed that these water tanks are sufficiently insulated to be able to hold water at about the same temperature for several hours, so can therefore be heated in advance of it being used.

Table 2 lists the power consumption of the constituent parts of the boiler.

Load	Make/Model	Peak Power kW_e	Usage	Is it possible to reschedule?
Boiler 1	Herz Biomatic 500kW	8.96	On full or partial load for 3000 hours per annum	Further information required
Boiler 2	Herz Biomatic 500kW	8.96	On full or partial load for 1000 hours per annum	Further information required
District Heating Pump 1		7.5	5000 – 6000 hours per annum. Speed at which pumps runs and power draw off is dependent on heat demand which is dependant on house build quality	Probably not
District Heating Pump 2		7.5	Backup for Pump 1	Further information required
Solar Module Primary Pump		2.5	1000 hours per annum. Will be running 50% of time when no boiler is running.	No – this will operate when sufficient solar resource is available
Solar Secondary Primary Pump		2.5	1000 hours per annum. Will be running 50% of time when no boiler is running.	No – this will operate when sufficient solar resource is available
Public Lighting		2	Further information required	No – this will depend on the time of day and time of year
Discharge pump to water treatment plant		1.5	Further information required	Further information required
Water treatment aeration pumps (x3)		7.5	Further information required	Further information required
Enterprise Centre			Further information required	Further information required
Total		**49 kW**		

Table 1 - Utilities Area Loads [5]

Boiler Part	Power consumption / kW	Comments
Stoker drive	0.55	Pulses on for short periods
Discharge	1.2	Pulses on for short periods
Ash Removal	0.37	Spur gear drive. Pulses on for short periods
Cleaning	0.55	Spur gear drive. Pulses on for short periods
Ignition	1.6	Herz Transformer, Triac. Used a few times a day for a few minutes
Suction Fan	3	Run almost continuously
Primary Fan	0.09	Run almost continuously
Secondary Fan	0.4	Run almost continuously
Shunt Pump	1.2	Estimate. Assumed to run almost continuously.
Total	**8.96 kW**	

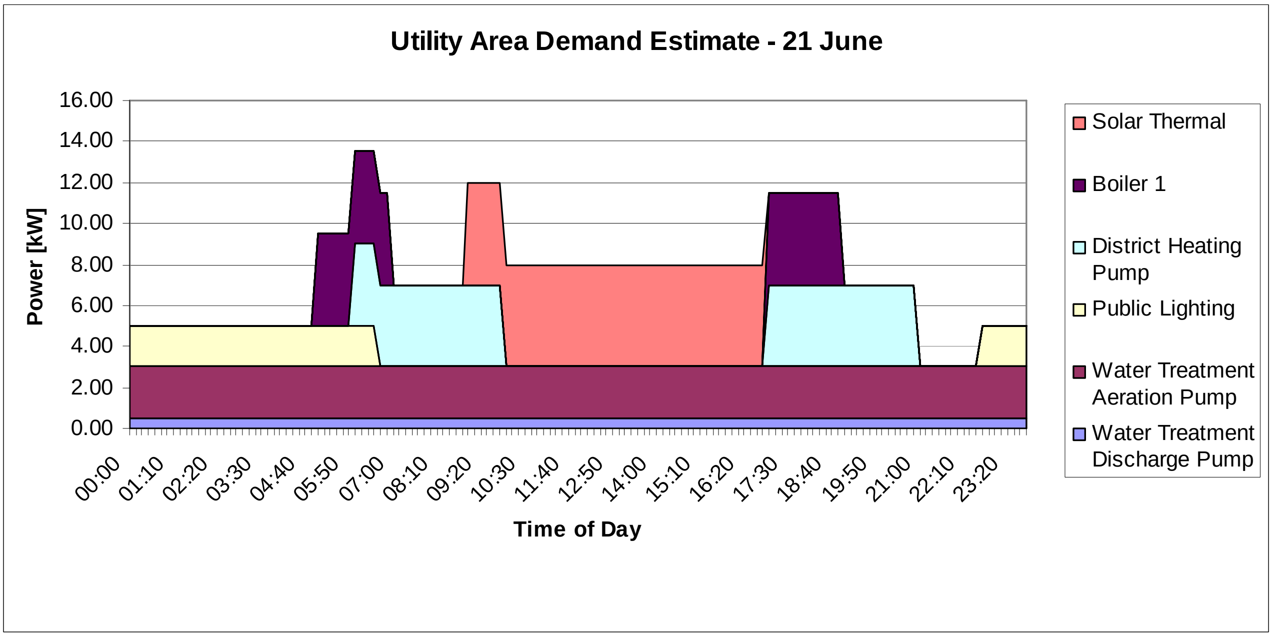
Table 2 - Herz boiler, power consumption of constituent parts [5]

4.3 Demand profiles

In order to carry out an initial assessment of load management for the Utilities Area, two days for load demand have been modelled: 21 December and 21 June. These are taken as typical high and low demand days respectively and assumed to be working days. Table 3 describes the demand profiles used for each load and for loads which can be rescheduled the Earliest Load Cycle Start Time, Latest Load Cycle Start Time, and Load Cycle Period. Figure 8 shows estimated demand profiles as cumulative totals for the whole Utilities Area.

<table>
<tr><th>Load</th><th>Demand Profile</th></tr>
<tr><td>Boilers</td><td>
Due to the feed and ash removal auger motors only running for short periods, and the ignition only running for a few minutes these have been ignored.
Boiler 1 running for 3000 hours per annum averages out at 8 hours per day.
Assume Boiler 2 only runs in the winter.
Assume total boiler demand is 9 kW for 6 hours twice a day in the winter and 4.5 kW for 2 hours twice a day in the summer
<table>
<tr><th></th><th>Winter</th><th>Summer</th></tr>
<tr><td>Load Cycle Start Time</td><td>00:00 to 04:00 for morning demand
12:00 to 16:00 for evening demand</td><td>00:00 to 05:00 for morning demand
12:00 to 17:00 for evening demand</td></tr>
<tr><td>Load Cycle Period</td><td>6</td><td>2</td></tr>
</table>
</td></tr>
<tr><td>District Heating Pumps</td><td>
Have assumed that this is not deferrable and depends on the heat demand of the house. The following profiles are used
<table>
<tr><th colspan="2">Winter</th><th colspan="2">Summer</th></tr>
<tr><td>Time</td><td>Power [kW]</td><td>Time</td><td>Power [kW]</td></tr>
<tr><td>22:00 – 06:00</td><td>2</td><td>21:00 – 06:00</td><td>0</td></tr>
<tr><td>06:00 – 08:30</td><td>7.5</td><td>06:00 – 10:00</td><td>4</td></tr>
<tr><td>08:30 – 16:30</td><td>4</td><td>10:00 – 17:00</td><td>0</td></tr>
<tr><td>16:30 – 22:00</td><td>7.5</td><td>17:00 – 21:00</td><td>4</td></tr>
</table>
In the winter it is assumed there will be a constant low level heat demand throughout the day and night, which peaks during the early morning and evening due to domestic hot water consumption and a higher thermostat setting at these times.
In the summer it is assumed that the only heat demand is domestic hot water which is mainly required in the early morning and evening.
</td></tr>
<tr><td>Solar Module Pumps</td><td>These will be running in the summer but not in the winter. It is assumed that they will run from 09:00 to 17:00.</td></tr>
<tr><td>Public Lighting</td><td>
Assumed to come on 30 minutes before sunset and 30 minutes after sunrise. The following times are used:
21 June: 22:30 – 06:30
21 December: 16:00 – 09:00
</td></tr>
<tr><td>Water Treatment Discharge Pump</td><td>Assumed to be a constant load of 0.5 kW. One third of maximum output.</td></tr>
<tr><td>Water Treatment Aeration Pump</td><td>Assumed to be a constant load of 2.5 kW. One third of maximum output.</td></tr>
</table>

Table 3 – Estimated Demand Profiles and Load Shifting Characteristics



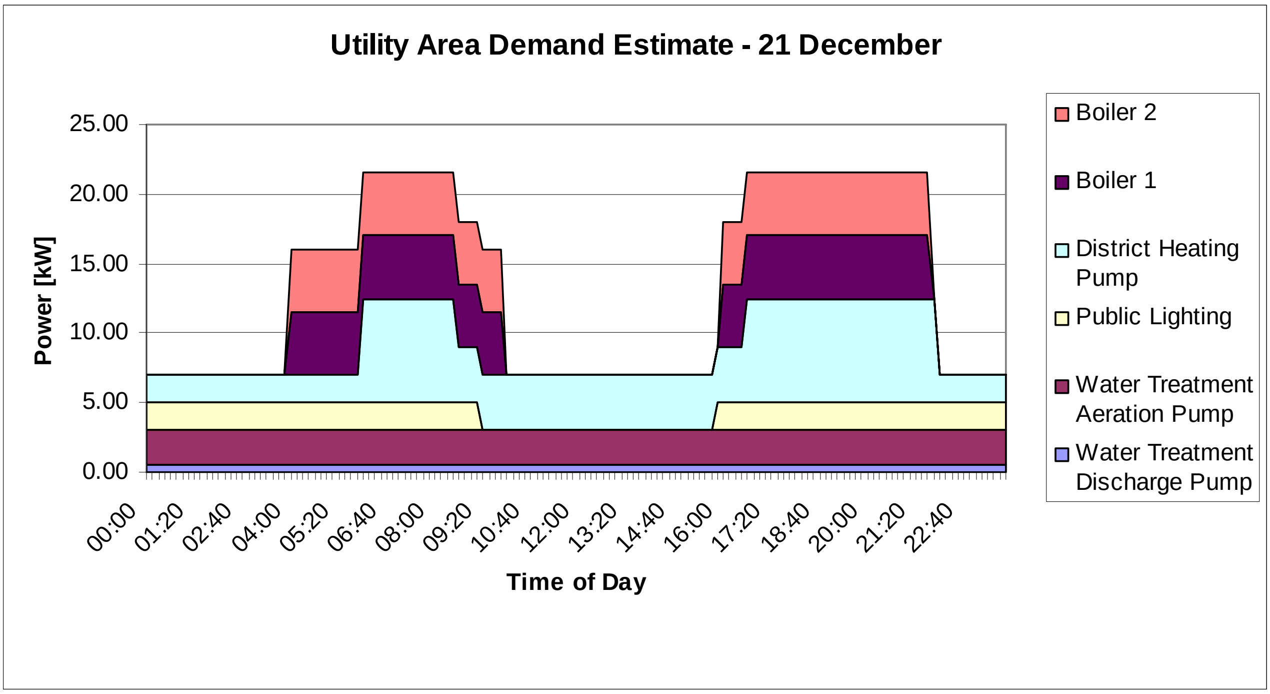


Figure 8 – Estimate of Utilities Area demand, typical summer and winter days

5 Power monitoring of loads to determine demand profiles

At present, no actual data is available for the loads in the Utilities Area. The previous section showed the preliminary estimates used in this report to make an assessment of a load management scheme for medium sized wind generation in the Utilities Area. These estimates need to be validated or corrected with actual load data before definite conclusions can be drawn in this report. This section defines the methods and equipment required to arrive at these actual values.

Power monitoring equipment would be used to establish the actual demand profiles of equipment in the Utilities Area. The requirements for this monitoring equipment are as follows:

- The monitoring equipment must be able to log the average power consumed at five minute intervals.
- The monitoring equipment must have enough memory to store 24 hours of logs and preferably should have enough memory to store one year of logs.
- The monitoring equipment should be able to monitor three phase supplies.
- The monitoring equipment should ideally be cheap enough to be able to be connected to all the loads in the Utilities Area.
- It should be straightforward to install and configure the monitoring equipment.

The market for power monitoring equipment is split into two main areas:

- Electricity monitors for domestic and small business customers. These are mass produced devices primarily designed to inform customers of their energy usage.
- Professional power monitoring equipment. Designed for electrical engineers to monitor all aspects electricity use from simple energy usage to power quality analysis.

Electricity monitors for domestic and small business customers

The main product on the market for domestic and small business customers is the OWL wireless electricity monitor. With the addition of a PC this can fulfil all the power monitoring requirements for the Utilities Area.

Description	Price per unit (€)	Quantity	Sub Total (€)
OWL Large Business Pack (sensor for three phase installation)	73	5	365
OWL Wireless Electricity Monitor (sensor for single phase installation)	37	5	185
OWL USB Connect	19	1	19
Laptop computer with Windows Vista	400	1	400
		Total (€)	969

Table 4 – OWL power monitoring equipment and costs

Sensors are connected to each of the loads required to be monitored. These communicate wirelessly with a hub (the OWL USB Connect) which is connected to the PC. The PC logs the power consumed at five minute intervals. The PC needs to be switched on and running continuously. As the sensors are relatively cheap and up to ten can be connected to the OWL USB Connect, it would make sense to monitor as many loads as possible in the Utilities Area to build an accurate picture of the demand profiles. The total cost of the monitoring equipment would be €969. This would be less if an existing PC or second-hand PC can be used. The equipment could then subsequently be used in other parts of the Eco Village to carry out other monitoring duties.

A cheaper option would be to measure the total Utilities Area power using a single three-phase sensor (estimated cost €492, for one sensor, the USB Connect and a laptop). This would provide the overall demand profile, but it would be necessary to deduce from the results which loads were operating at what time. If the budget allowed, one or more of the most significant or potentially deferrable loads could also be monitored, to provide a better understanding.

Further information about the OWL wireless electricity monitor is described in Appendix B.

Professional power monitoring equipment

Professional power monitoring equipment is much more expensive. The single phase SPC Mini is €299 and the three phase SPC Pro is €1194. This probably makes it cost-prohibitive to monitor all loads separately.

The advantage of using the professional equipment is that it is more physically robust and can run stand alone; it does not require a PC to be continuously switched on. It is also likely to be more accurate as it takes voltage as well as current measurements from the loads being monitored.

Further information about the professional power monitoring equipment is described in Appendix B.

Existing meter

Some meters can provide power output readings, either from a pulsed output or via a communications link to a datalogger or laptop. Again, this would only provide the Utilities Area demand profile, but may be a low-cost monitoring option.

Engineering time

In calculating the cost of the power monitoring equipment the cost of the labour involved in installing, configuring, retrieving the logged data and analysing the logged data must be taken into account. If we assume this would take an engineer in the region of one week this would cost €3000 (assuming an hourly rate of €80).

Summary

The benefit of having measured Utilities Area power data is that it will provide better information for system modelling to inform the selection of the optimum wind turbine rating, and the decision as to whether a load control system will provide sufficient value for money to justify its investment costs.

Purchase of load monitoring equipment for all major loads, plus support for installation, commissioning and analysis of the results could give a total cost for the power monitoring task of up to approximately €4000. As this is a significant cost, a judgement needs to be made as to whether this level of detail is necessary and even whether the task is worthwhile. At present, the OWL seems to be the best option as it provides the required data at a modest price. Further detailed investigation should allow the best option to be identified.

6 Load control schemes

Three types of load control scheme are considered: manual, advisory and automatic. All three schemes involve the operator understanding demand profiles and estimating future wind turbine output. Ideally they would also all make use of measurements of Utilities Area power consumption and wind turbine power output.

The demand profile for each device consists of the Load Cycle Period, the Latest Load Cycle End Time, and the Maximum Load Shift Period for their load. In the case of the district heating scheme boiler, this may change from day to day depending upon the predicted demand of the householders which can be both weather and day of week (week/weekend) dependent. The Load Cycle End Time can be shifted within the Maximum Load Shift Period to best utilise the on-site wind generation. To determine the optimum Load Cycle End Time, we need to estimate what the wind speed will be doing between the Earliest Load Cycle Start Time and the Latest Load Cycle End Time.

Wind turbine output can be estimated by looking at the recorded wind turbine output prior to the Earliest Load Cycle Start Time and/or by using weather forecast information.

In the case of the **manual** scheme, it may be a case of the operator setting a timer on the boiler to come on at a particular time, or to just start the cycle manually at the Load Cycle Start Time.

The **advisory** scheme is the same as the automatic scheme except the System does not directly control the loads. It simply advises the operator when the load cycles should start and stop. The operator then manually starts the loads based on this information.

For the **automatic** scheme, Figure 9, the operator inputs the Load Cycle Period, Load Cycle End Time and the Maximum Load Shift Period into the Load Control Management System. The System also takes as an input, the power output from the wind turbine. It stores this data internally so can use past data to determine if there are any trends present. It can also, optionally, take a feed from a weather forecasting service. This would be the most costly option, but would also require the least manual intervention.

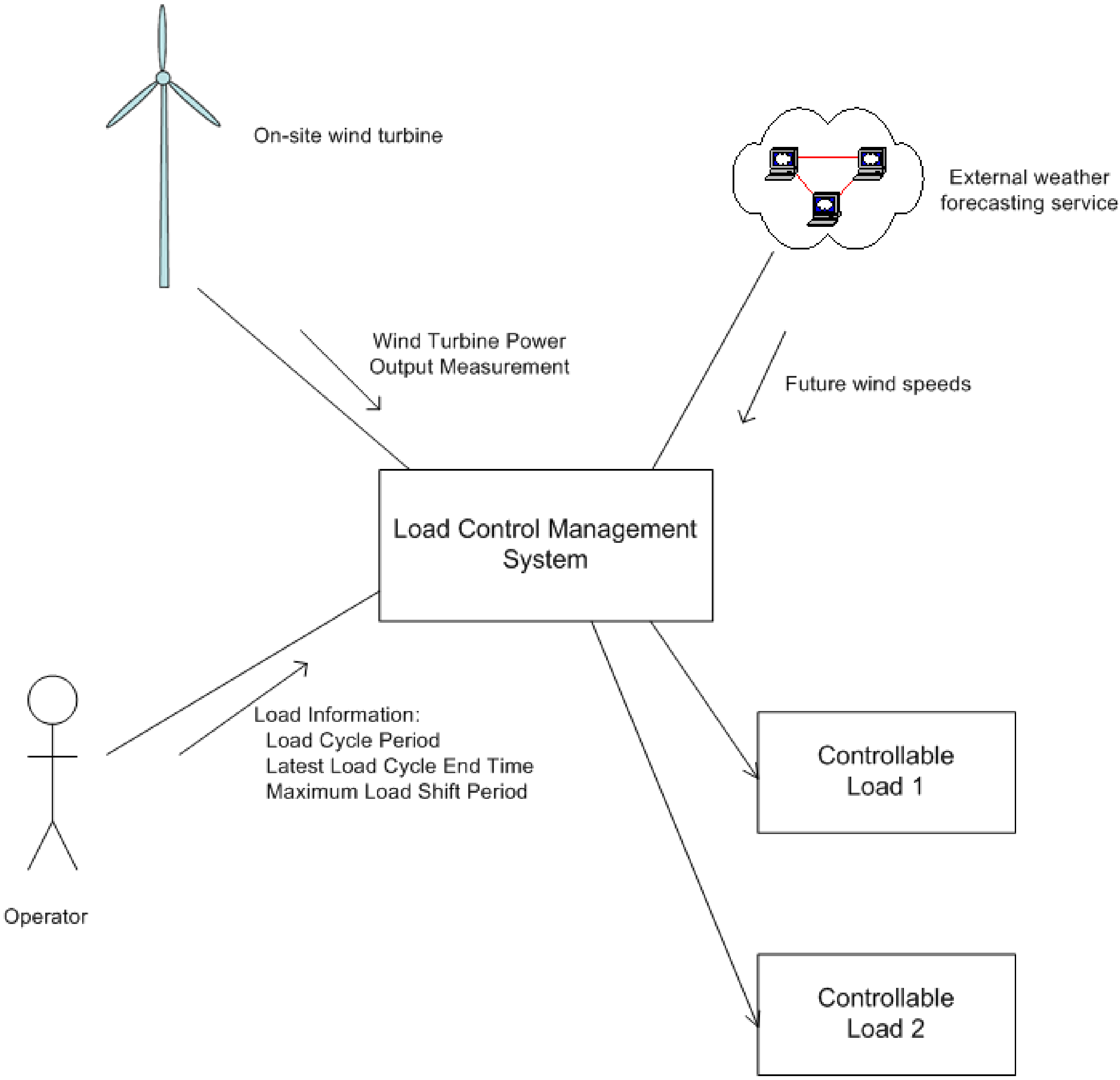


Figure 9 – Load Control Management System

7 The load management assessment

The following data has been collected:

- Estimated demand profiles for loads in the Utilities Area
- Estimated load shifting characteristics for the boilers
- Estimated wind turbine power output
- Electricity tariffs – see Appendix A

An import tariff of 16 cents per kWh and an export tariff for 9 cents per kWh[2] are used. Thus 7 cents can be saved by using on-site generation rather than imported power.

Two days have been chosen for the assessment; 21 December is chosen as a maximum demand day, and 21 June as a minimum demand day. On both days the wind turbine has been assumed to be generating power, with an output which varies through the day.

For 21 June, Figure 10, the worst case scenario is when the boilers are switched on later in the morning and later in the afternoon. The boiler load coincides with the district heating pump switching on, which causes energy to be imported. The best case is when the boiler is switched on earlier in the morning and earlier in the afternoon. This avoids the boiler load being on at the same time as the central heating pump. A similar picture is apparent for 21 December, Figure 11, but in this case the potential savings by using load shifting are greater, due to the district heating pumps being on for longer. Interestingly, the effect of the solar heat pumps being switched on between 09:00 and 17:00 on 21 June coincides well with the wind turbine output picking up during the day.

One conclusion is that having the boiler and district heating pumps on at different times can smooth demand and reduce the energy imported from the grid (a manual load control system).

The assessment results are summarised in Table 5. On both days, more wind energy is generated than the Utilities Area consumes. However some energy is still imported from the grid, because the timing of the loads does not match the timing of the wind output. Some energy is also exported to the grid. This means the system is somewhere between scenario (a) in section 2, and scenario (c).The maximum possible saving by using load shifting on 21 June is €0.24 and on 21 December is €2.43. If averaged out over a year, this gives an annual saving of €487, or €1.33 per day (compared with an estimated energy bill without wind generation of approximately €30,000).

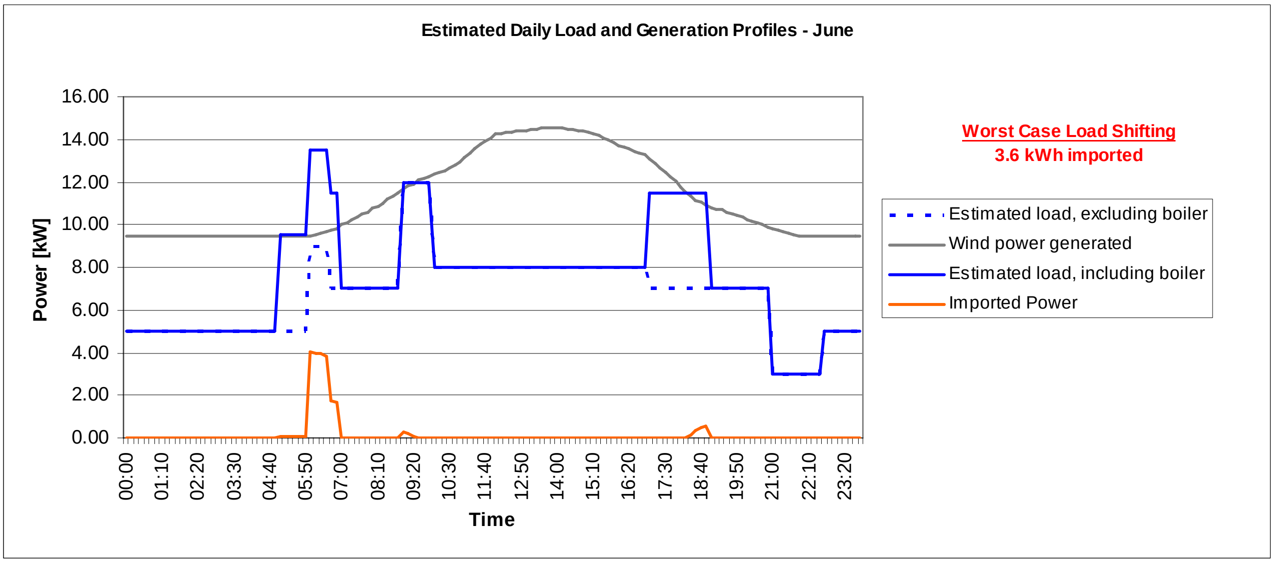
This is a relatively modest saving, raising the question of whether it is worth pursuing the load control study and installing power monitoring equipment at the Eco Village. However, the data used for this assessment is purely based on estimates, and relatively windy days have been assumed. Days on which the wind output is closer to the energy consumed would be likely to show a greater benefit from load control. Adjusting the model, so that the total wind energy generated for the day matches the total load demand for the day, the 21 June model shows that 12% of the total load energy is unnecessarily imported and exported (costing an extra €1.51 which could be reduced by load management); the 21 December model has 25% of the total load energy imported and exported (costing an extra €5.80).

If more accurate data is forthcoming, in particular wind anemometer readings or more detailed long-term information about the demand profiles of the loads, the assessment can be re-run and may well yield a more favourable result.

[2] ESB Customer Supply offers a micro-generation tariff of 9 cents per kWh for domestic customers. This applies to a rated maximum output of 11kW for a three phase connection. It is not clear what payment could be received for a 50kW wind turbine in the Utilities Area, but we assume 9 cents per kW for this study (see Appendix B).

	21 June	21 December
Total energy consumed	178 kWh	322 kWh
Wind energy generated	270 kWh	446 kWh
Best Case, kWh imported	0.2 kWh	3.0 kWh
Worst Case, kWh imported	3.6 kWh	30 kWh
kWh hours reduced by load shifting from worst case to best case	3.4 kWh	27kWh
Euros saved (7 cents per kWh shifted)	€0.24	€2.43

Table 5 – Results from load shifting on 21 June and 21 December



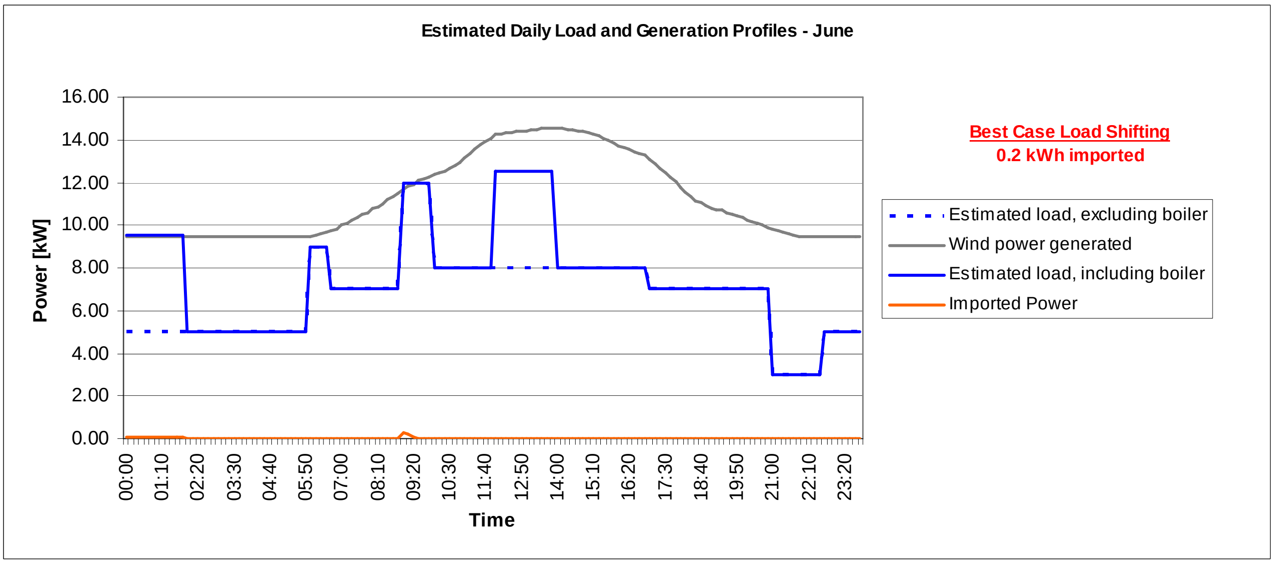
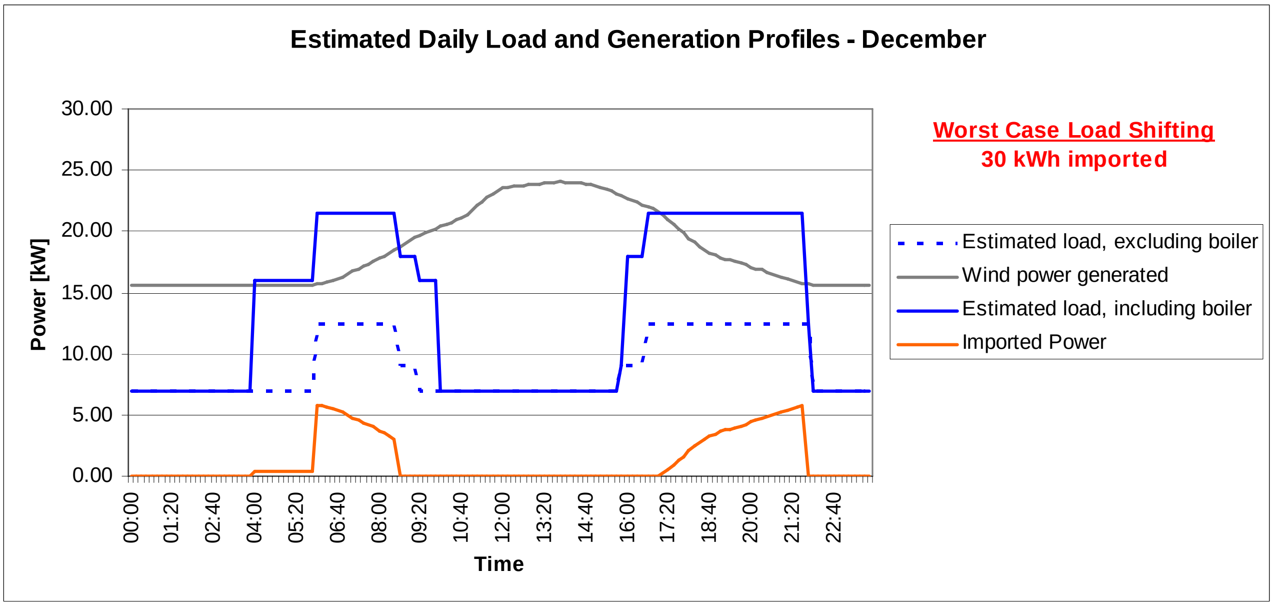


Figure 10 – Estimated generation profile, demand profile and imported power for 21 June



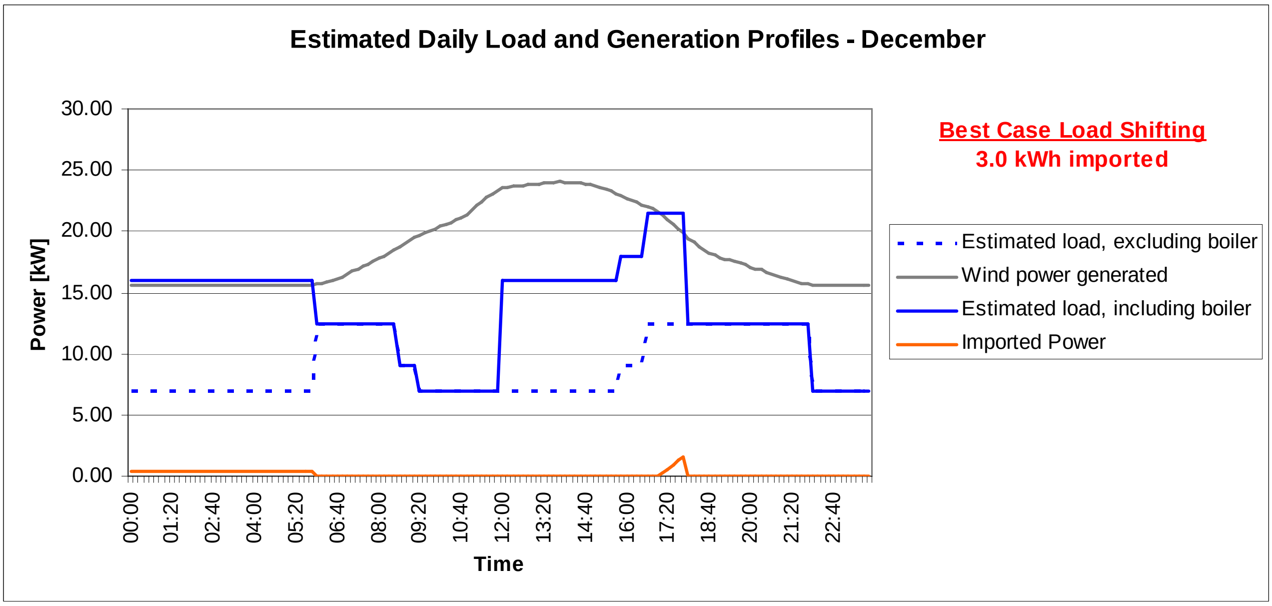


Figure 11 - Estimated generation profile, demand profile and imported power for 21 December

8 Benefits of medium sized wind turbine for the Utilities Area

The RETscreen analysis carried out by SPIL[3] indicated that the expected Utilities Area energy bill without a wind turbine would be approximately €30,271, with an average power consumption of 23kW (202MWh per year, with €0.15/kWh assumed in the RETscreen evaluation). The analysis also indicated that an Entegrity EW15 would produce approximately 97MWh per year. If all this was consumed within the Utilities Area, this would reduce the electricity bill by €14,550.

However it is unlikely that all the wind energy would be used within the Utilities Area without some type of load control to match equipment usage with wind output. A proportion of the wind energy would then be exported onto the grid (possibly at €0.09/kWh), reducing the effective saving. Only more detailed load and wind modelling than RETscreen provides would allow this effect to be estimated. This could be done using a program such as HOMER, and would benefit from measured load and wind data.

Turbines other than the Entegrity EW15 are also available within Ireland, and an alternative machine may offer advantages in terms of cost, energy output, ease of installation, visual impact, or supplier support. Once more investigation has been done to identify and cost possible wind turbine options for the Eco Village, it would be worth carrying out this modelling for each option, to allow comparison between the different investments required and the resulting rates of return.

9 Conclusions and recommendations

9.1 Conclusions

This report describes a simple assessment of the potential of employing load management in the Cloughjordan Eco Village Utilities Area. This follows on from work carried out by SPIL which identified clear benefits from installing a 50kW wind turbine to offset the energy demand of the loads in the Utilities Area. Load control could help to match energy demand with wind turbine output, reducing the amount (and hence cost) of energy purchased from the grid.

At the time this report was written, only limited data regarding the demand profiles of the loads and predicted output of the proposed 50kW turbine were available.

Modelling carried out for 21 June and 21 December, using assumed demand profiles and wind turbine output, suggests the following conclusions.

- Installing a 50kW wind turbine could provide significant savings in energy imported from the grid.
- Even basic load management, such as having the boiler and district heating pumps on at different times, can smooth demand and reduce the energy imported from the grid.
- Using estimated data, the modelling carried out for two relatively windy days indicated that installing additional load control which would respond to wind turbine output would only provide modest further savings (in addition to those generated by installing the wind turbine). However when the overall wind input was reduced for each of the days modelled, the load control benefits increased.

The pros and cons of measuring the Utilities Area power and energy consumption have been outlined. Such measurements would provide better information for system modelling to inform the selection of the optimum wind turbine rating, and the decision as to whether a load control system will provide sufficient value for money to justify its investment costs. However detailed

[3] spreadsheet "EcoVillage 2.xls" provided by Shane Barrett

measurements could prove costly. A judgement needs to be made as to the level of detail which is necessary. At present, the OWL power measurement system seems to be able to provide the required data at a modest price, however further investigation should allow the best option to be identified.

9.2 Recommendations

The following further actions are recommended.

- Identify and purchase suitable power monitoring equipment for the Utilities Area.
- Collect measured data for the Utilities Area demand profile, over a period of weeks or months if possible.
- Install an anemometer on site if possible, and collect measured data for local windspeeds.
- Monitor Utilities Area operation in detail over a short period (e.g. observations over a day, for a number of days with different weather and system operating conditions).
- Identify Utilities Area loads which would be suitable for being controlled to make best use of wind turbine output.
- Develop an outline design and costing for an automated load control system suitable for the Utilities Area.
- Establish what export tariff and grants would be available for all proposed wind installation options.
- Carry out a more detailed and extensive analysis of the energy balance, costs and benefits of different wind turbine types, including evaluation of a costed load control installation. Include measured demand profile and wind profile data, and simulate longer time periods, using a program such as HOMER.

Senergy Econnect can support or carry out these tasks as part of the SERVE project, subject to equipment being provided to make necessary measurements and/or data being made available.

Appendix A – Electricity tariffs

	Residential Business Premises	Residential Business Premises NightSaver	General Purpose	General Purpose NightSaver[5]	General Purpose Quarter Hour Tariff	General Purpose Quarter Hour NightSaver
Unit Rate	*Price in cents per kWh*					
Day Units Block 1 [1]	14.55	15.54	16.70	17.11	16.70	17.11
Day Units Block 2 [2]	16.70	17.11	15.04	16.07	15.04	16.07
Night Units	N/A	7.67	N/A	7.67	N/A	7.67
Night Storage [4]	7.67	7.67	7.67	7.67	7.67	7.67
Reactive Power Charges	*Price in cents per kVARh*					
Wattless Unit Price [3]	0.81	0.81	0.81	0.81	0.81	0.81
Standing Charges	*Daily charge in cents*					
Standing Charge	34.80	43.80	41.00	45.60	41.00	45.60
Standing Charge for Autoproducers[6]	19.56	21.60	19.56	21.60	19.56	21.60
Night Storage Heating Standing Charge	2.20	2.20	2.20	2.20	2.20	2.20

1 - First 5110kWh consumed annually pro-rated daily for Residential Business tariffs and first 47,815 kWh consumed annually for General Purpose tariffs
2 - Remaining kWh in excess of Block 1
3 - The Wattless Unit Price is the price charged for reactive power consumption. It applies to all wattless units (kVARh) in excess of one third of total day and night units (kWh) per bill.
4 – The Night Storage rate applies between 23:00 and 08:00 (winter) and 00:00 to 09:00 (summer)
5 – The Night Load rate applies between 23:00 and 08:00 (winter) and 00:00 to 09:00 (summer)
6 – An Autoproducer is a net energy exporter, where their Maximum Export Capacity ('MEC') is greater than their Maximum Import Capacity ('MIC')

Figure 12 – ESB Customer Supply tariff prices available to businesses with a MIC less than 50kVA, effective from 1 May 2009

Figure 12 shows published electricity tariffs from ESB customer supply. These tariffs may be more or less expensive from a green supplier. For the residential market, the greenest supplier is currently Airtricity, and their prices less than ESB Customer Supply for an introductory period.

Each tariff has different prices, and within each tariff the price paid depends on the number of units work (reflected by the Day Units Block 1 and Day Units Block 2 rates). For this study we shall assume an import tariff price of 16 cents per kWh.

ESB Customer Supply offers a micro-generation tariff of 9 cents per kWh for domestic customers. This applies to a rated maximum output of 11kW for a three phase connection. It is not clear what payment could be received for a 50kW wind turbine in the Utilities Area, but we shall assume 9 cents per kW for this study. Further information is available at:

https://www.esb.ie/esbcustomersupply/residential/energy_efficiency/micro_generation_tariff.jsp

Appendix B – Power monitoring equipment

The OWL Wireless Electricity Monitor

Website: www.theowl.com

Product	Price	Image	Description
OWL Large Business Pack (for 3 phase installation)	£69.95 inc VAT £60.84 ex VAT €73.01 ex VAT		1 x Transmitter 1 x Display 3 x large CTs (for cable diameter greater than 10mm and less than 17mm or where current greater than 71 A) Batteries
OWL Small Business Pack (for 3 phase installation)	£45.95 inc VAT £39.96 ex VAT €47.95 ex VAT		1 x Transmitter 1 x Display 3 x small CTs (for cable diameter of 10mm or less or where current less than 71 A)
OWL Wireless Electricity Monitor (for single phase installation)	£34.95 inc VAT £30.40 ex VAT €36.48 ex VAT		1 X Transmitter 1 x Display 1 x small CT (for cable diameter of 10mm or less or where current less than 71A)
OWL USB Connect	£17.95 inc VAT £15.61 ex VAT €18.73 ex VAT		1 x USB Receiver 1 x USB cable 1 x software CD (for Windows)

Professional power monitoring equipment

Product	Price	Image	Description
SPC Mini	£249 ex VAT €299 ex VAT		Single phase data logger. Rugged design. Enough flash memory storage for 1 minute logging for over 1 month. Comes with PC software for off-line analysis of data http://www.spcmini.com/
SPC Pro	£995 ex VAT €1194 ex VAT		Three phase data logger. Rugged design. Comes with PC software for off-line analysis of data http://www.spcpro.co.uk
Load Profiling Energy Pro	£2095 ex VAT €2514 ex VAT £175 per week for hire €210 per week for hire		Three phase power load profiling tool. Rugged design. Comes with PC software for off-line analysis of data http://www.elcomponent.co.uk/site/product/view-category/category-60/Load-Profiling-EnergyPro.html
Metrel MI2092 Power Harmonics Analyser (Standard Set)	£1290 ex VAT €1548 ex VAT		Three phase data logger. Includes other power quality analysis functions. Comes with PC software for off-line analysis of data http://www.sercal-testequipmentsales.co.uk/metrel-mi2092-power-harmonics-analyser-standard-set-308-p.asp