IGEN

OCHSNER GMLW 19 - Air Source Heat Pump Performance in Irish Climate Monitoring Study

Report

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Centre for Renewable Energy

DUNDALK INSTITUTE of TECHNOLOGY

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1.0 Introduction

A heat pump is a device that extracts heat from a low temperature energy source and raises the temperature of the heat energy to a suitable level so that can be used effectively to provide space heat and hot water to a domestic or commercial building. To date many heat pump installations in Ireland are *Ground Source* heat pumps that extract heat energy from the ground via horizontal loop collectors or vertical borehole collectors. The excavation for the horizontal collectors and drilling for vertical boreholes add to the overall capital cost of ground source heat pump systems. An *Air Source* heat pump can extract heat energy from the outdoor ambient air and raise it to a level suitable for domestic and commercial uses. Air source heat pumps use air exchanger instead of a ground loop to extract energy from the air. Air source heat pumps can also be used to extract energy from waste/exhaust heat in certain applications. The efficiency of heat pumps depends on a number of factors but one of the primary factors is the difference between the temperature of the energy source at the input and the required temperature at the output i.e. the temperature lift from input to output. In the case of a ground source heat pump the temperature of the ground (source) remains relatively constant at ~ 8C to 10C. In the case of air source heat pumps performance is influenced by ambient outdoor air temperatures and the relative humidity. However Ireland has a maritime climate and ambient air temperatures in winter do not fall as low as temperatures in continental regions such e.g. central European countries. This study monitors the performance an Ochsner GMLW 19 air source heat pump on the east coast of Ireland. The study was carried by the Centre for Renewable Energy at Dundalk Institute of Technology (CREDIT) and was funded by Enterprise Ireland under the Innovation Voucher scheme.

2.0 Installation Details

A 16kW Ochsner GMLW 19 air source heat pump was installed by IGEN in a crèche on the east coast of Ireland. It supplies the building's total space heat and hot water requirements. The building is well insulated and has under floor heating. The floor area of the building is ~ 400m^2. The building is shown in Figure 1.

Figure 1 – Building where heat pump is installed

The principal parts of the heat pump system is shown in Figure 2

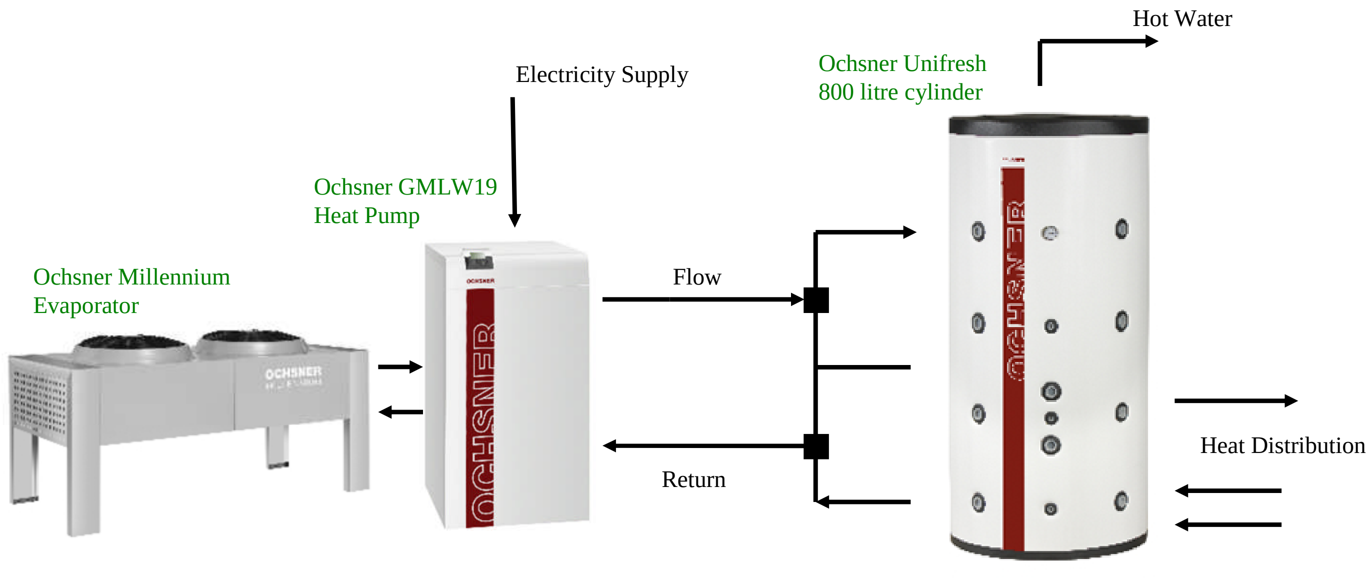

Figure 2 Ochsner Air Source heat pump system- principal parts

3.0 Monitoring System

The following parameters are being monitored

- Heat output from heat pump
- Electricity consumption of heat pump
- Flow and return temperatures (Tf &Tr) at output of heat pump
- Outdoor temperature
- Outdoor humidity

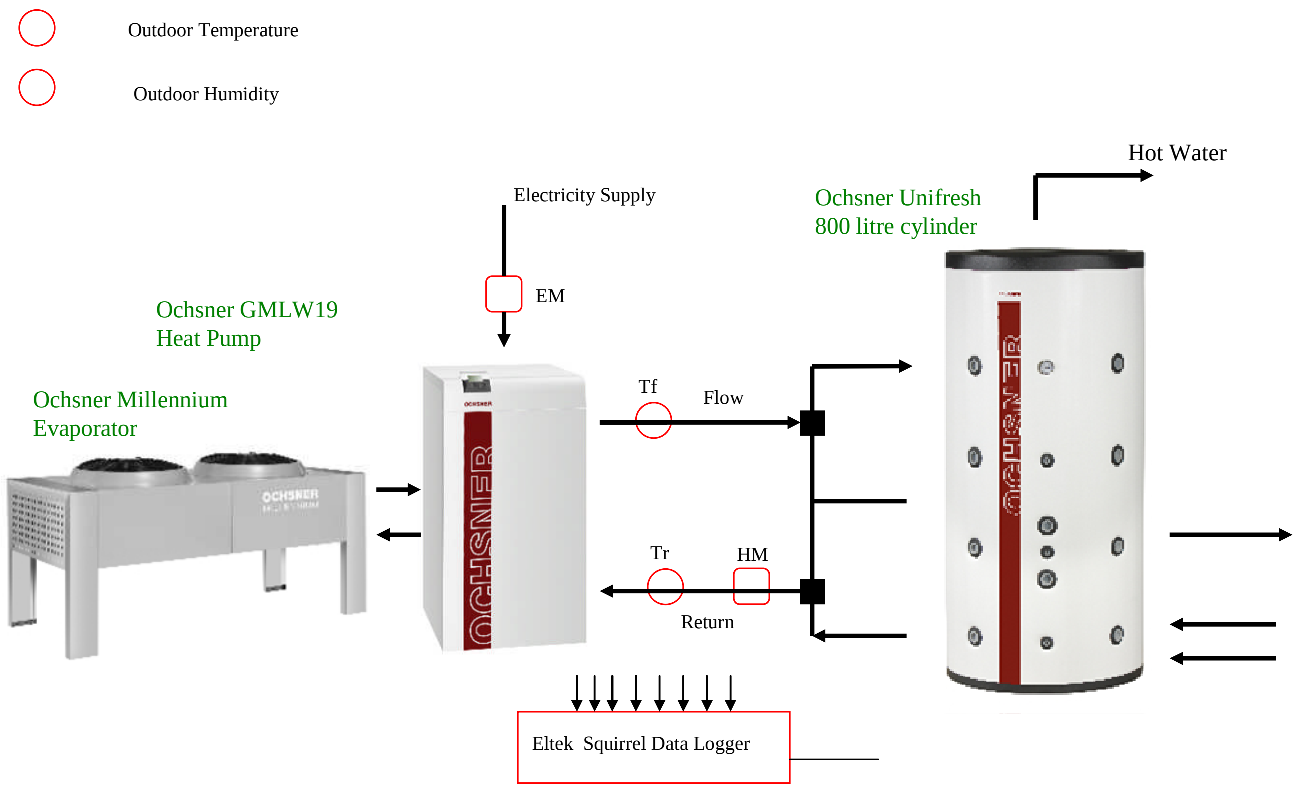

Figure 3: Heat Pump monitoring system. Components in red show the meters and sensors

HM = heat meter
EM = Electricity meter
Tf = Flow Temperature
Tr = Return Temperature
Outdoor temperature sensor
Outdoor humidity sensor

4.0 Monitoring Results

The following results are based on measurement take from 16th February to 7th July 2009

4.1 Total Energy Production and Consumption February 16th – July 07th 2009

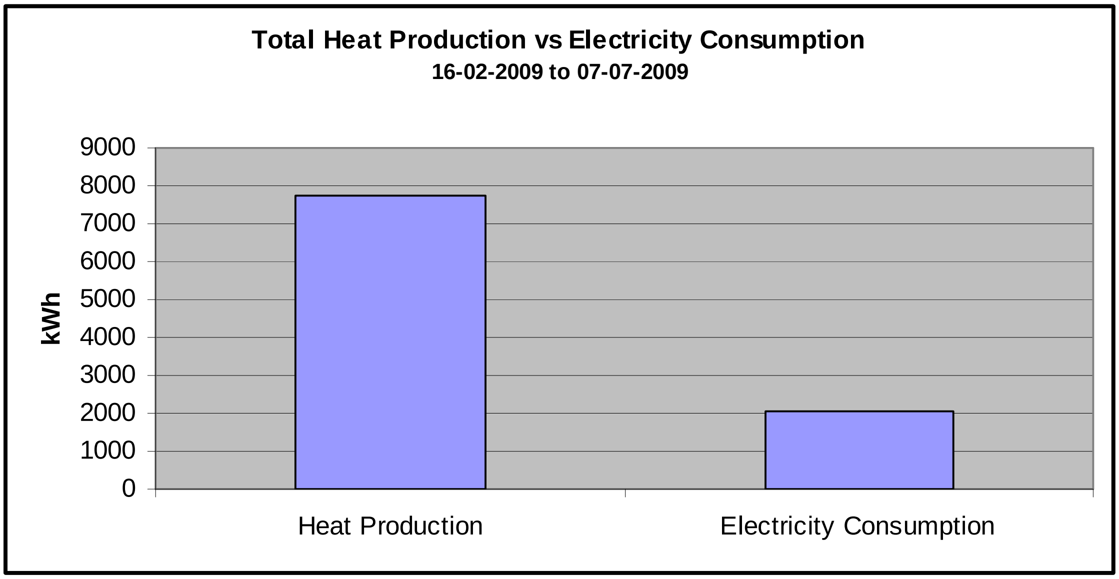

Figure 4: Heat production vs electricity consumption from 16 February to 7 July 2009

The graph shows the total heat produced for space heating and hot water and the corresponding total electricity consumed by the heat pump over the period from February 16th to July 07th 2009.

Heat production (kWh)	***Total electricity consumption (kWh)***	***Seasonal performance factor (SPF)***
7,760	*2,061*	*3.76*

Table 1: Heat production vs electricity consumption and SPF from 16 February to 7 July 2009

The seasonal performance factor (SPF) is the ratio of heat produced to the electricity consumed. Over this period the SPF was 3.76. The total heat demand of the building of 7,760kWh for a building in this size is relatively low and can be attributed to the building insulation, under floor heating and the heat pump controls.

4.2 Hot water and defrosting

The heating flow and return temperatures to and from the heat pump were monitored and used to indicate when hot water was being produced and also when the heat pump was carrying out a defrosting cycle. When the flow temperature rises above 40C the heat pump is producing hot water. When the return temperature is higher than the flow temperature the heat pump carries out defrosting of the air collector. Table 2 shows the proportion of the total electricity consumed by the heat pump used for delivering hot water and defrosting during the period.

Total electricity consumption (kWh)	***Electricity consumption for hot water (kWh)***	***Electricity consumed defrosting (kWh)***
2,061	*846*	*4*

Table 2: Proportion of total electricity consumed for hot water and defrosting

4.3 Breakdown of heat production and electricity consumption February 16th – July 07th 2009

The proportion of the heat produced by the heat pump for space heat and hot water and the corresponding electrical consumption is shown in Figure 5 and Table 3.

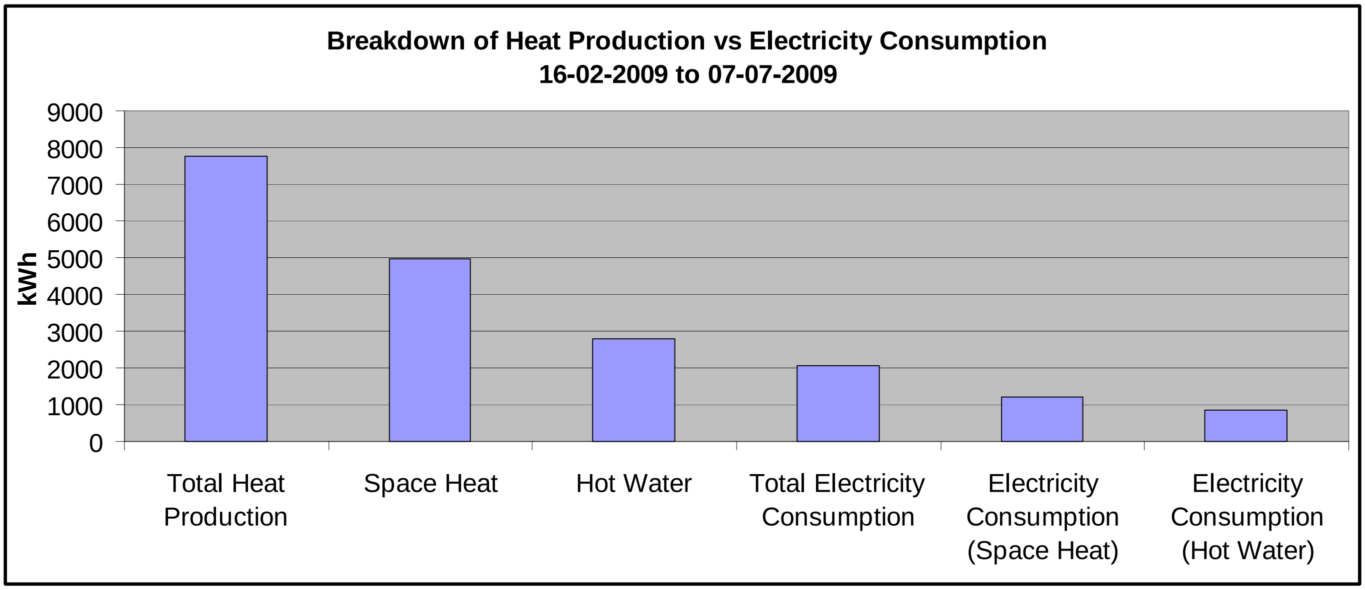

Figure 5: Proportion of heat production for hot water and space heat vs electricity consumption

Total Heat Production (kWh)	***Space Heat (kWh)***	***Hot Water (kWh)***	***Total Electricity Consumption (kWh)***	***Electricity Consumption (Space Heat) (kWh)***	***Electricity Consumption (Hot Water) (kWh)***
7,760	*4,970*	*2,790*	*2,061*	*1,215*	*847*

Table 3: Proportion of heat production for hot water and space heat vs electricity consumption

On the basis that hot water is produced when the flow temperature is above 40C then over the period from February 16th to July 7th 2009 approximately 36% of the total heat produced was for hot water. The average SPF for hot water was ~ 3.3 while the average SPF for space heating was ~ 4.1

4.4 Breakdown of electricity night rate and day rate consumption February 16th – July 07th 2009

From ESB data the night rate period is defined as 23:00 to 08:00 in winter (November to February inclusive) and 00:00 to 09:00 in summer (March to October inclusive). The breakdown of night and day rate electricity units consumed over the period is shown in Figure 5 and Table 6. Approximately 68.5% of the total electricity consumed over the period was at night rate. The associated running costs are given the economic and environmental benefit section later in this report.

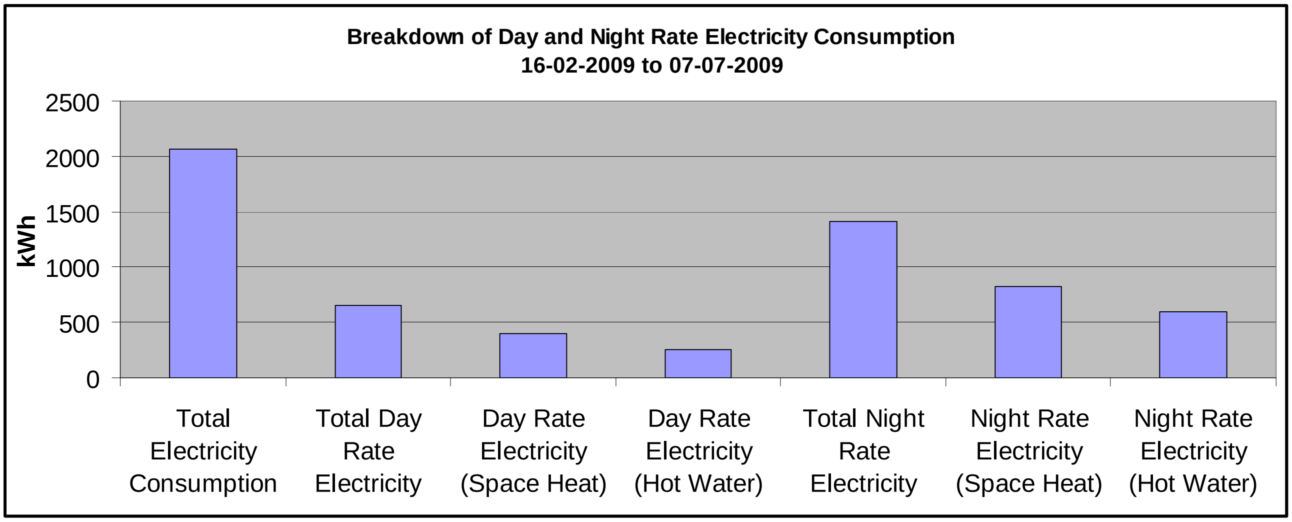

Figure 6: Heat production vs electricity consumption

Total Electricity Consumption (kWh)	***Total Day Rate Electricity (kWh)***	***Day Rate Electricity (Space Heat) (kWh)***	***Day Rate Electricity (Hot Water) (kWh)***	***Total Night Rate Electricity (kWh)***	***Night Rate Electricity (Space Heat) (kWh)***	***Night Rate Electricity (Hot Water) (kWh)***
2,061	*649*	*396*	*253*	*1,412*	*819*	*593*

Table 4: Day and night rate electricity consumption

4.5 Performance during a cold month February 16th – March 16th 2009

The coldest month so far since monitoring period commenced was from the 16th February to 16th March 2009. The heat pump performance for this month is shown below.

Average Outdoor Conditions	***Average Daily (08:00-20:00)***	***Average Nightly (20:00-08:00)***
Temperature (°C)	*9.26*	*6.6*
Relative Humidity (%)	*76.3*	*85.5*

Table 5: Average outdoor environmental conditions in June 2009 from 16th February to 16th March 2009

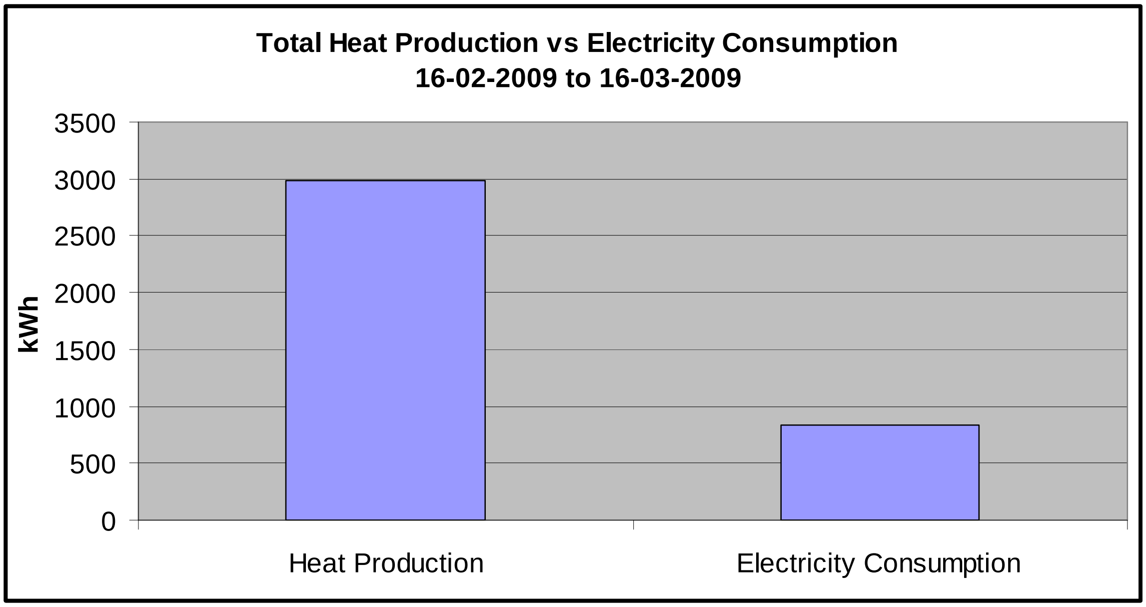

Figure 7: Heat production vs electricity consumption from February 16 to March 16 2009

Heat production (kWh)	***Electricity consumption (kWh)***	***Seasonal performance factor (SPF)***
2,980	*839*	*3.55*

Table 6: Heat production vs electricity consumption and SPF from 16th February to 16th March 2009

As expected the SPF is less than the average for the whole period but is working well at an average SPF value of over 3.55 during this time of the year.

Total electricity consumption (kWh)	***Electricity consumption for hot water (kWh)***	***Electricity consumed defrosting (kWh)***
839	*331*	*2.25*

Table 7: Proportion of total electricity consumed for hot water and defrosting 16th February to 16th March 2009

4.6 Breakdown of heat production and electricity consumption February 16th – March 16th 2009

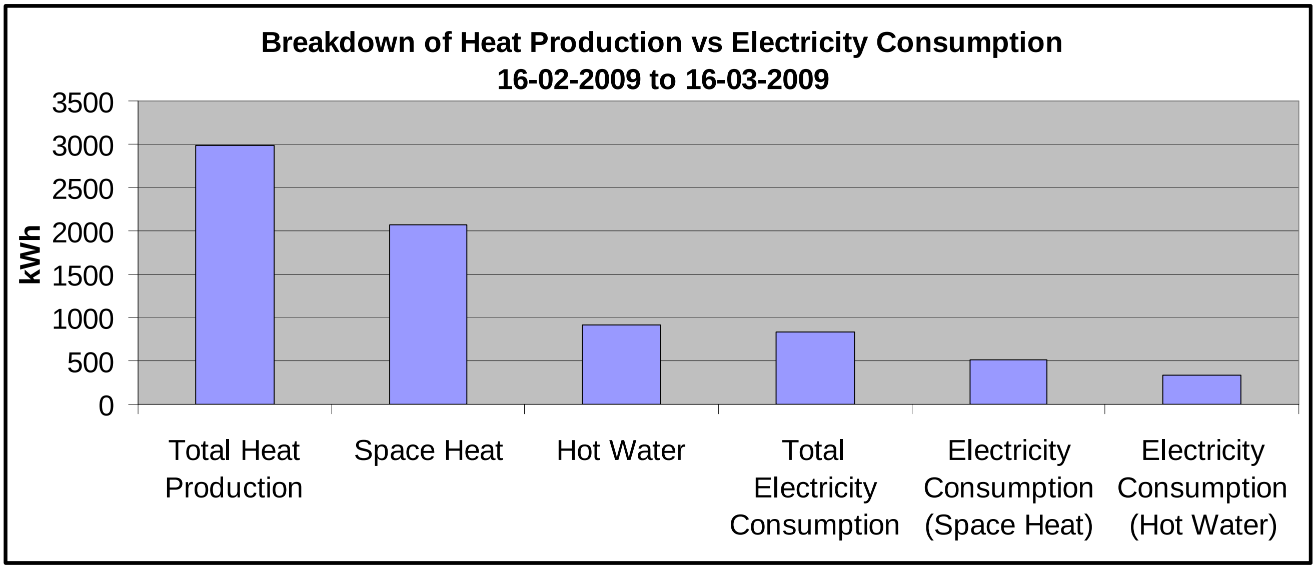

Figure 8: Heat production vs electricity consumption

Total Heat Production (kWh)	***Space Heat (kWh)***	***Hot Water (kWh)***	***Total Electricity Consumption (kWh)***	***Electricity Consumption (Space Heat) (kWh)***	***Electricity Consumption (Hot Water) (kWh)***
2,980	2,070	910	839	508	331

Table 8: Heat production vs electricity consumption and SPF from 16 February to 7 July 2009

On the basis that hot water is produced when the flow temperature is above 40C then over this month approximately 30% of the total heat produced was for hot water. The average SPF for hot water was ~ 2.75 while the average SPF for space heating was ~ 4.1

4.7 Breakdown of electricity night rate and day rate consumption February 16th – March 16th 2009

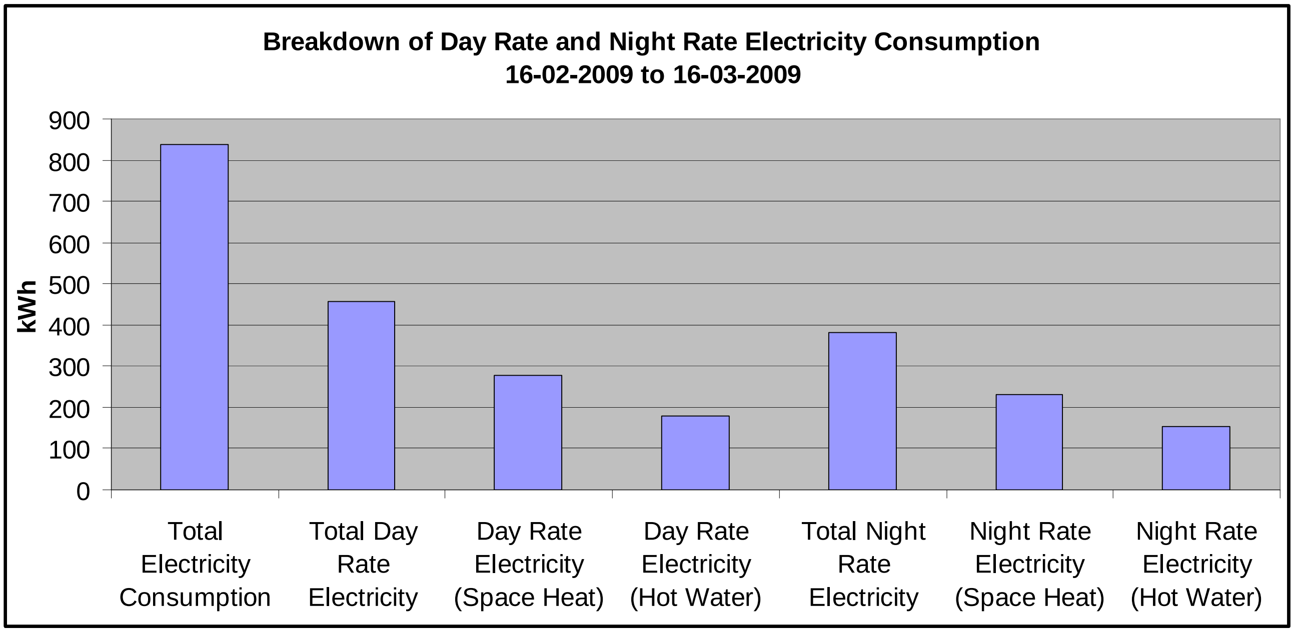

Figure 9: Breakdown of electricity consumption in day and night rate for space heat and hot water from February 16 to March 16 2009

Total Electricity Consumption (kWh)	***Total Day Rate Electricity (kWh)***	***Day Rate Electricity (Space Heat) (kWh)***	***Day Rate Electricity (Hot Water) (kWh)***	***Total Night Rate Electricity (kWh)***	***Night Rate Electricity (Space Heat) (kWh)***	***Night Rate Electricity (Hot Water) (kWh)***
837	*456*	*277*	*179*	*382*	*230*	*152*

Table 9: Breakdown of electricity consumption in day and night rate units for space heat and hot water February 16-March 16 2009

The breakdown of night and day rate electricity unit consumption over the period is shown in Figure 9 and Table 9. Approximately 45.5% of the total electricity consumed over the period is night rate. Due the outdoor environmental condition there is a significant space heat and hot water demand during the day time the total day rate electricity consumption is 54.4% of the total.

4.8 Performance during a summer month

The warmest month so far since monitoring commenced was June. The heat pump performance in June 2009 is shown below. Most of the heat provided was for hot water during this month with no energy required for defrosting

Average Outdoor Conditions	***Average Daily (08:00-20:00)***	***Average Nightly (20:00-08:00)***
Temperature (^oC)	*16.5*	*12.8*
Relative Humidity (%)	*67*	*82.2*

Table 10: Average outdoor environmental conditions in June 2009

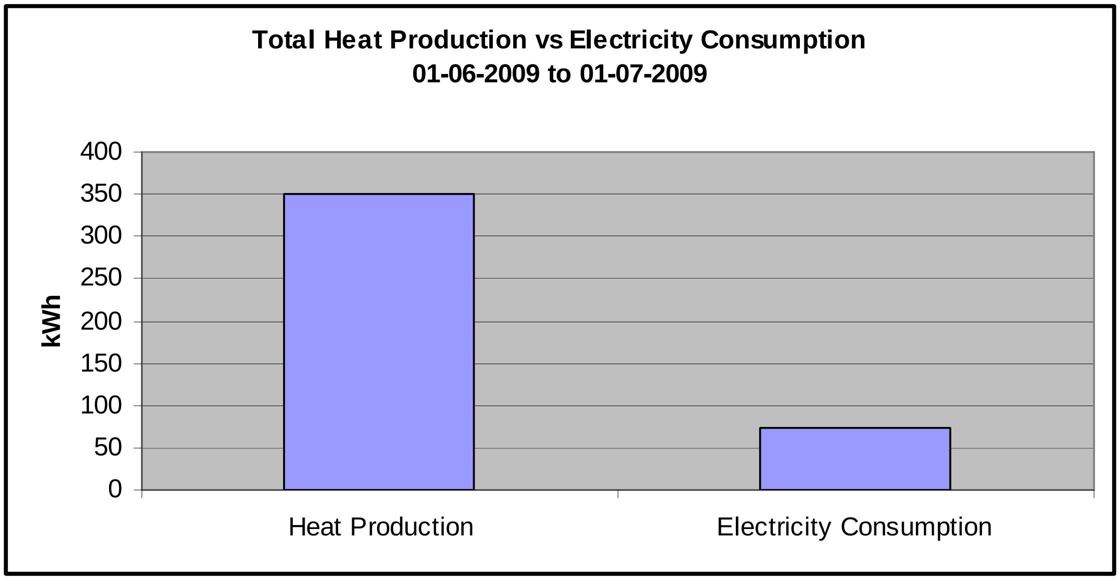

Figure 10: Heat production vs electricity consumption June 2009

Total Heat production (kWh)	***Total electricity consumption (kWh)***	***Seasonal performance factor (SPF)***
350	*73.3*	*4.8*

Table 11: Heat production vs electricity consumption and SPF in June 2009

Total electricity consumption (kWh)	***Electricity consumption for hot water (kWh)***	***Electricity consumed defrosting (kWh)***
73.3	*55.25*	*0*

Table 12: Proportion of total electricity consumed for hot water and defrosting in June 2009

As can be seen a large proportion of energy consumed by heat pump was for hot water during this month.

4.9 Breakdown of heat production and electricity consumption June 2009

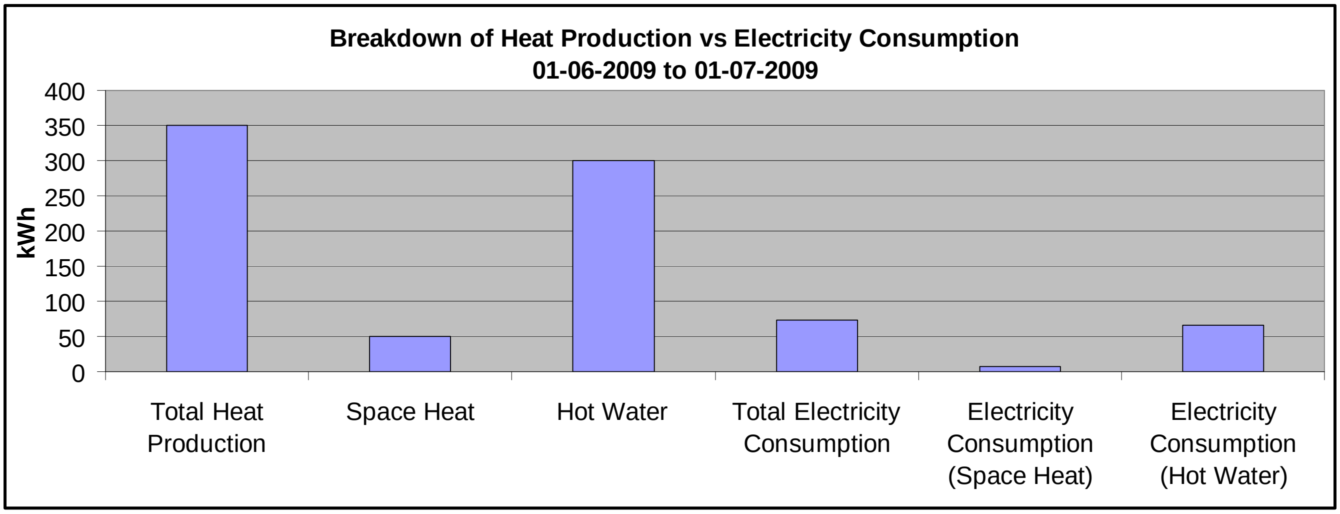

Figure 11: Heat production vs electricity consumption June 2009

Total Heat Production (kWh)	***Space Heat (kWh)***	***Hot Water (kWh)***	***Total Electricity Consumption (kWh)***	***Electricity Consumption (Space Heat) (kWh)***	***Electricity Consumption (Hot Water) (kWh)***
350	*50*	*300*	*73*	*7.4*	*66*

Table 13: Heat production vs electricity consumption June 2009

On the basis that hot water is produced when the flow temperature is above 35C in the summer then over the month of June approximately 86% of the total heat produced was for hot water. The average SPF for hot water was ~ 4.5 while the average SPF for space heating was ~ 6.8. As expected the SPF values are best in summer when both the outdoor temperature is higher and space heat demand is lower.

4.10 Breakdown of electricity night rate and day rate consumption June 2009

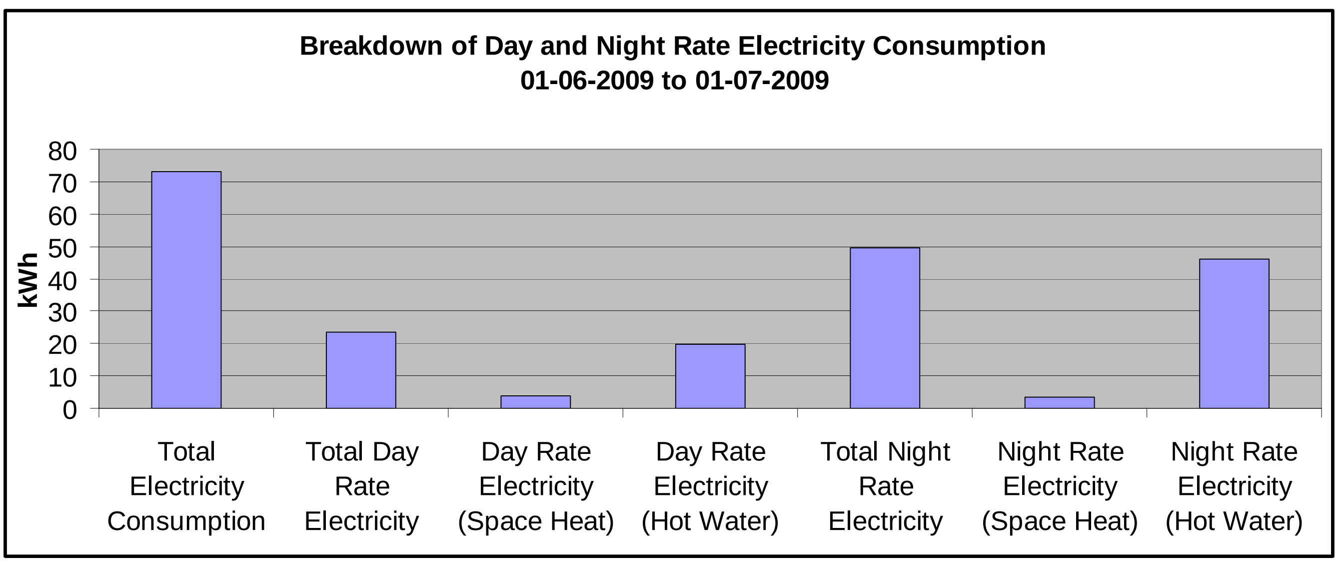

Figure 12: Breakdown of electricity consumption in day and night rate for space heat and hot water June 2009

Total Electricity Consumption (kWh)	***Total Day Rate Electricity (kWh)***	***Day Rate Electricity (Space Heat) (kWh)***	***Day Rate Electricity (Hot Water) (kWh)***	***Total Night Rate Electricity (kWh)***	***Night Rate Electricity (Space Heat) (kWh)***	***Night Rate Electricity (Hot Water) (kWh)***
73	*23*	*3.7*	*20*	*50*	*3.5*	*46*

Table 14: Breakdown of electricity consumption in day and night rate units for space heat and hot water June 2009

The breakdown of night and day rate electricity unit consumption over the period is shown in Figure 12 and Table 14. Approximately 63% of the total electricity consumed over the period is night rate. As can be seen from the graphs the space heat demand is June is very low.

4.11 Worst Case Performance of Heat Pump

The worst case performance of the heat pump over a 45 minute period occurred on 05th March between 5.05am and 5.50am. The SPF was 2.62 over the 45 minute period. It occurred when the heat pumps was producing hot water and the outdoor temperature was ~ 0C and the relative humidity was ~ 90%.The following graphs show the environmental conditions along with the heat pump output flow and return temperatures and their variation on the 05th March.

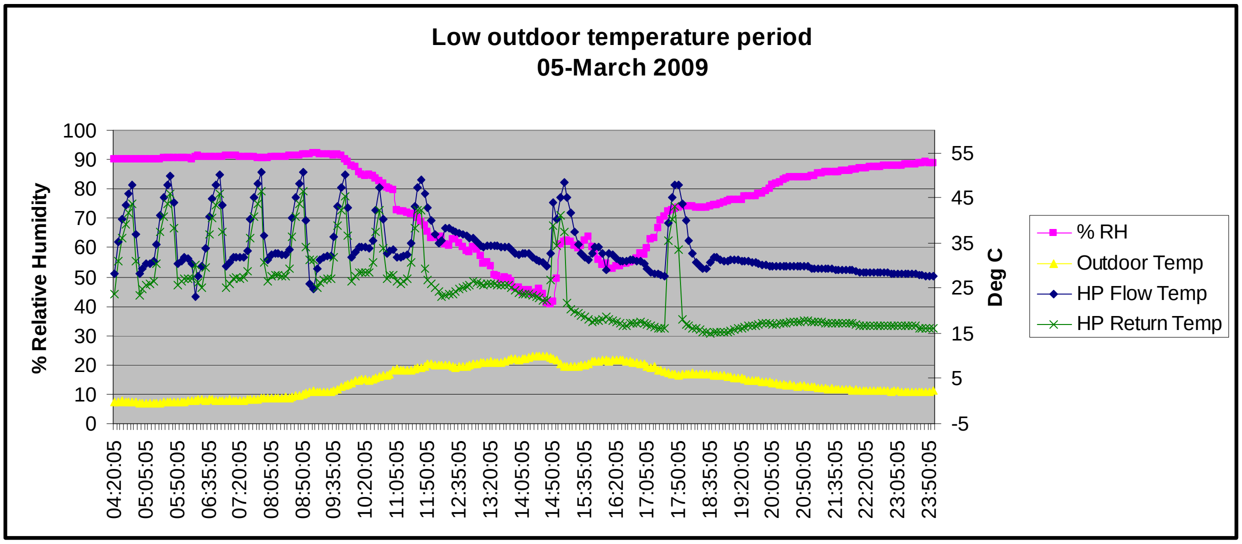

Figure 13: Outdoor environmental conditions and output flow and return temperatures on 05th March 2009

The outdoor temperature was ~0C for the most of the night with a minimum of -0.63C. The relative humidity was ~ 90% during the night time period also. This resulted in some defrosting where the difference between the flow and return temperatures (delta T) was negative as can be seen Figure 14.

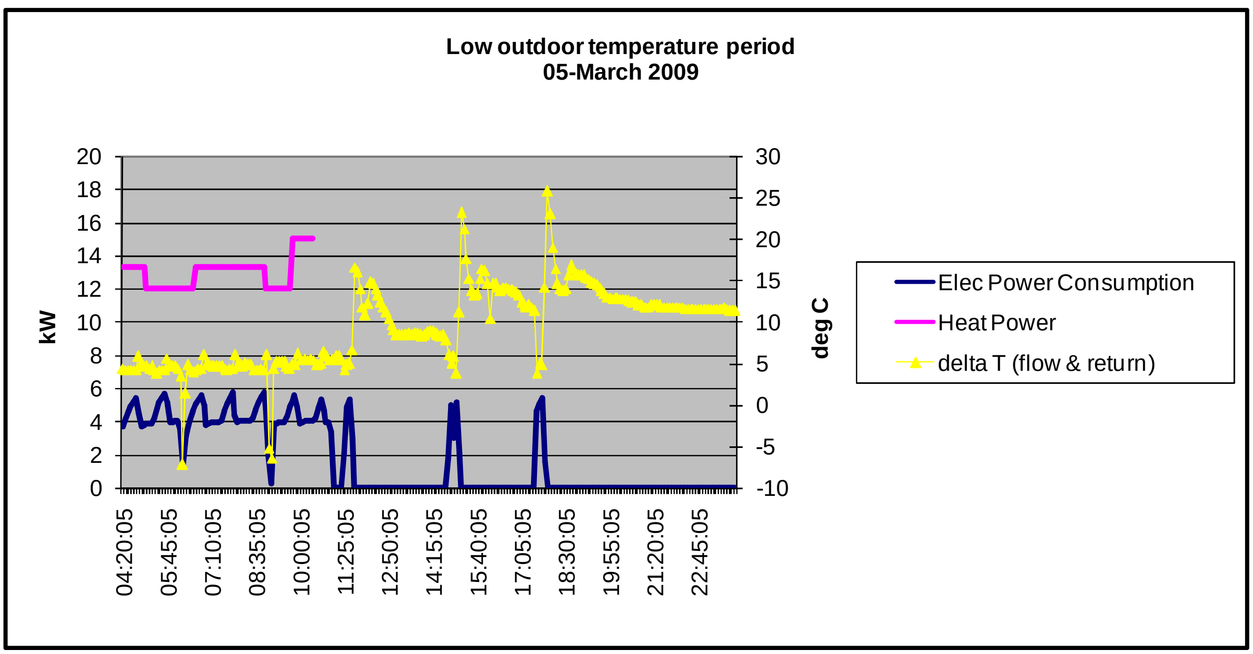

Figure 14: Heat power production vs electric power consumption and difference between output in flow and return temperatures on 05th March 2009

4.12 Operating Conditions on March 05 2009 05.05am – 05.50am

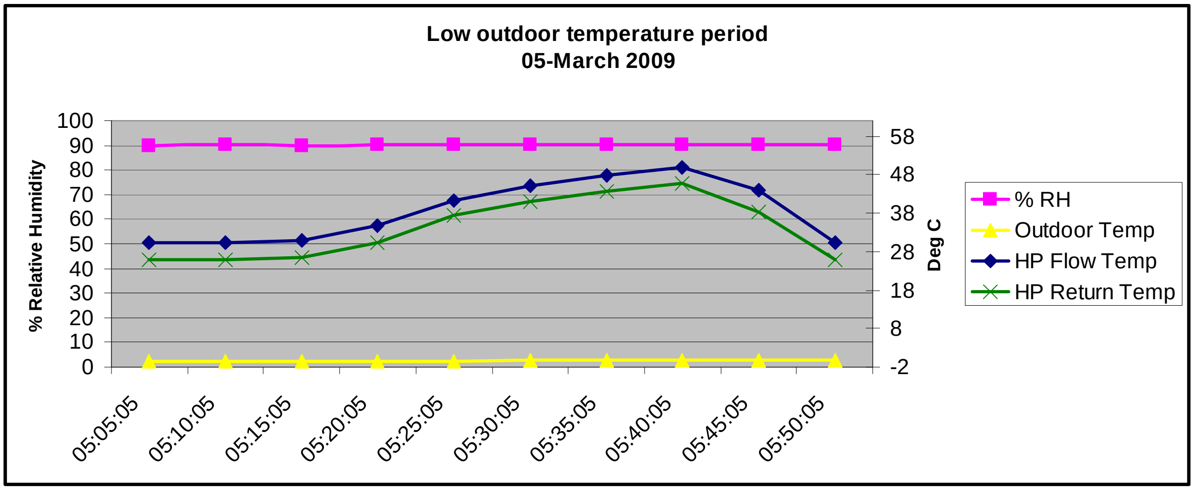

Figure 15: Outdoor environmental conditions and output flow and return temperatures on 05th March 2009 05:05am - 05:50am

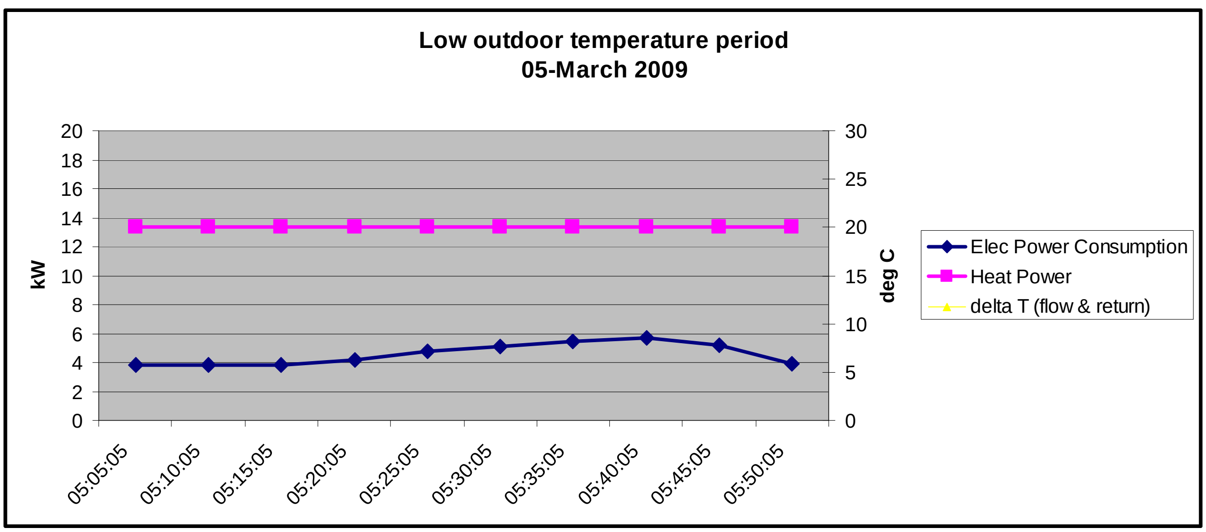

Figure 16: Heat power production vs electric power consumption on 05th March 2009 05:05 - 05:50

Total Heat production (kWh)	***Total electricity consumption (kWh)***	***Seasonal performance factor (SPF)***
10	*3.82*	*2.62*

Table 15: Heat production vs electricity consumption and SPF on March 05th 2009 05:05 to 05:50

5.0 Economic and Environmental Benefits

5.1 Cost of using Ochsner Air Source Heat Pump

A cost comparison between using the heat pump and oil, LPG and natural gas is given in this section for the period full period from 16th February to July 7th 2009.

Night rate electricity is availed of by the system. The current (May 1st 2009) ESB residential urban tariffs for are show below in Table 16.

Tariffs	***Rates (€/kWh)***
Day Rate	*0.1554*
Night Rate *23:00-08:00 Winter (Nov - Feb)* *00:00-09:00 Summer (March – Oct)*	*0.0769*
Standing Charge	*€0.3460/day*

Table 16: ESB tariffs – Domestic urban night rate

From Table 1 previously the total heat supplied was 7,760kWh and the total electricity consumed was 2,061kWh. The calculated heat pump electricity cost for whole period (16th February to 7th July 2009) is shown in Table 17.

Cost Breakdown	***Day Rate***	***Night Rate***
Electricity Consumption (kWh)	*649*	*1412*
Consumption Cost (€)	*€100.85*	*€108.58*
Total Consumption Cost (€) (ex VAT)	*€209.43*	
Total Consumption Cost (inc VAT @ 13.5%)	***€237.70***	

Table 17: Electricity consumption cost breakdown 16 February to 7 July 2009

A note in electricity standing charges-

Domestic night rate urban standing charge is €0.3460/day. Normal domestic Urban 24 hour standard tariff standing charge €0.2520/day (as may be the case when an oil or gas system is used). By having night rate the daily addition to the standing charge €0.064/day. Over the period 16th February to 7th July 2009 (141 days) the standing charge for night rate is €9.02 more expensive than the standard 24 hour tariff standing charge. When VAT of 13.5% is included the difference is €10.24. Therefore as night rate was chosen for use with the heat pump the effective cost is €237.70+€10.24= **€247.94**

In more general cases approximately 60% of the electricity would be consumed at day rate and 40% at nigh rate. In this case the cost breakdown be as follows

Cost Breakdown	***Day Rate***	***Night Rate***
Electricity Consumption (kWh)	*1,237*	*824*
Consumption Cost (€)	*€192.23*	*€63.36*
Total Consumption Cost (€) (ex VAT)	*€255.60*	
Total Consumption Cost (inc VAT @ 13.5%)	***€290.10***	

Table 18: Electricity consumption cost breakdown 16 February to 7 July 2009 in the general case split of 40% night rate and 60% day rate electricity consumption

The additional standing charge for night rate of €10.24 as was explained above results in cost of **€300.34**

5.2 Comparison with home heating oil

The price of home heating is relatively volatile at present. Current prices (July 2009) vary from 50c/litre to 70c/litre delivered to the home. In these calculations an average price of 60c/litre (including VAT) is used.

Oil Systems	
Energy in 1 litre of kerosene	*10.55kWh/litre*
Oil fired boiler efficiency	*70%*

Table 19: Energy in oil and efficiency of oil boiler- Source SEI

Cost Breakdown for Oil	
Heating Demand (kWh)	*7,760*
Raw fuel demand for efficiency of 70% (kWh)	*11,086*
Litres of oil required (10.55kWh/litre)	*1,050*
Total Cost @ 60c/litre	***€630.48***

Table 20: Heating oil cost to provide the same amount of energy as heat pump

5.3 Comparison with home LPG

The price of LPG is relatively volatile at present as it tracks the price of oil. Current prices from Flowgas for bulk LPG delivered (July 2009) 72.07c/litre (including VAT) delivered to the home.

LPG Systems	
Energy in 1 litre of Bulk LPG	*7.09 kWh/litre*
Condensing gas fired boiler efficiency	*90%*

Table 21: Energy in LPG and efficiency of condensing gas boiler- Source SEI

Cost Breakdown for LPG	
Heating Demand (kWh)	*7,760*
Raw fuel demand for efficiency of 90% (kWh)	*8,622*
Litres of LPG required (7.09kWh/litre)	*1,216*
Total Cost @ 72.07c/litre	***€876.43***

Table 22: LPG cost to provide the same amount of energy as heat pump

5.4 Comparison with natural gas using Bord Gas standard tariff (2009)

Bord Gáis (July 2009), "The Standard Tariff consists of two elements. There is a standing charge of 16.2 c/day and a consumption charge of 6.208c/kWh

Condensing gas boilers are ~ 90% efficient

Cost Breakdown for Natural Gas	
Heating Demand (kWh)	*7,760*
Raw fuel demand for efficiency of 90% (kWh)	*8,622*
Cost @ 6.208c/kWh (Standard Tariff)	*€535.25*
Standing Charge @ 16.2c/day (141 days)	*€22.84*
Total Cost	***€558.1***

Table 23: Heating oil cost to provide the same amount of energy as heat pump

5.5 Summary of Fuel Cost Comparisons

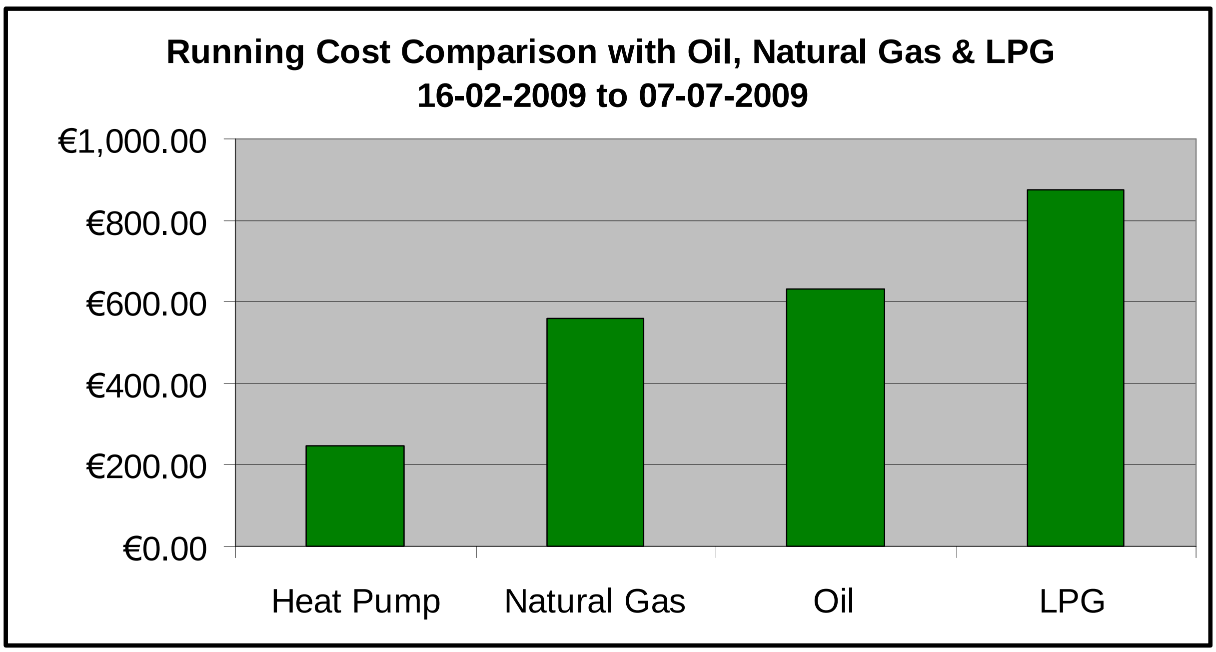

Figure 17: Cost comparison

Based on current (2009) electricity, natural gas and oil prices the cost of running the heat pump from Feb16 to July 07 is ~ 52% the cost of using natural gas and ~ 42% of the cost of using home heating oil as show in Figure 17. From Table 4 it was seen that 68.5% of the electricity consumed was at the night rate in this particular case. In many cases the proportion of the total electricity is 40% night rate and 60% day rate as this is evaluated in section 6.0 for a general domestic case.

5.6 CO_2 Emission Comparisons

A comparison of the CO_2 emissions is show below

Emission Factors	***gCO2/kWh***
Kerosene	*257.0*
LPG	*229.3*
Natural Gas	*205.6*
Conventional Electricity (depends on generation plant mix which can vary from year to year)	*542.8*

Table 24:CO_2 *emission factors for heating oil and natural gas- Source SEI*

	Heat Pump	***Oil Boiler***	***LPG Boiler***	***Natural Gas Boiler***
Energy consumption (kWh)	*2,061*	*11,086*	*8,622*	*8,622*
CO2 Emissions (kg)	*1,119*	*2,849*	*1,977*	*1,773*

Table 25: CO_2 emission comparison

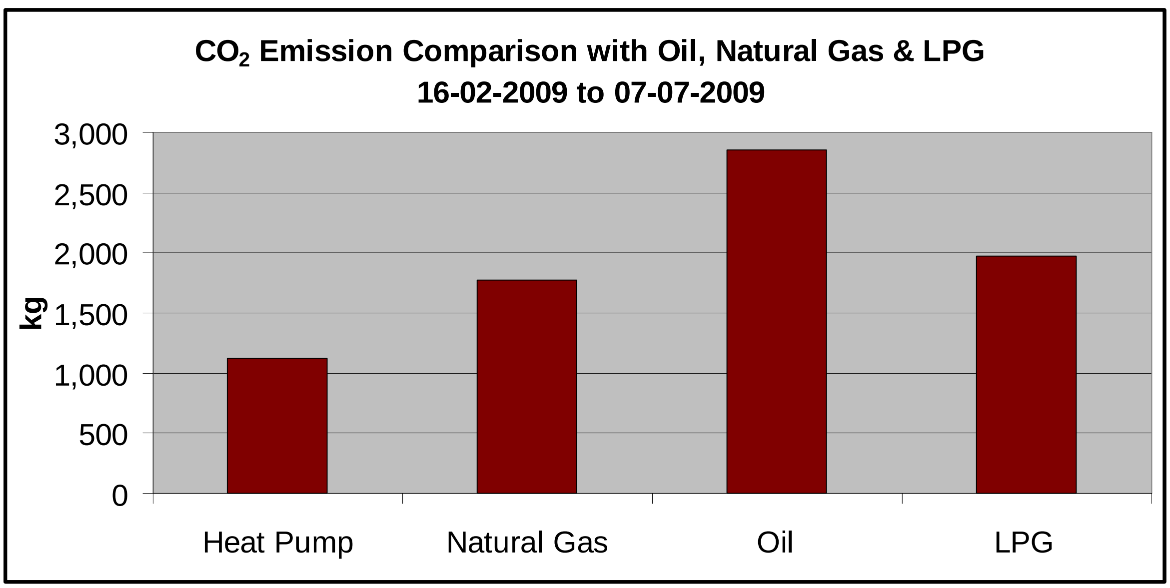

Figure 18: Heat production vs electricity consumption

The emissions as a result of using a heat pump depend on what the source of electricity is i.e. the generation plant mix. In recent Irish electricity generation stations have been moving from peat and oil to natural gas. The amount of wind generation is increasing which is also reducing emissions from the national grid. This has resulted in decreasing CO_2 emissions form electricity use. In this case the CO_2 emissions as result of the heat pump is 63% of using a natural gas heating system and 39% that of using a oil heating system.

6.0 Economic and Environmental Comparison of using an Ochsner Air Source Heat Pump in a 200m^2 house

Based on the monitored results we can extrapolate how an Ochsber air source heat pump would perform in a domestic house over a year and compare it with other heating systems. In 2007 Part L of the building regulations were modified to improve the energy efficiency in domestic building by 40% from 2008 onwards. Prior to this change the average combined hot water and space heat demand for a typical Irish house was in the region of 140-150kWh/m^2/yr. An improvement of 40% would results in an average space and hot water demand of ~ 100kWh/m^2/yr. A 200m^2 house built to current standards may typically have a space and hot water demand totaling 20,000kWh/year.

The following compares annual costs of using a Ochsner air source heat pump, heating oil system, LPG system and natural gas system for a 200m^2 house.

6.1 Annual cost of using an Ochsner Air Source Heat Pump

From Table 2 the SPF of the heat pump for space heating was measured to be ~ 4.1 and ~3.3 for hot water over the monitoring period from February 16th to July 7th. Hot water comprised of 36% of the total heat demand over this period. Extending this to 1 year in the domestic dwelling we can reasonably assume that the total hot water demand would be approximately 30% of the total heat demand.

Heat Demand	***kWh***	***Electricity Demand***	***kWh***
Space Heat Demand (70%)	*14,000*	*Space Heat (SPF 4.1)*	*3,415*
Hot Water Demand (30%)	*6,000*	*Hot Water (SPF 3.3)*	*1,818*
Total Heat Demand	*20,000*	*Total Electricity Consumption*	*5,233*

Table 26: Breakdown of heat demand and corresponding heap pump electricity demand in a 200m^2 *domestic house*

Typically for a domestic heat pump installation 60% of the annual electricity consumed is at day rate and 40% at night rate. Using the electricity tariffs show previously in Table 16 the annual costs of running the heat pump is shown in Table 27.

Annual Electricity Cost Breakdown	***Day Rate (kWh)***	***Night Rate (kWh)***	***Day Rate Cost (€)***	***Night Rate (€)***
Electricity Consumption Space Heat	*2,049*	*1,366*	*318.41*	*105.05*
Electricity Consumption Hot Water	*1,091*	*727*	*169.54*	*55.91*
Total	*3,140*	*2,093*	*487.95*	*160.96*
Total Consumption Cost (€) (ex VAT)	*€648.91*			
Total Consumption Cost (inc VAT @ 13.5%)	***€736.51***			

Table 27: Extrapolated annual electricity consumption cost by heat pump in a 200m^2 *domestic house*

If night rate is used solely as a result of installing the heat pump then the daily addition to the standing charge compared to not having nigh rate is €0.064/day. There for over one year (365 days) is €23.36 (ex VAT) = €26.51 (inc VAT). As the result the total annual cost of running the heat pump is ***€763.02***

6.2 Comparison with home heating oil

Using heating oil fuel costs shown previously in Table 20 the annual running cost using an oil boiler is show below in Table 28.

Cost Breakdown for Oil	
Heating Demand (kWh)	*20,000*
Raw fuel demand for efficiency of 70% (kWh)	*28,571*
Litres of oil required (10.55kWh/litre)	*2,780*
Total Cost @ 60c/litre	***€1,624.91***

Table 28: Extrapolated annual heating oil system fuel costs in a 200m^2 *domestic house*

6.3 Comparison with LPG using a condensing gas boiler

Using the fuel cost shown previously in Table 22 the annual running cost using an LPG condensing boiler is show below in Table 29.

Cost Breakdown for LPG	
Heating Demand (kWh)	*20,000*
Raw fuel demand for efficiency of 90% (kWh)	*22,222*
Litres of LPG required (7.09kWh/litre)	*3,134*
Total Cost @ 72.07c/litre	***€2,257.33***

Table 29: Extrapolated annual LPG fuel costs in a 200m^2 *domestic house*

6.4 Comparison with natural gas using a condensing gas boiler

Using the fuel cost shown previously in Table 23 the annual running cost using natural gas with a condensing boiler is show below in Table 30.

Cost Breakdown for Natural Gas	
Heating Demand (kWh)	*20,000*
Raw fuel demand for efficiency of 90% (kWh)	*22,222*
Cost @ 6.208c/kWh (Standard Tariff)	*€1,379.54*
Standing Charge @ 16.2c/day (365 days)	*€59.13*
Total Cost	***€1438.67***

Table 30: Extrapolated annual natural gas fuel costs in a 200m2 domestic house

6.5 Summary of Fuel Cost Comparisons

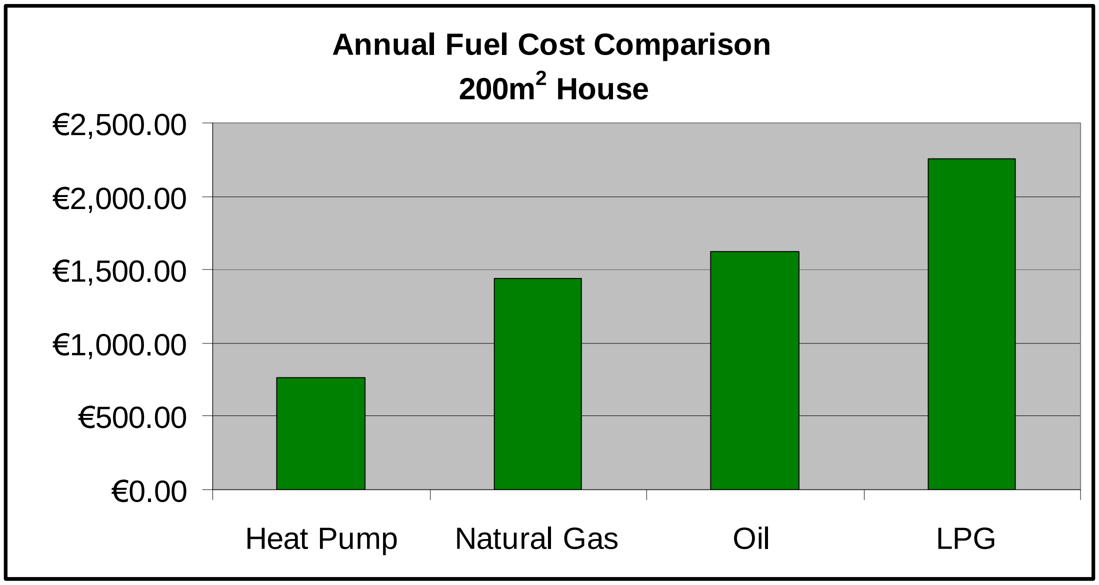

Figure 19: Annual Cost Comparison for 200m^2 house

Is should be noted the gas and oil boilers require annual an services and cost for this is not included in the figures. A properly installed Ochsner heat pump is maintenance free and this eliminates annual service costs.

6.6 CO_2 Emission Comparisons

CO_2 Emission factors for the different fuel types were shown Table 24. Using the emission factors a comparison of the annual emissions is show below in Table 31.

	Heat Pump	***Oil Boiler***	***LPG Boiler***	***Natural Gas Boiler***
Energy consumption (kWh)	*5,319*	*28,571*	*22,222*	*22,222*
CO2 Emissions (kg)	*2,887*	*7,343*	*5,096*	*4,569*

Table 31: CO_2 emission comparisons

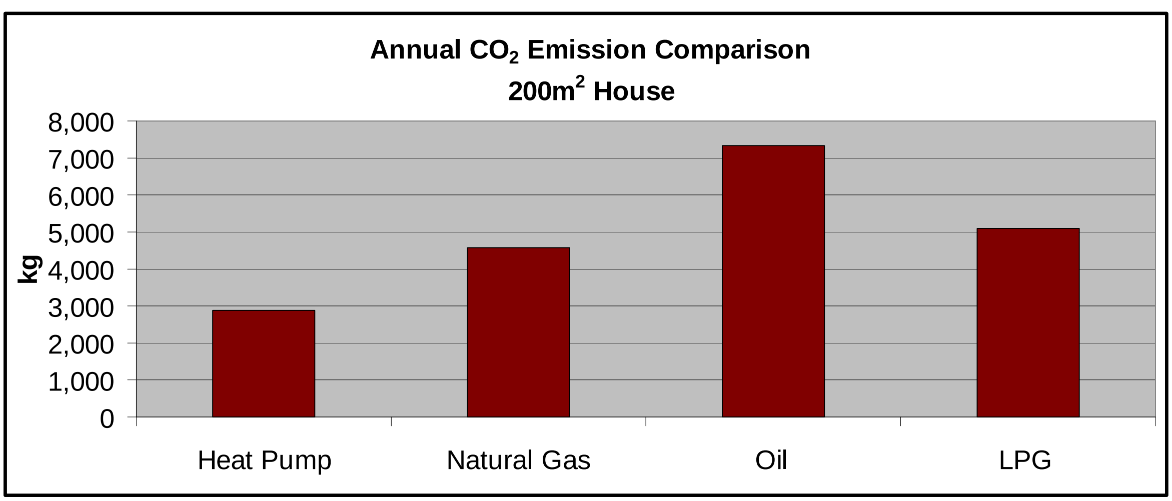

Figure 20: Annual CO2 emissions for 200m^2 house

7.0 Economic and Environmental Comparison of using an Ochsner Air Source Heat Pump in a 300m^2 house

From the data in section 6.0 a 300m^2 house built to current standards may typically have a space and hot water demand totaling 30,000kWh/year.

The following compares annual costs of using a Ochsner air source heat pump, heating oil system, LPG system and natural gas system for a 300m^2 house.

7.1 Annual cost of using an Ochsner Air Source Heat Pump

From Table 2 the SPF of the heat pump for space heating was measured to be ~ 4.1 and ~3.3 for hot water over the monitoring period from February 16th to July 7th. Hot water comprised of 36% of the total heat demand over this period. Extending this to 1 year in the domestic dwelling we can reasonably assume that the total hot water demand would be approximately 30% of the total heat demand.

Heat Demand	***kWh***	***Electricity Demand***	***kWh***
Space Heat Demand (70%)	*21,000*	*Space Heat (SPF 4.1)*	*5,122*
Hot Water Demand (30%)	*9,000*	*Hot Water (SPF 3.3)*	*2,727*
Total Heat Demand	*30,000*	*Total Electricity Consumption*	*7,849*

Table 32: Breakdown of heat demand and corresponding heap pump electricity demand in a 200m^2 domestic house

Typically for a domestic heat pump installation 60% of the annual electricity consumed is at day rate and 40% at night rate. Using the electricity tariffs show previously in Table 16 the annual costs of running the heat pump is shown in Table 33.

Annual Electricity Cost Breakdown	***Day Rate (kWh)***	***Night Rate (kWh)***	***Day Rate Cost (€)***	***Night Rate (€)***
Electricity Consumption Space Heat	*3,073*	*2,049*	*477.54*	*157.57*
Electricity Consumption Hot Water	*1,636*	*1,091*	*254.23*	*83.90*
Total	*4,709*	*3,140*	*731.77*	*241.47*
Total Consumption Cost (€) (ex VAT)	*€973.24*			
Total Consumption Cost (inc VAT @ 13.5%)	***€1,104.63***			

Table 33: Extrapolated annual electricity consumption cost by heat pump in a 300m^2 domestic house

If night rate is used solely as a result of installing the heat pump then the daily addition to the standing charge compared to not having nigh rate is €0.064/day. Therefore over one year (365 days) is €23.36 (ex VAT) = €26.51 (inc VAT). As the result the total annual cost of running the heat pump is ***€1,131.14***

7.2 Comparison with home heating oil

Using heating oil fuel costs shown previously in Table 20 the annual running cost using an oil boiler is show below in Table 34.

Cost Breakdown for Oil	
Heating Demand (kWh)	*30,000*
Raw fuel demand for efficiency of 70% (kWh)	*42,857*
Litres of oil required (10.55kWh/litre)	*4,062*
Total Cost @ 60c/litre	***€2,437.20***

Table 34: Extrapolated annual heating oil system fuel costs in a 300m^2 domestic house

7.3 Comparison with LPG using a condensing gas boiler

Using the fuel cost shown previously in Table 22 the annual running cost using an LPG condensing boiler is show below in Table 35.

Cost Breakdown for LPG	
Heating Demand (kWh)	*30,000*
Raw fuel demand for efficiency of 90% (kWh)	*33,333*
Litres of LPG required (7.09kWh/litre)	*4,701*
Total Cost @ 72.07c/litre	***€3,388.01***

Table 35: Extrapolated annual LPG fuel costs in a 300m^2 domestic house

7.4 Comparison with natural gas using a condensing gas boiler

Using the fuel cost shown previously in table 23 the annual running cost using natural gas with a condensing boiler is show below in Table 36.

Cost Breakdown for Natural Gas	
Heating Demand (kWh)	*30,000*
Raw fuel demand for efficiency of 90% (kWh)	*33,333*
Cost @ 6.208c/kWh (Standard Tariff)	*€2069.31*
Standing Charge @ 16.2c/day (365 days)	*€59.13*
Total Cost	***€2,128.44***

Table 36: Extrapolated annual natural gas fuel costs in a 300m^2 domestic house

7.5 Summary of Fuel Cost Comparisons

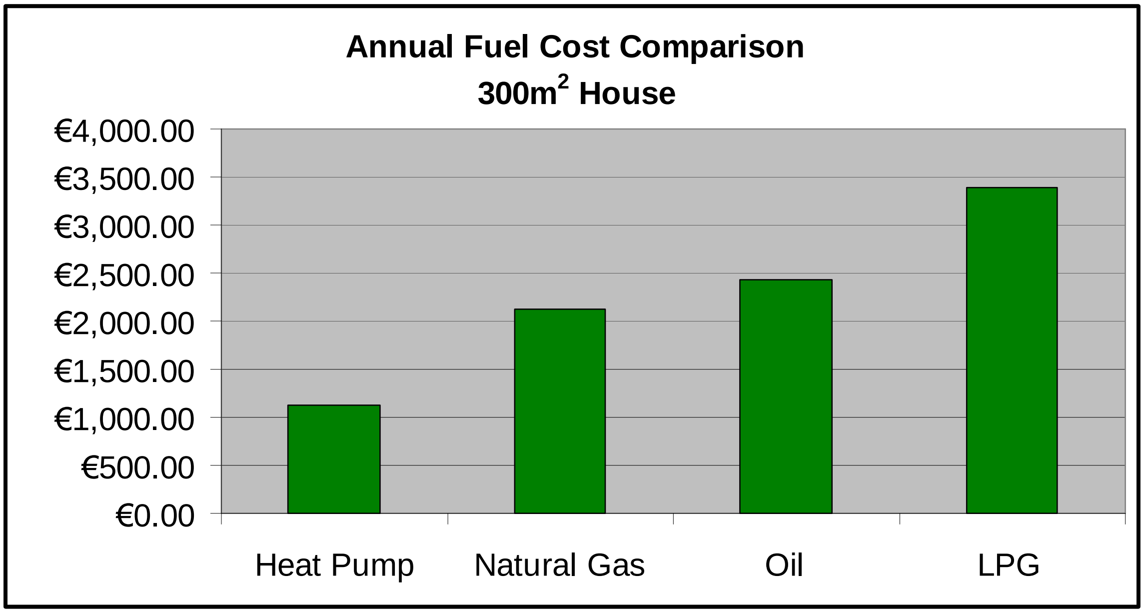

Figure 21: Annual Cost Comparison for 300m² house

Is should be noted the gas and oil boilers require annual services and cost for this is not included in the figures. A properly installed Ochsner heat pump is maintenance free and this eliminates annual service costs.

7.6 CO_2 Emission Comparisons

CO_2 Emission factors for the different fuel types were shown Table 24. Using the emission factors a comparison of the annual emissions is show below in Table 37.

	Heat Pump	***Oil Boiler***	***LPG Boiler***	***Natural Gas Boiler***
Energy consumption (kWh)	*7,979*	*42,857*	*33,333*	*33,333*
CO2 Emissions (kg)	*4,331*	*11,014*	*7,643*	*6,853*

Table 37: CO_2 emission comparisons

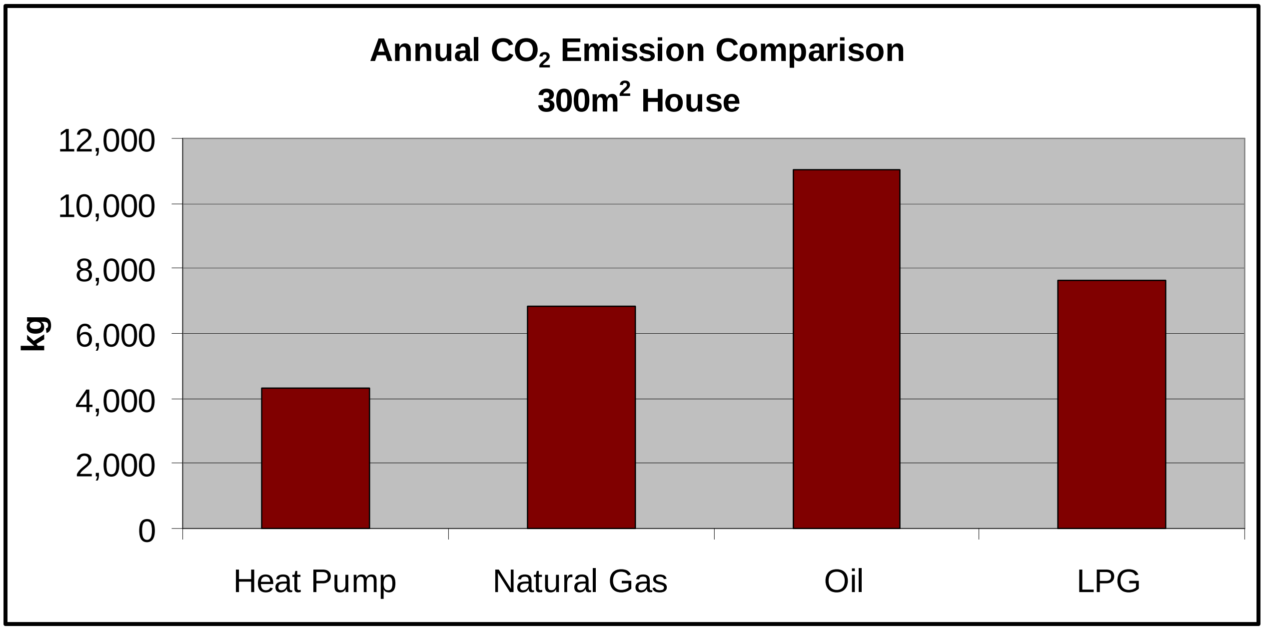

Figure 22: Annual CO2 emissions for 300m2 house

As expected due to the high SPF performance of an Ochsner air source in an Irish maritime climate the CO_2 emissions are lower than the other common fossil fuel systems. Emissions from a heat pump are indirect and depend on the power generation plant mix on the national grid. As wind energy penetration on the Irish national gird increases (40% wind penetration target by 2020) the resulting emissions will reduce year on year.

8.0 Conclusions

- This measured data for this Ochsner air source heat pump shows that it is performing very well in the provision of space heating and water heating under various outdoor environmental conditions. It had an overall average SPF of 3.76 over the monitoring period which comprised of an average SPF of 3.3 for hot water and an average SPF of 4.1 for space heat.

- The heat demand of the building was relatively low and can be attributed to the building insulation, under floor heating, Ochsner heat pump heating controls and the quality of installation by IGEN.

- During a cold winter/spring month of the year (16th February – 16th March 2009) approximately 30% of the total demand was for hot water and 70% for space heat. The average SPF was ~ 3.6 and this comprised of an average hot water SPF of 2.75 and a space heating SPF of 4.1.

- During a summer month of the year (June 2009) approximately 86% of the total demand was for hot water and 14% for space heat. The average SPF was ~ 4.8 and this comprised of an average hot water SPF of 4.5 and a space heating SPF of 6.8.

- It has been shown that the cost of running a heat pump is significantly less than using natural gas, LPG or heating oil at 2009 fuel and electricity prices.

- CO_2 emissions are less using the heat pump and will reduce in the future as more wind energy is connected to national grid. Also they can be reduced further by using a green electricity supplier.

- The study has shown that over the monitoring period an Ochsner GMLW19 air source heat pump is well suited to an Irish maritime climate in the provision of hot water and space heat to domestic and commercial buildings.