# Combining ground source Heat Pump with Wind and Solar Energy


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**Summary**

This case study examines the design of a new Environment Centre in Leeds with specific focus on the installed energy installations . The overall design strategy for the building is described to illustrate the benefits of an integrated design approach. A small wind turbine, roof-mounted photovoltaics and evacuated tube solar panels provide the renewable energy input to the building, whilst a ground source heat pump is used to supply underfloor heating. This paper examines the options for interlinking the energy generating and energy using equipment and why the chosen system was adopted, as well as providing a more general assessment of incorporating small scale renewable installations into services designs. An initial review of building performance is also provided.

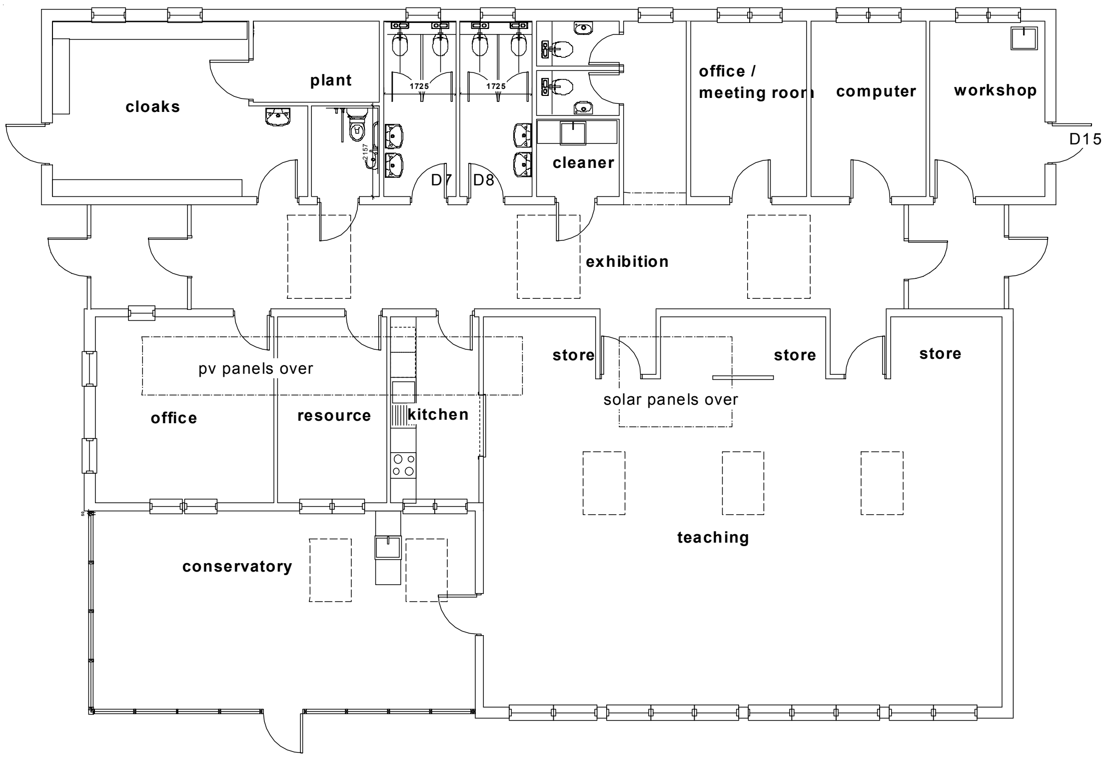

## 1. Introduction

The initial brief for the Environment Centre at Skelton Grange in Leeds was to provide a teaching facility for the local branch of the British Trust for Conservation Volunteers (BTCV). The building, which replaces a decrepit portacabin on their nature reserve, had to accommodate an office, workshop, kitchen and toilets as well as the main teaching space. The author's company produced an initial feasibility study in 1997, which included the environmental desires of the clients to "practice what we preach and showcase 'green' solutions through the project". Fundraising for the project took nearly five years to complete and the building went out to tender in the summer of 2002, started on site in February 2003 and was completed in June 2003.

## 2. Initial design concepts

A key policy adopted at feasibility was to use an integrated design procedure, which has been defined as: "a design process which considers all aspects of a building, its environment and life cycle, and is undertaken by a team which includes all relevant professionals and stakeholders working together throughout the process, rather than sequentially and independently." (1)

All members of the design team were involved in the feasibility study in an effort to translate the client's particular requirements into a sustainable building design. The primary use of the centre is as a teaching space for classes of young school children who visit the nature reserve, so movement of groups of people into and out of the centre needed consideration. Design team discussion produced the concept of an unheated "buffer space" in the building that could act as a passive solar collector, a draught lobby big enough to accommodate 30 children, and a plant conservatory. Basic calculations of heat losses, solar gains and daylighting were carried out at feasibility (and throughout the detailed design stage) resulting in a number of modifications to such things as window sizes and locations.




Plan Of Building Showing Location Of Solar & P.V. Panels

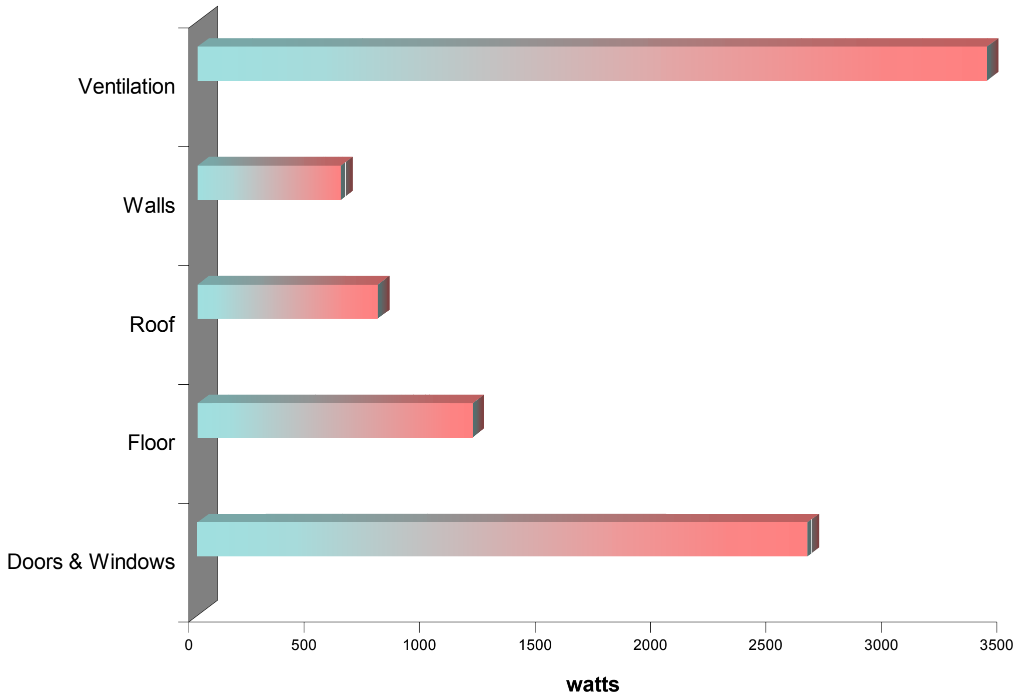
The proposed levels of insulation written into the feasibility were decided long before the latest "Part L" of the Building Regulations were drafted, but still look respectable:

| Element | U value (W/m2k) |
|---|---|
| Floor | 0.16 |
| Roof | 0.11 |
| walls | 0.18 |
| windows | 1.6 |

Floor, wall and roof insulation was originally specified as "Warmacell" shredded newspaper (later changed during construction – see section…

below). Window glazing was  argon filled double glazing with a soft low emissivity coating.

The overall fabric heat-loss for the building (excluding ventilation losses) was calculated at 6.0 kW   (at -3.5deg external), and heat loss distribution is shown below:

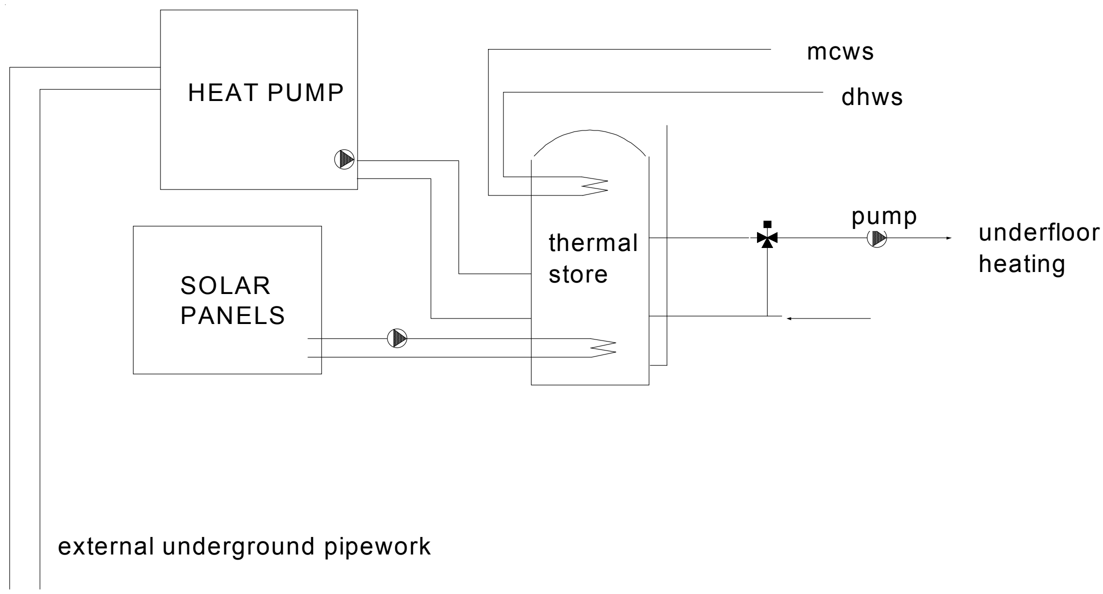



## 3. Services Design

When drawing up a services strategy for a building intended as a showcase of best environmental practice,  incorporation of some form of renewable energy is an obvious choice.  Justifying this in economic terms however can be difficult. Simple pay-back periods for photo-voltaic installations, for example, are over fifty years at current electricity prices. When working within a limited budget the designer also faces a potential conflict between investing in the most energy efficient building services and specifying renewable installations. The principle adopted for Skelton Grange was to specify what was considered best available services in terms of efficiency whilst allowing simplicity of design to keep costs within budget. Additional capital sums were allowed for renewable energy sources and justified on the basis of showcasing available technology rather than providing quick pay-back periods.

Various site specific factors affected the development of the design, not least the absence of any natural gas distribution pipework near the site. This prompted consideration of using a heat-pump as primary heat –source for the building, using pipework buried in horizontal trenches. The effectiveness of a ground-source heat pump is dependent upon its seasonal co-efficient of performance(c.o.p.) in operation, which is around 3.0 for typical installations [(2)]. At Skelton two site factors contributed to ensuring a high c.o.p.: firstly the proposed use of a leachfield for drainage meant one area of land would be kept moist (providing improved heat transfer) and secondly the presence of a 275kV underground cable feeding West Leeds running across the site. Permission was given by the cable owners to install heat-pimp pipework 0.5metres adjacent to this cable allowing it to benefit from the heat generated by the cable resistance.

The choice of a heat pump (a 13kW output model was selected) largely determined the rest of the design strategy. As the temperature output of the heat pump is typically around 50deg, underfloor heating was an obvious choice for heat distribution. The heat pump manufacturers recommend a buffer store between the heat-pump and the heating load to reduce short-cycling of the motors. A 280lts thermal store was specified which acts both as a buffer and a store for the output from  roof-mounted evacuated tube solar panels (see schematic diagram below).  Domestic hot water is provided from a high recovery coil in the thermal store. This arrangement was adopted to take advantage of any available heat from the solar panels to feed into the heating system in winter (as  opposed to just contributing to domestic hot water).




The arrangement shown also allows for a relatively simple control strategy. The heat pump operates during occupancy hours to  keep the thermal store at a temperature of 55degrees, and will hold off if the solar panels (which have a stand alone controller) heat the store above this temperature  A programmable thermostat linked to the underfloor heating pump provides time and temperature control of the heating.

The option of composting toilets was rejected by the clients, so to reduce water consumption a rainwater harvesting system was specified for supplying w.c. cisterns. Other cold water outlets are mains fed.

The specified electrical generation equipment aimed to meet the electricity demands of the heat pump. A 2.5kW wind turbine, sited 100m from the building on a 9m mast is predicted to provide 3,500kWh annual output and a 2.0kWp photovoltaic panel array fitted on the South facing roof will provide approximately 1,520kWh per annum.

The turbine and photovoltaic array are connected into the incoming 3-phase supply panel via inverter units approved for direct grid connection. This means that the clients will receive little, if any, economic benefit from exported electricity (on sunny, windy weekends for example). However the alternative of installing a battery store has the disadvantage of reduced overall system efficiency. The capital costs of a battery store with large enough capacity for two days full output generation would have been over £5,000, which a 10-15 year expected lifetime would negate their potential financial benefit.

The projected overall energy balance for the building is as follows:

| **Consumption** | KWh/m2 / p.a.(a) |
|---|---|
| Heating (Heat pump c.o.p. @ 3.5) (b) | 10.0 |
| Hot water | 2.0 |
| Lighting (8W/m2 load) | 7.7 |

| | |
|---|---|
| Other electrical use | 4.0 |
| **Generation** | |
| Wind turbine | - 10.9 |
| Photovoltaic Array | - 4.7 |
| Solar Panels | - 6.6 |
| **Total consumption** | **1.5** |

Notes:

(a) Figures in the second column are based on the 320m2 heated area of the building.

(b) Manufacturer's data for heat pump c.o.p. gives 3.05 at 55deg flow and 3.84 at 45deg flow.

(c) Solar panel output to hot water is based on manufacturer's declared output, with a 20% deduction to allow for reduced utilisation in summer.

## 4. Financial and Construction Issues

The overall costs for the building were calculated at £460,000 at Tender, including services costs of £71,000. However the lowest tender returned was over £750,000, which resulted in a re-appraisal of the project. This and subsequent events are not the subject of this paper, but one observation around costs is of general interest.: that specifying innovative construction methods and products was largely responsible for the higher than expected tenders.

Cost problems were resolved by negotiating a partnership contract with a construction company specialising in pre-engineered buildings who were able to supply a modular timber-frame building generally meeting the original environmental specifications within the original budget. Apart from a change in wall construction to include phenolic foam insulation, a simplification of the building footprint, and a small reduction in overall area, there were no significant alterations. During construction the insulation for the floor and roof was changed from "Warmacell" to "IsoGras" (made from grass cuttings) because of difficulty in finding registered installers for the former.

Final mechanical & electrical costs were as follows:

| ITEM | Total | £/m2 |
|---|---|---|
| Photovoltaic installation | 12,020 | 33 |
| wind turbine | 11,924 | 33 |
| Electrical installation | 24,188 | 67 |
| Mechanical installation: | | |
| Heat pump installation | 11,162 | 31 |
| Solar Panels | 7,508 | 21 |
| rainwater storage | 1,747 | 5 |
| Other | 15,283 | 42 |
| TOTAL | 83,832 | 233 |

A grant of £6,000 obtained under the Small Scale Photovoltaics scheme reduced overall costs to £216/m2. It can be seen from the above that total services costs were comparable with conventional "higher spec." installations in similar buildings.(3)

Apart from specifying relatively economical equipment, construction methods helped keep down costs. The pre-engineered building system allowed, for example, electrical containment in walls to be fitted within the factory assembled modules, significantly speeding up installation on site.

## 5. The Finished Building

The mechanical installation was commissioned in July this year, well ahead of the official opening in September. Apart from a teething problem with the rainwater pump feeding w.c.'s, no problems were encountered.

The commissioning of the photo-voltaic panels, wind turbine and solar panels was straightforward, although the arrangements for formal "witness testing" by the electricity supply company prior to grid connection have yet to be completed.

## 6. Conclusions

Involvement in this project has provided a number of lessons that have general application:

6.1.The integration of renewable energy sources into a project requires an analysis of all energy using and energy generating equipment to assess their impact on the prospective annual energy balance. "Bolting on" some photovoltaic panels to a conventional design does not make a building sustainable. Energy use of equipment often neglected by services engineers such as passenger lifts, maintained emergency lighting, kitchen equipment, and even fire alarms, needs analysing.

6.2. Adopting an integrated design approach is necessary if the benefits of, for example, increased insulation levels are to be properly assessed. For the building in this case study the available budget only allowed for relatively simplistic modelling and prediction techniques. Larger projects justify more careful modelling only if the whole design team are prepared to change their designs in response to the results provided.

6.3. Lack of demand and contractor's ignorance of installation methods contribute to the high costs of small scale renewable energy installations. On this project the lack of availability of wind turbines in the 3 – 20kW output range, for example, meant that a smaller than desired turbine was specified.

As a final footnote, a the author wishes to issue a general caveat to readers. The real success of the Skelton project should only be judged by its performance in operation, after at least a years detailed monitoring. There are already too many "environmental centres" around the country claiming to have the ideal solution to sustainable design, and too few monitoring studies of these buildings in use.

REFERENCES

1. Integrated Building Design BSRIA. 1999 (interactive CD)

2. Closed ground source heat pumps.. Robin Curtis.CIBSE Conference 1996

3. (for example) School Buildings cost model CIBSE Journal Jan 2002