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## **Energy Foundations – Potential for Ireland**

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### **ABSTRACT**

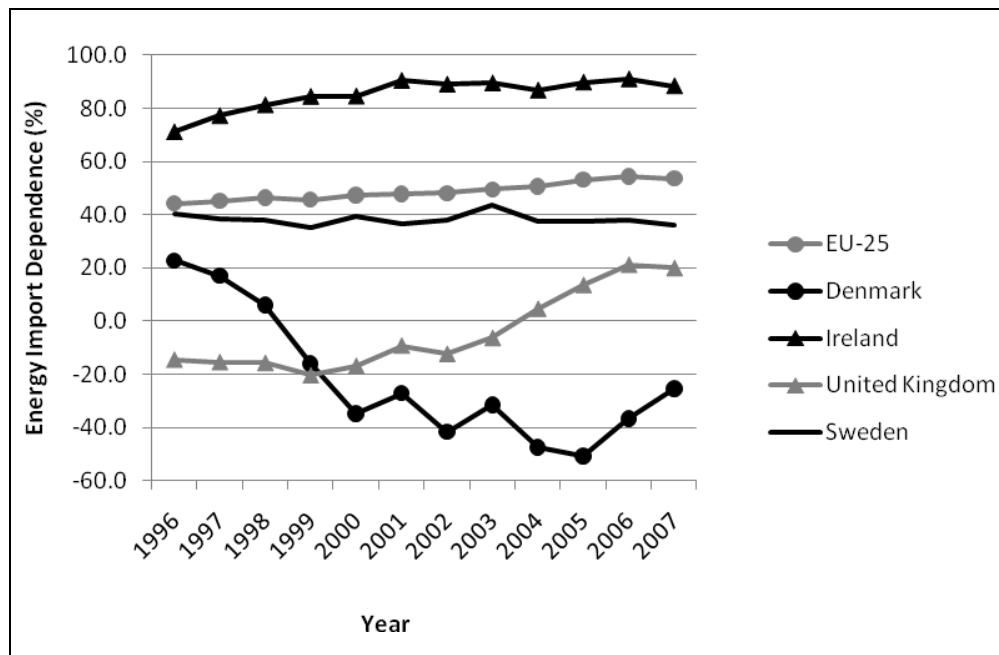
With one of the highest energy dependencies in the European Union, Ireland must adapt quickly to renewable energy technologies or risk paying the penalty in the form of high energy prices in years to come. Escalating energy costs have led to a renewed interest in alternative energy technologies and ground source energy is one such resource which is being increasingly considered. This paper presents some of the practical considerations of energy foundations, evidenced from the installation of a number of test energy piles. In addition, a preliminary feasibility study of an energy foundation system for a planned university administrative building and an overview of the current status of ground source energy technology in Ireland are presented. Building heating and cooling loads are estimated based on high building energy standards which the university hopes to implement in all building projects going forward. The proposed energy foundation system is shown to have the capacity to provide the heating and cooling base loads for the building.

### **INTRODUCTION**

Following investigation of the potential for exploitation of deep geothermal resources (depths typically up to and above 4/5km) to meet University College Dublin's energy needs, a decision has been taken not to pursue this avenue on the grounds of high exploration costs and high risk. The University has therefore embarked on assessment of how shallow geothermal (or ground source) energy technologies (depths typically less than 200m) such as energy foundations could form part of the energy strategy of planned new buildings. The primary difference between energy foundations and conventional closed circuit energy exchange systems is that for energy foundations, absorber pipes are installed within structural elements which are already required for the structural integrity of the building/structure (Katzenbach et al., 2007). Energy foundations have been installed in many buildings throughout the world (Boennec, 2008, Gao et al., 2008) however it is believed that no such systems exist in Ireland. The lack of any regulatory system with regard to ground source energy installations, a lack of specialist knowledge in the area and the consequent low-confidence in ground source energy technologies are some of the principal reasons for this. Research in the area applied to Irish climatic and geological conditions is an important first step in the development of these technologies in Ireland.

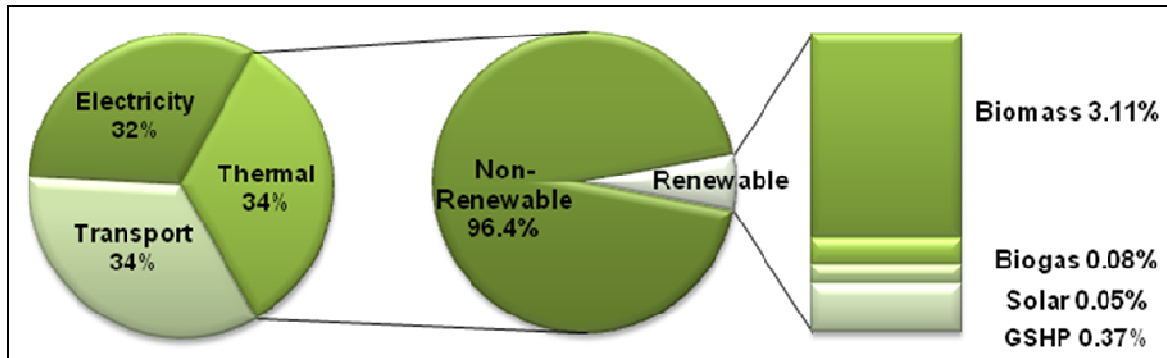
## THE ENERGY SCENE IN IRELAND

Following a return to high oil prices in the mid 1990's, development of 'green' energy technologies is once again firmly on the international agenda. For many years, Ireland has lagged behind its European neighbors in terms of development and installation of renewable energy technologies and is currently one of Europe's most energy dependent states. In 1996, Ireland relied on imports for just over 70% of its energy needs; by 2008 this figure had reached 90%.



**Figure 1. Energy Import Dependence.**

Comparison with Denmark, a country similar in land size and population, illustrates the extent to which Ireland relies on energy imports. Figure 1, data courtesy of the European Union's Statistical Information Office (Eurostat, 2010), shows that Denmark had an energy import dependence of negative 25% in 2007 (meaning that 25% of energy produced was exported) compared to Ireland's energy dependence of 88%. Malta (100%), Luxembourg (98%) and Cyprus (96%) are the only countries in the EU-25 with higher energy dependencies than Ireland.

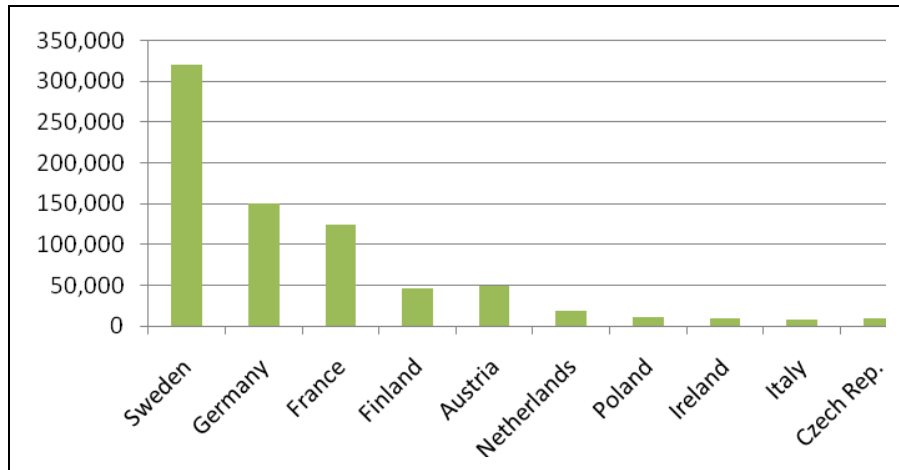


**Figure 2. Thermal Energy Generation in Ireland**

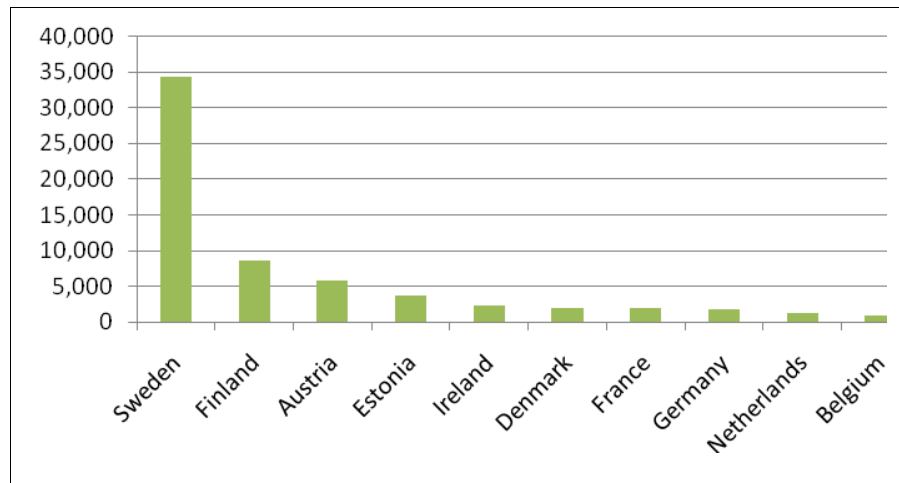
Primary energy generation may be split into three modes of application; electricity, transport and thermal, each of which account for approximately one third of demand. Further analysis of the technologies used to generate the thermal energy component shows that over 96% is generated by non renewable sources such as oil and gas. Figure 2, data courtesy Sustainable Energy Ireland (Energy Policy Statistical Support Unit, 2009), shows that the remaining 3.6% is generated from renewable resources with ground source heat pumps accounting for just 0.37% of thermal energy generation. As Ireland is a country which does not benefit from high ground temperatures associated with tectonic activity, no electricity is currently generated using geothermal resources. This means that the 0.37% thermal energy generation provided by ground source heat pumps accounts for the total energy generated by geothermal or ground source technologies in Ireland. (Note the term 'ground source heat pump' is generally referred to as 'geothermal heat pump' in America)

### **Ground Source Energy in Ireland**

Despite the historical low uptake of ground source heat pump technologies in Ireland relative to other European countries where it is considered a mature and well defined technology, statistics published recently indicate an increasing level of interest in ground source energy. High dependence on imported energy, increasing energy prices, price volatility and further research in the area applied to Irish soil conditions is likely to lead to increased confidence in the technology in years to come.



**Figure 3. – Number of GSHP installations in EU**



**Figure 4. – Number of GSHP installations in EU (normalized against population)**

Figure 3, data courtesy of Eurobserv'ER (Eurobserv'ER, 2009) shows Ireland to be in 8<sup>th</sup> position in the European Union in terms of the number of ground source heat pumps installed. Figure 4 presents GSHP Installations normalized against population (Eurobserv'ER, 2009) and shows that Ireland ranks 5<sup>th</sup> in the EU, with installations per capita remain significantly behind the market leaders by a factor of more than 15. This demonstrates the distance Ireland has to go in order to become a major player in the European ground source exploitation market.

## ENERGY FOUNDATIONS

Energy foundations are structural elements equipped with absorber pipes through which a fluid flows. Energy piles or thermal piles are the most common form of energy foundation installation, but retaining walls, tunnels and basement walls may also be used. Early forms of energy foundations were generally prefabricated reinforced concrete piles with piping incorporated, however large diameter bored piles are now commonly used.



**Figure 5. Installation of Test Energy Piles**

Energy piles are typically installed in one of two ways. Either the absorber pipes are tied to the reinforcing cage prior to lowering into the pile or they are lowered into the wet concrete pile using a plunging bar. An example of the latter is shown in Figure 5 where continuous flight auger drilling is used in order to achieve design depth, the auger and spoil are removed as concrete is pumped in and finally the absorber pipes are lowered into the pile.

### **The Practicalities of Energy Foundations**

Several construction issues must be considered prior to and during installation of energy foundations. As drilling/piling contractors in Ireland do not have experience with installation of energy foundations, a number of test energy piles were installed (see Figures 5 & 6) in order to gain ‘first-hand’ experience of potential installation difficulties. Achieving design depth in the required number of energy foundations is critical to the efficient performance of energy foundation systems. In certain instances where absorber pipes do not reach design depth, using an excavator bucket to push the plunge bar to design depth may solve this problem; however care must be taken not to apply excessive force as this could cause the plunge bar to bend, rendering further efforts unsuccessful. Figure 6(a) shows an example of where the absorber pipes and plunge bar did not reach the required design depth, compared to Figure 6(b) where design depth was reached. Where absorber pipes do not reach

design depth, there are two options; cut the plunge bar and pipes to fit the achieved depth or disregard this pile by pulling the pipes out or leaving them in-situ and filling with concrete. This illustrates the importance of applying a suitable factor of safety, particularly in cases where drilling contractors are not familiar with the installation process.



**Figure 6. Test Energy Pile Installation: (a) Unsuccessful; (b) Successful**

Tailoring the concrete mix in order to ensure easy installation of absorber pipes/plunge bar is an important consideration. If aggregates are too large or if the mix is not ‘fluid’ enough during installation it may be difficult to achieve design depth. It is therefore good practice to schedule installation of a small number of absorber pipes on the first day of the piling schedule, if installation problems present themselves it will be possible to alter the constituents of the concrete mix in time for subsequent piling operations.

In some cases, where plunge bars have been designed to be recoverable problems with pipes floating out of the pile have been experienced. This may be solved in one of several ways; ensure the absorber pipes are filled with water in order to increase their weight, tie the absorber pipes to the reinforcing cage before extracting the plunge bar, incorporate a weight onto the bottom of the pipes, leave the plunging bar in-situ for a short period after installation, alter concrete mix in order to reduce buoyancy or do not recover the plunge bar. It should be noted however that a non-recoverable plunge bar can lead to a significant increase in installation costs.

The risk to the integrity of the absorber pipes does not end following successful installation, careful monitoring of and communication with all operatives on site during construction works is vital. In particular, great care must be taken when breaking down the pile head to the required level and when works are being carried out in the vicinity of the ground-protruding absorber pipes as damage could render them useless.

## **PROPOSED UNIVERSITY BUILDING**

A cornerstone principal of the current building program in University College Dublin is to investigate the feasibility of incorporation of renewable energy technologies into planned building projects. The following paragraphs describe a preliminary feasibility study investigating the incorporation of energy foundations into a planned building. This feasibility study was carried out as a desk study using thermo-geological modeling software 'Energy Earth Designer 3.0'. The study examines whether the base load of the administrative building can be covered by energy piles, and assumes the hot water and peak loads will be covered by an auxiliary system. Designing the system to deal with peak loads in addition to base loads would mean selecting a heat pump which would operate at a fraction of its capacity the majority of the time.

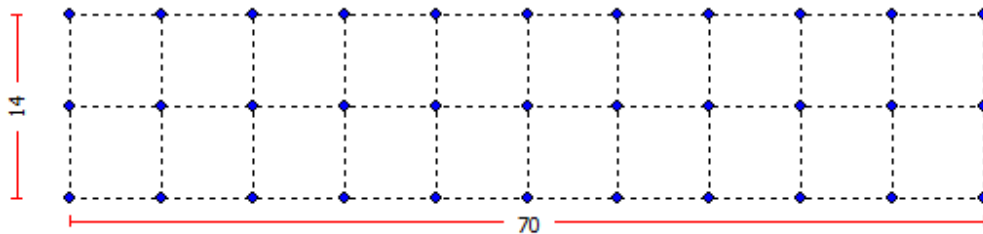
Geological conditions at the campus, underlain by Calp Limestone of Lower Carboniferous age, are representative of that which would be found in many areas throughout Ireland. The Calp, which is described as grey, fine grained limestone interbedded with black, poorly fossiliferous shales (Geological Survey of Ireland, 2006) is overlain by clay with depths ranging from 10m to 25m below ground level and pockets of undifferentiated glaciofluvial gravels. A deep fault line exists at the southern extent of the campus where the Calp Limestone Formation meets the Leinster Granite Formation. An initial desk study of historical site investigation records performed near the proposed site has shown that bedrock depths are encountered at approximately 15m to 20m. An important part of the preliminary feasibility assessment was therefore examining whether or not any proposed energy foundation system could operate over this range of depths. In addition, the equivalent length of borehole required by a conventional closed loop installation was calculated.

An increased focus on energy efficiency in buildings in recent years has led to clients (particularly in the public sector) demanding new buildings with low energy consumption requirements. This is good news for technologies such as energy foundations which may not have been suitable for incorporation into building projects in the past where energy consumption may have been too high. A space heating load of 25 kWh/m<sup>2</sup>/yr has been assumed for the planned building, although an ambitious target, this value has been shown to be achievable in several building projects across Europe (Eicker, 2009). Cooling loads in Irish buildings are typically very low, although the proposed building will contain a server room which will require some level of cooling, a cooling load of 10 kWh/m<sup>2</sup>/yr has been assumed. Other important parameters required for the study are outlined in Table 1. Note: as there are no Irish standards pertaining to the design of ground source heat pump systems, the German standard 'VDI 4640' was referred to in order to establish good practice fluid temperature constraints (The Association of German Engineers, 2001).

**Table 1. EED Input Parameters**

Parameter	Value
Thermal Conductivity of Moist Clay	1.6 W/(m.K)
Ground Surface Temperature	9.5 °C
Piping Configuration	Double-U
Pile Depth	20 m
Pile Spacing	7 m
Concrete Thermal Conductivity	1.6 W/(m.K)
Fluid Temperature Constraints	-1 °C to 21 °C

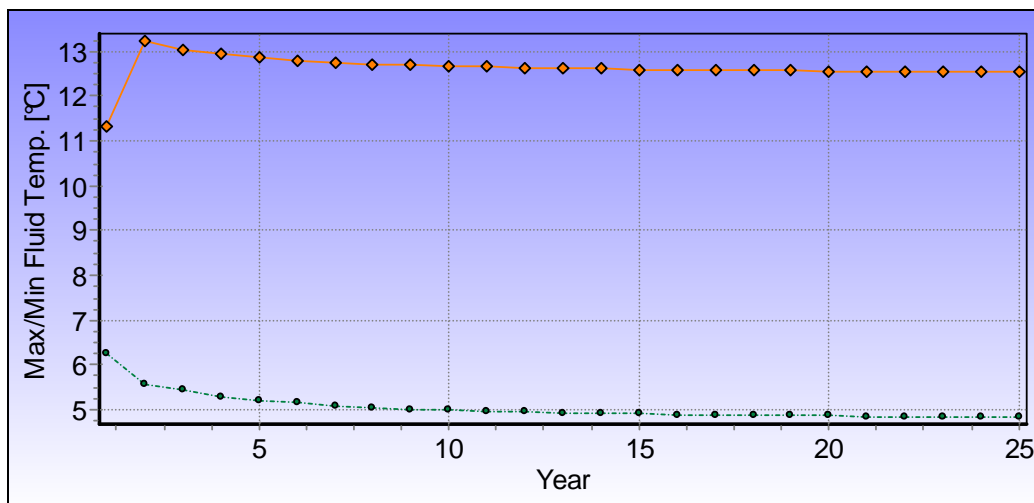
The approximate floor area of the proposed building is 1,960m<sup>2</sup> with a footprint of 980m<sup>2</sup>. An outline of the likely pile layout for the building (which was used in the modeling process) is shown in Figure 7.



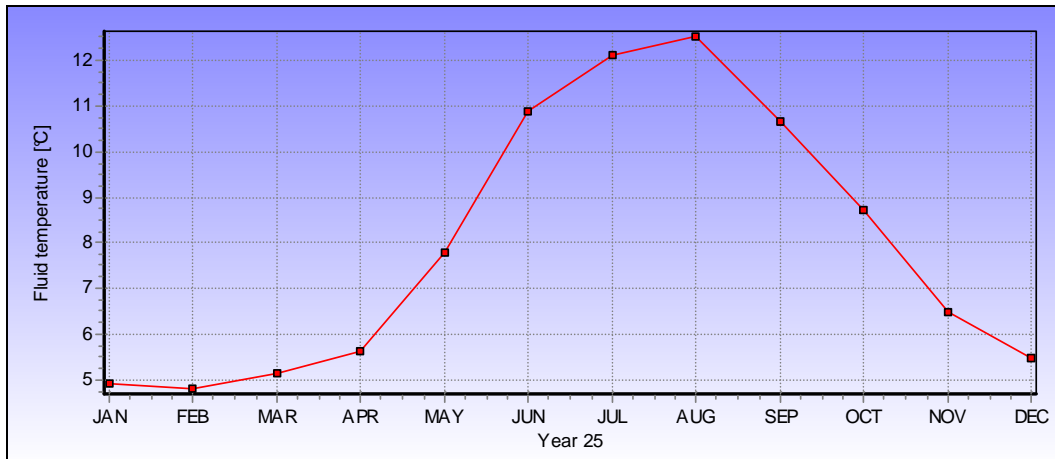
**Figure 7. Pile Layout of Proposed Building**

### Preliminary Feasibility Study Results

Computer modeling using the EED software has shown the previously described system to be feasible when modeled over a 25 year period. Figures 8 and 9 show the maximum & minimum annual fluid temperatures and the fluid temperature profile for year 25 of the simulation respectively. It is shown that the fluid temperature remains well within the defined limits of -1 °C and 21 °C.

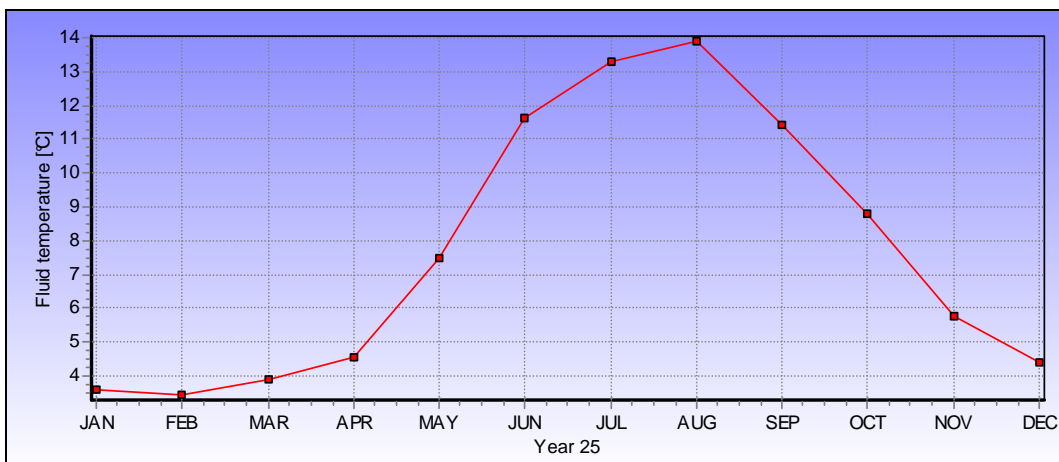


**Figure 8. Maximum & Minimum Annual Fluid Temperatures**



**Figure 9. Year 25 Fluid Temperature Profile**

The next facet of the study was required in order to examine whether or not the proposed system would still meet the stated heating and cooling loads if the limestone bedrock was met at a shallower depth. It is thought that bedrock will be met at between 15 m and 20 m at the site. Figure 10 shows a small increase in the maximum 25 year fluid temperature and a small decrease in the minimum, but the required system capacity is shown achievable with 15m pile lengths as the fluid temperature profile remains within the defined limits.



**Figure 10. Year 25 Fluid Temperature Profile – 15m Piles**

In addition to the findings above, further variations to the model have shown that, while keeping the cooling load constant, the number and configuration of energy piles initially proposed has the capacity to provide base load heating of up to 40 kWh/m<sup>2</sup>/yr. It may also be shown that three boreholes installed to a depth of 85m each would cover the proposed base load.

## CONCLUSIONS

As one of the most energy dependent states in the EU, Ireland remains in a vulnerable position going forward with global energy prices predicted to rise significantly. Although an increased awareness of renewable energy technologies has developed in recent years, these technologies currently contribute only a small minority of energy requirements.

Further increases in energy prices will likely lead to an increase in domestic ground source energy systems in Ireland due to the good availability of state grant schemes. The current government enthusiasm to provide leading examples in 'new' and sustainable energy technologies as part of any future building projects means that the immediate future of commercially sized systems will likely lie with public/state bodies where longer payback periods may be acceptable.

The provisional feasibility study performed has shown that the proposed energy foundation system is a feasible solution for the planned university building. The next steps of the study will be to confirm exact heating and cooling loads for the building. Improved confidence in the proposed energy foundation design will be achieved by verifying and altering parameters as the building design develops.

## ACKNOWLEDGEMENTS

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