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Briefing: Potential for seawater district heating and cooling in the UK

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The main source of the energy used for space heating in the UK built environment is gas. However, more sustainable and efficient sources could be employed that would not only contribute towards achieving the UK's carbon dioxide targets but would also benefit the nation's energy security. One alternative way of generating energy more efficiently is by the use of heat pumps, of which there are various types depending on the source of the heat and the sink utilised for the heat. One such source is seawater, and examples of seawater heating and cooling systems have been successfully implemented in several parts of the world. Presented here is a comparison of a seawater heating system in The Hague, the Netherlands, and another in Portsmouth continental ferry port, UK. Based on these comparative cases, together with discussions with district heating specialists, this paper briefly debates the current drivers and barriers for the future of seawater heating systems in the UK. It emphasises that as well as the financial and technical obstacles, governance barriers have also to be overcome.

1. Introduction: heat pumps and district heating

District heating is a mature technology, deployed effectively in many northern European countries. It is, however, used little in the UK (Macadam *et al.*, 2008). Currently, district heating coverage of the UK's heating demand is approximately 4%, mainly in hospitals, universities and industrial sites, although it is dwellings that account for 70% of national heat demand and therefore it could be argued should merit closer attention to district heating (Upham and Jones, 2012). The largest district heating system in the UK is in Nottingham, serving around 5000 houses and more than 100 businesses (LGID, 2010).

The main source of space heating in the UK is gas; however, in order to meet national and European carbon dioxide reduction targets, the UK needs to increase its proportion of renewable and more efficient sources of heat. One of the ways of generating energy more efficiently is by the use of heat pumps: rather than actually generating energy, energy is transferred from one source to another, with most of the energy coming from the ambient air, ground or water to which the pump is

connected. The coefficient of performance (COP) of heat pumps typically ranges from 2 to 4. However, in order to achieve any reduction in carbon dioxide emissions compared to space heating by means of gas-fired condensing boilers (for example), COP ideally has to be better than 2.5. If the electricity used is generated from renewable energy sources then heat pumps can be part of a carbon dioxide neutral or saving servicing strategy for providing both heating and cooling to buildings. Heat pumps are characterised depending on the source of the heat and the sink used for the heat. In the heating mode, energy can be extracted from the air, water or ground and delivered to the space by fan-powered air supply or a water circuit (such as underfloor heating or radiators) (Ochsner, 2008).

Seawater heating systems use seawater as the source of energy in order to change the working fluid of a heat pump from a liquid to a vapour state. This vapour is later compressed on the other side of the circuit, causing its pressure and temperature to rise and then, at the third stage, the vapour condenses, releasing its thermal energy to a central heating system that heats space

(NHBC Foundation, 2009). Alternatively, the system can be reversed to provide cooling to the building. However, in seawater systems the relatively cold seawater is often used directly to provide cooling, bypassing the carnot cycle (a cycle of expansion and compression of an idealised reversible heat engine that does work without loss of heat) and thus saving energy.

This paper presents a successful example of a seawater district heating system in The Hague, the Netherlands and discusses the potential of applying similar systems in the UK.

2. Duindorp/Scheveningen, The Hague

The city of The Hague has developed an innovative district heating concept consisting of a seawater central supply unit with a heat exchanger and heat pump unit that uses the nearby sea as a source of heating and cooling. The Hague and Vestia Housing Corporation partnered with Deerns, an engineering consultancy, to implement this energy source in the reconstruction of 800 highly energy-efficient houses located within Duindorp.

The technologies involved are not new: the innovation lies in their combination that allows constructing a very efficient system for making seawater or surface water the source of energy for heating homes as well as heating water all year round (Figure 1) (Stoelinga, 2011).

The seawater heating system extracts seawater and then processes it either by a heat exchanger or a heat pump to supply the entire residential area with space heating and hot water. In summer, when the temperature of seawater is more than 11°C, only the heat exchanger is used. The heat exchanger feeds heated water to the local district heating, drawing enough heat from the seawater to cover residents' needs. In the winter, when the water temperature is less than 4°C (but above 0°C), the heat pump is used. Using electricity, the heat pump works to move thermal energy from the cold source to

Figure 1. Schematic representation of the seawater heating system in The Hague

a warmer heat sink. The ammonia heat pump has an output of 2.7 MW and warms the water to approximately 11°C, which is then fed into the local grid. On reaching each household, the water is further heated by each home's own heat pump to either 65°C for hot water or 45°C for space heating (Figure 2).

A central industrial unit located by the harbour contains both the central heat exchanger and heat pump. Smaller individual heat pumps are installed in each home for additional heating when required.

The overall efficiency of the heat generation process with this system is more than 50% greater than conventional high-efficiency boilers, while the cost to the residents is the same, and the energy yield produced by drawing heat from the sea results in a 50% reduction in carbon dioxide emissions. Similar systems can be installed anywhere close to a large body of water. It would also be cheaper if fresh water was employed, as there

Figure 2. Schematic representation of the temperature inputs in a dual seawater heating system

	Output: kW	Temperature: °C	COP
Reversible heating/cooling heat pump, primary heating system	126	6–50	2.91
Cooling heat pump	134	6–12	3.94

Table 1. Technical specifications of the Portsmouth heat pumps

would be no need to protect the heat pump, heat exchanger and water pumps against salt corrosion (Stoelinga, 2011).

3. Portsmouth ferry terminal, UK

Heating systems using seawater are new in the UK and to date have only been employed in the Portsmouth continental ferry terminal. This £10 million (approximately €11.5 million in February 2013) project was funded by Portsmouth City Council and managed and designed by Halcrow. The first priority of the designers was to maximise the benefit of the climatic setting of the building by adding a series of passive measures, such as increasing the use of natural light and ventilation. Carrying out these passive measures allowed for the other building technologies, such as the seawater source heat pump, to be more effective, as they allowed a reduction in the overall heating and cooling needs.

The major benefit of this system is that the efficiency during the heating season is expected to be approximately five times higher than a traditional boiler and chiller system (Table 1). In addition, seawater can also be used to provide water for flushing the toilets in the new terminal building, thereby reducing potable water consumption (Portsmouth International Port, 2011).

This type of heating was chosen as the new terminal port was aiming for a BREEAM Excellent rating, and this system proved to be the most financially attractive way of achieving

this. Many parts of the UK have the potential for implementing this type of heating and cooling for both dwellings and non-dwellings, not only located on the coast but near any significant mass of water. However, at the moment the technique is still new to the UK and significant barriers exist.

4. Potential of seawater heating in the UK

Technically the systems used in The Hague and in Portsmouth are based on the same principle, although the system in The Hague is a two-stage system, in which the seawater system produces the heat for a low-temperature distribution network that serves as a heat source for the individual heat pumps in each of the 800 connected houses. Portsmouth is a one-stage system that directly provides the heat for just a single building.

The systems are also similar in terms of investment and aims (Table 2).

In order to discuss the seawater heating potential in the UK, a workshop (http://www.ucl.ac.uk/clues/files/hague_report) was held in November 2011 as part of the CLUES (<http://www.ucl.ac.uk/silva/clues>) research project, which brought together UK and Dutch practitioners, policy-makers and consultants to discuss the potential for seawater heating in the UK context, and to identify the main drivers and barriers in implementing seawater district heating in the UK. As can be seen from the workshop results (Table 3), the potential for seawater district heating in the UK has some similarities with the recent experience in The Hague.

5. Drivers for implementing seawater heating system in the UK

The main driver for The Hague was to prove that a 'sustainable Duindorp is possible'. All the main stakeholders had a strong belief in sustainability and faced the challenge of finding a way of heating the houses while emitting as little carbon dioxide as possible. Carbon dioxide reduction is also a common driver in the UK, but is usually stimulated by legal obligations rather than personal or organisational beliefs.

Location	The Hague, the Netherlands	Portsmouth, UK
Date started	1999	2006
Scale	750 houses	Ferry terminal building
Investment	€10 million	£10 million
Funding body and instigating party	Vestia (housing corporation)	Portsmouth City Council
Energy/carbon dioxide reduction	50% of carbon dioxide reduction	Not available
Aim	Sustainability	Profit/sustainability
Main drivers	Sustainability	Financial
Main barriers	Governance/financial	Governance

Table 2. Comparison of the seawater heating/cooling case studies

	Experienced in The Hague, the Netherlands		Potential for implementing in the UK	
	Barriers	Drivers	Barriers	Drivers
Governance	<ul style="list-style-type: none"> ■ Planning permissions ■ Stakeholder drop-out ■ Infrastructure plan conflicted with adjacent area development initiatives 	<ul style="list-style-type: none"> ■ Carbon dioxide reduction ■ Belief in sustainability 	<ul style="list-style-type: none"> ■ Planning permissions ■ Capacity and capability of local governments ■ Lack of qualified labour ■ Lack of government's belief in sustainability ■ Lack of long-term thinking ■ Regulatory uncertainties 	<ul style="list-style-type: none"> ■ Emissions reduction ■ Improved reputation for instigating parties ■ Political ambition
Finance	<ul style="list-style-type: none"> ■ High initial cost of the project ■ Gap in the budget ■ Longer than expected payback period ■ Phasing of the project 	NA	<ul style="list-style-type: none"> ■ High price of sea-based infrastructure ■ Lack of funding 	<ul style="list-style-type: none"> ■ High energy costs ■ Financial savings
Social	<ul style="list-style-type: none"> ■ Resistance to change habits ■ Lack of interest/understanding 	<ul style="list-style-type: none"> ■ Make social housing sustainable ■ Historical link between residential area and the sea 	<ul style="list-style-type: none"> ■ Resistance to change habits ■ Lack of understanding/interest ■ Unwillingness to be tied into district heating ■ Negative publicity about climate change 	<ul style="list-style-type: none"> ■ Publicity and availability of information ■ Locally produced energy as trend ■ Word of mouth ■ Non-financial incentives ■ Fuel poverty
Technical	<ul style="list-style-type: none"> ■ Dealing with seawater: corrosive and fouling 	<ul style="list-style-type: none"> ■ To prove that the system can work ■ Good location for installation ■ Availability of suitable sites 	<ul style="list-style-type: none"> ■ Corrosive nature of seawater ■ Old infrastructure 	<ul style="list-style-type: none"> ■ No limits of scale ■ Location ■ Use in fresh water ■ Flexibility of heat pump use

Table 3. Barriers and drivers for seawater heating systems identified in cross-disciplinary workshop

Improved reputation and sustainable visibility is also an important driver for many in the UK. This was not a driver for The Hague, but after the project was finished, it received both significant media attention and numerous visits, including high-level government officials, improving the reputation of The Hague as a sustainable city.

Although the project had to be made financially feasible, The Hague was not financially driven, but in the UK financial drivers play a significant (and often a primary or overriding) role, particularly if the costs of heating from the seawater system are lower than conventional energy costs and therefore could provide savings for local governments and/or end-users.

Social drivers did not play a critical role: the idea of making sustainable housing was embedded in the project's aim; however,

the end-users were not involved in the project's implementation. Similarly, social aspects in the UK are not usually a key driver regarding the type of energy system, although they are likely to play a more important role in the future due to wider social familiarity and belief in energy efficiency and renewable energy.

6. Barriers to implementing a seawater heating system in the UK

One of the main barriers for The Hague was planning permission, a common experience in the UK. The common critique with obtaining planning permission is the unnecessary level of complexity and the time it takes to obtain permission.

Financial barriers had a negative effect on the implementation of The Hague project. For example, the drop-out of one of

the stakeholders led to a 25% gap in the project budget that was eventually covered by the project owner, Vestia, with some financial support from the city of The Hague. Lack of government support and lack of trust in government are also often seen as common barriers in the UK. Institutions developing energy policies often co-evolve with energy markets and are often likely to be sympathetic to the incumbent energy systems. All this can create inertia, and makes policy instruments not as effective as they could be as they threaten the viability of the existing energy systems.

Social barriers can often affect the operation and efficiency of a system due to lack of understanding and interest in how the technology works, as well as a resistance to change embedded habits – that is, trying new heating systems.

7. Conclusions

There is significant potential for seawater district heating in the UK. It has already been successfully implemented in the Portsmouth ferry port and has proved to be reliable and efficient, as well as financially feasible.

Many of the barriers and drivers currently arising in the UK have already been experienced in The Hague, as well as other locations, thus providing a valuable learning example for potential future systems in the UK. The successful implementation of such systems in the future depends not just on technical capabilities and feasibility but also on other issues such as planning, and stakeholders' personal interests and beliefs, all

of which need to be incorporated and investigated early on for a project to be successful.

REFERENCES

- LGID (Local Government Improvement and Development) (2010) *Nottingham's Warmth from Waste System*. See <http://www.idea.gov.uk/idk/core/page.do?pageId=24413698> (accessed 27/09/2012).
- Macadam J, Davies G, Cox J, Woods P and Turton A (2008) *Potential and Costs of District Heating Networks*. A report for the Department of Energy and Climate Change. DECC, Oxford, UK.
- NHBC Foundation (2009) *A Review of Microgeneration and Renewable Energy Technologies*. IHS BRE Press, Bracknell, UK.
- Ochsner K (2008) *Geothermal Heat Pumps: a Guide for Planning and Installing*. Earthscan, London, UK.
- Portsmouth International Port (2011) *The New Terminal*. See <http://www.portsmouth-port.co.uk/docs/Portsmouth%20International%20Port%20New%20Terminal%20-%20LOWRES2.pdf> (accessed 27/09/2012).
- Stoelinga P (2011) Sea water heating power. *Proceedings of CLUES Workshop, UCL, London*, 23 November. See http://www-staff.lboro.ac.uk/~cvkc2/CLUES_SWH%20workshop_PStoelinga.pdf (accessed 27/09/2012).
- Upham P and Jones C (2012) Don't lock me in: public opinion on the prospective use of waste process heat for district heating. *Applied Energy* **89**(1): 21–29.

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