National Trust

Sustainable technology case study

- 300kW heat pumps use seawater
- Low maintenance conservation heating
- Renewable Energy Investment (REI) Programme
- Renewable Heat Incentive (RHI) programme

Marine source heat pump

Installation of a marine source heat pump

May 2014

Background

Plas Newydd in Anglesey is an 18th century mansion, home of the Marquis of Anglesey, on the edge of the Menai Strait. Owned by the National Trust since 1976, various parts of the building are open to the public. These rooms are equipped with conservation heating requirements only and the operation of the heating system is critical to the conservation of the building and its contents.

The property used an oil boiler which presented the Trust with issues relating to high operating costs, danger of leakage from the 15,000L of oil stored, and decreasing efficiency of the old boiler.

Plas Newydd was using 128,000 litres of oil each year to heat the mansion and was deemed to be the largest oil consuming property in the National Trust. On some winter days, the 18th century mansion consumed about 1,500L of oil a day; the same as a typical house would use in 10 months. This heavy oil consumption resulted in carbon emissions of 217 tonnes a year.

In 2009 the property implemented short term energy efficient improvements such as using smart meters to monitor energy use; roof insulation; energy efficient lighting; draught proofing windows and doors; secondary glazing and staff energy management training. These simple improvements reduced energy consumption by one-third in two years.

In 2010 as part of the National Trust energy strategy, the Trust committed to using 20% less energy, halve fossil fuel use and generate 50% of the energy needs from renewable resources by 2020. Hence in 2011, 50kW solar photovoltaic panels were installed in a nearby field at Plas Newydd. The PV panels produce 45,000kWh per year, which goes towards meeting the electricity demand within the mansion.

Above **Plas Newydd and Menai Strait**

However the property's issues with the oil boiler had not yet been resolved. It took two years of visits, discussions and design workshops to find the most appropriate way of addressing the problems and the conclusion was to replace the oil boilers with a marine source heat pump. The heat pump, extracting heat from the sea water in the Menai Strait, was the best option as it would enable an 80% reduction in carbon emissions and provide conservation-grade heat for the historic building.

The marine source heat pump was installed as part of the 2013 Renewable Energy Investment Programme, which piloted 4 other renewable energy projects making use of hydropower, biomass and heat pumps.

The project

Plas Newydd will be the first National Trust property to install a marine source heat pump and will be one of the largest of its kind in the UK.

The project was completed in collaboration with various organisations including the Bangor School of oceanographic sciences, the Royal National Lifeboat Institution (RNLI), The Crown Estate, Natural Resources Wales, the Environment Agency (EA), the countryside Council for Wales, the Carbon Trust, Anglesey County Council, designers and suppliers.

Following the development of a detailed specification, seabed dive surveys and assessments, together with stakeholder discussions with Natural Resources Wales, Trinity House, and The Crown Estate, it was concluded that an open loop system would be less invasive than leaving closed loop coils on the seabed and therefore more acceptable to statutory bodies and stakeholders.

Various different permits and permissions had to be granted in order for this project to go ahead. The consents consisted of:

Below **Pump-house building being lowered over the cliff**

Right **Divers in the Menai Strait**

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- A bespoke Discharge permit
- Crown Estates temporary works licence as well as easement to place a heat collector in the Menai Straits
- Countryside Council of Wales for the use of the SSSI – temporary works licence and statutory permission
- Environment Agency/Natural resources Wales Method statement approval
- Anglesey Council for statutory planning and listed building consent
- Navigation authority for implication of using the straits, and the updating of coastal navigation charts and almanacs
- Bangor School of Oceanographic Science to undertake all of the Marine survey work
- Detailed seabed diver survey work undertaken
- Welsh Government Marine License temporary works licence and licence to leave pipes in the sea
- Food and Environment Protection Act 1985 (FEPA) license
- Cadw approval for working within a historic listed environment
- Arboricultural and ecological permissions
- District Network Operator agreement to install and upgrade voltage management for the heat pumps within their substation

The installation will pump sea water from the Menai Strait in front of the property, through 53 metre length pipes to and from a heat exchanger on the shore, then up 30m of cliff face to the mansion's boiler house in the Stables block.

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The 300kW heat pump system will replace the two oil boilers in providing conservation heating for the building. It will also remove the need for storing large high-risk oil tanks (15,000L capacity) directly above the Menai Strait, which is a European special area of conservation and SSSI.

Installing the heat pump at the property will greatly reduce carbon emissions by replacing fossil fuels with a sustainable heating source. A further reduction in energy consumption will also occur as the system will implement a more efficient and better controlled heating strategy. Thus the project will provide an exemplar long-term sustainable heating approach for the property which concurrently is low maintenance.

However a small LPG tank will be installed, located to the rear of the Stables within the current gardener's compound area. This will act as both an emergency short-term back up, as well as provide a "top-up" to the heat pumps during extreme weather periods.

With this sustainable heating approach, yearly cost cuts of about £40,000 a year will be made, including cuts on operational costs alongside received payment from the Renewable Heat Incentive (RHI).

Design

Heat pump cycle

Due to the nature of the site with its high and fast moving tides, a hybrid marine source heat pump system was installed. This means that water from the Menai Strait (53m out) is continuously pumped towards the pump house on the shoreline. There the warm seawater (avg temp 6 – 17 degrees C) passes through a large titanium heat exchanger (then returns to the sea) which transfers the small amount of heat to water glycol. The warm glycol is carried through pipes up the cliff face about 30m to the heat pump system in the stable block.

The water glycol is then evaporated in the heat pump; subsequently the gas gets compressed, causing the temperature to rise significantly. A heat exchanger then extracts the heat from the warm gas and transfers it to the mansion's and stable block's hot water system (heating and hot water supply). The gaseous glycol turns back into a liquid after releasing the heat and is further cooled upon expansion. The cool glycol then travels back towards the pump house to be re-heated and the cycle begins again.

Pipework

A series of buried pipes were needed in order to extract the heat from the seawater. All of the new pipe work was completely buried and for the majority of the route followed the existing routes of the sewage pipework from the Stables to the foreshore; and the heat main from the Stables to the mansion house to ensure works were carried out within previously disturbed ground.

4 external mains pipes which had entered/exited the stable block plant room were replaced. 2 sets of pipes from the Stables to the foreshore were put in. The first connected the water supply in the plant room with the pump house. These pipes were 25mm diameter medium density polyethylene (MDPE) for the mains cold water service (MCWS). The other set of pipes was laid between the boiler house and the pump house. These consisted of 2 high density polyethylene (HDPE) pipes of 160mm diameter, with electro-fusion joints.

These 2 sets of pipes were insulated where they ran alongside buildings in order to minimise the risk of freezing induced heave. The pipes were buried in a 1200mm deep trench and bedded in sand blinding. To reduce the pumping energy requirement in the pipes, an intermittent carrier (water glycol) in a closed circuit was supplemented.

Pipes were also laid from the heat pumps in the Stables building down to the house. 110mm diameter pre-insulating pipes were used for these heating mains.

Intake and discharge pipes were extended into the Menai Strait. These pipes were also HDPE pipes, with an outside diameter of 200mm. HDPE was chosen since its chemically inert and marine growth finds it difficult to stick to, minimising internal pipe cleaning. These pipes were capped with a precast concrete trough and an additional ballast.

Bottom left **Pump house and pipes running up the cliff**

Bottom right **Pump-house building successfully lowered over the cliff and set into position**

Stable block

Minimal interruption to the landscape was again necessary when considering the location for the heat pumps as the landscape around the mansion house is very sensitive, encompassing a Grade I listed Humphrey Repton design. The heat pumps were housed in the already existing boiler house (in the stable block) to reuse the existing space and infrastructure.

A heat pump manager was also installed in a cabinet in the stables building to ensure constant heating water is provided at 60 degrees C. The heat pump manager facilitates the sequencing of the heat pumps to prevent more than one starting at any one time so that an electrical 'soft start' is always maintained.

The heat pumps are partly powered by a 50 kW system of photovoltaic panels, located in a field on the property. The PV system is directly connected to the old stables at Plas Newydd providing 45,000kWh per year. The rest of the electricity necessary to power the system is imported from the National grid.

Design

Pump house

A new pump house holding the titanium heat exchanger was craned onto the shoreline. Studies were conducted to ensure that it too would keep its visual impact to a minimum. Consequently it was built at low level, set back against an indent in the cliff base on the marine causeway. This location added the advantage of reducing the pump house's visual impact from the seaside.

Furthermore, following advice from a Ynys Mon planning representative and consultation with the NT's Architectural Panel, it was decided that the pump house structure would be black.

The pump house is water tight to a level of 1.4m above base level (4.8m above the ordinance datum). It was constructed in fibreglass to ensure this water-tightness and also so it has sufficient volume to act as a bund to prevent any leakages into the Strait. The building was also designed to be flood proof to minimise structural damage in the event of a flood but also to be able to be quickly returned to use in the aftermath.

Access

The design of the pump house also had to take into account the issues of access for operation and maintenance purposes. A marine walkway from the front of the mansion (via a locked access gate), along the foreshore provided a good existing route to the pump house structure. Only authorised access by staff and service engineers is allowed to the pump house, with access only being arranged once tidal charts/ conditions had been assessed.

However repairs had to be carried out to the marine walkway to ensure that rapid and safe access and egress could be made at all times.

Cost

Funding

- Internal – the project was part of the Renewable Energy Investment program

Programme

- Total project budget: approximately £600,000

Breakdown of costs:

- Equipment: 43%
- Installation: 51%
- Fees and extras: 6%
- **Total: Approximately £580,000**

On-going life-cycle costs

- Approximately £3,000 per annum

Left **Pump house in the back ground - sea Water main pipes installed on rubber matting and bolted down on to the bed rock**

Below **Setting concrete block on top of the pipes running into the sea**

Carbon reduction

The project will significantly decrease the CO_2 produced at Plas Newydd. The previous use of oil at the site accounted for 217 tonnes CO_2 annually. Instead, the imported electricity used to run the heat pump uses 52 tonnes of CO_2. The removal of oil from the site thus accounts for savings of 165 tonnes of CO_2 each year.

Another important factor is the reduction in environmental risks arising from storing oil onsite.

Review

Performance

The project was a great success and shows that highly designated sites (Grade I listed parkland, Grade I and II* listed buildings, a SAM, SAC, AONB, SSSI) can all have a part to play in delivering a fossil fuel free future. Furthermore, it only took 16 weeks to deliver the project, from the point of starting on site.

The system is performing better than expected:

- Gross Coefficient of Performance (COP) 4.03
- Nett COP 3.78
- Seasonal Performance Factor (SPF) 2.8

The system provides 100% of the property and tenant's heating and hot water and has generated 626MWH of in-hand heat and hot water requirement in its first year of operation.

The system has also proved easy to operate, particularly since full handover training was incorporated into the contract and delivered.

The marine source heat pump has saved the National Trust £40,000 per annum in operating costs at the property; money which will be fed back into conservation. With the addition of the RHI payment, this should see a payback period of less than 7 years.

The system has received both national and international attention and has been awarded external recognition both within the industry as well as the heritage sector. The project has won the Wales Green Energy Award for Outstanding Renewable Energy Project in 2014 and both the Business Green Leaders Award for Outstanding Project of the Year and best Property Retrofit at the 2Degrees Awards in 2015.

Many island and coastal communities are showing interest in learning, researching and emulating the project. The project team are also being approached by NGO's and organisations across the UK who are looking to replicate the project. This has achieved one of the visions for the project, sharing information and proving the project's 'repeatability'.

Left **Completed buried pipes in the Menai Strait**

Review

Energy generation/savings

In a 12 month period, the heat pump has only used 130 MWh of imported electrical input to generate 626 MWh of heat and hot water. During this period the photovoltaic system generated 45 MWh, feeding directly into the requirement of the heat pump.

Monthly generation and performance data is provided by property staff via a meter monitoring system so that a documented monthly evaluation of actual performance against anticipated can be made. The environmental practices team carry out these monthly comparisons and highlight any anomalies to relevant project boards and groups as well as property staff and contractors who can action efficiency rectification works if required.

Maintenance

A Full Service Level Agreement is in place for a two year period. This also includes remote monitoring of the pumps and controls on the foreshore, as well as standard emergency and servicing processes.

There was an initial key staff training day, which was followed up with a further day on site once staff had had the opportunity to live with the system. Due to changes of staff at the property there is a further training period arranged which is being supported by the regional Environmental Practices Advisor (EPA). This is to ensure that all understand the design and conservation settings to achieve the most efficient meeting of our conservation requirements within Plas Newydd.

Engagement

In 2014, the biggest story in the National Trust was the switch-on of this marine source heat pump at Plas Newydd. This gained 27 national pieces (print, broadcast and national online) and had an opportunity to see (OTS) of more than 80.5 million people.

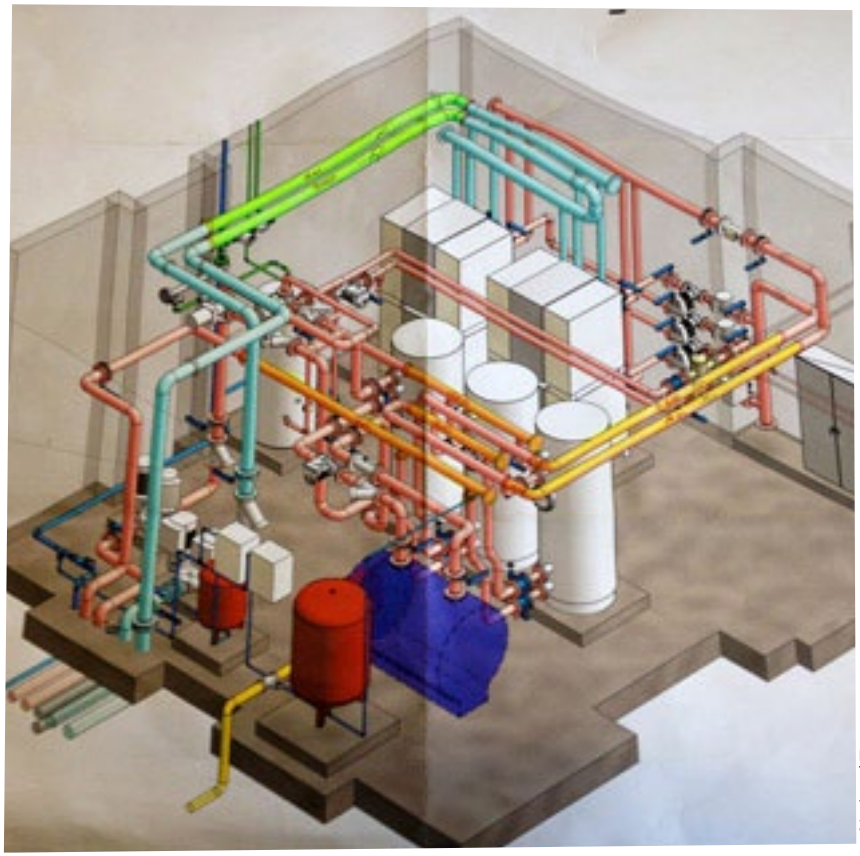
The project entailed a programme of open days and site visits to ensure a full understanding of this type of project. Visitors as well as volunteers benefitted from these open days and proved to be 'on board'. An educational 'green living trail' sheet was also produced at the property for children.

Lessons learnt

The LPG 'winter peak' boiler required adjustments to the burner ratios following the changes in gas supply legislation mid-project. This has meant that the point where the gas pipe supply connects above the ground had to be replaced with plastic rather than the steel that was originally installed. The contractor carried out this work at no additional cost, and the system has been re-commissioned.

Once operational it was found that the domestic hot water vessel from the stables block was not large enough. A replacement larger expansion vessel had to be installed, again at no additional cost to the National Trust.

As this was a unique type of heating project, the design calculations could only project the performance of the heat pumps within an older building, and the effects of the distribution and electrical loadings required.



Above **3D schematic of new boiler room**

Review

Future plans

Monitoring

Following the project completion the project manager/EPA will continue to work closely with the property to ensure that the heating system is operating as efficiently as possible.

There will be ongoing performance monitoring by the regional EPA, as well as the main contractor and the design team. This will ensure the most efficient heating system is maintained at the property. Monitoring will be ongoing with the contractor and designers for a year post project to ensure that the system is operating as efficiently as calculated.

The monitoring will take into account:

- Electrical usage (power required to run the heat pumps) factoring in the on-site generation from the 50kW photovoltaic system
- Offsetting of oil purchases
- Heat meter readings
- Seasonal sea temperature data and external air temperatures
- Electrical loading required to run circulation pumps and ancillary systems
- Coefficient of Performance
- Seasonal Performance

The tendering process had required the contractor to calculate the annual performance of the system both in terms of COP of the heat pumps themselves, together with SPF in order to formulate a baseline for monitoring actual system performance following commissioning.

An annual review will additionally be completed as part of the Wales Environment Management System review process. An independent external review is also completed in line with the requirements of "The Green Dragon Environmental Standard: 2006" and also BS EN ISO14001. Quarterly submissions of performance are made to Ofgem by the Environmental Practices team and regional business support.

Associated works

Improvements had been made during the project to the marine walk. The improvements and a report created on site are being used to specify the requirements for further reinstatement works to extend the marine walk. The property is still deciding whether or not to progress these works, however the property would benefit from a refurbished marine walkway as it could be used for tours to see both the heat pump building and the nearby caves.

These archaeologically significant caves were discovered on the seashore during the project. The discovery is being investigated further by a regional archaeologist.

Top right **Three buffer vessels and their accompanying pipe work**

Bottom right **Old oil boiler**

Review

Recommendations

Keep the project team small and dedicated with a strong decisive regional project board. Intimate knowledge of the property, personalities and statutory bodies helped greatly.

Take time at the design stage to address concerns, listen to the thoughts of not only property staff, but volunteers – as their 'buy-in' and engagement was critical to the smooth delivery of the project. Property buy-in ensured a smooth delivery programme.

The myriad of 16 statutory permits and permissions could potentially have delayed the project. In fact, everybody concerned engaged fully with the scheme and saw the benefit to ensuring a speedy granting of permissions.

The project delivery team identified an opportunity to incorporate gate valve controls based on the humidity needs of the cellars and monument rooms/medieval cellars at the property. This also assisted with increasing the performance and efficiency of the overall system, and delivered it within the original contractor's costings.

Contact

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Left **Educational 'green living trail' map**

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Appendix

Schematic of the heat pump structure