Edward Williams and Laura Carrara-Cagni in Conversation with Chris Davidson, Chief Technical Officer, Genius Energy Lab, UK

Summer 2023

Heat pumps are a relatively new technology for most people, and certainly for home owners, but are a really good technology in terms of using energy efficiently for heating (and cooling) our buildings. If chosen, most people tend to opt for Air Source Heat Pumps (ASHP) rather than Ground Source Heat Pumps (GSHP) for a variety of reasons. As part of our "In conversation with" series we explore some of the pros and cons of selecting ground source heat pumps with Chris Davidson, the Chairman and CTO of Genius Energy Lab.

Chris has a first-class honours degree in Theoretical Physics from Imperial College London, has worked in the heat pump industry since 2001 and has been involved in the design and implementation of over 750 MW of installed capacity in Europe and North America. He has been responsible for some of the most innovative GSHP systems and ground collectors globally such as One New Change in London where he pioneered energy piles in the foundations coupled with open loop water wells to achieve maximum efficiency for the system.

As an active member of the Association for Decentralised Energy and Chair of the Policy Development Committee at the Ground Source Heat Pump Association, Chris plays a key role in shaping UK energy policy via government access.

EW/LCC: In terms of mechanical systems, particularly in domestic settings, do you believe GSHP is disruptive compared to other options? Why? Can GSHP be used in high-density urban areas?
CD: Absolutely, GSHPs are highly suitable for high-density urban locations. The majority of our projects have been implemented in urban areas. In terms of internal disruption, both air source and ground source systems are similar. However, air source systems require an external box, while ground source systems require boreholes for vertical pipe systems (which take up less space) or a field for horizontal pipe systems.
In retrofit especially, the design of ground source heat pumps requires accurate heat loss calculations, assessment of existing distribution systems, and careful interface design. We do handle a significant amount of social housing work, which often involves poorly built and maintained structures, necessitating precise systems assessment.

EW/LCC: What is the payback period for GSHP installations, and what government grants are available? How do these incentives influence clients?
CD: Currently, there is only one government grant available, the Boiler Upgrade Scheme (https://www.find-government-grants.service.gov.uk/grants/boiler-upgrade-scheme). This scheme provides £5,000 for conversion to air source heat pumps (ASHP) and £6,000 for conversion to ground source heat pumps (GSHP). However, the second grant is seriously inadequate as it does not reflect the long-term value created by the infrastructure provided.
The external box of ASHPs typically lasts 10-15 years since it is exposed to the elements, while GSHPs have a much longer asset life of approximately 140 years or more. The internal equipment of ground source systems usually lasts around 20-25 years.
The payback period for ground source heat pump installations is currently estimated to be between 10 to 20 years when compared to gas systems. Although air source heat pumps are cheaper to install, they are more expensive to run and require more frequent equipment replacement. In terms of total cost of ownership (including installation, running costs, and equipment replacement), GSHP systems work out at half the cost of ASHP systems after around 10 years. It's important to note that sustainable electricity costs are currently artificially high due to the Merit order system, which allows the most expensive electricity generation (usually gas) to set the price every half hour .(https://www.goodenergy.co.uk/blog/why-does-the-price-of-gas-drive-electricity-prices-including-renewables/). Once this system is reformed, the payback periods will significantly reduce.

EW/LCC: How applicable are GSHP systems to retrofits and old buildings?
CD: The UK Government-funded Electrification of Heat project (https://es.catapult.org.uk/news/electrification-of-heat-trial-finds-heat-pumps-suitable-for-all-housing-types/) concluded that no housing building type or architectural era is unsuitable for a heat pump. However, more complex buildings require accurate assessments of heat losses and meticulous installation, particularly regarding distribution systems and controls.
Heat Pump systems cannot be designed or operated in the same way as traditional gas boiler systems. Instead of turning the heat pump system on and off on demand, the heat pump systems must be kept running continuously to maintain consistent building fabric temperatures. Controls and set-backs are used to manage low and high demand periods, ensuring energy usage is maximized, as heat pumps generate hot water at the same temperature as gas, but at high temperature they use more electricity. For retrofits and old buildings, an accurate room-by-room assessment helps size the system for minimum temperatures, optimizing energy usage.

For instance, in schools, when they shut down for Christmas, the caretaker would typically turn off the heating. However, with Heat Pumps, it would take several days to bring the building back to a comfortable temperature when the school term resumes. In such cases, a User Set Back, which reduces the temperature to around 14-15 degrees, is recommended. This approach keeps the system running, using less energy, reducing heat losses, and minimizing warm-up time when the term restarts.
The system needs to supply water temperature normally at 35 degrees for underfloor heating, and 65 degrees for domestic hot water, and everything in between is a blend. In domestic settings, underfloor heating is the most suitable system for GSHP. In public buildings, fan coils, air handling systems, and high thermal mass systems are equally efficient.

EW/LCC: Is GSHP the most sustainable solution for all sectors? What about healthcare? Can GSHP work for large general and acute hospitals?
CD: Yes, GSHP systems are applicable to buildings across all sectors. Very few building types are unsuitable for heat pumps, with the exception of facilities like outdoor pools. Large buildings, in particular, benefit from GSHP systems due to the economy of scale they provide. Additionally, GSHP systems free up significant space on the ground floor as most of the equipment is placed underground.
Designing GSHP systems for hospitals is not as complicated as some might think. Prisons, with their higher resilience requirements, are actually more challenging. In prisons it is crucial to ensure the heating systems function properly. As soon as people perceive the heating doesn't work, it can lead to unrest.

EW/LCC: Can rivers and the sea be used for GSHP systems?
CD: Indeed but surface water may not be the ideal solution in every location. We had a client on the island of Iona off the West of Scotland who initially requested a sea water open system. After considering both surface water and boreholes, we ended up installing boreholes due to significant maintenance issues associated with using untreated sea water. Open loop systems that use untreated water from the sea or rivers come with considerable maintenance costs. A good rule is to use closed loop systems whenever possible.

EW/LCC: What happens to the gases used in the GSHP system?
CD: There is a movement towards using natural refrigerants, particularly as the government is introducing stringent regulations concerning gas maintenance and zero emissions in disposal. However, once the GSHP system is installed, the box is sealed, and there is no further activity related to the gases, so it is not a major concern for designers or owners.

EW/LCC: What is the key energy advantage of GSHP over ASHP?
CD: In terms of native efficiency, GSHP is twice as efficient as ASHP. GSHP systems also have additional subtle advantages due to their underground installation and the ability to use off-peak energy tariffs. ASHP systems can be affected by the defrost cycle (where the heat exchange coils need to be defrosted) which reduces their efficiency, particularly in the UK's maritime climate.
As a rule of thumb, GSHP systems have a seasonal coefficient of performance (SCOP) of around 1:4 to 1:5, while ASHP systems have a SCOP of approximately 1:2 to 1:2.2. SCOP is a more accurate measure than the coefficient of performance (COP) as it considers seasonal variations throughout the year. To provide a reference point, a well-installed gas boiler typically has an SCOP of 0.9.

EW/LCC: What is an open-loop GSHP system, and is it suitable?
CD: In an open-loop GSHP system, water is sourced from the environment, such as the ground, sea, or river. This water is untreated, although groundwater from an aquifer can be very clean. For open-loop systems using more than 20 cubic meters of water per day, a statutory environmental permit from the Environment Agency in the UK is required, which usually takes about a year to get. Open-loop systems can be suitable if the location has access to an appropriate aquifer.

EW/LCC: What are the next-generation technical developments in the GSHP field? What do you see in the future?
CD: We are witnessing both technical and commercial developments in the GSHP field. From a commercial perspective, there is increasing interest in third-party ownership of ground loops, especially on a larger scale. These systems are highly efficient and benefit from the balanced use of heating and cooling. Refrigeration is incorporated into a communal ground loop, creating district-wide ground source systems with mixed loads, such as heating and cooling for supermarkets or offices combined with heating for domestic use.
We are also seeing the development of different network configurations, such as town borehole networks. For example, Kensa Heat Pumps in Cornwall (https://www.kensaheatpumps.com), is creating in Stithians, Cornwall, UK a town borehole network where people can tap into a shared system, benefiting from the network's diversity and resulting in more efficient SCOP. These networks are even more effective if heat recovery is incorporated.
The financial model involves a pension fund making the investment and forming an energy company that bills the homes accessing the ground loop. This long-term investment works well for pension funds, and the heat can be metered or charged based on factors like the number of rooms. In smaller towns, if around 40% of residents express interest, the investment can be financially viable.

EW/LCC: Is there something in development that could be comparable to GSHP but easier and cheaper to install?
CD: The combination of solar and ground source heat pumps is a promising solution, particularly when solar thermal is connected to recharge the ground loop and warm it up. Additionally, cooling the PV panels enhances their efficiency.
The future is in deeper and fewer boreholes. Conventional depths of 100-300 meters are being pushed to 800-2000 meters, which is more expensive but provides greater benefits. For example, 20 boreholes of 200 meters each could be replaced by a single 2000-meter borehole, resulting in significant cost savings. Deeper boreholes provide access to additional heat, with approximately 2 degrees gained for every 100 meters drilled in the UK. Deeper boreholes have a larger diameter and are based on a coaxial pipe design rather than a simple hairpin loop like shallower boreholes.
Dropping boreholes in the road network, around 200 meters deep with 12-meter spacing, can efficiently heat houses on both sides of the road. The ease and cost-effectiveness of installation are improved with market scale, making production and installation more efficient.

EW/LCC: What aspects should attract more attention for future development and investment?
CD: The development and investment in GSHP systems should focus on the aspects mentioned earlier, such as the commercial viability of third-party ownership of ground loops and the potential of town borehole networks. Also the combination of solar and ground source systems

holds promise, along with the exploration of deeper boreholes for enhanced heat extraction. These areas offer significant opportunities for future development and investment.

EW/LCC: Thank you for providing such detailed insights into GSHP systems and their potential. Is there anything else you would like to add?
CD: I think we've covered most of the important aspects of GSHP systems. However, it's worth mentioning that installing GSHP systems on a house-by-house basis can be expensive. While it is done in special cases, such as high-end projects or when planning requirements or electric supply necessitate it, scaling up the installations significantly improves efficiency and cost-effectiveness. We particularly enjoy designing GSHP systems for hospitals, and Colin Page at AECOM is a strong advocate for our work in this area.
Kensa conducted a study on social housing, funded by L&G and another major institution, with plans to cover 40,000 units within a year. Overall, I am responsible for overseeing 750 megawatts of successful GSHP installations. When problems arise, they are typically related to controls, distribution systems, or the presence of air in the system. Design problems are less common, as we have a thorough process and a highly skilled team.