Data centres: time to look down

As global demand for data ramps up, we look at industry efforts to persuade governments and data centre operators to look to the underground for storage space. By Kristina Smith

Those watching tech trends for 2023 will have seen much talk about a boom in artificial intelligence (AI), after the excitement about conversational chatbot ChatGPT, launched in November last year. Big players, such as Microsoft, have downed tools on new data centre developments, while they work out what the impact on design will be, since AI needs huge amounts of computational power – and the associated cooling.

Closer to home, construction's use of Internet of Things (IoT), robotics and machine learning – as well as AI – all lead to the same thing: lots more data.

As our use of data burgeons, so does our need for data centres to store it in. The challenge is that these data centres require energy, both to run their hardware and to cool that hardware, significant amounts of water for cooling, and land, sometimes close to city centres, where space is both precious and costly.

One solution is to go underground, freeing up land at ground level for other uses and potentially reducing energy demands for cooling. A pilot project run by the Swiss Centre for Applied Underground Technology (SCAUT) is demonstrating how that could work – with some clever ideas about how the waste heat created by data centres could be used for other purposes.

"Using space underground can work very well from an urban point of view," says Veronika Petschen, managing director of SCAUT. "It can free up space in a crowded city centre or help to retain or create more green space."

There are already a few underground data centres to prove the concept. ITACUS, the International Tunnelling and Underground Space Association's (ITA)'s Committee on Underground Space has just jointly published a detailed case study with the United Nations (UN) about an existing underground data centre in Finland's capital Helsinki (see box).

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Switzerland where many were created for protection during the World Wars, it could be an option to create data centres there," says Antonia Cornaro, co-chair of ITACUS and underground space expert at Amberg Engineering. "It is the same for some mines."

Yes to data, no to data centres

According to the International Energy Agency (IEA), the number of internet users has more than doubled since 2010 and global internet traffic has increased by 20 times. There are over 8,000 data centres around the world, (source: US International Trade Commission), which the IEA says are responsible for nearly 1% of all energy-related carbon emissions.

Forecasters are predicting huge growth in the sector. Research and Markets, for example, said in October 2022 that the data centre market will grow by 73% between the end of 2026 and the end of 2026.

The challenge is that although everyone wants data, not everybody wants a data centre nearby. Data centres, which tend to be concentrated in clusters, can put a strain on power supplies and there is concern over their water use, particularly in areas that are experiencing increasing periods of drought. They also take up large areas of land while providing few new jobs.

In European countries such as the Netherlands and in some US states, people have protested against new data centres because they feel that they are taking energy which should be for them. In London, the Greater London Authority turned down three housing planning applications because it said there wasn't enough power capacity due to all the data centres there.

With carbon reduction goals looming, and negative public sentiment in some locations, the threat of legislation is on the horizon. The EU, for instance, has suggested that data centres may be assessed and energy rated in a similar way to domestic appliances.

With all these factors in mind, it's not surprising that data centre providers are looking for ways to reduce their energy consumption – and their carbon footprints. Which is why now could be the perfect time to talk about the possibilities offered by underground space.

Veronica Petschen and Antonia Cornaro

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At the Edge

The idea for a demonstration data centre underground came from the project's two initial consortium partners, Datwyler IT Infra, which supplies racks for data centres and Amberg Engineering which designs caverns and other underground structures. The pilot was built in 2019 in the Hagerbach Test Gallery in Switzerland. The other partners of the project are SCAUT, geothermal energy consultancy Geoeg and Siemens.

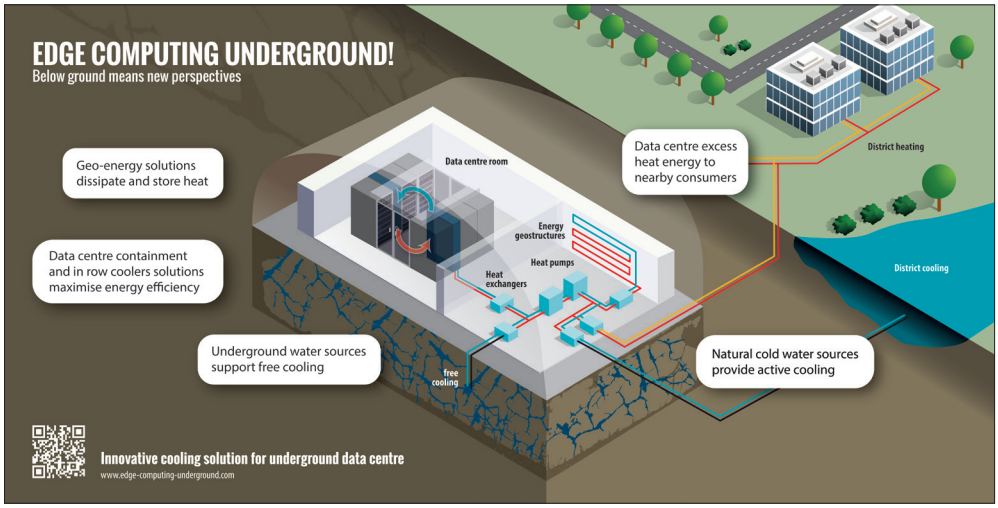
Built using a modular scalable concept, with 50 sq m of floor space, a capacity of 40KW and 50 servers accommodated in six racks, the centre would be an ideal size for an edge data centre. Cooling for the facility could come from nearby natural water supplies with excess heat being taken away to heat nearby buildings.

Edge data centres tend to be smaller capacity facilities located close to where data is generated and used and where fast processing and low latency are needed. They are often sighted close to city centres, but might be needed near automated manufacturing facilities too, explains Petschen:

"When you are just working on a computer the latency time is good enough but in some industrial applications you need the fastest possible times because a delay could cause problems . That's why this real time data has to be processed very quickly and the relevant information sent back very quickly. That means you need to process the data very fast locally."

A data centre such as the SCAUT prototype could be located in disused underground space beneath a city, such as tunnels or stations that are no longer used. Or space could be added to designs for new metro systems or utility tunnels and underground space. There is also a possibility that data centres could use green energy from the ground, in the form of cool ground water, says Petschen.

The SCAUT data centre isn't operational, but instead serves as a physical illustration of what could be possible and as a talking point. There has been interest from



government bodies from Hong Kong and Singapore, where land is in short supply, and also from some private sector developers and data centre operators, says Cornaro.

Decisions to locate more services and facilities underground need to be taken at a national level, says Cornaro. "Urban planners and the bigger infrastructure owners need to think about options when they are planning infrastructure and the use of underground space," she says. "That's why I am really happy that governments are interested because it has to be decided in the early phases of planning. Underground space should be planned and designed to provide more than one use at once, and the construction for all the uses combined."

Lettuce and a sleepover

In the spirit of circularity, SCAUT is looking to combine its Edge Computing Underground project with others that are underway or planned. "The idea of SCAUT is always to think in circuits, think about how we could make the link amongst our projects," says Petschen.

One suggestion would be to use the waste heat from the data centre to heat underground farms. This would work well, says Petschen, since the temperature underground is already around 15 degrees C, so only a little more heat would be required.

SCAUT already has such a project running, again in the Hagerbach Gallery: an aquaponics system where water is used in ponds to grow trout, fed into a hydroponics system for growing water and then back to the fish ponds.

Another idea, says Cornaro, would be to have an underground hotel, heated by the residual data centre heat, where guests could eat trout and salad vegetables from the farm. "In the beginning, it would be on an experimental basis," she says. "We feel there is a demand for people to have a special experience. They like staying in igloos, mountain cabins or tree houses, why not in a cave hotel underground?"

Transferring heat from data centres to district heating systems is already a well-established practice, commonly in countries where the district heating infrastructure already exists. However, some countries, such as the Netherlands, are building new infrastructure so that the heat from data centres does not go to waste.

Transferring heat from data centres to homes also lowers the operational carbon footprint of the data centre, so experts are expecting a surge of such schemes over the next few years. Amazon, Apple and Microsoft are among the companies that are looking at

UN leads call for underground data centres

December 2022 saw the publication of a case study about an underground data centre in Helsinki, Finland, by the Sustainable Infrastructure Partnership (SIP), part of the United Nations Environment Programme. The case study was jointly published with ITACUS - the ITA's Committee of Underground Space (ITACUS), which Antonia Cornaro, expert in underground space at Amberg Engineering, co-chairs with Han Admiraal, managing director of Enprodes Management Consultancy.

The case study, 'Use of underground space for resource-efficient data centres in Helskinki, Finland', was chosen by SIP to illustrate one of its ten guiding principles: resource efficiency and circularity. For ITACUS, and for the tunnelling industry, this is a great success story because it communicates the value of underground space to governments, development banks and other investors around the world.

The underground data centre in Helsinki is located in an old bomb shelter beneath the city's cathedral, mined out of the granite on which the city sits. Finish IT company Academica and publicly owned energy company Helsingin Energia installed servers with a 2MW capacity in the bunker, using water from the Baltic Sea to cool them. The heat removed from the servers is then transferred into a district heating facility, heating 500 homes.

It's not an approach that would work everywhere. Helsinki is blessed with granite and has located many facilities underground. It was also the first place to create an underground masterplan back in 2011 to plan and control underground development.

Although that data centre has been running since 2010, it has not been replicated yet. However other data centre providers have used the combined sea water cooling and district heating approach. Finland is promoting itself as a good destination for data centre operators who are keen to reduce their carbon footprints with the combination of sea cooling and district heating.

Read the report here https://d1bf23g64f8xve.cloudfront.net/sites/default/files/downloads/best-practices/Finland%20Principle%205%20SI%20case%20study.pdf

projects in Ireland, Denmark and Finland.

Looking ahead, existing underground space offers great opportunities for energy storage. Some of the big hyperscale data centre operators, such as Microsoft, are already looking at using battery storage rather than standby diesel generators as their back-up power. The idea is that these batteries could be connected to the national energy grid so that they could store electricity produced by renewable energy, encouraging investment in more renewable energy.

Underground space could also be used for storing energy. For instance, using compressed air, green hydrogen, hot or cold water, or hot sand which could then be stored in underground caverns or tanks. This is something that will be investigated in a Hagerbach project the Subspace Energy Hub, involving Normet, SCAUT, Xerotech, Amberg Group, Alumina Battery Systems, Fortescue Future Industries and Motics.

Yet another new project at the Hagerbach gallery – led by ETH Zurich with Paul Scherrer Institute, the University of Applied Sciences OST, SwissGeoPower, Amberg Group, Basler & Hofmann, Kibag/Geotherm and Sika – is looking into creating energy using a technique it calls Advanced Geothermal Systems (AGS) – which involves boreholes up to 10km deep and a technique called plasma pulse geo drilling.

"Up until now, fracking technology had to be used, with all the issues that can bring but this new technology melts the rock rather than splitting it which is more cost effective and doesn't cause vibrations or 'earthquakes'," says Petschen

Difficult sell

There are already several operational data centres around the world which make use of existing underground space. In the US, there are several located in disused limestone mines, such as Iron Mountain's WP-1 centre in Western Pennsylvania or SubTropolis in Kansas City. The Lefdal Mine in Norway, sometimes billed as Europe's greenest data centre, uses fjord water for cooling and renewable energy from hydropower. Other data centres are located in former bunkers, or in the case of Green Mountain Data Centers' DC1-Stavanger, in a former high-security NATO ammunition store inside a mountain.

Aside from freeing up of ground level space and reducing energy needs, there are other advantages to locating a data centre underground. Depending on the ground, less material may be needed to construct the facility, reducing embodied carbon; traditional data centre design typically involves a lot of concrete with its high carbon footprint. Physical security can be significantly better as can resilience in areas prone to tornados or hurricanes.

In general, though, it's difficult to make the case for underground data centres, says Cornaro. Amberg Engineering carried out a cost comparison of developing a data centre above and below ground in for a client and found that the costs were comparable. However, it would have required several elements of a data centre building to be redesigned. "The subsurface scheme would have required some reconfiguration and a change of mindset," says Cornaro. "For instance, the cooling system requires a complete rethink."

Perhaps if a few companies make a move underground with relatively small edge facilities like the SCAUT prototype, they will be more likely to consider underground space elsewhere.

"In Hong Kong and Singapore they are more willing to go underground because of the scarcity of space," says Cornaro. "But we should not wait until we're running out of space in other places too. We all know we're supposed to reduce carbon emissions and energy consumption. This solution enables that."

Underground farms

SCAUT's Underground Green Farming prototype at the Hagerbach Gallery isn't the only place where vegetables are being grown in unexpected places.

At Sangdo Station on the Seoul metro, there is a small, experimental farm, being run by salad vegetable farmer Farm8. Farm8 is also trialling three cafes underground on the metro system, where the produce from the underground farm can be eaten and children can learn about how the vegetables are is grown.

In London, Zero Carbon Farms has been operating its underground farm in a disused World War II air raid shelter, 22m below Clapham since 2017. The company says that it uses 100% renewable energy for its LED lighting and 70% less water than traditional outdoor farming. It also only supplies to business within a 5-mile radius.

Although they use less water than traditional farming, and according to these companies produce vegetables with higher nutritional value in a shorter time and in a smaller area, underground farms do require more energy for lighting and heating. Using waste energy from data centres, or geothermal energy extracted from underground could be a neat and sustainable solution.