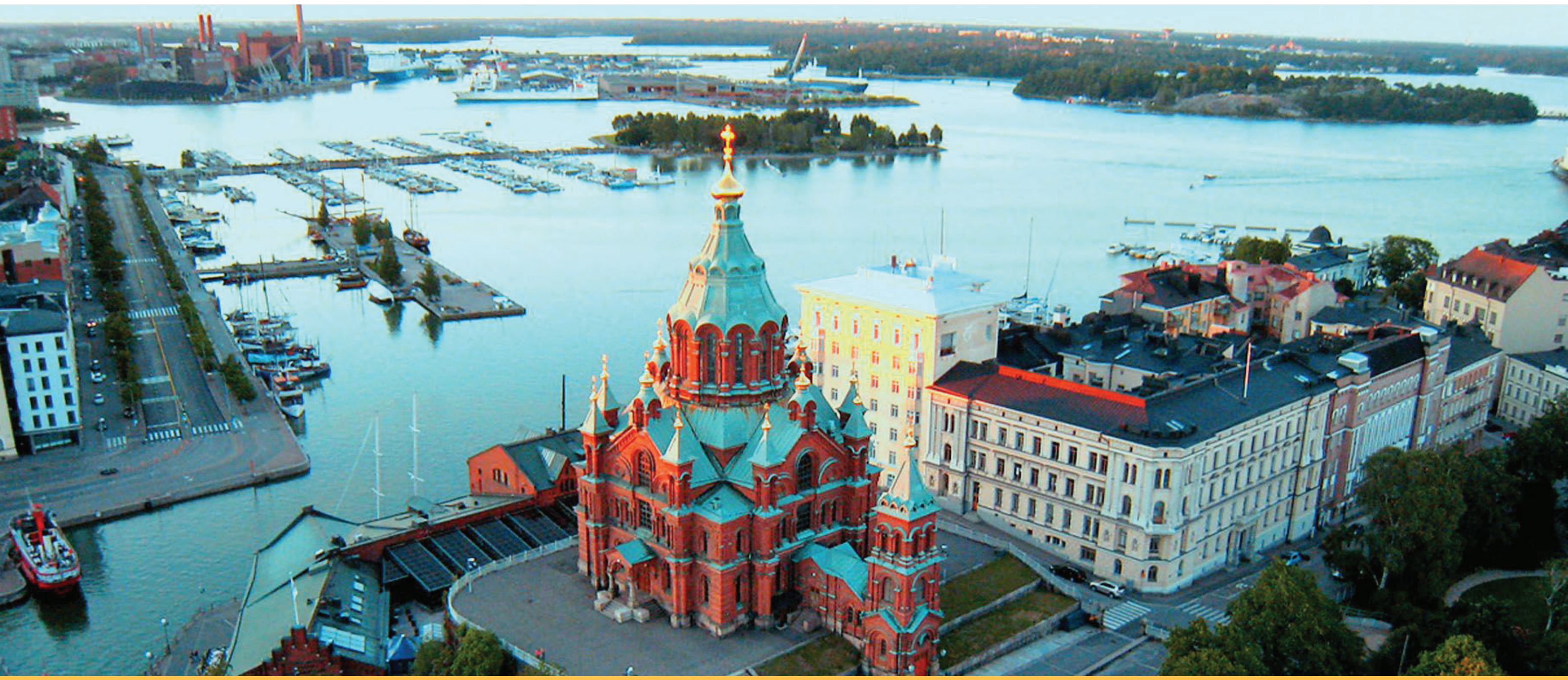

THE USPENSKI CATHEDRAL IN HELSINKI, FINLAND ©Jeremy Williams

FINLAND

USE OF UNDERGROUND SPACES FOR RESOURCE-EFFICIENT DATA CENTRES IN HELSINKI, FINLAND

The International Good Practice Principles for Sustainable Infrastructure

set out ten guiding principles that policymakers can follow to help integrate sustainability into infrastructure planning and delivery. They are focused on integrated approaches and systems-level interventions that governments can make to create an enabling environment for sustainable infrastructure. This case study illustrates specific aspects of one principle in a country context, showing good practices and challenges, and considering potential for advancement or replicability.

GUIDING PRINCIPLE 5: RESOURCE EFFICIENCY AND CIRCULARITY

Circularity and the use of sustainable technologies and construction materials should be planned and designed into infrastructure systems to minimize their footprints and reduce emissions, waste and other pollutants.

BACKGROUND

Helsinki is the capital city of Finland and serves as a leading seaport and industrial city in the country. Over time, Helsinki has expanded as an important centre for trade, industry and culture, and today it is home to over 1.3 million people (World Population Review 2022). To control the development of infrastructure and reduce natural resource use, Helsinki adopted principles of circularity by repurposing pre-existing underground tunnels and caverns. This was a part of a broader strategy to expand the use, planning and management of the underground. The city's bedrock – composed of Precambrian rock albeit with several fracture zones – is ideal for tunnelling and developing underground spaces in most parts of the city.

Helsinki began excavating tunnels in the 1960s to lay down power lines, sewers and other utilities. City planners acknowledged that the underground could be used for multiple purposes of retail and recreation, and even provide shelter to the entire city in the event of an invasion from the East. Since the 1980s, Helsinki has maintained an underground space allocation plan. In the early 2000s, public officials recognized the need for developing an underground master plan (UMP) for the city's underground facilities. In 2004, the Helsinki City Planning Committee approved a set of planning principles to prepare the UMP. After several rounds of public consultations, revisions and approvals, the UMP for Helsinki was approved in December 2010 and came into effect in 2011 (Vähäaho 2014). In 2021, a new UMP was created for the city to guide the planning of facilities and tunnels in the city's bedrock, including newer forms of infrastructure such as data centres (Finland, City of Helsinki 2021).

UNDERGROUND DATA CENTRE

The increasing use of the internet, cloud services and online storage of vast amounts of information has amplified the need for data centres around the world. These centres are energy-intensive and require continuous cooling; cooling data servers are the most expensive and energy-consuming part of operating a data centre. On average, a data centre uses only 40-45% of total energy consumed for actual computing, and the rest is used mostly for server cooling (Lipchis 2020). On a global scale, data centres consume nearly 200 Terawatt-hours (TWh) of electricity, which equates to nearly 1% of global electricity demand and contribute to 0.3% of all global CO2 emissions (International Energy Agency 2021).

A typical data centre converts almost all electricity it consumes into heat. This heat can be transferred to other buildings in surrounding areas that require heat. The quality of heat from these centres is steady 24/7 in all seasons and is low-grade heat at approximately 24°C, which can be captured and transferred to other areas via heat pumps (Syed 2012).[1]

ADVANTAGES AND DISADVANTAGES OF UNDERGROUND DATA CENTRES

Building data centres in underground spaces has several advantages and a few disadvantages. One key advantage of an underground data centre is that the speed to market is impressive, because there is no need to build or adapt a shell in these spaces. With the natural formations of underground space, all that is needed for an underground data centre is the framing and building of data halls. This also reduces construction costs and improves disaster resilience in most geographies – particularly in areas where hurricanes and tornadoes are frequent and intense. In flood-prone and earthquake-prone regions, an underground data centre is a possibility when the centre is well constructed in compliance with safety regulations and codes. For instance, in flood-prone areas, a pumping system should be installed. It should be connected to generator power and automatically activated if the electricity grid goes down.

However, there are certain limitations to underground data centres. For example, not all underground spaces are suitable for data centres, including mines that lack the structural integrity needed for an operational data centre. Water, dampness and ventilation pose challenges. Also, the remote locations of bomb shelters, caves and mines affect connectivity and increase latency which in turn limits the range of potential customers.

In Helsinki, an empty Second World War bomb shelter made of granite and situated beneath the Uspenski Orthodox Cathedral – originally meant to protect city officials in the event of a Russian air attack – has been given a new purpose by a Finnish information technology (IT) company, Academica, and Helsingin Energia, an energy company owned by the city of Helsinki (Schwartz 2009). Academica has installed a 2-megawatt data server 30 metres below the Cathedral – in this former bomb shelter – and sources cold water from the Baltic Sea to cool servers. Rather than returning the hot water to the sea, it is transferred via a separate pipe network of desalinated water and pumped into the city's underground tunnel network to the district heating system for which these underground tunnels were originally built. This transfer of excess heat is used for heating 500 homes in Helsinki, a city that often has temperatures of -20oC and where heating of buildings contributes more than 50% of Helsinki's annual emissions. After the extraction of heat, the water is recycled back to cool the servers again, and Academica estimates a cost saving of 375,000 euros a year from this facility (Vela 2010).

EMBEDDING CIRCULARITY INTO UNDERGROUND SPACE USE

In total, Helsinki has 10 million cubic metres of underground spaces, 220 kilometres of tunnels and a comprehensive UMP. This underground space provides diverse opportunities for Helsinki's vision of a sustainable, inclusive, resilient and liveable future. Helsinki's underground data centre demonstrates how an integrated approach embedding principles of circularity can be used to reduce energy, resource consumption and associated emissions. In general, underground data centres use 20% less energy compared to a typical above-ground data centre. For Helsinki, using cold seawater vastly reduces energy consumption for hundreds of computer servers at this data centre, bringing it within the range of 55-60% of the total energy used by a typical data centre (Kontturi 2011). The residual heat which is produced is then captured and channelled to heat 500 homes via a district heating loop comprising a system of water-heated pipes. Moreover, once expanded as planned, the data centre is estimated to reduce the annual power bill for Academica by 375,000 euros (Virki 2009). This is a significant cost saving as energy costs account for roughly 60% of operational costs for data centres, and half of these energy costs are linked to the cooling of the IT infrastructure (Tepper *et al*. 2012).

1 Low-grade heat has temperatures lower than 200oC; it is the waste heat discharged to the environment when recovery and utilization are not viable. Medium-grade heat has temperatures ranging from 200oC to 277oC, while high-grade heat has temperatures of more than 650oC.

With the increasing demand for data processing and high energy costs for operating data centres, Helsinki's example offers a roadmap for IT companies to reduce their emission footprints and improve the longevity of IT equipment through optimal cooling systems – ones that do not require investment for the cooling source, i.e. the intake of naturally cooled water. In addition, the underground environment provides a relatively low ambient temperature of approximately 15°C, which helps provide a relatively cool environment for data centres. However, in situations where there is no underground space that needs to be repurposed, creating new underground spaces impacts the environment in specific geological settings.

Developing new underground spaces need to be done in a sustainable manner if the overall solution is to benefit the environment. This holds true for any urban development, whether constructing data centres at or below the surface. Urban policy and planning could help here in defining areas where underground space development would be allowed. The creation of any underground space needs to be flexible and promote multiple uses over time. In essence, the development and use of underground spaces should not be limited to single purposes.

A SECTION OF THE DATA CENTRES BENEATH THE USPENSKI CATHEDRAL
©Data Center Knowledge

AN ENABLING ENVIRONMENT

Helsinki is home to more than 400 underground facilities. To integrate different city systems above ground with those underground, underground master planning in Helsinki is a significant part of the land-use planning process. The UMP maps both existing and future underground spaces and tunnels, as well as existing access points, to the underground. It also earmarks rock masses for the construction of various facilities – including transport, civil defence, sports, energy supply, water supply, parking, storage, waste management and other facilities for public use. In addition, it reserves rock mass for future use without precisely defining that future use.

Embedding circularity in the design and operation of underground data centres in Helsinki is enabled fundamentally by the city's expansive network of caverns and man-made tunnels, also by the policies and regulations of the legally binding UMP that actively promote the use and multipurpose use of the underground. The new UMP promotes more diverse use of the underground, more systemic utilization of facilities constructed in the bedrock, and better coordination between different types of operations.

Additionally, the city generally has a high energy-efficient district heating and cooling system, based on cogeneration of electricity, heat and cooling in the same process. This system is used to heat nearly 93% of buildings in Helsinki. The city's climate action plan aims to achieve carbon neutrality by 2035 and thereby focuses on energy-efficient solutions that reduce emissions and overall energy use (Finland, City of Helsinki 2021). This is further supported by Helsinki's 2016 city plan, which is guiding the city towards a higher density and may prompt even more operations and facilities to move underground. Furthermore, Finland's contribution to cloud services and data centre technology, the cool climate and the easy availability of cool water from the Baltic Sea render Finland an attractive test bed for developing and scaling resource-efficient data centres.

From a company perspective, embedding circularity and resource efficiency in the design, operation and maintenance of data centres stems from the need to reduce long-term spending on data centres, which account for up to 30% of many IT companies' energy bills. From a broader policy perspective, as Finland advances its green and digital economy, principles of circularity, resource efficiency and use of underground space for data centres could help meet demands for short-latency data more efficiently and sustainably.

REPLICABILITY

Academica's approach to embedding circularity and resource efficiency in data centres is replicable and has already been adapted and scaled in different contexts. For instance, in 2011, construction for another data centre in the city began for global IT outsourcer Atos. This project, built above ground, incorporates Academica's seawater cooling and district heating concepts. Google is also replicating Academica's seawater approach to cool its data centre in Hamina, Finland. For Google's data centre, Baltic seawater is sourced from an inlet pipe and travels into the data centre via large tunnels (Miller 2011).

The Atos and Google projects, though situated above ground, replicate the closed-loop approach of Academica's underground data server – i.e. using cold seawater to cool the server and recycling the heated water to reduce water demand. In addition, these two projects use the underground as a service layer to collect and transfer cool and hot water between the data centre and the district heating system.

The COVID-19 pandemic has highlighted the value of investing in digital infrastructure for flexible working, among other benefits. Expansion of digital infrastructure, and the associated data centres, is inevitable. At the same time, embedding circularity principles into data centre design, operation and management will be a win-win for the environment and the company and can be encouraged by policymakers, as demonstrated. Academica's experience beneath the Cathedral demonstrates the value of using underground spaces and pre-existing infrastructure to cut resource consumption and associated costs and emissions from data centres. A prototype for an underground data centre, known as Edge Computing Underground and housed in a cavern, was recently inaugurated in Switzerland's Hagerbach Test Gallery to promote the same principles of circularity.

There are certain challenges in scaling such resource-efficient data centres. Not all cities are equipped with large bomb shelters or other underground spaces like the one in Helsinki. Furthermore, not every city around the world has access to cold water throughout the year or a well-developed district heating network. On the other hand, cities are already questioning what to do with inner-city underground car parks, should they become defunct. New developments can utilize underground space through extended basements, allowing the placement of a data centre that can heat the building during the cold season.

Despite the limitations of using underground spaces, Helsinki's underground data centre sets a precedent for using underground spaces for multiple purposes in a very safe space, while delivering social and economic benefits to nearby communities and adapting to the severe winter climate. It helps reduce demand, costs and thus carbon emissions from fuel and energy – both of which are expensive in Finland and in many other countries worldwide.

EDGE COMPUTING UNDERGROUND AT HAGERBACH TEST GALLERY ©Antonia Cornaro (2022)

KEY INSIGHTS

- Helsinki's city plan and underground master plan complement each other and create an enabling environment to promote efficient use of resources on and beneath the surface, including for an abandoned underground bomb shelter.

- Repurposing an underground bomb shelter under a cathedral for a data centre in Helsinki highlights opportunities to maximize and monetize previously underutilized assets, particularly in dense urban areas where land availability on the surface is limited and real estate prices are high.

- Embedding principles of circularity and resource efficiency in the design, construction, operation and maintenance of underground data centres helps reduce consumption and costs of energy and other resources, and hence the emissions linked to these centres.

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