AERIAL VIEW OF THE CITY OF FLUMS, SWITZERLAND © GDMPRO S.R.O. / ADOBE STOCK

SWITZERLAND

ADVANCING SUSTAINABLE DATA INFRASTRUCTURE: A LIFE CYCLE ASSESSMENT OF AN UNDERGROUND DATA CENTRE IN FLUMS, SWITZERLAND

2024

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 3: COMPREHENSIVE LIFE CYCLE ASSESSMENT OF SUSTAINABILITY

Infrastructure's environmental, social and economic sustainability should be assessed as early as possible in the planning and preparation cycle, covering financial and non-financial factors across interdependent projects, systems and sectors over their life cycles. Life Cycle Sustainability Assessments should consider the cumulative impacts on ecosystems and communities as part of a broader landscape, beyond a project's immediate vicinity, and take account of transnational impacts.

BACKGROUND

In the Internet of Things age, the demand for data centres has skyrocketed and often comes with a substantial environmental cost, mainly in energy consumption and resource usage. With data centres estimated to consume 3 per cent of global power and projected to grow to 14 per cent of the world's total by 2040, their carbon footprint is increasingly being scrutinized (International Energy Agency 2023).

The urgent need for energy efficiency is reflected in initiatives like the Leadership in Energy and Environmental Design (LEED) certification. The US Green Building Council (USGBC) has tailored LEED for Building Design and Construction (BD+C) and LEED for Operations and Maintenance (O+M) to cater to the sustainability demands of data centres globally. As of December 2023, there are 1,200+ LEED-certified data centres worldwide (USGBC 2023).

The conventional approach to data centres involves a complex process of identifying suitable locations for large greenfield facilities, coupled with their high energy demand and environmental impact. Challenges of limited physical space, security threats, excessive heat due to hardware proximity and poor planning underscore the critical importance of effective infrastructure planning.

Small to medium-sized underground data centres emerge as a promising alternative, offering higher potential for mitigating environmental challenges, addressing the proximity issue, reducing latency and ensuring uninterrupted service.

A life cycle assessment (LCA) approach is key to fully understanding the environmental impact of data centres, as has been carried out in a pioneering underground data centre prototype situated in Flums, Switzerland. Spearheaded by the Swiss Center of Applied Underground Technologies (SCAUT), in collaboration with Datwyler Cabling Solutions and Amberg Engineering, the "Edge Computing Underground" project leverages the Hagerbach Test Gallery to explore the potential of using underground spaces for Edge Data Centers, presenting a cost-effective, space-saving and secure solution to address the challenges faced by cities and regions.

Switzerland's commitment to research and development (R&D), coupled with substantial investments in underground infrastructure nestled within the Alps, provides a uniquely advantageous setting for testing the efficacy of subterranean digital infrastructure. However, the legislative framework governing subsurface operations is fragmented and lacks specificity, with no dedicated federal law in place. While Article 667 of the Civil Code grants land ownership rights to the full extent of use, issues regarding ownership and management of the subsoil persist (Ruiz 2018). Despite these legal ambiguities, Switzerland's data centre market is forecasted to grow from 534.81 megawatts (MW) in 2024 to 676.21 MW by 2029. This rise in data consumption underscores the necessity for sustainable and efficient data centre solutions in Switzerland (Mordor Intelligence 2024).

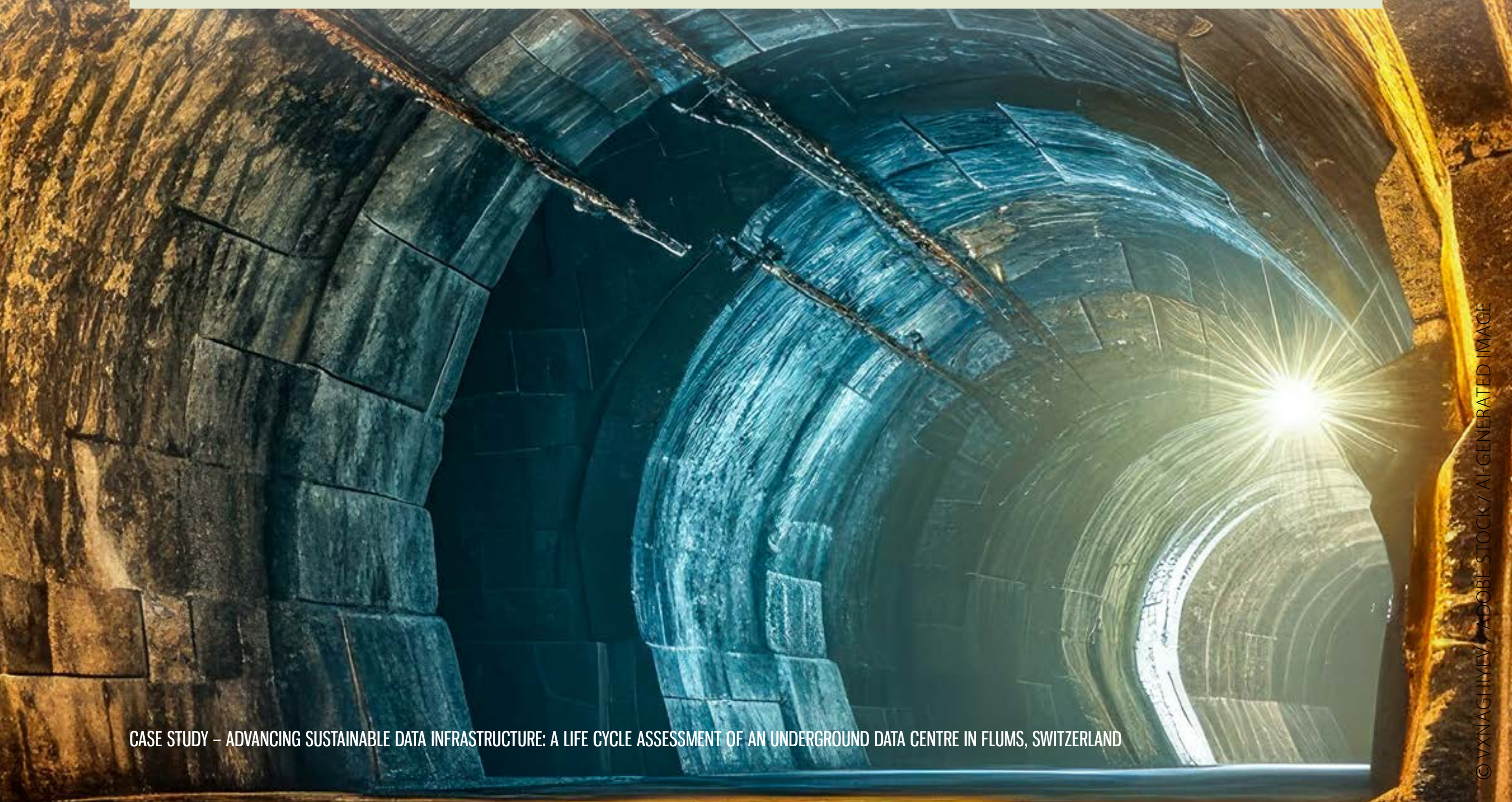
USING UNDERGROUND SPACES FOR INTERNET OF THINGS

Underground Data Centres (UDCs) provide extra protection against natural disasters and other outside influences. UDCs follow a comprehensive security plan; UDCs use a modular design to improve their cost-effectiveness and operational efficiencies.

Picking the right spot for UDCs is key: they need to be away from potential threats and high-security areas like embassies, military areas or chemical plants. The distance between UDCs also affects how quickly data can travel between them. The risks of things like water leaks, earthquakes or vibrations from nearby transportation need careful consideration when choosing the site.

UDCs use a clever design strategy called hot aisle containment (HAC) to optimize data centre cooling by directing hot exhaust air from server racks to the AC return system, increasing cooling efficiency by over 30 per cent. By keeping hot air separate and dry, HAC enhances the AC's cooling capacity, leading to more effective cooling and potential doubling of cooling tonnage (SCAUT Consortium 2020). UDCs with an open ceiling can save even more money because they do not need extra systems to move hot air around. In some cases, UDCs can work without a cooling system, which makes them very energy-efficient.

UDCs need to follow rules set by international standards to make sure they are safe and reliable. Standards like BS EN 50600, TIA 942-A, and Uptime Institute Standards help guide the consistent and reliable operations of UDCs (SCAUT Consortium 2020).



UNDERGROUND EDGE COMPUTING AT HAGERBACH TEST GALLERY, SWITZERLAND

The Underground Edge Computing project at the Hagerbach Test Gallery leverages the potential of distributed computing in Switzerland. It brings data storage closer to where it is needed. The core motivation behind this initiative lies in addressing the escalating demand for instantaneous data processing and limited land space above ground.

Project planning and design encompass thorough consideration of geotechnical aspects, structural and environmental regulations, digital security and socio-economic impacts. The iterative process involves progressively refining the level of detail to address the unique challenges inherent in underground construction. Some of the key benefits noted from the UDC at Hagerbach are as follows:

1. Expedited speed to market: the absence of the need to build or adapt a shell, coupled with pre-existing underground spaces, allowed for quicker deployment. Construction is unhindered by weather-related delays, facilitating more efficient and timely implementation.

2. Hagerbach UDC exhibits potential cost savings, as the absence of a concrete shell and weather delays eliminates significant expenses. The subterranean structures not only reduce construction costs but also offer inherent disaster-proofing, contributing to long-term resilience.

3. Hagerbach UDC provides inherent security advantages. Access is controlled as it is hidden from public view, plus it is well protected against external influences and natural disasters.

4. UDCs inherently maintain cooler temperatures, providing a natural advantage for cooling data centre equipment. While heat rejection remains a challenge, the constant temperatures of the underground environment enable energy savings. The use of average soil temperatures, such as the 21 degrees Celsius at a depth of 4 metres, contributes to efficient cooling strategies.

5. It boosts the local economy by creating new job opportunities including roles in construction, maintenance, security, IT support and facility management. Additionally, it attracts ancillary businesses such as suppliers and service providers. Excess heat energy from the UDC can be used efficiently by nearby consumers.

THE UNDERGROUND EDGE COMPUTING PROJECT AT THE HAGERBACH TEST GALLERY

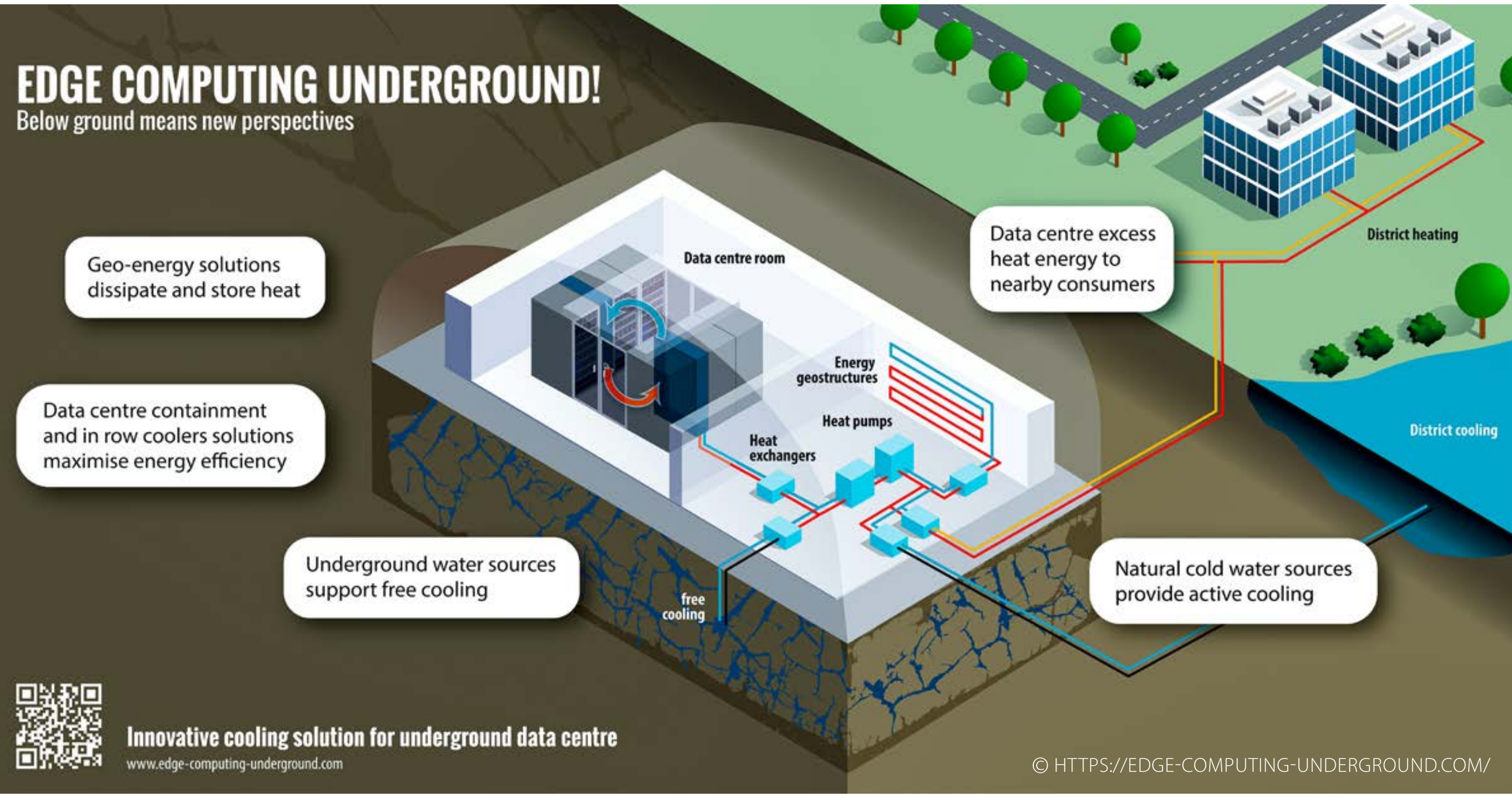
While Hagerbach UDC offers numerous benefits, its construction and management come with significant challenges that require thoughtful mitigation strategies. For instance, the allocation of space within UDCs can be complicated by the necessity to house certain mechanical and electrical equipment, such as generators and air-cooled chillers, in an exterior yard to facilitate ventilation. Additionally, the implementation of a chilled water-cooling system introduces complexity, particularly regarding the management of indoor and outdoor equipment over extended distances. Ensuring fire protection in UDCs demands sophisticated alarm and suppression systems. Mitigating water leaks from thermoregulation systems, water pipes and external sources requires complex water leakage detection systems. This is key for minimizing the water use of the overall asset, and the centre's impact on the surrounding environment.

LIFE CYCLE ASSESSMENT

LCA has emerged as a crucial approach in response to the worldwide proliferation of data centres, and mounting concerns about their sustainability and environmental impact resulting from power-intensive operations. As governments and regulatory bodies like those in Switzerland design environmental regulations, LCA becomes a crucial tool for compliance, ensuring that organizations track and mitigate their impact effectively.

Data centres undergo distinct life cycle phases, including raw material extraction, manufacturing, transportation, building, operation, maintenance and end-of-life management. In this context, LCA provides a comprehensive examination of the environmental impact of data centres across these phases, including carbon footprint water usage, and other ecological footprints. It facilitates the quantification of Scope 1, 2, and 3 emissions and helps organizations to develop targeted emission reduction strategies.

FIGURE 1 A SCHEMATIC DIAGRAM OF UDC BY SCAUT CONSORTIUM



The SCAUT Consortium 2023 conducted an LCA of the Hagerbach UDC to understand the feasibility of future scaling up of UDCs. As part of the assessment, it examined the economic and environmental costs and savings of constructing and operating the UDC at Hagerbach compared to building and operating the same capacity servers above ground in Switzerland.

The assessment concludes that, regarding capital and operation costs, the underground location is more feasible than aboveground data centres in Switzerland. The total cost of constructing and operating a data centre below ground - without including the property costs - is 82 per cent of the total cost of constructing and operating a data centre of the same capacity above ground. In terms of annual carbon dioxide (CO_2) emissions, the UDC's annual emissions were estimated to be around 7 per cent of similar-sized data centres operating above ground (SCAUT Consortium 2020). This remarkable emission saving for UDC is primarily an outcome of reduced cooling needs due to the subterranean location.

TABLE 1 LIFE CYCLE COMPARISON FOR CONSTRUCTING AND OPERATING A 500 KW DATA CENTRE IN SWITZERLAND ABOVE GROUND AND UNDERGROUND, AS PER SCAUT CONSORTIUM (2020)

KEY FINDINGS	DATA CENTRE ABOVE GROUND		UNDERGROUND DATA CENTRE	
	[USD]	[USD/M²]	[USD]	[USD/M²]
Investment costs / CAPEX				
– Property costs	Depends on location		Zero	Zero
– Construction	$ 1,000,000.00	$ 2,000.00	$ 600,000.00	$ 1,200.00
– IT Infrastructure	$ 1,250,000.00	$ 2,500.00	$ 1,250,000.00	$ 2,500.00
– Power & cooling	$ 2,050,000.00	$ 4,100.00	$ 1,580,600.00	$ 3,200.00
– Engineering & Design	$ 800,000.00	$ 1,600.00	$ 800,000.00	$ 1,600.00
– Security and fire protection	$ 505,400.00	$ 1,000.00	$ 469,600.00	$ 900.00
Operational costs / OPEX				
– Power & cooling	$ 10,445,400.00	$ 20,900.00	$ 8,580,500.00	$ 17,200.00
– Security and fire protection	$ 222,000.00	$ 400.00	$ 222,000.00	$ 400.00
Total	**$ 16,272,800.00**	**$ 32,500.00**	**$ 13,502,700.00**	**$ 27,000.00**
Power Use Efficiency (PUE)	1.85		1.52	
Annual CO_2 emissions	2100 tonnes		150 tonnes	

Note: Key assumptions for LCA of Hagerbach UDC:

- number of racks = 100
- power load per rack = 5 kW
- Time period = 10 years
- Availability level = Tier II
- Total space = 500 m²
- IT space = 350 m²
- Data centre room height = 4 m
- Energy costs = 16 cents per kWh
- For estimating CO_2 emissions, only electricity-consumption-related emissions are considered.
  - Swiss mix CO_2 footprint: 169 gCO2/kWh

In essence, Hagerbach UDC offers competitive advantages in terms of low construction costs, low power consumption and cooling costs, and reduced security and fire protection fees. While Hagerbach UDC is a prototype, its theoretical LCA offers insights into key economic and environmental benefits and challenges of constructing and operating data centres underground versus aboveground.

REPLICABILITY

UDCs are emerging as catalysts for sustainable development and circular economies at the sub-national level. Integrating UDCs aligns seamlessly with the reuse of excess heat by local industries and communities, fostering resource efficiency and resilience. Additionally, UDCs can be strategically linked with other underground activities to maximize heat reuse, exemplifying their potential to contribute to urban resilience strategies and sustainability goals.

While challenges exist in scaling such resource-efficient data centres, the Hagerbach prototype sets a precedent for leveraging underground spaces effectively, demonstrating their viability in delivering multifaceted benefits to server operators and nearby communities while adapting to diverse urban contexts.

Moving forward, it is also crucial to thoroughly assess the social impact of scaling up such subterranean solutions. Understanding how these facilities affect nearby communities, including employment opportunities, infrastructure development and community well-being, is crucial for their successful replication and widespread adoption.

Furthermore, the use of LCAs in evaluating the impact and viability of UDCs presents a promising approach. By systematically assessing a range of environmental, social and economic factors, we can better assess their overall sustainability and potential benefits. This approach not only enhances our understanding of the environmental implications of UDCs but also offers a valuable framework that can be applied across a range of assets and contexts, facilitating informed decision-making and scaling up of sustainable infrastructure.

SWISS ALPS IN THE WINTER

KEY INSIGHTS

- Switzerland's extensive R&D and capital investments in underground infrastructure and bunkers in the Alps create an enabling environment to test the efficacy of digital infrastructure beneath the surface.
- Repurposing part of a cavern in the Swiss Alps as a Test Gallery for a data centre, among other things, highlights opportunities to maximize and monetize previously underutilized assets.
- Comprehensive life cycle assessment of underground data centres' impact on the natural environment and people across multiple phases illuminates reductions in costs and negative externalities, including resource consumption and associated emissions.

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