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The ULISSE Project: an Opportunity for a Large-Scale Recycling of CERN's Waste Heat

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Abstract

The ULISSE project originated from the author's Master's thesis at the Swiss Federal Institute of Technology in Lausanne (EPFL, 1993–1995), which focused on CERN's massive waste heat recovering to correct the winter temperature drop of Geneva's potable water network (CORSAIRE 'free preheating' process, i.e. without a heat pump). A year after, this was linked to a sub-lake seasonal heat storage system (Lake Geneva) and presented (poster session) as a Contribution on the 10^th General conference of the European Physical Society, Sevilla 1996.

Today, 30 years later, the ULISSE project integrates this basic CORSAIRE process (beside CERN's and industrial waste heat recycling, i.e. air-conditioning, datacentres, etc.), includes solar energy and expands its applications and environmental objectives, such as protecting lakes from the harmful effects of Global Warming (GW).

*The **ULISSE (Under Lake Infrastructure for thermal capture and Storage of Solar Energy)** system/project aims to restore deep oxygenation and the circulation of nutrients vital to the ecosystem of large Alpine lakes under GW stress, as well as to save winter electricity for the surrounding Thermo-Lacustrine Networks (TLN) used for urban cooling and heating services. As an example, the implementation of ULISSE, combined with the development of TLNs in Switzerland's 15 largest lakes, would eliminate one-third (3 TWh) of the projected national structural electricity deficit for the winter semester of 2050 (electricity to meet our needs for transportation, heating, and cooling through renewable energy sources, involves to phase out fossil fuels by 2050).*

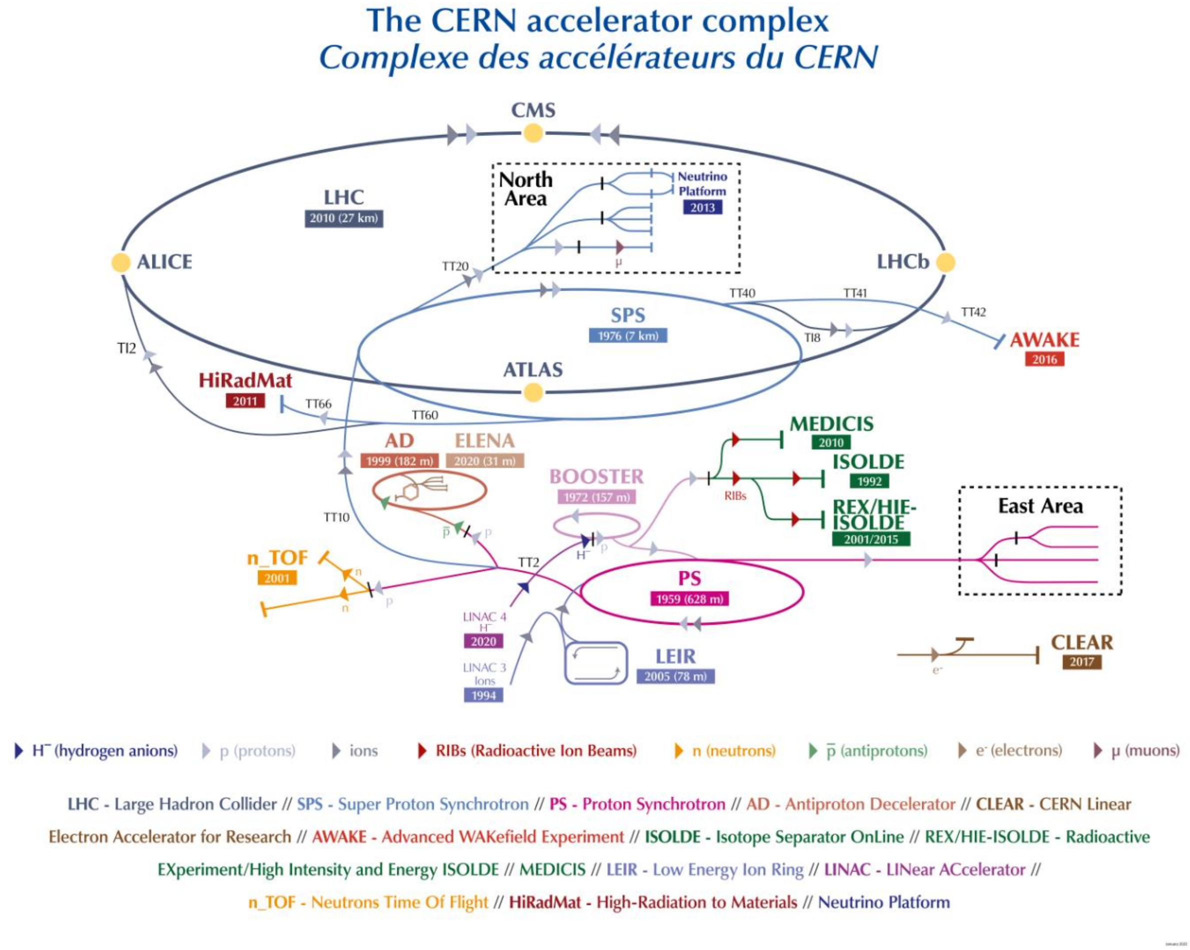
*The exploratory study for the ULISSE project, with a case study on the GeniLac TLN project in Geneva, was funded by the Swiss Federal Office of Energy (SFOE) and conducted at Geneva's University of Applied Sciences (HEPIA, 2021–2023). Today, the ULISSE project is in the process of forming a public-private advanced research consortium, followed by a demonstration pilot in 2030 and where **CERN is also invited to join the ULISSE consortium to explore the feasibility of integrating the waste heat from the futures HI-LHC and perhaps FCC.***

Keywords: CERN, HI-LHC, FCC, data centres, waste heat recycling, thermo-lacustrine network, heat pump, potable water free preheating, free cooling,

Introduction

CERN (European Laboratory for Particle Physics) situated in Geneva is the largest laboratory in the world for fundamental research in particle physics. CERN's complex of accelerators and associated experiments is with the LHC today the flagship facility of High-Energy Physics (HEP). The accelerator complex serves not only the LHC (where the total energy at the collision points in the centre of the Experiments reach 13.6 TeV), but also a rich and diverse experimental programme.

Most of the other accelerators in the chain have their own experimental halls where beams are used for experiments at lower energies. As shown in the figure below, the LHC is the last ring (dark blue line) in a complex chain of particle accelerators. The smaller machines are used in a chain to help boost the particles to their final energies and provide beams to a whole set of smaller experiments, which also aim to uncover the mysteries of the universe. *(Image: CERN) Source:* CERN (CDS)



CERN's past, present and future Energy and cooling water budgets and their improvements

All of CERN's facilities consume electricity (and cooling water), whether for general services, powering the accelerators and experiments, as well as its data centres. in 2024 CERN consumed 1.3 TWh of electricity and 2.9 M m^3 of mostly (potable) cooling water (roughly ½ for the LHC). It also consumed 43 GWh (155 TJ) of heat-energy generated by fossil fuels. Energy and water account (OPEX) for around 5% of CERN's annual budget (1.5 G CHF).

Scheduled for June 2030, during the **HI-LHC (Run 4)** operation, it's estimated that CERN will consume around 1.5 TWh/y of electricity (overall peak power of 450 MW) and 3 to 3.5 M m^3/y of potable water. The HI-LHC accounts for approximately half of this consumption.

From 2040, CERN with the electron–positron collider FCC-ee will reach 1.1 -1.8 TWh/y electricity and 3 M m^3/y of potable water consumption. Finally, from 2070, with the proton–proton collider FCC-hh, CERN will reach respectively 4 TWh/y electricity (overall peak power of 580 MW, size-based scaling of the LHC) and 3 M m^3/y of potable water.

It is worth noting here that, **substantial progress has been made over a period of around 30 years –** during which time the LEP was running from 1989 until 2000 and the LHC came into operation –. The **electricity consumption has risen today by only around 30 % regards the 0.9 TWh in 1994** (overall peak power < 200 MW)**.** In 1994, the heating energy consumption stood at 330 TJ, twice of 2024.

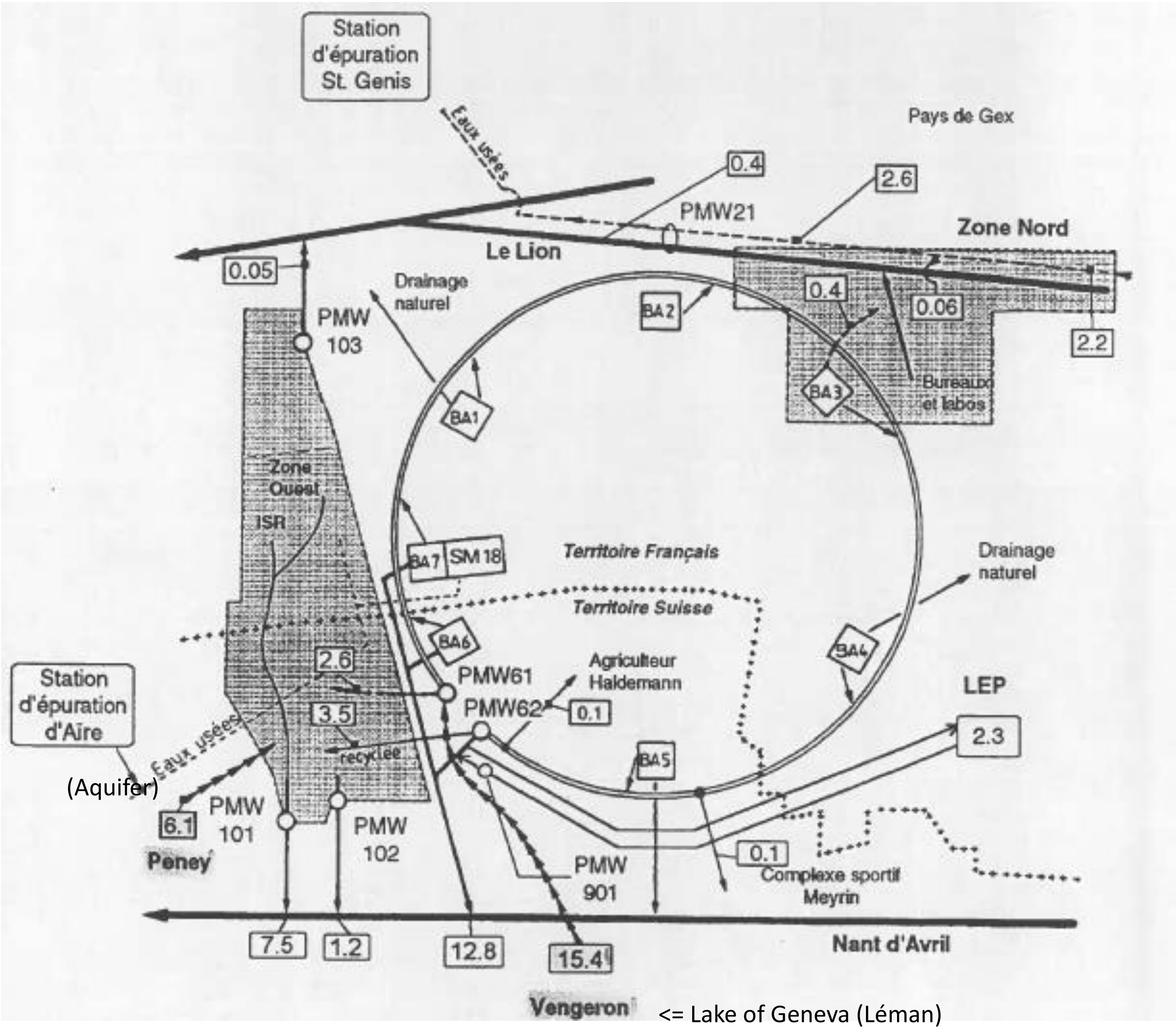
Drastic cooling water drops measures

During the same period, the (initially potable) cooling water usage has fallen by 95% (regards the peak of 25 M m^3 in 1994 or by 80 % regards 15 M m^3 in 2000). This spectacular water drop is notably through the conversion of cooling towers from "open circuit" to 'semi-open' systems, especially for the SPS.

CERN’s water supply system [C5]

Historically CERN was supplied by the groundwater at Peney (6.1 M m³ in 1993), where three pumping stations send the water directly to the Meyrin site, where it is filtered and treated to drinking water standards before its industrial and domestic use. Starting with the increased need for cooling water of the SPS, followed by LEP and LHC, most (≈ 80 %) of its potable water obtains from Lake Geneva.

The *Services Industriels de Genève* (SIG) supply the water at CERN, from the Vengeron pumping and filtration station in Bellevue, via a 9 km long DN1200 mm pipeline, which runs partly along the border and Geneva International Airport (15.5 M m³ in 1993).



CERN’s potable water supply [M m³] in 1993, Meyrin and Prevessin sites, SPS and LEP (total 21.5 M m³/y)

Conventionally, accelerator and detector equipment such as electronic racks, conventional magnets, cryogenics plants (for superconducting - accelerator cavities and - magnets), will require industrial and demineralised water. Chilled water (6/12°C) will be needed for the air handling units of the ventilation systems (dehumidification or air cooling in order to prevent condensation on equipment and structures). Raw water will be used in primary cooling circuits and for firefighting purposes. Potable water will be needed for sanitary purposes as well as for the make-up of raw water-cooling circuits.

Most produced heat in the CERN complex (200 MW @ HI-LHC/HEB => 600 MW @ FCC-hh) is evacuated by wet-air cooling towers trough a primary raw/industrial water circuit (ΔT≈15K), which could reach 40°C at the inlet of the cooling towers and 25°C at their outlet; The cumulated total cooling water flow could reach roughly between 3 m³/s (LHC/HEB) and ultimately 9 m³/s (FCC-hh)…

CERN's energy and water consumptions comparison with Geneva

As CERN is located in the Franco-Geneva region, it is worth comparing CERN's electricity (≈ 80 % from France RTE, ≈ 20 % Swiss EOS) and water consumption trends with those of the canton of Geneva. The canton of Geneva in 2025 (with around 520'000 inhabitants and its economic activity) has an annual electricity consumption of around 3.0 TWh and a potable water consumption of 58 M m^3. In 2030, it expects roughly 3.3 TWh/y electricity and 60 M m^3/y of potable water for 570'000 inhabitants.

Around 2050 (***Paris Climate Accords and Swiss Energy Transition deadlines)***, Geneva will reach 620'000 inhabitants, 65 M m^3/y potable water and roughly 4 TWh/y electricity. (*OCSTAT population projections for 2021–2050*). This electricity consumption increase is in line with Geneva's Energy Master Plan and the Swiss Energy Strategy 2050, who aims to be "carbon neutral" by 2050 and "nuclear neutral" by 2035 **[1]**. They are largely based on the energy renovation of buildings, with almost widespread use of heat pumps (HP) for heating and air conditioning, requiring 1/3 electrical energy (COP≈3), plus the electrification of mobility and industry decarbonisation.

In terms of electricity (and potable water until 1994-2000), CERN is today roughly equivalent to one-third of Geneva, and as such has a major impact on the region. But in the future, with the FCC-ee and later FCC-hh, CERN and Geneva could approach the same annual electricity consumption (4 TWh/y) and are expected to meet the same climate commitments to phase out fossil fuels by 2050.

These commitments are aligned with the **ISO 50001 certification obtained in 2023 by CERN** and is based on three pillars, namely minimising energy use, increasing energy efficiency and **recovering waste heat** [**C11**].

Past CERN's waste heat recycling exploring [C1-C4]

Due to the high energy consumption of its facilities, CERN has always been aware of the energy implications of its activities, even before the first oil crisis of 1973, during the design of the SPS in the early 1970s. Several innovations, such as pulsed-mode control of power supplies and, later, superconductivity, ensure energy savings. Consequently, this also reduces the power required to cool the equipment, and thus the Capital and Operational Expenditures (CAPEX & OPEX).

The optimal use of energy was to become a key element of the Laboratory's policy, and an Energy Committee[1], chaired by a member of the Executive Board, was established in 1977. The result of this energy policy was that, "over a ten-year period (73–83), total savings amounted to nearly 250 GWh of electricity per year, as well as a reduction of nearly 50% in specific heating consumption.

In addition to the focus on energy efficiency incorporated into the design of the equipment, the Energy Committee has explored numerous ways of recovering the significant amounts of waste heat produced [**C1-C4**]:

- Production of chilled water (2–5°C) for air conditioning. (absorption chiller)
- Electricity generation (vaporised fluorocarbon expansion turbine and Nitinol shape-memory motor)
- District heating (DH)
- Heat storage
- Temperature recovery via heat pumps (absorption or compressor)
- Heating of swimming pools and fish farming (warm-water fish farming)
- Heating of horticultural and market-garden greenhouses (CERN Pilot Greenhouse 1988)
- Low-temperature heating in open agricultural land
- Grain drying
- Snow-clearing system for the runway at Geneva Airport
- Supply of warm water for irrigation at the Meyrin sports centre.

[1] Ref: report CERN/DIR/EN/83-1

However, virtually all these techniques have come up against four major obstacles:

1) The winter shutdown of the accelerators in favour of summer operation. Whilst this avoids the high cost of winter electricity, it reduces the commercial value of the thermal energy produced and thus the possibility of subsequent use. The volume required for seasonal storage of thermal energy, in the form of hot water, would be very large (300 GWh @ ΔT=30°K; > 8 M m³).
2) Apart from the fact that most of the waste heat is at a relatively low temperature (25-35°C), using it for heating is also hampered by the high cost of a District Heating Network (DHN). More, conventional DHNs using water superheated up to 130°C, which made it impossible to incorporate waste heat at significantly lower temperatures without resorting to heat pumps with very high operating temperatures and low coefficients of performance (COP).
3) For a DHN service, a supply must be guaranteed regardless of occasional shutdowns at CERN. This requires backup boilers and therefore additional financial costs (CAPEX).
4) The market price of energy, particularly heat.

CERN's operational adaptation on the electricity strategies in Geneva and France

Originally (50-60's), CERN was mainly supplied with electricity from EOS via a 130 kV high-voltage line linking the Verbois hydroelectric power plant on the Rhône River in Geneva (100 MW) to the Meyrin site. Subsequently, with the construction of the SPS in the 1970s, the majority of the electricity supply came from France (EdF) via a 400 kV line from the Genissiat hydroelectric power plant (400 MW).

In the aftermath of the first oil crises of the 1970s, France embarked on a massive programme to build nuclear power plants (the Mesmer plan); this was done to meet the growing demand for electricity, particularly to power direct electric heating (Joule-effect), which, incidentally, it had strongly encouraged. The consequences today are that for every 1°C drop in the average winter temperature, peak demand increases by 2.2 GW (equivalent to the electrical power output of two nuclear reactors).

However, within the current context of France's energy transition, this points to enormous potential for electricity savings if replace its electric heating by heat pumps, which, when operated in reverse mode, could function as air conditioners in summer, powered by solar power in perfect harmony!

But, as a result at the time, *Électricité de France* EdF was faced with summer overcapacity in its nuclear power fleet, which had been designed to meet peak winter demand for electric heating. In an attempt to spread demand throughout the year, EdF offered its major customers, such as CERN, a contract which, in return for a discounted annual electricity price (207 => 174 FF/GWh), required them to reduce consumption on 'Critical Days' for 22 random days in winter (*Effacement Jours de Pointe* EJP). For obvious reasons of immediate financial savings of around 14 %[2], **CERN adopted this EJP contract, which obliged it to schedule its annual major shutdown in winter.**

Consequently, as the generation of waste heat was halted during the winter period, any new attempts to utilise it were 'nipped in the bud'. Since thermal energy has little commercial value outside the heating season, CERN is therefore forced to discharge it entirely, as mentioned previously. Furthermore, the fact that CERN is virtually closed during the winter also gives employees from the Organisation's 25 member states the opportunity to return to their home countries for the year-end festivities.

Actual CERN's waste heat recycling investigations and projects

In 2011, CERN had 19 cooling towers through which it evacuated 962 MWh (≈ 1 TWh/y or 3.6 PJ/y) waste heat into the atmosphere [**C6**]. Today, an always growing potential exists and is again considered for waste heat recovery from the LHC as well as the FCC (up to 2 - 4 TWh/y or half if we consider or not only the cryogenics). However, the needs and opportunities and the infrastructure conditions need always to be evaluated for the specific colliders (LHC, FCC) and for each specific technical system (e.g. whether a medium/low temperature

[2] ≈ 207 => 174 K FF/GWh: Δ=- 8.3 K CHF/GWh (AMPTAR and DOP 10 mm simulation by DOPEE for EdF, in 1994)

district “anergy” heating system, with end-user heat pumps, exists already, or whether it could be implemented for a new industrial or housing area close to a surface site).

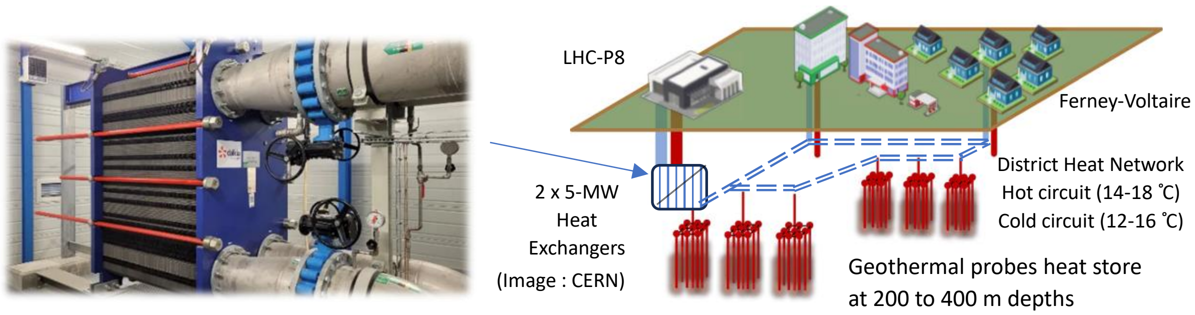
Points P1 and P8 of the LHC and PA, PB, PC of the FCC, are currently located in areas with a high population density, whereas most of the other points are located in rather rural areas. The investment cost for a district heating system is generally affordable in case of a sufficient energy density demand by the end users (≥ 700 MWh/y per hectare is considered suitable [**12, 13**]. As mentioned before, the amount of recoverable energy increases with the density/proximity to the consumer as but also with the temperature of the heat source, who’s for CERN at minimum 25-30°C.

The most promising candidates for waste heat recovery are the cryogenic plants, which are the top electrical energy consumers (roughly 50 %) and the conventional cooling systems. For the HI-LHC and the FCC, this represents respectively at least between 1 - 2 TWh/y or 3.6 – 7.2 PJ/Y waste heat.

Beside this, there is a wide range of other equipment associated with accelerators and experiments that also requires cooling water at 25 – 45 to 50°C (magnets, resistive RF cavity amplifiers, synchrotron radiation absorbers, ventilation and air management systems, electronics racks, data centres, etc.) and even above 60–70° C (transformer oil, klystrons, etc.). Apart from cryogenics, these also account for the other half of electricity consumption, which is ultimately converted into heat that needs to be dissipated and, ideally, recycled also via low-temperature or “anergy” district heating networks.

Currently, a project is being implemented to connect the cooling system of LHC at Point 8 to a “anergy” district heating network (anergy means the possibility to integrates low temperature waste heat), which will supply a new industrial zone near Ferney-Voltaire (France) with Hot-water circuit (14-18 °C) and Cold-water circuit (12-16 °C) for both heating and refrigeration purposes (Fig. below).

This hybrid system, consisting of waste-heat recovered from the LHC cryogenic machinery that is stored by heating the ground and which is made available via geothermal probes. The inter-seasonal geothermal storage allows energy that is more abundant during the summer to be stored so that it can be released in winter when demand is higher and (normally) CERN is in annual winter shutdown. Its capacity is estimated at 24 MW (@ ≈ 40/20 °C), and it will supply heating to the town of Ferney-Voltaire (23 GWh/year) and the commercial zone (20 GWh/year), as well as cooling need (6 GWh/year).

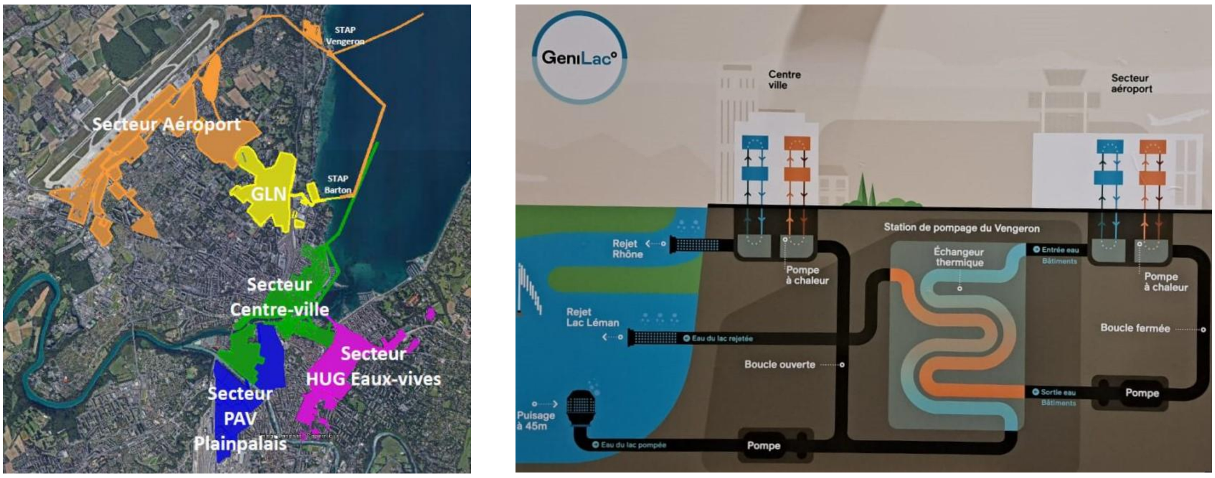


Concept of the waste heat recovery facility supplied from LHC point 8 to consumers 2 km away in an industrial zone of Ferney-Voltaire (France) and completed by inter-seasonal geothermal storage probes

However, the Long Shutdown 3 (LS3) for LHC upgrade, from June 2026 until 2030, will reduce CERN’s output to the new heating system to between 1 and 5 MW excluding several months while the system isn’t operational. Similarly, plans have been developed to feed **waste heat from LHC Point 1 into CERN's distributed heating system**. https://doi.org/10.1140/epjst/e2019-900087-0

Ultimately, CERN’s waste heat at LHC points P1, P8 (and FCC in particular nearest point PB), which is just a few kilometres away, could be connected to Geneva’s **GeniLac** network. Developed by **Services Industriels de Genève (SIG),** this *Thermo-Lacustrine Network* (TLN) uses water from Lake Geneva to cool buildings by “free cooling” (without heat pump) and to heat them with the assistance of local heat pumps. With a dual (cool & heat) capacity of roughly each 250 GWh mostly cooling in summer semester and mainly heating purposes in winter semester

@ 280 MW, it's currently under construction and will be fully operational in 2035. This provided that the temperature of CERN's cooling water is compatible with that of GeniLac, which operates during Summer at approximately 7/12 ℃ between the supply and return pipes to the lake, and 6.5/3.5 ℃ respectively during Winter.



Schematic diagram of the GeniLac cooling and district heating system with Lake Geneva (Source: SIG)

Wast heat case study of the FCC (GINGER BURGEAP)

The engineering consultancy (GINGER BURGEAP), commissioned by CERN to assess the potential for utilising waste heat from the FCC-ee (leptons collider), analysis that the ***Waste Heat Production*** **(WHP)** by the FCC depends on the working mode and is different for each site (as for the LHC).

In Shutdown mode (SD) the thermal power generated is only 9 MW and could reach 190 MW in Operation mode (OP). The total amount of WHP for FCC-ee (modes Z, W, H, T) would be for 14+1* years (2045-2060) gradually rise up from 836 – 1'128 and ultimately 1'603 GWh/y. (* LS1 in 2054). The total WHP is estimated at 5'288 GWh (19 PJ).

During this period of 15 years, the electricity consumption of the FCC-ee is estimated at 20'350 GWh, with a corresponding CO_2 emission of 506 K t CO_2 (25 t CO_2/GWh-e on the Mix UE grid). The energy-heat recovery rate potential is 26 % of the 5,3 TWh-t WHP regards the 20.3 TWh-e electricity consumption (≈ 1.4 TWh/y). This is in view of the FCC-pp's projected power and annual electricity consumption of 580 MW and 4 TWh/y during 25 years (2070-2095) …

The heat recovery rate, around the FCC sites depends of the annual ***Territorial Heat Demand*** **(THD)** for space heating, domestic hot water and industrial use. The THD is estimated at 2'561 GWh/y within a radius 5 km around the FCC and beyond (Extend) this radius the TDH potential reach 5'545 GWh/y.

Except the sites PD, F, G, J and PL, the THD is globally higher than the WHP availability of FCC. The annual and "static" potentially recyclable waste heat production (WHP) in the region of the FCC-hh is 461 GWh (5 km radius) and 727 GWh (extended). But, due the daily, weekly and seasonal (dynamic) mismatch between both, these values are less considering this dynamic mismatch.

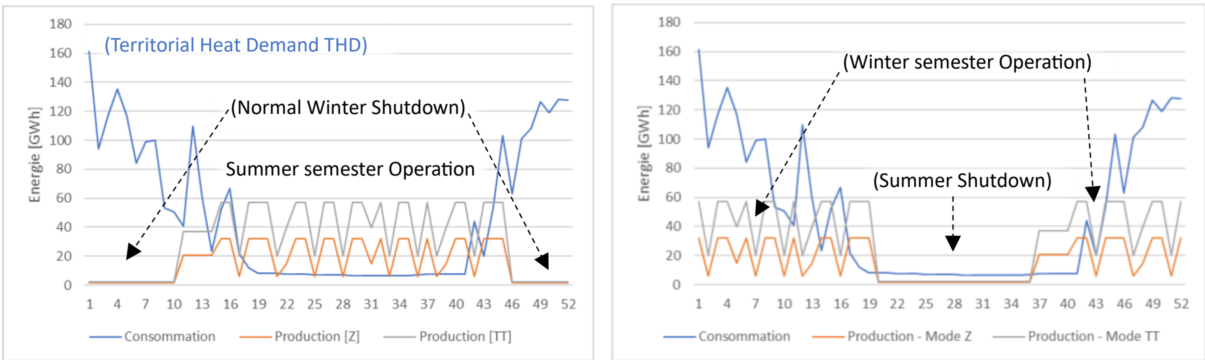
GINGER BURGEAP shows this (Table below): Increasing the area over which heat is distributed (extend beyond the 5 km radius) makes it possible to achieve a waste heat recovery rate (WHR) up from 39 to 60 % in Z mode (325 => 504 GWh THD / 836 GWh WHP) by 2050 and from 29 to 49 % in -tt "Top Quark" mode (461 => 727 GWh THD / 1603 GWh WHP) by 2070.

As proposed in the study, the cooling water could also be transported to remote points through the FCC tunnel (maybe also the LHC tunnel). So, 18 GWh heat in Z mode and 59 GWh in tt mode, could increase slightly the heat recovery rate (+2 % in Z mode, 60 => 62 %).

Local THD [GWh]		WHP [GWh]		Heat Recovery rate [%]		Recycled heat [GWh]	
FCC site	**Local THD**	**FCC-Z**	**FCC-tt**	**FCC-Z**	**FCC-tt**	**FCC-Z**	**FCC-tt**
PA (max)	1 678	138	225	100 %	100 %	138	225
PD, F, G, J, L	49	138	225	36 %	22 %	49	49
PH (min)	15	230	524	6 %	3 %	15	15
Total	**2 561**	**836**	**1 603**	**39 %**	**29 %**	**325**	**461**
Extend THD [GWh]		**WHP [GWh]**		**Recovery rate [%]**		**Recycled heat [GWh]**	
PA (max)	**3650**	138	225	100 %	100 %	138	225
PH (min)	15	230	524	6 %	3 %	15	15
PD, F, G, J, L	49	138	225	36 %	22 %	49	49
Total	**5 545**	**836**	**1 603**	**60 %**	**45 %**	**504**	**727**

Table: FCC-ee Waste Heat Production (WHP) and the Territorial Heat Demand (THD) one [GWh] around Local 5 km radius and Extend radius of the FCC sites and heat recovery percentage (values one a "static" annual base!)

A 26-week FCC Operation displacement (from mid-September to mid-May) rises the weekly utilisation rate/ratio between THD (blue curves on figures below) and WHP, respectively from 27 % to 37 % in FCC's -Z mode and 19 % to 28 % in -tt mode. **That means an annual Shut Down unusual in Summer!**



Weekly change in THD (blue line) and WHP supply [GWh of FCC-ee [orange Z mode] and [grey line -TT mode]: Left: normal operation (Winter Shutdown), Right: 26 weeks operation displacement (Summer Shutdown) week 1 is the first week of the year. (source GINGER BURGEAP)

CERN's Shutdown shift and Seasonal heat storage

GINGER BURGEAP proposes, in order to manage (partially) the seasonal imbalance between FCC's WHP and THD, within its sites two technologies for storing 84 GWh of heat (table below):

• Geothermal using 5'260 vertical boreholes, 200 m deep (15 cm diameter), occupying a total area of nearly **526,000 m²** (≈ 53 ha). By comparison, the 8 FCC's surface sites will require approximately 40 ha.

• Storage via liquid water reservoirs, with a temperature between 20 °C and 40 °C, representing a total theoretical water volume of nearly **2.8 million m³.**

		PD	PG	PH	PJ	PL	Total
Gisement non valorisé [GWh]		113	115	223	127	16	**594**
Energie fournie par le complément [GWh]		25	25	9	9	25	**93**
Capacité de stockage [GWh]		25	25	9	9	16	**84**
Géothermie	Nombre théorique de sondes de 200 m	1580	1570	550	550	1010	**5260**
	Surface au sol [m²]	58 020	157 000	55 000	55 000	101 040	**526 060**
Réservoir d'eau	Volume théorique [m³]	842 800	837 450	293 340	295 000	539 440	**2 808 040**

Estimate of the number and surface area of geothermal probes and/or the volume of the reservoir required to theoretically store 84 GWh of heat @ ΔT 20 K (gross, excluding losses) (source GINGER BURGEAP)

Without FCC Operation displaced in Winter semester (when territorial heat demand THD is maximum and annual Shutdown placed in Summer, when THD is low, but taken in account the winter electricity demand and prices), It seems evident that the 1'603 GWh/y of waste heat (WHP) generated annually in tt mode by the FCC-ee, at best only 786 GWh/y is valorised (49%).

Reference: GINGER BURGEAP Étude de valorisation de la chaleur du FCC. Partie II : Étude du process de valorisation et voies d'optimisation (V01.00). Zenodo. https://doi.org/10.5281/zenodo.11192180

Comments on the GINGER BURGEAP study of potential utilising waste heat from the FCC

A. Total seasonal heat storage

Given the annual THD (Territorial Heat demand) of 5'546 GWh/y, it should be possible to utilise the entire amount of FCC-ee's WHP, if sufficient seasonal heat storage were available, in principle equivalent to the unused portion, i.e. 817 GWh/y. This is nearly 10 times the 84 GWh of storage proposed by the GINGER BURGEAP study. That means proportionally, 53'000 geothermal vertical boreholes, occupying a total area of 5.3 M m² (≈ 530 ha); or liquid water reservoirs, working between 20 °C and 40 °C (ΔT 20 K), representing a total water volume of 28 million m³… The cost and the space required are prohibitive and roughly equivalent to CERN's current land area in France (516 ha).

B. CO_2 emissions

The study overestimates the impact of CO_2 emissions reductions by assuming that the recovery of waste heat of the FCC, via district heating networks (DHN), will proportionally reduce the use of fossil fuels within those networks (estimated in the study at 190 t CO_2/GWh thermal). However, residual heat from the FCC will not be available until 2038/2045 (start of FCC-ee operations, Z mode). Until then, the new energy infrastructure currently under development, including the DHNs, will be based on renewable (carbon-free) energy sources (solar thermal, geothermal, wood, biogas,) and will operate at relatively low temperatures.

Solar thermal district heating systems typically operate at medium to low temperatures (85/65 °C and lower 65/45 °C, @ ΔT 20 °C). Lower temperatures increase the thermal efficiency of solar collectors (0.3–1 % per °C), reduces heat losses of the network (≈1 % per °C, **source Enerplan**) and is easier to feed in residual heat (without heat pump). Transport of cooling water from CERN to a local district heating network (DHN) will probably take place between 20 °C - 40 °C, a lower temperature than the solar DHN and require a heat pump to feed in residual heat into the network (which is not necessarily a problem).

C. Waste heat variability

The thermal power generated by the CERN complex (PS, SPS, Hi-LHC, FCC) will vary considerably depending on the operating mode and on the long shutdowns (LS) of the accelerators and experiments (maintenance, upgrades, etc.): LHC-LS3 (June 2026-2030), FCC-ee-LS1 (2054), FCC-LS2 (-ee => -pp: 2060-2070). This means that every DHN network must have a variable, long-term alternative energy source (big seasonal heat storage or individual heat source). But the use of additional 'fossil fuel' heat will no longer be an option (climate commitment) and will only be permitted as a last resort (backup).

D. Waste heat competitivity

However, the DHN network's basic infrastructure will need to be sized to meet the nominal heat demand. The network's infrastructure for capturing, storing and distributing heat from renewable sources will account for the bulk of the investment (CAPEX). As there will no longer be any purchases of fossil fuels, the cost of supplying heat to end users will be primarily linked to distribution (OPEX) and the amortisation of the investment. CERN's offer to supply heat to this DHN "anergy" network, even at cost price, will therefore be difficult to accept and less competitive.

Anergy district heating networks will, of course, use heat pumps to supply end users with heat at the required temperature (space heating, domestic hot water, etc.). However, these heat pumps operate with a coefficient of performance (COP) that can easily reach 3 or more; in other words, for the same amount of heat supplied, they use only one-third or even less electricity than direct electric heating!

E. Potential financial saving

The estimated potential savings of 50 €/MWh can no longer be sustained, by the middle of the 21st century, compared with gas heating, and 140 €/MWh with electricity (in case of thermodynamic absurd direct "Joule" heating and based on energy prices as at 1st November 2023, references of the mentioned study).

F. Source of electricity determines ultimately CERN's water consumption

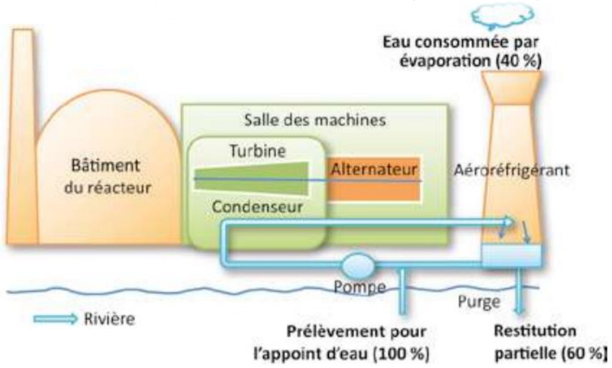
CERN's power supply is generally, and will continue to be by 2050 also for the FCC, sourced from the Franco-Swiss or European grid (RTE). By 2040, renewable energy will account for 70 to 90 % of power generation in the EU [**69**].

Despite CERN's desire to introduce an increasing proportion of renewable energy, such as solar and wind power (in addition to Switzerland's existing hydroelectricity), a significant proportion is and will continue to be 'thermo-electric', i.e. mainly from French nuclear power. This is particularly the case during the winter months and, of course, at night (reduced or absent solar power) and due to the lack of substantial storage capacity.

The Bugey nuclear power plant on the River Rhône is the closest to CERN. The power plant is fitted with wet cooling towers supplied by water of the Rhône, who evacuate 2/3 of the energy of the nuclear reactor in form of waste heat (resulting mainly from the Carnot thermodynamic efficiency). Relative to the net electrical energy produced, approximately **2.5 M m^3 water/TWh evaporate in the cooling tower**, emitting a plume of vapour, and does not return to the watercourse [**19.1, 19.3**] :https://www.edf.fr/sites/default/files/contrib/groupe-edf/producteur-industriel/nucleaire/ENVIRONNEMENT/guide_2020).

Certainly, the reuse of CERN's waste heat helps to reduce the consumption of cooling water (which evaporates in its own actual 19 cooling towers) and representing approximately 2 to 3 M m^3/y, based solely on the FCC-ee and the FCC-pp. But we must also take into account the indirect water consumption resulting from the proportion of nuclear-generated or other thermo-generated electricity consumed by CERN, which corresponds to the **2.5 M m^3 water per TWh electricity!**

≈ 2.5 million tonnes of water evaporated per TWh of nuclear electricity



Synoptic of the Bugey Nuclear Power Station cooling on the River Rhône (4 × 900 MWe) © EDF – Matthieu Colin
(≈ 40% of the cooling water evaporate; ≈ 2,5 M m^3 / TWh electricity) [**19.1, 19.3**]

Moreover, we must not lose sight of the fact that, as the summer drought increases, and is exacerbated by more recurrent heatwaves, the increased need for water for other uses (prioritisation), including agriculture, will (already has) become critical. As a result, thermoelectric power stations (nuclear as well as fossil-fired, coal, fuel oil or gas) that cannot operate without cooling water (except by using their thermal waste in cogeneration) will be forced to shut down or drastically reduce their production in the summer half-year, what we have already been observing now.

In the future, this could make them less competitive and a fortiori also less present or available in the winter. Apart from other considerations (financial, security, foreign fuel, nuclear and chemical waste, decommissioning or bacteriological such as legionella in cooling tower basins [**19.2**], France and Switzerland, face the same water problems [**19, 19.1, 19.3**] and the same climate commitment ...

Consequences of Swapping the "Operation" and "Shutdown" periods

The Operating period and the annual Shutdown, not only affects the utilization of waste heat and the cost of electricity, but also results in significant changes to cooling and ventilation requirements. This depends on whether the synchrotron radiation and beam losses by magnet electric power cuts during Operation (OP) reaches the ambient air in the tunnels (as is the case for the SPS and the former LEP, which have water-cooled open bending magnets), or luckily to a lesser extent for the LHC and FCC, which are confined within the cryogenic enclosure.

Where this is the case, to reduce the radiation activation of the air, strong tunnel ventilation is required (≈ 1 m/s at the time of LEP). The combination with the air humidity in the tunnels lead to corrosion hazards on all the underground infrastructure. The radiation produces ozone (O_3) which in the presence of nitrogen monoxide (NO) in the air, leads to the production of nitrogen dioxide (NO_2) and finally, in the presence of water vapor, is converted into nitric acid (HNO_3), a strong oxidizing agent.

To limit this, in addition to ensuring an adequate ventilation airflow, the air must be dehumidified to achieve a low dew point (Tr) of and a medium dry (Td) bulb temperature at the tunnel entrance, which requires a supply of cold or ice-cold water, in this case provided by a refrigeration unit (heat pump) and finally conduct on a relative high electricity consumption.

For example, during the Summer Operation (SOP) of the LEP+LHC era (I do not have other current data), the mechanical ventilation power was in the order of 2.5 MW (645,000 m^3/h) and dehumidifying the air required 5 MW of heat to be extracted from the air before it entered the tunnel.

In contrary, during the annual Winter Shutdown (WSD), the air velocity is halved to 0.5 m/s (LEP) and no dew point correction is required. The ventilation power is then reduced to 2 MW instead of 7 MW.

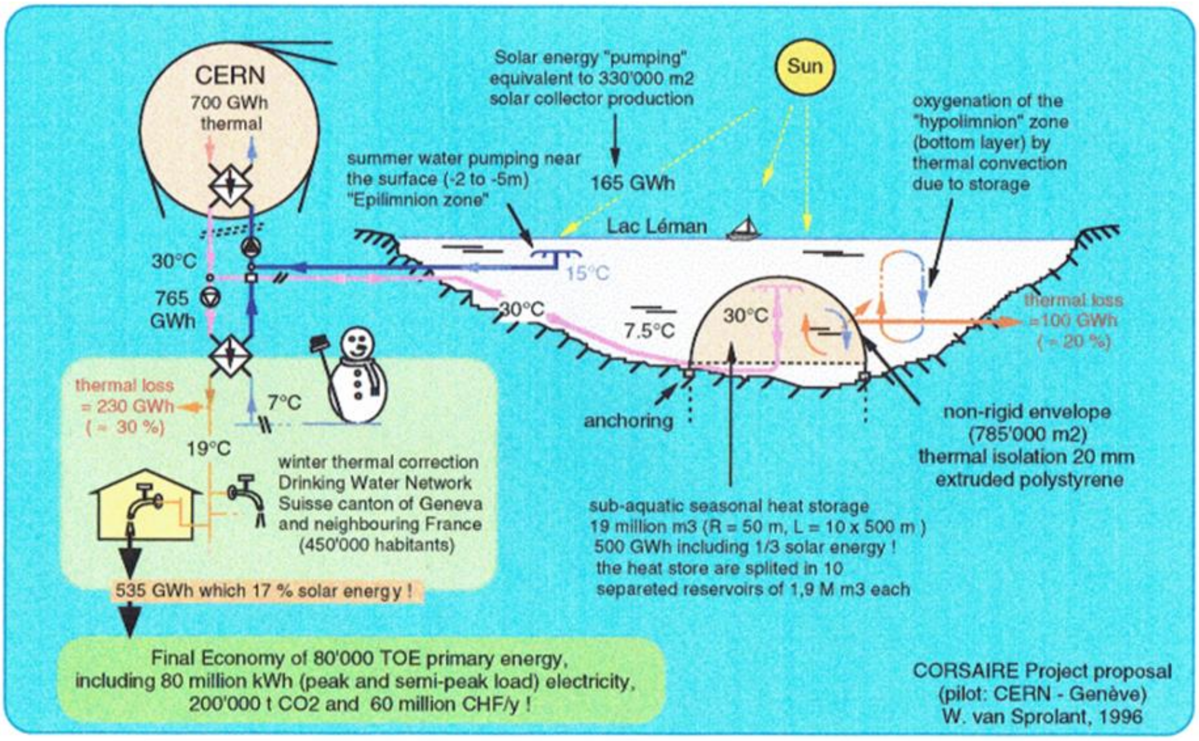
However, for the staff working inside the machine and in the surface buildings, the absence of heat waste meant that the air had to be heated electrically (15 MW @ -14 °C outside temperature). In 1994, the LEP absorbed 19 % (48 GWh) of his total electricity consumption (253 GWh) just for his air conditioning and ventilation. If we add 'cooling' and 'cryogenics', the LEP's cooling system accounted for 1/3 of its electricity consumption.

Therefore, when choosing operating (OP) and shutdown (SD) periods, it is important to bear in mind that, just as with air-conditioning efficiency, the thermodynamic performance of heat pumps and cryogenic cooling systems (e.g. helium-based), which ultimately depends on outdoor atmospheric conditions (temperature and humidity), is easier in winter, when the air is cold and dry. Finally, unlike in winter when they are rare, summer thunderstorms (which are becoming more frequent as a result of global warming) can cause power cuts and thus disrupt the smooth running of a Summer Operation.

1992-2026: From VERTCAD via CORSAIRE to the ULISSE project

All these considerations will not mean that the waste heat of CERN is difficult or not recyclable. On the contrary, this preliminary analysis shows how we might circumvent the problem of a priori limitations or incompatibilities and thus better justify the possible adaptive solution(s) for improving the potential for utilizing CERN's waste heat; this against the backdrop of our urgent energy transition in the face of the challenge of climate changes. More, these considerations for the HI-LHC, FCC and others accelerators, especially since FCC approval has not yet been obtained and that, whatever the final decision, it must not compromise CERN's future.

This has motivated me for the past 35 years to propose, in three successive stages, alternative projects aimed at making extensive use of CERN's waste heat. Namely, the VERTCAD project in 1992, the CORSAIRE project in 1995 (as part of my master's thesis in energy systems at EPFL), supplemented the following year by a seasonal sub-lake storage scheme. I presented this latest configuration (poster session) as a contribution paper at the 10th General Conference of the European Physical Society, EPS 10 Trends in PHYSICS, September 9-13, 1996 Sevilla Spain [**44**].



Synoptic of the recycling project of CERN's thermal waste in the winter preheating of the potable water network of the canton of Geneva (EPFL master's thesis 1995) completed by a sub-lake seasonal heat storage. Contribution on the EPS 10 TRENDS IN PHYSICS, 10th General conference of the European Physical Society, September 9-13, 1996 Sevilla Spain [**44**]

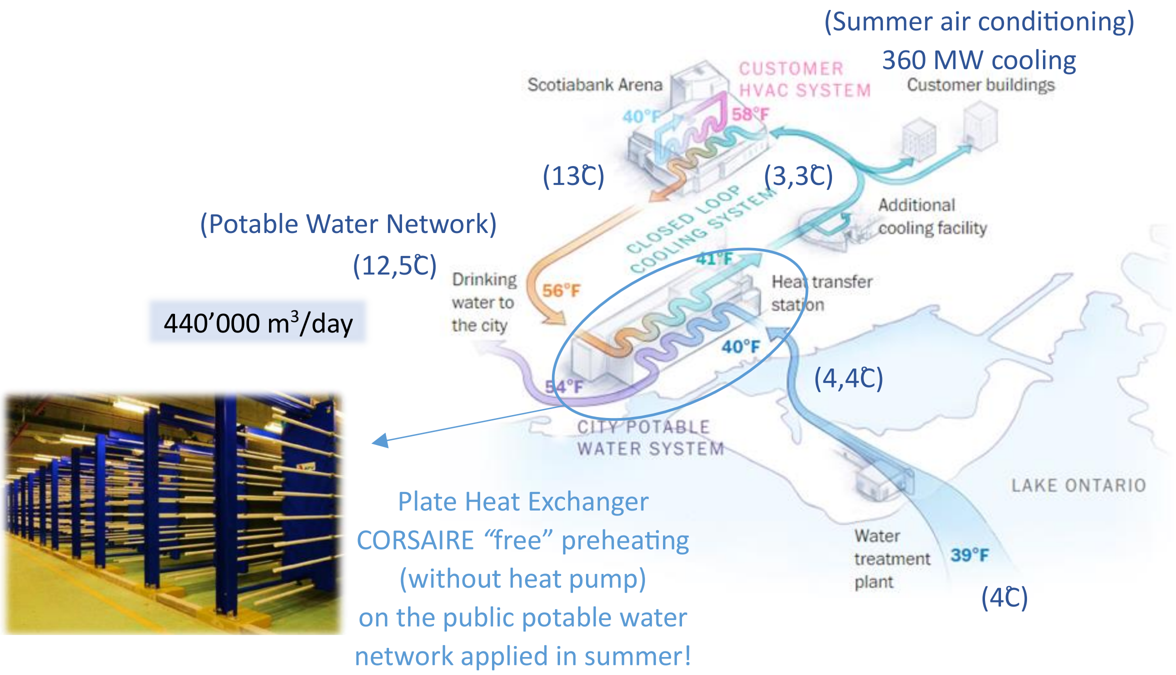
5 years later, at the instigation of the Office Cantonal de l'Energie (OCEN), **the CORSAIRE project (without de lake storage) was included in the Canton of Geneva's Energy Master Plan (2001-2005).** In November 2005, under my supervision of the project, the OCEN financed, part -1 of the multidisciplinary impact study on a pilot residential building made available by the City of Geneva **[46]**. Alas, 3 months after the study began, it was abruptly halted, due to an unforeseen budget cut by the OCEN! Since then, the project has never been reconsidered, despite Geneva's ambitious energy objective (a *2000 W nuclear-free society by 2050*)!

Without realising it at the time (!), meanwhile since 2006 (10 years after EPS 10 paper), the CORSAIRE principle has successfully been used (in summer) in the Canadian city of Toronto (3 million inhabitants, 1/3 the size of Swiss's population) with its "*Deep Lake Water Cooling*" (DLWC). With a cooling capacity of 360 MW, the thermal energy extracted from the air conditioning is injected into Toronto's downtown potable water network (400'000 m^3/day, twice Geneva's daily winter water consumption), via a battery of plate heat exchangers, in the same way as CORSAIRE winter free preheating process but only in summer for Toronto by lack of a big seasonal heat storage!

Since 2006, Toronto's DLWC on Lake Ontario has been the world's largest thermo-lacustrine air-conditioning system (second only to GeniLac in Geneva). Similar to the GeniLac Thermal Lacustrine Network (TLN) in Geneva, thanks to free cooling it saves 90 GWh of electricity and 1 million m^3 of water a year, compared with compression and wastewater refrigeration machines (electricity savings ≈ 80%, source Enwave) [**51, 52, 53**].

The advantaged compared by GeniLac who discharge the waste heat in the Lake Léman, DLWC don't discharge the waste heat in the Lake Ontario. But, by the help of heat pumps, the GeniLac TLN supply in winter heat taken from the Léman. However, in seasonal contrast to CORSAIRE free preheating in the winter semester and without a seasonal heat storage, the waste heat from the DLWC Air Conditioning is used only in summer to "deglaze" (4 => 12.5 **℃**) 1/4 of Toronto's potable water network (downtown). This without considering potential energy savings in the usage of the potable water.

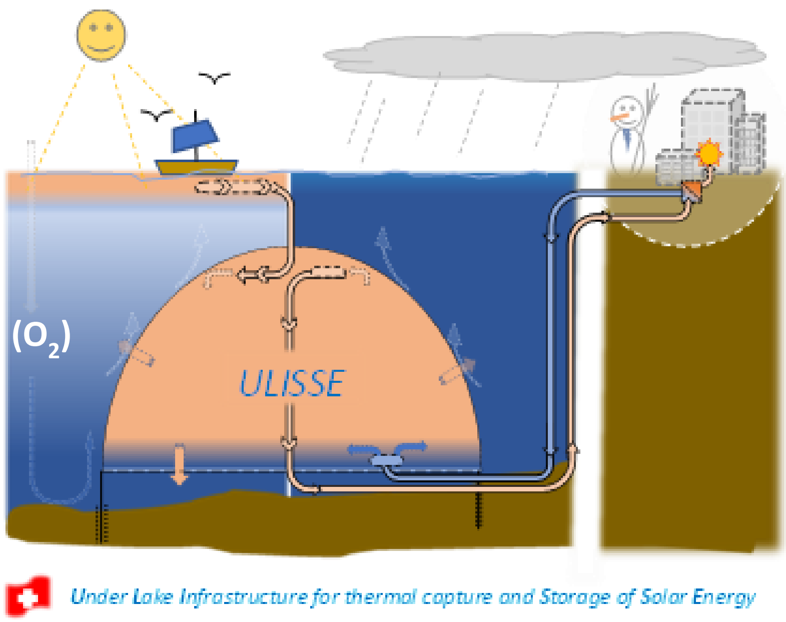
https://www.washingtonpost.com/climate-solutions/interactive/2021/toronto-deep-latke-water-cooling-raptors/



Synoptic of Toronto's Deep Lake Water Cooling system (DLWC), with thermal energy injected into the urban potable water network via a 360 MW battery of plate heat exchangers (source: Enwave) [**51, 52, 53**]

Today, after a 20-year hiatus (maybe it was ahead of its time), I am finally presenting a summary of these studies which all converge on the ULISSE project (Under Lake Infrastructure for thermal capture and Storage of Solar Energy). This project also stems from alternative solutions developed in response to the objections I received regarding my previous proposals. I observed that several of the measures or solutions I had proposed were adopted a few years later, by CERN, SIG and others (Toronto).

The ULISSE project was initially my response to the Swiss Federal Office of Energy (SFOE). In 2021 the SFOE launched the first '**SWEET Out the box Rethinking' SOUR Call 1-2021** for Switzerland's Energy Transition 2050. With SOUR programme, **the SFOE has created an instrument to give unconventional, riskier projects a chance.** Out of a total of 77 proposals, independent foreigners' experts carried out a double-blind evaluation and selected four projects for funding. **ULISSE was the top-ranked project.**



(*Image generated by **A**rtisanal **I**ntelligence*)

The ULISSE exploratory study took place at the **host institute HEPIA** (Geneva University of Applied Sciences for Landscape, Engineering and Architecture), from September 2021 to the end of May 2023. The ULISSE project report, appendixes (Eng. & French), and poster of the SFOE SWEET conference 2023 are available on the SWEET-DeCarbCH research consortium website:
https://www.sweet-decarb.ch/news/article/ulisse
and on the ARAMIS database of research, innovation and evaluation projects financed or executed by the Confederation: https://www.aramis.admin.ch/Texte/?ProjectID=49267&Sprache=en-US

Initially I focused the ULISSE concept, based on large seasonal heat storage reservoirs in the 15 greatest lakes of the Swiss Plateau, to compensate partially (1/3) of Switzerland's structural electricity shortfall forecast by 2050 (9 TW). Nevertheless, ULISSE also stems from my reflections in mind on CERN's waste heat recovery and valorisation; which is why here I am now turning my attention again back to CERN.

The ULISSE reservoirs could also manage CERN's waste heat and therefore the Organisation could integrate the consortium to continue the Next Step of the project who consist in an Advanced Research Phase (ARP) with a prototype. In case of positive results, the construction of a full-scale pilot reservoir connected to an existing *Thermal Lacustrine Network* (TLN) as GeniLac offers the latter (and CERN) the opportunity to expand their capacities in the future …

1992: CERN's first massive waste heat recovery precursor, the VERTCAD concept proposal

Following the 1992 Rio Conference (UNCED), on October 20, 1992, the author makes a private proposal to local authorities for the VERTCAD project (***Valorisation of Thermal Waste by District Heating),*** involving sources from CERN, industrial installations in the Canton of Geneva (Lignon central heating plant, Cheneviers incineration plant) and that of Bellegarde in neighbouring France, as well as from à complementary *combined Gaz-Turbine-Steam Power station* (GTS) for CERN's electricity.

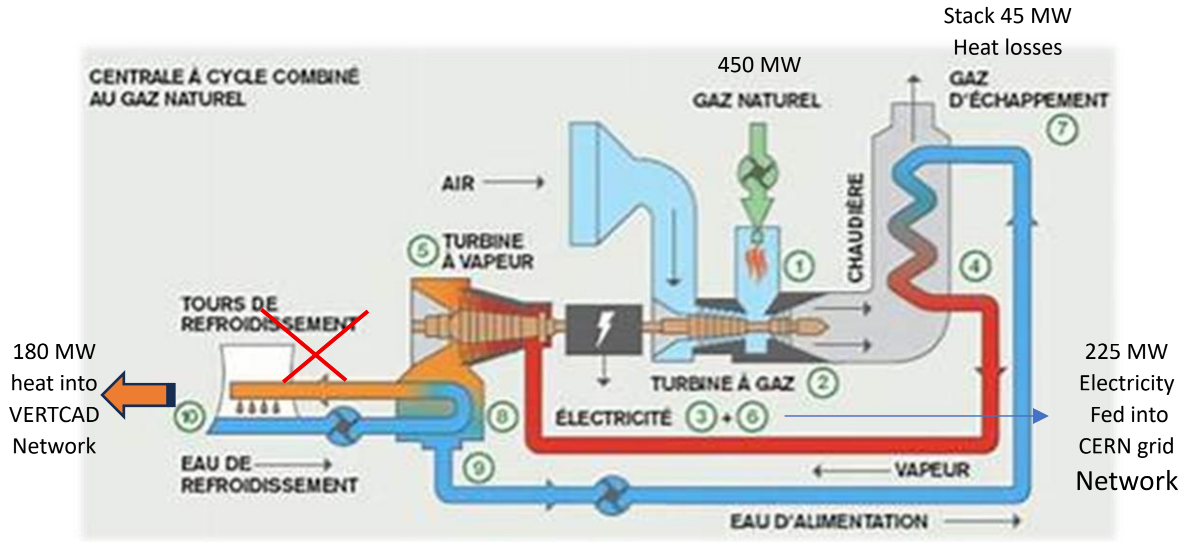
The challenge was, beside a regional reduction in CO_2 emissions, also to focus CERN's operational period on winter semester, with the annual shutdown in Summer. **This would mean giving up the preferential annual tariff under EDF's EJP contract (see p5, lines 30-36) and support the higher winter electricity price.** The additional annual electricity cost of around 37 M CHF/y (900 GWh @ ≈ 41 K CHF/GWh[3]) by the Winter Operation and Summer Shutdown compared to the conventional inverse planning, need to be at least offset. But this makes it possible to recover and sale 580 GWh waste heat and part of which is used to meet CERN's own heating requirements (reducing 8'000 toe fossil fuels in 1992).

Based on CERN's annual electricity consumption of around 900 GWh, reducing 200 GWh base load for general services, the 700 GWh electricity for accelerators end experiments produces with 90 % heat recovery and 8 % of losses during distribution, the net supply and sale of approximately 580 GWh of thermal energy represents 35 M CHF/y (@ ≈ 60 K CHF/GWh-t, SIG price district heating in 1992).

Furthermore, as mentioned before (pg. 12), the specific energy requirements, for ventilation and production of chilled water for the general cooling of machinery during winter operation, are significantly lower than those required during summer operation. The corresponding reduction in power consumption can be estimated at over 10 % of the total power consumed (≈ -25 MW for the entire CERN complex at the time).

The resulting 225 MW electrical energy required (in 1992) for CERN's winter operation of the particle accelerators and their associated experiments would be supplied by a Combined Gas-Steam power station (CGS), who has a heat recovery (cogeneration) for the VERTCAD district heating network.

[3] ≈ 174 => 337 K FF/GWh: Δ ≈ 41 K CHF/GWh (AMPTAR and DOP 10 mm simulation by DOPEE for EdF, specially requested later on in 1994 for my EPFL master thesis)



Principle of combined cycle Gas-Turbine-Steam power station (GTS) + Combined Heat and Power (CHP) plant for CERN's 225 MW electricity in winter semester operation
Image: http://www.eos.ch/eos_chavalon_fonctionnement_rendement.pdf

The combined cycles (Brayton-Rankine) of a Gas-Turbine-Steam power station (GTS) has an efficiency of 50 to 55%, who's the most efficient way of generating electricity from fossil fuels. With an additional 40 % useful heat recovery (cogeneration) on the steam condenser of the Plant (which names a *Combined Heat and Power* plant or "CHP"), the overall efficiency of the GTS+CHP plant reaches 90 %.

Furthermore, the use of natural gas results in CO_2 emissions that are one-third lower than those from heavy fuel oil. The corresponding CO_2 emissions are to be deducted from those resulting from the shutdown of the Lignon thermal power station which was also fuelled by natural gas at the time and heavy fuel oil (as a backup). The latter remains in standby mode only (backup).

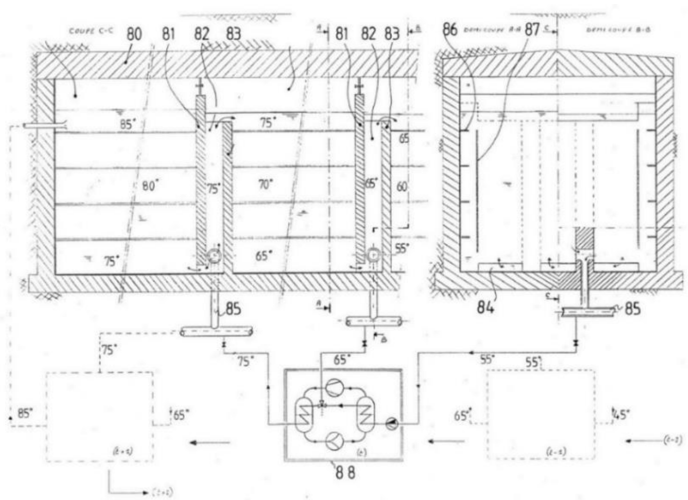
The GTS+CHP power station could have been installed near the Verbois hydroelectric plant or the Cheneviers incineration plant, which is located nearby and connected to the VERTCAD network. Another option would have been at the centre of the former ISR ring on CERN's Meyrin site.

On the regional scale of "Grand Genève", compared at the time to traditional district thermal networks as from SIG (CAD) with superheated water (130˚ C), VERTCAD was an avant-garde concept of a medium to *Low Temperature district heating Network* (LTN), working between 85/58˚C (day/night modulation) and with a return temperature of between 20/10˚C (summer/winter modulation).

A particularity concerns the low temperature (10˚C) of the return pipe of the network obtained, through a heat exchanger, only by the winter "free" (without heat pump) preheating of the urban or local (inside buildings) potable water network (PWN). This announcing already its successor, the next CORSAIRE project.

The heat power difference between summer and winter is also modulated by the water flow in the LTN. The VERTCAD system featured initially with a 100'000 m^3 hydraulic heat storage unit (24 TJ), installed in the former circular ISR building at CERN. The new nicknamed "*Intermediary Storage Reservoir"* (ISR) is designed to manage the daily modulation mismatch between WHP - THD and a breakdown, with a storage capacity assignation of around 10 TJ (daily, weekly modulation) & 14 TJ (backup reserve).

The ISR is divided in a cascade of 12 reservoirs of 8'000 m^3 each, at different temperatures steps from 25 to 85**˚C.** They are interconnected by vertical stratification channels and intermediary heat pumps to optimise the "eXergetic" (based on the 1st and 2th thermodynamic laws) potential for heat recovery according to the temperature levels of the various waste heat sources.



Thermal interconnections and intermediate heat pumps principle for managing the hot water storage tanks in CERN's former ISR circular building (100'000 m³, 12 x 8,000 m³; 25°C – 35 – 45 – 55 …– 85 °C; ∑≈ 24 TJ)

In summary, the VERTCAD project, which focuses on recovery of waste heat, can potentially provide annually district heating of around 2.4 TWh (≈ 9 PJ/y), with an average power capacity of 677 MW, for around 400'000 population, equivalent to the Canton of Geneva (numbers of 1992)!

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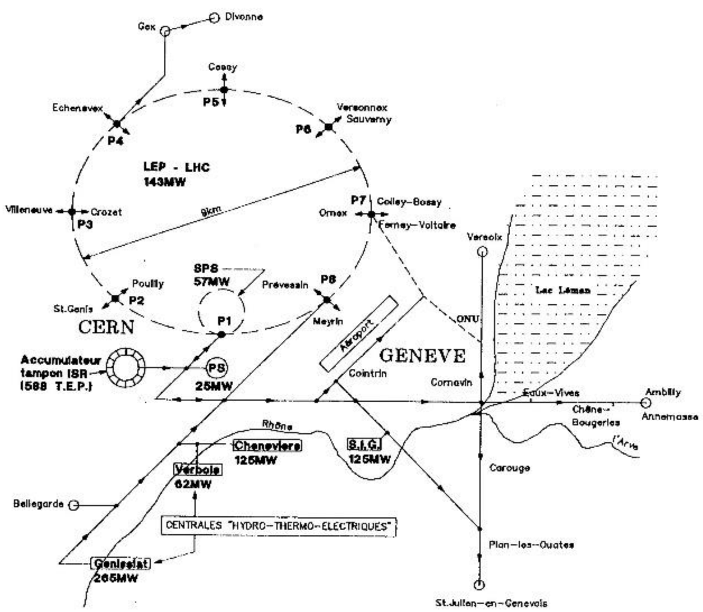
UTILISATION DES REJETS THERMIQUES POUR LE CHAUFFAGE DES AGGLOMERATIONS URBAINES

William van Sprolant*



Synoptique du projet (VERTCAD)

Synoptic of the VERCAD project proposal in CERN's Graviton quarterly magazine (November 1992)

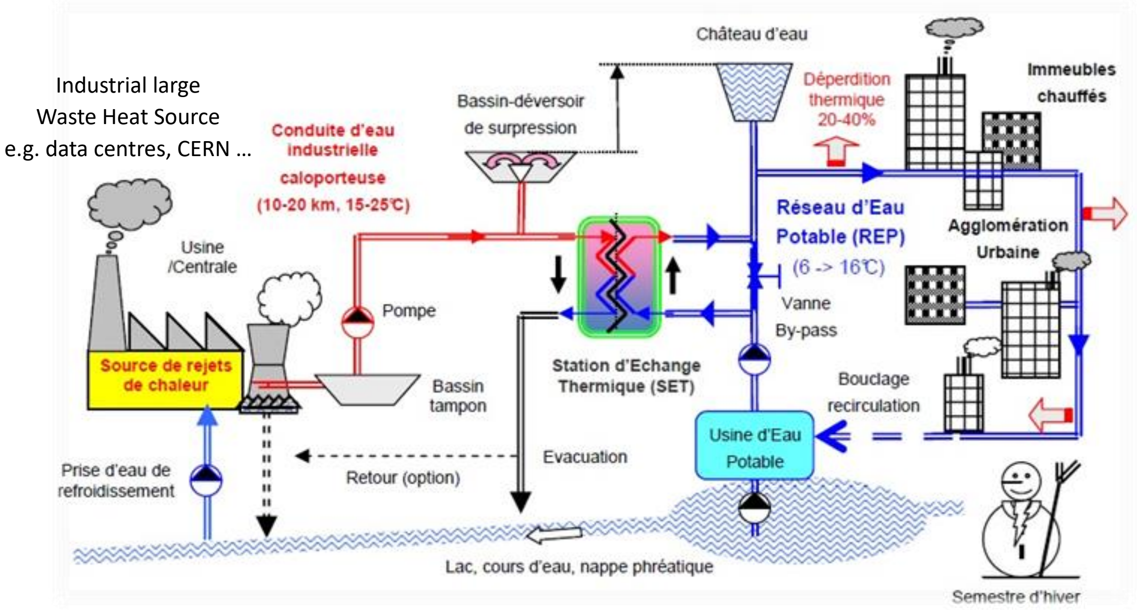
Except the acknowledgements by Nobel Prize Carlo Rubbia, at the time CERN's DG, the (manuscript) of the VERTCAD personal proposal was received "freshly"; notably on the pretext that it discloses the significant amounts of electricity consumed and drinking water for CERN's cooling (*In stark contrast to CERN's current promotion of the FCC*). A few years after CERN closed its "open" cooling circuits on the wet cooling towers, in order to drastically reduce its potable water consumption (pg. 2, line 20).

On the other side, a decade later, SIG had planned for the winter of 2010–2011 on the site of Lignon his own combined Heat (cogeneration) and Power plant (CHP), fired with natural gas (source: RTS, 07.02.2007). Unlike the GTS-CHP plant for VERTCAD, the SIG plant has only a single gas turbine with cogeneration and an overall efficiency of 75 % (vs 90 % for the GTS+CHP of VERTCAD). In 2012, the Geneva State Council rejected SIG's CHP project, objecting to the CO_2 emissions from natural gas used for electricity generation compared with hydroelectricity who's Geneva's main domestic source [**42**].

More, for the VERTCAD network, SIG has been claimed that half of Geneva's streets would have had to be cut open to connect the buildings to this new Low Temperature heating Network (Fig. 2.2 below). Despite these objections, nearly 20 years later, also in the early 2010s, Geneva began building its GeniLac low temperature lacustrine energy network (with the help of heat pumps for space heating and sanitary hot water production) and full commissioning scheduled by the SIG for 2035 (pg. 6, lines 18-26). Source: sig-ge.ch

1995: CORSAIRE proposal with CERN's Summer Shutdown (EPFL energy master thesis)

Nevertheless, as a complementary manner to reach a 10˚C cold return pipe in the VERTCAD project using CERN's waste heat, the winter semester "free preheating" (without heat pump, just a heat exchanger) of the public or local (inside the buildings) potable water networks, is an approach that was not yet been explored more in detail at the time in 1995 (as late as a decade after, in 2006, as mentioned before with the DLWC of Toronto, pg. 13).



Principle of the CORSAIRE winter "free" preheating (without heat pump) of the Potable Water Network (PWN)

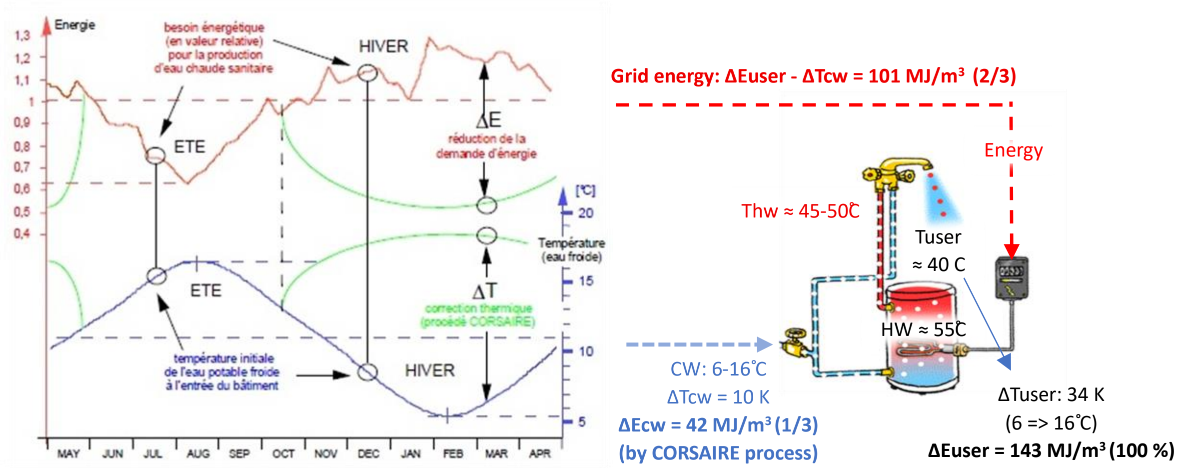
It inherently avoiding the aforementioned obstacles objected by the SIG (e.g. construction of a large district heating network and a backup heating power plant). On the opposite, it taking advantage of the synergy with the all-existing potable water network (PWN), apart some complementary features (e.g. possibly thermal insulation of the final distribution pipes, recirculating loops in the water mains, etc.), it presents more investigations: general feasibility, bacteriological issues, energy billing, etc.

This was the subject of the author's EPFL master's thesis (1995) who use the waste heat from CERN (700 GWh thermal or 2.5 PJ) in the winter correction (5 to 10°C) of the temperature of the (existing) Potable Water Network in the canton of Geneva : the CORSAIRE free preheating without heat pump, from there the nickname of **CORSAIRE** process, acronym of ***Cor****rection* ***Sai****sonnière de la température du* ***R****éseau d'****E****au potable* [**43**].

The main challenge was also to avoid the use of a classic seasonal heat storage (geothermal, tank, pit, borehole or aquifer), given the thermal capacity required to store the summer semester's production who's roughly two-thirds of total CERN's waste heat (450 GWh or 1'620 TJ = **37 times the World's biggest Vojens storage basin in Denmark, 210'000 m^3, 44 TJ @ ΔT = 50 K**) [**36**].

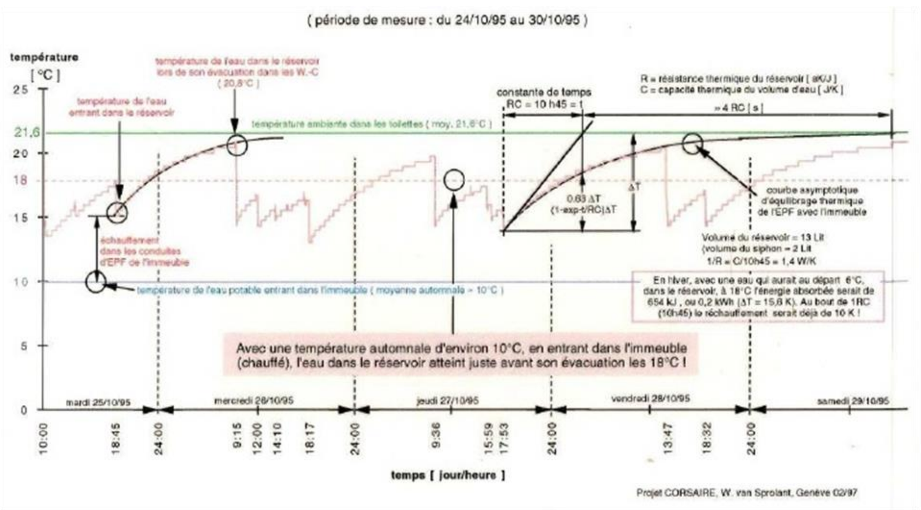
Supposed with a ΔT = 20 K, CERN's 1.6 PJ summer semester waste heat need a storage volume of roughly 19 M m^3. This was initially supposed to have a fatal flaw due to its excessive size & CAPEX. This would mean that the waste heat would have to be produced only when it has a "use-value", during the winter semester. This means also the challenge that CERN's annual shutdown (of accelerators and experiments) was displaced in Summer as for the VERTCAD project proposal, and also suggested as an option by GINGER BURGEAP for the FCC waste heat recovery study (2024, see pg. 8, line 20 [**C12**]).

The fundamental appeal of the CORSAIRE concept lies in the observation that, In the Swiss Plateau and Alpine Arc regions, the temperature of the potable water network varies seasonally. This variation has an amplitude of around 10°C between summer and winter. As a result, a 10°C drop in temperature in winter compared with summer represents a difference in heat content of nearly 42 MJ or 12 kWh/m^3 (4.18 MJ/°C/m^3) in the water supplied to buildings heated at 20°C in winter semester.



Seasonal trends in the public DWN temperature and heat demand for DHW and potential CORSAIRE impact

In winter, there is little or no external use of potable water (no watering, outside swimming pool), which reduces the water consummation between 10 and 20 % vs summer (Genva). But in winter all the chilled drinking water flowing through residential heated buildings (≈ 70 % of the total public water consumption) is then heated intentionally (by being mixed with domestic hot water, dishes- & washing-machines, etc.) and even unintentionally in toilet cisterns (around 30 % of total consumption in winter). The stagnation of cold water in toilet cisterns and bowls is an unexpected (neglected) source of heat loss during the heating semester in buildings. Each flush of a toilet can remove up to 0.7 MJ (0.2 kWh) of heat energy (13 litres of water @ 13K ΔT).



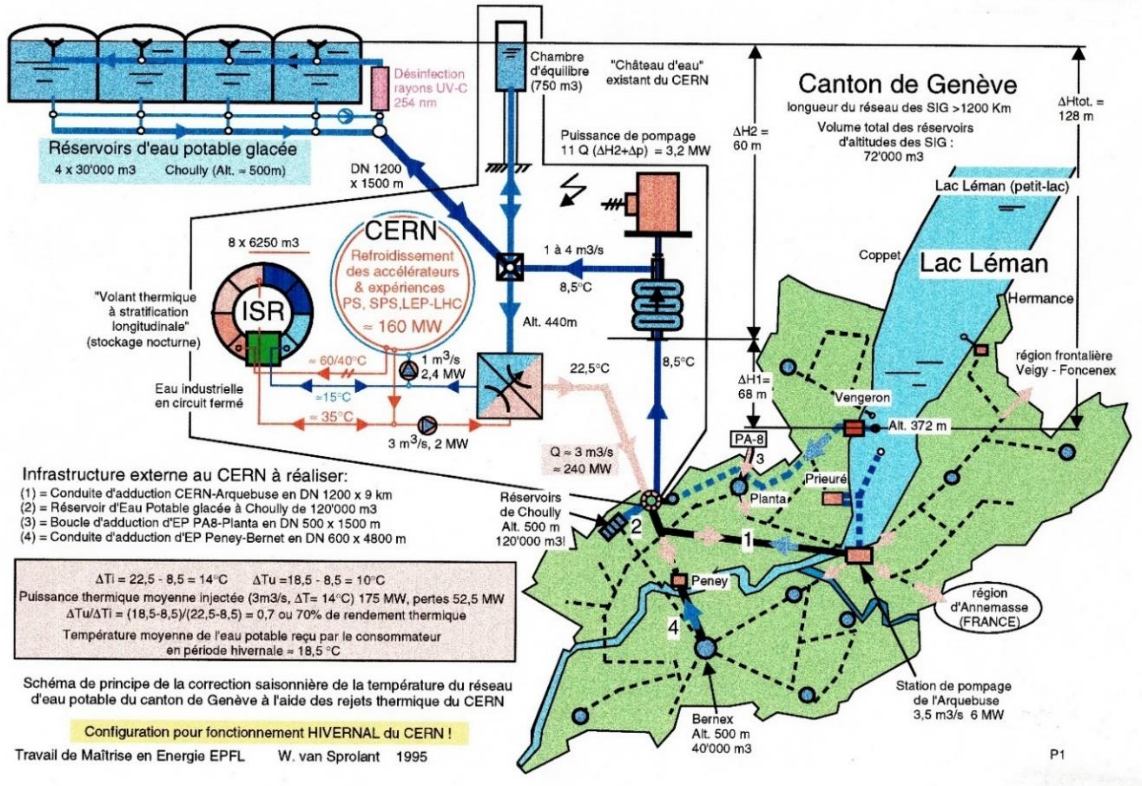
Asymptotic evolution of the temperature of cold water in toilets (WC) in Geneva (average increase of 8C already at the beginning of the heating semester). Toilets (WC) ≈ 1/3 of household drinking water consumption!

This makes that, all other things being equal, every m^3 potable water consumed in winter absorb up to 12 kWh (42 MJ or equivalent of 1 kg of heating fuel) more than in summer for the same services. The daily winter water consumption of the canton of Geneva is around 120'000 m^3/day; that means an energy surplus vs summer of 5 TJ/day, equivalent of 120 t heating fuel/day and electricity consumption involves in all the indoor corresponding heating processes.

Winter "free" preheating of the potable water network of Geneva with CERN's waste heat

The logic conclusion was to correct this natural winter temperature drop of the potable water network by means of industrial waste heat and a single battery of plate-heat exchanger placed after the water treatment and pumping plant.

For the master thesis study of 1995, carried out at the CERN complex, numerous elements and numbers were taken from the 1992 VERTCAD study. The difference was that at time that CERN planned to combine the LEP200 and the LHC (placed above the LEP but subsequently abandoned), with an annual electricity consumption of around 900 GWh/y.



Synoptic of the winter "free" preheating (without heat pump) of the public potable water network of Geneva, neighbouring France within LEP200 and LHC (at the time) areas and CERN's waste heat with Summer Shutdown (master thesis EPFL, 1995)

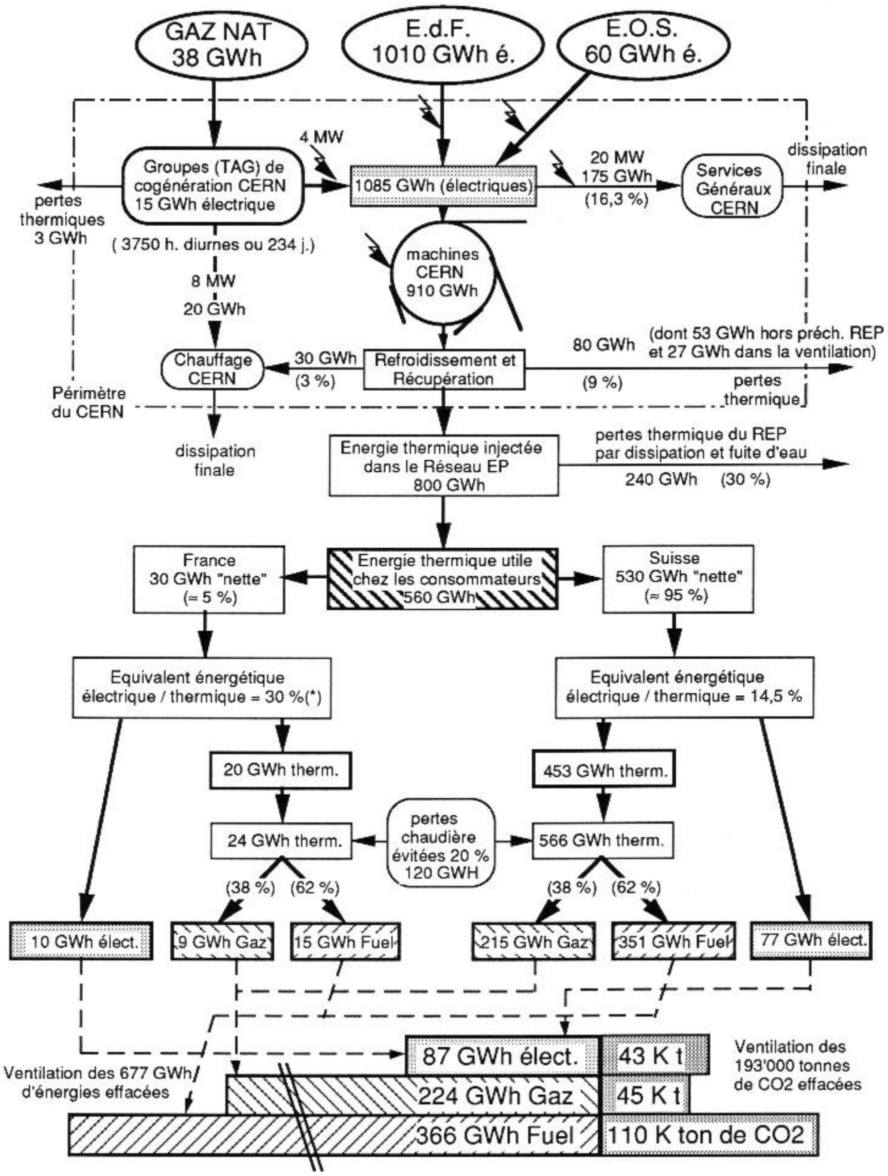
Taking into account the baseline electricity consumption for general services, the heat used for the laboratory's own heating requirements, and various internal losses, the thermal energy that could potentially be fed into the potable water network during the winter half-year was estimated at approximately 800 GWh. Given that 30% of heat is lost in the potable water network (which is not normally insulated), 560 GWh was supplied to the entrances of end-users' buildings, 95% (530 GWh) to the canton of Geneva and approximately 5 % (30 GWh) within the LEP/LHC perimeter in France.

As with VERTCAD, winter operation results in additional costs for electricity, resulting in the loss of the EJP contract with EdF and the higher cost of "winter electricity". Beside the reduction in electricity consumption, for cooling the CERN complex (better thermodynamic performance of the cooling heat pumps – 10 %), the additional electricity bill is around 40 M CHF. But regards less natural gas (heating) and no more needs of potable water for cooling, CERN save around 5 M CHF. His net additional energy cost therefore amounts to around 35 M CHF.

Based on existing (1995) heating equipment and their efficiency in the use of potable water (boilers, domestic hot water systems, washing machines, dishwashers, etc.), the net supply of 560 GWh heat from CERN to consumers of the preheated potable water will offset 677 GWh, divided in 87 GWh electricity, 224 GWh natural gas and 366 GWh heating oil. Taking into account the cost of the energy vectors, the total cost saved by consumers amounts to CHF 62.5 M CHF, to which must be added 6.7 M CHF CO2 tax savings by reducing nearly 200'000 t CO_2 emissions (≈ 36 CHF/t CO_2 Swiss forecast @ 2000).

The average unit selling price of the thermal energy supplied by the REP should be such that there is a balanced sharing of the benefits between CERN and the local Community consuming this recovered energy, bearing in mind that consumers are captive to the single public Potable Water Network (PWN).

The fair unit Energy selling price Esp (CHF/KWh) of the 560 GWh heat supplied by CERN trough the preheating of the PWN, is based on a 50/50 split of the overall profit, corresponds to half the difference between CERN's additional (35 M CHF) cost of energy and the (62.5 + 6.7 ≈ 69 M CHF) financial savings on energy and CO_2 tax made by the Consumers: Esp = [(69 – 35)/2] 560 ≈ **0.03 CHF/KWh**.



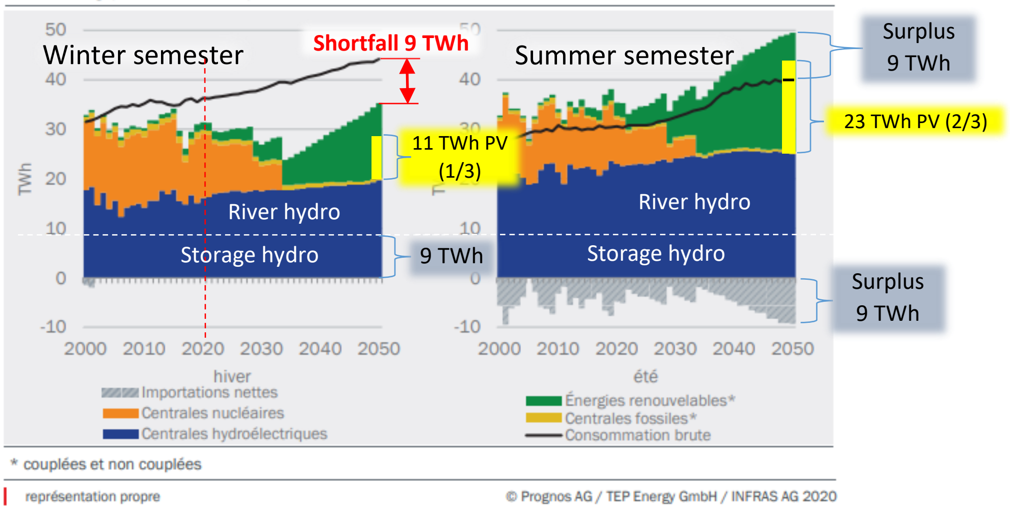
Representation of CERN's energy flows to the Consumers, trough the preheating of the Potable Water Network and the breakdown of the various energy sources and the corresponding CO_2 emissions avoided.

2021-2023: The ULISSE project, the ultimate opportunity for CERN's waste heat recycling

Background

In the face of climate change, **the *Swiss Energy Strategy* (SES-2050)** which aims for a "double neutrality" Nuclear & Carbon (2035-2050**)** [**1**]**, forecasts a structural deficit of 20 % or 9 TWh electricity in the winter semester 2050, equivalent to the national hydroelectric storage capacity** [15]**.** This results from the planned withdrawal of nuclear power in 2035 and the increase in demand for electricity, for electric mobility, air conditioning, heat pumps for room heating, domestic hot water, as well as for the decarbonisation of industry.

The major challenge of the SES-2050 is therefore to have enough "doubly neutral" electricity available in winter, with a foreseeable shortage of imports [**1.1**], either through increased domestic production (with seasonal storage) or by reducing demand (in particular by improving the efficiency of its use).



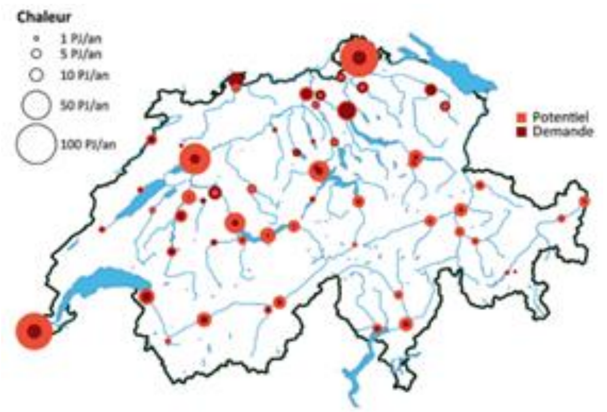
Development of gross electricity production during the winter and summer months in the ZERO-baseline scenario, "balanced annual balance" strategic variant in 2050, in TWh (source: SFOE EP2020+) [**1**]

Increased production of undifferentiated electricity could amount to a "headlong rush":

- Adding even more photovoltaics to the 34 TWh already planned for 2050, while naturally only having 25-30% of annual production available in the winter semester, would only accentuate the risk of having to resort to the paradoxical summer "*solar peak shavings"* and negative spot market prices for electricity [**17.1, 17.2**].
- Further development of hydroelectric storage capacity is limited by the number of acceptable potential sites. Added to this is the problem of summer loading of dams with water under water stress due to global warming. Generally speaking, the requirement to increase "residual flows" will reduce hydroelectric productivity. The potential for developing annual hydroelectricity production between now and 2050 is between 1 and 3 TWh (**SFOE 2012b**).
- Maintaining nuclear or other thermal power plants would exacerbate water stress on rivers already impacted by global warming and will be forced to shut down or drastically reduce their production in the summer semester, and will be consequently also less present in the winter semester [**67**].

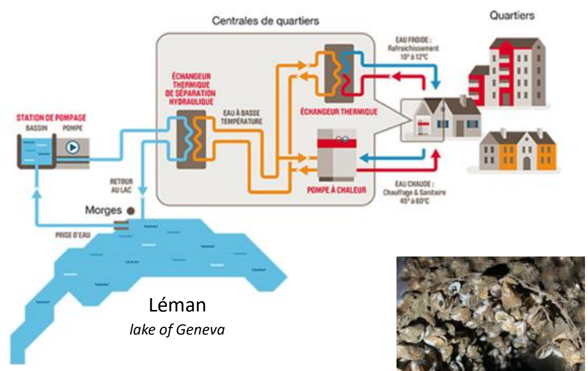
Therefore, the SET-2050 calls for massive development of district heating and cooling networks, with renewable energy sources and waste heat [**13, 14, 26**]. Although the thermal potential of Switzerland's 15 major lakes (> 10 km^2) is several times greater than local needs (1/4-1/3 national population), there use by means of "Thermal Lacustrine Networks" (TLN) is regulated (*Federal Water Protection Ordinance*) [**30**].

But Global Warming threatened already the lakes (asphyxiation, eutrophication) and invasive quagga mussel posing serious problems by obstructing for water pumping intakes for TLN and drinking services.



Swiss lakes potential for heat extraction (winter) and cooling (summer) Source: Thermal use of surface waters A. Gaudard; M. Schmid, Eawag; A. Wüest, Eawag and EPFL, AQUA & GAS Nº 6 [**27**]

Example of TLN "MorgesLac" of the city of Morges (CH/VD)



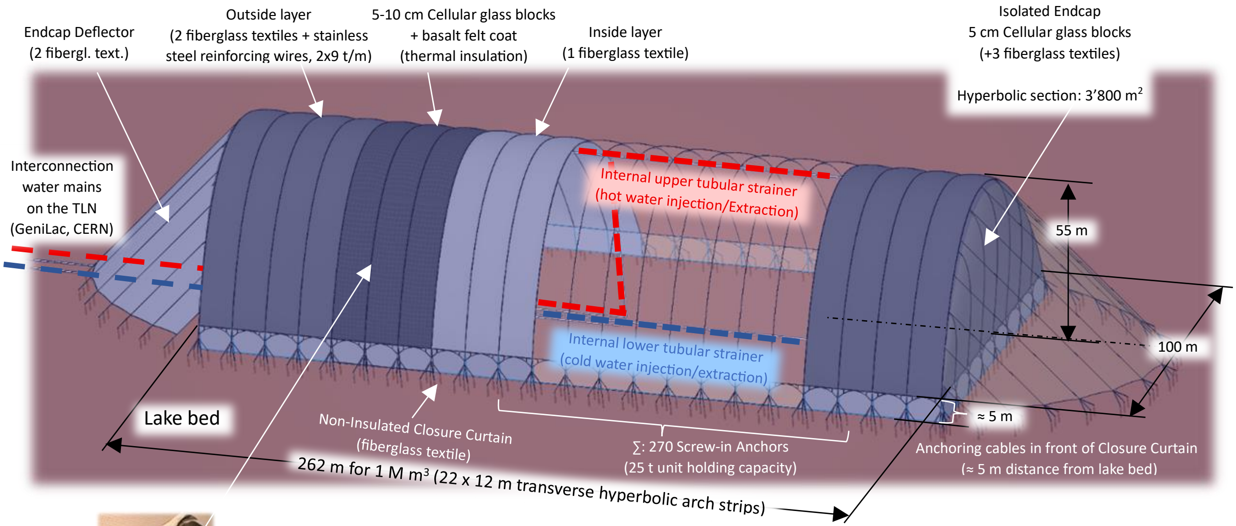
Quagga mussels' obstruction of lake water intake (EPFL)

ULISSE project Proposal

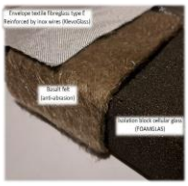
ULISSE is proposed here as part of a potential solution (trick) to this previously mentioned multifactorial problem. In support of the SET-2050, **ULISSE aims to boost the Thermal Lacustrine Networks (TLN) for Heating and Cooling services, of Switzerland's major lakes while protecting them from the effects of Global Warming**.

Under Lake Seasonal Heat Storage Reservoir

The ULISSE system consists of large "tunnel-shaped" **Under Lake Seasonal Heat Storage Reservoirs** (50 m hyperbolic transverse radius), with a unit storage volume of 1 to 2 million m^3 and a thermal capacity up to 125 TJ each (@ 2 M m^3, ΔT=15 K). Screw-in anchored to the lake bed, the envelope of a reservoir is made of a biocompatible, triple layer of stainless-steel wire reinforced **fiberglass textile** and **cellular-glass** blocks for thermal insulation, with individual **basalt coat for abrasive protection** and which enables a seasonal thermal storage efficiency of around 80% to be achieved.



Semi-rigid Insulated Envelope



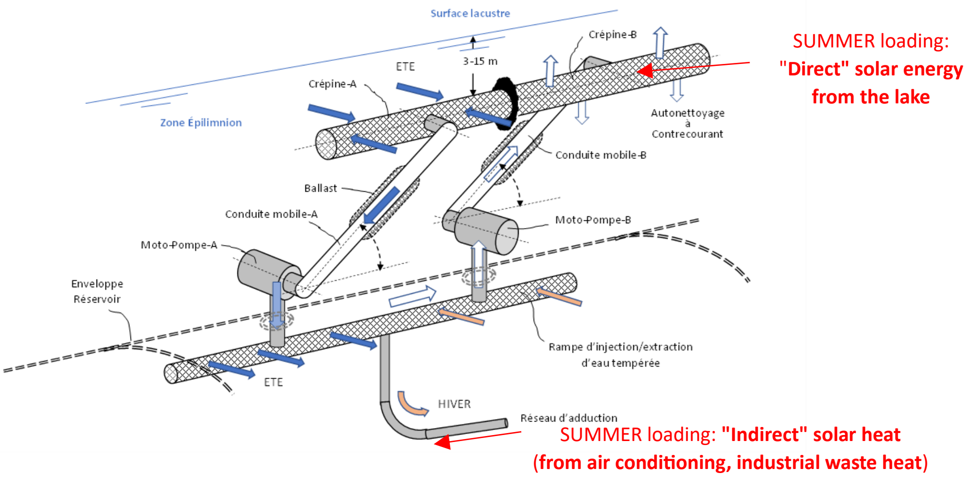
Screw-in Anchor
Impact of inking
at the bottom of the lake

Perspective view of the ULISSE sub-lacustrine seasonal heat storage reservoir (standard unit volume: 1 M m^3)
Self-supporting insulated envelope: 49'000 m^2; lake bed footprint: 26'000 m^2; Buoyancy: ≈ 4'000 t @ ΔT = 20°K
Version: Closed-Circuit Interconnection with TLN (Drawing SolidWorks Ir. Valentin van Sprolant 2026)

Charging modes

In Summer, the ULISSE Reservoir can be charged in two ways or from two sources: via “Direct” Solar Heat from the lake or via “Indirect” Solar Heat from air conditioning and waste heat recovery (e.g. data centre, CERN).

Direct lake solar heat is coming from the warmer water of the **upper layer of the lake** (*Epilimnion*) heated by the Sun (20-25˚C). By means of a Pump and a mobile and self-cleaning suction strainer “pantograph”**,** the warmer, lighter water is introduced at the top of the Reservoir, while the colder, heavier water inside is pushed downwards out the Reservoir at the bottom of the lake (figure below).



*Schematic diagram of the mobile temperate lake water collection device (Epilimnion zone). Here the internal **injection/extraction manifold is closed during the strainer self-cleaning process**. The water sucked into the A-strainer is pumped back to the B-strainer for counter-current cleaning and vice versa.*

Indirect solar heat (air conditioning and industrial waste heat) is introduced at the top of the ULISSE Reservoir via the TLN, in a closed-circuit water circulation between the “Cold Pipe” (blue line on the pictures) and the return “Hot Pipe” (red line) to the Reservoir (no exchange with the lake water). **This supresses the risk of the water intakes becoming blocked by quagga mussels (major problem with TLNs)! Furthermore, it eliminates the harmful summer waste heat discharge from the TLN into the lake.**

If the temperature of the water is high enough (20-25˚C), the heat transfer can be operated in a “free cooling” mode (without Heat Pump), or slightly boosted by the Heat Pumps of the TLN normally used for Winter heating services. The latter also reduces the volume/flow rate of warmer water for the same amount of heat transported and stored. Circulating - and Heat-Pumps are powered by photovoltaic (PV) electricity, which absorbs the summer production peaks and reduces their so-called *peak-shavings* and induced negative spot-market electricity prices.

Discharging mode and usages (services)

During the winter semester the ULISSE Reservoir constituted a Winter Lake Heat Source of around 20°C and even more up to 25°C, higher than the usual 5-6°C of the lake water, mainly for heating services supplied by the “Hot Pipe” of the TLN. After extracting the warmer water from the Reservoir and transferred the heat content to the end users, the colder water returning via the “Cold Pipe” of the TLN back to the lake at as usual 3°

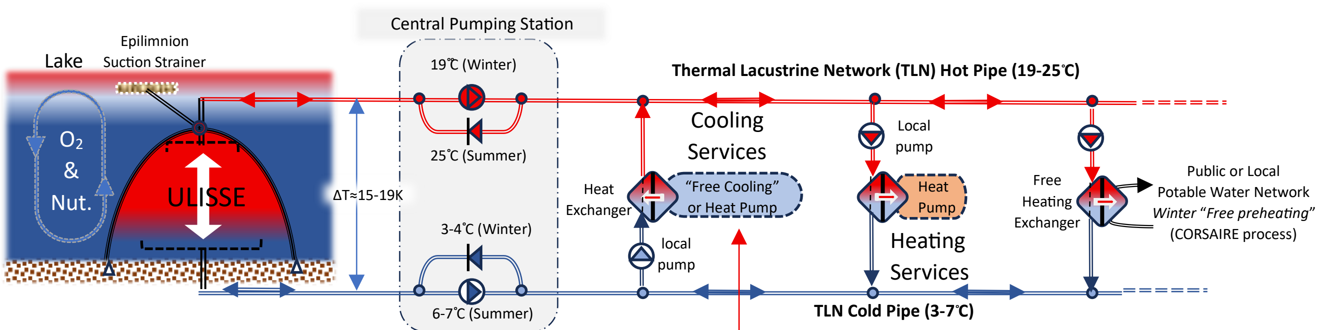


Diagram ULISSE Reservoir connected in a Closed-Circuit with the TLN (less lake water exchange) in Summer and Winter

<u>This could be a configuration for a CERN interconnection</u>

The fact that the energy density of the water increases by a factor of 5 (≈12.5 => 63 MJ/m^3 @ ΔT ≈ 3K => 15K), the water flow reduces by 80 % and the energy required to pump and circulate water through the TLN network by 95 %. Finaly, the increased temperature of the ULISSE lake heat source will increase significantly the efficiency of the Heat Pumps (≈ 50 %), which with the Circulation Pumps reduces the overall power consumption of the TLN system by nearly half (COPsys ≈ 3 ≈> 6), this also in combination with the complementary CORSAIRE process.

Complementary CORSAIRE process

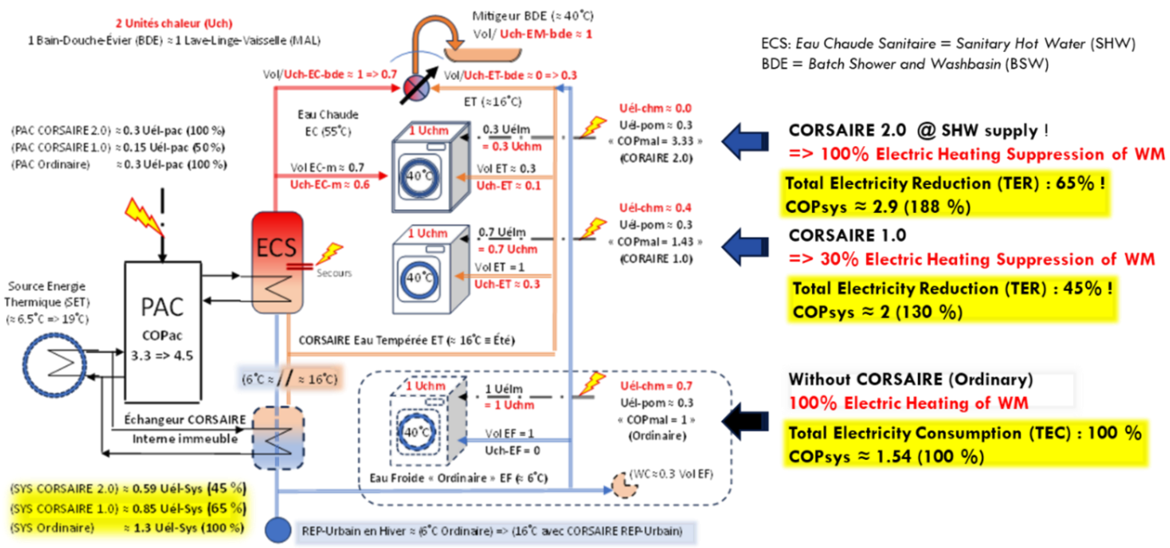
The CORSAIRE process is a second way of using the tempered water supplied by the ULISSE Reservoirs or other thermal discharges (outside lake regions). Like the *free cooling* for air conditioning, CORSAIRE *Winter free preheating* uses only a heat exchanger as a thermal "slide", located inside de buildings or outside on the public PWN, to correct the typical drop in temperature of the potable water during Winter (ΔT≈10°K).

It can supply 30% of the energy for Domestic Hot Water (DHW) production via the PWN and increases the electrical efficiency of the TLN, as well as all Heat Pumps for DHW. This even outside TLN networks or lake regions by a suitable waste heat source.

Electricity Impact by free preheating inside the building or on the public Potable Water Network for Washing Machines (including outside lake regions)

In comparison with ordinary cold water (6°C), supplying the washing machines and dishwashers with simple “free” preheated PW (CORSAIRE without heat pump) at (16°C or more), could already reducing their electricity consumption by around 45%. Supplying DHW to washing machines and dishwashers can reduce their electricity consumption by around 65-70 %. Only a residual 30-35 % supply the circulating pumps and **eliminates the electric “Joule” heating of the water.** This means that the amount of domestic hot water will therefore increases.

Provided that the domestic hot water is partially produced by a heat pump (which is expected to be the case by 2050) and around 1/3 benefits from free preheating (without a heat pump) will help to improve the system’s overall efficiency (COPsys => 6.32).



Electricity Impact by free preheating inside the building or on the public Potable Water Network on the Domestic Hot Water (DHW) production and for Washing Machines (WM) connected on the DHW (including outside lake regions)

Comparison with ULISSE & CORSAIRE as applied to GeniLac in 2050 (case study)

A: GeniLac without ULISSE nor CORSAIRE

Based on the *ClimaBau - BFE 2017* study **[3],** the case study integrates the effect of Global Warming (+20% Air Conditioning & -20% Room Heating needs) in 2050. For GeniLac in 2050, the furnishing of 250 GWh-t useful heat (Qu$^+$) in winter semester needs a total **electricity consumption (Ec) of 79 GWh-e**, including hydraulic pumps (Ep) and heat pumps (Ehp)**). The winter COPsys = 3.16 (250 GWh-t/79 GWh-e)**.

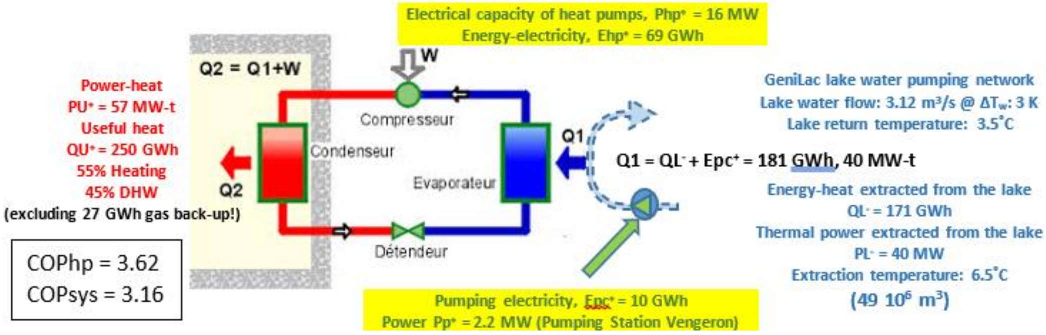


Diagram of winter water and energy flows for GeniLac pumping and heat pumps without ULISSE nor CORSAIRE in 2050

B: GeniLac with ULISSE & CORSAIRE (by free preheating exchanger inside buildings or by public PWN)

The difference between furnishing 35 GWh of preheating potable water direct inside the buildings (trough the GeniLac TLN) or externally trough the public PWN, is that for the later 30 to 40 % of the heat is loses through his non insulated pipes. In any case, for a total same useful heat (Qu^+) of 250 GWh in 2050, GeniLac's TLN must furnishing the difference or 215 GWh on the Heat pumps.

Given that ULISSE is a heat source furnishing 211 GWh with an average temperature of between 19 and 25 °C, the COPhp rises from 3.62 to 5.51 (215 GWh-t/39 GWh-e), an increase of around 50 % compared with GeniLac alone and a gain of 30 GWh electricity.

In addition, with an increase of the round trip of the lake water temperature (ΔT: 3 => 15 K), the water flow and the corresponding pumping energy decreases by 96 % (10 => 0.1 GWh-e, proportional to the square of the water flow difference). **The final COPsys increases from 3.16 to 6.32, what means a total electricity consumption reduced by half with ULISSE & CORSAIRE compared with GeniLac alone.**

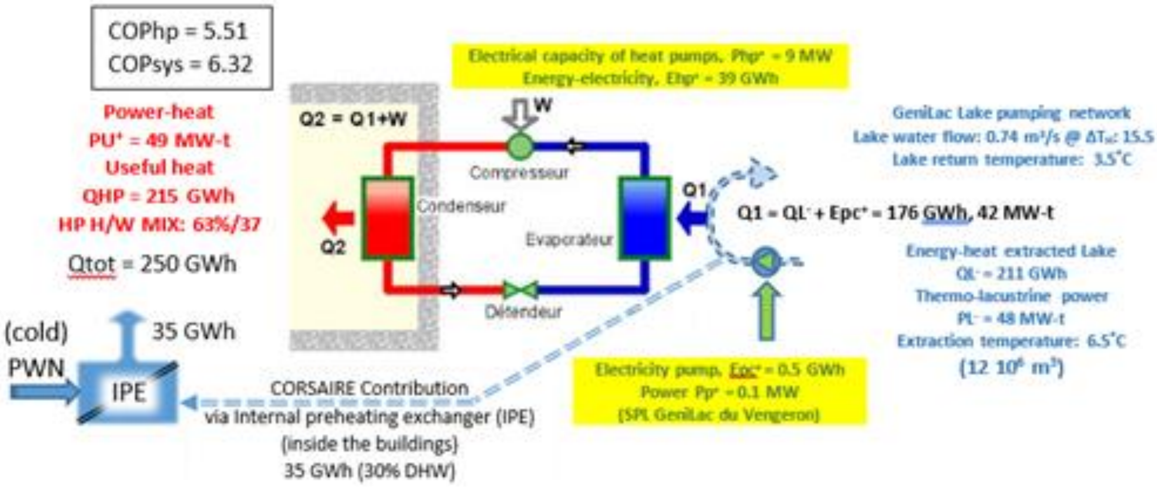


Diagram of winter water and energy flows for GeniLac pumping and heat pumps with ULISSE & CORSAIRE in 2050

The CORSAIRE preheating inside the buildings is considered here because it's not necessarily implemented on the public PWN who concerns the entire urban agglomeration, well beyond the capacity of the GeniLac TLN network. For example, the PWN in the canton of Geneva covers more than 1,200 km, i.e., 40 times more than the GeniLac network (30 km). It also has a daytime flow rate of around 2 to 3 m^3/s.

An "External" contribution of CORSAIRE, via the public PWN, except additional heat losses of 30 to 40 % in the non-insulated mains, involves practically no additional electrical energy, other than that linked to pressure drops in the CORSAIRE External Heat Exchanger (EHE). This because the potable water is anyway transported and distributed to all the buildings in the town.

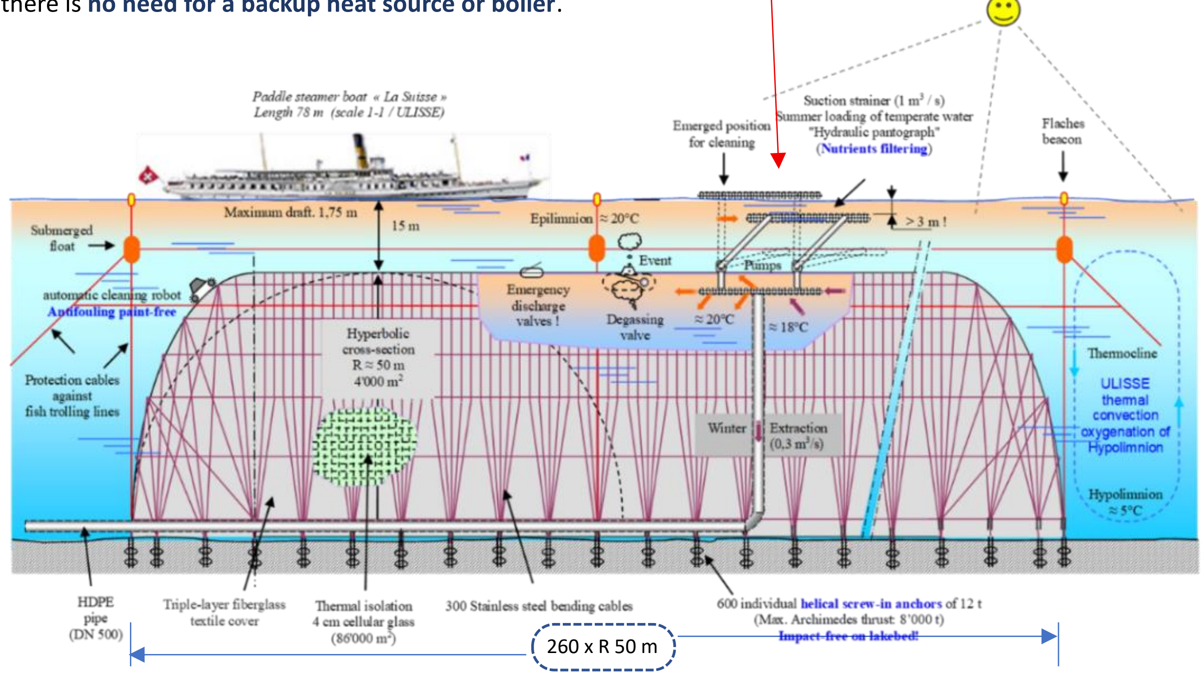
The public PWN offers also the possibility of utilising waste heat via CORSAIRE, without necessarily requiring ULISSE, no district heating network (DHN) nor backup boilers and therefore also applicable outside lake regions.

Consequences for CERN's waste heat valorisation

In terms of heat recovery, the net supply of 211 GWh (760 TJ) of waste heat, via the TLN system (GeniLac) enhanced by ULISSE (+ CORSAIRE trough TLN, not via public PWN), results in a saving of 40 GWh of electricity during the winter semester. Given that ULISSE's seasonal heat losses amount to around 20 % (53 TJ), the gross amount of waste heat fed into ULISSE during the summer semester is 264 GWh (950 TJ).

Applied to CERN in the same proportion, **1 TWh (3.6 PJ) of summer semester waste heat (derived entirely from CERN's electricity consumption) and recycled in this way via ULISSE, furnishing 80 % or 800 GWh (2.9 PJ) heat, in winter semester, on the end users and saves electricity of 150 GWh (15% of the 1 TWh electricity of CERN).**

A very important factor for the technical and economic feasibility of utilising CERN's waste heat is that, **in the event of a Long Shutdown, ULISSE can be recharged directly using heat from the lake.** Admittedly, the temperature may be slightly lower (25 ≈> 20°C), but it will nevertheless ensure a satisfactory COPsys. In this way, there is **no need for a backup heat source or boiler**.



Principle of a ULISSE Reservoir of 1 M m³ configurated for direct lake solar heat storage (CGN boat to scale).
The layout of the bending and anchoring cables is in reality significantly different.

Last but not least: Lake-environmental impacts

The external thermal convection currents induced by the ULISSE Reservoirs can **improve the circulation of nutrients and oxygenation of the lake bed**, **protecting the aquatic ecosystem from eutrophication, which is exacerbated by Global Warming**. In addition, the presence of a **no-fishing zone around the ULISSE Reservoirs** can create **ecological niches**, encouraging the development of aquatic fauna.

Selective capture (filtration of phytoplankton, quagga leaves and maybe inside UV-C protection) would make it possible to regulate toxic algal blooms, recovering greenhouse gases and CH_4 (for energy use) as well as **protecting water pipes against quagga mussels' (Closed-Circuit)**. Containing the heat captured in the ULISSE Reservoirs would **lower the surface temperature of the lakes**, thereby **reducing water loss through evaporation and increasing the oxygen dissolved in the water**. More, the summer charging in the ULISSE Reservoirs, of waste heat from air conditioning by the TLN, **prevents a direct heat discharge and harmful dissemination in the lake**.

National Implementation Potential/phase (NIP)

The ULISSE project, with around 600 or 300 (@ 1 or 2 M m³/unite) Reservoirs distributed invisibly across the 15 major Swiss lakes and **in association with the CORSAIRE *free preheating system* (including outside the lake regions)**, could supply almost **60 PJ or 30 % of 200 PJ of national heat requirements** for room heating and domestic hot water. This would save 3 TWh of gross electricity in the winter semester (1/3 of the 9 TWh or 20 % winter electricity deficit, equal twice the winter production of the Grande Dixence hydroelectric complex) [**16.1**].

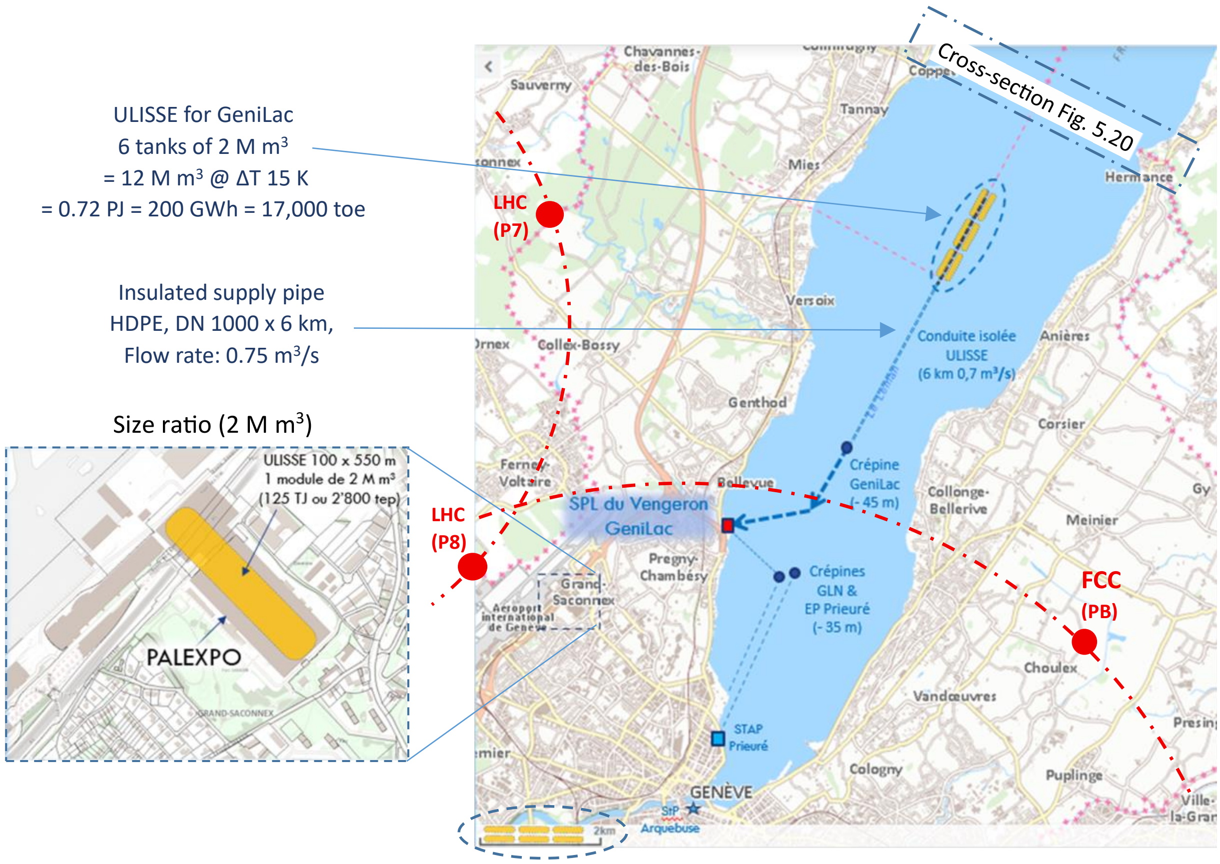
Approach, methodology and results of the ULISSE exploratory study

Following an analysis of Switzerland's Energy Strategy 2050 and a presentation of the ULISSE project, including the background to the initial concept (CORSAIRE-ULISSE), the workings of the Thermal Lacustrine Network (TLN) and the urban Potable Water Network (PWN) were developed. The whole was then applied and quantified, as a **case study**, on the largest TLN network in Switzerland, "**GLN - GeniLac**" and the PWN in the canton of Geneva.

To establish the impacts, we have taken into account climate change and assumptions of changes in the energy efficiency of buildings between now and 2050**. In the long term, we have also considered the (essential) widespread use of domestic hot water (DHW) for household appliances.** It has been observed that this changes the heat expenditure index for room heating and DHW and opens up the economic prospect of extending TLNs.

The application for **GeniLac study case** showed that supplying 250 GWh of heat in the winter semester would require (instead of 60 M m^3 at 6.5 °C only 1/5 or 12 M m^3 of lake water at 19 °C, coming from 6 ULISSE Reservoirs (2 M m^3 each) anchored at the bottom of the *Petit lac* Léman 6 km from GeniLac's main pumping station located at the Vengeron.

In combination with CORSAIRE *Winter free preheating of the PWN*, the winter electricity consumption of the TLN system GeniLac, for 250 GWh room heating and PHW, is reduced by 50 % (**COPsys: 3.16 => 6.32**). For GeniLac and the canton of Geneva, this corresponds to **winter electricity savings of nearly 40 GWh**.



Location of the 6 ULSSE Reservoirs in the Petit-Lac Léman for GeniLac and in conjunction with the Vengeron main pump station. ***CERN's cooling water has also historically (since the SPS) come from the Vengeron (SIG)***

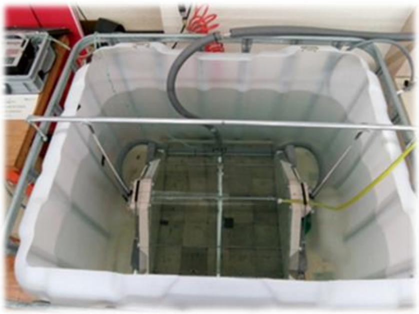
In the third stage, the exploratory study analysed more precisely the shape and structure of the main shell of the ULISSE Reservoir: triple layers of biocompatible stainless-steel wire reinforced **fiberglass textile** (KLEVERS GmbH), **cellular-glass** thermal isolation blocs (FOAMGLAS) and **basalt coat** protection (Final Advanced Materials), as well as ***screw-in* anchoring** with very low impact on the lake bed (Marine Flex Ltd).

The efficiency of the ULISSE Reservoir's seasonal heat storage was determined using 3 approaches: 1) calculations using a theoretical model of both the full-size Reservoir and a Mock-up, 2) laboratory measurements on the

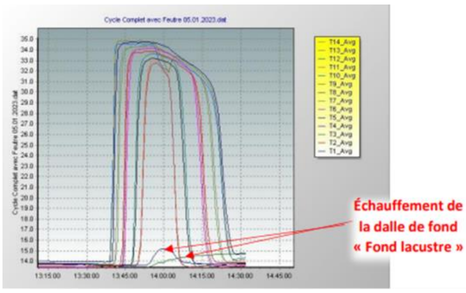
Mock-up, and 3) a numerical simulation (COMSOL). The ***Temporal Scale Factor* (TSF = 13,715)** between the Mock-up and the real full-size Reservoir was established beforehand, making it possible to determine the duration of the various phases of the annual cycle of their respective operations.

The results of the three approaches converge with very few differences (a few %). **The energy efficiency of the Net seasonal Heat Storage (NHS) of the ULISSE Reservoir is around 84%.** It starts from the end of *Summer Loading* (SL: 2 months of real Reservoir vs. 6 minutes of Mock-up), the *Autumn Stagnation* phase (AS: 2 months vs. 6 minutes) and that of *Discharging in the Winter semester* (WD: 6 months vs. 19 minutes).

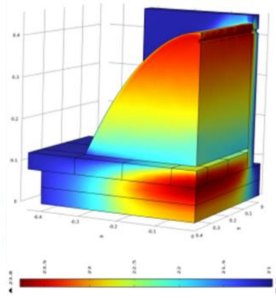
The convergence of the results confirms the good value of the TSF and that the temperature supplied to the TLN networks by the ULISSE Reservoirs could be at least 19-20°C (initial loading at 20-23°C compared with a lake summit temperature: ≥ 25°C in 2050, +3, +4 °C end 21st Century). This determines the effectiveness of the TLN with ULISSE.



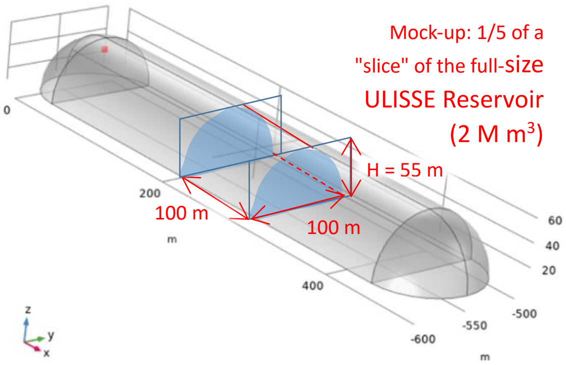
1) Mock-up



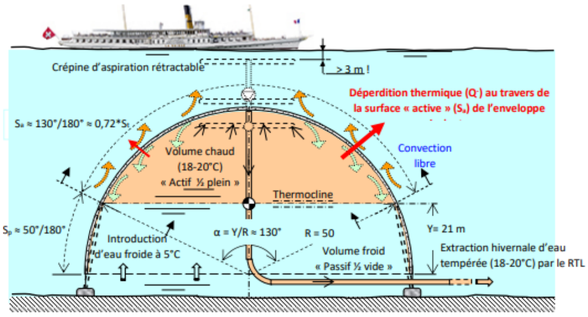
full cycle reproduction on Mock-up



2) Mock-up numerical simulation (COMSOL Multiphysics)



3) Full-size model recalculation step by step (Excel)



Triple approach of seasonal storage efficiency evaluation of ULISSE reservoir (Mock-up + Numerical simulation)

The financial cost of the ULISSE & CORSAIRE system for Switzerland (apart from the TLN infrastructure!) has been estimated with reservations, given the absence of a precedent. However, this exploratory study has made it possible to sketch out an order of magnitude **of CHF 3 to 4 billion**, based on the world's greatest achievements in the field of seasonal storage of sensible heat of water. **Financial saving around 1 G CHF and a ROI of 4 years.**

The cost of the ULISSE system (600 or 300 sub-lake storage reservoirs of 1 or 2 M m^3/unite @10 CHF/m^3) should be put into perspective with alternative solutions (insofar as they are feasible), which would be CHF 19 billion for an additional winter hydroelectric production capacity of 3 TWh or around CHF 7 billion for a supply of 60 PJ of solar thermal energy via heat networks, comprising 35 km^2 of flat thermal collectors, 26 M m^3 of covered seasonal storage basins and 91 km^2 of land surface (≡ surface area of Lake Zurich).

From this exploratory study of the ULISSE system, it appears that the environmental impact is probably not neutral but could potentially even be positive, in particular by offering protection against the negative effects of global warming. With regard to the cohabitation of ULISSE Reservoirs anchored on the lake bed, with the "inhabitants" and users of the lakes, it can be considered that there is practically no impact on navigation and that the loss of 0.8 % of the fishing area can be compensated by the environmental protection provided by the ULISSE Reservoirs fishing restriction zones (creates fish nurseries and overall development of fish population).

ULISSE NEXT STEP Roadmap proposal

The exploratory study of the ULISSE project shows that it's in line with Switzerland's energy strategy 2050. It will enable the development of thermal networks and seasonal heat storage, reducing the structural winter electricity deficit, as encouraged by the aeesuisse *Swiss Energy Storage Forum* (FESS) [**41**].

More, the complementary CORSAIRE process gives a new double function on the already existing Potable Water Networks (PWN): distribution of material (potable water) and simultaneously energy (heat), who saves electricity ***"The Potable Water Network is an ignored/neglected Energy Network"!***

The positive potential of seasonal heat accumulators has been studied by the *Swiss Competence Centre for Energy Research* (SCCER) and is currently being pursued as part of the SWEET-DeCarbCH project.

Nevertheless, the exploratory study of **the ULISSE project needs further in-depth multidisciplinary investigations and validations.** *Cine qua non,* favourable results of an **Advanced Recherche Phase (ARP)** could step forward a **Pilot + Demonstration Phase (PDP)** with a full-scale ULISSE pilot Reservoir in a lake and connected on an already existing TLN. **A final National level Implementation Phase (NIP)** concerns the 15 largest Swiss lakes (and also outside lake regions for the CORSAIRE process).

For the **ULISSE pilot**, the exploratory study proposes the **Léman and the TLN for heating and cooling the EPFL-UNIL campuses**. As well as for a **CORSAIRE pilot, the Cité du Lignon** (6'500 inhabitants) with the residual heat of Geneva's main **Wastewater Treatment Plant (WTP) of Aïre.**

Typically, beside a CORSAIRE Pilot in Switzerland (Geneva?), additional research into the CORSAIRE process part could be also conducted in Belgium (without lakes) with the collaboration of the Flemish Institute for Technological Research (VITO) and eventually other countries if interested.

This Roadmap would be carried out within the framework of a **ULISSE Consortium for the *NET STEP* of the ULISSE project: *TLN Booster and its complementary PWN CORSAIRE Winter free heating process*** *(also outside lake regions).* The **ARP** and **PDP** could be pursued more precisely along the following research work packages:

A. For the ULISSE sub-lake seasonal heat storage Reservoir

Advanced Research Phase (ARP) Work Packages <u>**Provisional estimated budget (PEB): 2-3 M CHF**</u>

1. In-depth environmental impact assessment for the lakes concerned (**proposal on CIPEL's call for projects**).
2. Continuing the numerical Multiphysics simulation (COMSOL) of the Mock-up, reduced size prototype and the full-scale simulation of the sub-lacustrine Reservoir.
3. Carrying out an in-depth study of the hydrodynamic behaviour of the Reservoirs in relation to lake currents; in particular, the structural integrity of the Reservoirs in relation to the internal seiches causing adverse internal shear currents in large lakes.
4. Development and test of the mobile water collection device with, filtering, quagga larvae UV-C treatment (?) and counterflow self-cleaning suction strainer "pantograph" (Epilimnion zone).
5. Development and test of an autonomous cleaning (fouling, quagga mussels) and inspecting underwater ROV of the Reservoir (exterior and interior shell surfaces and equipment).
6. Development of a prototype of a reduced size Reservoir (e.g. 1/1'000 scale of 1'000 m^3: transverse radius of 5 m x 25 m length) for an initial behaviour study in a closed test basin and lake.
7. Development of an open two cross-sectional sectors of the reservoir envelope with intermediate connection at full-size (transverse radius of 50 m, with 5-10 m); screw-anchoring on lake bed.
8. Analysing the national level potential for installing full-size ULISSE Reservoirs (1 to 2 M m^3) in the 15 major Swiss lakes (NIP), e.g. bathymetry, anchors, connections to TLN networks, etc.

Pilot & Demonstration Phase of the ULISSE Reservoir (PDP) work packages <u>**PEB: 10 or 20 M CHF**</u>

1. Production and installation in a real-life situation of a test pilot at full size (1 or 2 M m^3)
2. Observation of the physical and environmental behaviour in relation to the receiving lake.
3. Connection on the TLN and energy efficiency measurements.
4. Cleaning and inspection underwater ROV (Remotely Operated Vehicle).

ULISSE PDS Proposal (not fixed/limited!)

As explain before, under de *sine qua non* condition of the ARP success, the ULISSE Pilot and Demonstration Phase (PDP) could advantageously be installed in Lake Geneva opposite EPFL and UNIL and connected to the Pumping Station (SPP) on both campuses, for cooling and heating with lake water and the heat pumps (HP) located in the EPFL thermal power station (CCT)!

The new EPFL-Ecublens heating system is being upgraded mainly at the Pierrettes Lake Pumping Station (SPP) and the Central Heating Plant (CCT), with 4 new heat pumps totalling 24 MW of thermal power, plus 4 MW waste heat from the data centre above the CCT.

The ULISSE Pilot could be located near the EPFL-UNIL suction strainer, which is only 900 m from the shore where the SPP is located and 75 m deep (ideal for a typical ULISSE Reservoir). Its connection to the CCT would make it possible to test the energy impact on the performance of the new heat pumps.

*Proposed installation in Lake Geneva and connection of the ULISSE pilot to the heating and cooling infrastructure (SPP + CCT) at EPFL-UNIL, with environmental and physical observation by the LéXPLORE (**or a similar research platform)**.*

Physical and environmental observation of the ULISSE Reservoir

Photo https://lexplore.info/fr

The LéXPLORE platform for lake research on Lake Geneva, currently anchored opposite the port of Pully (VD)

Physical observations of the underwater Reservoir and its environmental impact could be advantageously carried out using the LéXPLORE (**OR A SIMILAR RESEARCH PLATFORM)** and helped by a dedicated underwater ROV. Since 2018, the LéXPLORE platform has been anchored at 110 m deep and 570 m from the shore, on Lake Geneva, opposite the port of Pully (VD) 6 km from the Lausanne campus.

B. For the complementary CORSAIRE process

As seen before, **the CORSAIRE project was included in Geneva's Cantonal Energy Master Plan (2001-2005).** In November 2005, Part 1 of the multidisciplinary impact study began on a residential building made available by the City of Geneva. Unfortunately, it was halted 3 months later due to an unforeseen and abrupt budgetary restriction (reduction in the Confederation's funding for the OCEN).

As part of Switzerland's Energy Strategy 2050 and in response to the SFOE's call for SOUR projects, the ULISSE project, with the complementary CORSAIRE free preheating process, could take over the entire initial CORSAIRE project, which was officially registered and initiated in Geneva but has remained pending since 2005. The *Services Industriels de Genève* (SIG) is both responsible for the Potable Water Network (PWN) in the canton of Geneva and fully involved in the GeniLac project, the TLN "*flagship*" in Switzerland.

As mentioned earlier, winter temperature correction of potable water can also be achieved with the **CORSAIRE free preheating exchanger installed inside the buildings, which avoids preheating of the urban PWN**, but obviously requires the heat source to be supplied via the TLN or another heating network.

The following points need to be addressed for the CORSAIRE process (work packages):

1. The basic study (master's thesis by W. van Sprolant EPFL 1995).
2. In-depth study of the heat loss from the urban Potable Water Network (PWN).
3. Reduction of heat losses by thermal isolation of critical sectors of the urban PWN (also beneficial for fresh water in summer).
4. Investigation of free preheating day/night modulation of the urban PWN with recirculation.
5. Investigation of a complementary UV-C water treatment (WEDECO).
6. In-depth study of the physical integrity of the urban PWN undergoing winter free heating.
7. In-depth study of the sanitary integrity of potable water under winter temperature correction.
8. Psycho-sociological study of public acceptance of winter potable water temperature changes at the tap.
9. **The CORSAIRE free preheating impact study(s) on a pilot and demonstration building (PDP)**.

PDP CORSAIRE Proposal (not fixed/limited!)

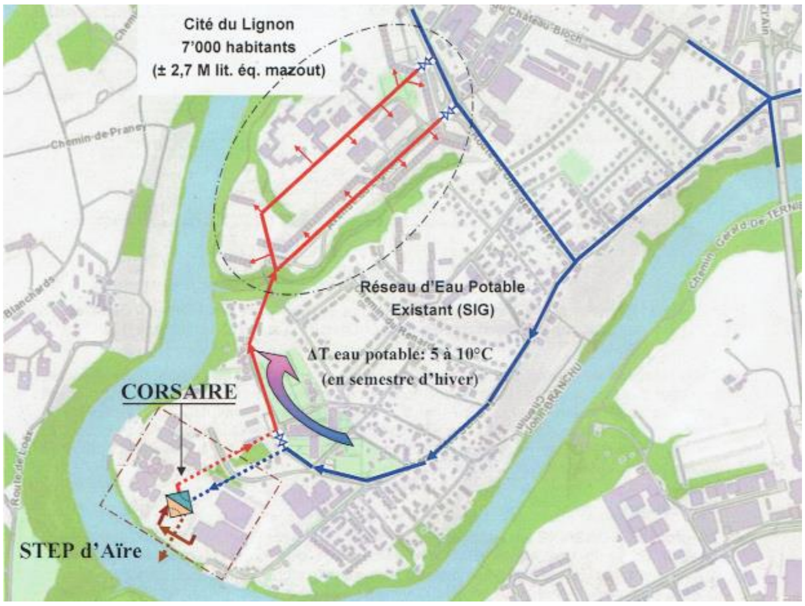
In order to carry out an effective multidisciplinary study of the impact of the CORSAIRE winter free preheating system on a building stock that is representative of an urban area, a large group of buildings should be chosen, at least equivalent to a residential area with a variety of shops (large number of different potable water users).

To simultaneously test the transfer of heat from the source of thermal waste to the urban PWN, it would be useful for it to be close and/or inside the buildings concerned. This would also make it more practical to conduct multidisciplinary studies within a limited area. The Cité du Lignon, with its 2’780 homes, 6’500 inhabitants, various businesses and just a few hundred metres from the Aïre WTP, could be suitable pilot and demonstration site. The CORSAIRE “2.0” of the washing machines and dishwashers’ connection on the DHW, and the CORSAIRE free preheating exchanger inside the building could also be tested.

The Cité du Lignon "the longest building in Europe" (1 km)

Initially, under a mandate from ScanE/OCEN (*Service/Office cantonal de l’Energie*), the impact study(s) planned for 2005 on the City of Geneva building (87 Servette Street) was one of the 9 stages in the CORSAIRE project listed above. For the purposes of experimentation and energy observation, the building was to be instrumentalised at the overall level of the building's energy installation and communal equipment (laundries), but also more individually on a number of representative flats, including water and energy meters on household appliances (dishwashers, washing machines).

In the absence of a suitable waste heat source, the temperature of the initial cold drinking water at the entrance to the building (87 Servette Street) was artificial corrected with the CORSAIRE free preheating exchanger inside the building's boiler room. For the Cité du Lignon, this would be eventually done in the Aïre WTP and, if not, reproduced on the same manner as for the initial building of the City of Geneva.



Proposal for the Cité du Lignon in Geneva connected to the Aïre WTP
as Pilot for the multidisciplinary study of the impact of CORSAIRE free preheating on the PWN

The energy measurements were planned to be carried out over two winter semesters on a comparative basis (with/without free heating). It was also planned to test a "daily alternation" procedure, i.e., to artificially correct the temperature of the cold water every other day, in order to statistically eliminate external variables such as heating degree days, changes in tenants, etc.

At the same time as the energy experiment on the building, **the quality of the potable water was monitored during the experiment** (microbiological analyses) by a laboratory in Geneva.

Similarly, a **psychosociological study** conducted by a company in Geneva was planned on an exploratory basis (outside the building, representative sample of the Geneva population) and as an internal observation within the building with users in the situation; in order to assess the acceptability of "captive" consumers of the urban potable water network.

Finally, a **communications strategy** was also planned to ensure that information was communicated to tenants in the pilot building and to SIG (in the event of a telephone call from a "diverted" tenant).

WTP Aïre

The main Wastewater Treatment Plant (WTP-Aïre) in Geneva, with around 140’000 m^3/day and 2 m^3/s, is a good example of an ideal source of low-temperature waste heat for CORSAIRE free preheating of the public PWN.

Insofar as the Waste Water Network is separate from the Rain Water Network, and in addition to the capacity of the wastewater basins, the wastewater is logically in phase with the consumption of potable water. After treatment, the temperature of this water is still higher than the potable water network (PWN) in mid-winter, especially as the Aïre WTP basins are completely covered. Heat can then be transferred to the PWN simply by *free preheating* using a heat exchanger. The distance from the Aïre WTP is only a few hundred metres from the PWN loop that supplies the Cité du Lignon.

Timeline

Backstory Milestones in relation with the PWN Winter free preheating (CORSAIRE process)

- 1992 VERTCAD project proposal for "CERN's and Industrial waste heat recycling by medium temperature District Heating Network" in the Geneva area. (W. van Sprolant)
- 1995 EPFL Mater thesis "CERN's waste heat recycling by PWN winter free preheating",
- CORSAIRE on Club Ravel Conference,
- 1996 CORSAIRE on the EPS 10 Trends in Physics, 10th General conference, Seville, Spean,
- 1997 CORSAIRE on Eco Campus Meeting Audes-97 Conference, Chambery, France,
- 1997 CORSAIRE on Kernfysisch Versneller Instituut (KVI), Groningen, Nederland,
- 1997 Construction Toronto's Deep Lake Water Cooling system (DLWC)
- 2-1997 Meeting OCEN, SIG, CERN, Energy service City of Geneva, Hygiea Europe Foundation,
- 1999 CORSAIRE on 4th World Congress *Recovery•Recycling•Re-integration* R'99 Geneva,
- 2001-2005 CORSAIRE project included in Geneva's Energy Master Plan,
- 2003 "*Le Procédé CORSAIRE: une Histoire d'eaux calo-porteuses* », Nuit de la Science Genève,
- 2004 Commissioning of Toronto's DLWC system (1er CORSAIRE free heating of the DWN)
- 2005 Launch & Stop of the CORSAIRE impact on a test building (City of Geneva),
- 2011 CORSAIRE on World Engineers Convention (WEC), CICG – Geneva.

Actual & Future ULISSE project (provisional)

- 9-2021 / 5-2023 Exploratory study of the ULISSE project SFOE funding (SOUR Call 1-2021),
- 10-2023 ULISSE on the COMSOL Conference, Munich, Germany,
- 8-2025 Delivery Swiss Invention Patent (CH 719 465 B1)
- 9-2025 ULISSE on the Urban Futures Symposium EMPA Dübendorf,
- 12-2025 Meeting EMPA, UESL Dübendorf, CvS énergies sàrl,
- 2-2026 Meeting OCEN, SIG, HEPIA, CvS énergies sàrl.
- **8-7-2026 ULISSE project on the Sustainable Hich Energy Physics (HEP) Workshop, online 8-10 July 2026:** https://indico.global/event/16058/overview
- **16-9-2026 Public presentation of the ULISSE project at CERN (organisation: CERN Alumni Sustainability Groupe, CERN Solar Club): https://indico.cern.ch/event/1676946/**

- **2026 (ULISSE Consortium Establishment)**
    - Partners prospecting,
    - Commitment letters,
    - Work packages description with partners, including human, time and financial resources,
    - Public & Private Fundraising,
    - Final signature by the consortium partners for ARP & PDP.

- **2027-2028 (Advanced Research Phase, ARP) Provisional estimated budget (PEB): 2-3 M CHF**
    - Environmental impact assessment for lakes
    - ULISSE prototype Reservoir,
    - CORSAIRE process on PWN (inside building or district).

- **2029-2030 (Pilot + Demonstration Phase, PDP) PEB: 10 or 20 M CHF**
    - Environmental impact assessment for the lake
    - ULISSE full-scale Reservoir (1 or 2 M m^3) connection on TLN,
    - CORSAIRE 1.0 (and 2.0 version in option) on building with WTP.

- **2031-2050+ (National Implementations Phase, NIP) + abroad (?)**
    - ULISSE on the Swiss 15 greatest lakes (connecting on TLN).
    - CORSAIRE 1.0 (2.0 version in option) on PWN (with ULISSE and outside lake regions).
    - Connection of CERN on ULISSE & GeniLac network in Geneva.

Appendix: Étude d'impact environnemental du système ULISSE sur le Léman, candidature pour l'Appel à projets scientifiques CIPEL 2026-2027 **https://www.cipel.org/appel-a-projet-26-27/**

Conclusion

Facing Climate Change, nearly 200 countries, including Switzerland, France and the other CERN member states have signed the Paris Climate Accords which aims to phase out fossil fuels "Net Zero" by 2050. This global energy transition relies increasingly on electricity to meet transportation, heating, and cooling needs as well as decarbonisation of industry, through renewable energy sources. One of the major challenges is ensuring there is enough electricity in winter and the seasonal storage of renewable energy will be an essential adaptive key.

CERN, situated on the French-Swiss border, is a major actor in the region. In the past, it was equivalent of nearly half of the canton of Geneva's electricity and potable water requirements in 2025 (≈3.0 TWh, 58 M m^3/y for Geneva). Whilst CERN has now drastically reduced its water consumption, its electricity consumption has risen in line with the expansion of its accelerator complex and experiments. Tomorrow, with the upgrade of the LHC and perhaps the FCC, from the second half of the 21st century onwards, its water consumption will undoubtedly rise again, unless corrective measures are taken, and its electricity consumption will reach the same level as that of Geneva (4 TWh/y). Water and Energy are the main resources underpinning our development and sustainability.

For environmental and economic reasons, CERN has for a long time (since the first oil crisis) sought to reduce its electricity and water consumption (which it has succeeded, notably for the water since 1994) and to valorise its waste heat (a more complex challenge).

The present ULISSE project (Under Lake Infrastructure for thermal capture and Storage of Solar Energy) proposes an original way for CERN's massive waste heat recovering. ULISSE is based on a network of very large seasonal heat storage reservoirs (1-2 M m^3, up to 125 TJ/unit) to boost the efficiency of Thermal-Lacustrine Networks (TLN) used for urban cooling and heating services. As well as direct solar energy from the lake, the ULISSE reservoirs could also be recharged by industrial waste heat, such as the vast quantities generated by CERN (TWh). The unique design of the ULISSE sub-lake reservoir makes it the most cost-effective seasonal heat storage system available (≈10 CHF/m^3), in terms of construction material requirements and no expensive land space required.

More, by his limited (≈ 20 %) heat losses, who creates external convections courants, the ULISSE reservoir could restore deep oxygenation and the circulation of nutrients vital to the ecosystem of large Alpine lakes under Global Warming stress. Combined with the development of TLNs in Switzerland's 15 largest lakes, the connected ULISSE boosters would eliminate one-third (3 TWh) of the projected national structural electricity deficit (≈ 20 % or 9 TWh) for the winter semester of 2050.

The exploratory study for the ULISSE project, with a case study on the GeniLac TLN project in Geneva, was funded by the Swiss Federal Office of Energy (SFOE) and conducted at Geneva's University of Applied Sciences (HEPIA, 2021–2023). The fact that CERN is considering integrating its waste heat into the GeniLac system could, in turn, enable ULISSE to play a part in this integration.

Today, the ULISSE project is in the process of forming a public-private advanced research consortium, followed by a demonstration pilot in 2030 and where CERN is also invited to join the ULISSE consortium to explore the feasibility of integrating the waste heat from the futures HI-LHC and perhaps FCC.

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sweet swiss energy research for the energy transition

hepia Haute école du paysage, d'ingénierie et d'architecture de Genève

Hes·SO GENÈVE Haute Ecole Spécialisée de Suisse occidentale

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