EPFL

The class will start at 08h15

Also part of :

E4S
Enterprise for Society

sia
Schweizerischer Ingenieur- und Architektenverein
Société suisse des ingénieurs et des architectes
Società svizzera degli ingegneri e degli architetti
Swiss society of engineers and architects

Innovation for construction & the environment

Dr. Dimitrios Terzis

27/11/2023

EPFL

Today’s class

Innovation from the perspective of accelerating the integration of geothermal energy in moderf infrastructure

With special thanks to Margaux Peltier, Lyesse Laloui and Benoit Cousin

BELOW / SUBSURFACE

m3 Lausanne

OVERVIEW

LOCATION

Lausanne, Switzerland

YEAR

2022

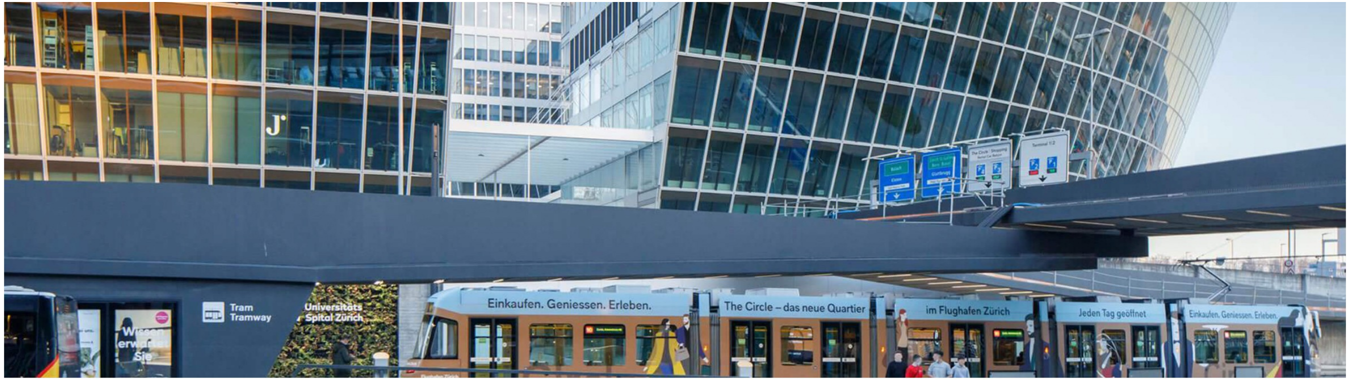
In order to respond to the **increase** in passengers transiting through the **Lausanne train station** and to serve the developing **districts** to the north of the city, a t**hird metro line** will complete the actual underground network.

In the present project, GEOEG provided expertise on **quantifying** the impacts of **geothermal activation** of the Lausanne m3 tunnel.

The study involved preliminary analysis of the implications of incorporating **heat exchangers** and **analysis of structural aspects** related to geothermal activation.

INFRASTRUCTURES

BSR – EST GESSIEN
BRENNER BASE TUNNEL
UNDERGROUND DATA CENTER
BRUSSELS MÉTRO NORD
THE LIGHTWALK



Alternative energies

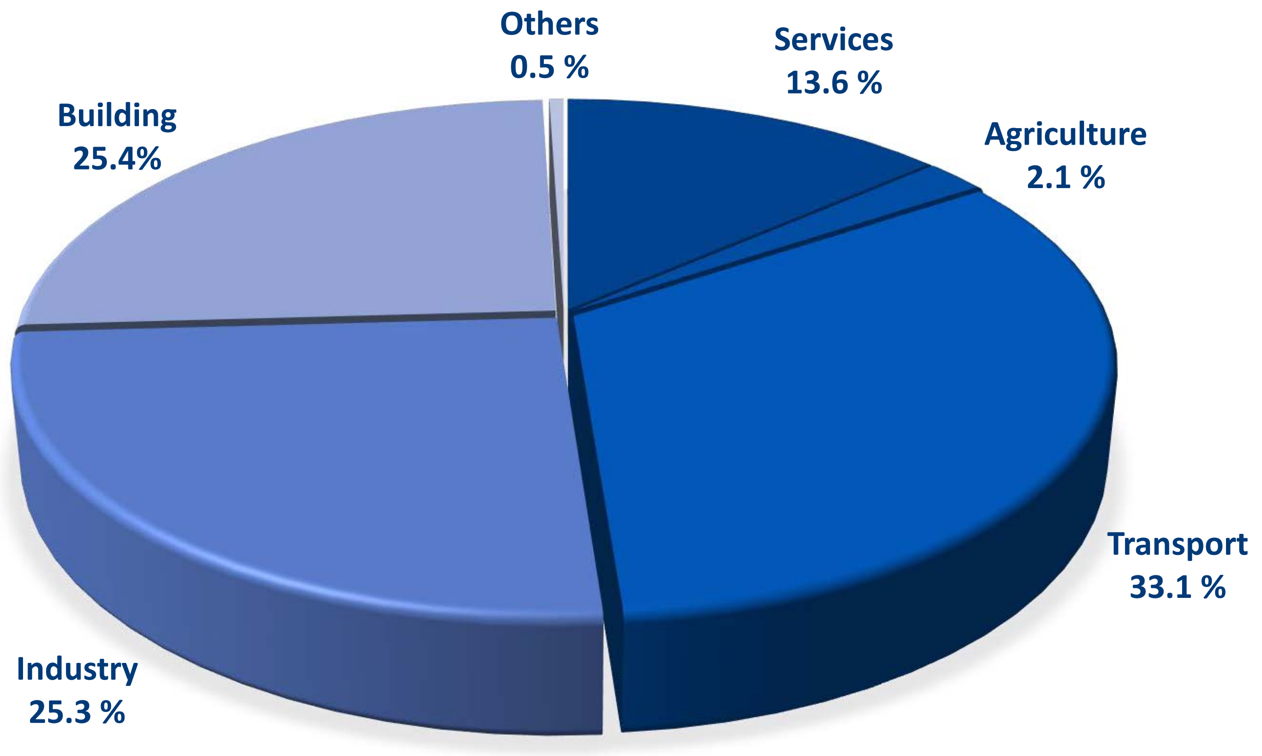
Alternative energies are an important pillar in achieving the objectives. Since 2003, a photovoltaic system located on the roof of Dock E has been producing electricity, and energy piles located underground have been producing energy for heating and cooling. There are now eleven photovoltaic systems in operation, which together produce an annual output of 2.2 GWh.

The decentralised use of geothermal structures is crucial for the heating supply. These are already in use in Dock E, the Circle and the maintenance area. In this way, CO2 emissions can be almost completely avoided.

› Electricity production at the photovoltaic systems

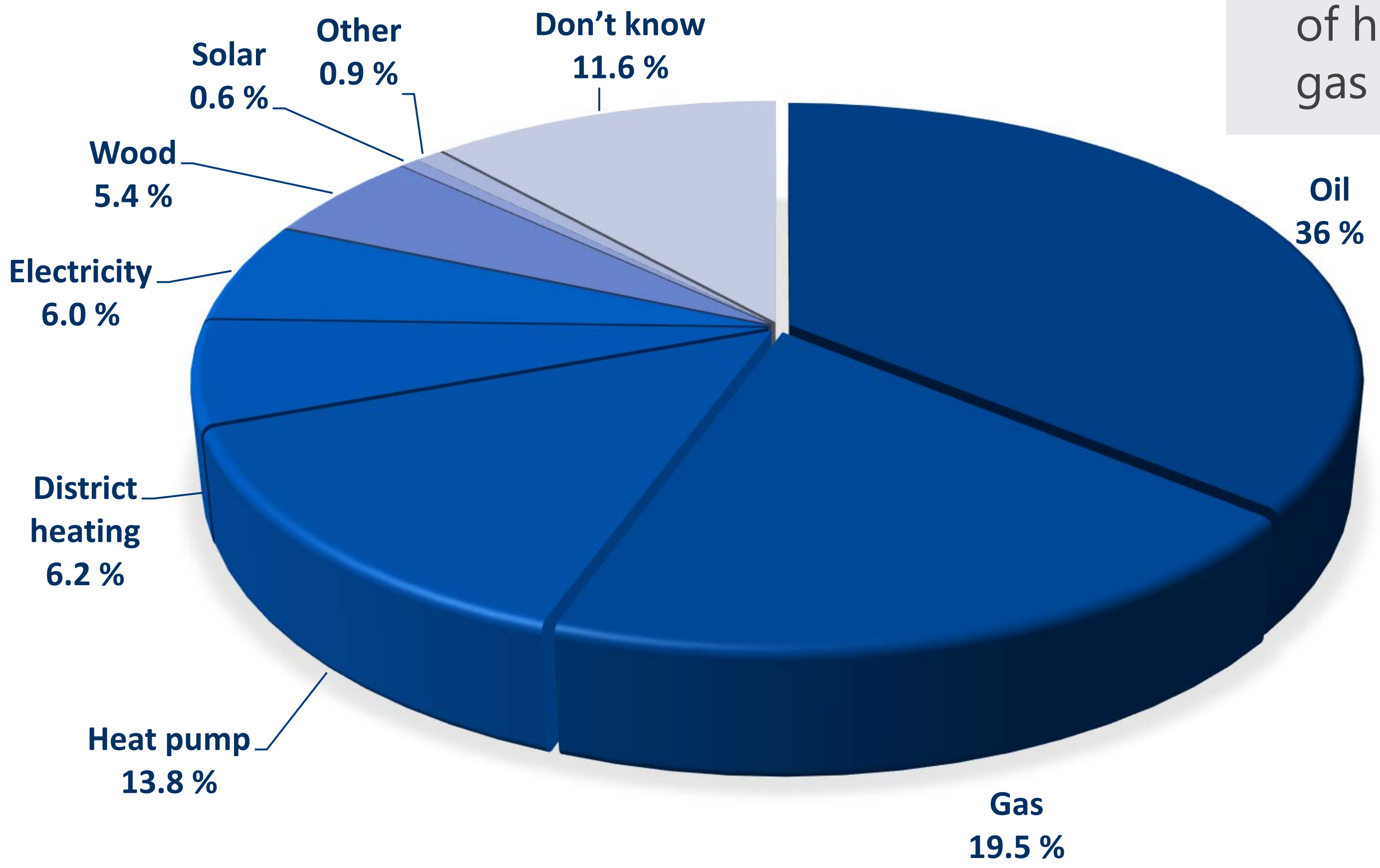
General framework: energy consumption

In the EU and typical OECD countries, 3 end users dominate the final energy consumption: the building, industry and transportation sectors



Source: Eurostat (2018)

General framework: energy supply



56%
of households heat with gas or oil.

CO_2

$\cong$ **1/4** of Switzerland's greenhouse gas emissions

Source: Suisse Energie,
SCCER CREST (2018)
FOEN (2021)

New directives in the construction sector

From 2020, **new buildings and infrastructures** need to harvest **renewable energy sources available on site**

EU - NZEB:

"a building with very high energy performance"

France - BEPOS:

"a building producing more energy than it consumes for its operation"

USA – ZNEB:

"a building with zero net energy consumption"

NZEB

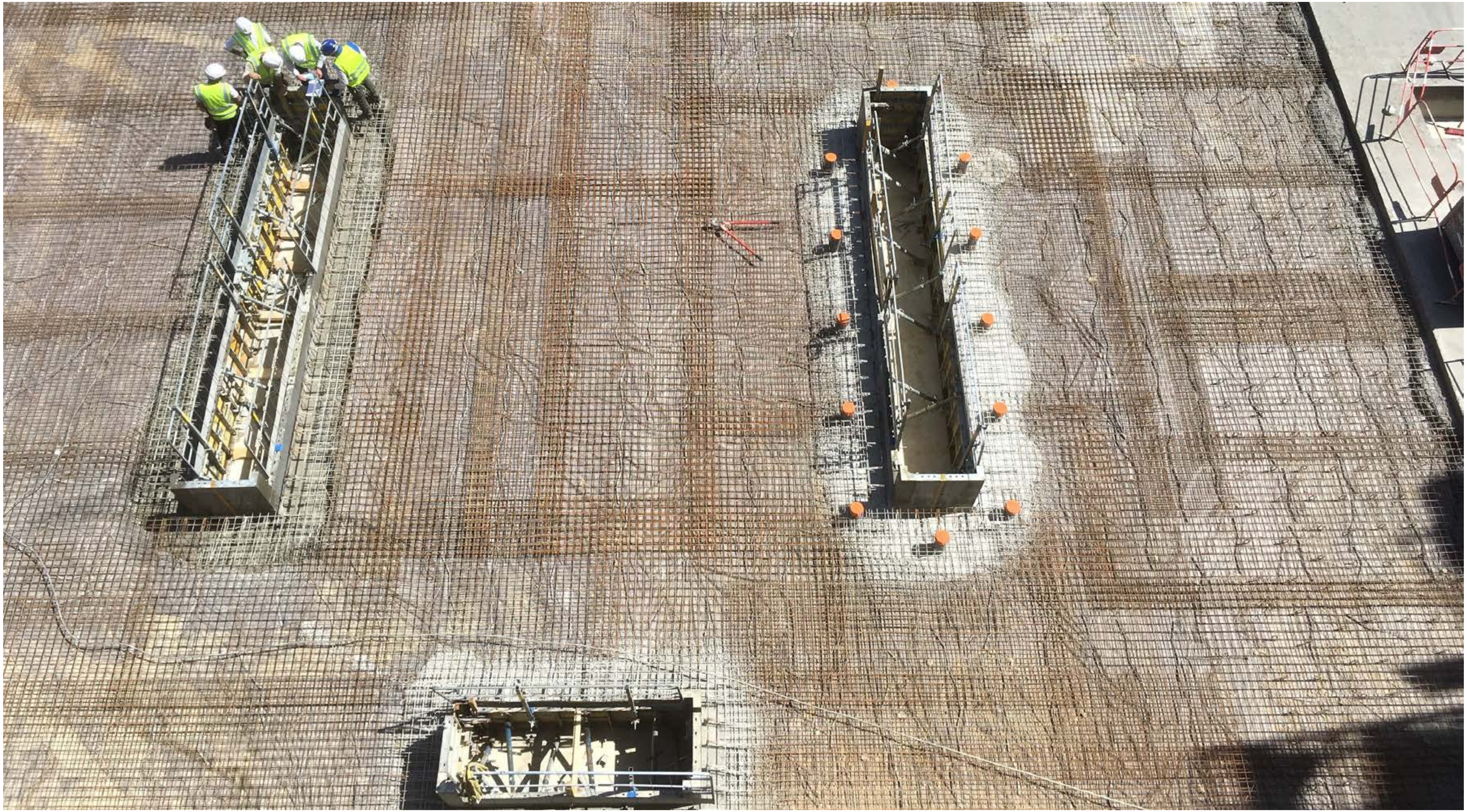
Nearly Zero Energy Building

Bepos

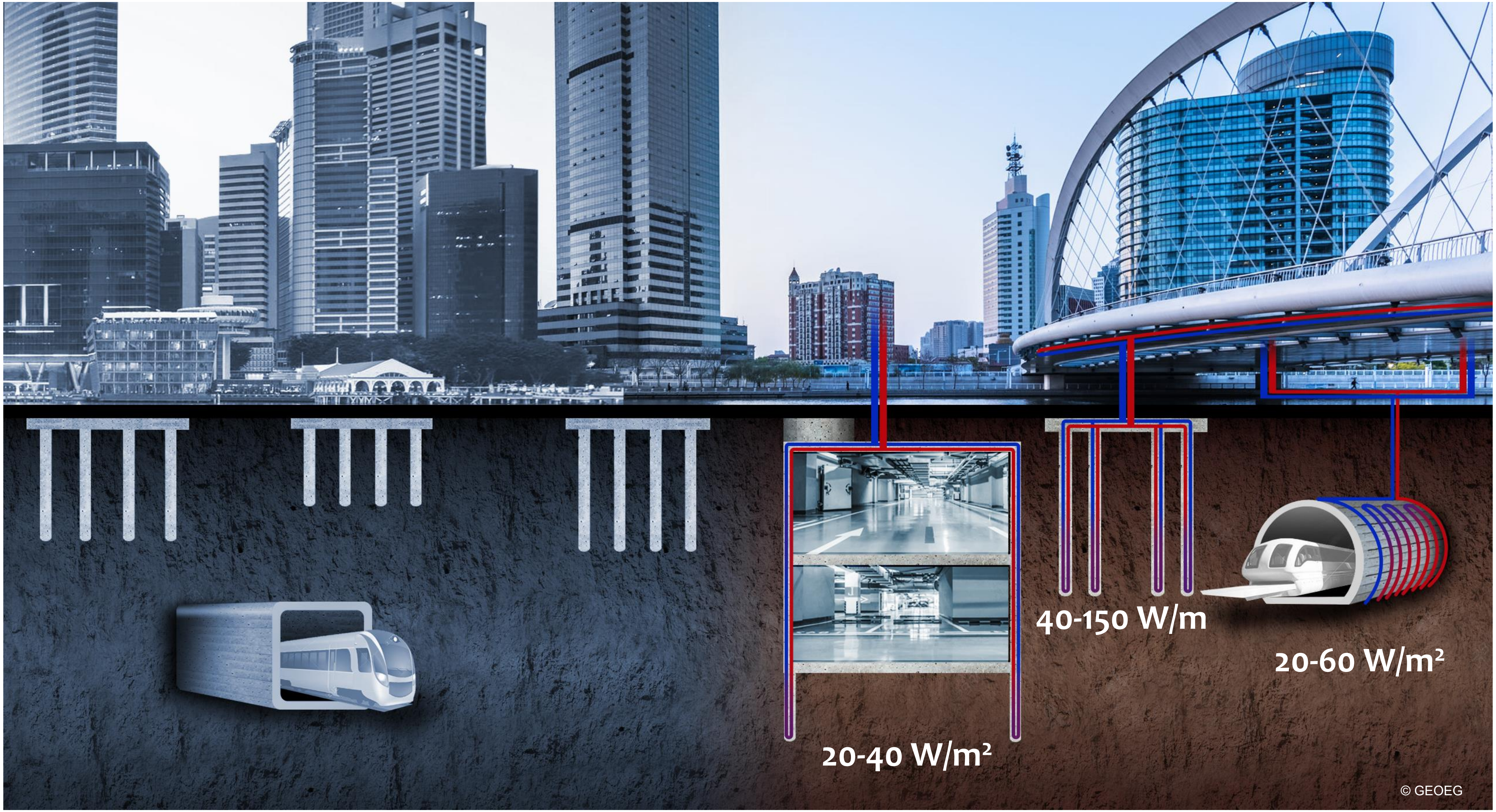
ASHRAE

Soils: the oldest means for storing/capturing heat

Geostructures: the oldest means for supporting construction



Energy geostructures: a breakthrough



Energy geostructures: source of renewable thermal power

Technology to provide structural and energy supports to buildings and infrastructures

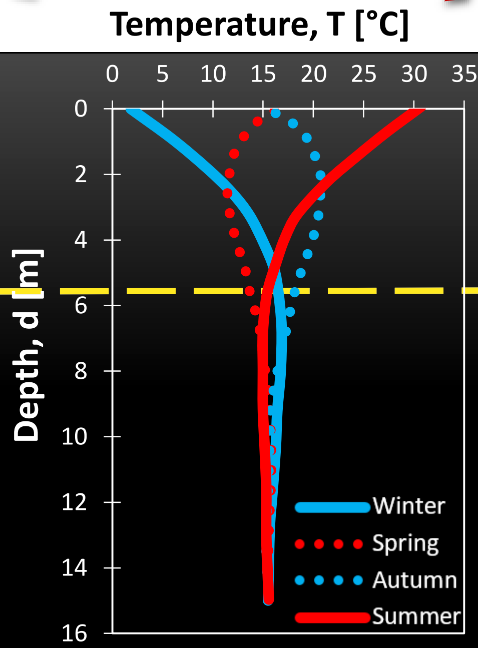
Heat exchanger tubes introduced in geostructures

Geothermal energy
at shallow depths (< 100 m)

Zone affected by seasonal T variation

Zone of steady T
T ≈ 10-15 °C (Temperate zones)
T ≈ 20-25 °C (Tropics)

Geothermal heat flow



Energy geostructures: source of renewable thermal power

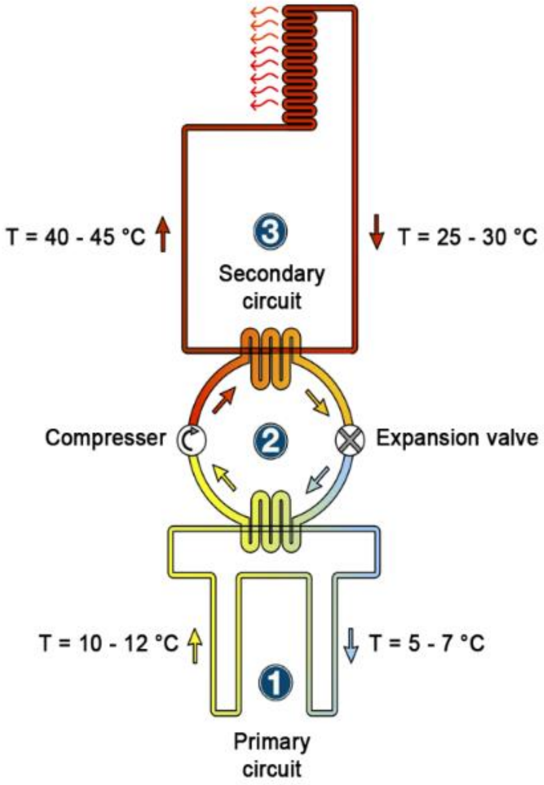
Ground Source Heat Pump System (GSHP)

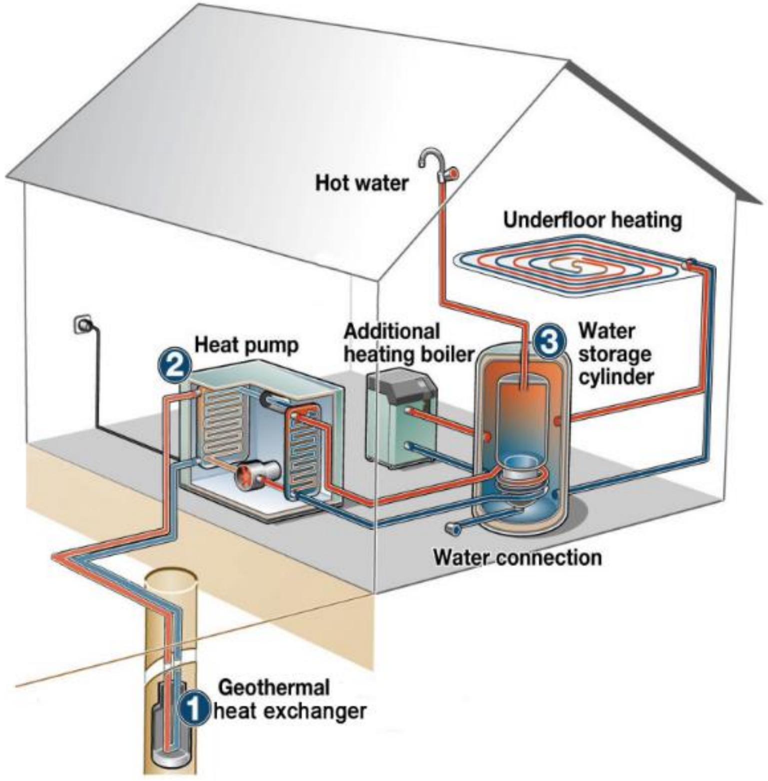
1 kW supplied
> 4 kW generated

¼ energy from external power

+

¾ energy from the ground





The three circuits of the system

Heat Pump

Thermal device used to convert electrical power into heat.

Made of:

a compressor
a reducing valve
an evaporator
a condenser

$$COP = \frac{Q}{W} \quad [-]$$

Q = heat supplied/removed from the reservoir
W = heat pump work

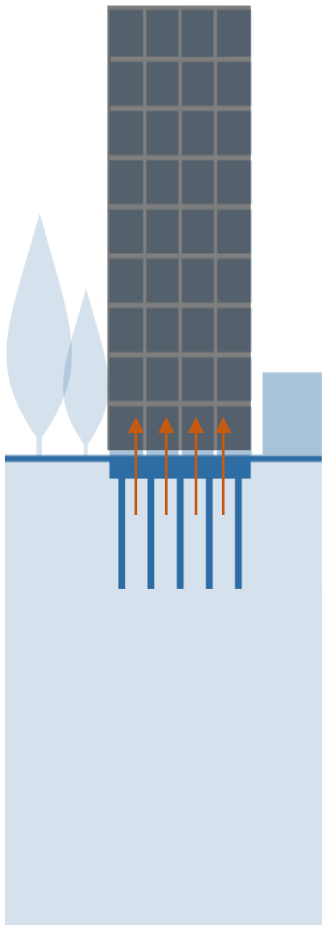
Energy geostructures: source of renewable thermal power

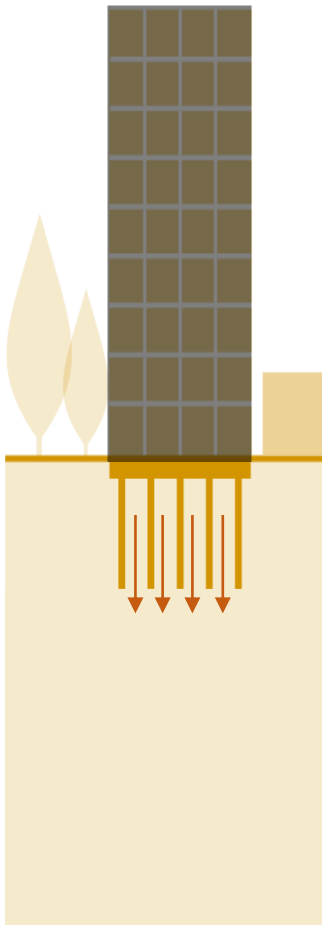
WINTER

Heat is extracted from the ground

Building is heated

Heat carrier fluid return is hotter





SUMMER

Heat is injected into the ground

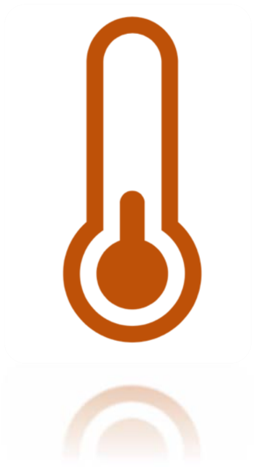
Building is cooled

Heat carrier fluid return is cooler

Uses of energy geostructures

1

Heating
&
cooling



2

Hot water
production

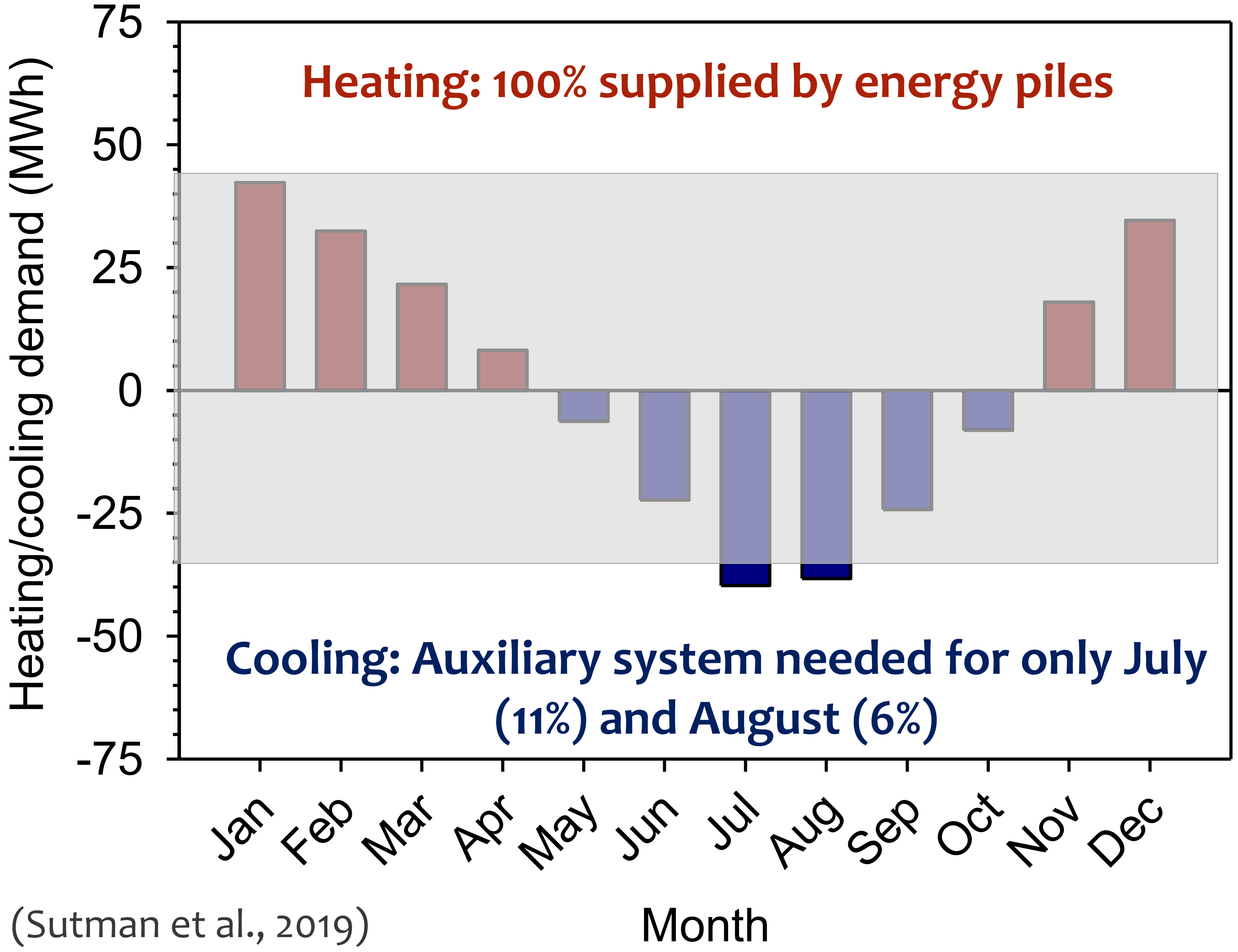
3

De-icing

4

Underground
thermal energy
storage

Energy potential



(Sutman et al., 2019)

Reference building

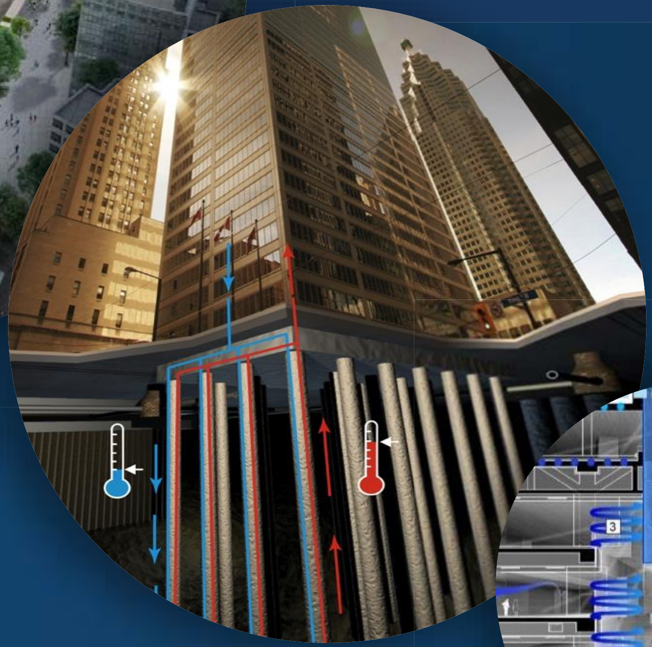
5-storey office building (Heated area of 2400 m2)

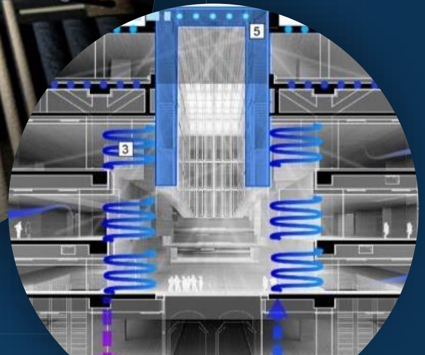
Structural support

32 piles with D=0.5 m and L=20 m

Energy support

Single U-loop and 30-kW GSHP





RECENT PROJECTS

Recent projects

South Korea

JUNGLM CONSORTIUM

Image courtesy of M. Furlan

Recent projects South Korea

LIGHTWALK

GANGNAM INTERMODAL TRANSIT CENTER / LIGHTWALK DESIGN DEVELOPMENT

THERMAL COMFORT

and ENERGY GEOSTRUCTURES

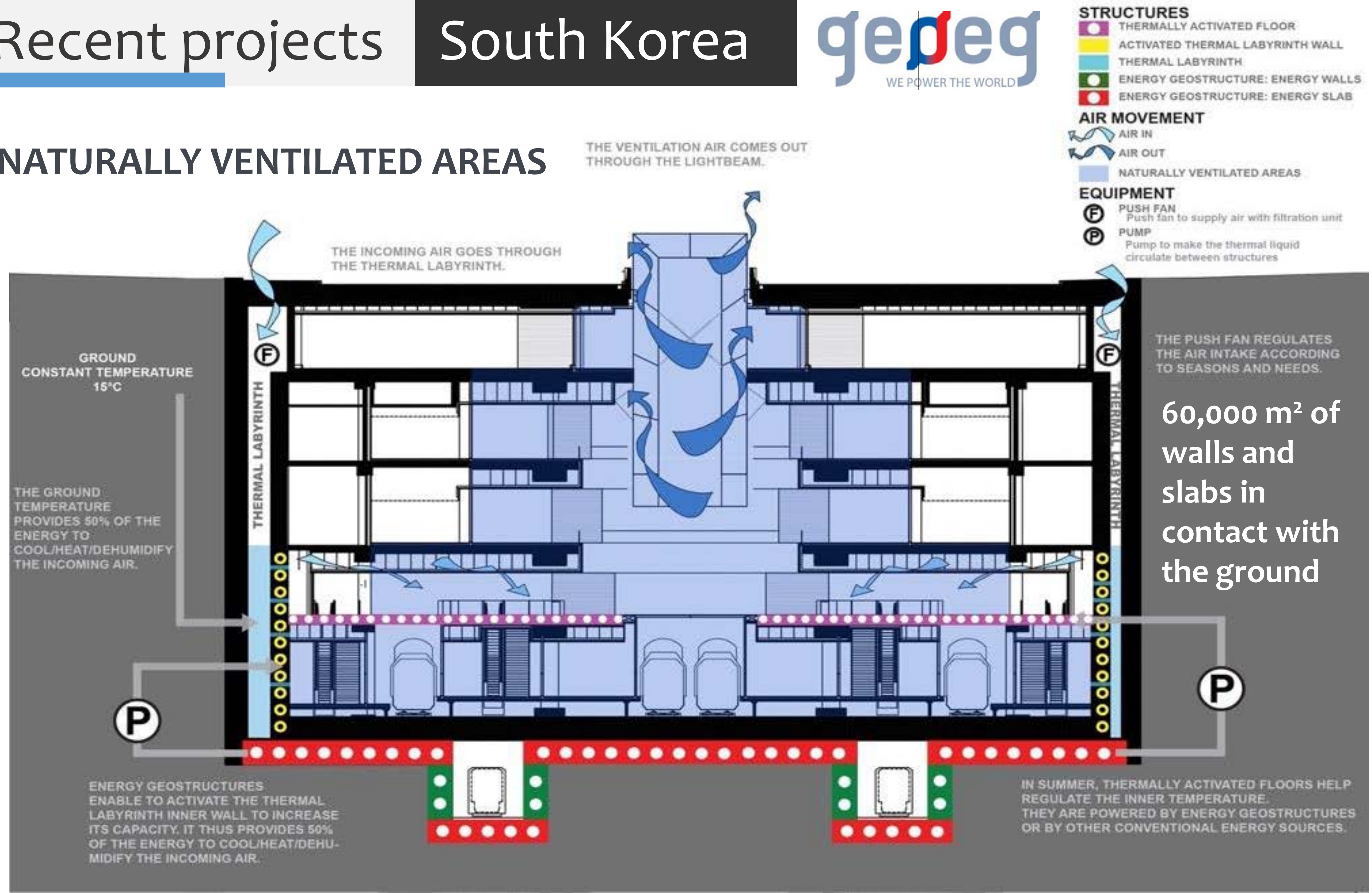
20’000.- m2

60’000.- persons per day

Image courtesy of M. Furlan

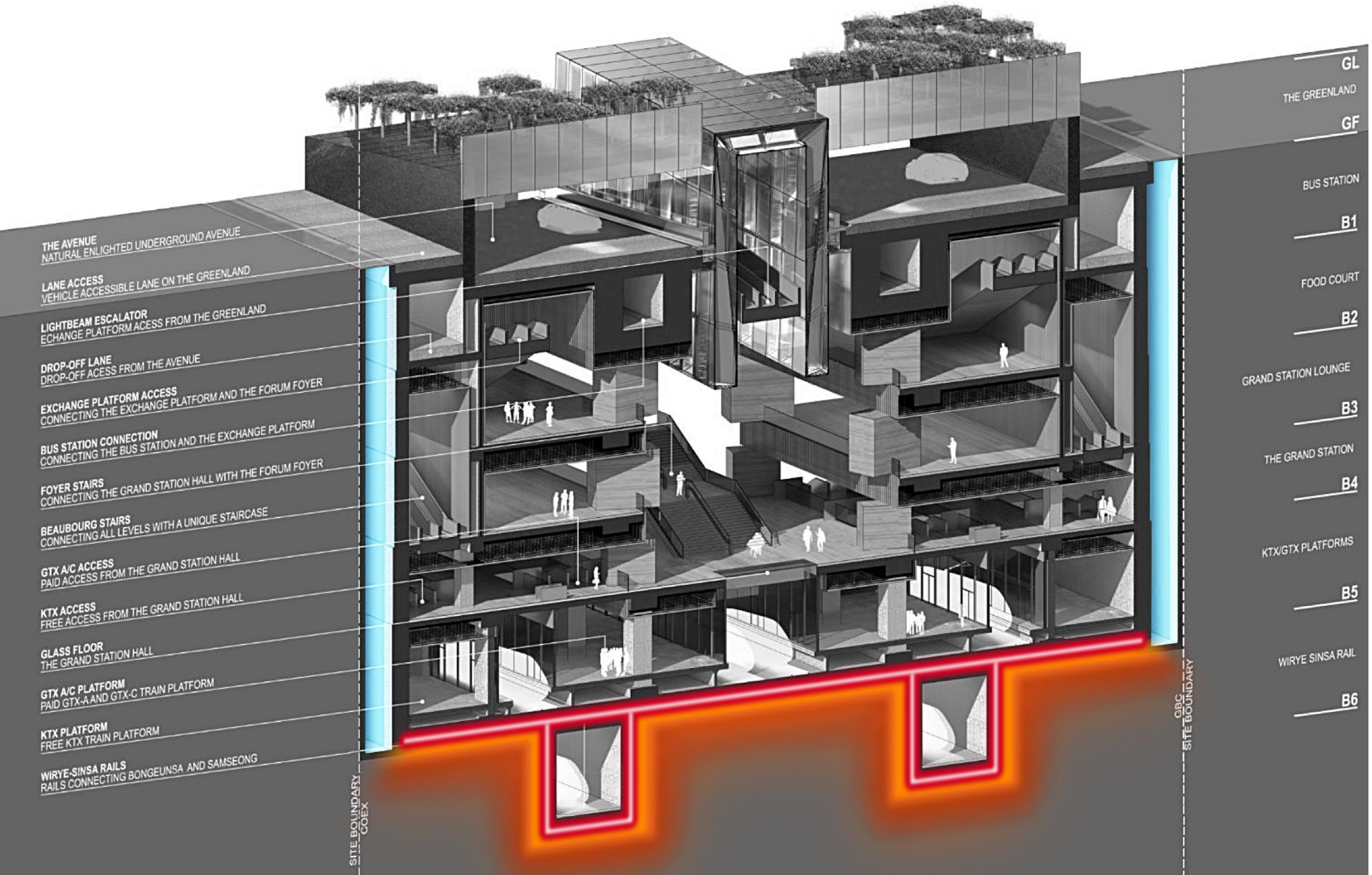
Recent projects South Korea

NATURALLY VENTILATED AREAS



60,000 m² of walls and slabs in contact with the ground

Recent projects | South Korea



A geothermal energy potential of **11003 MWh for heating** and **9628 MWh** for **cooling** (100% of energy needs)

Design example of a mixed energy foundation

Are EG cost efficient to provide 233 kW of renewable energy?

150 units of State housing

An international school for 700 pupils

A 50-place crèche

A 7-floor underground parking

Various energy foundations for a 233 kW goal

LEGENDE :

4 natures d'équipements

- Barrettes équipées Grande fouille
- Barrettes équipées Aval Florida
- Pieux équipées
- Sondes géothermique *
- Option radier géothermique à étudier

Barrettes / Pieux non équipés

Zone de collecte

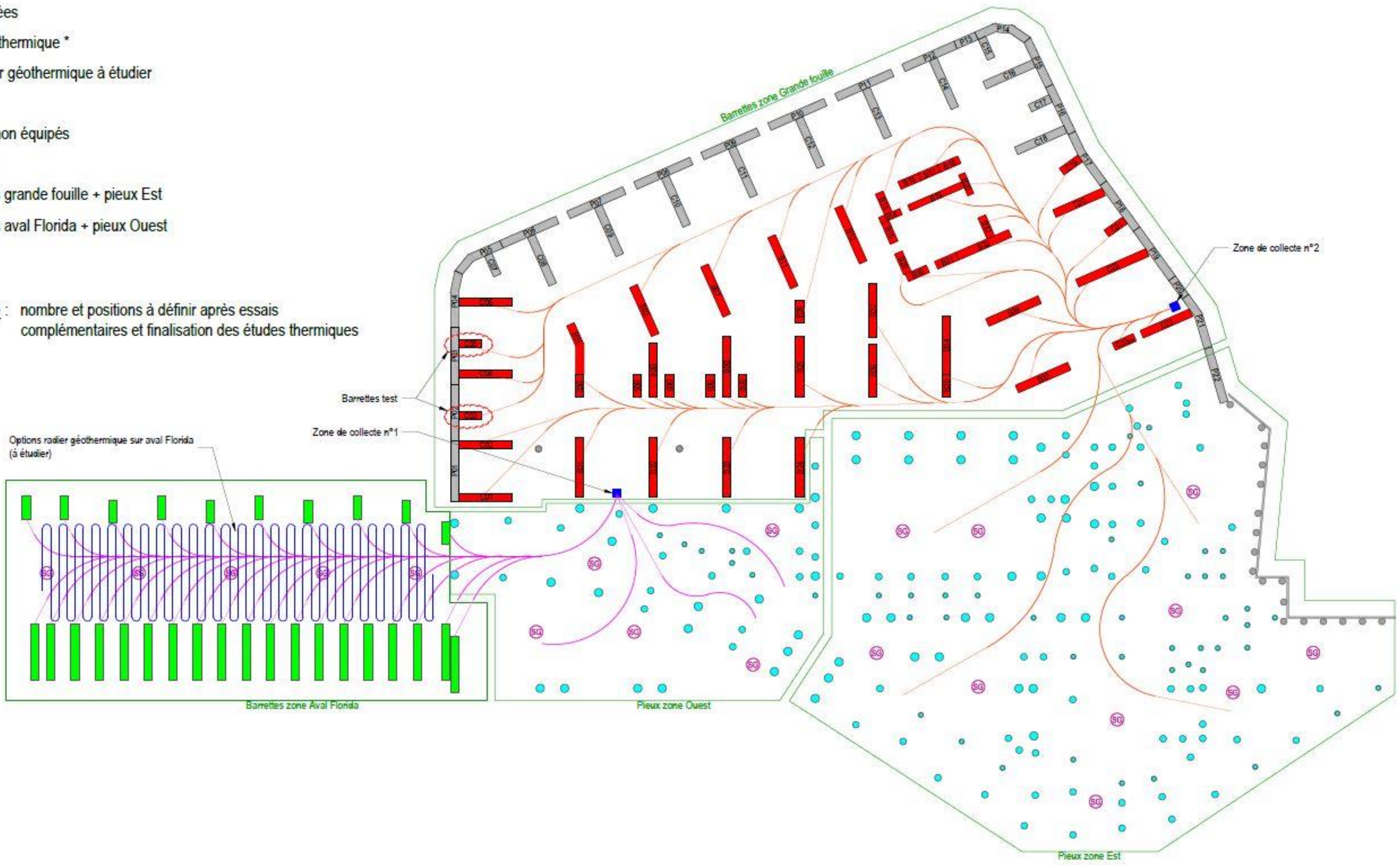
Réseaux barrettes grande fouille + pieux Est

Réseaux barrettes aval Florida + pieux Ouest

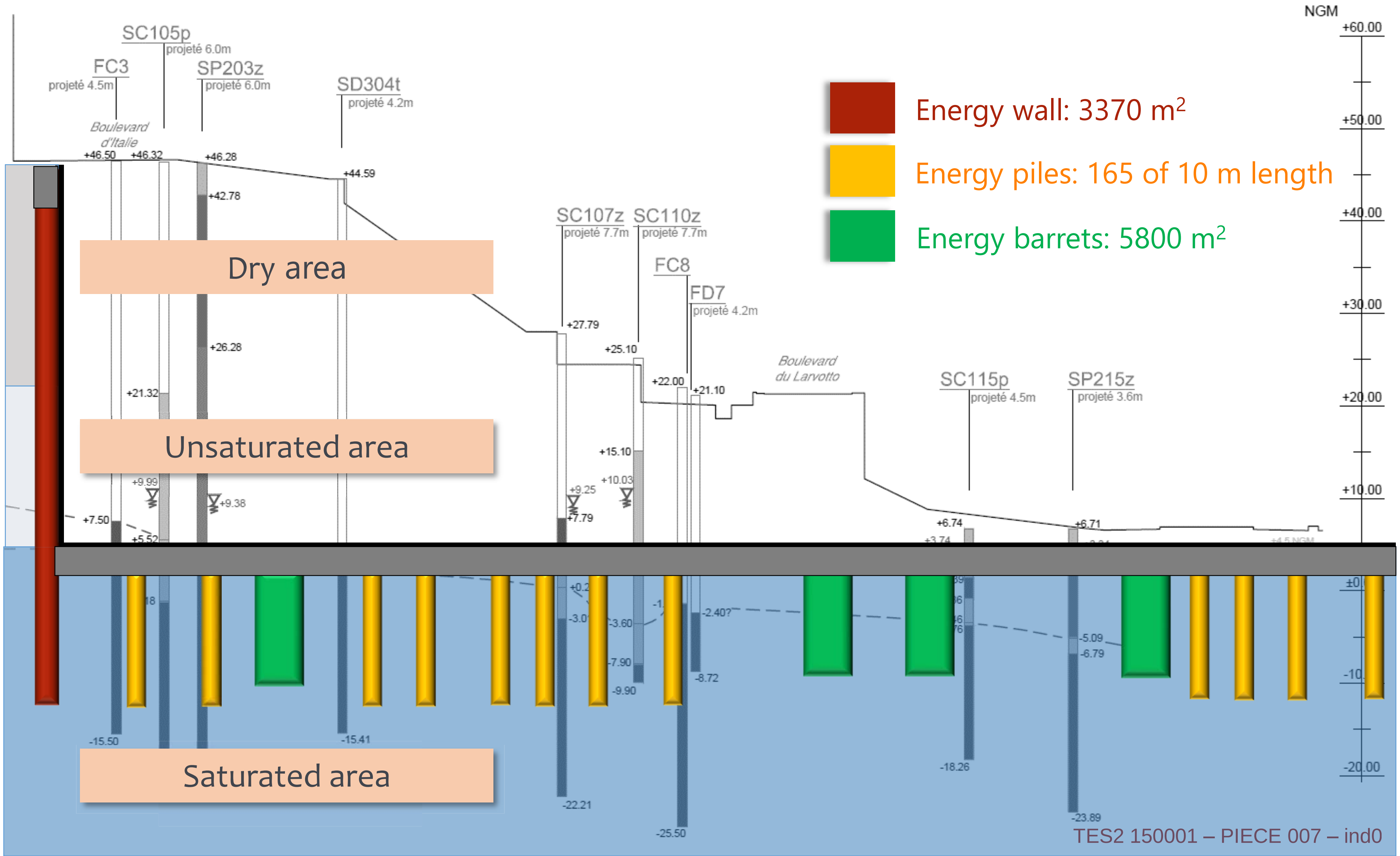
Zoning

* nota sondes géothermique : nombre et positions à définir après essais complémentaires et finalisation des études thermiques

(EXE ENT 05 PLN TN TZ 00001 A)



Various energy foundations for a 233 kW goal

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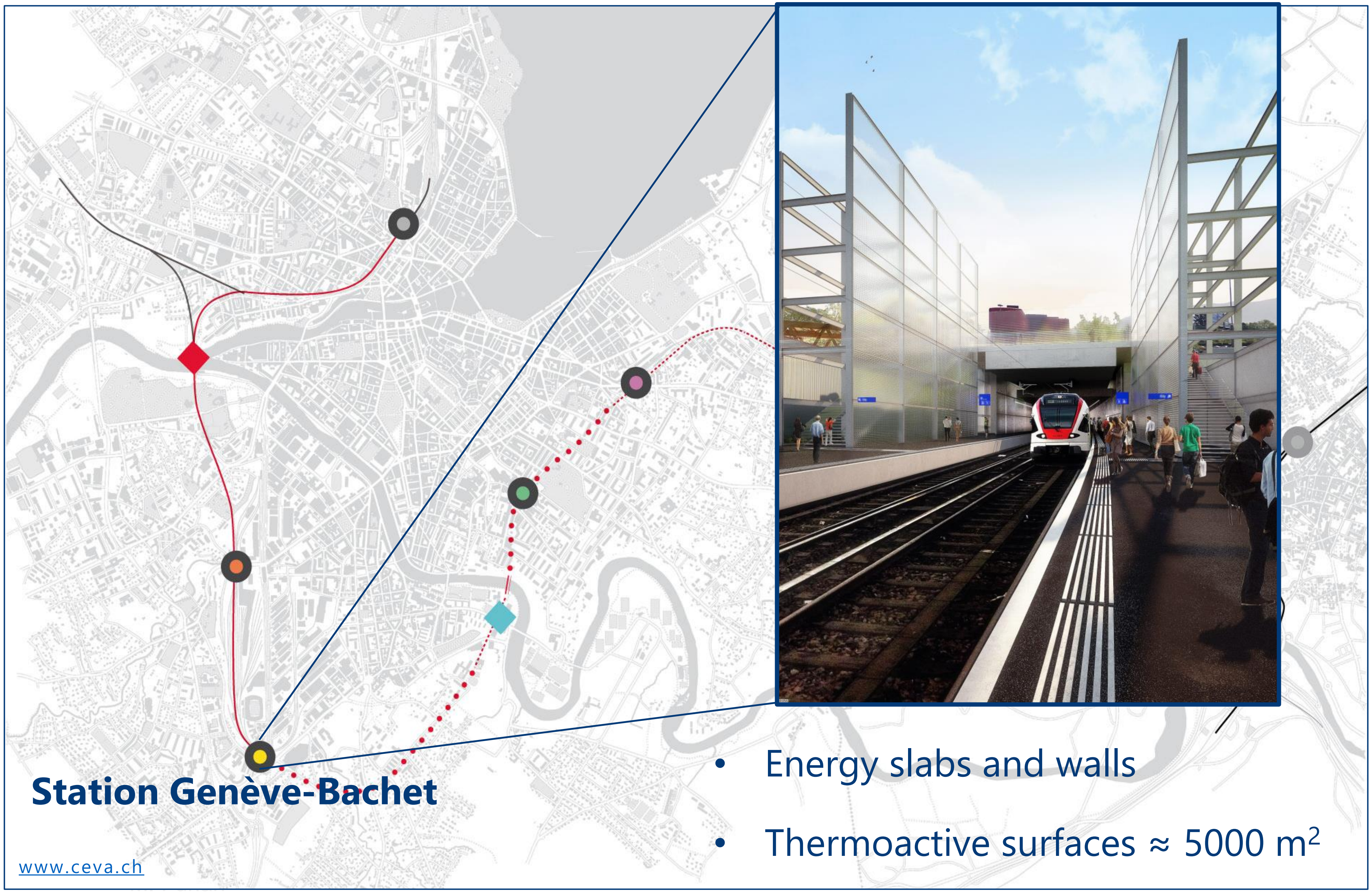
Example of underground infrastructure pilot project

CEVA
Geneva

Example of underground infrastructure pilot project

CEVA
Geneva



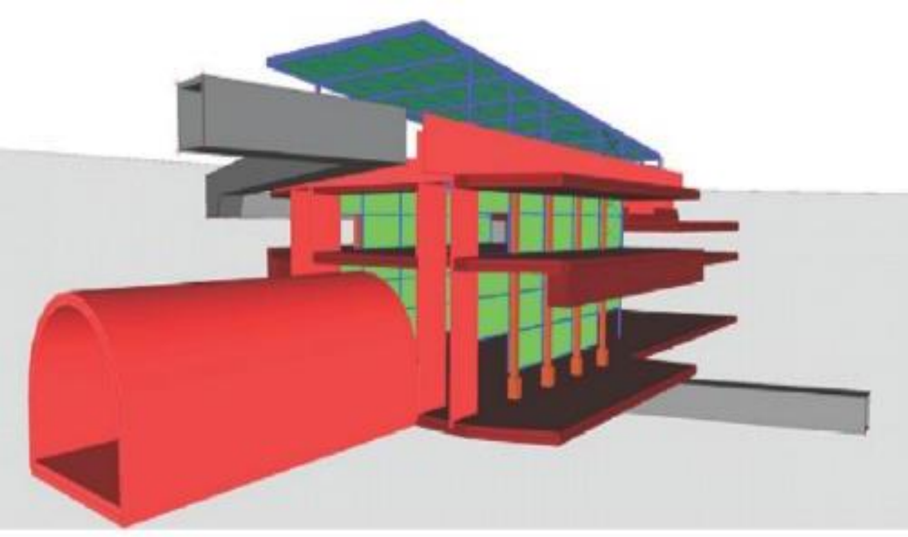
- Energy slabs and walls
- Thermoactive surfaces ≈ 5000 m²

Example of underground infrastructure pilot project

CEVA
Geneva


Cross-section Carouge-Bachet

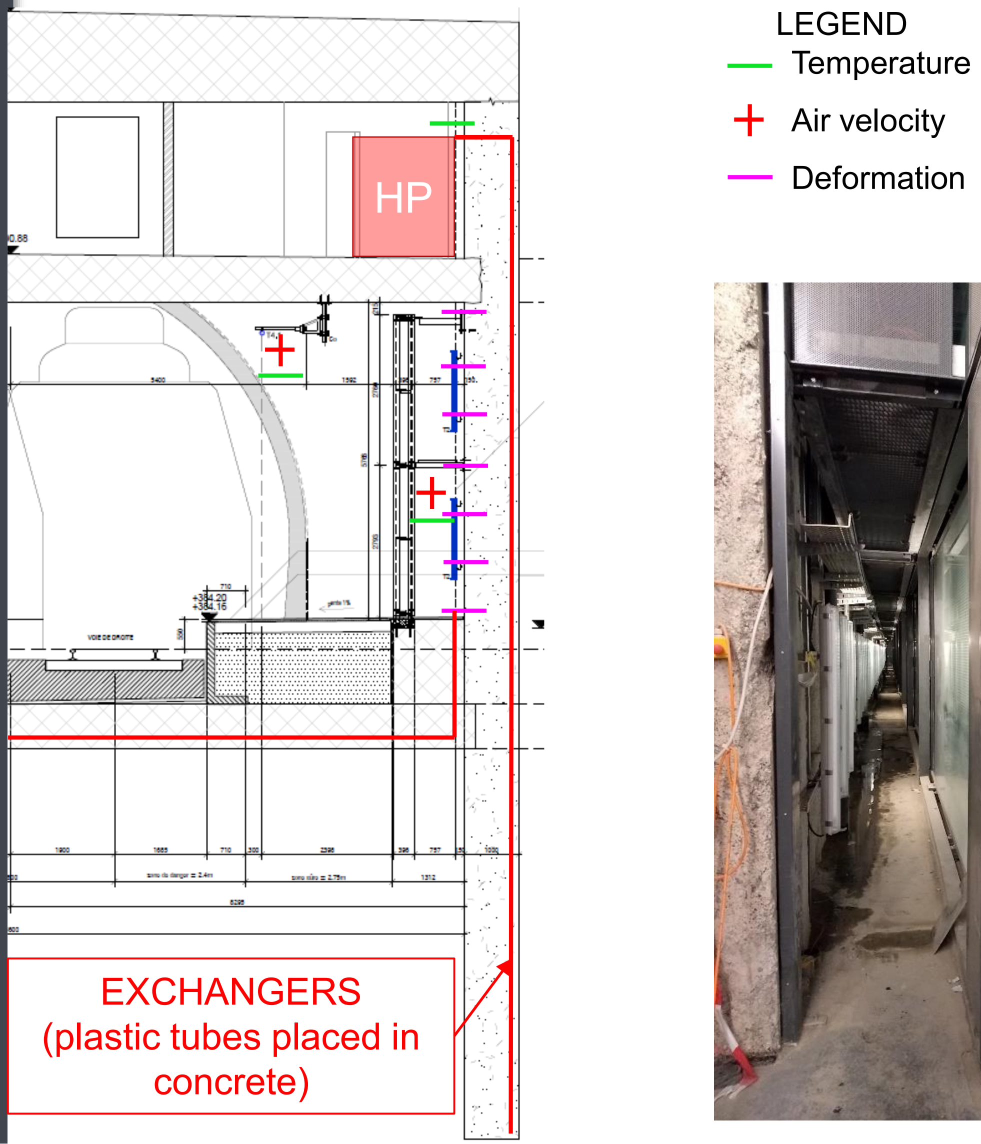
- Area of project: 4'200 m^2
- Area of slabs : 3'430 m^2
- Thermal energy: 200 kW



(www.ceva.ch)

Monitoring system

Zannin et al. (2021)



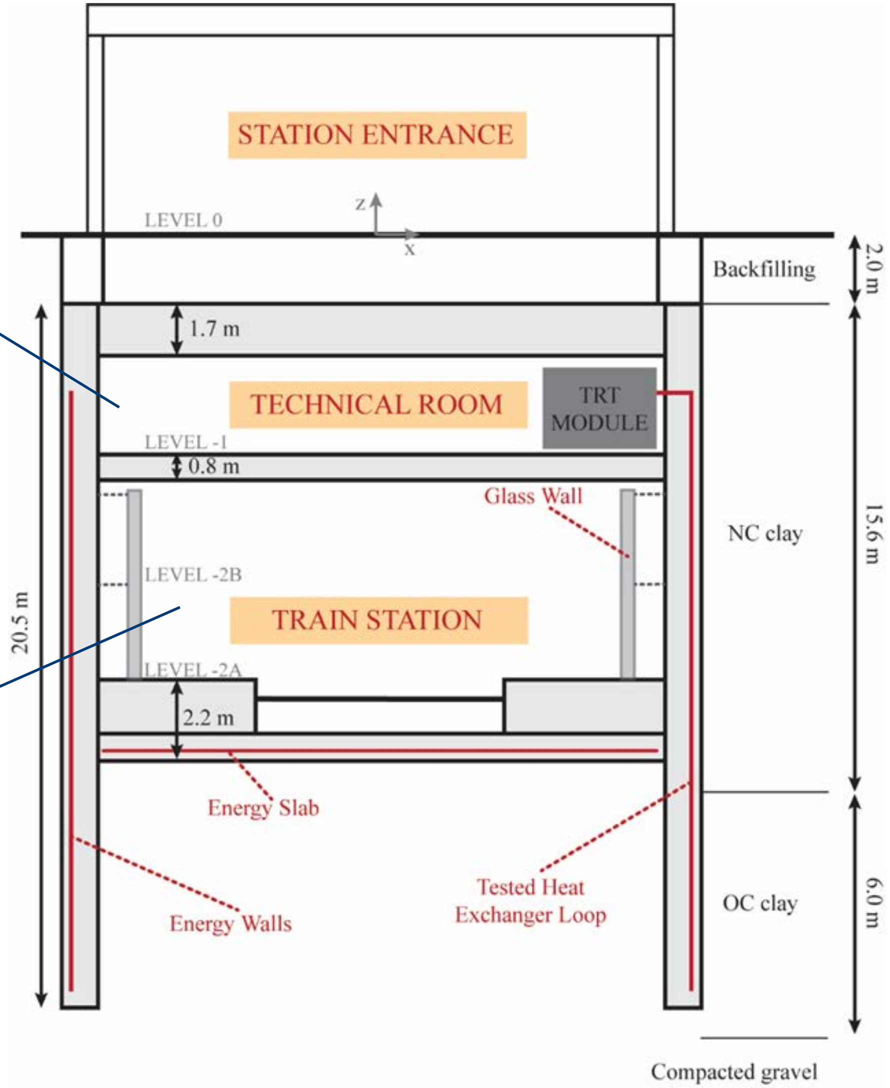
- Thermal-hydraulic properties of the heat transfer fluid
- Temperature and air speed in the tunnel
- Deformations in the walls (intrados)

Example of underground infrastructure pilot project

Zannin et al. (2021)

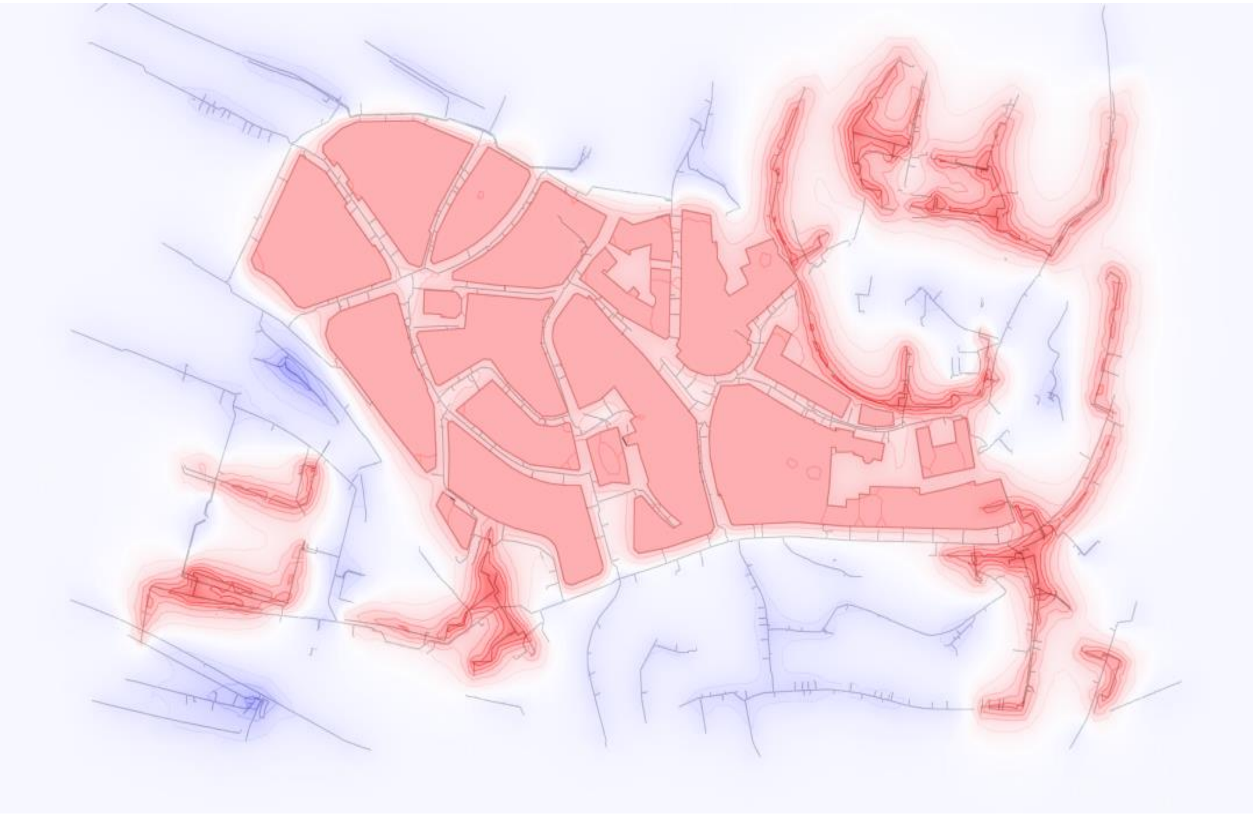
Geometry details

- Heating module
- Hydrothermal monitoring system
- Thermomechanical monitoring system



Why should you be interested in your city's underground?

Thermal characterisation of the urban subsurface consists of assessing the underground heat island effect, determining its sources and effects in order to propose sustainable and multi-dimensional strategies for urban energy planning.



Underground heat islands, Saint Laurent district
City of Lausanne, Switzerland (© GEOEG)

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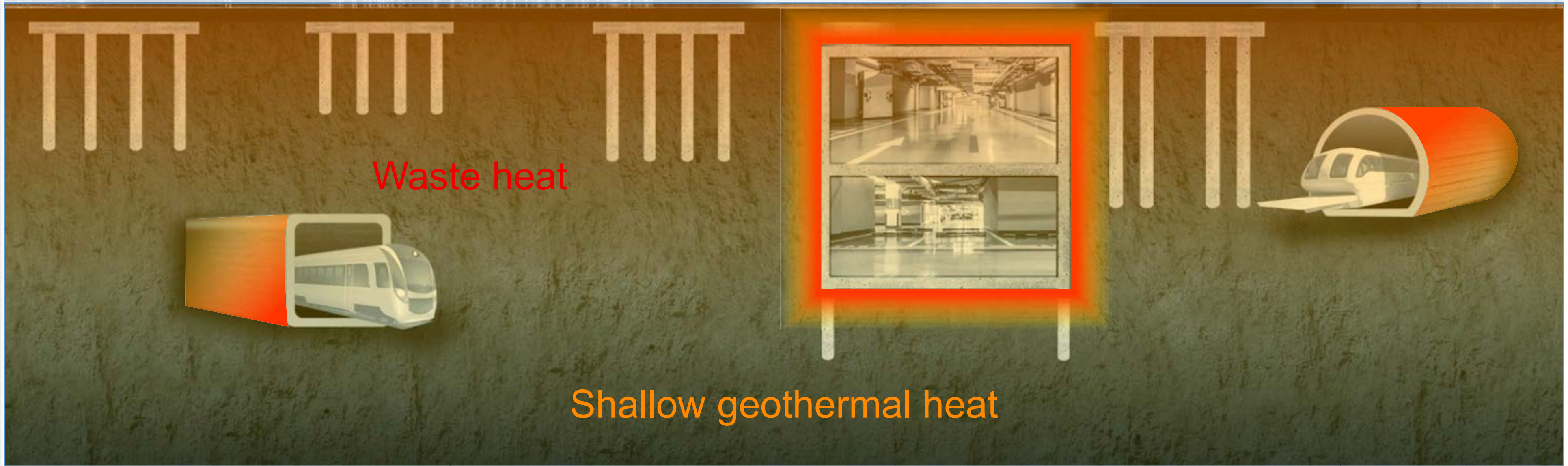
The untapped space and energy resources of cities

Residual heat in the urban subsurface comes from anthropogenic sources, including heat loss from buildings, underground transport networks and infrastructure.

This results in thermal saturation of the land (37°C in London in winter 2019) and residual heat flows (5 to 15 W/m^2 in New York, London, Singapore, Karlsruhe).

This waste heat contributes to local heat islands and represents a vector of energy efficiency and a potentially valuable renewable energy source.



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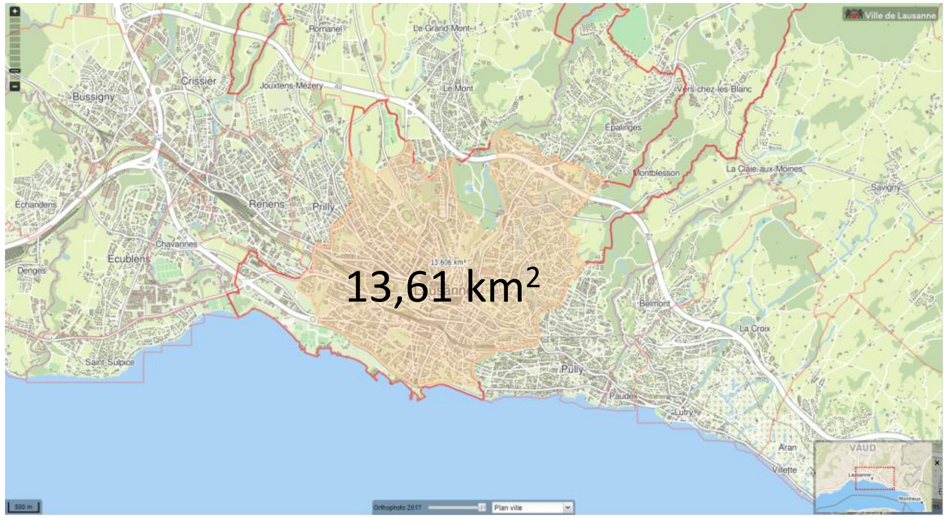
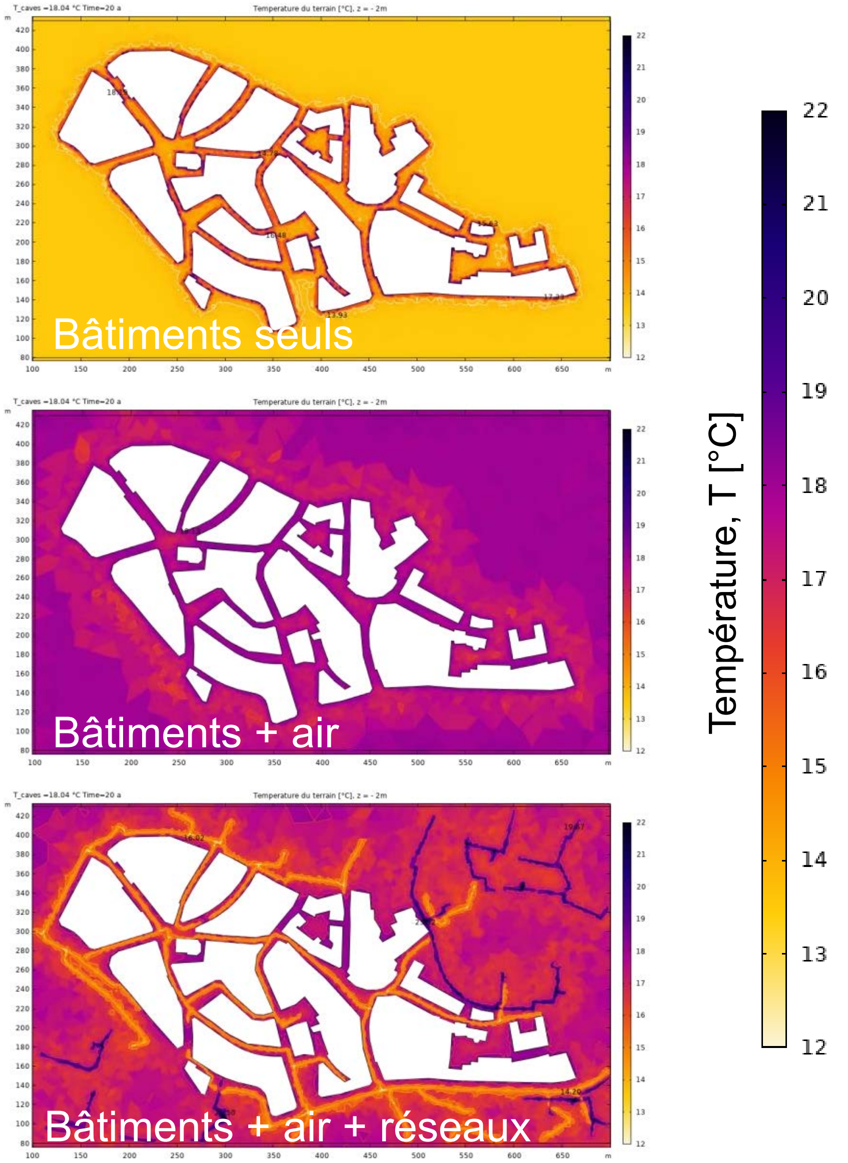
Analysis of subsurface heat island in Lausanne



Every year, the following amount of heat is rejected from Lausanne buildings in the subsurface and lost:

2445 kW – 20.8 GWh/an

This is equivalent to:
- 6900 low-energy buildings (MINERGIE)
- 1380 existing buildings



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Cutting-edge project

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enerdrape

2021
서울도시건축비엔날레
Seoul Biennale
of Architecture and Urbanism

CROSSROADS

Cutting-edge project | Chicago the city of layers

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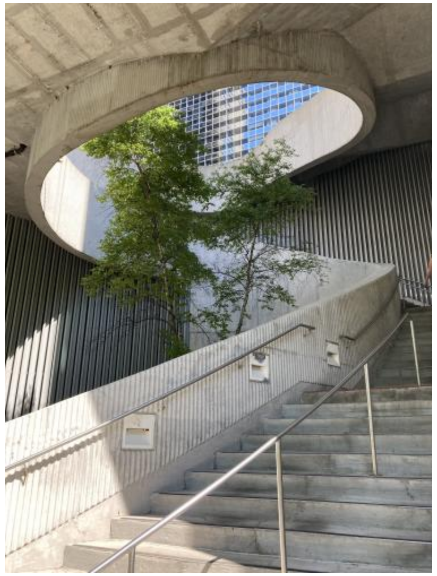

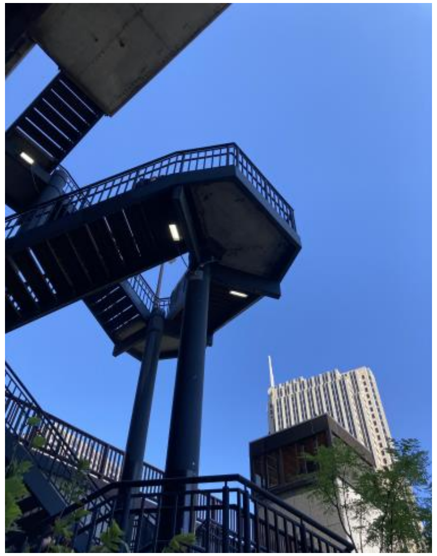

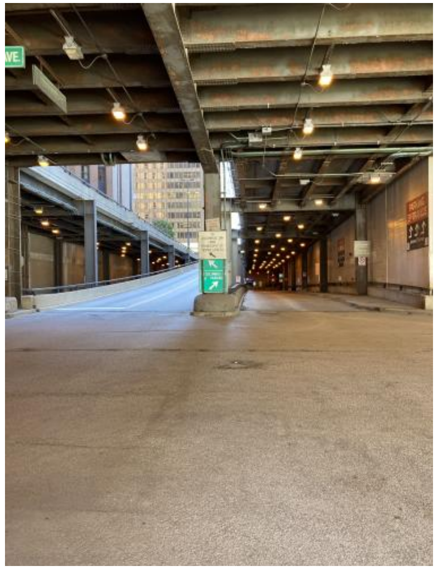

Vertical crossroads and layers above and below the ground surface

Cutting-edge project transforming 280 km of tunnels

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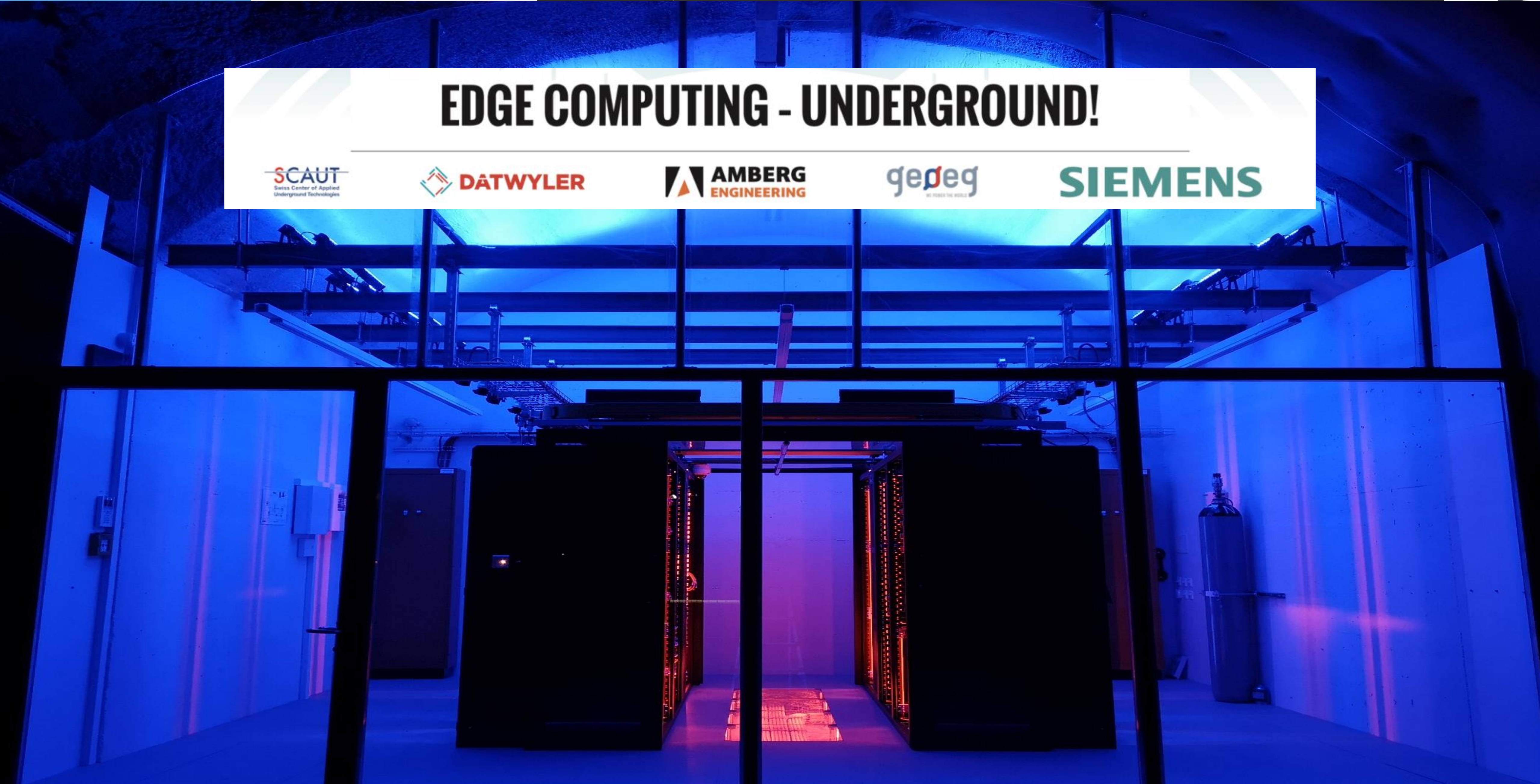
Below ground means new perspectives

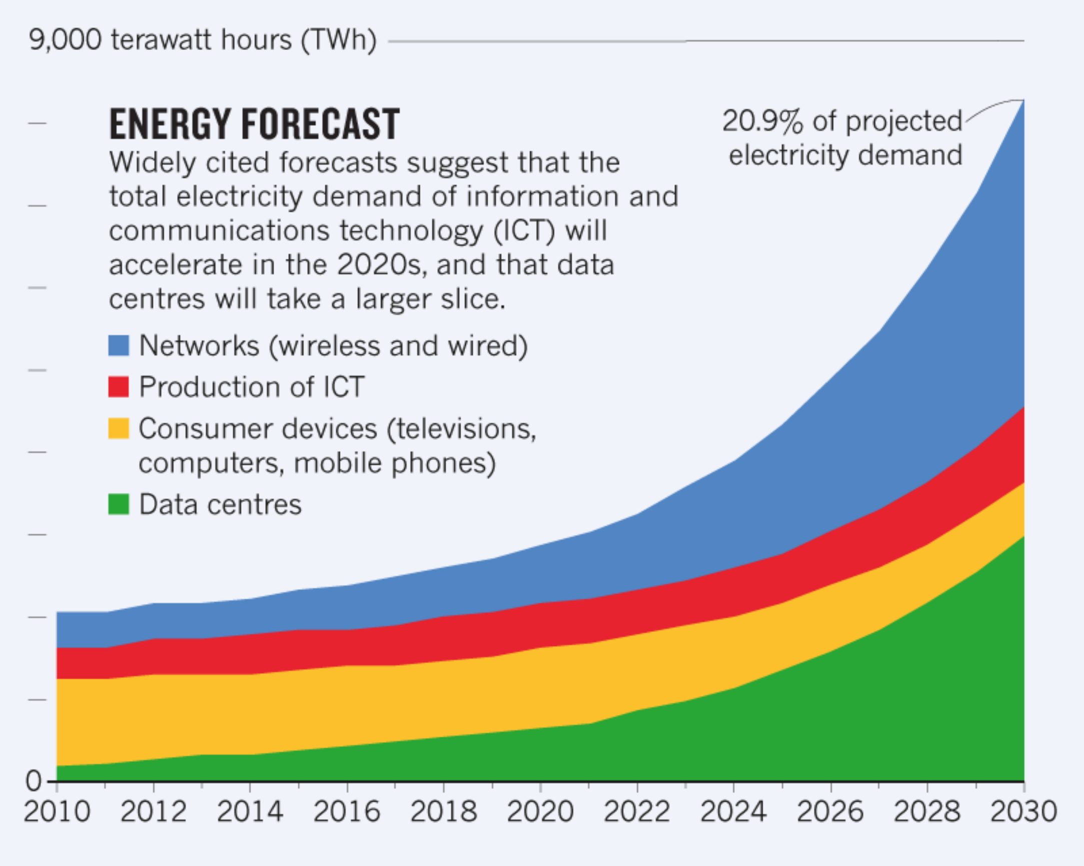


Why underground?

- High demand of land in urban areas
- Going underground offers space and flexibility
- Reduced energy demand
- Sustainable and resilient solution
- Cool and secure environment

A 20% more effective energy solution

- Today, data centres consume 1% of the world electricity
- Accounting for 0,5% of CO_2 emissions worldwide
- 40% of the electricity is used for cooling
- In 2030, data centres are expected to consume 21% of the total electricity demand!



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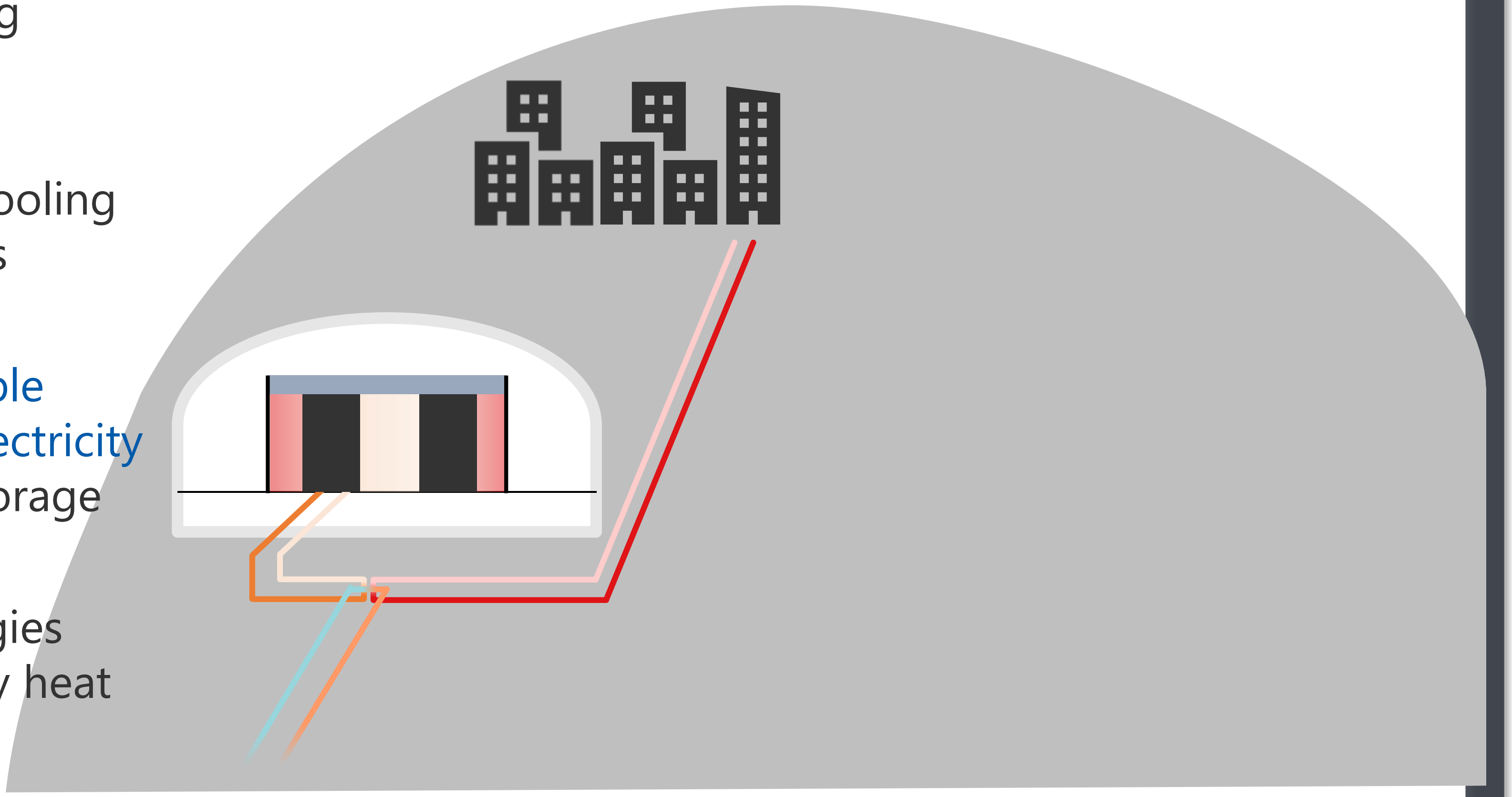
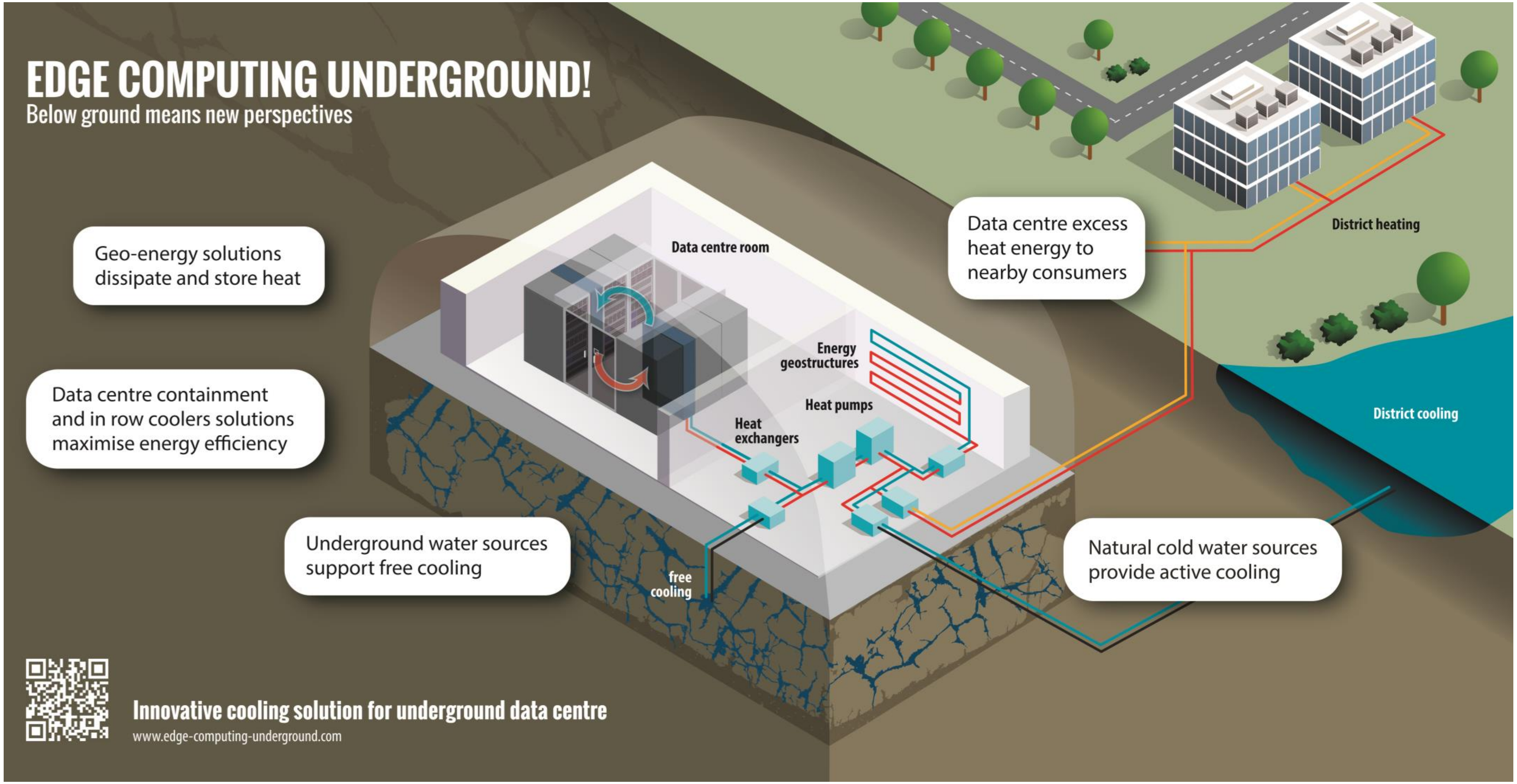
Innovative cooling solutions

- Decreasing the cooling needs by being underground
- Increasing efficiency with optimised cooling architecture and efficient technologies
- Optimising the use of on-site renewable energies and decreasing the use of electricity by favouring free-cooling and heat storage
- Closing the loop, by leveraging synergies between heat generators and close-by heat consumers



Innovative cooling solutions



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Key benefits

- ✓ Up to 20% less energy consumption
- ✓ Up to 20% lower construction costs
- ✓ No land purchase and permitting process
- ✓ Higher security
- ✓ Flexible expansion options
- ✓ Sustainable solution

Enerdrape

We need more solutions to access renewable sources in cities

Solar thermal
Variable production
Requires large storage space
Limited roof integration (sloped roof, PVs…)
No cooling

Pellets
Requires large storage space
High maintenance costs
Limited authorisations (NO_x limitation)
No cooling

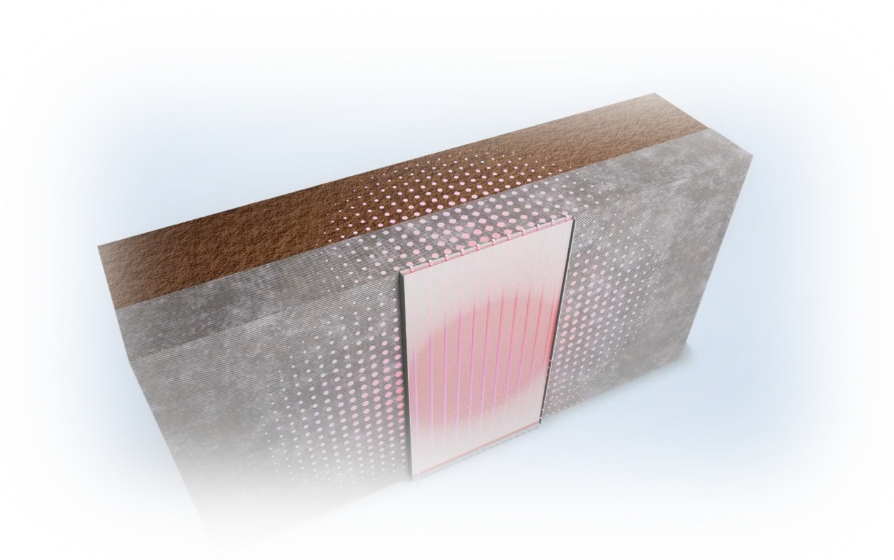
District heating/ District cooling
Limited availabilities

Geothermal probes
Limited drilling space
Authorisation

Air heat-pumps
Low heating power
Noise generation

Groundwater
High investigation costs
High heating power
Authorisation

Enerdrape makes it easy to tap into a huge potential that lies underground



Retrofit-friendly
Minimal impact on the structure & minimal use of space

Easy to Install
Quick installation & quick coupling

Modular
Scalable & customizable

Constant efficiency
Independent of exterior conditions.

C02 savings
On-site renewables & smart use of materials

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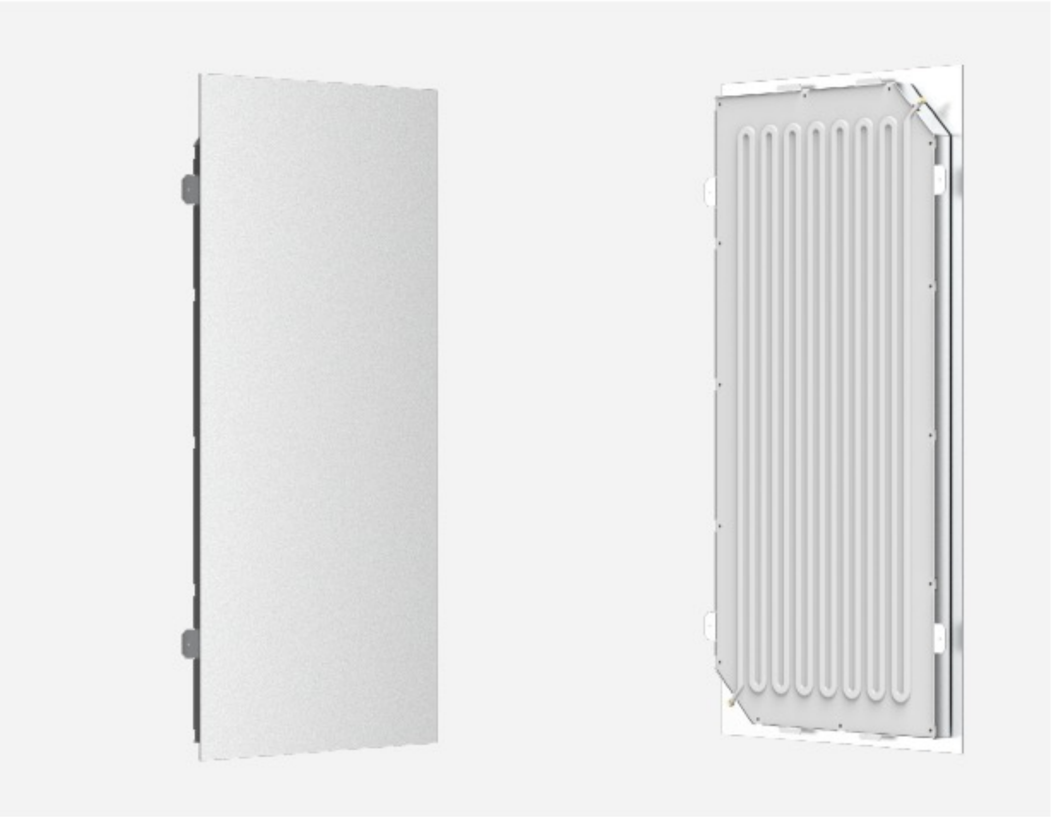
Added value

- Possibility of retrofitting
- Easy to install
- Modular
- Constant efficiency
- Savings of CO2
- Integration aesthetic
- ROI 6-8 years | IRR 4-5%



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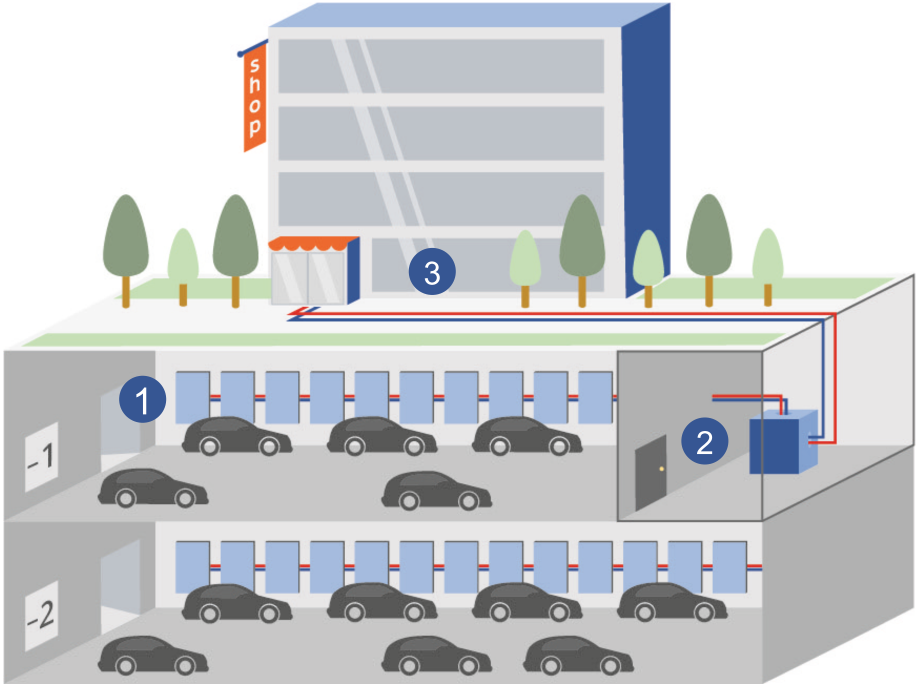
How does it work?

1. Panels installed on surfaces in contact with the ground, such as the walls of a parking lot.

2. A hydraulic network connects the panels to a heat pump or other equivalent energy system.

3. The collected thermal energy is redistributed to the building.



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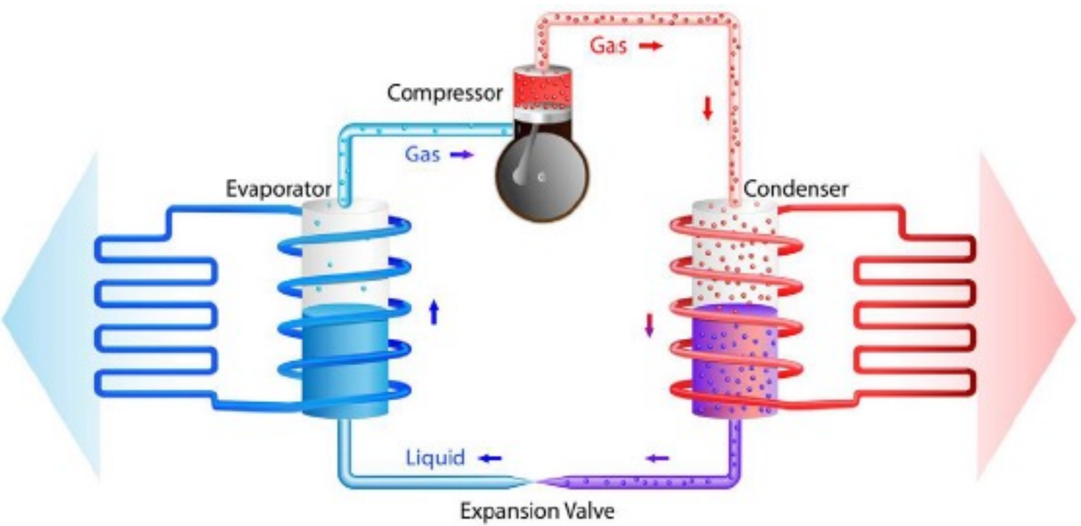
Heat pump principle

Energy from environment
(air, ground,water…)



Useful Heat/cool for the building

Pilot project

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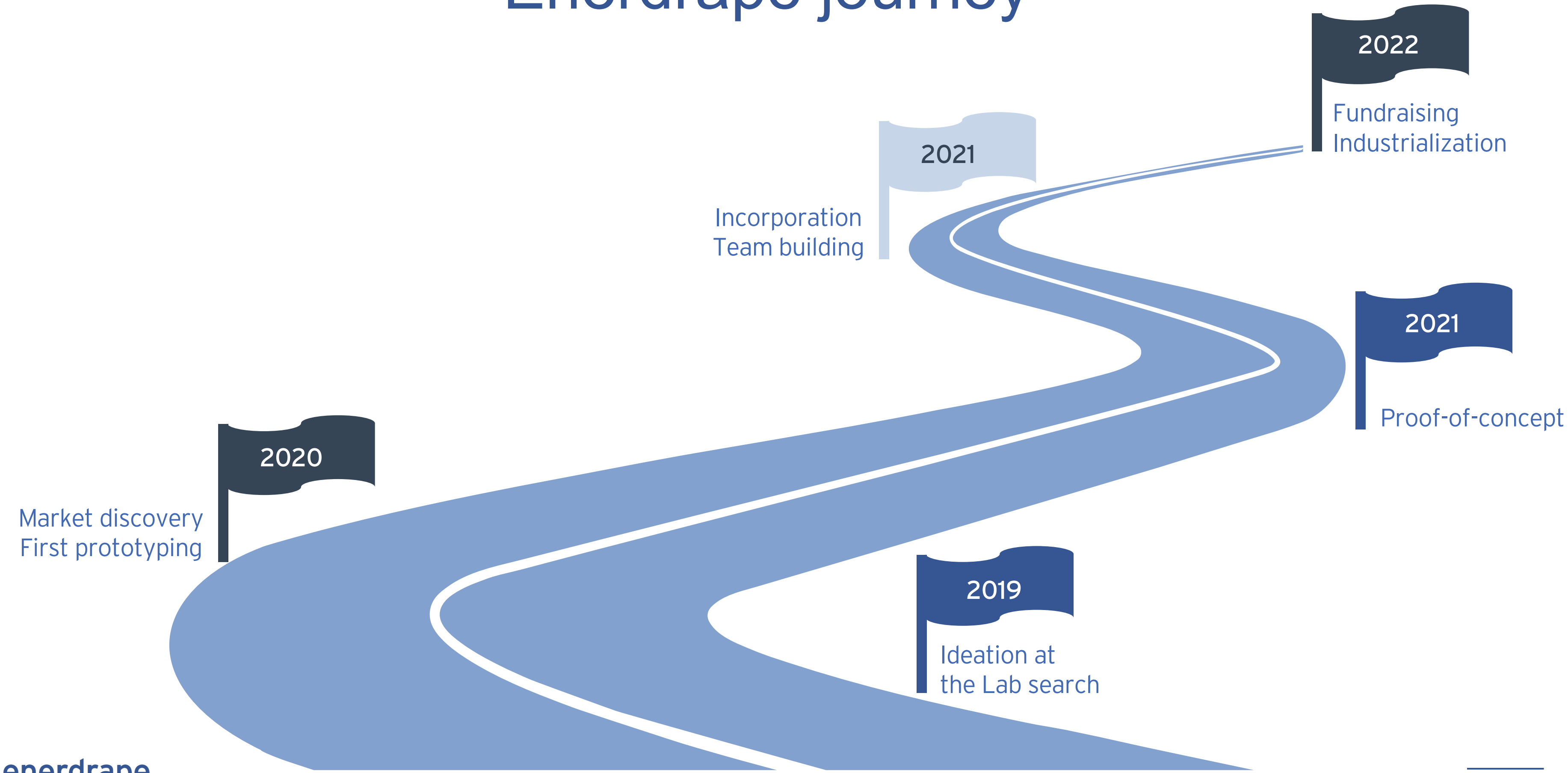
Enerdrape journey



Market discovery

The ecosystem

- Product/Project lifetime
- Several actors
- Several decision maker
- Customer ? Client ? Ambassador ?
- Different objectives
- Different values

Table 2: Value chain description (after McKinsey,2021)

		Financing	Designing & planning	Processing materials & equipment	Constructing	Upgrading	Operating and using
Players in the construction value chain	Financier /Shareholder /Building owner						
	Developer						
	Designer/engineer/ planner/technology developer						
	Raw and material supplier /distributor						
	Contractor/builder						
	Long term owner/occupier/ facility manager						
Other Players	Energy Procurement Construction Contractors						

Enerdrape ecosystem

Parking operators

INDIGO

PMS

PARKGEST

QPARK

Contractors

LOSINGER MARAZZI

ROMANDE ENERGIE

STEINER

VINCI ENERGIES

Consultants

ROMANDE ENERGIE

SIG

BKW

SiL SERVICES INDUSTRIELS LAUSANNE

VINCI ENERGIES

Clients/ Building owners

SWISS PRIME SITE

REALSTONE

Retraites Populaires

SBB CFF FFS

UBS

SwissLife

IKEA

Nestlé

coop

MIGROS

PHILIP MORRIS INTERNATIONAL

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Value for all

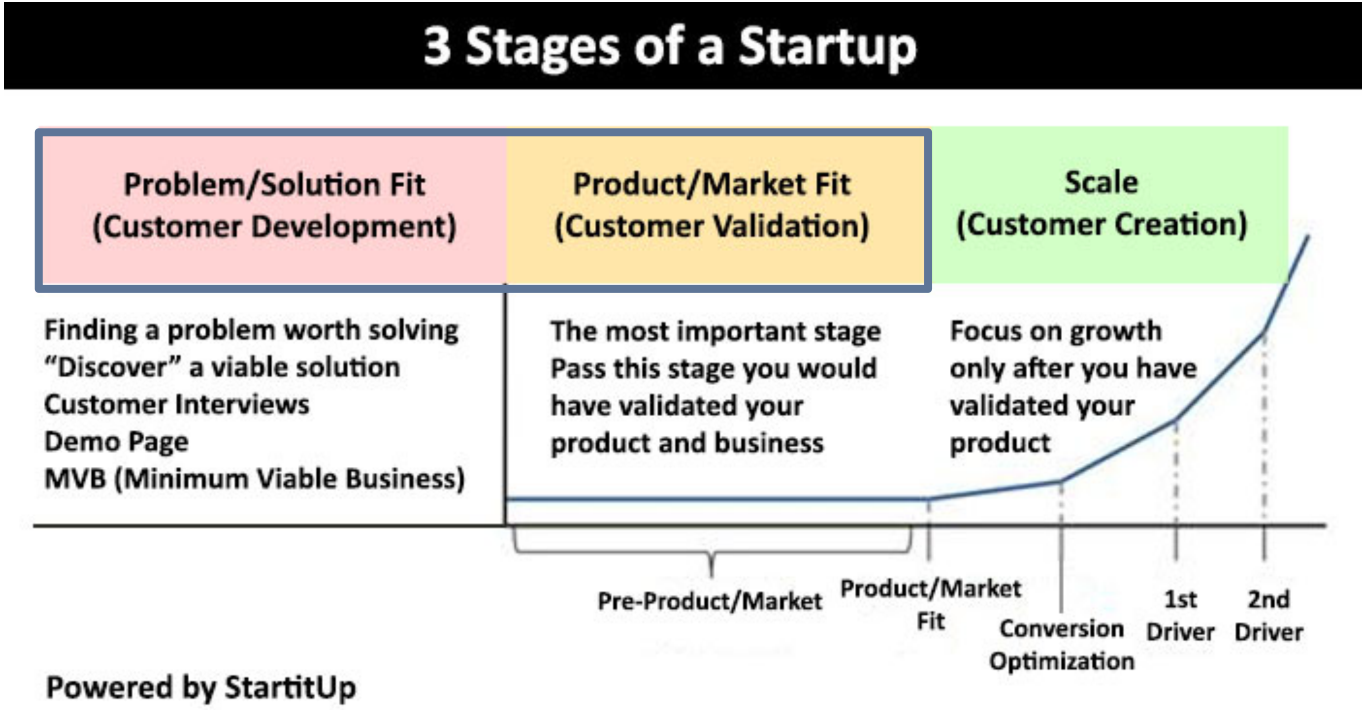
For parking operators	For energy specialists	For building owners
No impact on their activity	Easy-to-install & Easy-to-maintain	Cut-down OPEX
Marketing / Advertising	Scalable	Save CO_2
Potential additional revenues	Increased productivity	Added-value or Marketing argument

Who are they ?

INDIGO, PMS, PARKGEST | ROMANDE ENERGIE, SIG, EDF, VINCI ENERGIES, BKW | SWISS PRIME SITE, REALSTONE, IKEA, SBB CFF FFS, coop, MIGROS

Product development

Product market fit



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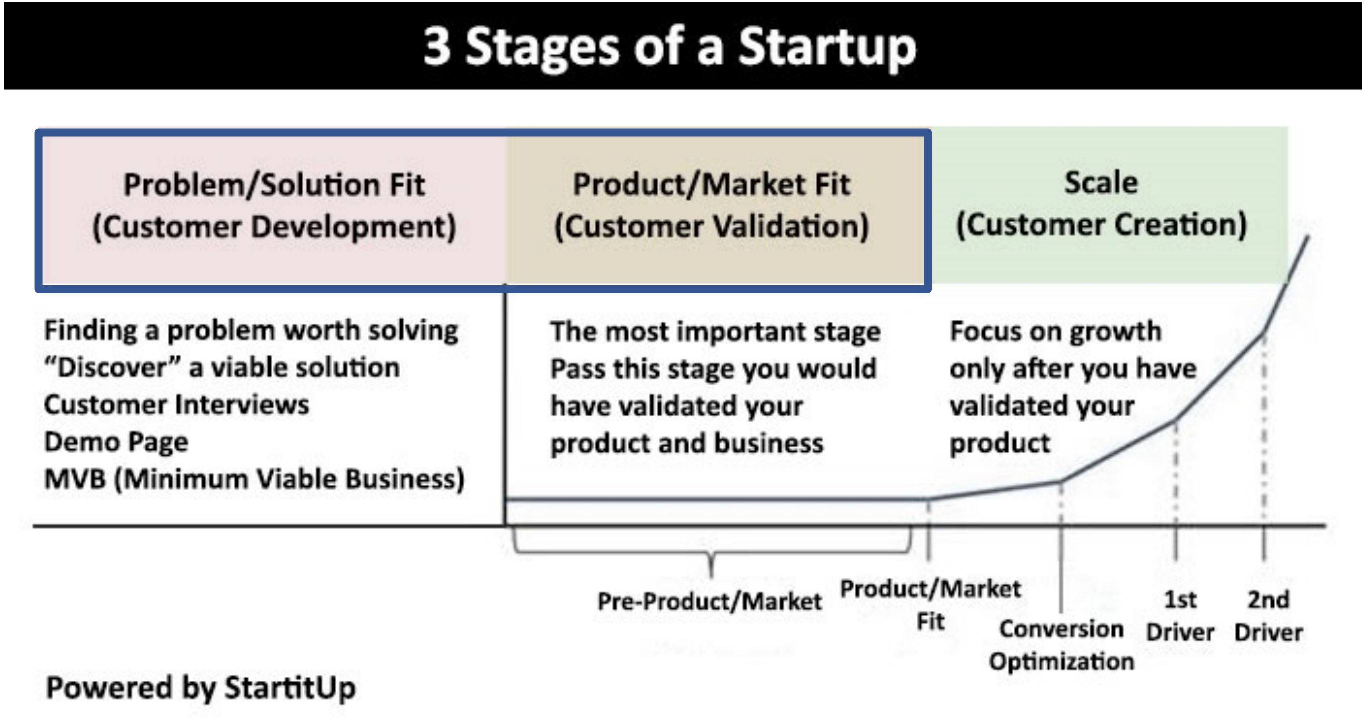
Product market fit



enerdrape

enerdrape
What if underground parking garages could be transformed into a renewable heat source for the heating and cooling of buildings? Enerdrape is the world-first geothermal panel that makes this possible.
Modular, scalable and easy-to-install, Enerdrape is a low-carbon, energy-efficient and cost-competitive solution that helps reduce CO2 emissions in present and future cities by turning underground infrastructures like parking garages into renewable energy sources. Enerdrape is a startup of EPFL.
EPFL
BRIDGE
ENABLED BY DESIGN
REALSTONE
Enerdrape transforme
les parkings souterrains
en sources d'énergies

Proven patent pending technology

Technology

- Pilot installation, Lausanne
- Up to 200 W/m^2
- Pre-industrialisation phase

Traction

- 3 pilots signed REALSTONE amag
- +15 projects in definition SWISS PRIME SITE SIG
- +40 Hot interest BayWa r.e. BKW
- Recognition from the industry

RENT REAL ESTATE & NEW TECH SWITZERLAND Klimastiftung Schweiz VSE AES IMMOBILIEN INNOVATION

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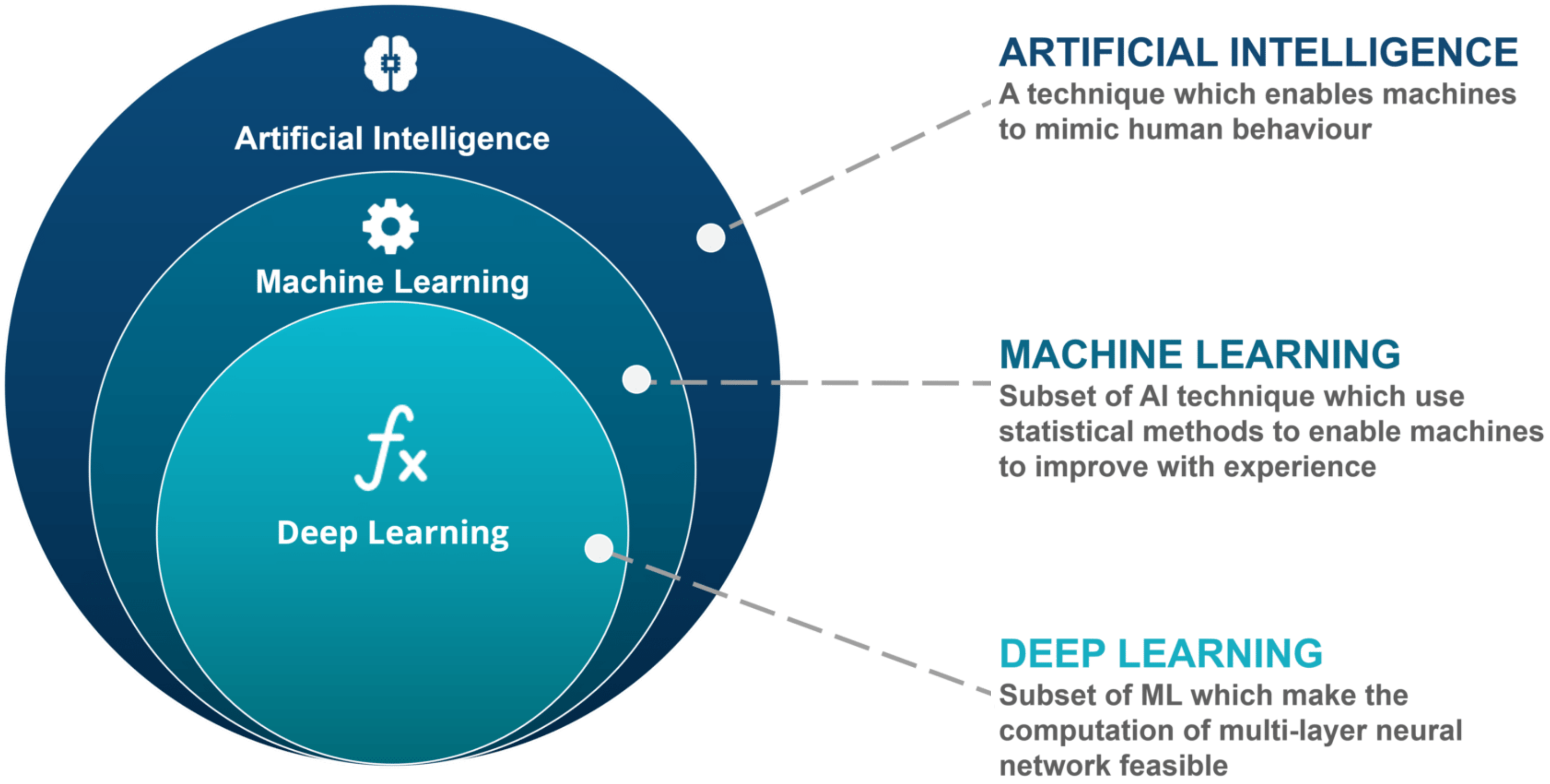
A quick introduction

to data science

AI > ML > DL



Main applications

- Image/speech recognition
- Virtual assistance
- Prediction

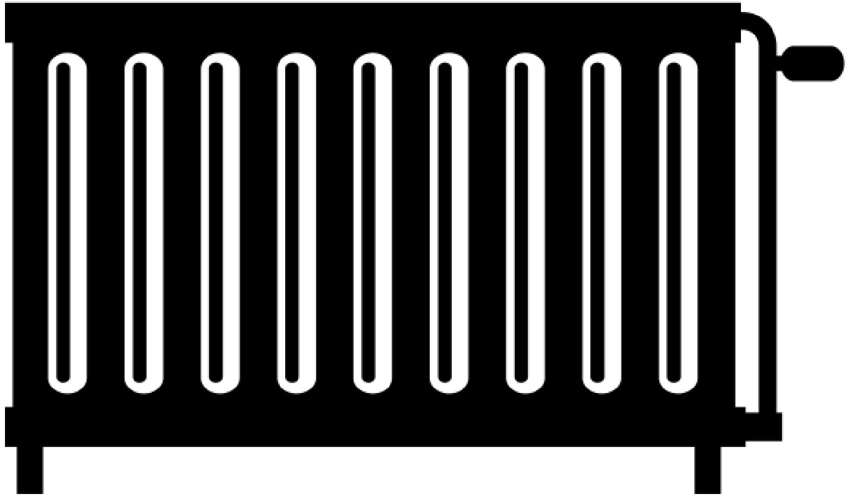
! DATA !

source : www.inteliment.com

Machine learning for geothermal systems

A world in need for sustainable heating energy

Heating
64,7 %



DHW
14,5 %

Lighting and appliances
13,8 %

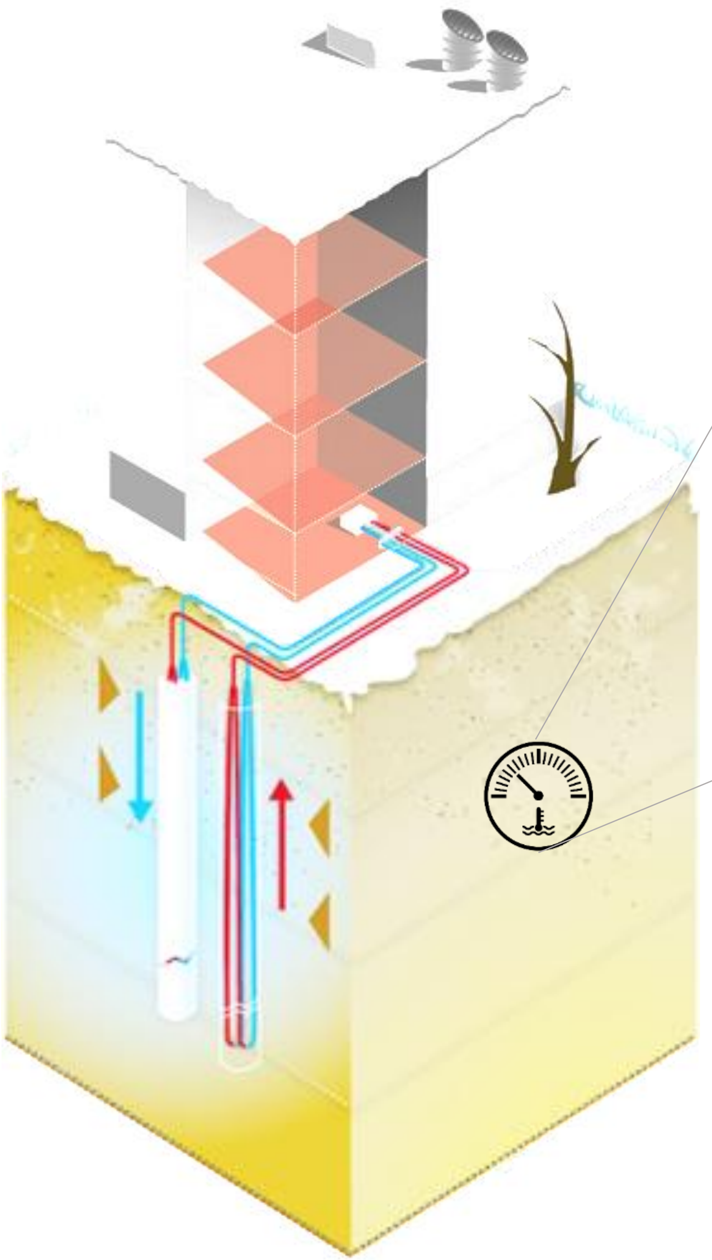
Cooking
5,4 %

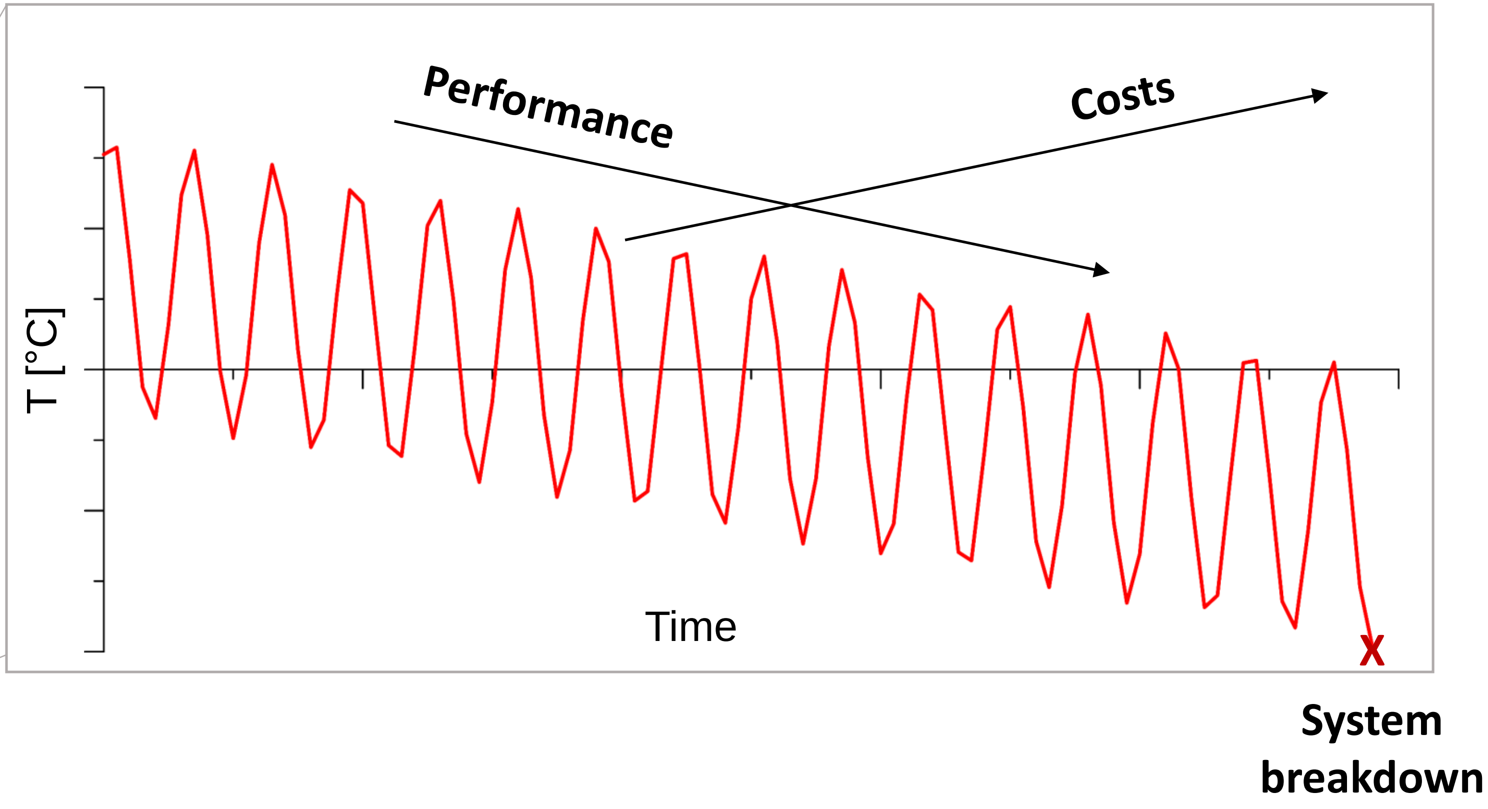
Cooling
0,3 %

Other
1,3%

Source: Eurostat
Images: Noun Project

A challenging lifetime

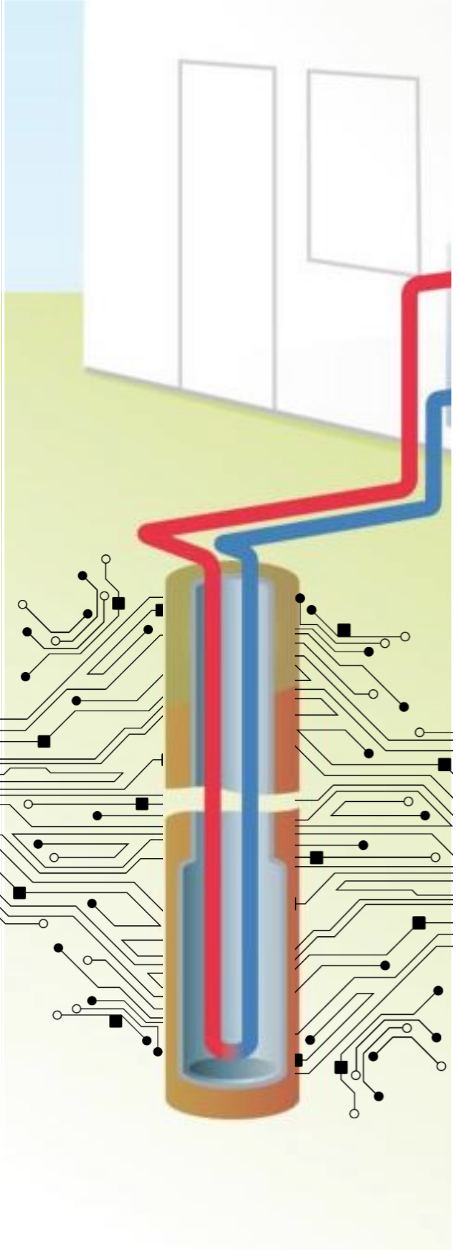




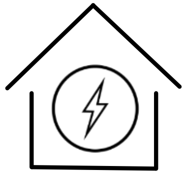
«All the professionals interviewed consider that those systems are often poorly realized» Suisse Energie Report, 2017

GEOBRAIN

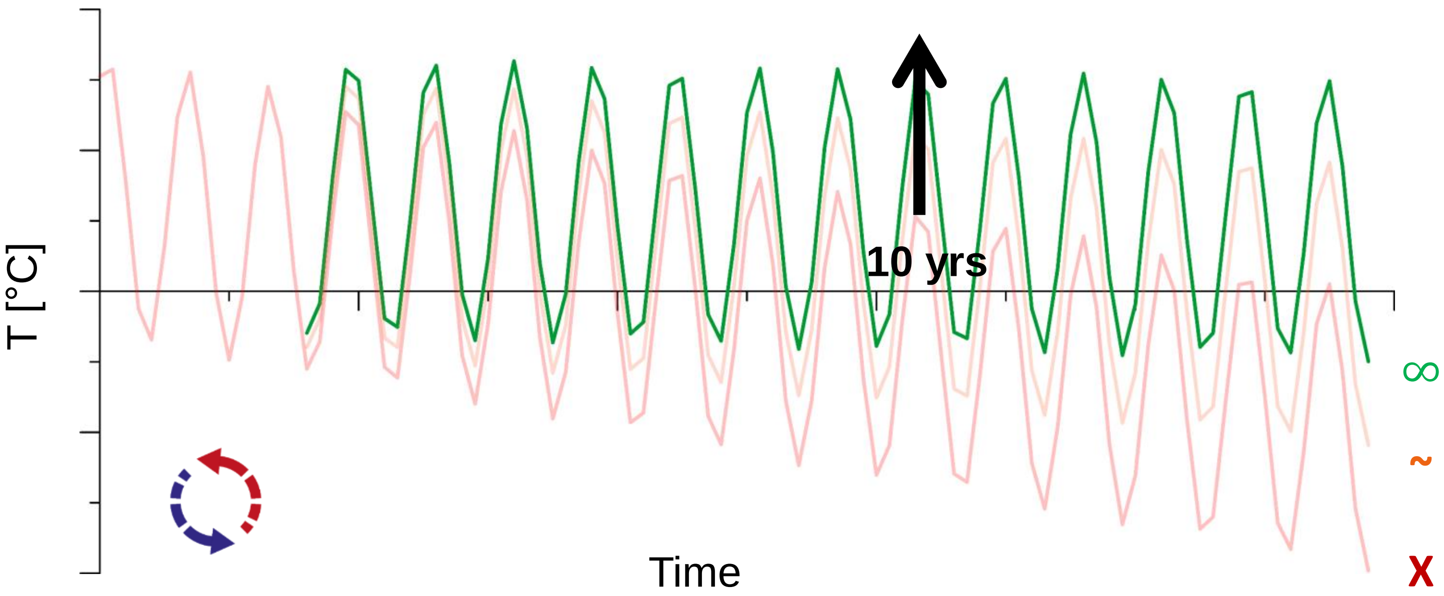
Predict to optimise

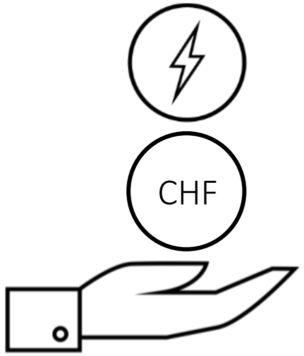


Modified from Adobe Stock



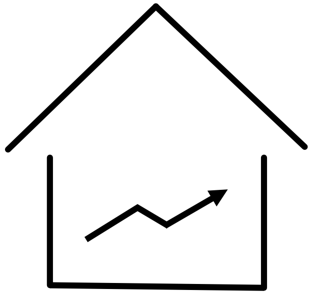
- CHF 3200 / installation





Energy savings

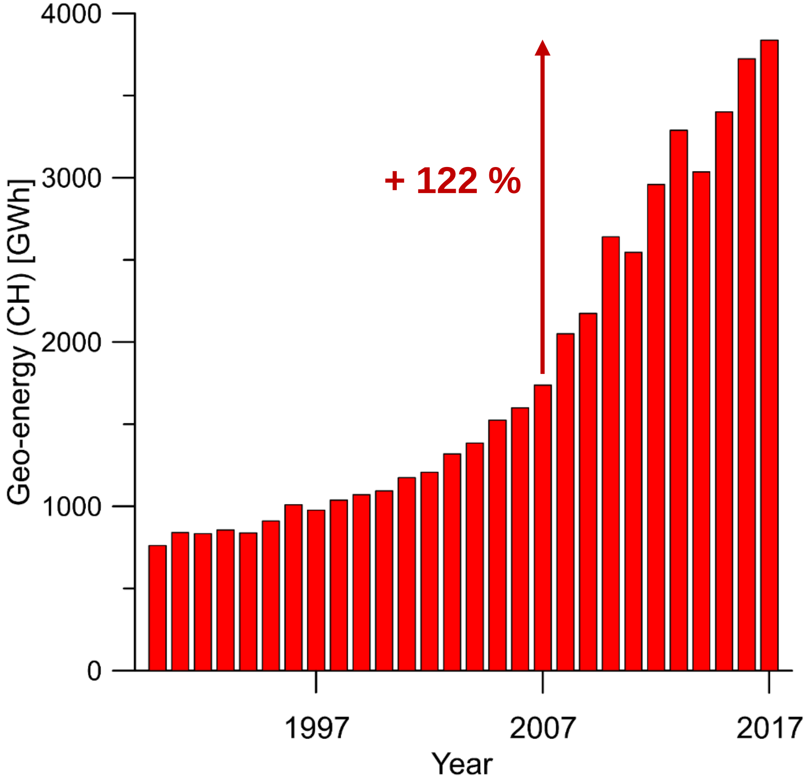
Secured investment



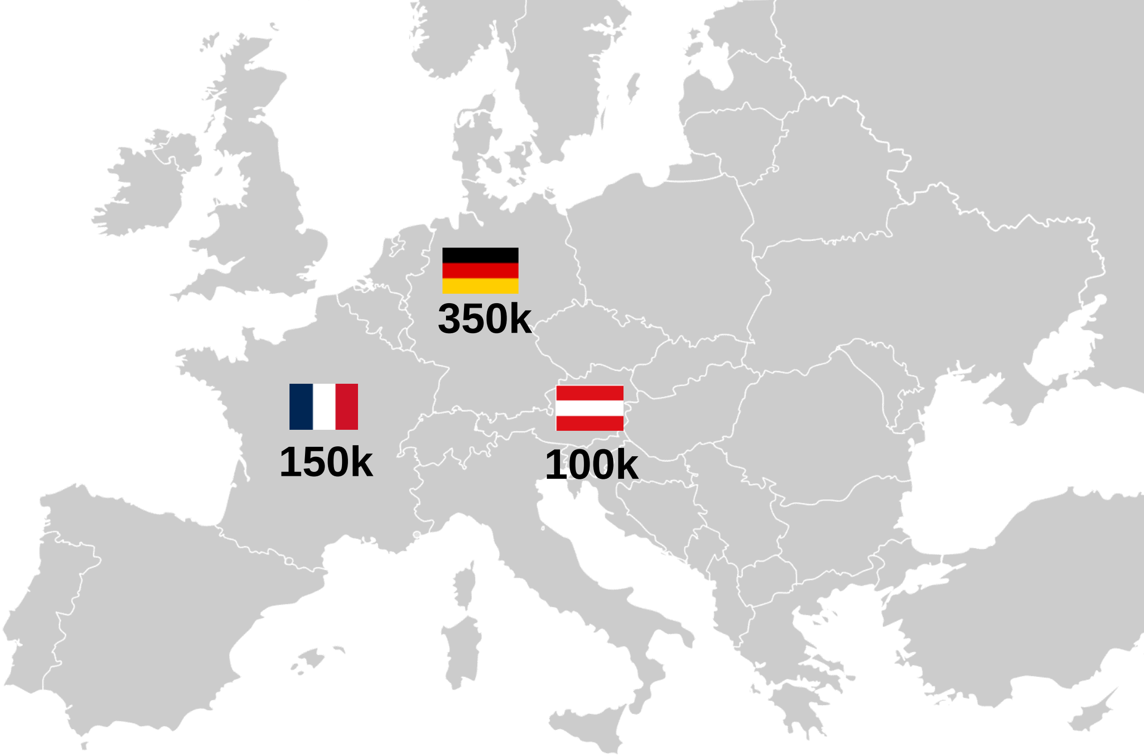
Increased property value

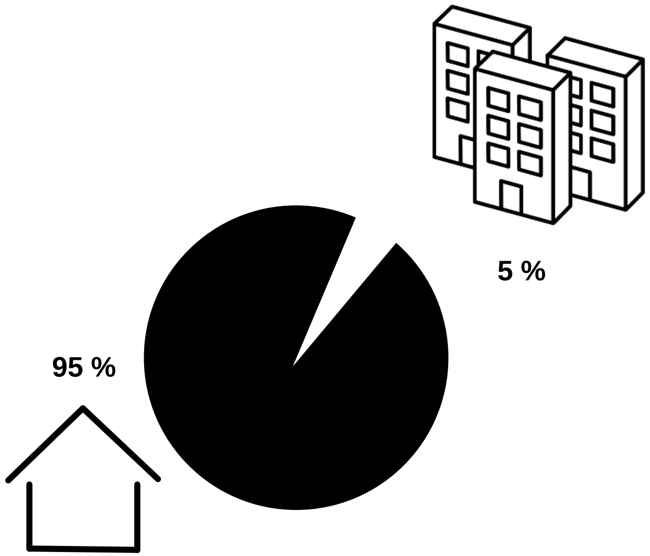
Market opportunity

Switzerland as an entry market



Source: SuisseEnergie, EurObservER-Heat-Pumps-Barometer





EPFL

The class will start at 08h15

Innovation for construction & the environment

Dr. Dimitrios Terzis

27/11/2023

Also part of :

E4S
Enterprise for Society

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Swiss society of engineers and architects