HEATSTORE: D6.3
REPORT ON EVALUATION OF NEW BUSINESS MODELS FOR FLEXIBLE ENERGY SYSTEMS WITH UTES IN EUROPE

GEOTHERMICA

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heatstore
High Temperature Underground Thermal Energy Storage

TABLE OF CONTENT

WP 6 FAST-TRACK MARKET UPTAKE IN EUROPE & DISSEMINATION (LEAD TNO)

- **Task 6.3 Evaluation of new business models for flexible energy systems with underground thermal energy storage in Europe (Fraunhofer IEG** (former GZB), STY, SIG-UNIGE, TNO, IFT, NIOO)
- **D6.3** Report on evaluation of new business models for flexible energy systems with underground thermal energy storage in Europe (**M30**)
- **Objective**: to evaluate (identify and validate) new business models for combining distributed energy resources, self-consumption and storage with optimised utilisation of distribution networks from all energy carriers. Evaluation and validation of new business models will be executed by compiling information from literature, the specific results from the case study and demonstration projects (WP4), stakeholder interviews with partners directly involved in the demonstration projects and members from relevant branch organisations and institutes (EASE, EUROHEAT & POWER). This allows to set economic boundary conditions for business models and provide recommendations for replication of new business models for UTES in Europe. In the task:

ROLE OF PARTNERS FOR THE TASK

- TNO: will develop the methodological framework to identify and evaluate new business models.
- IF: determine interesting markets for HT ATES and high-level translation of WP3 results to identified European markets.
- NIOO will provide technical, operational and financial data on its HT ATES system as input for developing new business models.
- SIG: in collaboration with UNIGE will develop business models for the Swiss market
- Fraunhofer IEG: will evaluate the commercial integration and reuse of the Fraunhofer IEG mine thermal energy storage into the heat distribution network of the unique Wärme GmbH.
- STORENGY: contribution for setting up new business models for flexible energy systems based on HT-UTES in Europe (French focus).

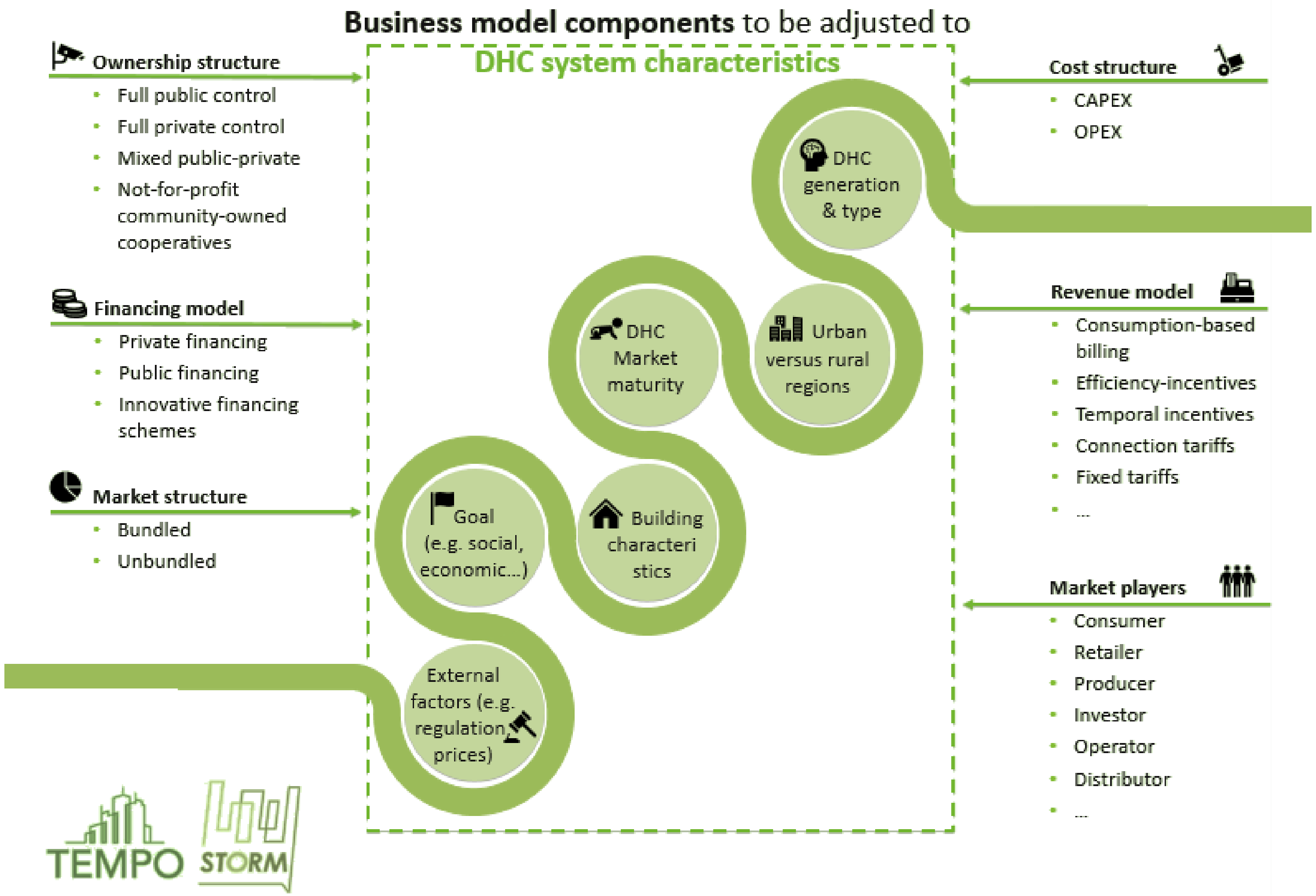
KEY COMPONENTS OF HEAT STORAGE BUSINESS MODELS

KEY COMPONENTS OF HEAT STORAGE BUSINESS MODELS

- Ownership
- Financing
- Market structure
- Market players
- Cost structure
- Revenue model

BUSINESS MODELS FOR THE DEMONSTRATION CASES

BUSINESS MODEL COMPONENTS - DETAILS



HEAT STORAGE SERVICES/ACTIVITIES/VALUE PROPOSITION

HEAT + ELECTRICITY + GAS NETWORK

Reduced peak generation / peak shaving	DHN investment deferral	Conventional generation replacement	Time-shifting for curtailment avoidance of sustainable heat and waste heat	Support thermal ramping	Reduce distribution grid congestion electricity grid (with heat pump)
Optimal performance for generators - Stabilizing demand for generators	Optimal performance for generators - co-gen plants	(Seasonal) Arbitrage	Security of supply (N + 1)	Strategic reserve (beyond DHN boundaries)	Optimisation of RE output
Time shifting for Industrial process optimization	Energy autarky	Surface space conservation	Public image	Ecological value	New service

HEAT STORAGE SERVICES/ACTIVITIES/VALUE PROPOSITION NETHERLANDS demo

Reduced peak generation / peak shaving	DHN investment deferral	Conventional generation replacement	Biomass generation replacement	Time-shifting for curtailment avoidance of sustainable heat and waste heat	Support thermal ramping
Reduce distribution grid congestion electricity grid (with heat pump)	Optimal performance for generators - Stabilizing demand for generators	Optimal performance for generators - co-gen plants	(Seasonal) Arbitrage	Security of supply (N + 1)	Strategic reserve (beyond DHN boundaries)
Optimisation of RE output	Time shifting for Industrial process optimization	Energy autarky	Surface space conservation	Public image	Ecological value
Pevent damage geothermal doublet, reducing maintenance costs	Other energy sources (solar thermal) become interesting option due to storage	Future upscaling of geothermal energy, storage is needed			

HEAT STORAGE SERVICES/ACTIVITIES/VALUE PROPOSITION

GEMRANY: Bochum demosite

Reduced peak generation / peak shaving	DHN investment deferral	Conventional generation replacement	Time-shifting for curtailment avoidance of sustainable heat and waste heat	Support thermal ramping	Reduce distribution grid congestion electricity grid (with heat pump)
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=Future

=Current

HEAT STORAGE SERVICES/ACTIVITIES/VALUE PROPOSITION

SWITZERLAND: Geneva demosite

Reduced peak generation / peak shaving	DHN investment deferral	Conventional generation replacement	Time-shifting for curtailment avoidance of sustainable heat and waste heat	Support thermal ramping	Reduce distribution grid congestion electricity grid (with heat pump)
Optimal performance for generators - Stabilizing demand for generators	Optimal performance for generators - co-gen plants	(Seasonal) Arbitrage	Security of supply (N + 1)	Strategic reserve (beyond DHN boundaries)	Optimisation of RE output
Time shifting for Industrial process optimization	Optimization of waste heat use	Surface space conservation	Public image	Ecological value	Mutualization of heating and cooling

=Future

=Current

HEAT STORAGE SERVICES/ACTIVITIES/VALUE PROPOSITION

FRANCE: ANNECY demosite

Reduced peak generation / peak shaving	DHN investment deferral	Conventional generation replacement	Time-shifting for curtailment avoidance of sustainable heat and waste heat	Support thermal ramping	Reduce distribution grid congestion electricity grid (with heat pump)
Optimal performance for generators - Stabilizing demand for generators	Optimal performance for generators - co-gen plants	(Seasonal) Arbitrage	Security of supply (N + 1)	Strategic reserve (beyond DHN boundaries)	Optimisation of RE output
Time shifting for Industrial process optimization	Energy autarky	Surface space conservation	Public image	Ecological value	New service
		Conversion of geothermal wellbore exchanger into heat storage	Improve performance of existing installations	Extend the life of existing installations	

BACKGROUND: ELECTRICITY GRID SERVICES FOR ENERGY STORAGE (EASE)

Generation/Bulk Services	Ancillary Services	Transmission Infrastructure Services	Distribution Infrastructure Services	Customer Energy Management Services
Arbitrage	Primary Frequency Control	Transmission Grid Upgrade Deferral	Distribution Grid Upgrade Deferral	End-user Peak Shaving
Electric Supply Capacity	Secondary Frequency Control	Contingency Grid Support	Contingency Grid Support	Time-of-use Energy Cost Management
Support to Conventional Generation	Tertiary Frequency Control	Transmission Support	Dynamic, Local Voltage Control	Particular Requirements in Power Quality
Ancillary Services RES Support	Load Following	Angular Stability	Intentional Islanding	Maximising self-production & self-consumption of electricity
Capacity Firming	Frequency Stability of Weak Grids		Reactive Power Compensation	Continuity of Energy Supply
RES Curtailment Minimization	Black Start			Limitation of Upstream Disturbances
Limitation of Upstream Perturbations	Voltage support			Compensation of the Reactive Power
Seasonnal Arbitrage	New ancillary services			EV integration
Power-to-X				

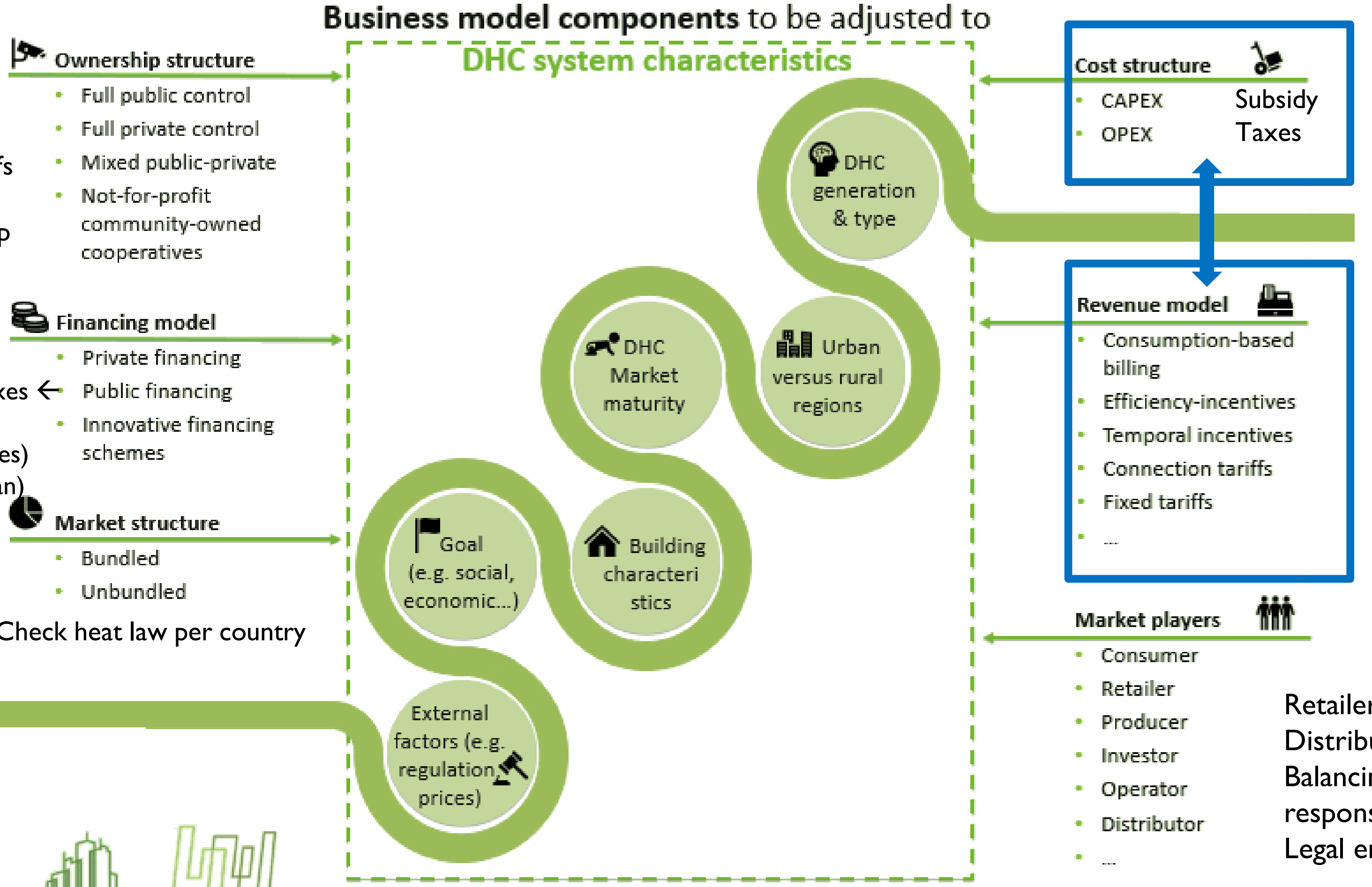
BUSINESS MODELS FOR THE DEMONSTRATION CASES
BUSINESS MODEL COMPONENTS

Multi-actors → long term contracts, negotiated tariffs

Neighbourhood ownership structure

Public financing: subsidy + taxes ←

Balance financing (loans, shares)
Project financing (interest loan)



Extra component:
Risk perception

Retailer = trader = energy company
Distribution System Operator (DSO) (regional)
Balancing responsible party/program responsibility (who is responsible for balancing network)
Legal entities/persons

UTES BUSINESS MODEL CANVAS OVERVIEW

<table>
<tr>
<td rowspan="2">Key partners:

• Who are our Key Partners and suppliers in the thermal energy sector?</td>
<td>Key activities:
• What Key Activities do our Value Propositions require?
• What are the key activities in: Distribution Channels, Customer Relationships and Revenue streams?
• Which Key Activities do partners perform?</td>
<td rowspan="2">Value proposition:
• What value do we deliver to the customer in the thermal Energy sector?
• Which one of our customer's problems are we helping to solve?
• What bundles of products and services are we offering to each Customer Segment?</td>
<td>Customer relationships:
• What type of relationship does each of our customer segments expect us to establish and maintain with them?
• Which relation have we established? How are they integrated with the rest of our business model</td>
<td rowspan="2">Customer segments:

• For whom are we creating value in thermal energy sector?
• Who are our most important customers?</td>
</tr>
<tr>
<td>Key resources:
• What Key Resources do our; Value Propositions? Distribution Channels? Customer Relationships? Revenue Streams require?
• Which Key Resources are we acquiring from partners?</td>
<td>Channels:
Through which Channels do our Customer Segments want to be reached? How are we reaching them now? How are our Channels integrated? Which ones work best? Which ones are most cost-efficient?</td>
</tr>
<tr>
<td colspan="2">Cost structure:
• What are the most important costs inherent in our business model?
• Which Key Resources and key activities are most expensive?</td>
<td colspan="3">Revenue streams:
• For what value are our customers really willing to pay?
• For what do they currently pay?
• How are they currently paying?
• How would they prefer to pay?
• How much does each Revenue Stream contribute to overall revenues?</td>
</tr>
</table>

COUNTRY PERSPECTIVES

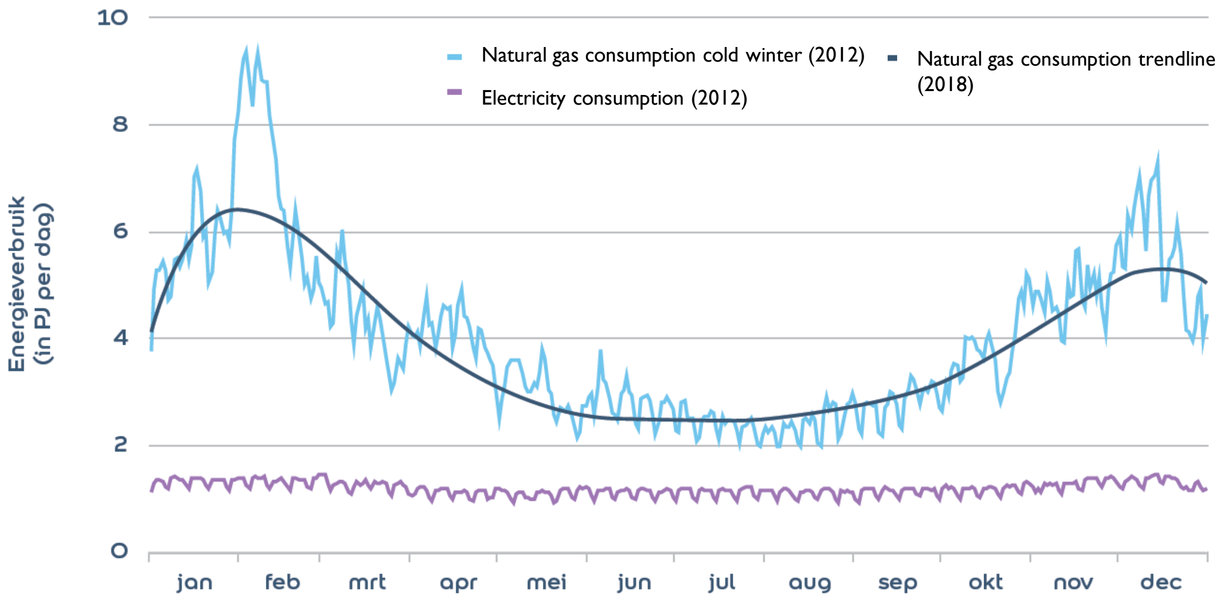
NETHERLANDS

MARKET OVERVIEW NETHERLANDS

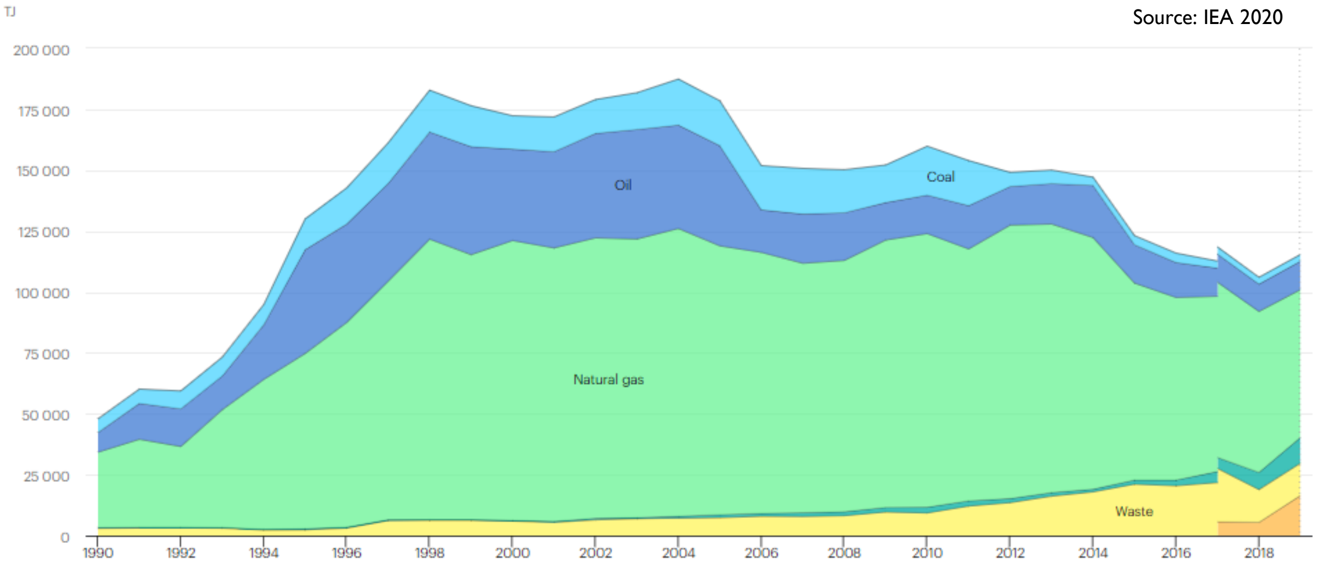
There are several properties of the Netherlands' energy system en trends that set important boundary conditions for the market potential for HT-UTES systems:

- Currently strong seasonal profile for heat demand (see upper figure)
- Current heat supply dominated by natural gas (lower figure)
- Trend: phasing out gas from Groningen area with impact on dominant heating source for longer term
- High density of heating needs (urban areas / district heating)
- Good knowledge position on subsurface
- Experience with shallow geothermal heat & cold storage (WKO) and large national storage potential
- Longer track record on high temperature ATES (see link)
- First insights in technical storage potential for ATES and HT-ATES
- High industry presence, also near dense urban areas. This brings an opportunity for waste heat applications in heat grids
- Eperience with geothermal and solar thermal heat sourcing of district heating networks; further expansion starts unfolding.

Source: EBN, 2020 www.energieinnederland.nl



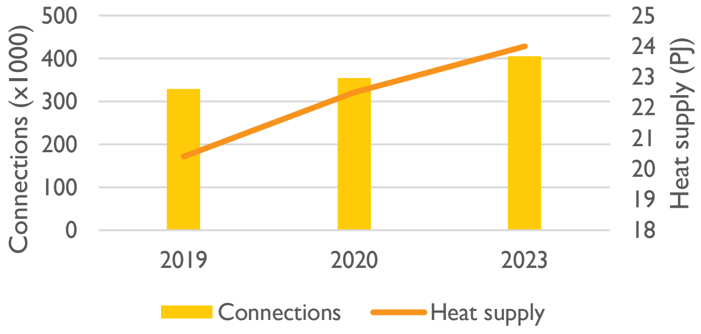
Source: IEA 2020



DEMAND AND INFRASTRUCTURE: RESIDENTIAL AREAS AND HEATING GRIDS

District heating grids (large and small) supplied 22.8 PJ of heat in 2019, this is 4% of the total heat demand of the built environment.

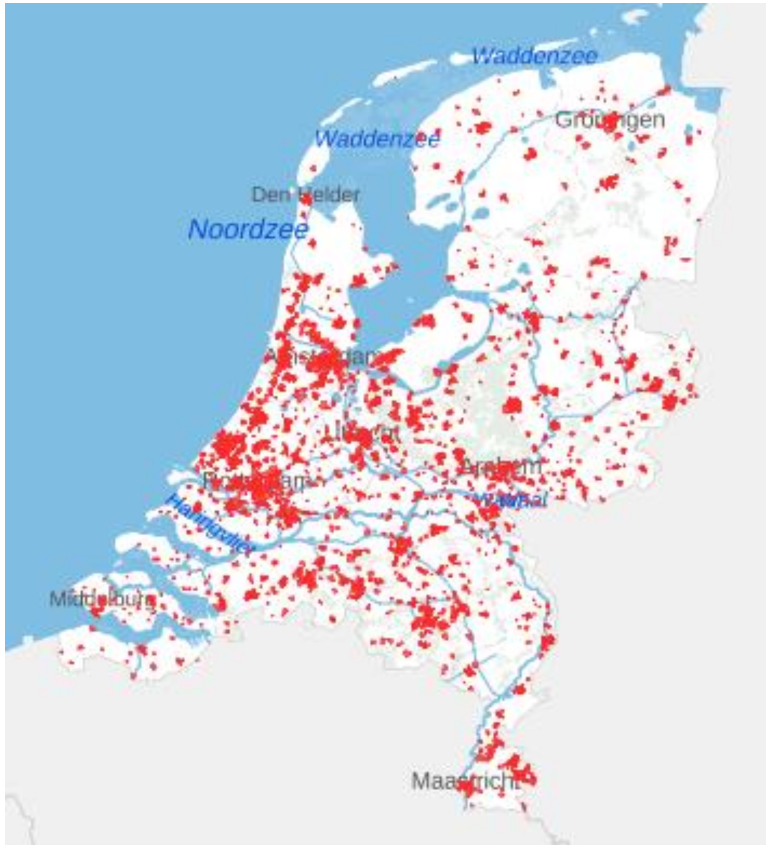
Projections for growth in heat supply and amount of connections to the large district heating grids:



Residential areas (figure left) show densely populated residential areas where heat grids might have potential to develop.

Source: Warmtemonitor (2019)

District heating networks in the Netherlands (2019)
www.warmteatlas.nl



Residential areas
www.warmteatlas.nl

SUPPLY: WASTE HEAT AND GEOTHERMAL HEAT POTENTIAL

Figure left: the supply of waste heat from industries in TJ.

- Waste heat potential in district heating networks (residential and agricultural) is estimated to be 50 PJ in 2050.

The figure on the right shows the geothermal heat potential of low- and high temperature geothermal energy.

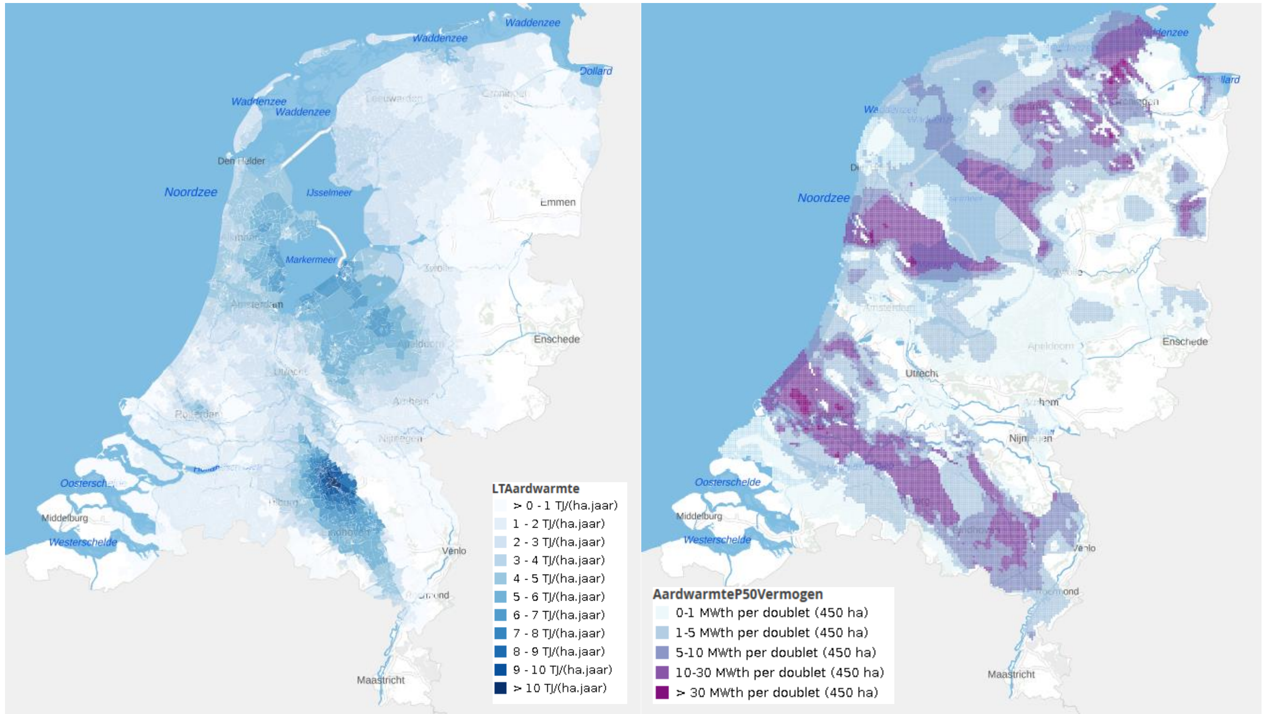
- For 2030 the geothermal heat potential in urban, agriculture and industrial heating networks is estimated to be ~54 PJ.
- In 2050, the total geothermal potential in all sectors is estimated to be 210 PJ.

Source: Berenschot (2018). Het 'warmtescenario': Beelden van een op warmte gerichte energievoorziening in 2030 en 2050

TITEL

Industry waste heat map (in TJ)

source: : Pico Geodan.



National potential for low- and high temperature geothermal energy

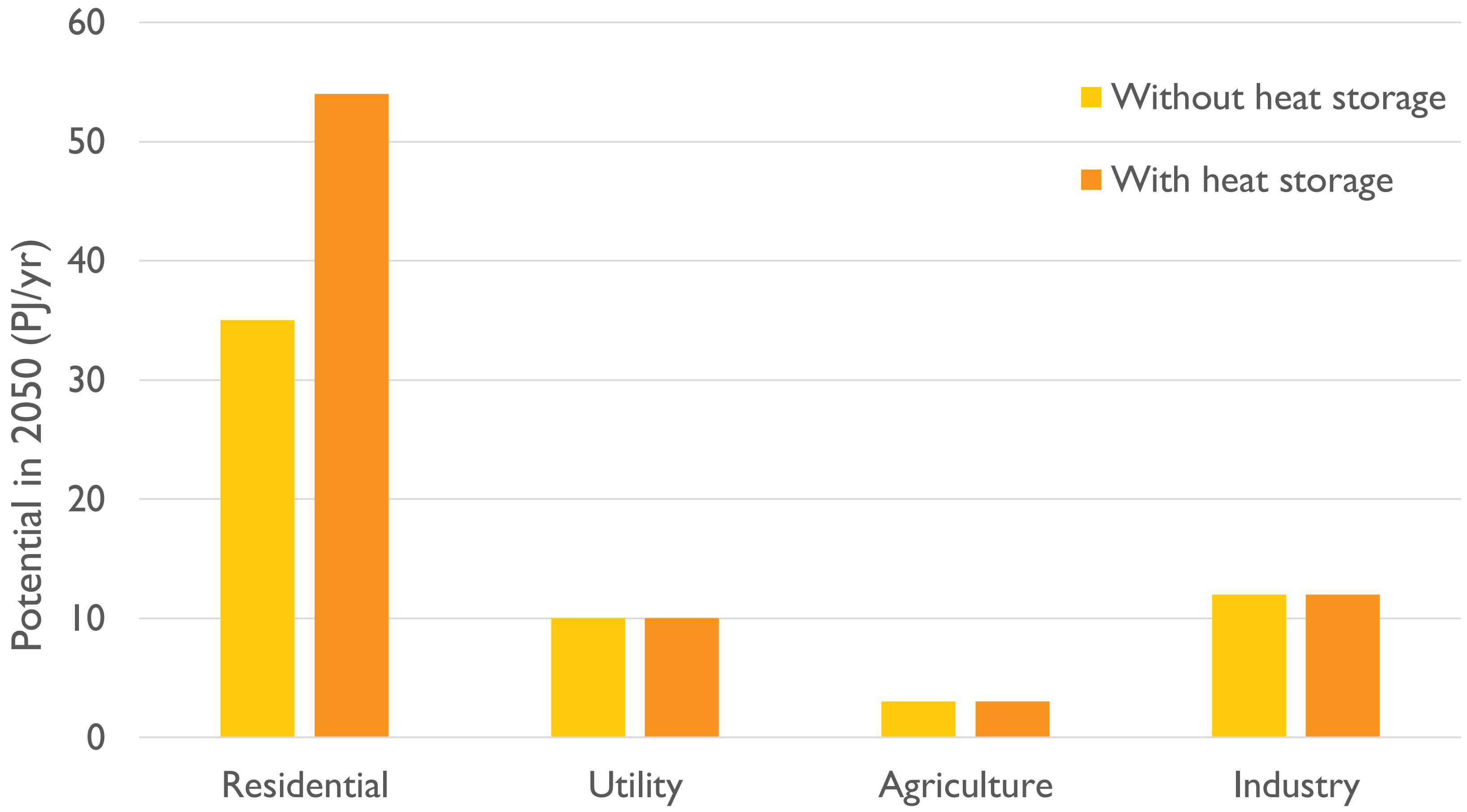
Left: Low temperature (25-45°C) geothermal heat capacity

Right: High temp (45-145°C) geothermal heat capacity (P50)

https://rvo.b3p.nl/viewer/app/Warmteatlas/v2

SUPPLY: SOLAR THERMAL HEAT POTENTIAL

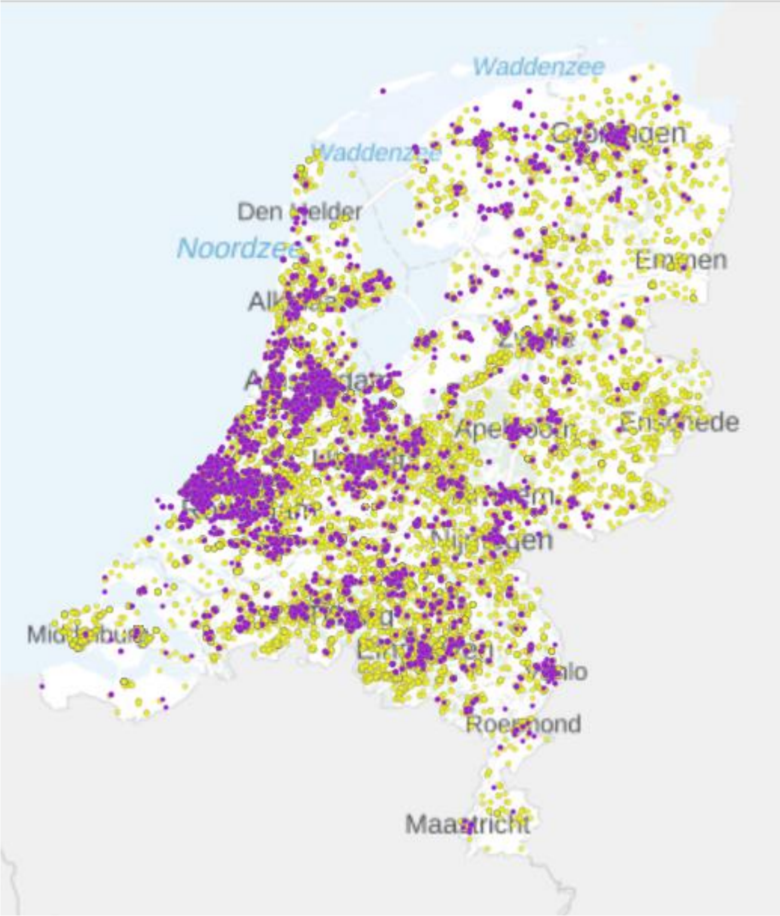
The graph shows annual solar thermal heat potential for the year 2050, with and without storage. With seasonal storage the total potential for solar thermal energy is 80 PJ in 2050 (this is ~10% of the estimated total heat demand). Storage is expected to enable higher penetration levels of solar heat in the residential sector. Storage potentially enables19 PJ of solar heat.



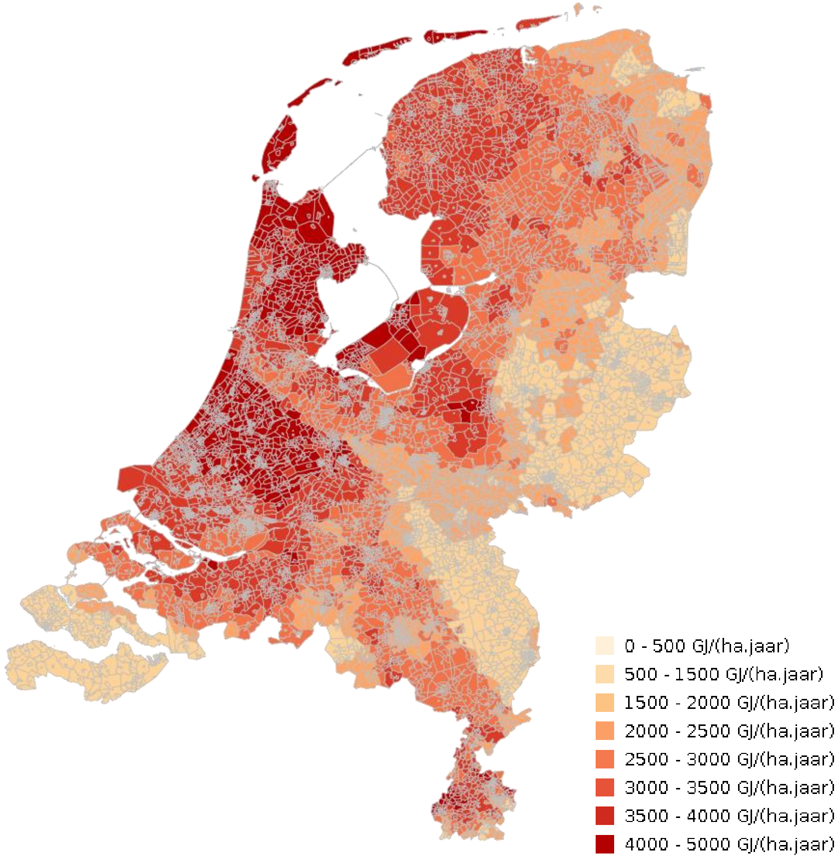
Source: https://hollandsolar.nl/u/files/tno-2020-r10975.pdf

EXPERIENCE WITH SHALLOW GEOTHERMAL HEAT & COLD STORAGE

- The Netherlands has experience with (low temperature) open heat and cold storage (ATES) systems since the end of the 1980s.
- About 85% of all ATES sytems in the world are installed in the Netherlands (~2500 ATES systems, see figure left). In figure right: the estimated potential of ATES systems in the Netherlands (0-250m depth).
- Well established supply and value chain exists for heat & cold storage and knowledge on the subsurface



Current heat & cold storage installations: purple shows open systems (ATES) and yellow shows closed systems (BTES). Source: wkotool.nl/



Heat and cold storage potential in open heat and cold storage systems (ATES) in the Netherlands (in GJ/(ha.jaar) up to a depth of 250 m. Source: nationaalgeoregister.nl

POTENTIAL FOR AQUIFER THERMAL ENERGY STORAGE

The Dutch subsurface shows areas of high interest and opportunity for HT-ATES. Within the HEATSTORE and WINDOW research programme, the potential for HT-ATES has been assessed and translated into a potential map (see figure). This map shows areas in the Netherlands that range from 'favourable' to areas with 'one or more barriers'. These barriers indicate that from a subsurface perspective challenges have to be overcome to realise a HT-ATES project.

In total 9 criteria have been used, 8 are shown in the table below. The potential has not yet been translated into a national or local energy potential (e.g. GJ/ha/year) as has been done for low temperature ATES (as shown on the previous page).

- Criteria used for potential maps:

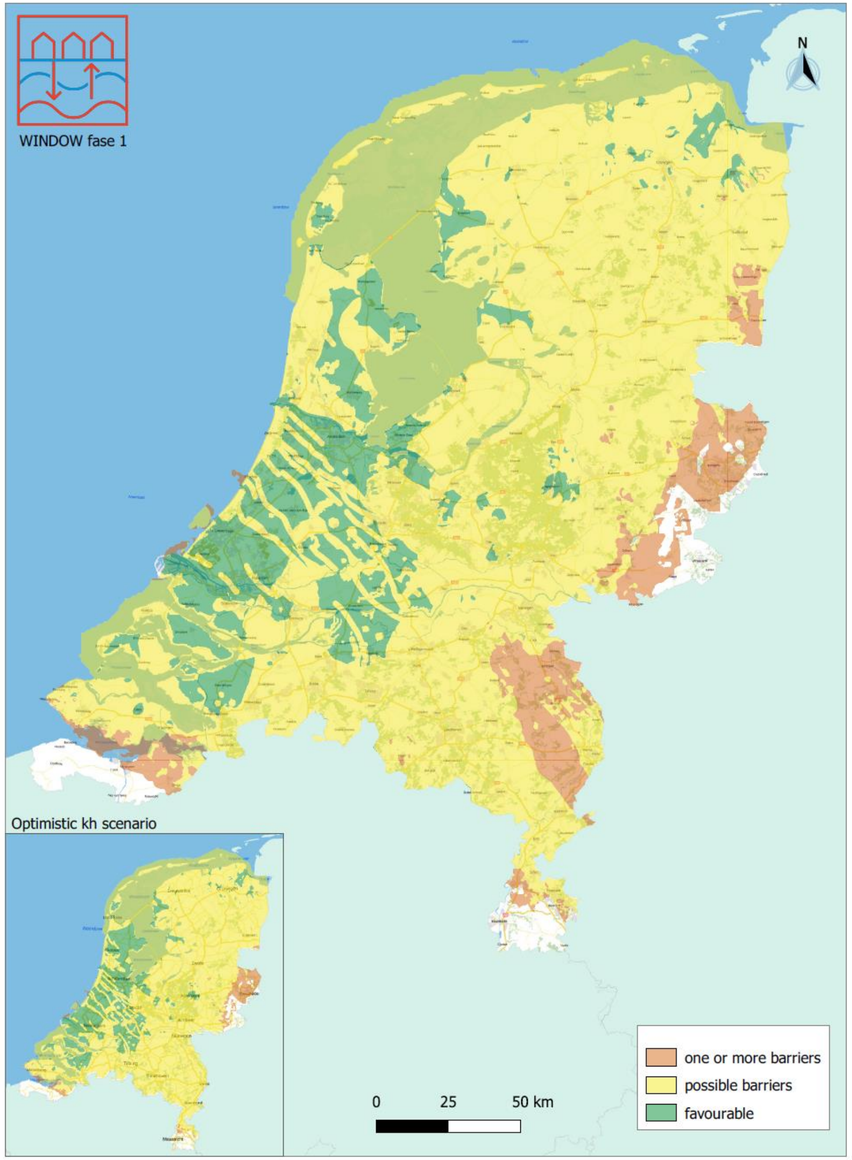
	Criterion	Barrier	Possible barrier	Favourable
1	Depth water bearing sand layer		<50, >500 mbgs**	50-500 mbgs**
2	Thickness sand layer	< 10m	10-15 m	> 15 m
3	Horizontal hydraulic conductivity – kh value	< 5 meter/day		≥ 5 meter/day
4	Presence of confining cap layer (clay)		Risk absence cap layer	Certainty about presence
5	Faults		< 1 km	> 1 km
6	Groundwater flow velocity		> 20-30 meter/year	< 20-30 meter/year
7	Chloride concentration		Fresh and brackish water (saline/fresh water interface)	Saline water
8	Protected areas		Inside protected area zone	Outside protected area zone

* Note that lithology is not included
** Meter below ground surface

Detailed information is provided in: Dinkelman et al. (2020). Geological model, shallow subsurface temperature model and potential maps for HT-ATES in the Netherlands. WINDOW research programme.

TITEL

Potential map HT-ATES Dutch subsurface



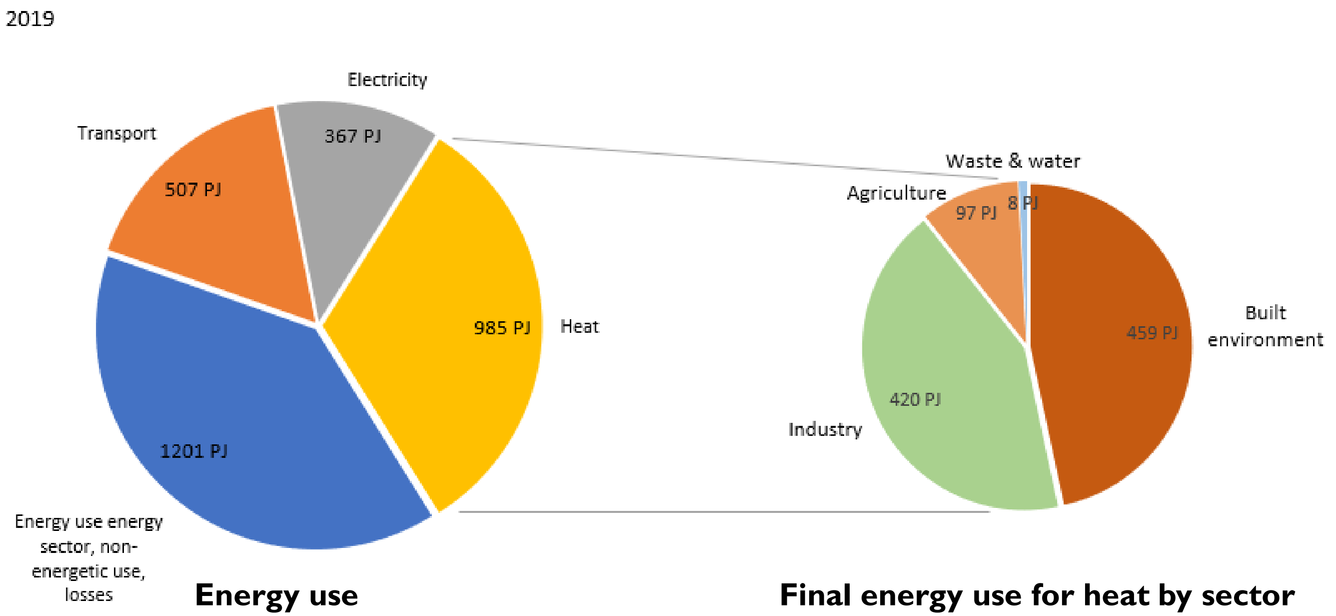
HT-ATES potential for the Netherlands

source: https://www.warmingup.info/window-potentieel-kaarten

ENERGY DEMAND AND HEATING GRIDS NETHERLANDS

In 2019 the heat demand in the Netherlands is 985 PJ, of which 459 PJ in the built environment. Currently, 22.8 PJ (2% of total heat demand) is delivered by heat networks. Large heating grids (>0.15 PJ/year) represent about 20.4 PJ per year and supply to 329 thousand consumers. 6 large heat suppliers cover most of the demand. Smaller heat grids (<0.15 PJ) supply 2.4 PJ and fulfil the demand of 64 thousand consumers. Growth towards 24 PJ in large heating networks is expected in 2023. A total of 450 thousand dwellings are currently estimated to be connected to large district heating networks.

The heat demand has a strong seasonal signal and is currently dominated by natural gas as energy source. Although the share is in decline. Renewable heat sources increased their share from 17% in 2017 to 30% in 2019. Many of the smaller heat networks make use of heat & cold storage and heat pumps.



Energy use **Final energy use for heat by sector**

TNO, CBS. Warmtemonitor 2019

www.warmteatlas.nl

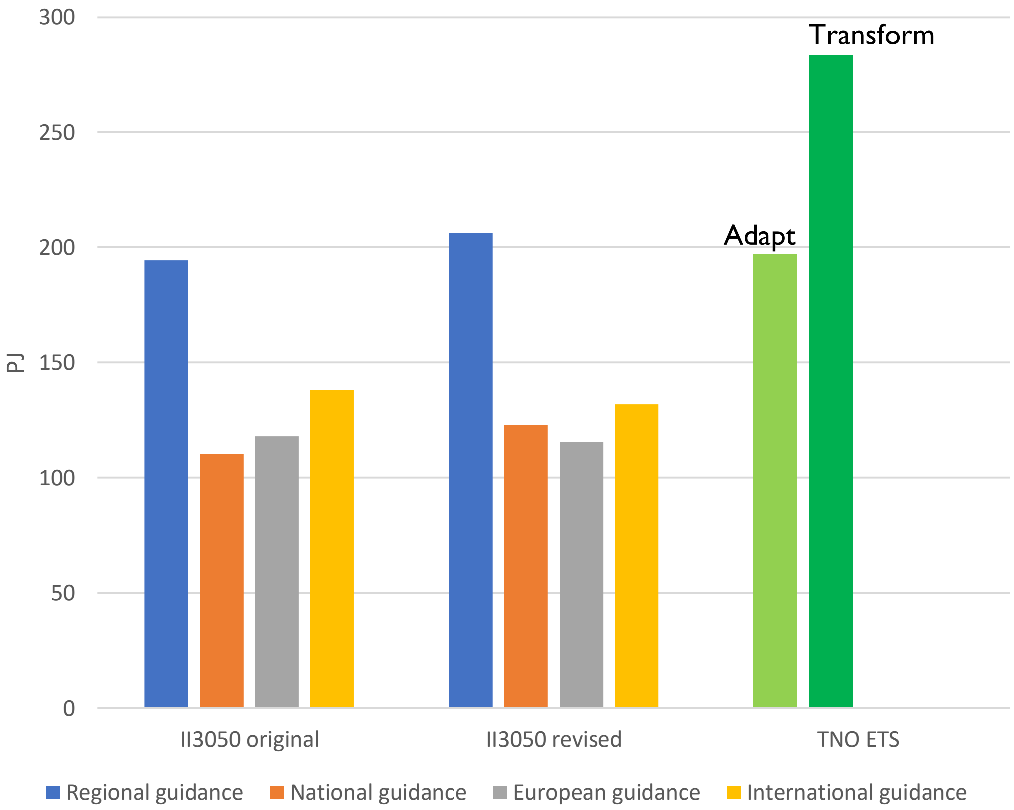
District heating networks in the Netherlands (2019)

HEAT DEMAND FUTURE IN HEAT GRIDS Netherlands

The current 22,8 PJ of heat supplied via heat grids is expected to grow in future energy scenarios for the Netherlands. In the national Climate Agreement a target of 1,25 million households are connected to heating grids in the year 2030. Recent scenario results for the year 2050 are presented in the graph. The results indicate a wide range, but all assume a growth towards 110 -283 PJ/yr via heat grids.

Model	Scenario	Key elements future energy scenario
II3050 - ETM model (Berenschot/ Kalavasta)	National*	National government steers, Lower growth in heating grids and very large capacity of solar and hear with electrifcation of demand sectors.
	Regional *	Local communities steer. Electrification and geothermal fed heating grids dominate. High growth of solar and wind capacity. Highest growth for heating grids of all scenarios.
	European*	CO_2 pricing at EU level steers. Typically higher import levels and emphasis on green gases.
	International*	International market dominates the energy environment. This leads to higher import of hydrogen in the future. In comparison the lowest national capacities for renewable electricity. Heating grids represent smaller share in energy consumption and are fed by waste heat from industry and waste-to-energy facilities.
Climate-neutral scenarios– OPERA model (TNO-ETS)	Adapt **	CO_2 emissions fall by 95%. In this scenario, the Dutch choose to maintain employment and comfort. Sustainability is less important to them.
	Transform **	Netherlands leads the way when it comes to climate and sustainability. The demand for energy from mobility, industry and the agricultural sector will decline. CO_2 emissions also fall by 95%, no support for CO_2 capture and storage and the importation of biomass is limited.

Energy supplied through heat grids



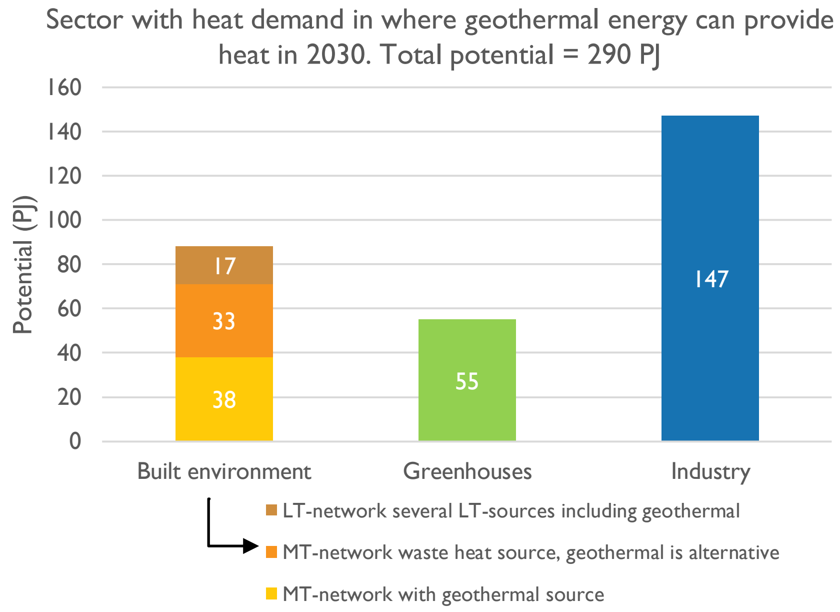
EBN, TNO (2020). OPVIS 2.0 – visie ondergrondse opslag. Concept results.

* https://www.rijksoverheid.nl/documenten/kamerstukken/2020/04/15/kamerbrief-klimaatneutrale-energiescenarios-2050

** https://www.tno.nl/en/focus-areas/energy-transition/roadmaps/towards-a-reliable-affordable-and-fair-energy-system/scenarios-for-a-climate-neutral-energy-system/

HEAT DEMAND FUTURE IN HEAT GRIDS NETHERLANDS

From: Schellekens et al. (2020). WARM project.



On a national level market potential, estimates have not yet been established. HT-ATES and many other UTES technologies have not yet been incorporated on a adequate level in energy system integration models. This shortcoming renders that market models and future scenarios neglect the potential for large scale underground heat storage. Up to now, only basic and ex post-analysis modelling results have been used to estimate the national (market) potential from energy system perspective. Nevertheless, with some approximations it is possible to assess the market potential.

A rough number could be presented when looking at a recent outlook for geothermal heat in the Netherlands (graph). This is especially relevant as the combination of HT-ATES with geothermal systems looks promising from technical and economical perspective. On the right a 'back of the envelope' calculation is performed to see how much HT-ATES projects could be required if a geothermal potential of 143 PJ would be reached in 2050. This would sum up to 470 HT-ATES projects. Obviously this is a ballpark estimate but gives some indication of how much HT-ATES projects could be expected and needed in a very optimistic scenario.

For comparison, in another study by EBN/TNO[1] in 2018 the storage need was roughly established at 17-34 PJ. With the same assumptions this would entail 314-944 HT-ATES projects.

Again, these insights should be only seen as a first order estimate to understand order of magnitude. Further scrutiny with proper implementation of UTES technologies in national modelling exercises is required to decrease the uncertainty of this estimate and better understand its role in the energy transition.

Given the future scenarios discussed earlier it is highly likely that heat storage will play an growing role. Certainly considering that the heat supply via heat grids will likely quadruple and where (low marginal cost) renewable heat sources and waste heat have an important role. A prudent estimate of tens to hundreds of HT-ATES projects is not unlikely for the coming decades in the Netherlands.

Back of the envelope calculation for HT-ATES potential in combination with geothermal energy

- Key assumption: Approx. 9-15% of HT-ATES heat from geothermal heat[2,3,4]
- Geothermal potential in build environment & greenhouses (lower temperatures) = 143 PJ
  - 143 PJ * 8-12% = 11-17 PJ from HT-ATES
  - 10-15 GWh production per HT-ATES project = ~200-470 HT-ATES projects in combination with geothermal energy
  - Heat grids with other baseload sources or solar heat will add extra potential for HT-ATES.

Sources:
1. TNO/EBN, 2018, Ondergrondse Opslag in Nederland - Technische Verkenning
2. Dinkelman, 2019. Optimization of technical and economic efficiency of HT-ATES combined with geothermal energy (thesis).
3. De Jonge, 2017. Hoge temperatuuropslag Agriport in Middenmeer. Effectenstudie open bodemenergiesysteem.
4. Results from WINDOW project (not published yet).

ECONOMICAL MARKET POTENTIAL AND BOUNDARY CONDITIONS NETHERLANDS

Clear boundary conditions for an economical market potential are:

- Low marginal cost of heat production and sufficient roundtrip efficiency of heat storage
- Seasonal profile of the heat demand
- Suitable subsurface conditions
- Temperature level of heat demand and supply within range of UTES technology
- Suitable scale: a guideline of achieving 5-10 MW and 2500 full load hours per year

As shown in the previous sections the prospective sectors and markets for storage are:

Horticulture:

- Geothermal energy with HT-ATES
- Solar thermal energy plus HT-ATES
- Waste heat energy plus HT-ATES

Built environment:

- Heat grids with low marginal cost heat as baseload: solar, geothermal, aquathermal, heat pumps at times of low power prices, waste heat (industry, and maybe waste heat from future hydrogen production)
- Unsustainable peak demand for grids partly covered by HT-ATES (this will be also determined by the emission price of CO_2)

Industry:

- For higher temperature levels typically encountered in industry more research is needed into very high injection temperatures. Competing (surface) heat storage technologies are also entering pilot and demonstration phase here.

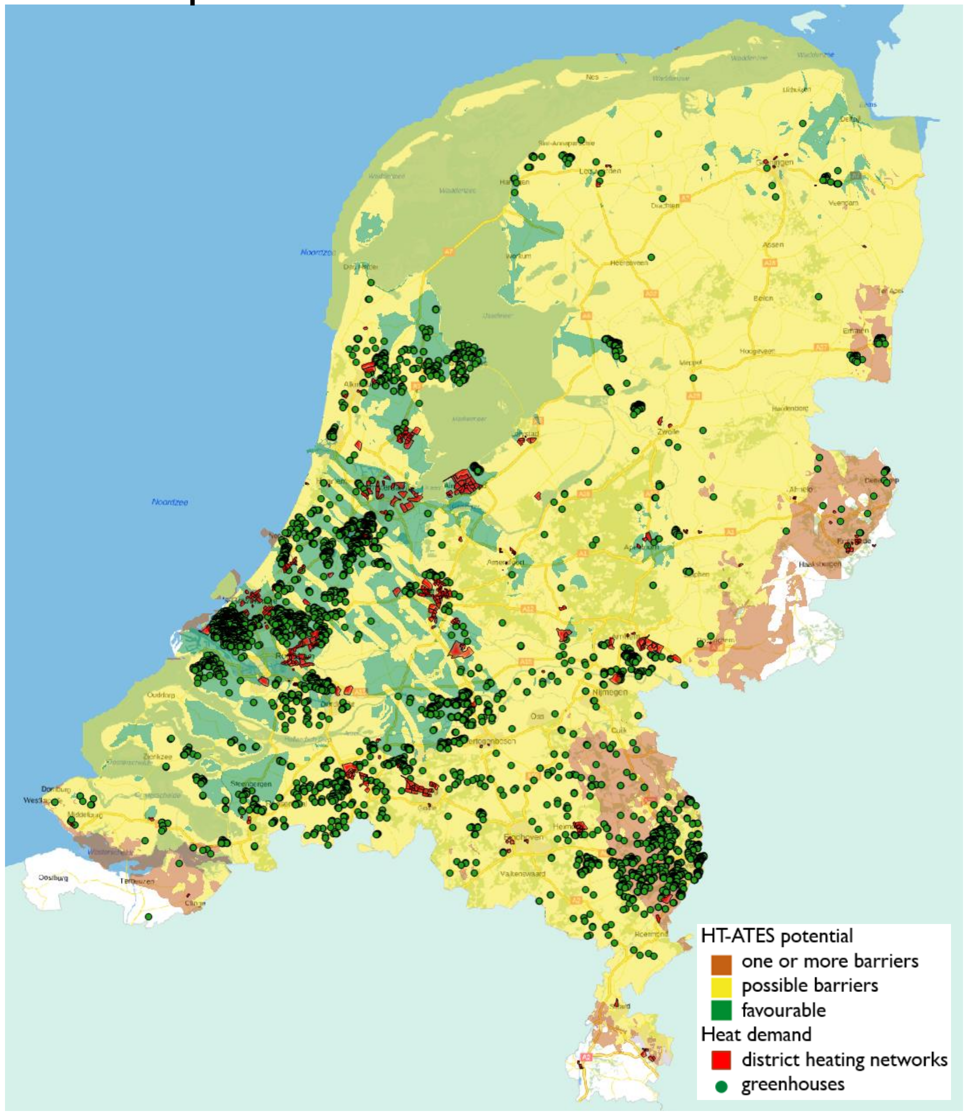
Incentives and insurances

It is currently not a sound business case to invest in HT-ATES with the current market conditions. Incentives for storage are not established. Not through direct subsidies or other incentives for storage, but through subsidies of energy supply (solar, geothermal etc). Investment subsidy for HT-ATES could help to minimize investment risks in the deployment phase for HT-ATES development. Comparable to an investment insurance for geothermal projects. For geothermal projects there is a public insurance/ guarantee scheme that covers the risk of dry wells. Operators can use this scheme to insure themselves against a lower than expected capacity (P90).

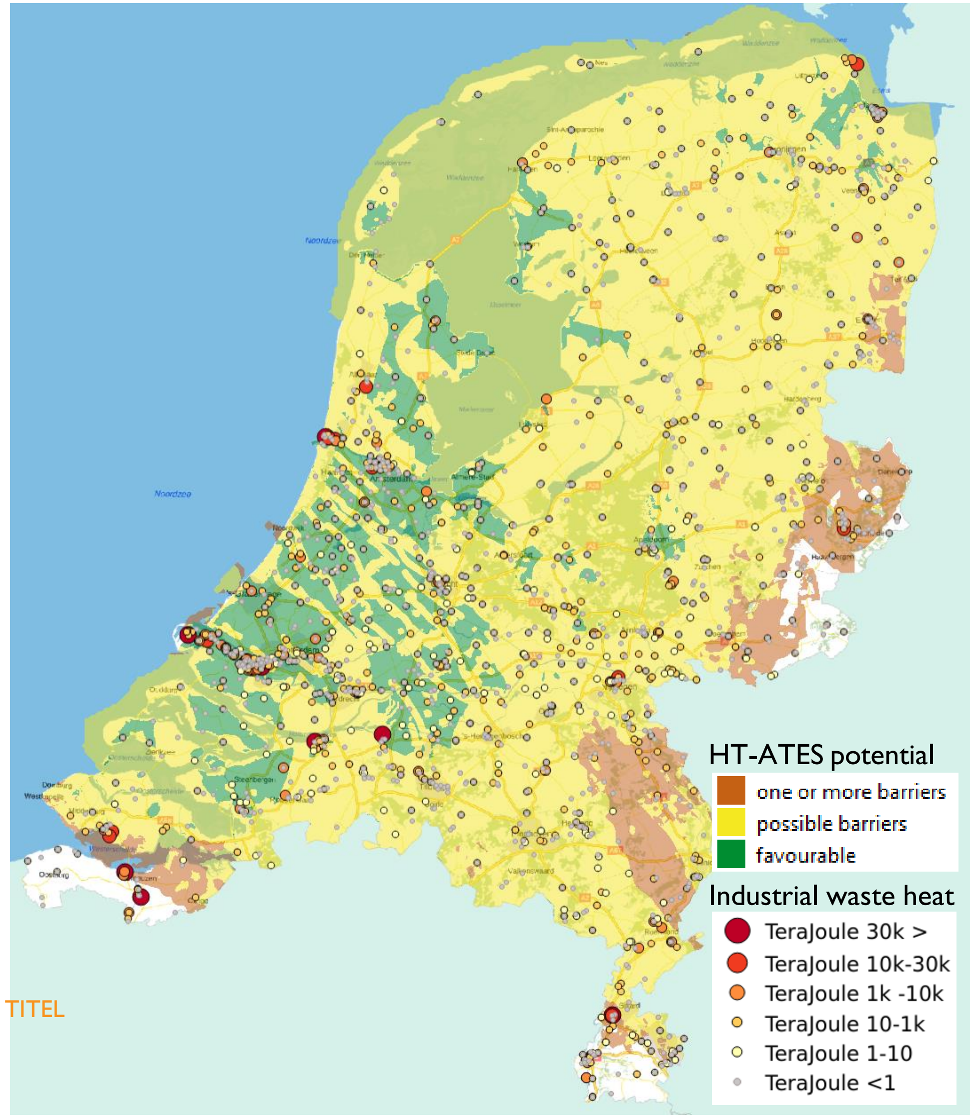
Competition

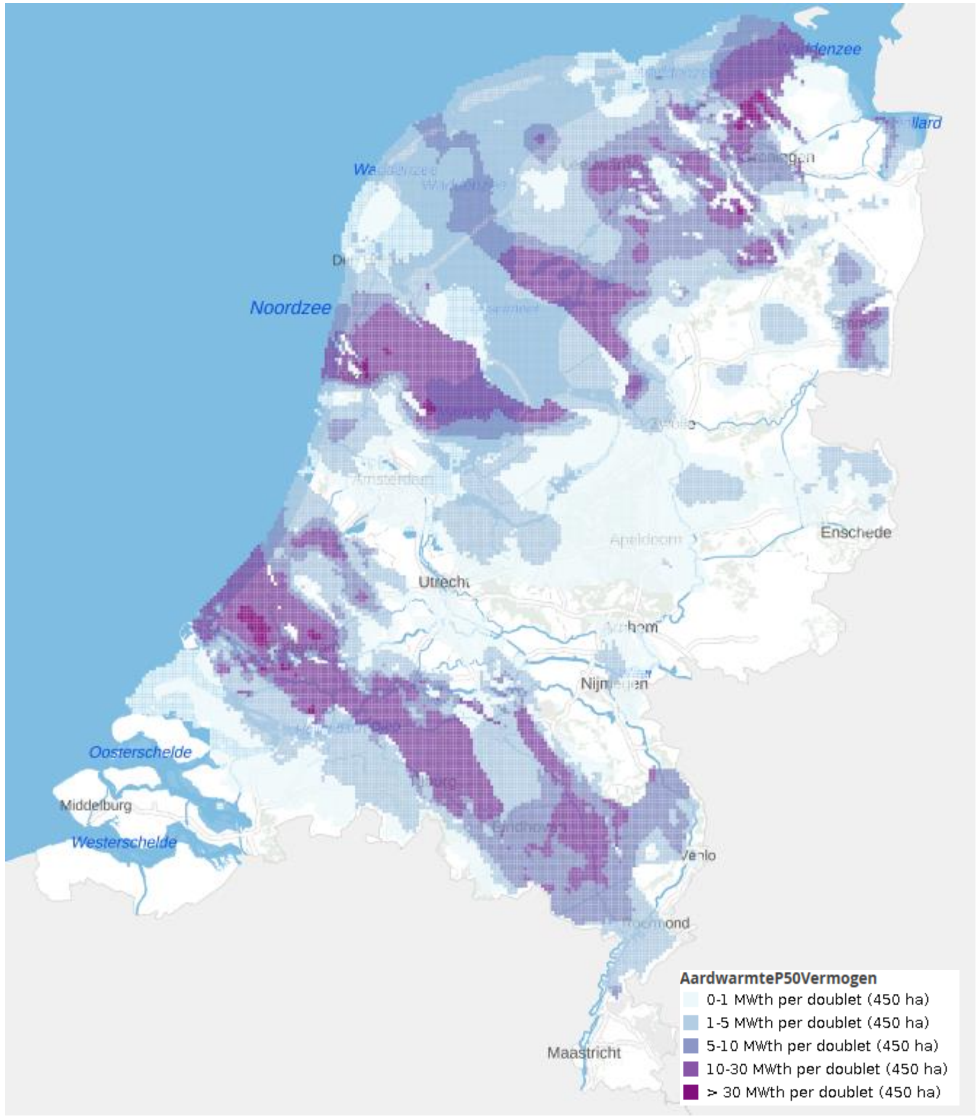
It is very important to keep track of competing alternatives for heat storage (PIT, Tank/Ecovat and chemical storage/salt) and for heat supply (electrification) options. Local situations often determines to very high extent the possibilities and barriers for HT-ATES systems. An assessment on national, regional and local level is needed to understand the robustness of HT-ATES potential in the Netherlands.

HT-ATES potential and heat demand



HT-ATES POTENTIAL AND HEAT SOURCES





HEAT STORAGE SERVICES/ACTIVITIES/VALUE PROPOSITION
Example Netherlands demo
Value proposition for HT-ATES ECW

Reduced peak generation / peak shaving	DHN investment deferral	Conventional generation replacement	Biomass generation replacement	Time-shifting for curtailment avoidance of sustainable heat and waste heat	Support thermal ramping
Reduce distribution grid congestion electricity grid (with heat pump)	Optimal performance for generators - Stabilizing demand for generators	Optimal performance for generators - co-gen plants	(Seasonal) Arbitrage	Security of supply (N + I)	Strategic reserve (beyond DHN boundaries)
Optimisation of RE output	Time shifting for Industrial process optimization	Energy autarky	Surface space conservation	Public image	Ecological value
Pevent damage geothermal doublet, reducing maintenance costs	Other energy sources (solar thermal) become interesting option due to storage	Future upscaling of geothermal energy, storage is needed			

KEY PARTNERS (NL)

- Who are the Key Partners and suppliers?
  - ECW is the supplier of heat and the local grid operator of heat (geothermal, biomass, CHP, gasboilers)
  - Key partner: the ATES will be connected to the heating installation of heat consumer horticulture entrepreneur Helderman
  - Hired/supplier partners: banks (financial partners), IF Technology and TNO (research/knowledge partners within HEATSTORE), drilling company Haitjema, other contractors for surface equipment and installation.
  - Together, all heat customers at Agriport A7 are also shareholders in ECW and also share the investment risk of the HT-ATES.
  - Helderman is envisoned to consume all heat stored in the HT-ATES. Under envisioned normal operation the ATES will allow for additional winter production capacity improving security of supply and pushing higher cost heat our of the merit order. When the HT-ATES cannot produce at the required temperature or is out of service, heat from the grid (geothermal and biomass installation) will be supplied. This way the technical and financial risk is manageable. For Helderman alone, this risk would have been too high.

KEY ACTIVITIES (NL)

- What Key Activities do our Value Propositions require?
  - Key activities for ECW: supply of (low-cost) heat and providing heat security of supply for customer.
  - ECW is responsible for the development, realisation and maintenance of the HT-ATES and integration into the heat grid. Charging the ATES is responsibility of ECW
- Which Key Activities do partners perform?
  - Key activity for farmer/greenhouse owner Helderman: buy and use heat from HT-ATES. Dispatch production (heat consumption) from ATES lies with Helderman.

KEY RESOURCES (NL)

- What Key Resources do our;Value Propositions? Distribution Channels? Customer Relationships? Revenue Streams require?
  - Key resource that the HT-ATES requires is the geothermal doublet for low marginal cost of heat.
  - Furthermore: monitoring equipment, staff, knowledge on operating and maintaining geothermal systems.
- Which Key Resources are we acquiring from partners?
  - Key partner
    - Farmer/greenhouse owner: space/location available
  - Hired partners:
    - Banks: financial resources, loans etc.
    - Research partners: support in engineering, procurement and construction, knowledge on subsurface monitoring and performance optimization.
    - Drilling company: drilling equipment and knowledge
    - Surface contractors: casings, materials etc.

VALUE PROPOSITION (NL)

- **Reduced peak generation/peak shaving**: the bathtub model applies here, the peak generation for heat will partly be done by the HT-ATES.
- **DHN investment deferral**: the HT-ATES has been placed on the most favourable place in the heat network in case upscaling is needed. For now they are working on the adaptations to the network in case the geothermal doublets run on full capacity and need to fill the HTO, as this might become a problem.
- **Conventional generation replacement**: CHP on gas will eventually be replaced. But CO2 demand is an important factor to factor in the future equation. Other sources become interesting due to storage: for example, storage is needed for solar thermal energy.
- **Biomass generation replacement**: for the future HT-ATES can help to phase out biomass generation.
- **Time-shifting for curtailment avoidance of sustainable heat and waste heat**: shift summer production of the geothermal heat to winter. This avoids curtailment of the geothermal doublets.
- Support thermal ramping: not, as the process is leading.
- Reduce distribution grid congestion electricity grid: no. not at this moment
- **Optimal performance for generators – stabilizing demand for generators**: due to a base load for the ESP and reducing fluctuations in cooling/temperatures, this will help improving well integrity of the geothermal well and of the system as a whole. Thermal fluctuations in geothermal doublet are a challenge for long term sustainable operation and performance. Prevent damage geothermal doublet, reducing maintenance costs: one of the most important reasons for HT-ATES.
- Optimal performance for generators – co-gen plants: no.

VALUE PROPOSITION (NL)

- **(Seasonal) arbitrage**: ATES will benefit from the difference in heat costs between summer and winter.
- **Security of supply**: more wells will increase the reliability of the whole energy system. Especially the preferential location of the ATES. It is located near the end of the backbone and as such this is a place prone for challenging heat delivery in periods of high demand. The ATES can alleviate this challenge. However, the decreasing temperature in the HT-ATES near the end of the winter season makes the heat of lower quality an more difficult to dispatch and consume.
- Strategic reserve: as the volume of the HT-ATES is relatively small, it is not applicable.
- **Optimisation of RE output**: geothermal and biomass heat can fill the HT-ATES. Solar and wind will only be used for electricity generation, not for heat. Imbalance in the electricity net using as heat will probably take place in only small amounts. Investments to make this more efficient will not be cost-effective.
- Time-shifting for industrial process optimization: not, as the process is leading. It will take 3 years of monitoring to get the efficiency of the HT-ATES.
- **Energy autarky**: HT-ATES is part of the geopolitical plan to become less reliable on gas. More electrification is then needed.
- Surface space conservation: the current drilling technique is vertical, the wells are spaced a 250 m from each other, and the location at Agriport is suitable for this. A controlled driling is needed to decrease this footprint, but this will increase the CAPEX.
- **Public image**: becoming green plays a role.
- Ecolocial value: no. Operation and monitoring of the system will show whether there are negative thermal or scaling effects.
- **Future upscaling of geothermal energy**: storage is needed when installing more geothermal baseload, otherwise the peak load cannot be sustainably delivered.

VALUE PROPOSITION (NL)

- What value do we deliver to the customer in the thermal Energy sector?
  - Security of (affordable) heat supply. With a continuous focus on development and optimization of de network and its assets to support a sustainable energy system.
- Which one of our customer's problems are we helping to solve?
  - No direct problems for customer, but "problems" for ECW. Namely the damage of geothermal doublet, peak shaving, replacement of conventional resources etc.
  - The most important value propositions are the income from more renewable energy dispatch and the optimal performance of the geothermal doublet by avoiding or reducing fluctuations in flow and temperatures in those systems
- What bundles of products and services are we offering to each Customer Segment?
  - Heat
- Future outlook: in the future, when heat for peak generation can be fulfilled by HT-ATES instead of CHP/gas boilers, CO_2 has to be imported to the greenhouses, which will involve extra costs.

CUSTOMER RELATIONSHIPS (NL)

- What type of relationship does each of our customer segments expect us to establish and maintain with them?
  - Supplier-customer relationship (long-term)
  - Stakeholder relationship (long-term)
- Which relation have we established? How are they integrated with the rest of our business model
  - The relationship between ECW and the farmer/greenhouse owner is supplier-customer.
    - After subsidy application and before the start of the implementation of the HT-ATES, a contract regarding the main aspects is settled (also for other customers in network). Also has been agreed on an expansion of the greenhouse so enough demand is created. The detailed contract with Helderman will be set up at the end of the realisation phase of the HT-ATES. This will include the boundary conditions for operating the ATES and also the incentives for optimally operating the ATES.
  - All other customers are also stakeholder of ECW.

CHANNELS (NL)

- Through which Channels do our Customer Segments want to be reached?
  - Direct channels: direct personal communication between ECW and farmer/greenhouse owner.

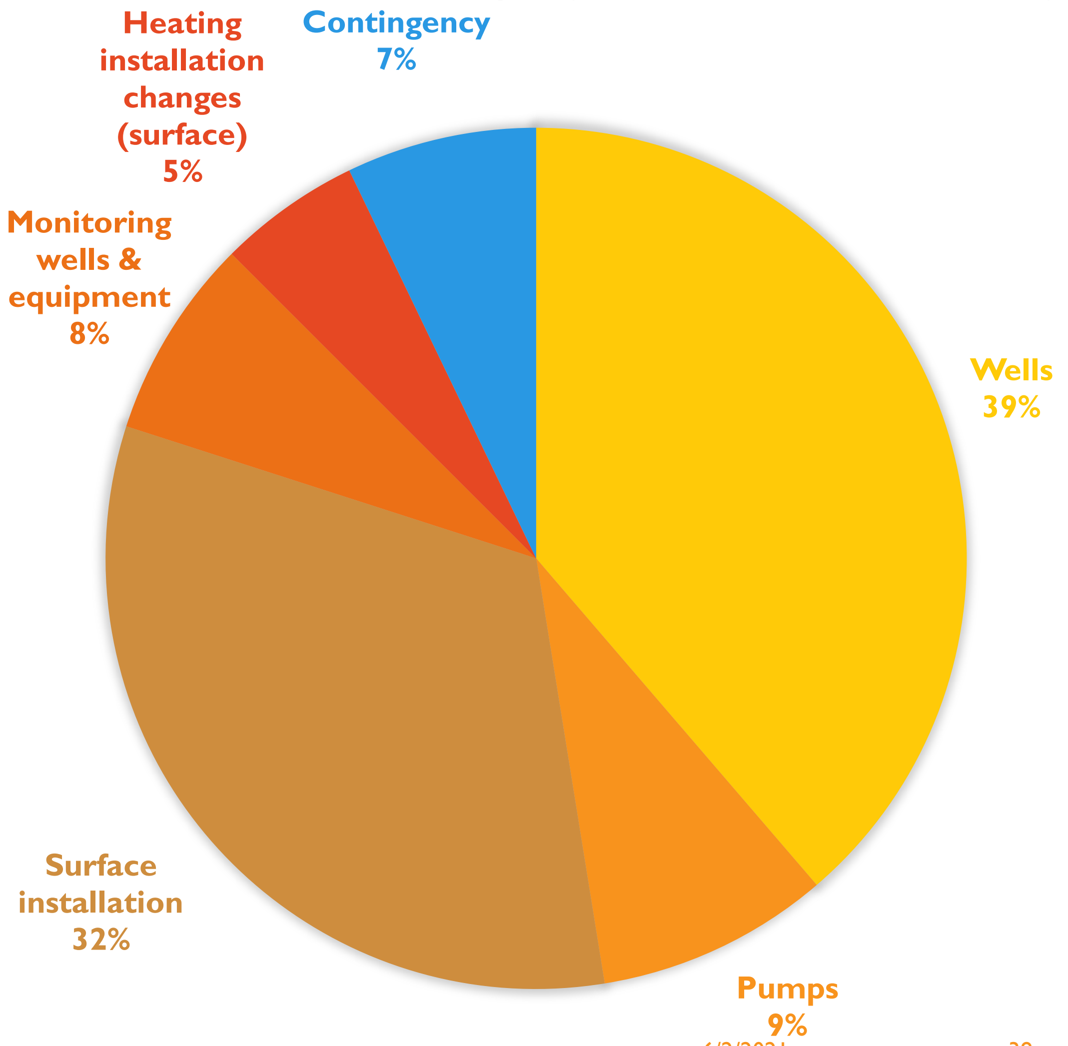
CUSTOMER SEGMENTS (NL)

- For whom are we creating value in thermal energy sector?
  - ECW mainly creates value for its own business with the HT-ATES, heat delivery/security of heat supply is a value created for the customer.
- Who are our most important customers?
  - Farmer/greenhouse owner

COST STRUCTURE (NL)

- CAPEX (3 million EUR wells and surface infrastructure to connect to network and greenhouse + 0,7 million EUR for exploration well)
- OPEX (~200.000 EUR/yr)
  - Maintenance, electricity and monitoring, including filters and ESPs (electric submersible pumps)
  - Water treatment with CO2 (dose has to be increased each year, this implies an increase of the OPEX and gas pressure)
- Which Key Resources and key activities are most expensive?
  - CAPEX (see indicative breakdown in the pie chart)
    - Drilling wells takes up a considerable part of the investments. This includes drilling and casing material (GRE). This represents ~40% of the investments.
    - Constructing the surface installation and connecting it to the heat infrastructure represents also a significant part of the investment costs.
  - OPEX
    - Replacement of pumps

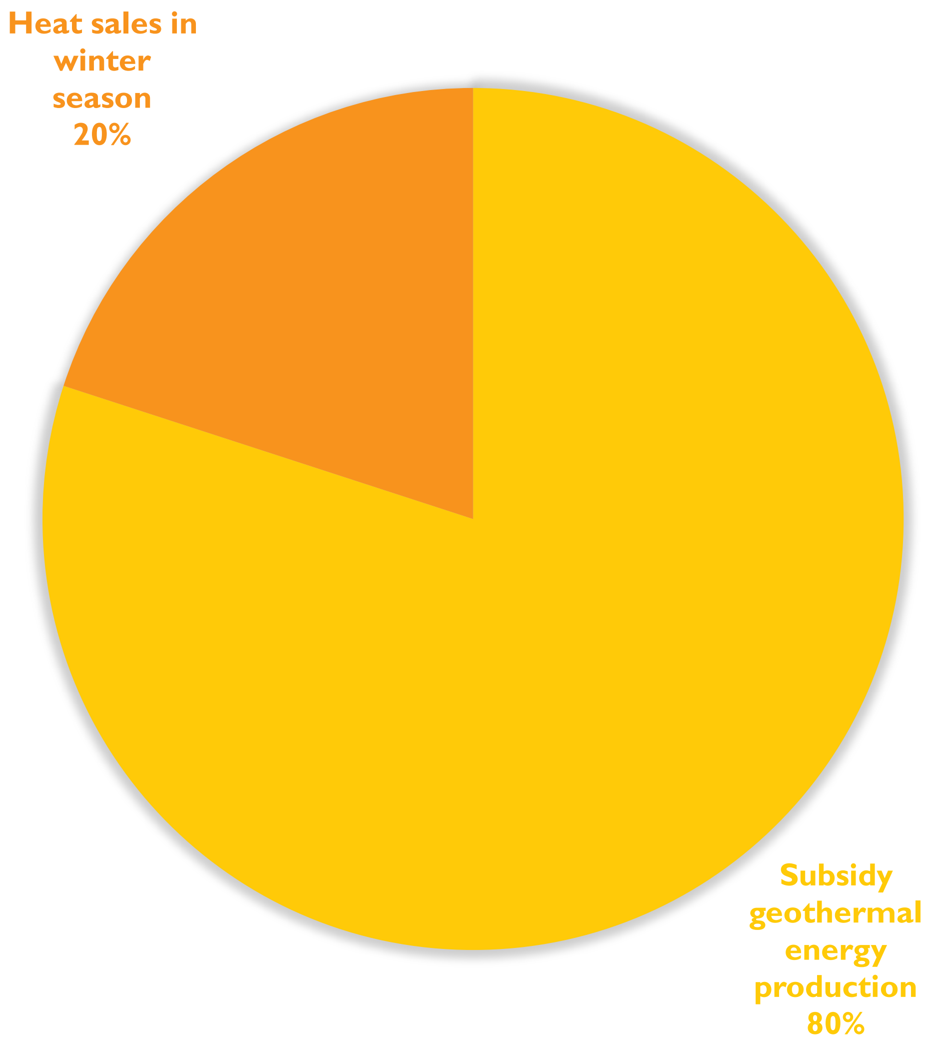
INVESTMENT HT-ATES



REVENUE STREAMS (NL)

- For what value are our customers really willing to pay?
  - Security of heat supply
  - Affordable heat
  - ECW has a variable cost fee that stimulates lower return temperatures from the customers
- How much does each Revenue Stream contribute to overall revenues?
  - Envisaged revenues for the HT-ATES system of ECW:
    - 80% revenue comes from subsidy for geothermal energy
    - 20% from selling heat in winter

REVENUES HT-ATES

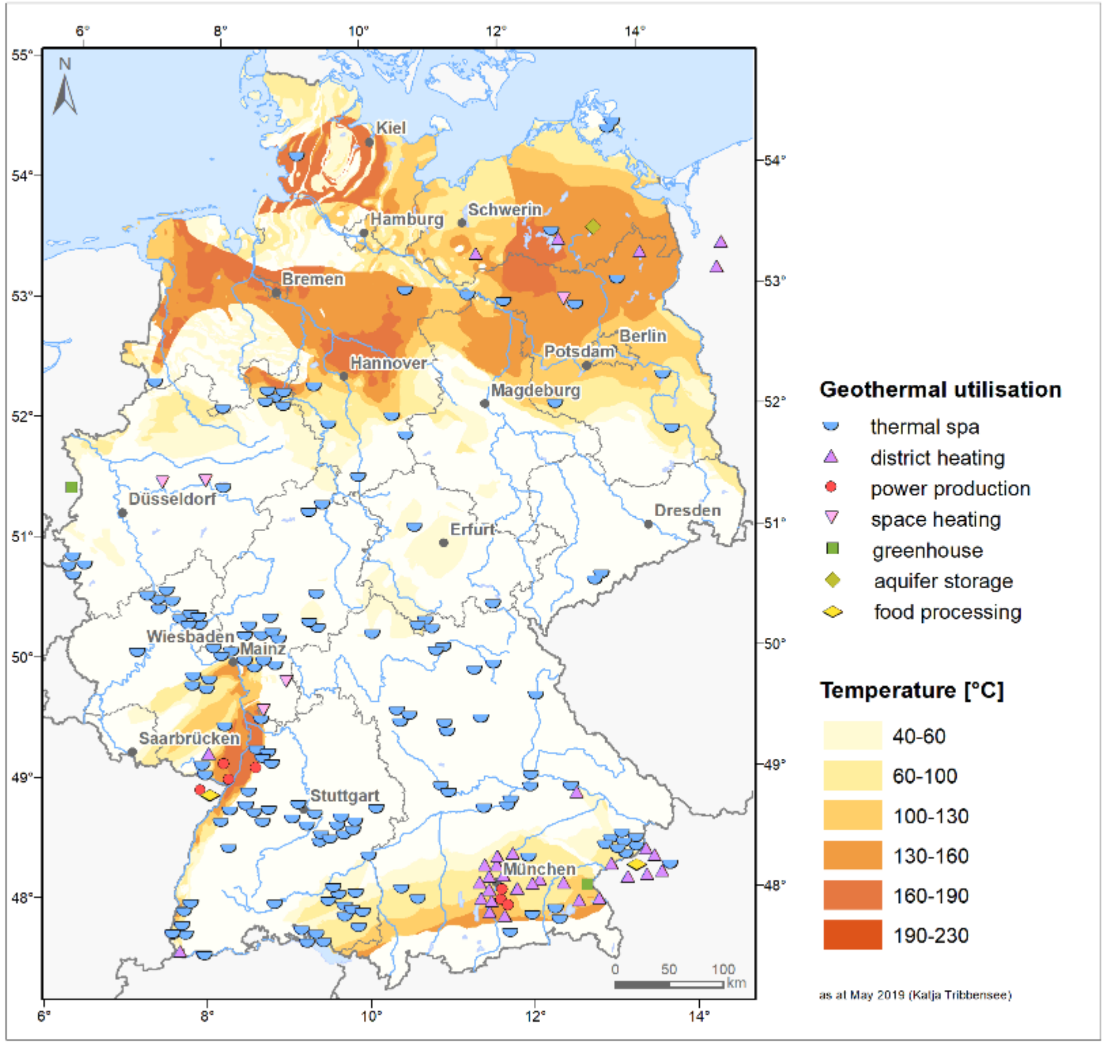


COUNTRY PERSPECTIVES

GERMANY

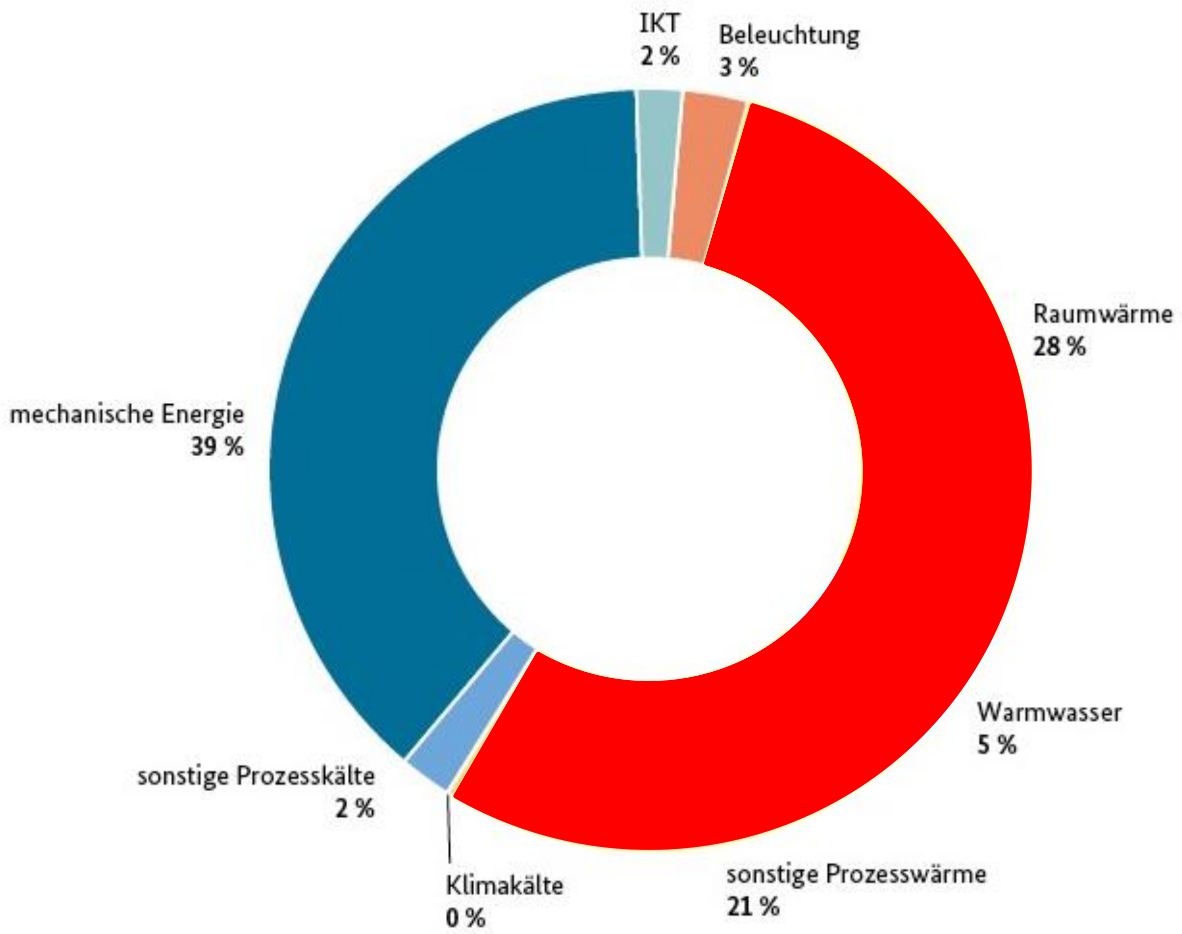
MARKET OVERVIEW (DE)

- Deep geothermal energy (drilling depth > 400 m)
  - Number of plants in operation: 37
  - installed thermal output: 336,51 MW
  - installed electrical capacity: 37.13 MW
- Shallow geothermal energy (drilling depth < 400 m)
  - Number of installations: over 400,000 with approx. 4,400 MW
  - newly installed systems per year (figures for 2019): 20,000
- installed geothermal heat capacity (deep and shallow geothermal energy): approx. 4,600 MW
- installed geothermal electrical capacity (only deep geothermal): 34.83 MW
- Amount of electricity provided in 2016: 0.162 TWh
- Amount of heat provided in 2016: approx. 9.1 TWh
- Investments made in 2017: 1.3 billion euros
- Number of jobs in 2016: 20,300 (19,500 shallow geothermal, 800 deep geothermal)

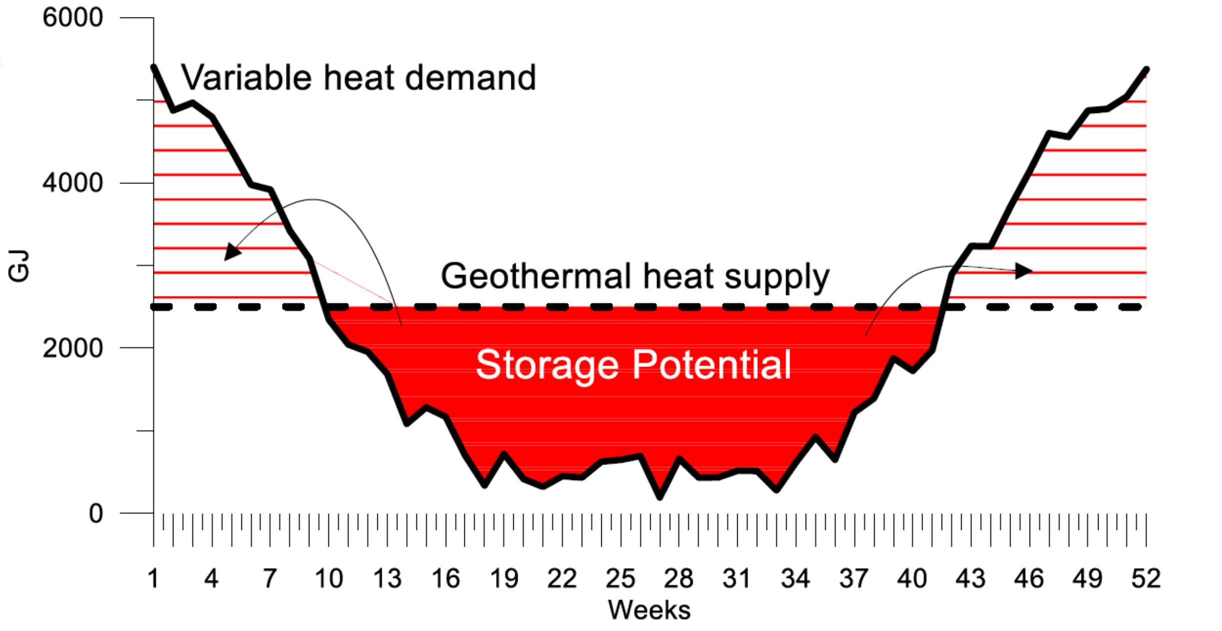


Sites of deep geothermal utilization in Germany. The background colors represent predicted temperature ranges of the respectively deepest identified geothermal resources in sedimentary or volcanic rocks (map generated in GeotIS, 2019)

GERMAN ENERGY DEMAND



	Percentage	RE portion [%]
Overall heating	54	6,02
Space heating	28	4,34
Domestic hot water	5	0,57
Mis. Process heat	21	1,11



[BMWi, 2016]

KEY PARTNERS (DE)

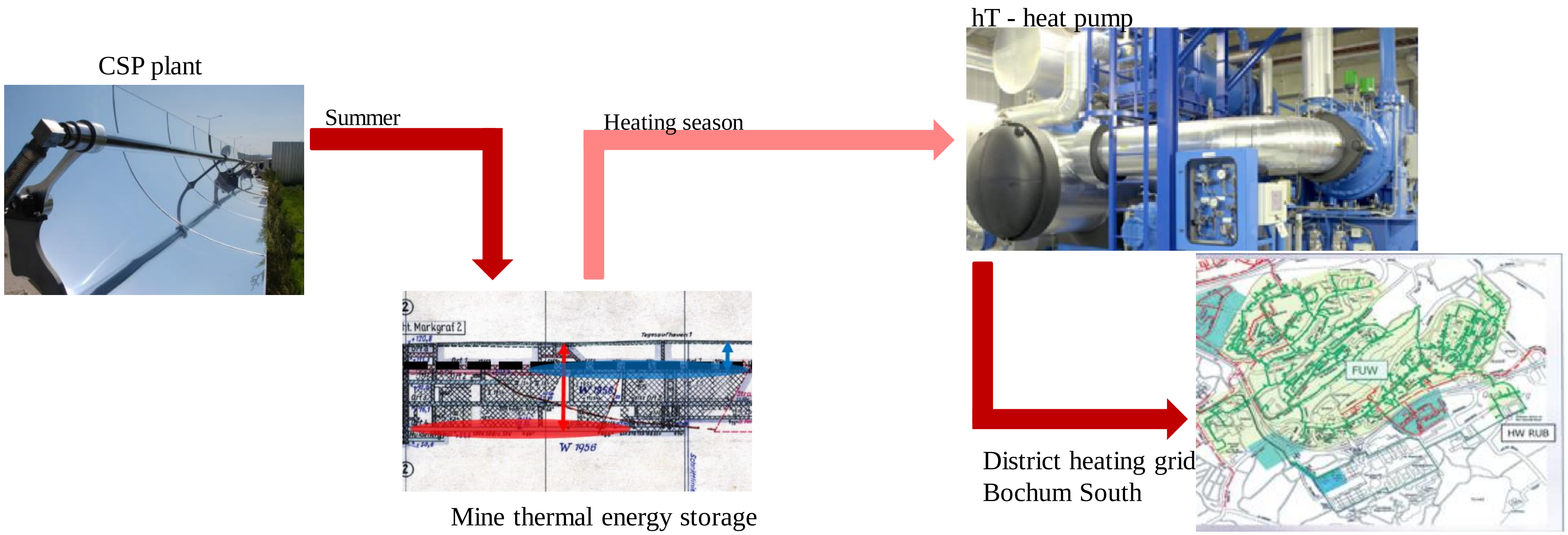
- Who are our Key Partners and suppliers in the thermal energy sector?
  - Municipal utilities, energy producing companies, district heating grid owners

KEY ACTIVITIES (DE)

- What Key Activities do our Value Propositions require?
  - Successful demonstration of pilot plant, in order to overcome uncertainties for large scale projects
  - Possible connection to district heat grid
  - Renewable surplus heat during the summer for storage
  - Costumer demand during heating season, which requires additional heat resources
- What are the key activities in; Distribution Channels, Customer Relationships and Revenue streams?
  - Increasing renewable share for heating purposes within the overall energy demand
  - Transformation of existing heating grid infrastructure to include storage capabilities
  - Merge consumer and producer towards "prosumer" to increase energy efficiency
- Which Key Activities do partners perform?
  - Technical design and operation of surface heating infrastructure with possible connection to district heating grid

KEY ACTIVITIES (DE)

Coupling of MTES with district heating grid



KEY RESOURCES (DE)

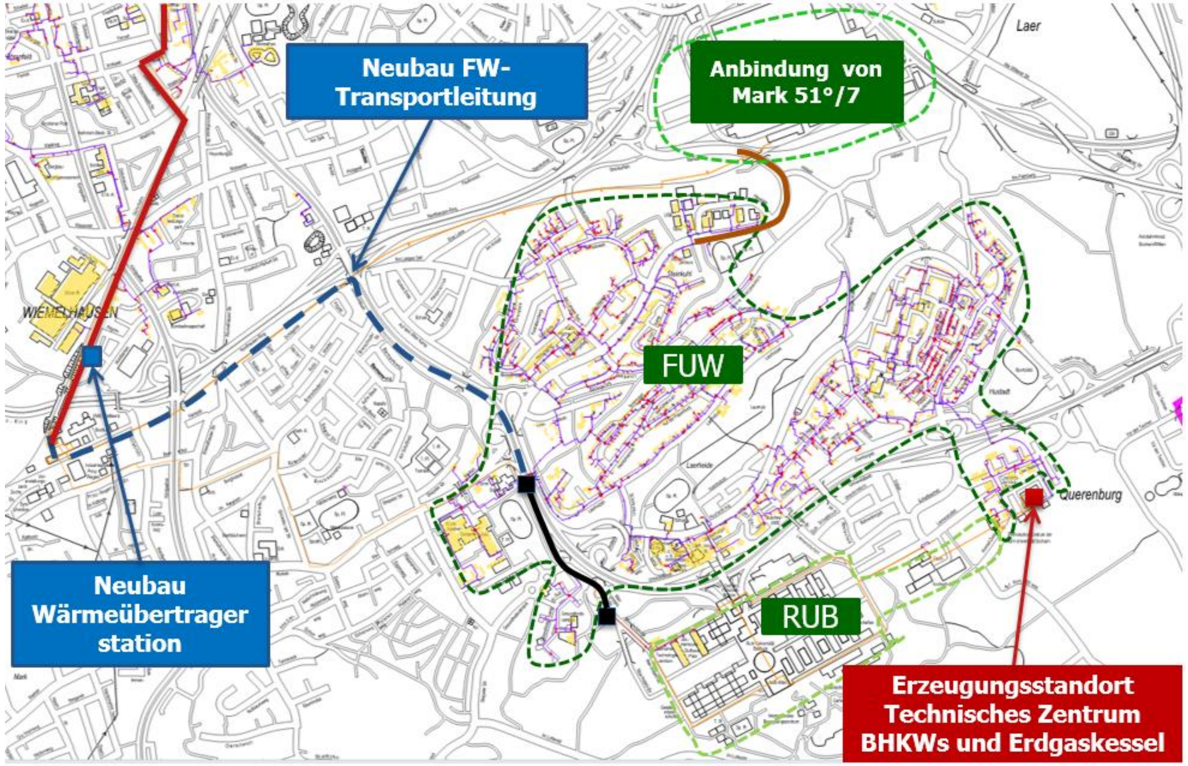
- What Key Resources do our;Value Propositions? Distribution Channels? Customer Relationships? Revenue Streams require?
  - Surplus heat availability
  - Possible connection between district heating grid, heat source and suitable underground storage location (e.g. abandoned flooded coal mine) in spatial vicinity
- Which Key Resources are we acquiring from partners?
  - Access to mine layouts
  - Permission of mine owner to establish a mine thermal energy storage
  - Legal approval by mining and water authority
  - Approval of district heating grid owner to include MTES into the overall system

VALUE PROPOSITION (DE)

- What value do we deliver to the customer in the thermal Energy sector?
  - Secure heat delivery, due to storage capacities
  - Increased utilization of renewable energy
  - Decrease CO2 footprint/emission
  - Reutilization of abandoned mining infrastructure
- Which one of our customer's problems are we helping to solve?
  - Improving (heat) energy autarky and flexibility
  - Increasing overall efficiency of energy production (combined heat and power) especially during the summer
- What bundles of products and services are we offering to each Customer Segment?
  - (Heat) energy storage during the summer, in order to increase revenue stream during peak demand during the winter

CUSTOMER RELATIONSHIPS (DE)

- What type of relationship does each of our customer segments expect us to establish and maintain with them?
  - Long term relationship with district grid owner, in order to implement a MTES in the overall system
- Which relation have we established? How are they integrated with the rest of our business model
  - Close collaboration with the municipal utility Bochum for integrating mine water projects into the overall district heating grid scheme



- **FUW district heating grid in Bochum**:
- Heat demand:
  - 270 GWh/a
- 2 CHP: 9 MW
- 3 peak boiler:
  - 105 MW
- Base load:
  - Mine water utilization (Mark 51°/7)
- Peak load:
  - Thermal energy storage @ Fraunhofer IEG

CHANNELS (DE)

- Through which Channels do our Customer Segments want to be reached?
  - Conferences, articles, webinars, results of feasibility studies and demonstration sites
- How are we reaching them now? How are our Channels integrated?
  - Integrated collaboration during feasibility studies and project development
- Which ones work best?
  - Direct project collaboration
- Which ones are most cost-efficient?
  - Subsidized projects, which reduce the financial risk of municipal operator/energy producer/operator

CUSTOMER SEGMENTS (DE)

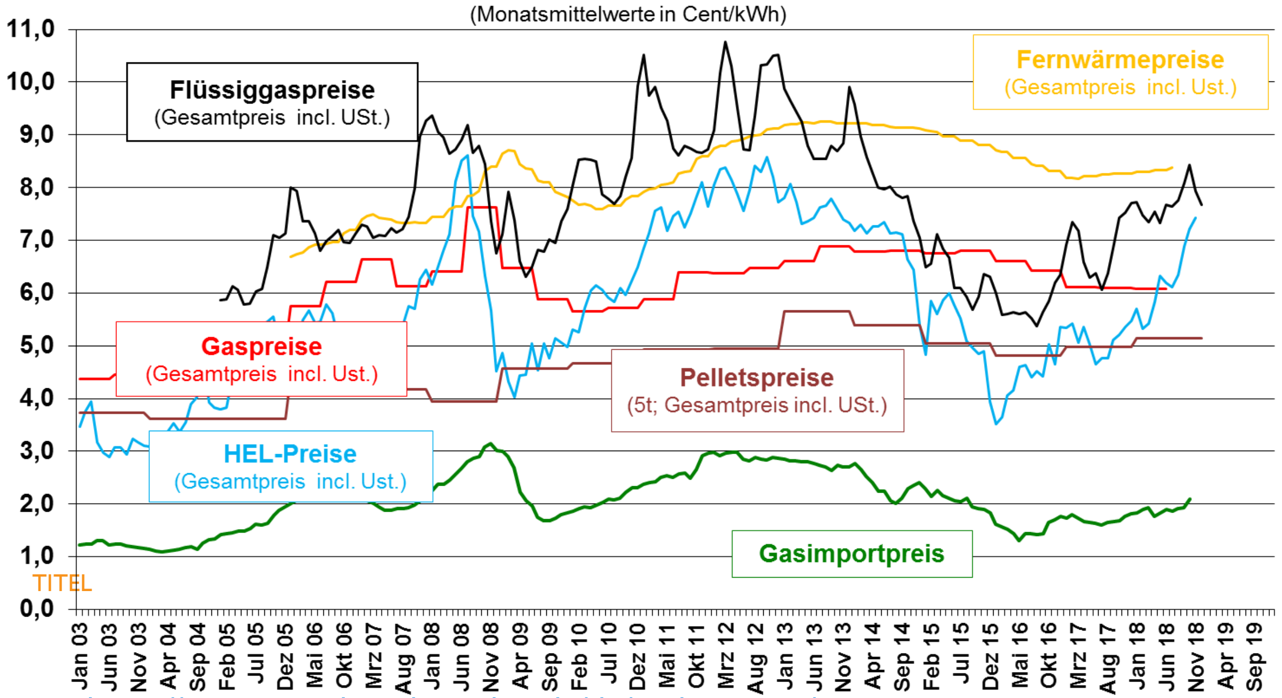
- For whom are we creating value in thermal energy sector?
  - Energy provider and grid owner, due to the increased possible usability of renewable energies (surplus heat)
- Who are our most important customers?
  - Municipal utilities, which also operate a district heating grid and CHP plants

COST STRUCTURE (DE)

- What are the most important costs inherent in our business model?
  - Drilling costs (Capex)
  - Surface and subsurface infrastructure (Capex)
  - Heat and supply pump (Opex)
- Which Key Resources and key activities are most expensive/time-consuming?
  - Obtaining information and right to utilize abandoned mining infrastructure

REVENUE STREAMS (DE)

- The following economic evaluation is based on a previous feasibility study for the reutilization of an abandoned colliery as a mine thermal energy storage with a storage volume of 250.000 m³/a and a storage capacity of 7,72 GWh/a, which would be coupled with the (FUW) district heating grid.
- The results indicated that heat could be supplied for a price of 8,22 Cent/kWh, which would be in the range of the district heating prices (Fernwärmepreise;see yellow line below).



https://www.energieverbraucher.de/de/preise__981/

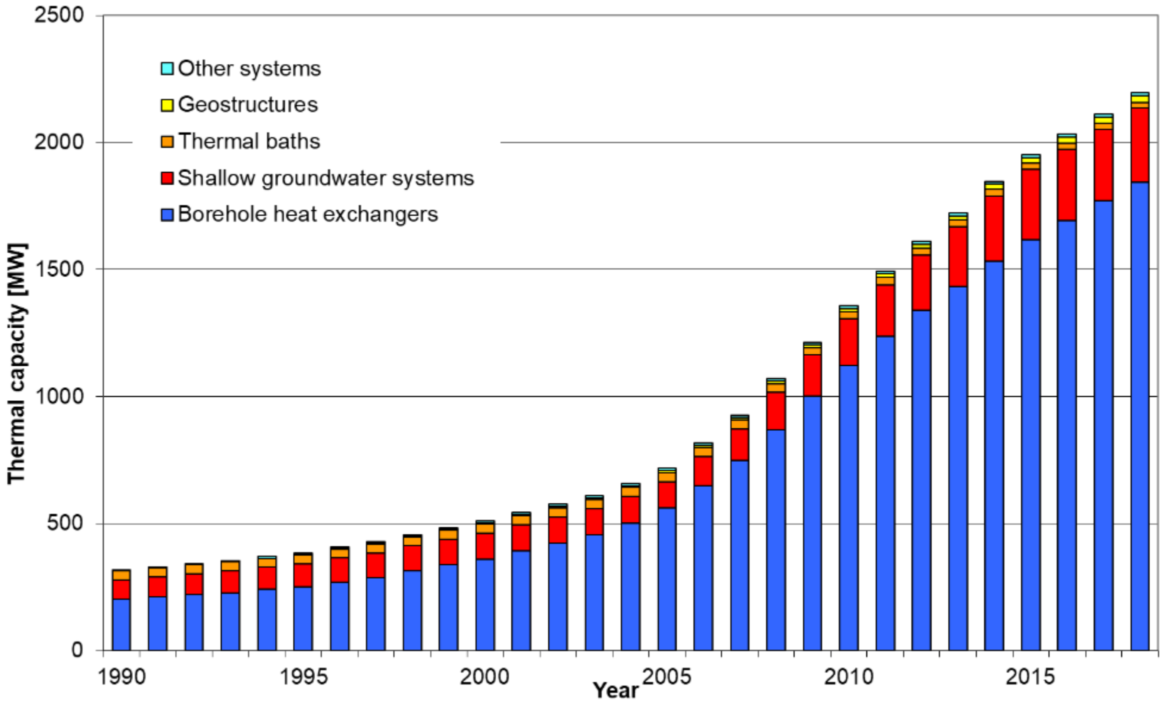
Investment costs	%
Heat pumps (6x)	19,42
Electrical submersible pumps (2x)	12,50
Drilling of two wells (2x)	41,01
Buffer tank	5,81
Planing and approval	9,45
Installation	7,87
Contingency	3,94
Sum	100,00

COUNTRY PERSPECTIVES

SWITZERLAND

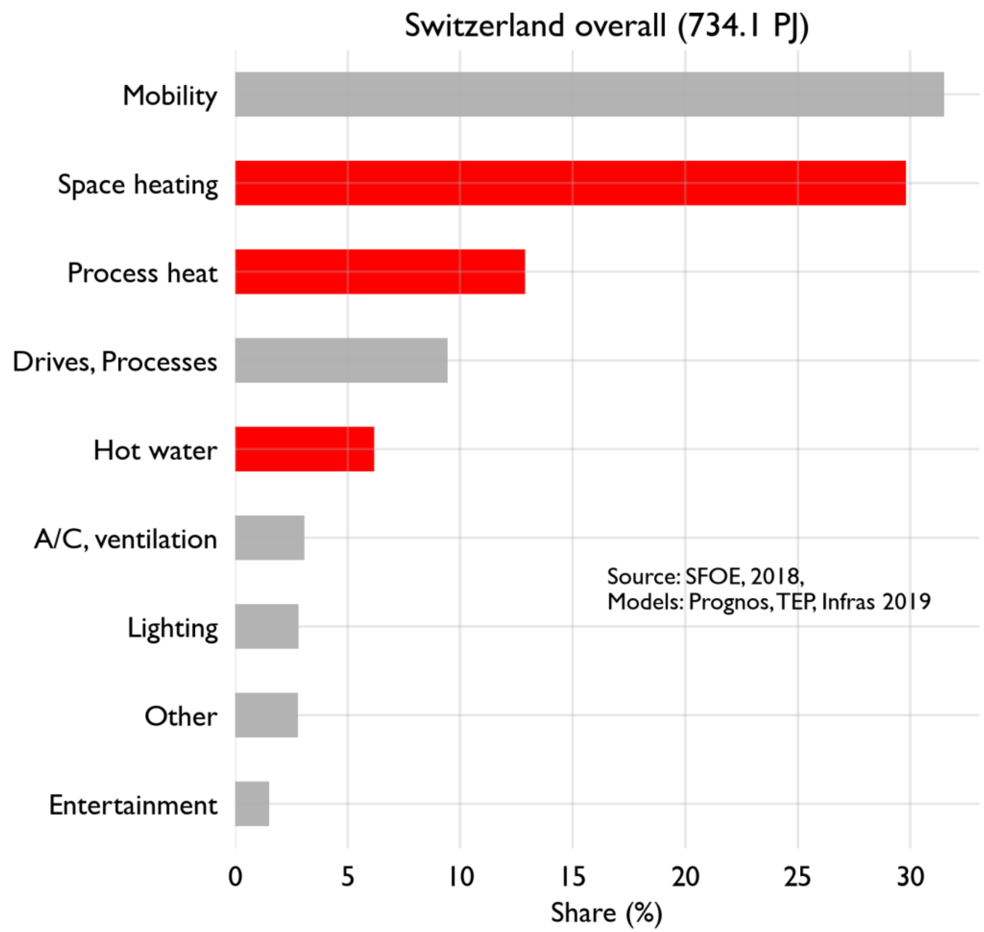
MARKET OVERVIEW (CH)

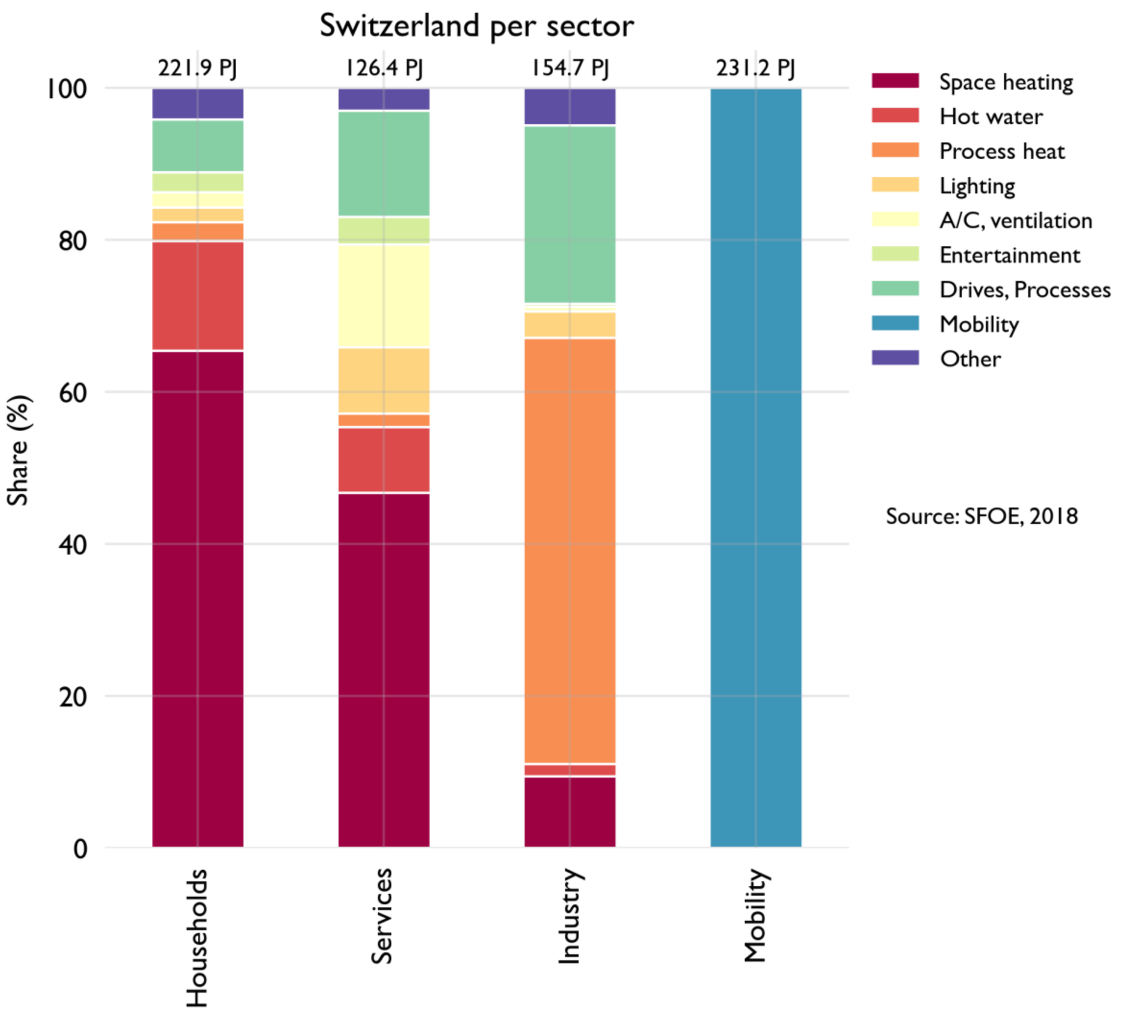
- CH: 8.5 m inhabitants, area of 41,000 km^2
- Mature market (shallow geothermal - BHE), moving towards larger & more complex systems, competition on price
- Deep geothermal not mature, incentive schemes in place
- Direct-use geothermal:
  - 83.9 % of capacity from Borehole Heat Exchangers (BHE)
  - 85.4 % of energy from BHE + 12.2 % from HP
- National R&D program:
  - thermal grids (including storage)
  - Efficiency improvement
- **Geneva: 60% CO_2 emissions reduction and 80% share of renewable energy in DH by 2030**
- Geneva: obligation to connect to District Heating



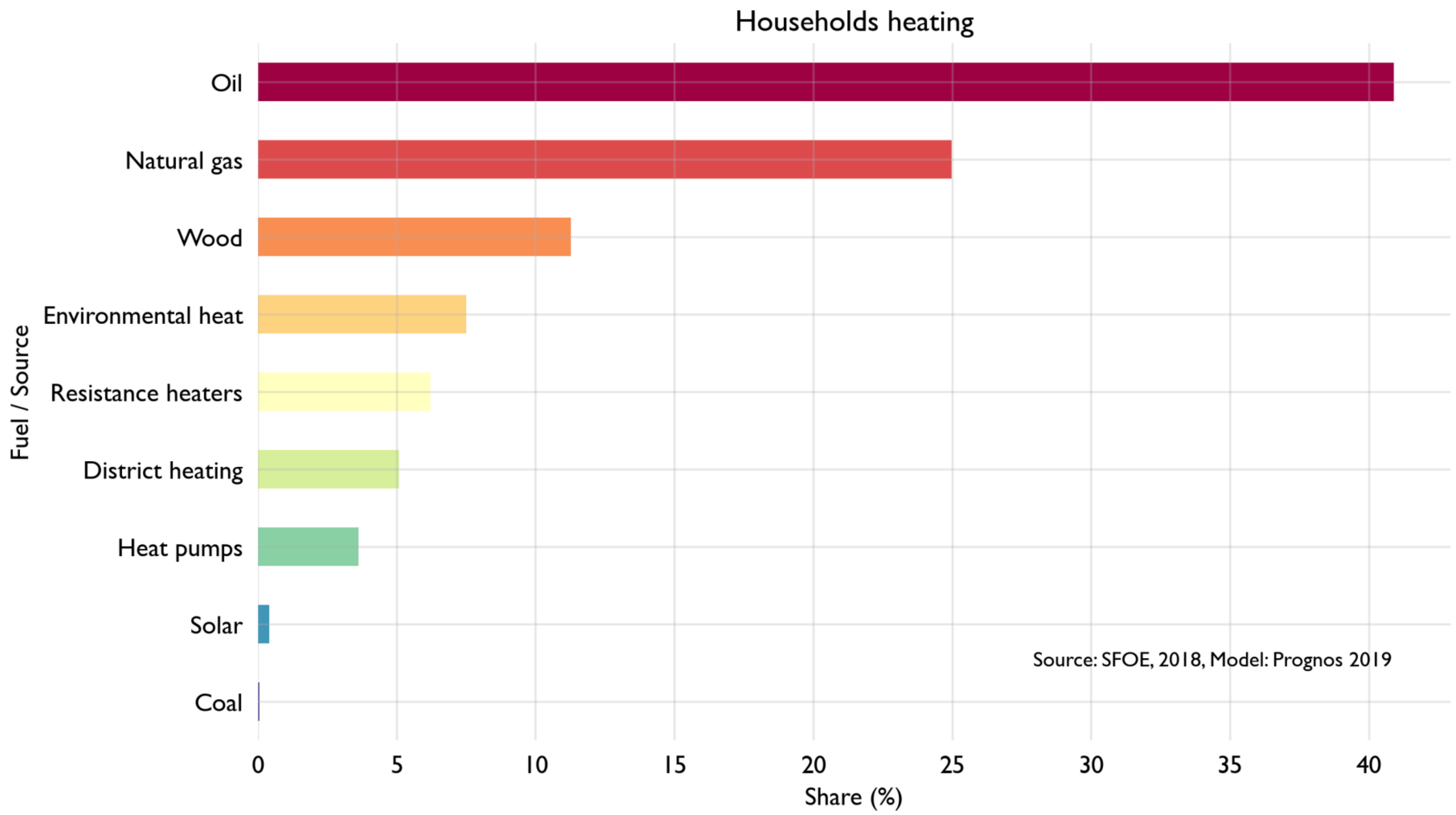
Thermal capacity of geothermal systems in CH (up to 2018). Image source: Link, Lupi & Siddiqi WGC 2020 with data from: Link 2019

ENERGY DEMAND (CH)





ENERGY DEMAND (CH)



KEY PARTNERS (CH)

- Who are our Key Partners and suppliers in the thermal energy sector?
- SIG (self), Municipal, Canton, GazNat (gas provider), electricity providers (open market), property developers, Urban developers, Pension funds (CFF, owners of building stock), building maintaining companies, energy consultants, civil engineering companies, energy engineering companies, end users, Confederation Offices of Energy (Municipal, Canton and National levels)
- Research and Knowledge partners: UniGe, UniNe, UniBe, ETH

KEY ACTIVITIES (CH)

- What Key Activities do our Value Propositions require?
  - Production, distribution and maintenance of the heat supply, security of supply guarantor (monopoly)
  - deliberation on and implementation of policy goals for heat supply
- What are the key activities in; Distribution Channels, Customer Relationships and Revenue streams?
  - Design, operation and maintenance of distribution channels
  - System monitoring
  - Customer support and new contracts
  - Metering and billing to final consumers
- Which Key Activities do partners perform?
  - Maintenance of substations (beyond heat exchangers, interface between DH and building)
  - Construction of network/plants
  - Provide gas
  - Provide heat
  - Market and price regulation (Canton)
  - Strategic energy planning/roadmap (Canton)
  - Enable (or not) expansion of heat network (developers)
  - Research

KEY RESOURCES (CH)

- What Key Resources do our;Value Propositions? Distribution Channels? Customer Relationships? Revenue Streams require?
  - Capital streams, Expertise, Energy resources, (Spatial resources)
- Which Key Resources are we acquiring from partners?
  - Expertise, Energy, Capital (municipality, (Canton))

VALUE PROPOSITION (CH)

- What value do we deliver to the customer in the thermal Energy sector?
  - Heat supply
  - Locally produced energy (heat)
  - Low carbon energy
  - Security of supply
- Which one of our customer’s problems are we helping to solve?
  - Comfort
  - Problem reporting
  - Conform to the legal framework
- What bundles of products and services are we offering to each Customer Segment?
  - Heat
  - Heat + electricity
  - Heat + cooling
  - Energy saving measures
  - Take over of assets

CUSTOMER RELATIONSHIPS (CH)

- What type of relationship does each of our customer segments expect us to establish and maintain with them?
  - Commercial relationship – long term subscription
- Which relation have we established? How are they integrated with the rest of our business model
  - Commercial relationship – long term subscription

CHANNELS (CH)

- Through which Channels do our Customer Segments want to be reached?
  - Social media, promotion video about challenging projects, regular mailings, direct contact to support them with their own project development, support financial risk and organise/perform exploration phase to characterise resource.
- How are we reaching them now? How are our Channels integrated?
  - Social media, promotion video about challenging projects, regular mailings, direct contact to support them with their own project development, support financial risk and organise/perform exploration phase to characterise resource.
- Which ones work best?
  - support financial risk and assume exploration phase to characterise resource
- Which ones are most cost-efficient?
  - direct contact to support them with their own project development

CUSTOMER SEGMENTS (CH)

- For whom are we creating value in thermal energy sector?
  - Society
  - Consumer
  - Businesses
  - Grid owner
- Who are our most important customers?
  - Building owners – not the same as end user – signs the contract
  - End users – pays the bills but doesn't sign the contract

COST STRUCTURE (CH)

- What are the most important costs inherent in our business model?
  - CapEx: network and power plants
  - OpEx: maintenance, fuel, salaries, infrastructure
- Which Key Resources and key activities are most expensive?
  - Energy supply (heat)
  - Investments of new projects

REVENUE STREAMS (CH)

- For what value are our customers really willing to pay?
  - Comfort
  - Conformity with legal framework
  - Low carbon energy (some)
- For what do they currently pay?
  - Comfort
  - Conformity with legal framework
  - Low carbon energy (50% renewable share)
- How are they currently paying?
  - Connection fee
  - Service fee – subscription
  - Energy costs – variable (graded)
- How would they prefer to pay?
  - Connection fee
  - For actual consumption
  - Most don't want to pay for new investments (included in the service fee)
- How much does each Revenue Stream contribute to overall revenues?
  - Depends on project cost structure (representative is 30% fixed cost / 70% variable costs)
  - Smaller projects higher fixed costs 40-50%

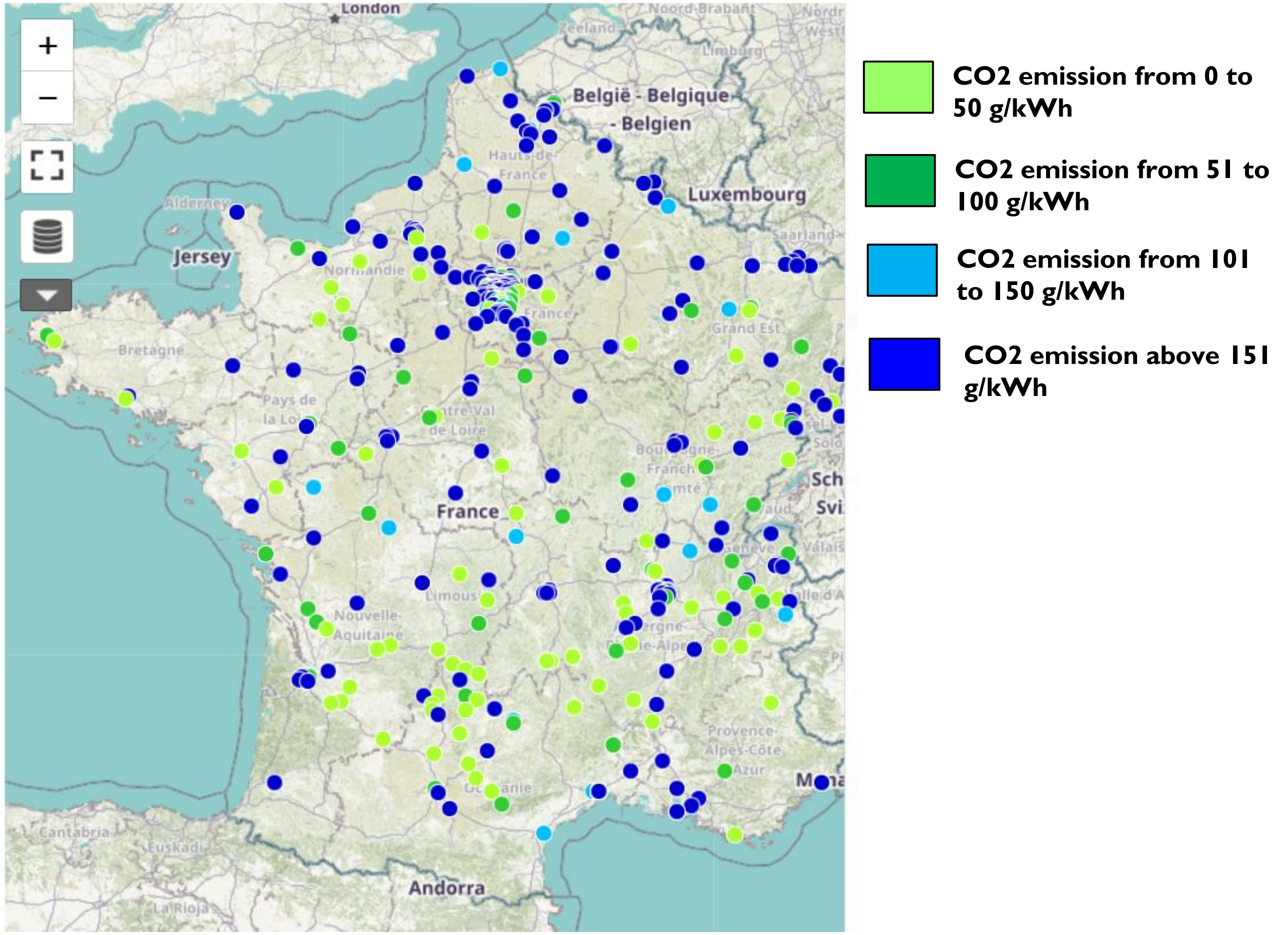
COUNTRY PERSPECTIVES

FRANCE

FRENCH MARKET OVERVIEW

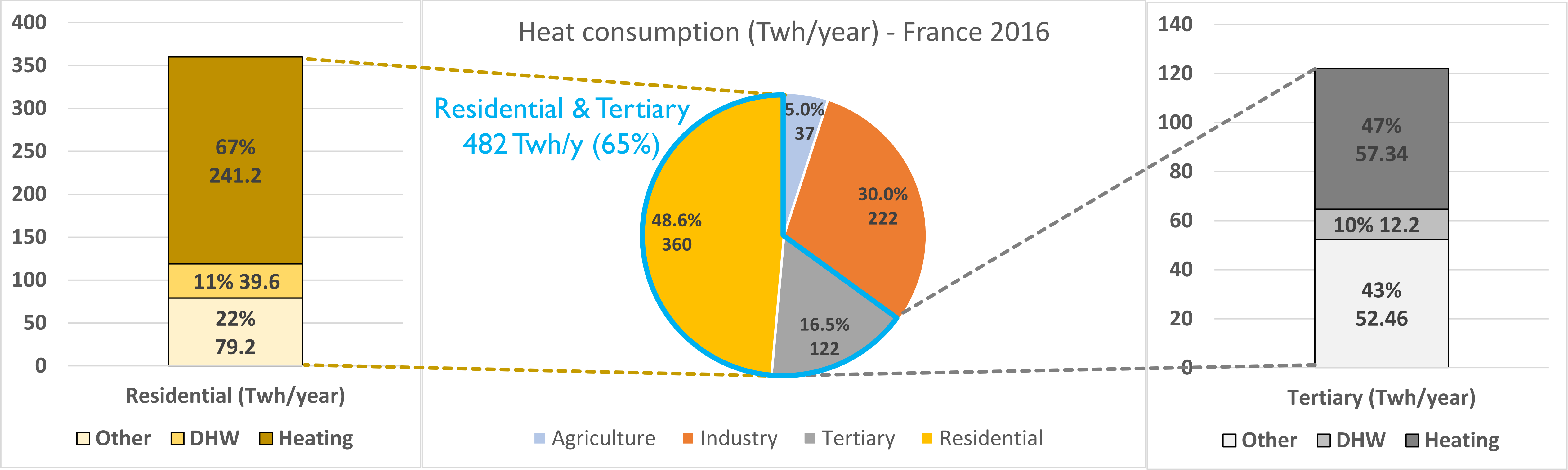
- Temperate Climate well suited for ATES/BTES technologies
- Large available underground availability
- A new regulation, RT 2020 (BEPOS) favorable with "obligation to achieve" for new constructions and renovations.
- Market Size :
  - 200 000 GSHP (1800 MW)
  - Growth: 20 000 GSHP /year
- Commercial Projects
  - ATES et BTES
- UE Directive : Energy efficiency
- « Fonds chaleur » ADEME
- Regulations to be improved
- 33% of renewable heat in 2020

French national map of CO_2 content of heating and cooling network (2012 Data)



Source http://reseaux-chaleur.cerema.fr/

HEAT DEMAND (FR)



[BMWi, 2016]

Source : CEREN, Chiffres-clés Climat Air et Energie, ADEME & PPE

KEY PARTNERS MAPPING (FR)

Project Management / Implementation

Local Authorities
Launch urban development projects through real estate projects and district heating networks

Project Developers
Bring real-estate, office buildings, shops and stores or sustainable neighborhood projects.

Real Estate, property and office buildings development

Project implementation or project implementation advisory

Heat / Cold Supply

Engineering Companies
Provide advisory, feasibility studies, business plan analyses and design technical solutions for project developers and / or local authorities

Advisory for design and optimization

Utilities
Operate district heating networks, industrial assets providing waste heat, also potential customers of heat / cold supply

Operations and Management Contracts / Project Implementation

French National Public Entities
Implement sustainable development policies for geothermal energy, district heating networks and Energy / heat storage.

ADEME, brgm

NGO / Associations
Promotes geothermal energy and district heating at national and European level.

afpg, EUROHEAT & POWER, via sèva, AMORCE

Main Players:

Local Authorities

Bouygues Immobilier, ALTAREA COGEDIM, ICADE, VINCI, unibail·rodamco, etc…

BE Géothermie

anteagroup, SAFEGE, GEOTHER, GINGER BURGEAP, thétis, ALTEREA, etc…

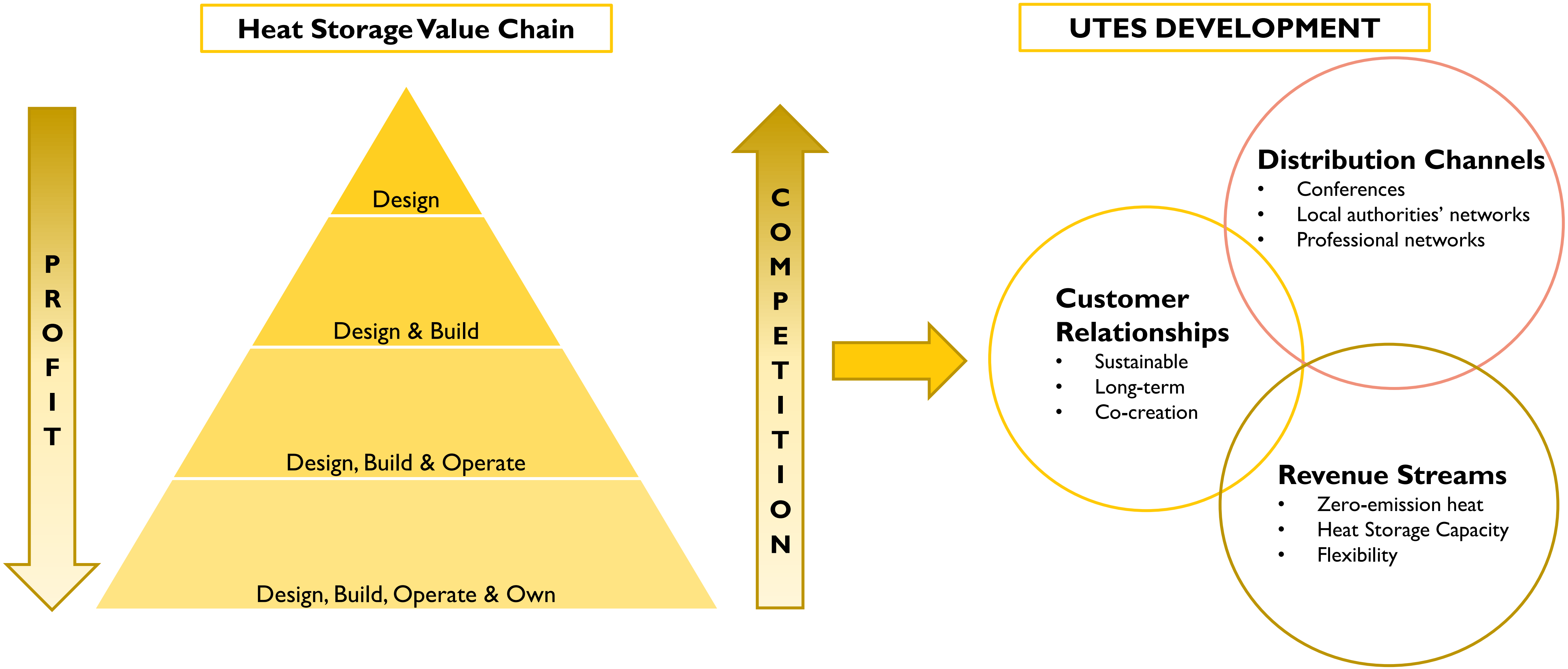
BE CVC[1]

Sfica, TERAO, setec, etc…

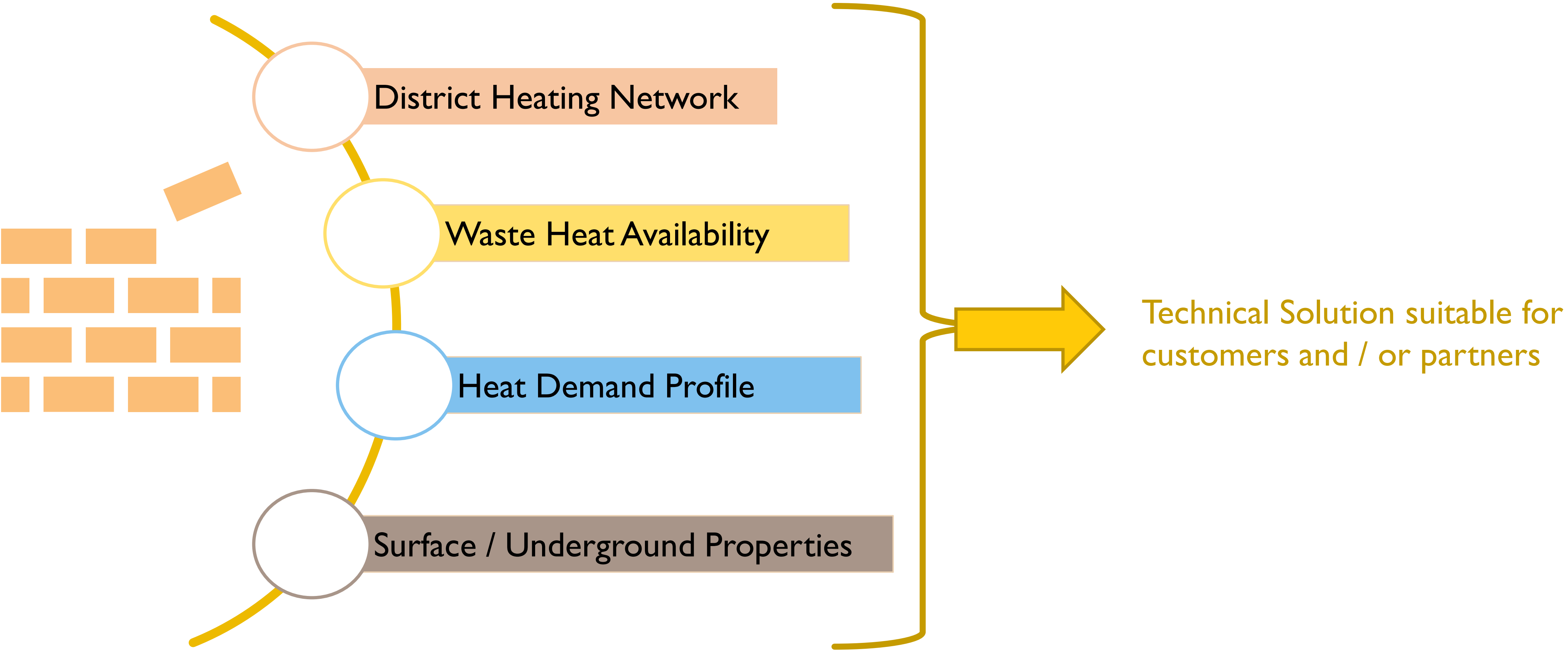
ESCOs

ENGIE, idex, dalkia GROUPE EDF, Coriance, etc…

KEY ACTIVITIES TO DEVELOP UTES (FR)

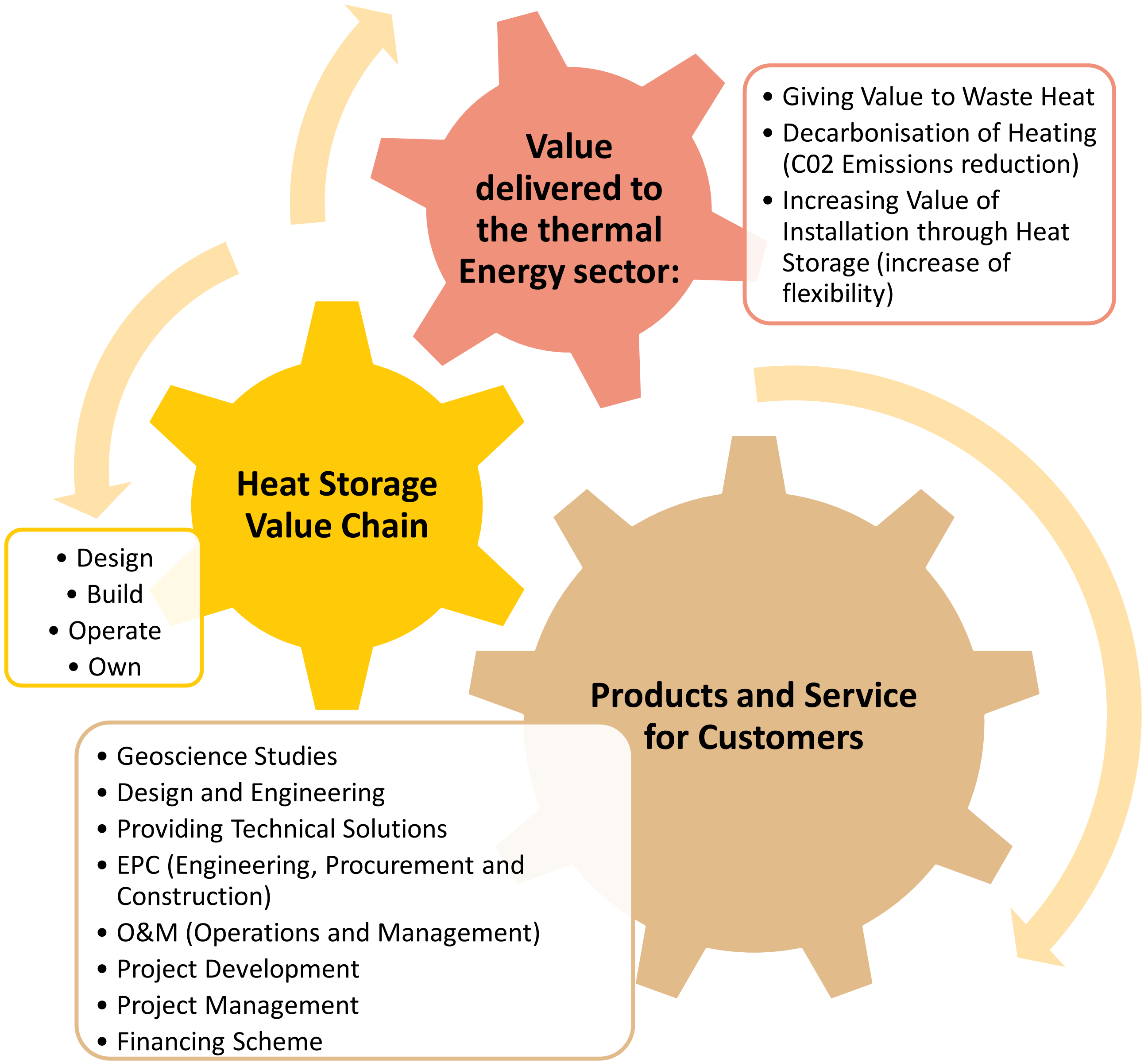


KEY RESOURCES (FR)



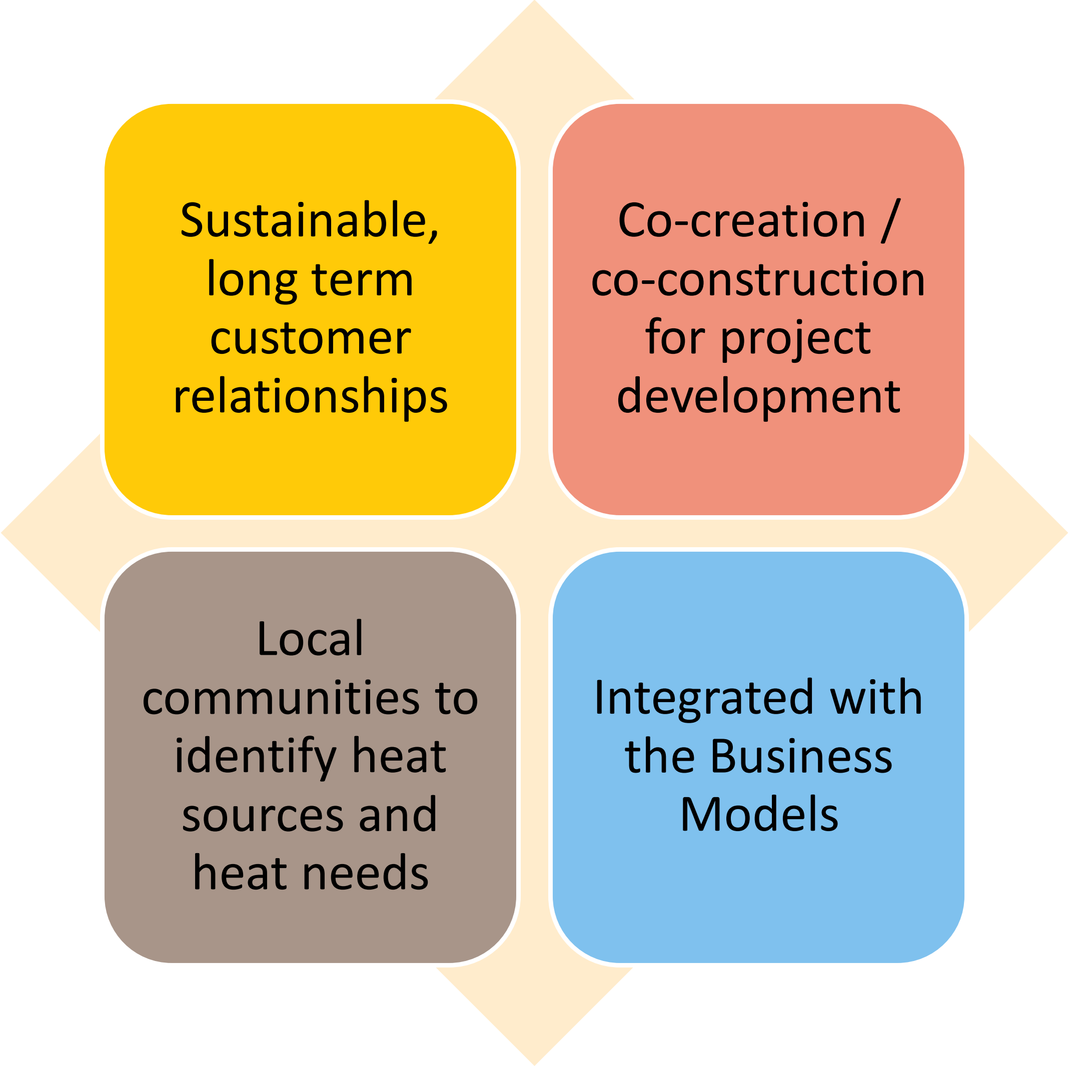
VALUE PROPOSITION (FR)

- Suitable products and services for customers are derived from the value delivered to the thermal Energy sector and the heat storage value chain:
  - Geoscience Studies
  - Design and Engineering
  - Providing Technical Solutions
  - EPC (Engineering, Procurement and Construction)
  - O&M (Operations and Management)
  - Project Development
  - Project Management
  - Financing Scheme



CUSTOMER RELATIONSHIPS (FR)

- Developing market, sustainable long term relationship are essential to build trust

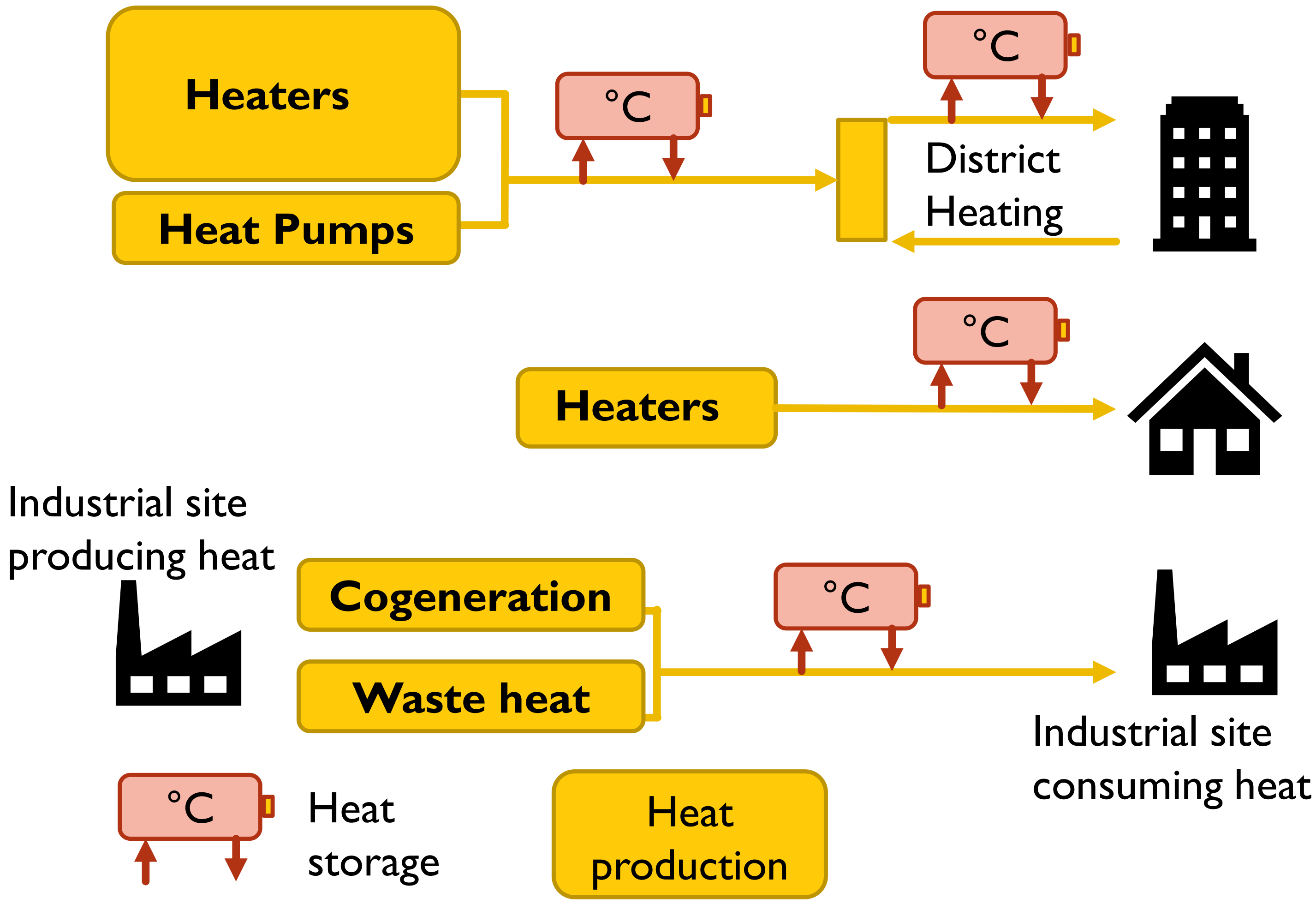


CHANNELS (FR)

- Main Channels to reach our customers:
  - Regular contact with district heating networks
  - Local Authorities Networks
  - Industrial / Energy / Geothermal Networks
  - Partners
  - Professional conferences / workshops
  - Social networks

CUSTOMER SEGMENTS (FR)

- Main customer segments
  - Residential / Tertiary (Buldings, offices, shopping mall, hospitals,…)
    - Linked with heat generation
    - Integrated to district heating network
  - Small residential (houses)
  - Industrial



From Etudes de Valorisation du Stockage Thermique et du Power-to-heat, Novembre 2016 - ADEME

COST STRUCTURE FOR UTES DEVELOPMENT (FR)

- **Main Investment Costs**
  - Drilling 40-80% of CAPEX
  - Heat Pumps 0 – 30%
  - Piping 5 – 30%
  - Others (Control, Project Management, Studies,…): 5 - 40%

- **Operating and Maintenance Costs**
  - 2 – 15 % Investment Costs

- **Example for an ATES with a 1.3 MWth heat storage capacity**

- Wells : 510 k€ (65%)
- Heat pump : 280 k€ (35%)
- Operating and Maintenance costs : 33 k€/year (4% of investment costs)

REVENUE STREAMS (FR)

- **Identifying and quantifying revenue streams is essential to design viable project**
  - Heat Supply
  - Heat storage capacity
  - Waste Heat Outlet
  - Zero-Emission Heat
  - Services, studies
  - Costs avoided
- **Example for France**
  - A seasonal heat storage is installed instead of a standard installation of a gaz heater and centralised air conditionning
  - The heat storage, thanks to heat pumps, can supply heat in winter and cold in summer in an efficient way
  - The sytem only consumes power to run pumps and heat pumps, instead of burning gas for heat and using a significant amount of power for air conditionning
  - Assuming a power price of 70€/MWh and a gas price of 40€/MWh, the savings on operational costs are important and allow reaching a ROE of 8%
  - ROE is further increased with the avoided investment in gas heater
  - This system is all the more economic as heat is more expensive and as power is cheaper

BUSINESS MODELS FOR EXISTING AND HEATSTORE DEMONSTRATION PROJECTS

BUSINESS MODELS FOR THE DEMONSTRATION CASES
DIFFERENT REVENUES (DHN)

Direct Revenues

Income directly related to the delivery of heat, obtained through heat tariffs that the end-customer has to pay.

Consumer ↓ DH operator

Indirect Revenues

Income directly related to the delivery of heat, obtained through an internalization of social and environmental benefits.

Funding ↓ DH operator

Non-linked Revenues

Stakeholders not involved in the direct provision of heat (e.g. selling components). There is no variable income depending on the provision of heat.

… ↓ Manufacturer

Linked Revenues

Stakeholders not involved in the direct provision of heat, rewarded for a more efficient DHC system through linking part of their income to heat provision.

DH operator ↓ Manufacturer

Transferred Revenues

In case the generation of heat is not done by the DH operator, the operator of the grid has to pay the generator for the heat supply.

DH operator ↓ DH generator

BUSINESS MODELS FOR THE DEMONSTRATION CASES

DIRECT REVENUES

ITEMS IN BOLD ARE APPLICABLE FOR GENEVA

Direct Revenues

Income directly related to the delivery of heat, obtained through heat tariffs that the end-customer has to pay.

Consumer

↓

DH operator

- "The invoice"
- Pricing Methodologies
  - Market-based pricing mechanisms
    - Cost of competing heat sources (NMDA)
  - **Cost-based pricing mechanisms**
    - **Geneva: Cost-plus method (actual cost + some margin)**
    - Marginal cost method (non-profit business, e.g. Denmark, infrastructure owned by local stakeholders)

BUSINESS MODELS FOR THE DEMONSTRATION CASES

DIRECT REVENUES

ITEMS IN BOLD ARE APPLICABLE FOR GENEVA

Direct Revenues

Income directly related to the delivery of heat, obtained through heat tariffs that the end-customer has to pay.

Consumer → DH operator

- Heat tariff usually consists of three components
  1. **Fixed cost fee**
     - Administration and maintenance costs
     - Not linked directly to consumption
     - € / year
     - =f(m², MW, building type, consumer type, …)
  2. **Connection fee**
     - Covers fixed cost of DHC network
     - Paid once

     → Margin / negotiation
  3. **'Variable' cost fee**
     - Depends on consumption, secondary: temperature, flow, load, …
     - € / MWh
     - Often limited choice of tariff for consumers (e.g. single tariff)

     → Incentive for the customer to change behavior (e.g. Motivation tariff)

     → **For cooling there is a bonus for staying below a certain load**

     → Charges for capacity or peak loads

BUSINESS MODELS FOR THE DEMONSTRATION CASES

DIRECT REVENUES

ITEMS IN BOLD ARE APPLICABLE FOR GENEVA

Direct Revenues

Income directly related to the delivery of heat, obtained through heat tariffs that the end-customer has to pay.

Consumer → DH operator

- Five possible methods to determine capacity charges:
  1. Total consumption method
     → Determine tariff based on total consumption during a certain period
  2. Category number method
     → Each consumer is divided in a group that is linked to a specific load profile
  3. Load signature method
     → Predict customer consumption based on weather conditions
  4. Measured peak method
     → Based on real customer peak load (or average of multiple peaks)
  5. **Subscribed / exceeded level method**
     → Customers subscribe to a certain load and pay more when they exceed it

BUSINESS MODELS FOR THE DEMONSTRATION CASES (NL)
VARIABLE COST FEE

Example: Aabenraa-Rødekro Fjernvarme https://www.aabenraa-fjernvarme.dk/profil/motivationstarif/

- High return temperature = higher water consumption
- Example of a house that uses 18 MWh of district heating per year at a flow temperature of 65 degrees C
  - Return temperature: 25 ° C / Used district heating water 442 m^3
  - Return temperature: 30 ° C / Used district heating water 516 m^3
  - Return temperature: 35 ° C / Used district heating water 619 m^3
  - Return temperature: 40 ° C / Used district heating water 774 m^3
- Motivation tariff:
  1% of the price of energy for every degree
  higher than the average temperature per year.

BUSINESS MODEL FOR ECW (NL)

ECW = Energie Combinatie Wieringermeer (energy network owner in greenhouse/farm area Agriport A7 Wieringermeer, Netherlands)

ECW is the owner of the new HT-ATES system that is located at a greenhouse in Agriport A7.

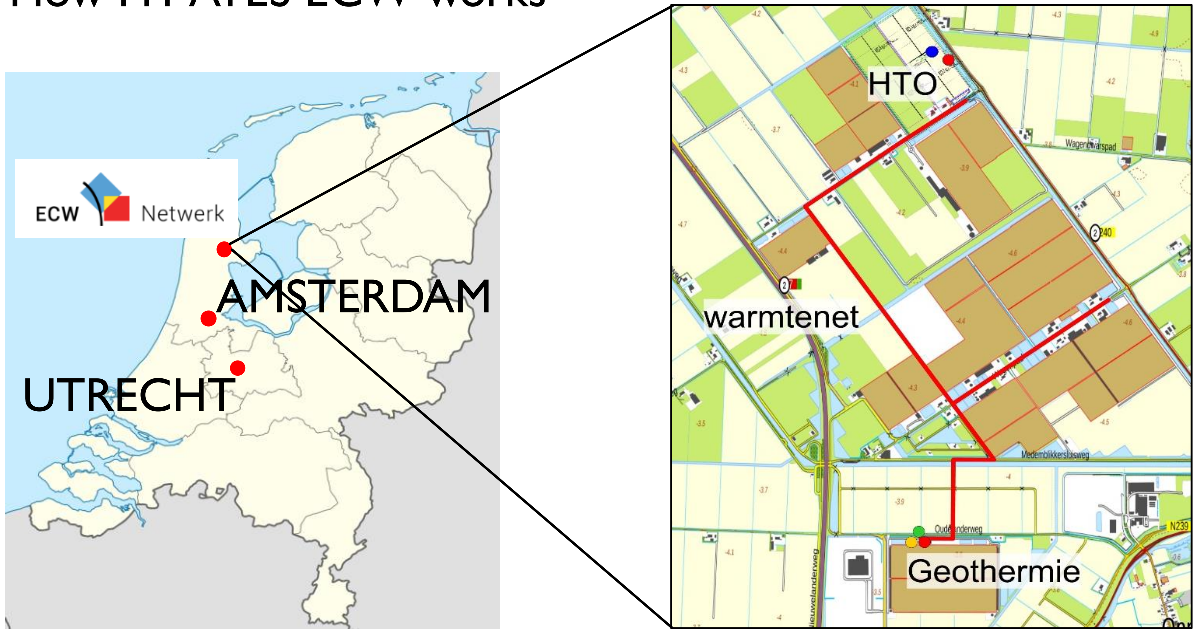
https://www.linkedin.com/posts/ecw-netwerk_ecwnetwerk-verduurzaming-energietransitie-activity-6680750847816806400-hk1u

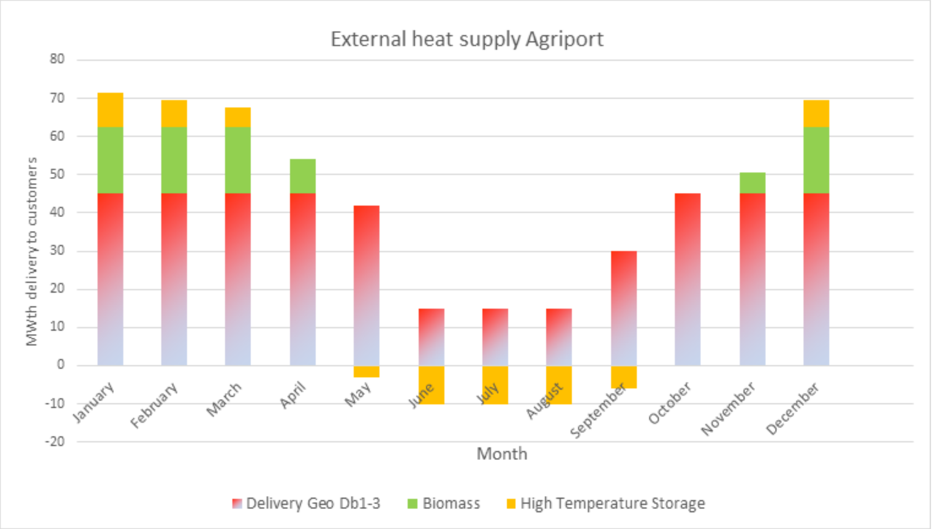
NETHERLANDS

HEATSTORE partners

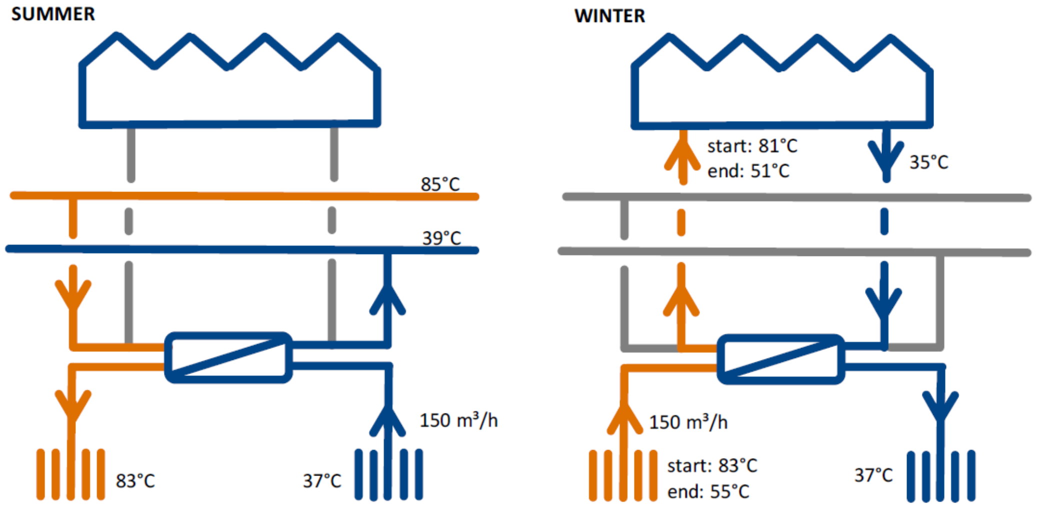
DEMONSTRATION PROJECT ECW

How HT-ATES ECW works





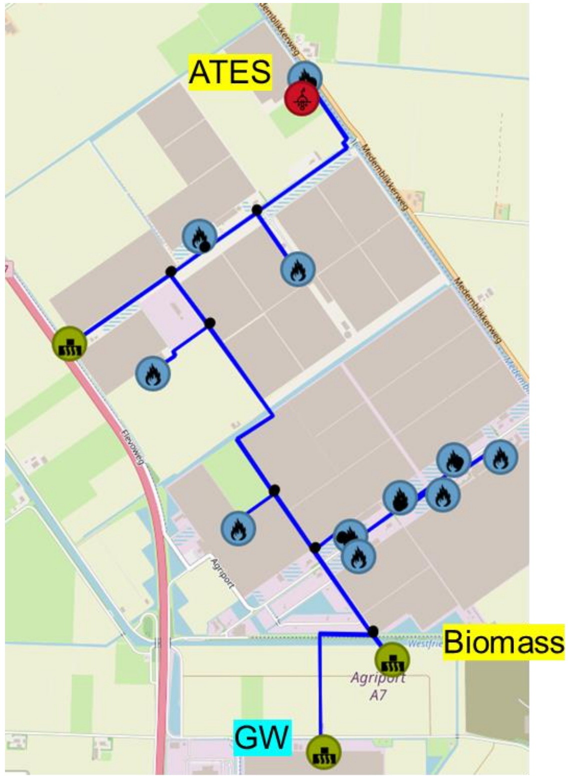
1) Geothermal heat (orange) stored in summer and to be used in winter
2) HTO results in higher redundancy of heat supply in winter
3) Continues and constant production of the geothermal wells in summer is highly preferred because of technical reasons

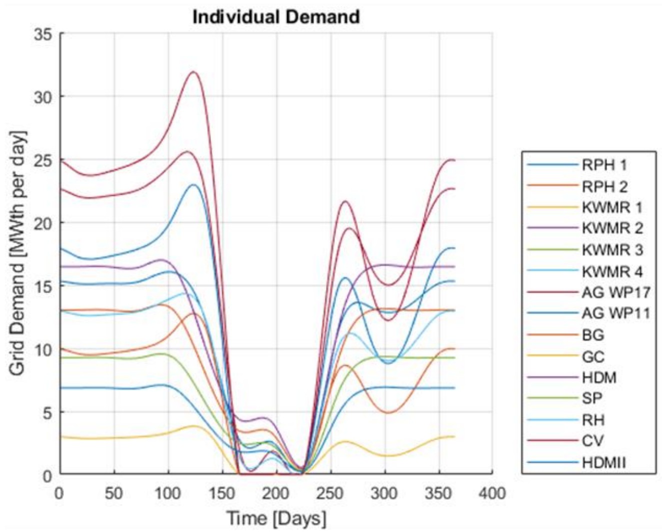


Parameters permit application		Winter	Summer
maximum water displacement	[m³/season]	350.000	350.000
Target flow	[m³/hour]	150	150
Average injection T	[°C]	35	87

DEMONSTRATION PROJECT ECW (NL)

- The production for ECW network currently exists of a 43 MW (3 doublets) geothermal well, and two additional biomass plants of 18MW each are under construction.
- Additionally, the ATES is in development; expected to be completed in September 2020. This is located at the end of the heat grid, which is in periods of high heat demands 'difficult to supply with heat'. i.e. in principle a very good location for storage.
- The network is feeding multiple greenhouses; growing divers mix of crops.
- Each greenhouse's heat supply is composed of the heat supplied by the above network and local installed heat supply. This local supply is generated by CHPs, gas boilers and local storage tanks. As a CHP can generate heat, power and CO2, the actual demand from the network depends on the requirements of the crop (e.g. is lighting necessary, or more CO2 required).
- In terms of merit order, geothermal is dispatched first, then the biomass plants and then additional CHPs at the discretion of the individual companies / entrepreneurs.





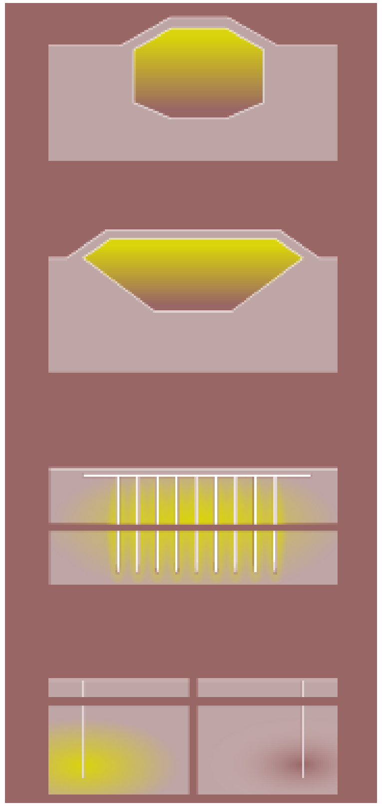
12 December 2019

The ECW heat network on satellite image, including future developments. Red icon is storage (ATES), green icons are production (Geothermal well on the bottom, others are the planned Biomass installations) and blue is demand (greenhouses, currently represented in modeling software as 11 distinct demands).
https://www.heatstore.eu/documents/HEATSTORE_WP3_D3.6_Final_v2019.12.12.pdf

EXISTING PROJECTS (DE)

- Systems for seasonal heat storage have been developed in Germany since 1984. The following table indicates all the realized pilot storage systems in Germany.
- The table on the right hand side indicates all the realized pilot storage systems in Germany.
- All information regarding existing projects have been retrieved from the working group "long term heat storage", which is organized by the Solites research facility

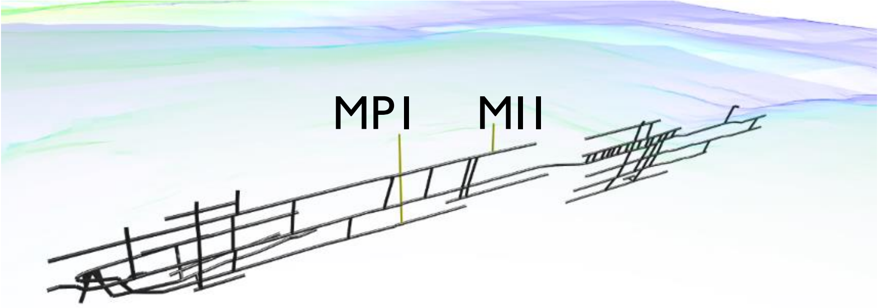
Location	Year	Type
Friedrichshafen	1996	TTES
Hamburg I	1996	TTES
Hamburg II	2010	TTES
Hannover	2000	TTES
München	2007	TTES
Augsburg	1998	PTES
Chemnitz	2000	PTES
Eggenstein	2008	PTES
Steinfurt	1998	PTES
Stuttgart	1985	PTES
Attenkirchen	2002	BTES
Crailsheim	2008	BTES
Neckarsulm	2001	BTES
Berlin	1999	ATES
Neubrandenburg	2004	ATES
Rostock	2000	ATES



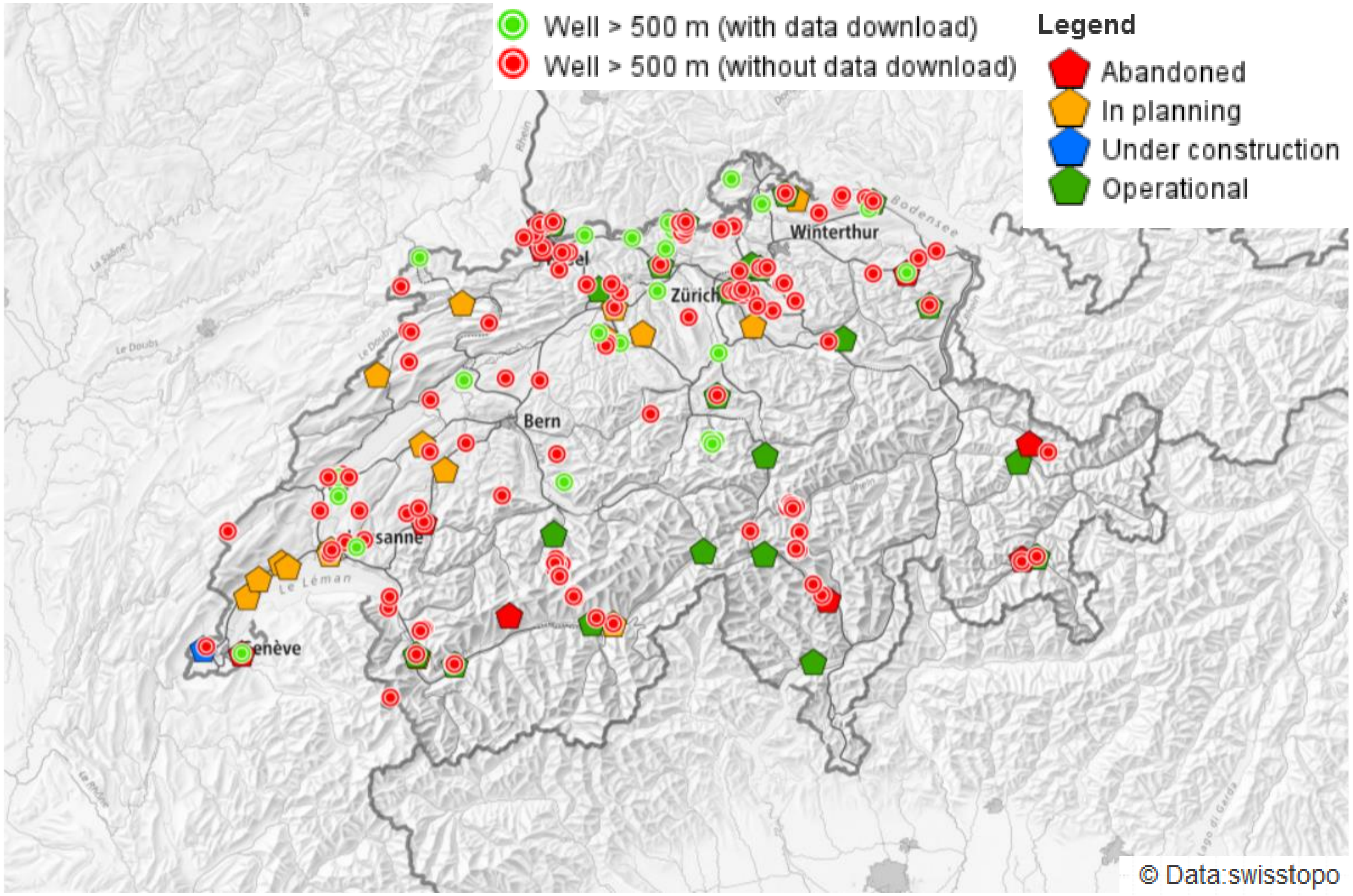
http://www.saisonalspeicher.de/Projekte/ProjekteinDeutschland/tabid/91/Default.aspx

DEMONSTRATION PROJECT (DE)

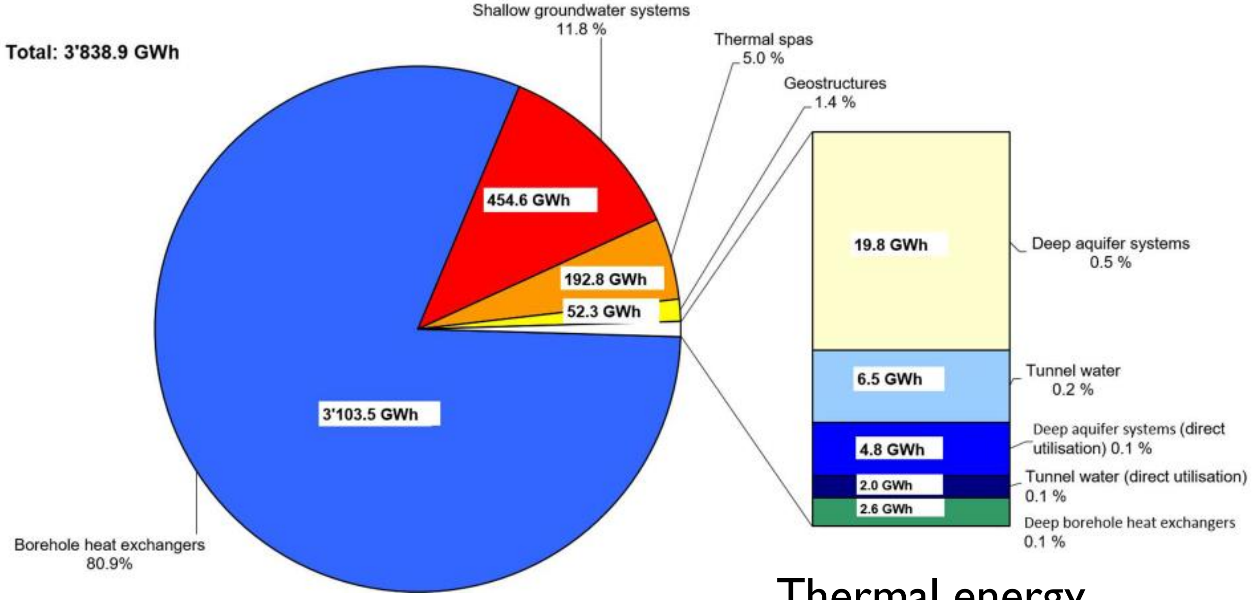
- Abandoned small colliery below the IEG premises in Bochum
- Mine is flooded to a level of 22 m bsl
- Heat source: 60 kW CSP plant
- Heat sink: G4 building on well site
- Seasonal heat storage in drift 4 (Ort 4) at a depth of 62 m bsl
- Liability agreement signed in Q2/2020
- Drilling of MP1, MO1 and MI1 well in Q3/2020
  - All wells reached their target within the stone drifts of the mine!
  - 2 out 3 wells showed high hydraulic conductivities during pump tests
- Preparation of first injection test in Q4/2020 with 60°C
- Planned production test in Q1/2021



EXISTING PROJECTS – NO ATES, GEOTHERMAL >500M (CH))

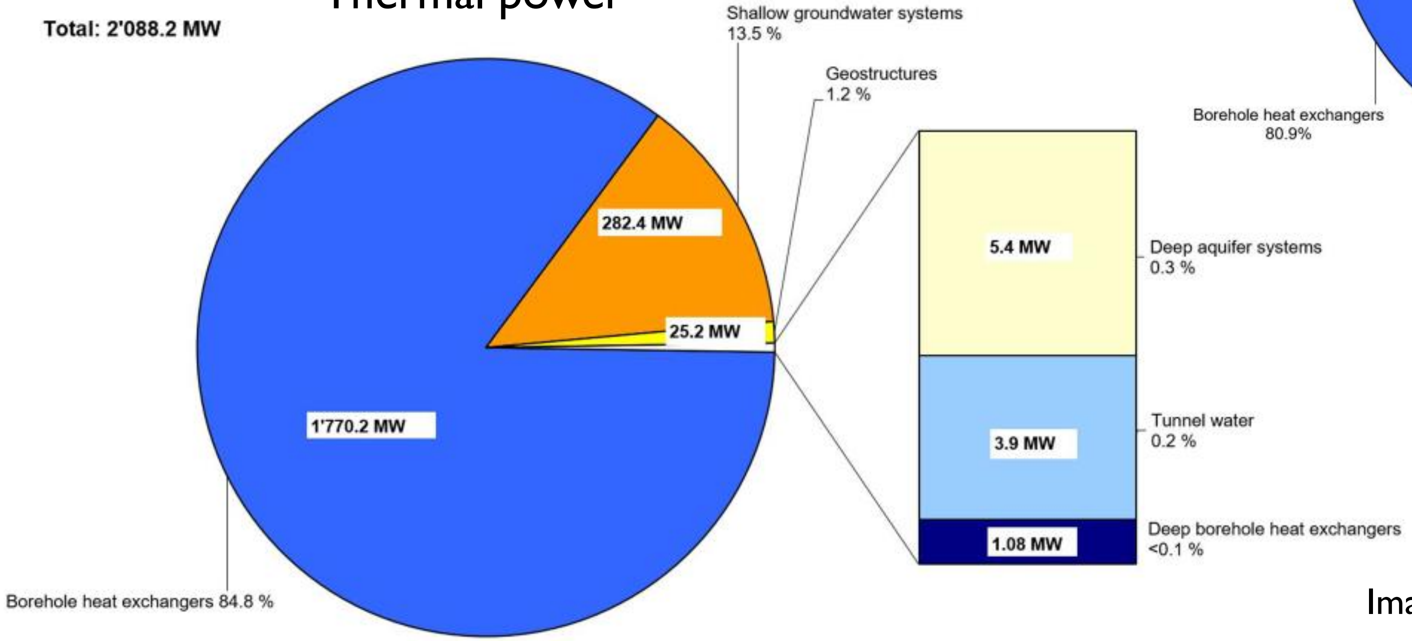


EXISTING PROJECTS – DIRECT USE GEOTHERMAL (CH)



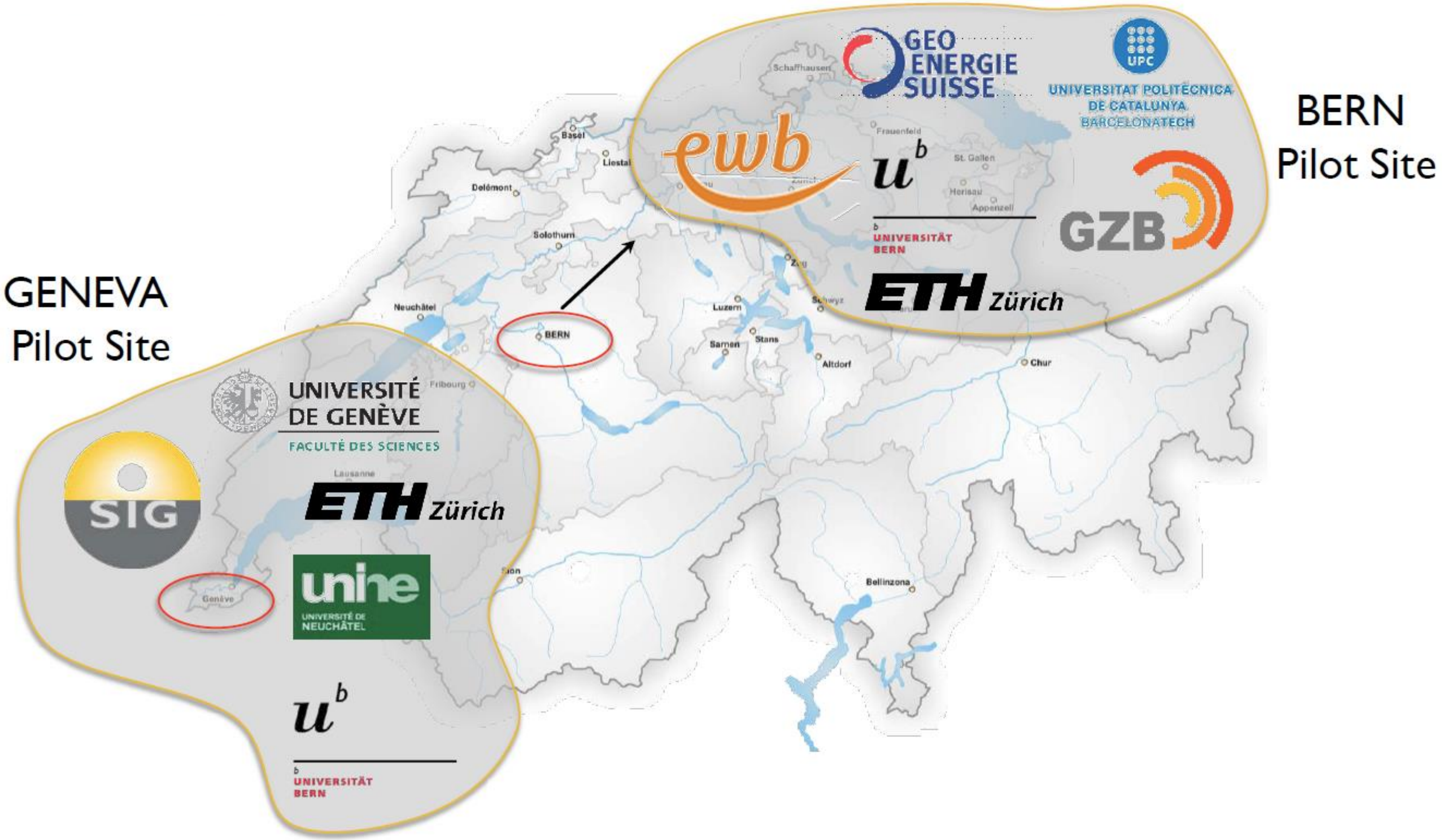
Thermal energy

Thermal power



Images source: Link, Lupi & Siddiqi WGC 2020 with data from: Link 2019

DEMONSTRATION PROJECT (CH)



DEMONSTRATION PROJECT (CH - GENEVA)

THE GENEVA PILOT PROJECT

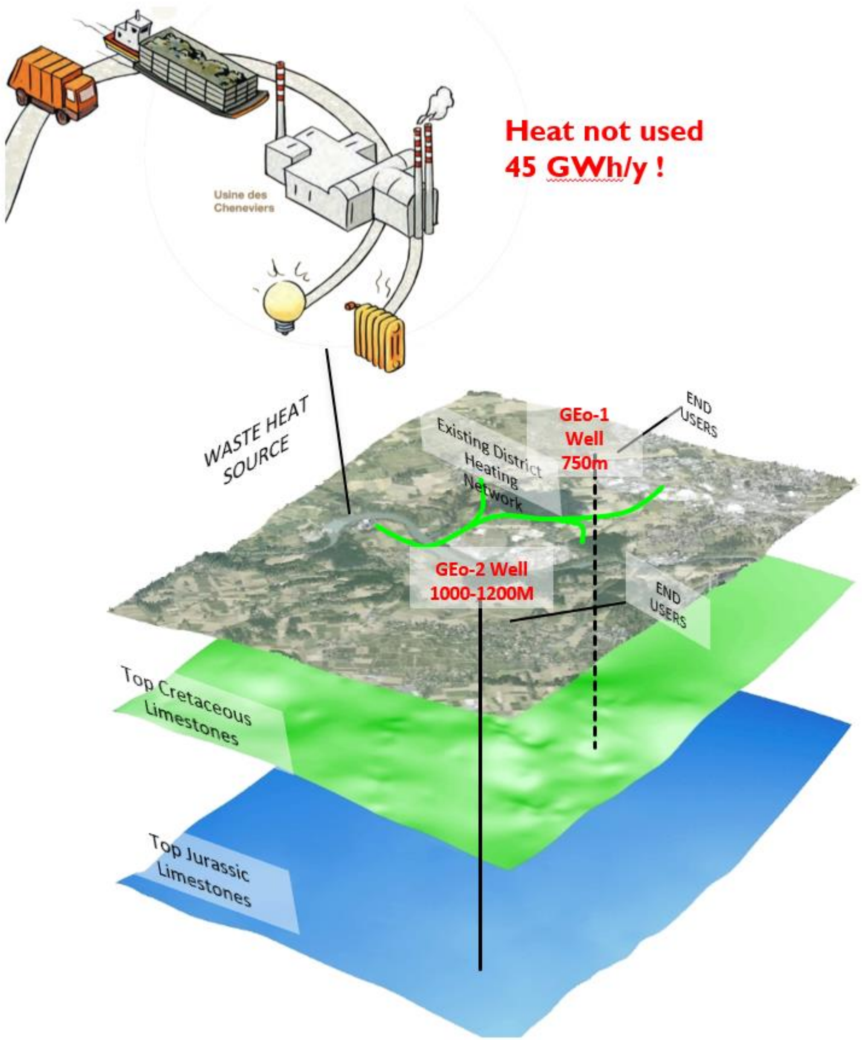
SIG — Drilling, data collection, business case modelling, regulatory framework

Université de Genève, Faculté des Sciences — Subsurface data integration and characterization, energy system scenarios, business modelling, EIA, national coordination

ETH Zürich — TH, THM reservoir modelling

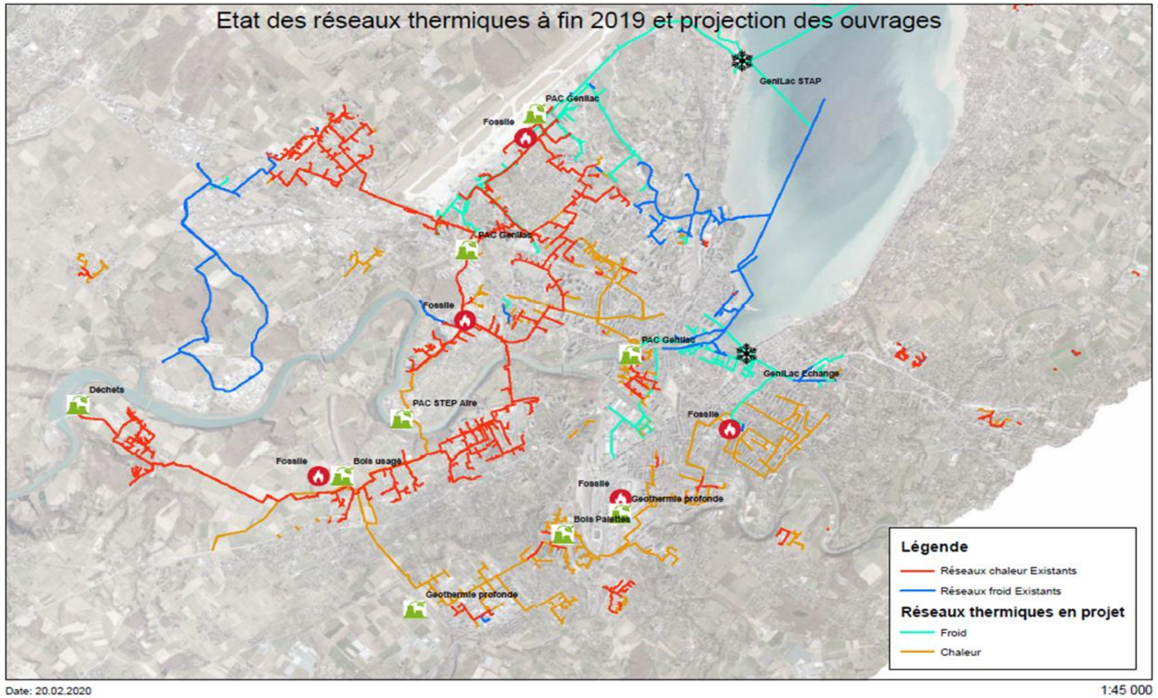
unine, Université de Neuchâtel — Reservoir geomechanical characterization

Universität Bern — THC modelling, Water-rock interaction laboratory experiments



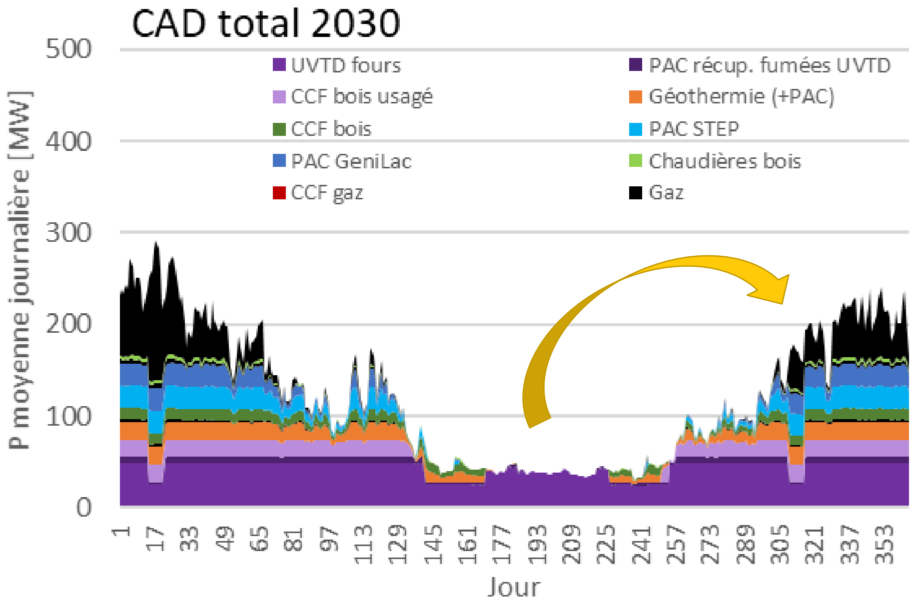
DEMONSTRATION PROJECT (CH - GENEVA)

Existing and planned extension of DHC networks
District heating sales:
From 450 GWh in 2019 to 1000 GWh in 2030



Potential for seasonal storage

Power injection	**8 MWth**
Annual injection	~20 GWhth
Loading temperature	75-90 °C
Unloading temperature	65-85 °C
Loading time	100 d
Unloading time	100 d
Storage losses	~20-40%
Flow rates	50 l/s



DEMONSTRATION PROJECT (CH - BERN)

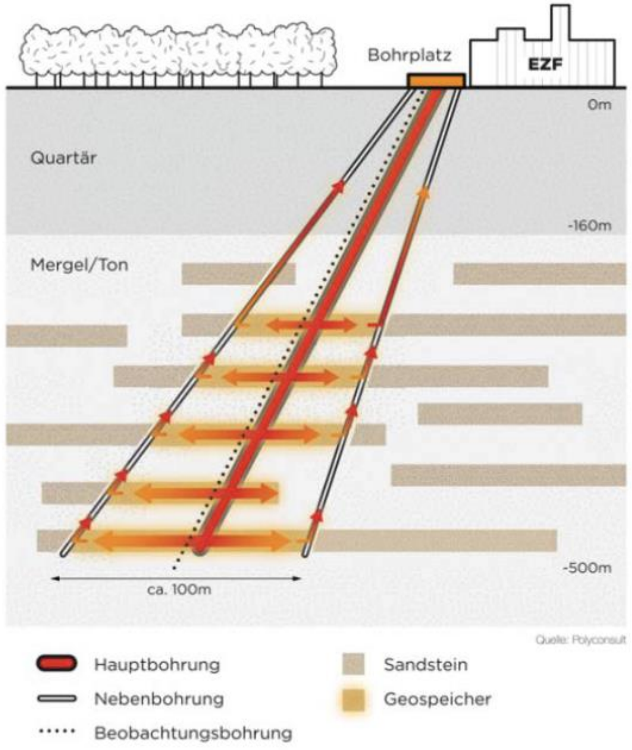
THE BERN PILOT PROJECT

ewb — Project owner

Geo-Energie Suisse — Project engineering partner

Universität Bern — Water-rock interaction laboratory experiments and modelling

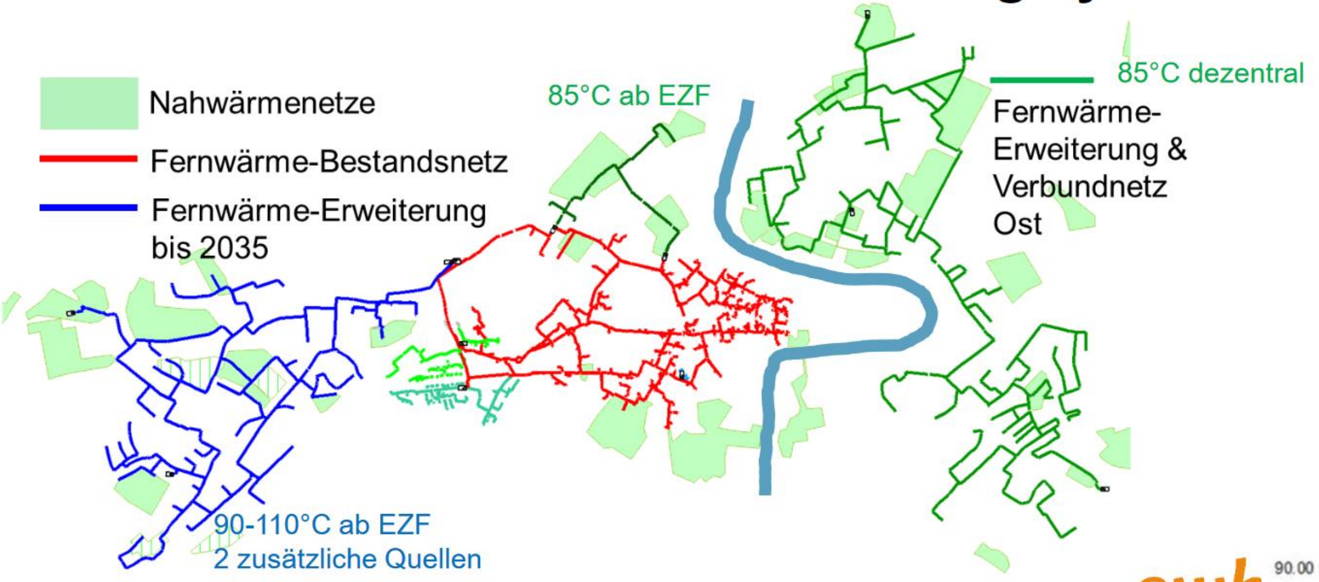
UPC Universitat Politècnica de Catalunya BarcelonaTech — THMC reservoir modelling



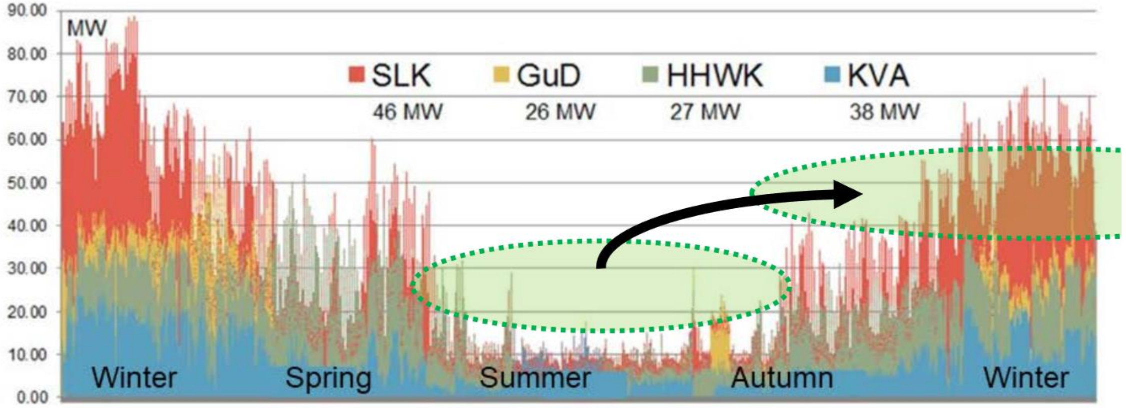
- Underground heat storage (P_{th} 3-12 MW of excess industrial heat) in sandstones of the Lower Freshwater Molasse (USM)
- Loading cycle during summer; un-loading during winter into the existing and expanding district heating network

DEMONSTRATION PROJECT (CH - BERN)

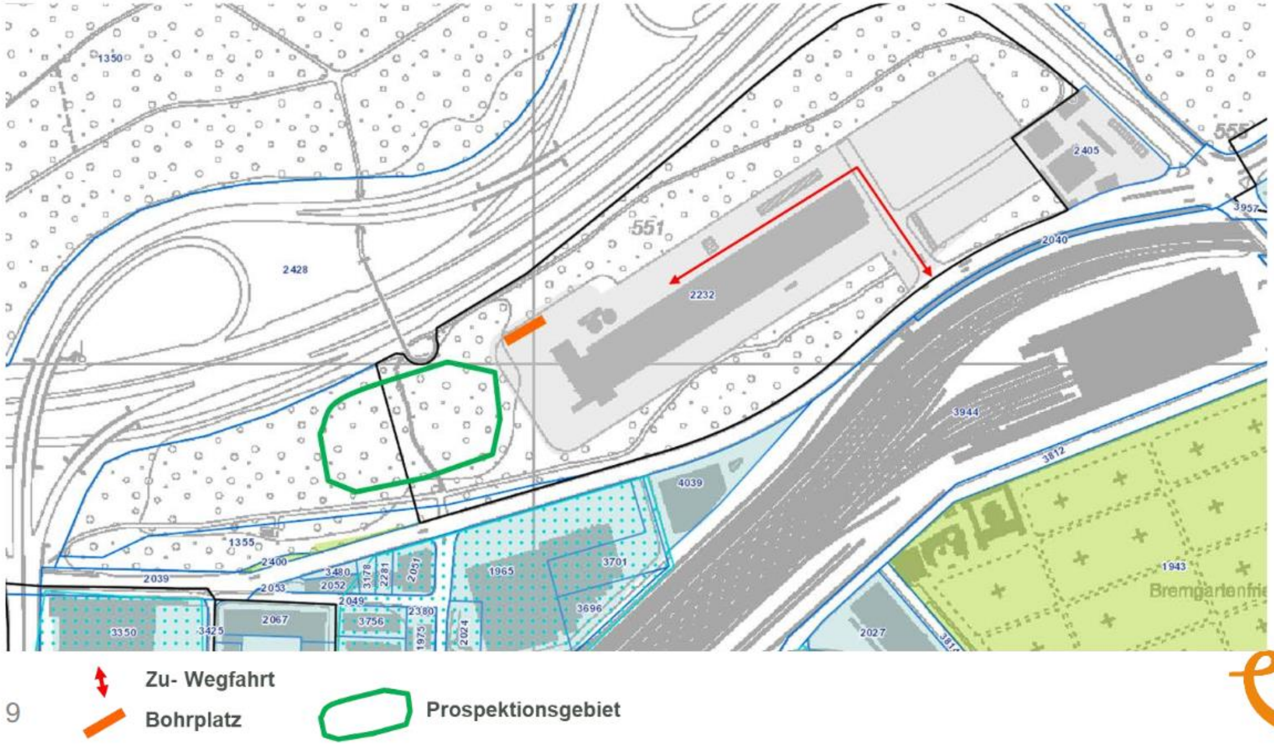
Planned extension of district heating system

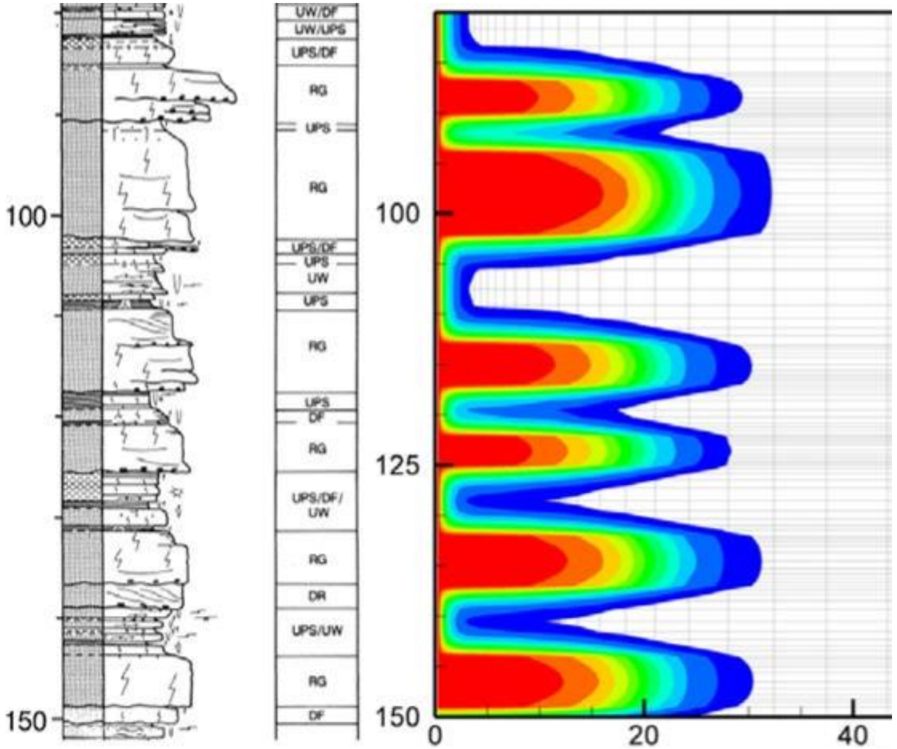


Power	**4 MWth**
Loading temperature	90 °C
Unloading temperature	60-85 °C
Loading time	217 d
Unloading time	146 d
Storage losses	~40%
Flow rates	25 l/s



DEMONSTRATION PROJECT (CH - BERN)





DEMONSTRATION PROJECT (FR)

- Initial location of the demo site within an Underground Gas Storage of Storengy made the costs above initial budget mainly due to the COMAH (Seveso) regulations
- New project identified in Annecy within a school in Vallin Fier neighborhood.
- The school is already equipped with 17 geothermal boreholes (100 m deep)
- The geothermal temperature is depleting faster than anticipated
- The new project consists in the conversion of the existing geothermal boreholes into a heat storage
- Additional thermal solar panels to be installed for heat recharging during summer
- Remedial project which can be replicated to extend the life of shallow geothermal systems
- No permitting required to drill the thermal borehole exchangers. Drilling of monitoring borehole contemplated.

SYNTHESIS & CONCLUSIONS

UTES BUSINESS MODEL CANVAS OVERVIEW

Key partners:	Key activities:	Value proposition:	Customer relationships:	Customer segments:
• Who are our Key Partners and suppliers in the thermal energy sector?	• What Key Activities do our Value Propositions require? • What are the key activities in; Distribution Channels, Customer Relationships and Revenue streams? • Which Key Activities do partners perform? **Key resources:** • What Key Resources do our; Value Propositions? Distribution Channels? Customer Relationships? Revenue Streams require? • Which Key Resources are we acquiring from partners?	• What value do we deliver to the customer in the thermal Energy sector? • Which one of our customer's problems are we helping to solve? • What bundles of products and services are we offering to each Customer Segment?	• What type of relationship does each of our customer segments expect us to establish and maintain with them? • Which relation have we established? How are they integrated with the rest of our business model **Channels:** Through which Channels do our Customer Segments want to be reached? How are we reaching them now? How are our Channels integrated? Which ones work best? Which ones are most cost-efficient?	• For whom are we creating value in thermal energy sector? • Who are our most important customers?

Cost structure:	Revenue streams:
• What are the most important costs inherent in our business model? • Which Key Resources and key activities are most expensive?	• For what value are our customers really willing to pay? • For what do they currently pay? • How are they currently paying? • How would they prefer to pay? • How much does each Revenue Stream contribute to overall revenues?

SYNTHESIS

- Future market potential not structurally assessed across EU countries, but indicatively positive.
- Value proposition evolves around
  - Security of heat supply for customers
  - Applying surplus and locally produced heat at low cost
  - Delivering low carbon heat supply to customers
- Value chain consisting of key partners, resources (including heat sourcing) and customer segments is varying considerably per country and heat network configuration.
- Ownership and contractual relationships between partners are important for structuring the business case.
- Business case for UTES is location and technology specific, depending strongly on:
  - Surface level value chain (see comment above)
  - Subsurface conditions
- The shown example projects indicate value stacking of value propositions adding to a positive business case. But in many situations requires (policy) incentives to achieve a positive business case. Decreasing financial risk for project developer and operators required.
- Cost & Revenue:
  - CAPEX is project specific but roughly shows an obvious high share for subsurface drilling, wells and pumps. Surface level equipment is considerably smaller part of total CAPEX but certainly not to be neglected.
  - OPEX is dominated by heat for loading and pumps (operation and replacement)
  - Revenue is influenced by time-value of heat sales, but is very case specific. And heat sales is certainly not the only prospected revenue (monetary and not) for UTES projects.

Recommendation

- Although projects are unique; follow a structural approach to establish a robust business case model for UTES in early phase of project development.

1. Characterise heat network and optimal embedding of UTES

2. Define key activities/services/ resources

3. Define actors/roles (ownership models and market structure)

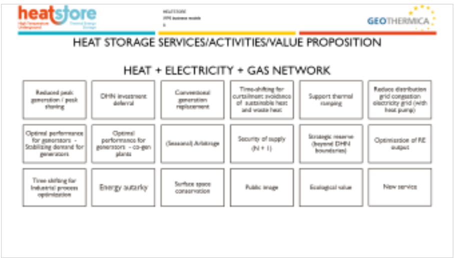
4. Define business case per actor

5. Identify and mitigate barriers & risks

METHODOLOGICAL FRAMEWORK BUSINESS MODEL UTES

1.Characterise network type for UTES
- Network temperature
- Sources and demand profiles, MW, MWh, seasonal signal)
- Topology of network
- UTES concept

2. Define key activities/services/ resources
- Describe the system services delivered / value proposition by UTES



3. Define actors/roles (ownership models and market structure)
- Which actors can take responsibility for which role?
- How is the market structured / governed
- Who are the customers? (households, greenhouses)

4. Define business models per actor
- Financing model
- Cost/resources structure
- Revenue/income model
- Partnerships
- Check investment and revenue division
- Contracts and risks sharing

5. Barriers & risks
- Regulatory barriers
- Technical barriers
- Market barriers
- Societal barriers

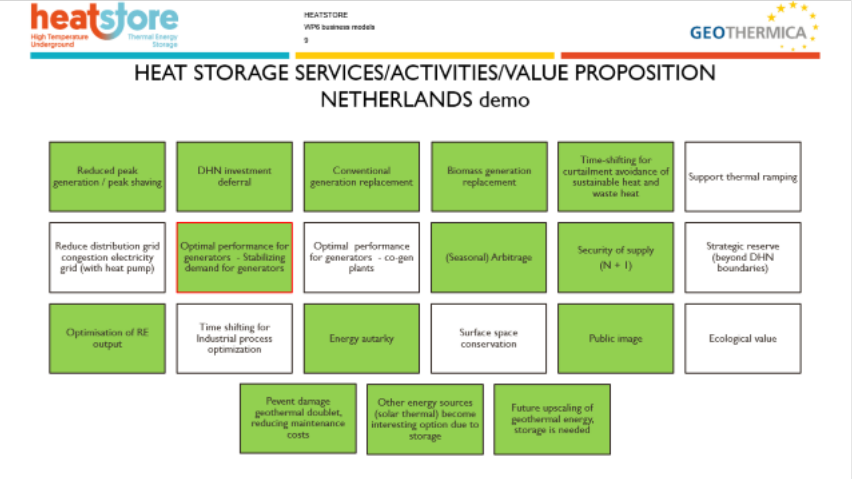
SYNTHESIS OF VALUE PROPOSITIONS: CASE EXAMPLES

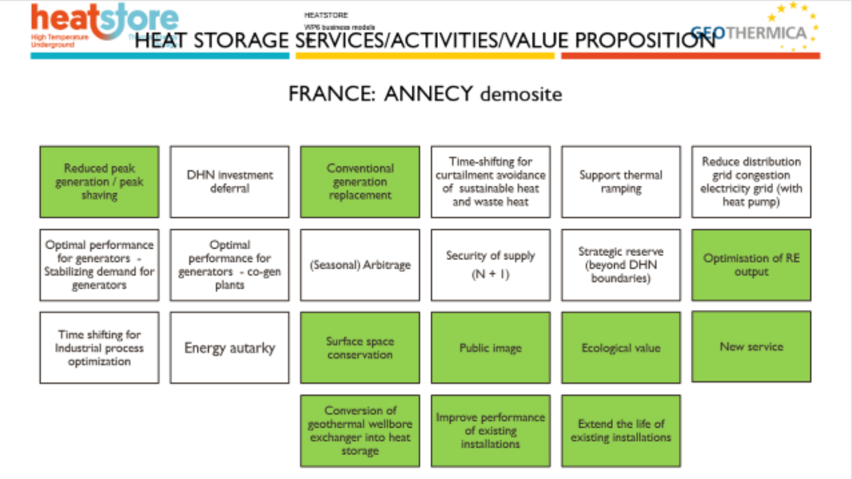
Observations:

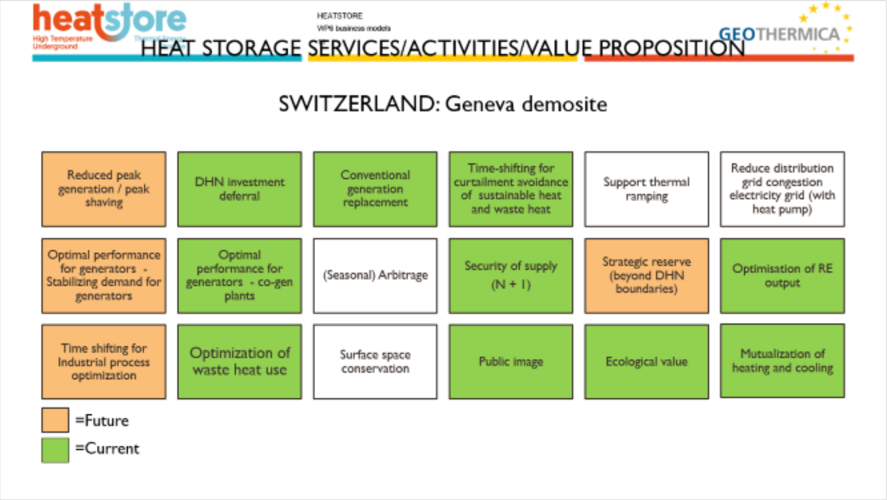
- Value stacking at all demonstration projects
- Site specific value propositions

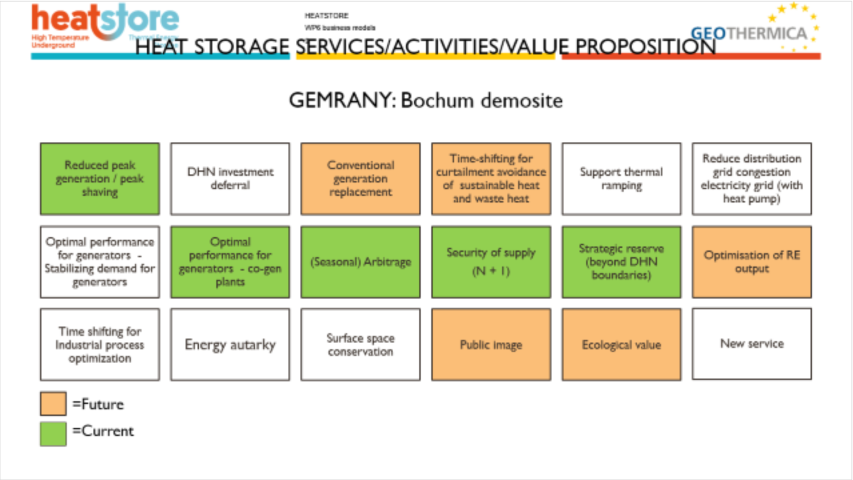
Recommendation

- With actors in value chain define system services by UTES in early phase of project development for all actors involved.









BUSINESS CASE RELATED BARRIERS HIGHLIGHTED

Lack of skills in the technology and/or not	knowing the technology exists/ non standard (Too few UTES examples)	**Large initial investment**	Finding the place for a storage in an urban environment	**unfair/indirect subsidy of fossil heat**
lack of attention for insulation,	reducing heat demand	Legislative & policy boundary conditions hinder fast-track uptake,	missing European policy	missing science-based concepts
Integration in heat grid (if not it won't grow)	Smart control to optimize efficiency	**The costs of storage solutions.**	**Good coordination between the heat suppliers, the network operator and the storage operator.**	**Financial questions associated with technological capacities.**
Environment(e.g. induced seismicity)	**Legal and policy framework**	**Economical feasibility**	Lack of geothermal systems	Underdeveloped district heating potential / infrastructure
Industry needs to see the opportunities and will want UTES	**Policy makers and scientists need to make the UTES business cases attractive and take away barriers**	The public needs to discover the potential and ownership of UTES and drop scepsis	Lack of knowledge about the relevance (feasibility) of UTES to decarbonise energy systems (market potential).	

Key takeways

- Observability and experience
- Relative advantages Economics
- Spatial implementation
- Environmental impacts
- Market competition and dynamics
- Policy and regulation
- Compatibility (integration in heat grid, smart control)
- Complexity vs simplicity. Good coordination needed

HEATSTORE consortium partners were asked what the Top 3 barriers: are for HT-UTES deployment

BUSINESS CASE RELATED DRIVERS HIGHLIGHTED

seasonal mismatch in availability and demand for heat	Reducing CO2 emissions and fossil fuels	Clear targests for industry and policy	**available funding schemes, national and international**
operator champions	Energy efficiency	The "sexy" and innovative side	self-sustained societies/ Energy autarky
Improving usability of renewable energy	**Technical and economical benefits**	Environmental benefits	Reduce barrier:1) Driving down risk 2) Driving down costs 3) Driving down resistance break down legal barriers
utilisation of excess heat.	Long-term strategic energy planning.	Expansion of existing networks and new thermal networks (district heating and or low-temperature prosumer H&C networks)	**good business cases**
	power to heat		

Key takeways

- Reduce CO2 emissions and fossil fuel use
- Security of supply
- Seasonal mismatch in supply and demand
- Utilisation of renewable energy and excess heat (avoid curtailed heat and power)
- Expansion of existing and new thermal networks
- Niche market business case
- Targets and funding schemes
- Need for industry champions

HEATSTORE consortium partners were asked what the Top 3 drivers: are for HT-UTES deployment

UTES BUSINESS MODEL CANVAS: KEY PARTNERS

SIMILARITIES	• Local authorities • Engineering companies • Heating grid owners • Energy producing companies
DIFFERENCES	• Research partners (e.g. UniGE, UniNe, UniBe) • Differences depending on the amount of investment (e.g. banks) • The amount of involvement of authorities and their ranks (e.g. municipal, Canton,…)

UTES BUSINESS MODEL CANVAS: KEY ACTIVITIES

SIMILARITIES	• Low-cost heat • Security of supply • Integration to existing networks • Renewable sources • Design • Support • Maintenance and monitoring
DIFFERENCES	• Pilot demonstration (related to market maturity) • Policy goals (depends on interpretation) • Strategic planning where public actors are involved • Differences in legislation causes some extra activities (Metering & billing the end consumer) • Projects have tasks (transforming existing heat grid) done by ECW or sometimes partners

UTES BUSINESS MODEL CANVAS: KEY RESOURCES

SIMILARITIES	• Specific technical expertise from partners • Services from partners • Financial resources • Geological Information (e.g. Underground Properties)
DIFFERENCES	• Spatial distance of demand and source (depending on ATES type) • Legal constraints (e.g. mines) • Availability of surplus heat

UTES BUSINESS MODEL CANVAS: VALUE PROPOSITION

SIMILARITIES	• Reduced peak generation / shaving • Load shifting • Security of supply • CO_2 emission reduction • Energy autarky • Becoming "Green"
DIFFERENCES	• Customer characteristics (single vs multiple) • Complexity of end product (only heat vs additional products) • Legal constraints (e.g. obligation to conform) • Adding value to waste streams (e.g. FR and CH) • Reusing of abandoned, unused Mines (e.g. DE)

UTES BUSINESS MODEL CANVAS: CUSTOMER RELATIONSHIPS

SIMILARITIES	• Long term relationship • Stakeholder relationship (in most cases)
DIFFERENCES	• Mostly related to the supply-demand structure of stakeholders (single vs multiple)

UTES BUSINESS MODEL CANVAS: CHANNELS

SIMILARITIES	• Direct supplier – customer contact
DIFFERENCES	• Complexity increases with the supply-demand structure of stakeholders (single vs multiple) • Social networks • Conferences / webinars • Promotion videos • Regular mailings • Articles

UTES BUSINESS MODEL CANVAS: CUSTOMER SEGMENTS

SIMILARITIES	• Industrial • Heat grid owner
DIFFERENCES	• Segments depend heavily on the situation (e.g. Building owner or end user) • Municipal utilities • Heat delivery varies (e.g. CHP Plants, farmers)

UTES BUSINESS MODEL CANVAS: COST STRUCTURE

SIMILARITIES	• CapEx / drilling costs dominant • Connection with existing infrastructure • OpEx / maintenance and operating cause constant cost
DIFFERENCES	• Characterisation of resource a significant cost (market maturity dependent)

UTES BUSINESS MODEL CANVAS: REVENUE STREAMS

SIMILARITIES	• Security of supply • Affordable
DIFFERENCES	• Low carbon energy • Heat / Energy storage

CONCLUSIONS

NL	DE	CH	F
• Inclusion of UTES in energy system scenarios and planning. • Incentive for renewable/waste heat/curtailed heat utilization. • Opportunity to stack value in system services to heat grid. • Energy storage support scheme on investment and/or operational expenses."valley of death' support through early market uptake. • Regulatory framework development (currently only under pilot permitting regime).	• Streamlining the process of granting permission. • Close cooperation with heat grid owner (e.g. local municipality) for integration into district heating grid. • Energy storage regulatory framework development including incentives for increasing utilization of surplus heat. • Development of economically efficient downhole pumps for HT applications.	• Techno-economic assessment of case studies (underway). • Integration of ATES to overall energy system / DHN needs further strengthening. • Larger scale assessment of ATES (multiple systems).	• Incentive for waste heat usage and/or decarbonized heating. • Development of district heating network for new neighbourhood rehabilitation.

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HEATSTORE (170153-4401) is one of nine projects under the GEOTHERMICA – ERA NET Cofund aimed at accelerating the uptake of geothermal energy by 1) advancing and integrating different types of underground thermal energy storage (UTES) in the energy system, 2) providing a means to maximise geothermal heat production and optimise the business case of geothermal heat production doublets, 3) addressing technical, economic, environmental, regulatory and policy aspects that are necessary to support efficient and cost-effective deployment of UTES technologies in Europe. The three-year project will stimulate a fast-track market uptake in Europe, promoting development from demonstration phase to commercial deployment within two to five years, and provide an outlook for utilisation potential towards 2030 and 2050.

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