INTEGRATE

Integrating seasoNal Thermal storagE with multiple enerGy souRces to decArbonise Thermal Energy

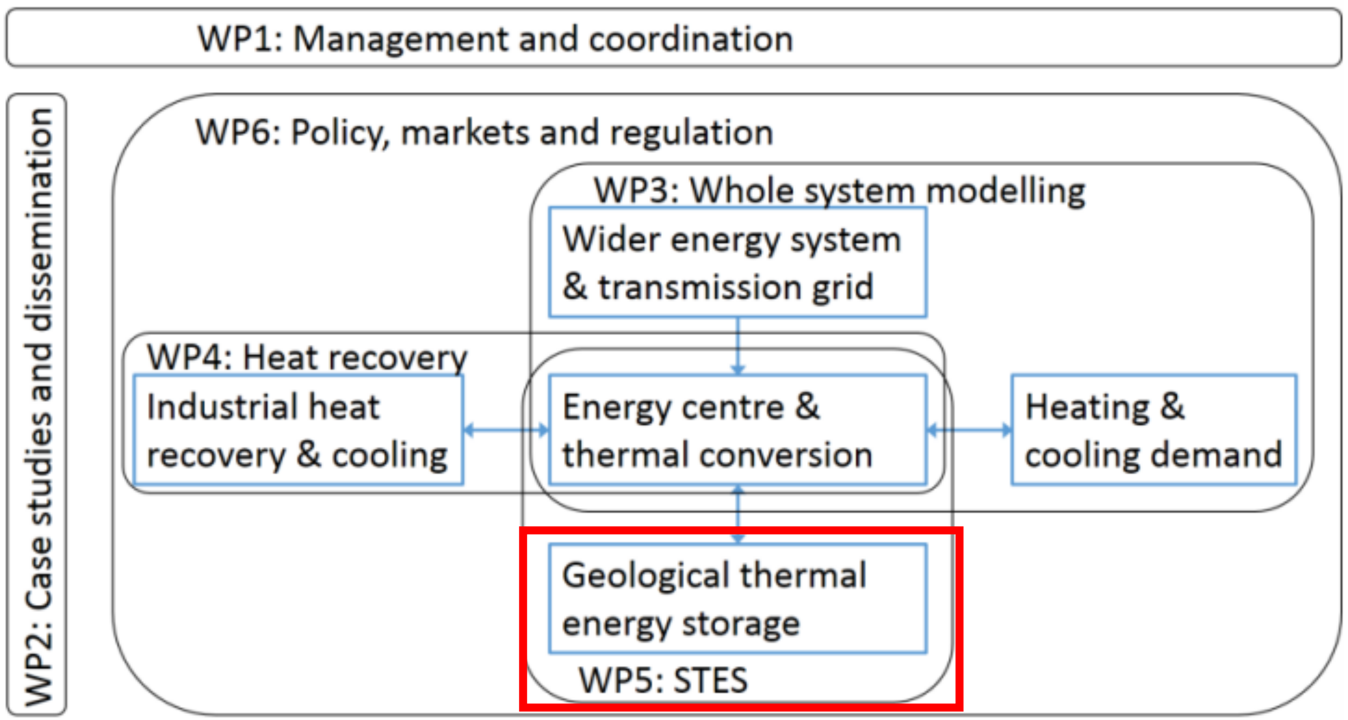
Subsurface Modelling

Presented by **Prof. Gioia Falcone**

University of Glasgow

Co-I: Dr. R. Westaway

Seasonal underground thermal energy storage



WP5

This work package will assess ATES and BTES options to identify the most efficient and resilient solutions, based on the case studies and the estimates of thermal energy storage requirements.

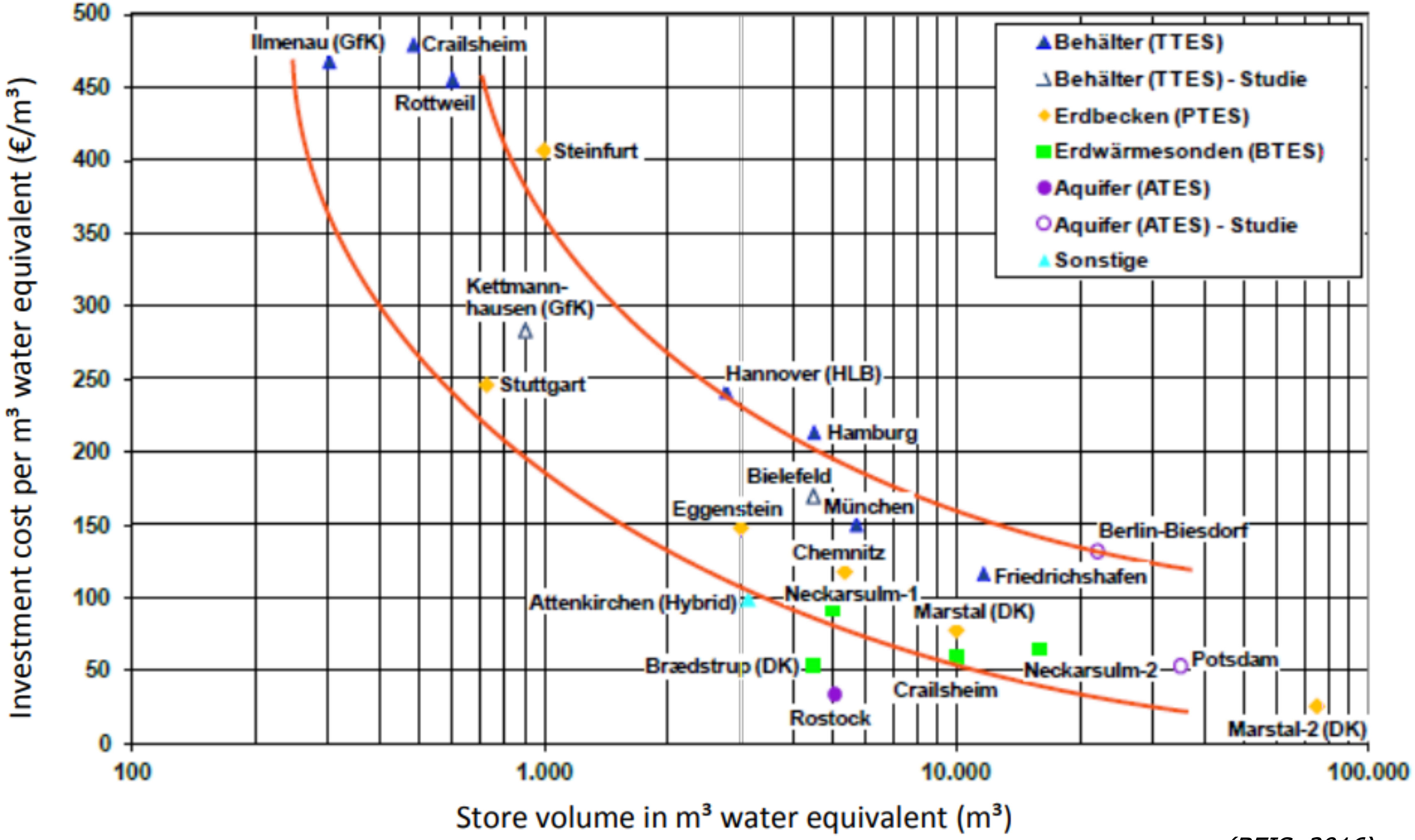
Thermal Energy Storage (TES) technologies

(BEIS, 2016)

Type of TES	Description	Energy input	Key application areas[4]	System efficiency[5]	Market status (TRL)
TTES	Tank systems usually storing hot water, but molten salts and heat transfer oils have also been used extensively (depending on temperature required).	All conventional and renewable heating systems (boilers, CHP, heat pumps, biomass, solar thermal).	D / C / DH	50-90%	9
PTES	Shallow pits dug in the ground, which are then lined and filled with gravel and / or water for energy storage.	Larger solar thermal installations, as PTES is most beneficial at scale (plus interaction with other heat inputs for district heating).	C / DH	Up to 80%	6-8
BTES	Regularly spaced vertical holes are drilled into the ground, with heat exchangers inserted to transfer heat to and from the ground.	Solar thermal, ground source heat pump for extraction, potentially CHP, gas turbines, waste heat.	D / C / DH	6-54% (Efficiency commonly increases the longer system is in operation)	6-8
ATES	Open-loop system utilising natural underground water-bearing permeable layers from which groundwater is extracted.	Ground source heat pump, waste heat, CHP.	C / DH	70-90%	5-8
PCM	Using organic or inorganic compounds to store energy in the form of heat in the material's change of phase (usually from solid to liquid, but also from liquid to gas).	All conventional and renewable heating systems (boilers, CHP, heat pumps, biomass, solar thermal), solar PV.	D / C / DH	75-90%	5-8
THS	Reversible chemical reactions to store large quantities of heat in a compact volume.	Most likely industrial heat, but theoretically variety of heat sources.	C / DH	Potentially very high (up to 100%), but in practice so far low.	1-5

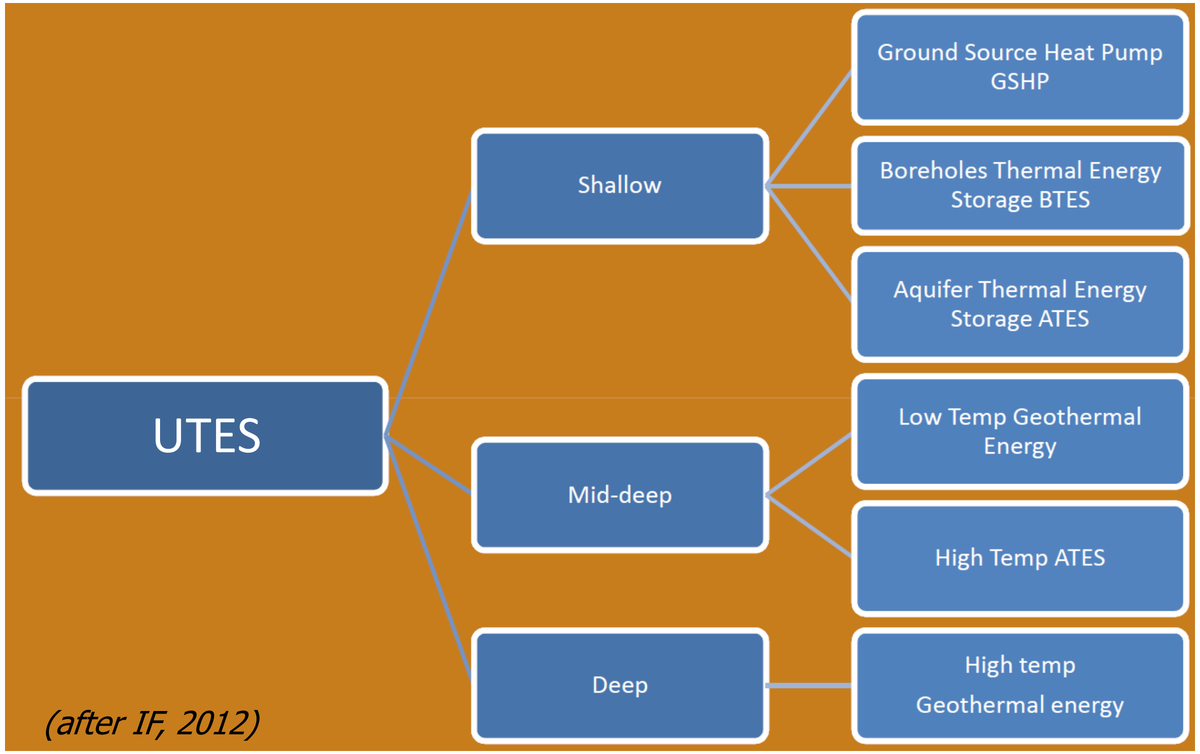
Category	Type of TES	Description	Key advantages	Disadvantages
Sensible heat storage	TTES	Tank systems usually storing hot water, but molten salts and heat transfer oils can also be used.	Established and proven Scalable Usable for wide range of applications Cost effective	Space requirements Smaller stores have higher heat loss rates and are not designed to store heat over long periods of time
	PTES	Shallow pits dug in the ground, which are then lined and filled with gravel and / or water for energy storage.	Potential very large storage capacity Interseasonal potential (e.g. solar heat storage)	Low energy density Not suitable for built-up areas Potential land cost constraints
	BTES	Regularly spaced vertical holes drilled into the ground, with heat exchangers inserted to transfer heat to and from the ground (closed loop system).	Interseasonal potential (e.g. solar heat storage) Relatively small excavation requirements	Relatively low efficiency Limited charging and discharging capacity
	ATES	Open-loop system utilising natural underground water-bearing permeable layers from which groundwater is extracted.	Efficient provision of heating and cooling Easily integrated into building design, thus small land footprint	Hydrogeological restrictions Balancing of heat input and extraction Limited to places where extraction is possible
Latent heat storage	PCM	Using organic or inorganic compounds to store energy in the form of heat in the material's change of phase (usually from solid to liquid, but also from liquid to gas).	High energy density Low volume of store Constant temperature during charging and discharging.	Relatively immature technology in the domestic segment Limited availability of suitable PCM materials with desired melting points
Thermo-chemical heat storage	THS	Reversible chemical reaction to store large quantities of heat in a compact volume.	Very high energy density Long term storage without degradation	Very far away from market commercialisation Lack of real world proof of potential performance

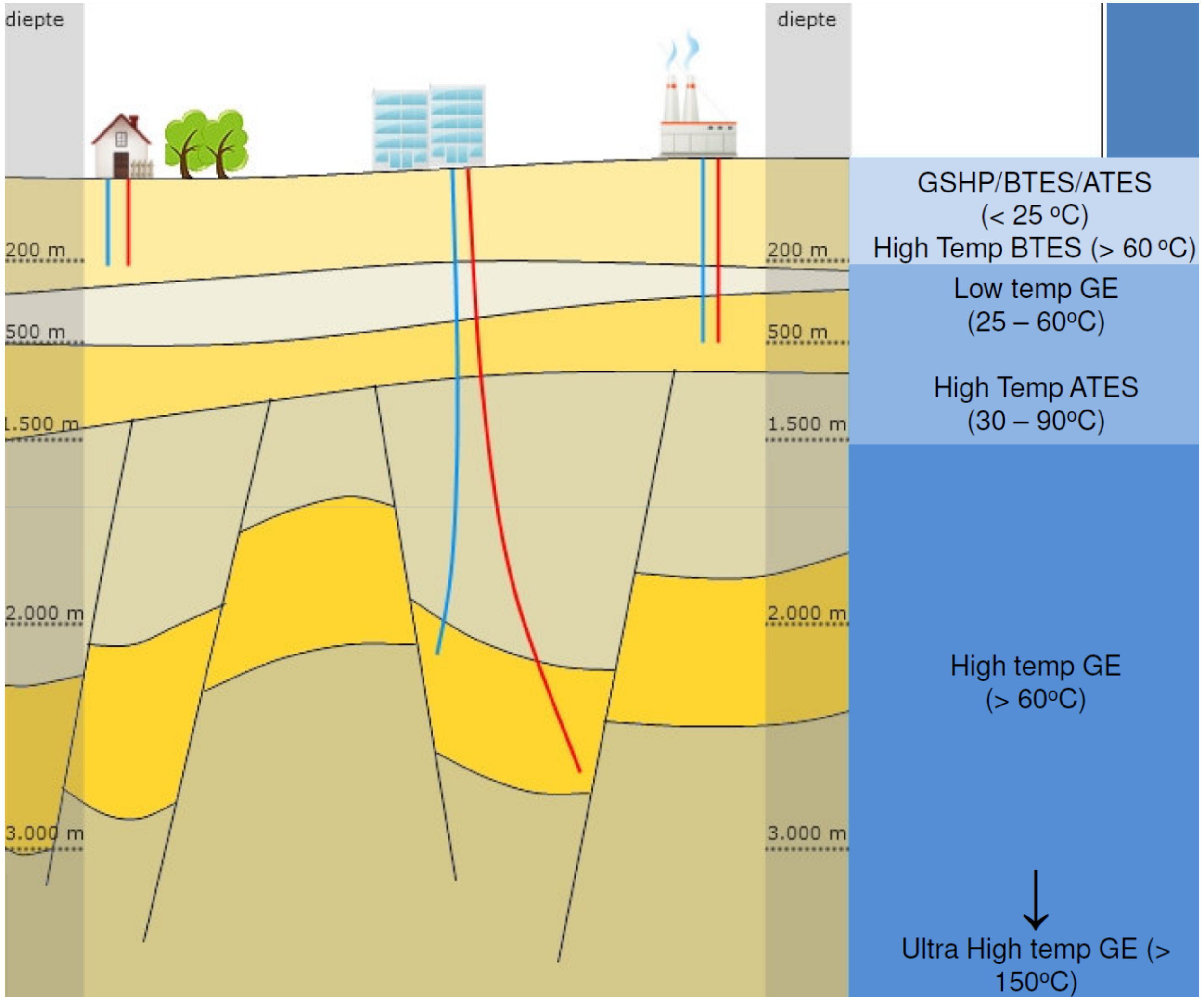
TES costs



(BEIS, 2016)

Underground Thermal Energy Storage (UTES)



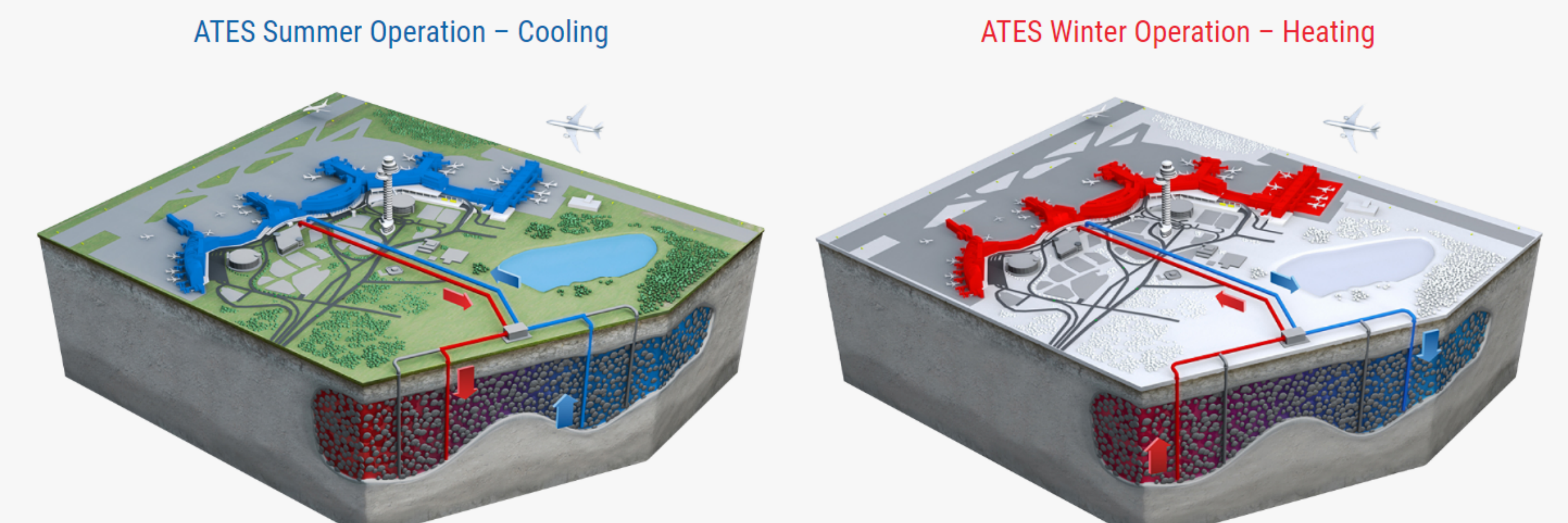


Main Applications

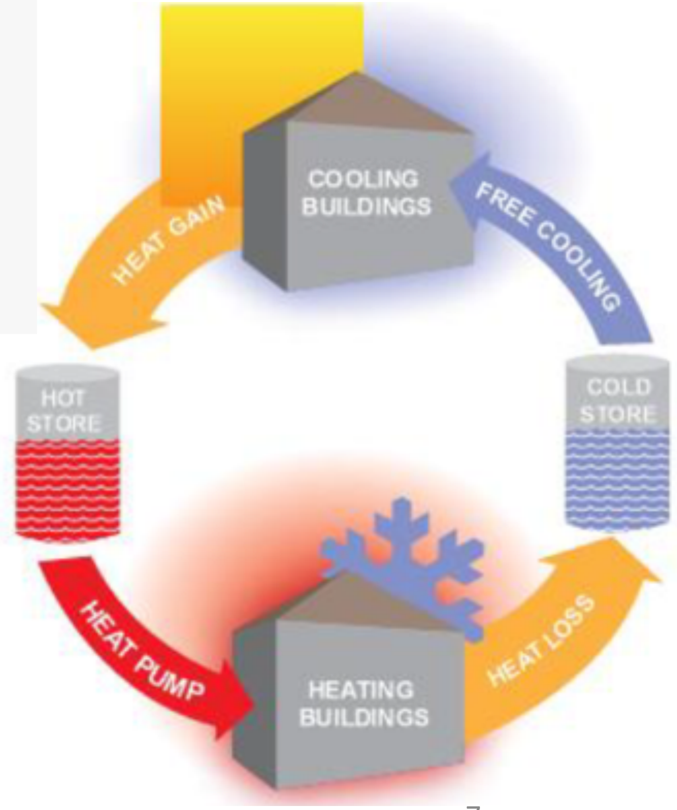
- Boreholes
  - Ground Source Heat Pump (GSHP) for heating
  - BTES and heat pump for heating and (limited) cooling
- Aquifer Thermal Energy Storage (ATES)
  - Cooling only (charging cold in winter)
  - Heat pump for heating (charging heat in summer)
  - Cooling and heat pump for heating (energy balancing)
- High temp ATES/BTES
  - Direct heating by storage of (waste) heat

(after IF, 2012)

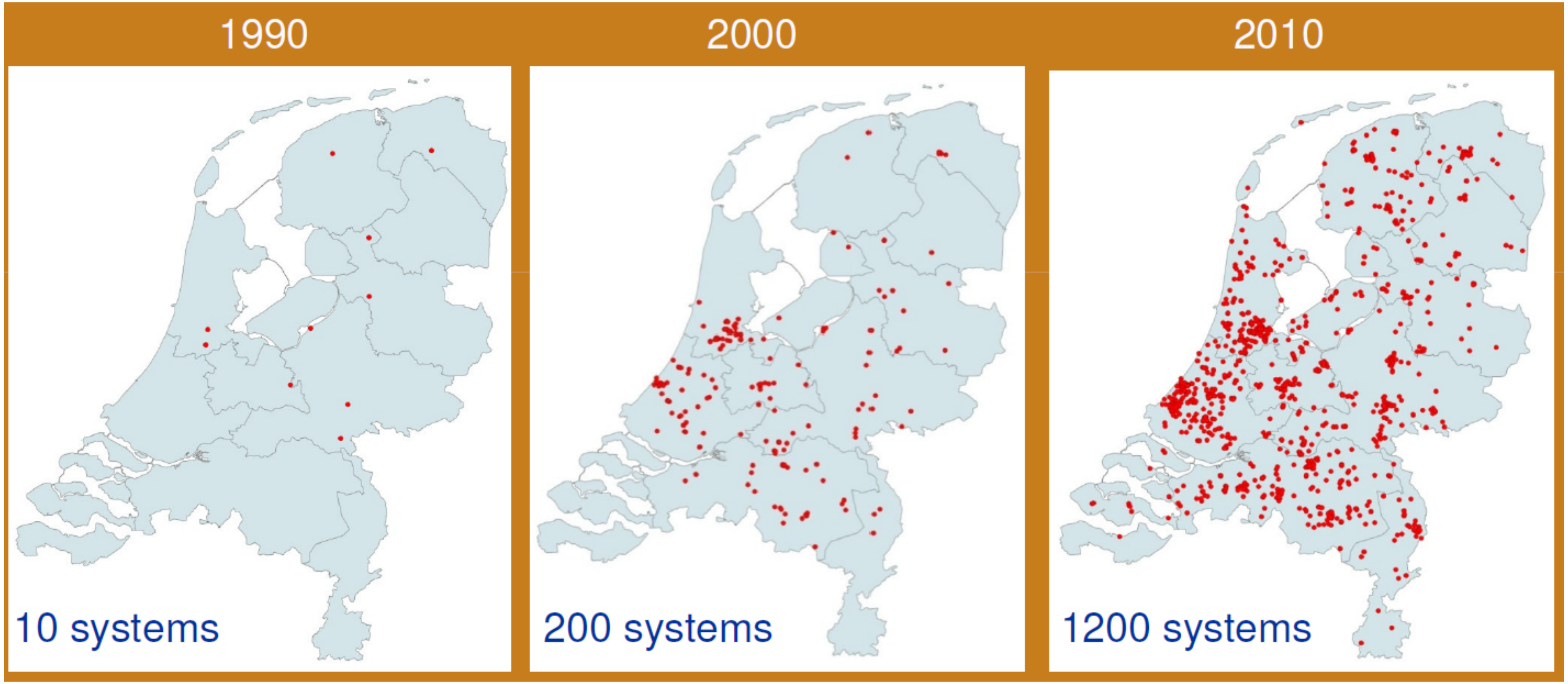
ATES Principle



(underground energy, 2019)



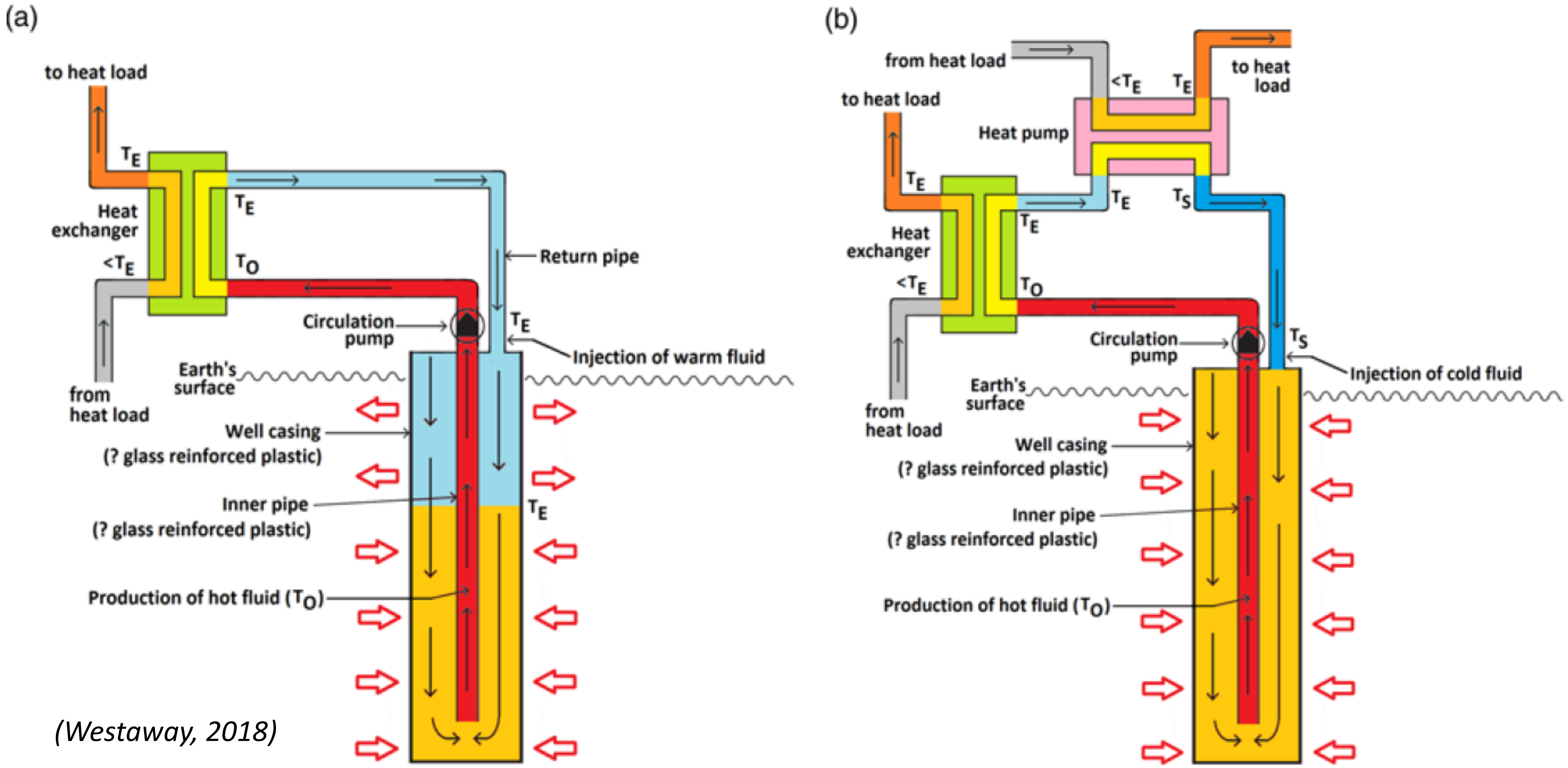
Growth of ATES systems in The Netherlands



(IF, 2012)

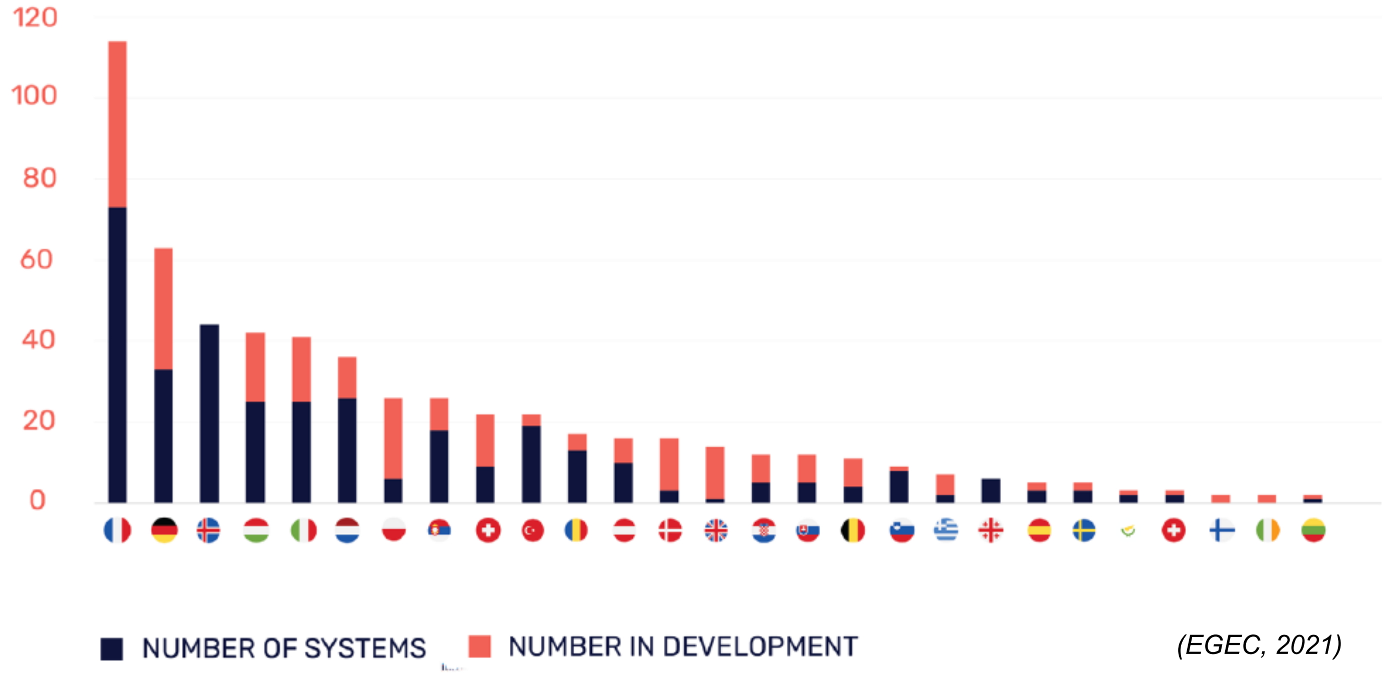
…now over 3000 systems!

Deep BTES

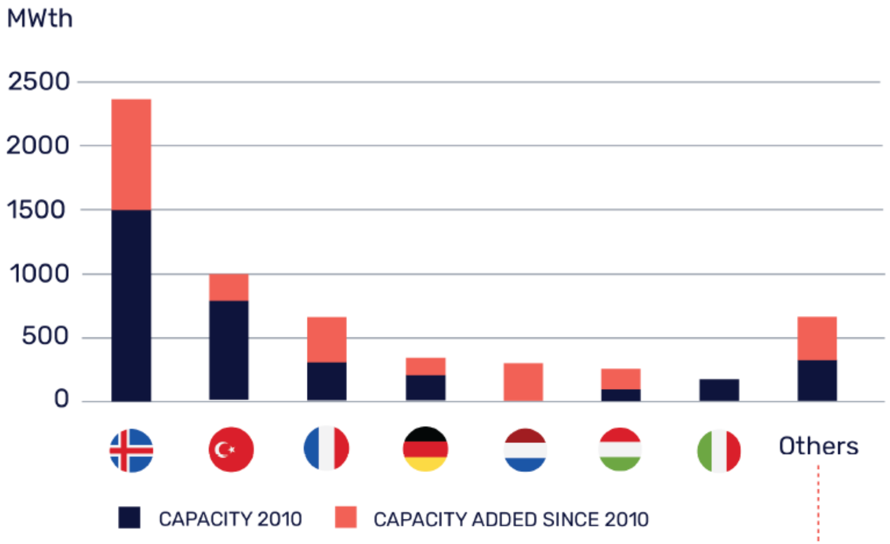


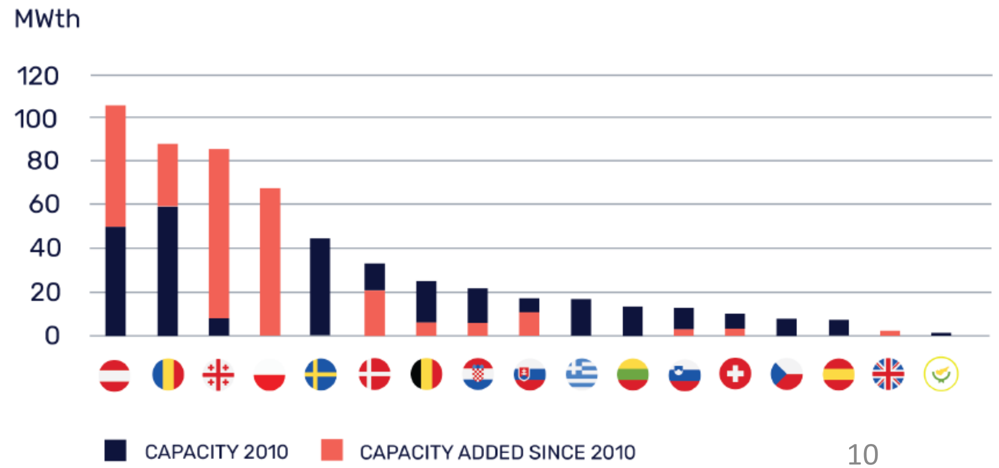
(Westaway, 2018)

Geo-District Heating & Cooling in EU



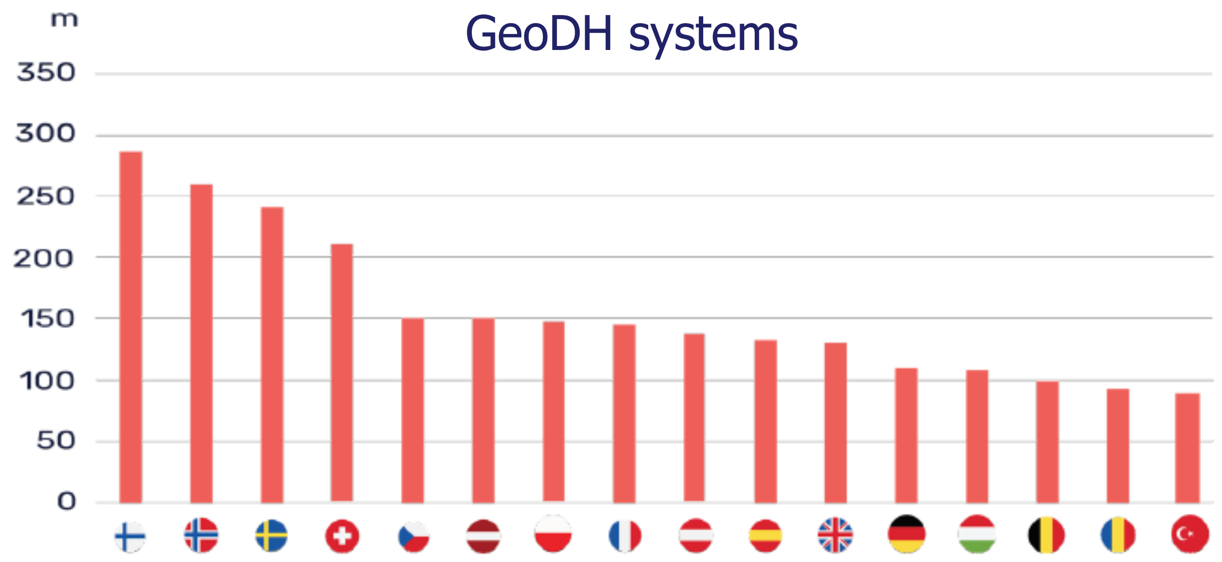
(EGEC, 2021)





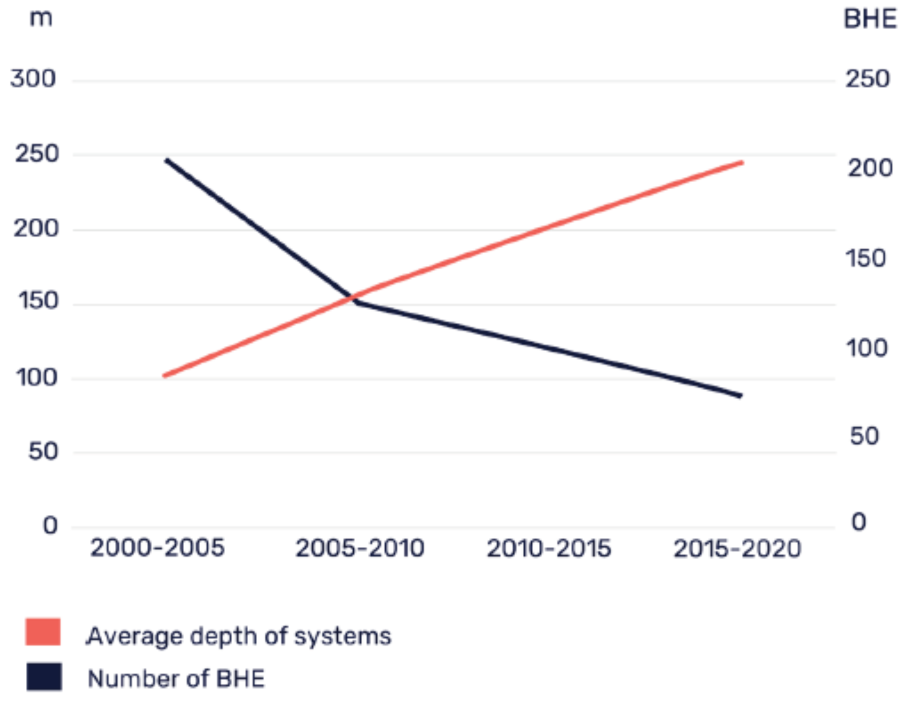
Average Well Depth

GeoDH systems



(EGEC, 2021)

Large heat geothermal pump systems



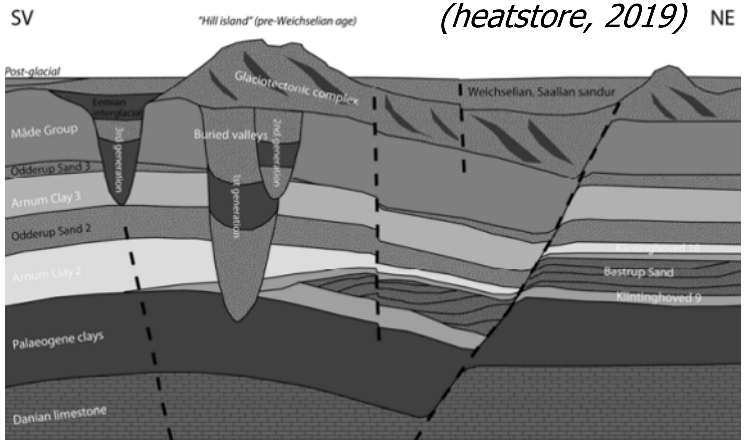
Trend is to develop deeper wells and larger systems.

Subsurface Modelling – Integrated Approach

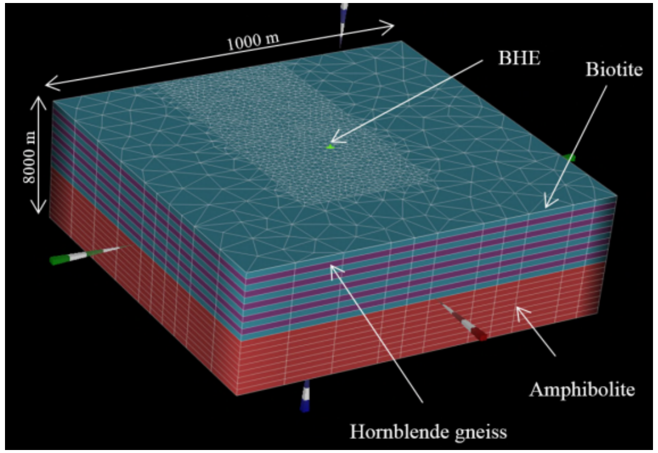
- **Geological model**
- **Groundwater & heat transport model**
- **Geochemical model**
- **Boreholes/wells performance model**

(e.g., HST3D, Modflow/SEAWAT, FEFLOW, ANSYS, TOUGH, T2Well)

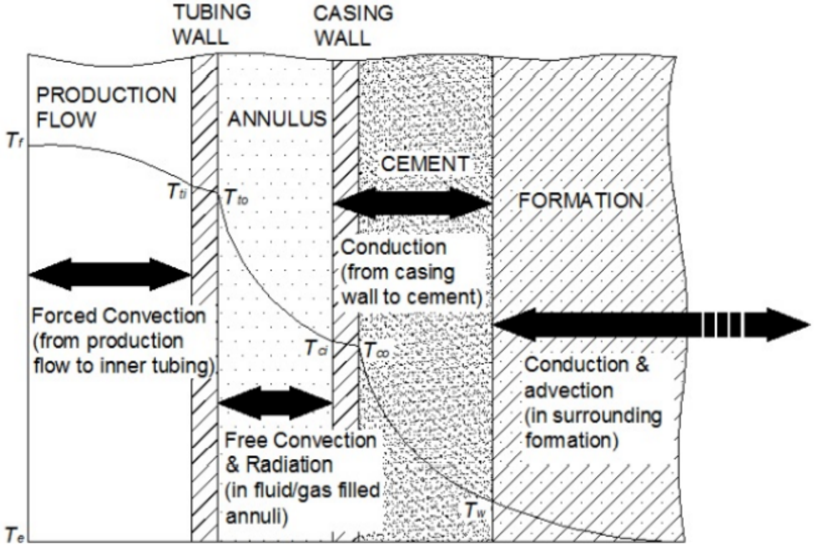
- **Dynamic interface with surface model**

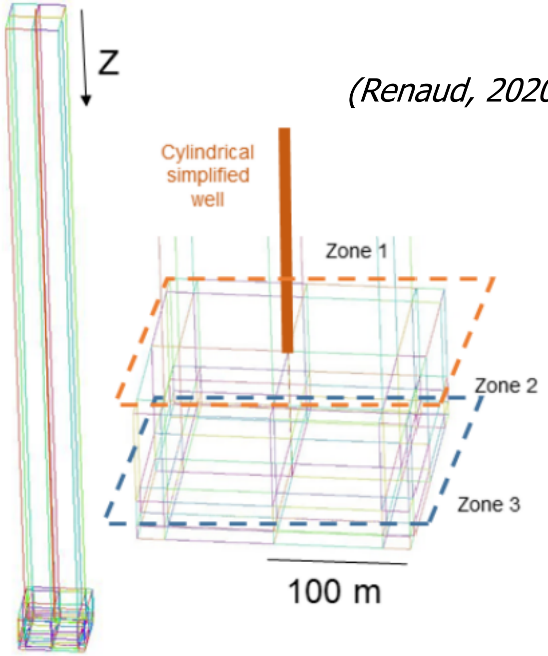


(heatstore, 2019)



(Falcone et al., 2018)





(Renaud, 2020)

Subsurface Modelling – Integrated Approach

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Dynamic interface with surface model

Analytical & numerical modelling will be performed to assess the steady-state and transient output of BTES & ATES systems vis-à-vis seasonal demand.

Solutions tailored to geological settings and network integration of different case studies.

Simulations aim to assess the operating envelope of each UTES solution and the overall uncertainty in storage potential.

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Thank you!