HEATSTORE

Public acceptance of UTES and geothermal projects – best practice learnings

Prepared by: Kristian Borch (PlanEnergi)

Checked by: Per Alex Sørensen (PlanEnergi)
Joris Koorneef (TNO)

Approved by: Holger Cremer (TNO), HEATSTORE coordinator

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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.

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About HEATSTORE

High Temperature Underground Thermal Energy Storage

The heating and cooling sector is vitally important for the transition to a low-carbon and sustainable energy system. Heating and cooling is responsible for half of all consumed final energy in Europe. The vast majority – 85% - of the demand is fulfilled by fossil fuels, most notably natural gas. Low carbon heat sources (e.g., geothermal, biomass, solar and waste-heat) need to be deployed and heat storage plays a pivotal role in this development. Storage provides the flexibility to manage the variations in supply and demand of heat at different scales, but especially the seasonal dips and peaks in heat demand. Underground Thermal Energy Storage (UTES) technologies need to be further developed and need to become an integral component in the future energy system infrastructure to meet variations in both the availability and demand of energy.

The main objectives of the HEATSTORE project are to lower the cost, reduce risks, improve the performance of high temperature (~25°C to ~90°C) underground thermal energy storage (HT-UTES) technologies and to optimize heat network demand side management (DSM). This is primarily achieved by 6 new demonstration pilots and 8 case studies of existing systems with distinct configurations of heat sources, heat storage and heat utilization. This will advance the commercial viability of HT-UTES technologies and, through an optimized balance between supply, transport, storage and demand, enable that geothermal energy production can reach its maximum deployment potential in the European energy transition.

Furthermore, HEATSTORE also learns from existing UTES facilities and geothermal pilot sites from which the design, operating and monitoring information will be made available to the project by consortium partners.

HEATSTORE is one of nine projects under the GEOTHERMICA – ERA NET Cofund and has the objective of 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 maximize geothermal heat production and optimize 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 2 to 5 years, and provide an outlook for utilization potential towards 2030 and 2050.

The 23 contributing partners from 9 countries in HEATSTORE have complementary expertise and roles. The consortium is composed of a mix of scientific research institutes and private companies. The industrial participation is considered a very strong and relevant advantage which is instrumental for success. The combination of leading European research institutes together with small, medium and large industrial enterprises, will ensure that the tested technologies can be brought to market and valorised by the relevant stakeholders.

Document Change Record

This section shows the historical versions, with a short description of the updates.

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1 Introduction

In the recent past, public acceptance, or the lack thereof, has been a barrier for the implementation of technologies utilizing renewable energy (RE) sources such as hydro, wind, and solar power, as well as geothermal energy and subsurface heat storage.[1]
In this report we study public perception (often referred to as social acceptance in the literature) of underground heat storage (UTES) and geothermal technologies. This is done partly as a literature review on public acceptance, and partly as a case study on UTES and geothermal technologies performed by partners within the HEATSTORE project.
Public acceptance is central in many debates surrounding energy projects. However, the existing literature has mostly used wind energy as a 'learning laboratory' in terms of social acceptance of energy projects ([2]). Despite its emerging significance, public acceptance of RE storage has been overlooked to date by energy researchers and thus, acceptance of underground thermal energy storage (UTES) technologies and geothermal technologies is not well understood. This is problematic as it provides a deficient evidence base to inform policy making and practice, and may lead to resistance towards technical solutions, which are based upon flawed assumptions about user or public expectations.

1.1 Community acceptance

A subcategory of public acceptance is community acceptance that refers to the specific acceptance of siting decisions and energy projects by local stakeholders, particularly residents and local authorities (fig 1.). Community acceptance refers to the specific acceptance of siting decisions and energy projects by local stakeholders, particularly residents and local authorities.

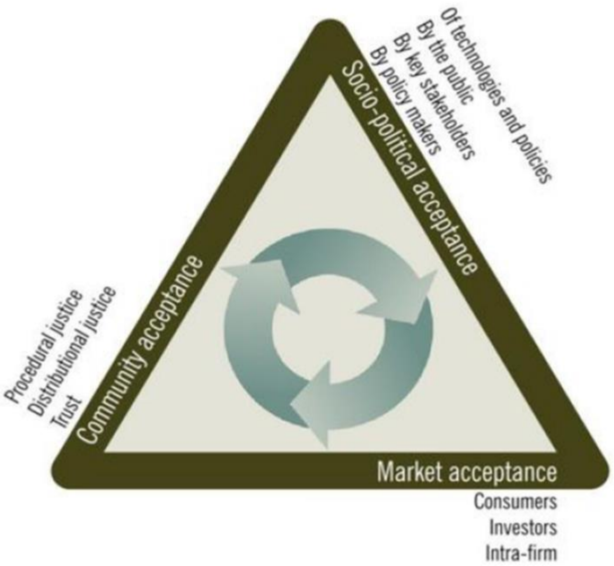

Figure 1. Three categories of interdependent categories of public acceptance: Socio-political, Market and community acceptance.[3]

Lately it has been documented that the reason for lack of favourable or positive response to energy projects originate in one or more of the following generic shortcomings: Inadequate economic incentives; lack of local ownership; inexpedient communication, and opaque planning process.[4] Conversely, support for energy projects, as exemplified by wind power, is stronger in communities where the wind farm has broad local ownership, and where the income from the facilities contributes to local value creation.[5, 6]
Studies have clarified that although different stakeholders support similar energy policies, they differ in interests and values. However, Diaz et al[7] have demonstrated that the stakeholders are willing to invest time to reach long-term solutions. These collaborative decision-making processes can ultimately increase the probability of reaching a more nuanced and robust solution that may not necessarily focus on being the most optimal in terms of time, but rather focusing on serving the common interest and therefore with higher likelihood of success.

In addition, von Wirth et al. indicate that local co-ownership and awareness of local benefits tend to improve the acceptance of distributed energy infrastructures among stakeholders.[8] Thus, ownership models are important to consider for stakeholder and community acceptance both with regard to their influence on consumer prices and their capability to handle the multitude of coordination tasks in a transition from sector-based to integrated smart energy systems.[9]

1.2 Technologies considered

This report considers four types of UTES, Pit Thermal Energy Storage (PTES), Aquifer Thermal Energy Storage (ATES), Borehole Thermal Energy Storage (BTES), Mine Thermal Energy Storage (MTES), and Geothermal heat.

1.2.1 PTES

The technology was first developed by the Technical University of Denmark DTU during the 1980s. The first full scale storage was built in Marstal, Denmark during 2011-2012 (75,000 m^3), and the second full scale storage in Dronninglund, Denmark during 2013-2014 (60,000 m^3) – both in connection to large solar collector fields. The PTES is visible from a distance as ramparts surround the pit. Moreover, the heat loss to the surrounding soil and groundwater is not considered a high risk and it is up to the local authorities (municipality) to decide whether an Environmental Impact Assessment (EIA) is necessary.
Two cases (1 & 2) of PTES have been analysed and both are situated in Denmark.

1.2.2 ATES

The ATES technology is rather mature and has been widely used in the Netherlands, Belgium, Sweden and Germany since the 1990s. Low Temperature (max 25 ˚C) energy storage in aquifers at 50-100 m depth is currently a well-known and widely distributed (>2000 sites) in the Netherlands. Because of the low temperature and the shallow nature of the wells, the effects on the underground in (geo)physical, chemical and microbiological terms is considered low. For this reason, the potential risks for underground drinking water supplies are also considered low. However, medium and high-temperature ATES systems storing energy at greater depths have so far been very scarce. A handful of pilot systems originating from earlier years (‘90’s-‘00’s) terminated their activities after a few years because of technical and/or economic reasons.
One ATES case situated in the Netherlands (case 3) has been analysed here.

1.2.3 BTES

BTES facilities exist today in several countries, including Germany, Sweden, Canada, USA and Denmark. BTES is a well-known technology in France, thus, 261 projects were financed by “Fonds Chaleur” (Heat Funds) during the last 10 years. Shallow geothermal has got an ambitious target set in the multi-year energy policy plan (PPE 2028) with 5 TWh en 2028, against the existing 3,6 TWh. On the other hand, is BTES not a common technology in Denmark and Brædstrup was the first project to be operational in 2012 for district Heating (DH) supply in conjunction with a large solar thermal capacity.
Two cases on BTES have been analysed here; one in France (case 4) and one in Denmark (case 6).

1.2.4 MTES

Mine water from abandoned and flooded former coal mines can be used as a UTES for example in connection with solar power plants. The idea of obtaining thermal energy from an inoperative colliery has already been pursued for a long time, although to a rather limited extent.
One MTES case in Bochum, Germany has been analysed here (Case 7).

1.2.5 Geothermal

UTES is a geothermal technology and lessons learned from geothermal projects could provide valuable insights for the UTES portfolio of technologies. Geothermal energy is directly used in 32 European countries. However, Iceland is the world leader in the use of geothermal district heating, where 90% of all homes are heated with geothermal energy. The energy comes from low temperature (<100°C) and high temperature (>250°C) systems. Geothermal technology is considered low-probability but high-consequence risk projects, and induced seismicity has been the cause of delays and threatened cancellation of at least two geothermal

projects worldwide, and therefore risk communication is an important part of these projects.[10], [11], [12], [13] Although, micro-seismicity has had few adverse physical effects on operations or on surrounding communities public concern remains over the amount and magnitude of the seismicity associated with geothermal systems.[14]
Four cases have been analysed here; two in Belgium (Case 8 & 9) and two in Iceland (case 10 & 11).

2 Method

A limited literature review was performed using Aalborg University library search engine Primo and Google searching for combinations of words such as “renewable energy”, “energy storage”, “social acceptance”, “public acceptance”, “community acceptance”, “Environmental impact assessment” etc.
Moreover, a questionnaire was developed asking questions about experience with public acceptance from HEATSTORE cases of UTES and geothermal technologies (figure 2). It builds on a process design framework inspired by combining the work of McGovern and Klenge [15], and Borch [16]. The framework extends beyond the scope of technical and business processes to understand different drivers and barriers of (and possible measures to increase) community acceptance including perspectives related to economical, psychological, sociological, and environmental values (figure 3) beyond single commercial interests.
A number of cases (Table 1) delivered by partners to HEATSTORE has been subject to the questionnaire (fig 2). The cases are described according to technical design, ownership and value perspectives (fig 3).

Questionnaire

Country	
General country description	
Case	
Ownership	
Technical design	
Guiding questions	
Initiation:	*How strong is the local political support for the project (e.g., green vision)?*
	What was the mission statement of the project?
	Who are the customers?
	Who made the final decision to initiate the project?
• Economical	*What is the value proposition to the community and individual neighbours?*
	Did project or running cost increase due to e.g., technical challenges or protests (please explain)?
• Psychological	*If subjective concerns were expressed from individuals, what was most important (e.g., health, visual impact, or other types of subjective nuisance)?*
• Sociological	*Was appropriate stakeholder analysis performed?*
	How were the stakeholders engaged?
	What is the organizational relationship with the local community (e.g., co-ownership)?
	How does the UTES technology benefit the community beyond economy?
	How was the decision process communicated or discussed with the local community?
	Did the project struggle with previous stories about technological changes in the neighbourhood?
• Environmental	*Was concerns over the impact on the environment expressed?*
	Did environment impact concerns differ between stakeholder (e.g., between NGOs and locals)?
	Was environmental impact assessment part of the decision process?
Evaluation	*How was achieved stakeholder benefits assessed after it was put operation?*
	Was the mission statement achieved?
Other issues?	

Figure 2. Questionnaire developed to collect information about community acceptance for HEATSTORE demonstration projects and case studies.

Figure 3 The Value Framework of social acceptance.[12]

Table 1 Cases of community acceptance analysed in the context of the HEATSTORE project.

<table>
<tr><th>Case</th><th>Technology</th><th></th></tr>
<tr><td>1</td><td>PTES</td><td>The Sunstore 4 project, Marstal District Heating (DH), Ærø Municipality, DK
Stakeholders: Heterogene (consumers, neighbours, politicians, authorities, naturalists)</td></tr>
<tr><td colspan="3">Marstal DH is a consumer-owned cooperative currently suppling district heating to 1,602 buildings (basically all buildings) in the city of Marstal. The Sunstore 4 plant comprises: 15,000 m^2 solar thermal system, CHP system with a low emission 4.0 MW wood chip thermal oil boiler and a 750 kWel ORC, 75,000 m^3 pit heat storage (water), 1.5 MW (thermal) heat pump with CO as refrigerant - supplementing the existing demonstration plant (Sunstore 2) including 18,365 m^2 solar thermal and 10,340 m^3 PTES. The storage is used directly and as heat source for the absorption heat pumps.</td></tr>
<tr><td>2</td><td>PTES</td><td>The Sunstore 3 project, Dronninglund DH, DK
Stakeholders: Heterogene (consumers, neighbours, politicians, authorities, naturalists)</td></tr>
<tr><td colspan="3">Dronninglund DH is a consumer owned cooperative. The main components in the production plant is a large solar thermal plant consisting of 37,573 m^2 solar collectors (26 MW), pit heat water storage of 60,000 m^3, and a 3 MW_{heat} absorption heat pump driven by a biooil boiler. The storage is situated in an abandoned gravel pit, making the excavation relatively easy. The storage is charged to 85 °C during summer and discharged to 10-15 °C during winter. The storage is used directly and as heat source for absorption heat pumps.</td></tr>
<tr><td>3</td><td>ATES</td><td>NIOO 45 ˚C MT-ATES, private initiative of NIOO-KNAW, NL
Stakeholders: Heterogene (authorities, users of the building, neighbours, academia)</td></tr>
<tr><td colspan="3">A MT-ATES system (45 ºC) has been coupled to a regular LT-ATES system (< 25 ºC) to form a four-well system: The hot well of the MT-ATES system at 220-295 m depth stores water at 45 ºC to heat the buildings in autumn and winter through efficient floor heating without the need for a heat pump. Hot water for storing energy in the MT-ATES is generated by a solar thermal energy system on the roofs of part of NIOO's buildings and compressor systems used for e.g., cooling of climatized 4 ºC rooms. The regular LT-ATES at 80 m depth is predominantly aimed for storing water of 11 ºC in its cold well (cold water loaded in winter) to cool the buildings in summer. In addition, residual heat from greenhouses, compressor systems and e.g., freezers in the NIOO buildings are used to store in the warm well of the regular ATES system.</td></tr>
<tr><td>4</td><td>ATES</td><td>Koppert-Cress, MT-ATES, NL
Stakeholders: Homogene (industrial neighbours with similar activities, authorities)</td></tr>
<tr><td colspan="3">Koppert-Cress is a horticulture producer (greenhouse) placed in the Westland region, which is a dense region of urban and industrial areas with many greenhouse complexes. Waste heat from internal industrial processes is stored in the ATES system for heating purposes.</td></tr>
</table>

<table>
<tr><th>Case</th><th>Technology</th><th></th></tr>
<tr><td>5</td><td>BTES</td><td>BTESmart Fier Vallin, City of Annecy, F
Satekholders: Heterogene (Neighbours, users of the building, politicians, authorities, academia)</td></tr>
<tr><td colspan="3">The existing BTES is facing a loss of performance, and the facilities cannot guarantee the expected 25 years of service of heating a school as initially planned. Therefore, the city of Annecy and STORENGY are going to develop a joint project adding 60 m^2 thermal solar panels on the roof of the school. It is planned to recharge an existing field of 17 boreholes (100 m deep) in the summer period and reuse it to heat the school during winter. Two temperature measurement probes are installed in the subsurface (approximately -100m) to monitor the temperature of the storage.</td></tr>
<tr><td>6</td><td>BTES</td><td>Brædstrup DH, DK
Stakeholders: Heterogene (consumers, neighbours, politicians, authorities, naturalist)</td></tr>
<tr><td colspan="3">Brædstrup DH is a consumer owned cooperative. In 2007 an 8,000 m^2 solar thermal plant was added. Brædstrup Totalenergianlæg (Brædstrup Total Energy Plant) was the first full scale example of combining solar thermal and natural gas fired CHP. The yearly heat production for the plant is app. 40,000 MWh. The plant already had 8,000 m^2 solar collectors, two gas engines, two gas boilers and a 2,000 m^3 accumulation tank. The pilot plant should, according to the application to Energinet.dk add a pilot borehole storage of app. 19,000 m^3 soil volume, a solar thermal plant of app. 8,000 m^2, a 5,500 m^3 buffer tank and a heat pump (app. 1 MW_{heat}).</td></tr>
<tr><td>7</td><td>MTES</td><td>Fraunhofer IEG / Bochum Municiplaity, D</td></tr>
<tr><td colspan="3">The aim with the project in Bochum is to create a technically and fully functional high temperature mine thermal energy storage (HT-MTES) pilot plant by reutilization of an abandoned shallow colliery in combination with a concentrated solar power plant (60 kW). In the first stage the Fraunhofer IEG in Bochum will implement the storage concept within the heating scheme of their own facility management. In the second phase, it is planned to couple the MTES with a high-temperature heat pump, to provide thermal energy to the local district heating grid, which is operated by the Bochum public services.</td></tr>
<tr><td>8</td><td>Geothermal</td><td>GEO@Turnhout, B
Stakeholders: Heterogene (consumers, politicians, regional authorities)</td></tr>
<tr><td colspan="3">The city of Turnhout has hired a private company to investigate the geothermal potential. In addition, the city has a heat plan drawn up by a specialized company. The results of both studies will provide more insight into whether the project is technically and financially feasible.</td></tr>
<tr><td>9</td><td>Geothermal</td><td>Kempens Warmtebedrijf (DH), B
Stakeholders: Heterogene (consumers, politicians, authorities, academia)</td></tr>
<tr><td colspan="3">The Balmatt geothermal plant site in Mol was partial completed in May 2019. Until then deep geothermal energy was quite unknown in Flanders. Furthermore, the residual heat is used to produce electricity. With the current operational parameters and a production temperature of 121 °C aboveground, the Balmatt plant can potentially produce about 4-5 MWth, or in total 1,7 GWh. The water is re-injected at 55-60 °C. Currently the plant is not operating due to challenges with seismicity.</td></tr>
<tr><td>10</td><td>Geothermal</td><td>Reykjavík Energy, seasonal injection heat, IS
Stakeholders: Heterogene (consumers, neighbours, politicians, authorities, naturalists)</td></tr>
<tr><td colspan="3">Simulation of seasonal injection of surplus hot water from the Hengill area into the Reykir/Reykjahlíð low temperature system within Iceland´s capital region.</td></tr>
<tr><td>11</td><td>Geothermal</td><td>Reykjavík Energy, Hengill, magmatic heat, IS
Stakeholders: Heterogene (consumers, neighbours, politicians, authorities, naturalists)</td></tr>
<tr><td colspan="3">Intertwining academic process models of conditions around magmatic heat sources and the conventional field scale model of the Hengill area.</td></tr>
<tr><td colspan="3"></td></tr>
</table>

3 Results

3.1 PTES

PTES in connection with solar panels is the dominating UTES in Denmark. Environmental impact assessment focuses on visual impact, impact on nature, CO_2 reduction and impact on ground and drinking water. Resistance towards PTES in Denmark are seldom and often targeting solar panels and not the PTES itself. However, Economic concerns from the owners (users) has been an issue.

Marstal DH (case 1), DK did not receive any complaint about the PTES in connection with the Sunstore 4 project. The municipality is the planning authority and did not find it necessary to perform an EIA. The pit is placed in a built environment, which probably can explain the lack of complaints about visual impact. Moreover, Marstal DH has a long history of support in the local community and has supplied cheap heat to the city of Marstal since 1962. The Municipality of Ærø strongly supports RE solutions and the aim is to be self-sufficient with RE before 2025, and a 100% fossil free municipality by 2030.

Dronninglund DH (case 2), DK is consumer owned and it is the general assembly who decides new investments. The project was approved with 124 votes for, 87 against and 11 voted blanc. This is a rather small margin to accept such investments. A statutory hearing was conducted and at the end of the 8-week hearing period 5 neighbours and a farmers' association had filed complaints about consequences for protected species, and the special soil conditions in the abandoned gravel pit. Concerns over raising temperature in the groundwater were also raised. Initially the Municipality did not find it necessary to perform a full EIA. Meetings with the neighbours was conducted to negotiate a retraction of the complaint, but with no success. The Environmental Complaints Board overruled the municipality and decided that an EIA was necessary. To accommodate the complaints, it was decided to plant covering vegetation and establish control drillings to monitor the groundwater temperature. These measures delayed the project with 1 year. Communication on the project was primarily performed as an information folder and later via the Dronninglund DH homepage and in connection with general assemblies. The local newspapers also covered the project occasionally.

3.2 ATES

The NIOO 45˚C ATES system was at the operational start in 2011 the sole pilot demonstration system operating in the Netherlands. However, in the last years, several new initiatives for upgrades of LT-ATES systems to MT/HT-systems have occurred as well as the design and realisation of new HT-ATES systems (ECW demonstration site).

NIOO-KNAW MT-ATES (case 3) is sited at the institute and owned by KNAW. The aim with the project is to design a fully self-supporting system for both heating and cooling of the NIOO complex via the floors throughout the year. The project fits in the national EOS-DEMO scheme of the Ministry of Economic Affairs 2007-2009 allowing funding to ameliorate the technological and economic risks of the demonstration project. In addition, the regional authority (Province of Gelderland) also contributed to financing the project as they were interested in learning from the project, on the chemical and microbiological effects on the underground. A limited stakeholder analysis was performed in the proposal for the NIOO MT-ATES Demonstration Project made for requesting co-financing from the Ministry of Economic Affairs in de EOS-DEMO subsidy programme. Also, the project coincided with the construction of the new highly sustainable NIOO building in Wageningen. At the time of construction, NIOO sent out press releases, invited local and regional newspapers to get acquainted with the experimental technology in the new building, and NIOO organised several open days and weekly tours through the building for the local community as well as students, technical experts, building companies, future customers and investors, and governmental organisations. This created significant enthusiasm in the local community and contributed to the local community's drive to establish sustainable energy projects elsewhere in the region.
Few concerns about effects on drinking water quality and health risks was raised in connection with the NIOO-KNAW MT-ATES. The fact that there was a monitoring programme of NIOO on these aspects was sufficient to meet these concerns.

Koppert-Cress, MT-ATES project (case 4) stores waste heat from internal greenhouse processes for heating purposes. The project has received strong local political support and was initiated as a green deal with provincial and municipality authorities. An EIA was performed as well as an assessment of impacts on other underground users/interests before the permit was issued. The project did not have any problems with community acceptance.

3.3 BTES

BTESmart Fier Vallin, City of Annecy (case 5) is the first demonstrator of its kind, with detailed monitoring for modelling and future replication. The local political support is strong as the City of Annecy is managed by a new ecological team (Green Party), elected in May 2020, which support such innovative projects. The project is expected to reduce the operation hours of an electric boiler. The project was developed with the City of Annecy and Storengy, and the final decision during municipal council was broadcasted on internet. During development, some concerns were expressed by the City of Annecy considering safety aspects for drillings in the schoolyard and from solar thermal equipment on the roof. No environmental concerns were expressed from the community.

The pilot BTES project at Brædstrup DH (case 6), DK is a borehole storage of ca. 19,000 m^3 soil volume in connection with a solar thermal plant of ca. 8,000 m^2. The main stakeholders are the local community supporting CO_2 neutral DH, and to maintain their trust and consent a penetrating information campaign was initiated. The Board of Representatives of the owners (i.e., the consumers) was sceptical towards the economic sustainability, but was later convinced by the project prospects that demonstrated reduced costs and by the perspective to be a front runner on solar heat. Moreover, since geological and geotechnical site investigations did not find problematic groundwater tables the project was approved with no complaints.

In summary, it can be observed that the studied BTES plants have not experienced problems with community acceptance. Placed in an urban environment BTESmart Fier Vallin project successfully communicated with the neighbours about concerns in the construction phase. Brædstrup on the other hand is a DH plant in a rural area, and appropriate communication was facilitated by the fact that the main stakeholders are residents, consumers, and owners at the same time. These stakeholders where mainly concerned about the economic risk.

3.4 MTES

In North Rhine-Westphalia, the reutilization of abandoned mining infrastructures could highly increase the share of renewable energy within the heating and cooling sector, which currently equals to over fifty percent of the primary energy consumption in Germany.

The German HEATSTORE sub-project (case 7) aims at creating a technically and fully functional high temperature mine thermal energy storage (HT-MTES) pilot plant for the energetic reuse of an abandoned small coal mine, with the emphasis on an extended operating and monitoring phase during the project lifetime of three years. The reutilization of existing mining infrastructure will benefit the local community by increasing the share of renewable energies and decrease of local CO_2 emissions as the (local) district heating grid will be connected to the MTES if the MTES concept reveals promising results.
Concerns of environmental impact considered possible ground deformation and possible surface fractures. To address this, the mine stability had to be evaluated by a state-appointed assessor beforehand. Also, effects on the ground water body with associated chemical and biological changes were raised as possible concern. Information sessions were organized for the local neighbourhood beforehand, to increase awareness and acceptance of the upcoming projects.

3.5 Geothermal

In the City of Turnhout in Belgium a new project (Case 8) is under development with the objective to use geothermal energy to heat the local hospital, some new residential areas, and the city centre is undergoing research. The drilling of the doublet (production and injection well) is scheduled for 2022. After the double tests, the construction of the above-ground installation can begin.
Deep geothermal energy has now been included in the administrative agreement between the various parties as the energy source to make the heat supply in the city more sustainable. Concerns were mainly raised during the seismic campaign. Some homeowners have been concerned about the seismic vibration and whether it would cause damage to their houses. To accommodate these concerns residents were

extensively informed about the seismic campaign, and the largest heat consumers were informed about the planning of the project in general.

In 2019 the Flemish Institute for Technological Research (VITO) developed and constructed the first deep geothermal energy plant in Flanders (Case 9).
In recent decades, the region has been severely affected by business closures and highly polluting industries, leading to serious deterioration. As a result, citizens are very critically towards any new initiative including another VITO project on (bio)energy conversion. Formally, the project had to go through several complex procedures with several public hearings. VITO arranged these hearings, and after objective presentations of the project the public had the opportunity to ask questions and express their concerns. Informally, a lot of effort went into organising several information campaigns to make the population familiar with the concept of deep geothermal energy and heat networks. To attract even more attention from the public, the project was communicated at as many possible occasions, for instance during 'The Week of Technology' and the 'Open days'. One communication event that should be explicitly mentioned is a musical arranged for the school-going youngsters, bringing deep geothermal energy into the living room in a very specific and unique way. This science fiction musical was called ‘ontSTEMd’ where STEM stands for Science, Technology, Engineering and Mathematics. VITO received with this musical the Eos public's choice award for science communication.
Since the partial completion of the plant on 14th May 2019, it has operated for 16 days accumulatively, with a last joint period of 10 days i.e., about 46 % up-time. However, on Friday 21st June 2019 the geothermal powerplant shut down because there were problems with the surface installations that needed inspection. On Sunday 23rd June 2019, 2 days after terminating the longest operational period, an induced earthquake had occurred close to the injection well MOL-GT-02 with a magnitude of 2.1 on the Richter scale. Currently the plant is under investigation and when it is unknown when it will be put back into operation.

Case 10 and 11 are both owned by Veitur Utilities, a subsidiary of Reykjavik Energy (OR), who operates 13 district heating systems. Most of them are fed by geothermal water from low temperature fields. The large district heating system in Iceland´s capital area (Case 10), is fed by two different types of water that cannot be mixed within the distribution system. These are geothermal water from low temperature fields and heated groundwater from two co-generative power plants in the Hengill area. The power plants operate on base load and one of them produces excess 80 °C hot water over the summer months.
Since demand for hot water in the capital area has been increasing rapidly in recent years the Research and Development department at Reykjavík Energy in agreement with the local authorities decided to investigate the possibility of a seasonal injection of surplus hot water from the Hengill area into the Reykir/Reykjahlíð low temperature system to be used during winter. Due to the risk of seismicity injection of more than 10 L/s or into active fracture systems always requires an assessment of seismicity risk in Iceland. Thus, injection is simulated and modelled by the Iceland Geosurvey. Based on the simulations members of the scientific community discuss the potential risks. The conclusions are used for permit applications to the municipality and the Energy Authority. Before any injections take place, the plans are announced in local media and to kids in schools in the vicinity.

ON Power, a subsidiary of Reykjavik Energy (OR) (case 11), operates two co-generating high temperature geothermal power plants in the Hengill area. Before the next well will be drilled, intertwining academic process models of conditions around magmatic heat sources will be developed including a conventional field scale model of the Hengill area. About 27 % of the electricity production in the country comes from geothermal resources. Eight conventional geothermal power plants are currently operated in Iceland with a combined installed capacity of 708 MW_e (2018). Production wells in these power plants generally reach depths of 2-3 km and the production temperatures are between approximately 230-330 °C. In recent years, there have been plans to drill deeper into existing production fields within the Iceland Deep Drilling Project (IDDP) in order to enlarge the resource downwards and to reach formations at higher temperature where conditions might be supercritical.

4 Discussion and conclusion

The report has analysed 11 cases of UTES and geothermal technologies. For UTES technologies the main public concern has been economic risk and risk of negative consequences for groundwater and drinking water quality. For geothermal technology, the risk of induced earthquakes is likely the most important concern judging from previous experiences.
In the following different issues related to community acceptance of UTES and geothermal technologies are discussed based on reports from case owners in HEATSTORE and the literature review.

4.1 Value perspectives of community acceptance

Value perspectives of community acceptance are related to economical, psychological, sociological, and environmental issues (figure 3).

Economic issues and concerns are normally not in focus for community acceptance; however, in cases with local ownership (case 1, 2, 6) the community runs an economic risk (i.e., increased cost of heating). Concerns about economic risks were in the Danish cases ameliorated by documenting the potential benefits in terms of cheap heating, and by public R&D grant that significantly reduced the costs.
In general, the projects did not experience significant cost-overruns, except case 6 (BTES) due to delays, and geothermal production project in case 9 due to challenges with seismicity. Moreover, since many of the reported cases were pilot projects, they were also subsidised and, thus, economically feasible for the shareholders.

Physiological issues are first and foremost present in the geothermal production cases (case 9-11) due to seismic risks. In these cases, pre-studies, modelling, simulation, and communication about assessed risks where important tools to cope with citizens anxiety towards earthquakes. In this context the positive public perception of renewable energy (e.g., geothermal energy vs. exploration of shale gas), can be used in the communication strategy as reported by Stauffacher et al.[10]

Sociological issues are best addressed true appropriate communication and the more heterogenic the stakeholders are the more important it is to focus the communication. The geothermal cases (case 9-11) are the cases that take issues of community acceptance to a very high level, due to the low risk but high consequences of induced seismicity (see paragraph on risk communication below).
In the Danish cases the key stakeholders are the local community who at the same time are the owners (case 1-2, 6). This does not mean that they automatically are informed, which can explain why the PTES project in Dronninglund (case 2) was poorly supported by the owners compared to the cases of Marstal and Brædstrup DH (case 1 & 6) where communication with the community was very intense during the early phases.
Building local capacity also seems to an important social driver that support RE investments. Thus, many small communities take pride in being active in CO_2 reduction measures, and to be part of projects involving RE.[17, 18, 19] As a result several rural regions have developed specific institutions, organisms, and authorities to deal with RE deployment in reaction to large investment and top-down national policies. This dynamic has been observed both in regions where local communities fully support RE and in regions where the population is against potentially harmful developments[17]. Most important for a successful integration of RE projects is the consideration of structure and needs of the local community through intensive processes of sensing and priming linked to the local population.[18]

Environmental issues in relation to PTES, ATES, BTES and MTES technologies on the (geo)physical, chemical, and microbiological terms is considered low, but geological and geotechnical site investigations are in most cases performed to assess impact on ground and drinking water. However, experience with medium and high-temperature ATES systems storing heat at greater depths is limited. To accommodate these concerns several of the cases have performed control drillings to monitor potential impacts on the ground water.

4.2 Cross cutting issues

Communicating risks appropriately is a key for community acceptance in most studied cases. Thus, in the Danish cases the difference in trust and, thus community acceptance, can to a wide extend be ascribed to appropriate communication throughout the project period and after. Also, in the Icelandic and the Belgian cases (case 9-11) risk communication was important using both traditional communication channels such as newsletters as well as presentations for school kids and science fiction musical. In this context appropriate risk communication is to reflect the benefits, but also concerns about the risk of induced seismicity.[10, 11]
Moreover, to establish trust between affected parties the risk communication must also reveal what is at stake, who is responsible, and the mitigation measures that are taken. Thus, Knoblauch et al.[13] conclude that careful elaboration and testing of risk communication format and uncertainty statements are very important when designing risk communication.
Risk communication is helped by the RE nature of HEATSTORE technologies, thus, risk communication on geothermal energy is perceived more positive than e.g., exploration of shale gas due to the problematic environmental challenges of the latter.[13]

Ownership models are considered important for community acceptance and attractiveness of investments.[19, 20] Although this cannot be shown from the cases studied here it can be noted that the cases with many and homogenic stakeholders in this limited survey was either non-profit cooperatives (the three Danish cases 1-2 & 6) or public owned i.e., the case from Turnhout, B (case 8) and the cases from Iceland (case 10 & 11).

Political support and comprehensive green visions is very important for community acceptance especially in cases with many and heterogenous stakeholders due to the complexity of interests and values. Thus, lack of participation, and responsiveness to different interests and values among the public, in the early stages of project design, may make implementation difficult, more costly and lengthy, or even deadlocked. Instead, it is recommended to invest time to reach more nuanced and robust solutions that may not necessarily focus on being the most optimal in terms of time, but rather focusing on serving the common interest and thereby increase likelihood of success.[15]

4.3 Recommendations

Table 2. An overview of recommendations on community acceptance will be based on reported perceived risk of the HEATSTORE cases combined with insights on community acceptance from comparable technologies.

Initiation phase	Concerns about pollution of drinking water and seismic risks are reported public concerns and especially geothermal projects have a history of challenges with community acceptance and the reported cases have gone a long way to accommodate concerns in the local community. The following issues should as a minimum be addressed in the initiation phase:
• Visioning	Build a vision that are in line with local interests and values and include alternative technology scenarios for a specific purpose and community.
• Political support	Establishment of political support with the objective of equipping potential supporters with a mandate for engagement and support of the vision.
• Community enrolment	Share the vision with identified stakeholders and develop it further to identify and discuss potential value propositions and benefits for these stakeholders.
Planning phase	The planning phase focuses both on technical alternatives, risk concerns and local value-creation interests and culture.
• Risk Communication	Communicating risks appropriately is a key for community acceptance leading to absence of hidden motivations and risk transparency. Careful elaboration and testing of risk communication format and uncertainty statements are very important to build trust and thus community acceptance in later phases. In geothermal cases with low-probability but high-consequence risk multiple communication channels are used to reach the public with results from simulation.
• Value creation	Integral view on value is needed to secure solutions that bring value to users and society. Such an integral view should include potential harmful effects and support creative processes to reduce harm and increase value.

	Ownership models that guarantee local anchorage and value creation should be considered as they are important for community acceptance.
• Alternatives	It is important to show and, if necessary, to simulate different future solutions and their consequences for environment, economy, and employment (value creation). The alternatives could profitably be compared through multi-criteria feasibility studies.
Implementation phase	To show that the agreed project fulfils the legal requirements, the consequences of the project must be described. For example, how fits the project into national and local energy strategies, visualization of landscape integration, cost and benefits including socio-economy, local economic consequences, distribution of benefits, creation of local workplaces, process to involve local stakeholders and implementation strategy.
• Assessment	Assessment of the project deliveries relates both to the energy services provided, and to the civic undertaking of delivering the projected benefits to the designated recipients.

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