Deliverable Proof – Reports resulting from the finalisation of a project task, work package, project stage, project as a whole - EIT-BP2018

Name of KIC project the report results from that contributed to/ resulted in the deliverable	E-Use - Europe wide Use of Sustainable energy from aquifers
Name of report	3.2.5 E-USE Market opportunities lessons learned
Summary/brief description of report	This report gives an overview of the lessons learned for unlocking markets for ATES application.
Date of report	11 December 2018

Supporting Documents: Report attached

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1. Introduction

The E-USE(aq) project focuses on paving the way for Europe-wide implementation of ATES systems. In the Netherlands, ATES is a proved technology that is widely applied. However, in other European countries this innovation is hardly applied. The predecessor of this project already concluded that there is huge potential for European countries to implement more ATES systems. The current E-USE(aq) project aims to bring the innovation a step further on the road to Europe-wide implementation. This is done by the installation of several successful demonstration projects in different European countries.

This market analysis deliverable (180267-D03 3.2.5 E-USE Market opportunities lessons learned) gives an analysis of the market potential for ATES systems in Europe, by analysing the market potential for ATES systems in the countries in which ATES demonstration sites have been constructed. The market potential is assessed in this deliverable by using the SWOT analysis method. The SWOT analysis is provided per pilot, and overall for ATES systems in general.

In deliverable 180267-D06 3.2.5 E-USE Final project results report, an analysis is provided of all the barriers for ATES implementation. This analysis complements the market analysis in this deliverable.

Results E-USE(aq) pathfinder project

The E-USE(aq) Pathfinder project (i.e. the predecessor of the current E-USE(aq), which is a Demonstrator project) delivered a global analysis of the potential for European countries to implement ATES systems. Although ATES has proven to be profitable and benefits for climate change mitigation are obvious, a wider application of the technology encounters barriers. The E-USE(aq) Pathfinder project showed that most of these barriers are presumed difficulties, risks and draw-backs that either do not exist in practice or can be overcome by innovative smart design adaptations and additions, sound monitoring and sensible management. This makes ATES an attractive product for property developers, owners of building complexes, housing corporations etc. all over Europe. Not only for clients looking for affordable sustainable energy sources, but also for operators that just want to save on their fossil energy costs. And for investors, who – confronted with volatile financial markets – are looking for sound and safe investment possibilities in the growing green economy; especially when governments, in order to meet their sustainability goals, will use incentives like tax reduction possibilities for deploying green technology. However, all these parties still have to be convinced ATES is a reliable enrichment of the local energy mix. To accomplish this, there is a need for demonstration projects showing that overcoming the (partially virtual) obstacles is quite feasible.

Based on the analyses in this Pathfinder project, a division was made between mature and immature markets. For each type of market, barriers for implementation were defined. The project also delivered an analysis of the potential of European soils for ATES systems, based on the availability of suitable aquifers. The result of this analysis is visualized in the figure 1 (see below). Feasibility of ATES is dependent on local conditions; presence of local aquifer and building types with a suitable demand pattern: demand for both heating and cooling is best, since ATES-systems are especially fit for buildings that need both. Geological suitability is based on the presence of adequate aquifers. Results are that about 1/3 of the total urban area in Europe has appropriate aquifers available for applying ATES. Almost that entire area also has the right climatic conditions. So the potential for ATES-technology is high in about 30% of all urban areas in Europe (these key-output Pathfinder results are shown in figure below; red = unsuitable, green = ideal). Those high potential urban areas are mainly concentrated in North-Western and Eastern Europe, with some local hotspots in Central Europe as well. In southern Europe suitability is less generic but local opportunities are nonetheless significant (due to the scale of the map, local ‘green spots’ are not visible).

The E-USE(aq) Pathfinder project also defined potential test sites for demonstration projects. Aim was to address all the defined barriers within the demonstration projects. The potential test sites have been developed into pilot sites in the E-USE(aq) Demonstrator project.

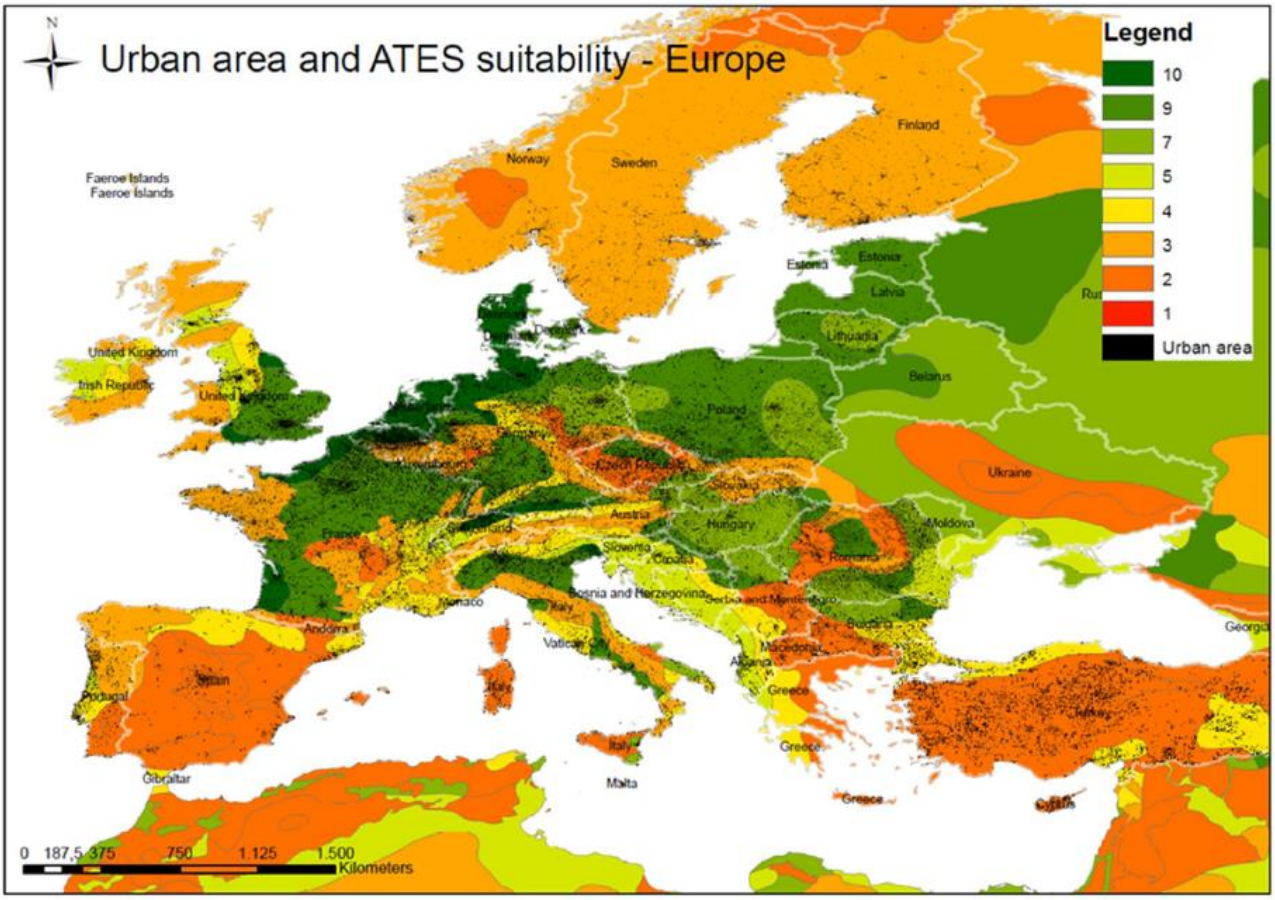


Figure 1: urban areas and ATES suitability in Europe. 1 = low suitability, 2 = high suitability (source: E-USE(aq) Demonstrator project proposal, 2015).

In total, nine different barriers for implementation have been defined in the E-USE(aq) pathfinder project.

For all countries:

1. Disappointing quality levels and hampering robustness of the installations;
2. Knowledge and skills divided between consulting and contracting companies and maintenance staff;
3. Unpredictability’s because of unfamiliarity with the underground and its characteristics.

For countries with an immature market:

4. Lack of knowledge and experience;
5. Lack of adequate regulations;
6. Presumed relatively large initial investments with unclear savings during operation.

For countries with a more mature and grown market:

7. Interference between ATES systems;
8. Interference with polluted groundwater;
9. Shifting opinions considering presumed negative impact on groundwater quality.

Climate-KIC is supported by the EIT, a body of the European Union

Results E-USE(aq) Demonstrator project

The pilot projects in the current Demonstrator E-USE(aq) project are located both in countries with mature markets (i.e. the Netherlands, Belgium and Denmark) and in countries with immature markets (i.e. Italy and Spain). In the technical performance reports of the different pilots, which are all gathered in deliverable 180267-D01, 3.2.5 E-USE(aq) Technical performance report & monitoring, technical pilot results are described in detail. In Deliverable 180267-D02 3.2.5 E-USE Validation of business cases, the economic potential of the ATES systems at the pilot locations is analysed. In 180267-D06 3.2.5 E-USE Final project results report the technical, economic and market analysis for the separate pilots are linked with the barriers for implementation, which may differ between pilots and immature or mature markets. The barriers are translated to lessons learned for the different countries in which the pilots of this project are located. In doing so, the Final Deliverable aims to give insight in the potential for Europe-wide implementation for ATES systems and how this could be achieved.

This deliverable focuses specifically on an analysis of the market potential for ATES systems in Europe. The idea is that the pilots will contribute to the market uptake of ATES systems in the countries in which they are installed. In the process of constructing an ATES system at a pilot location, the E-USE(aq) project partners work together with local companies. Via this process local consortia are formed. These local consortia can, after the completion of the E-USE(aq) project, continue their work on ATES systems and contribute to the national adoption of ATES systems in their countries. In this way, a local flywheel effect is started which, ultimately, leads to an overall increased market uptake of ATES systems in Europe. See also the figure below.

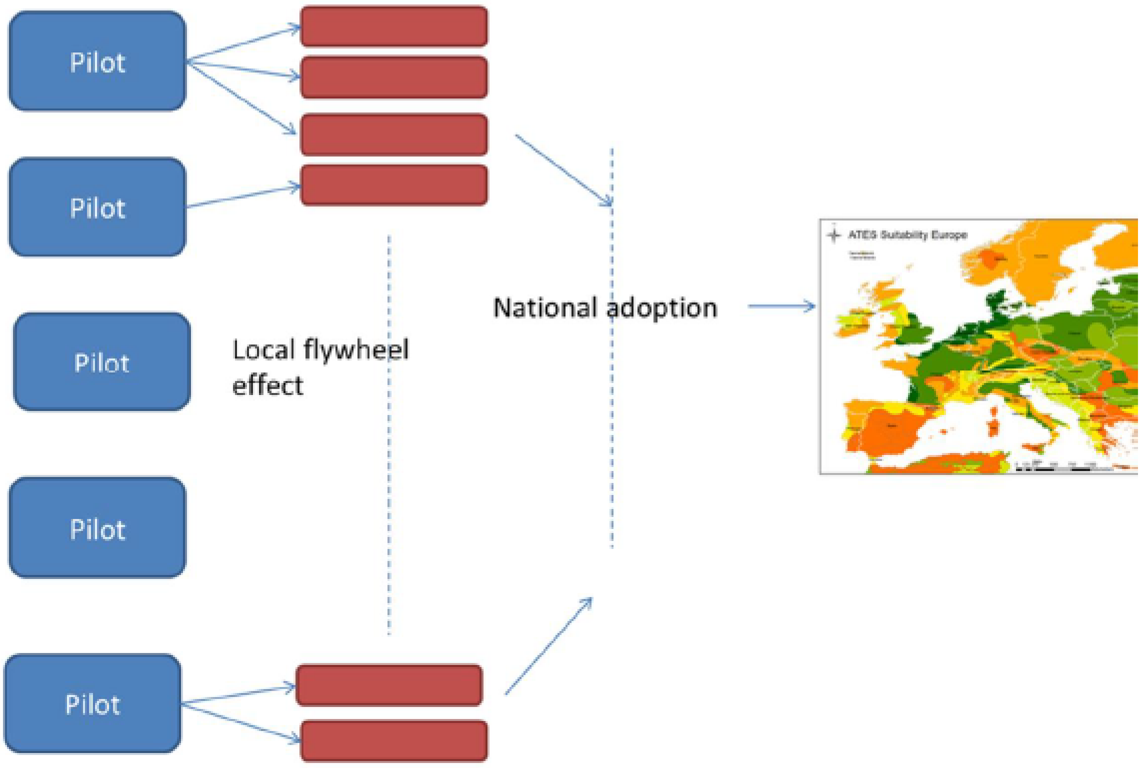


Figure 2: visualisation of the flywheel effect (source: E-USE(aq) Demonstrator project proposal, 2015).

The analysis of the potential market uptake of a technology generally starts from a clear distinction between metrics such as technical potential, economic potential and market potential. By technical potential the potential implementation for an ATES system is indicated from a pure technical perspective, considering physical limits such as the availability of aquifers, geothermal heat, etc. This was already addressed in the Pathfinder project as described above. The economic potential is defined by the share of the technical potential that can be realised at acceptable costs for a relevant investor, taking into account the costs of the reference technology, financial parameters such as required return on equity. For this, sees Deliverable 180267-D02 3.2.5 E-USE Validation of business cases. The market potential builds on the economic potential and takes into consideration also obstacles and drivers such as the demand for the product, regulatory limits, business model characteristics, etc. The relationship between technical, economic and market potential is visualized in the figure below.

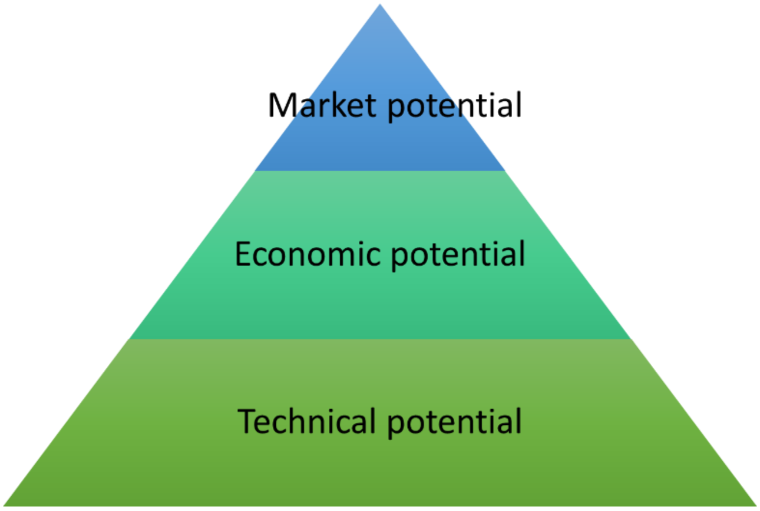


Figure 3: Relationship between technical, economic and market potential

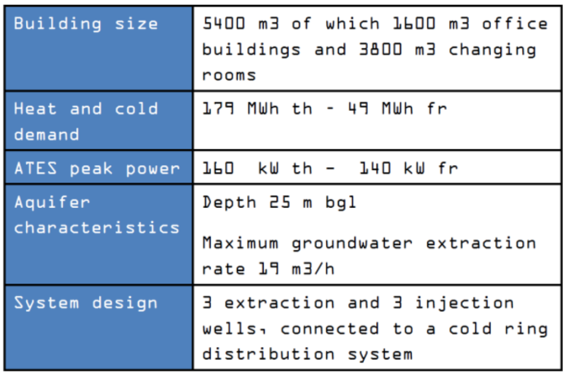
The following analysis will focus on the market potential.

This market analysis is structured around the different pilots within this project. The two pilots where bioremediation is combined with ATES have been grouped together. Reason for this is the fact that the combination of ATES and bioremediation is a new innovation which is in an earlier innovation phase than the other innovations in this project. The pilots in our project are one of the first cases in which bioremediation + ATES have been tested in the field. Therefore, the bioremediation + ATES pilots within this project have a more experimental set-up than the other pilots and have therefore (still) a lower market potential, which does not differ very much between countries. The two pilots in which ATES is combined with PVT are located in countries with relatively mature markets (i.e. the Netherlands and Belgium) and the scale and set-up of the pilots is comparable. Therefore, to assess the market potential of ATES with PVT, these two pilots have also been grouped together.

For the market potential analysis, a SWOT analysis is used. SWOT stands for Strengths, Weaknesses, Opportunities and Threats and is a strategic tool that can be used by organizations to give insight in their improvement points and could help with strategic decision making. In this case, the tool is used to assess the potential for ATES systems for Europe-wide implementation.

2. Brief pilot descriptions

Italian pilot



Building size	5400 m3 of which 1600 m3 office buildings and 3800 m3 changing rooms
Heat and cold demand	179 MWh th - 49 MWh fr
ATES peak power	160 kW th - 140 kW fr
Aquifer characteristics	Depth 25 m bgl Maximum groundwater extraction rate 19 m3/h
System design	3 extraction and 3 injection wells, connected to a cold ring distribution system

Figure 4: specs of Italian pilot

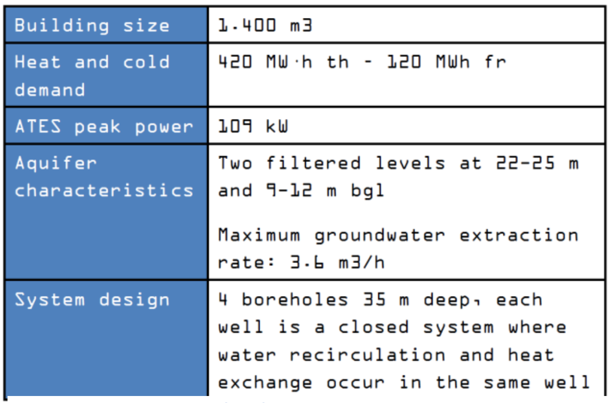
Italy has a solid experience in the field of geothermal energy, which has been practiced in spas since ancient times and in the exploitation of geothermal energy for power generation. In fact, the first experiments of electricity generation from geothermal steam took place in Larderello (Tuscany) in 1904. Conversely, the development of other direct uses of geothermal resources is still very limited compared to other countries in Europe and throughout the world. Very low temperature groundwater resources (needed for ATES systems) can be found almost everywhere, but the development of thermal energy installations have been limited up to now, in particular for open-loop application (such as ATES), since its regulatory approach is not straightforward because of the overlap with groundwater resources protection regulations. Such regulatory process have also led to delays in the E-USE(aq) pilot implementation. Instead, the use of closed-loop systems is regulated by a simpler Regional Law, and closed loop thermal energy systems are therefore more common than open loop systems such as ATES. No ATES systems have been realized in Italy so far for this same reason, even if some lab scale tests have been carried on.

The Italian pilot project represents a first attempt to develop this technology. The pilot is located within the electric station of Martignone, owned by Terna SpA, the national electricity Transmission System Operator. The pilot will give energy to two buildings, including also some data processing center rooms which need cooling all over the year. The project includes the installation of three reversible heat pumps, each one of about 70 kWth, plus one chiller of about 55 kW fr. Heat exchange with aquifers water was provided through plate exchangers and three couples of extraction-injection wells. The estimated water flow rate at peak demand was about 5.4 l/s.

Spanish pilot

The pilot is located in the municipal covered sports pools of the Town of Nules, on Avenida Jaume I, the northern edge of the town. It is a sports facility that houses a semi-Olympic heated pool, as well as showers and changing rooms and various offices.

The building has a dehumidification system by direct expansion in an Air Treatment Unit, plus a fan coil system for heating and direct expansion Split units with outdoor units for air conditioning. Also, the heating system of the pool originally installed has two boilers of 320kW each that use natural gas as a primary energy source.

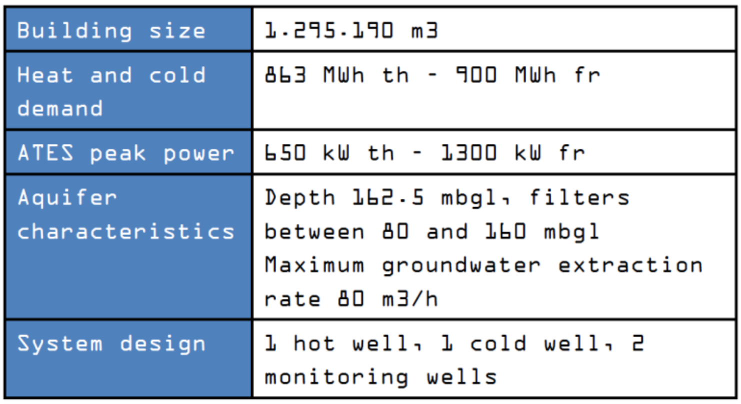


Building size	1.400 m3
Heat and cold demand	420 MW·h th - 120 MWh fr
ATES peak power	109 kW
Aquifer characteristics	Two filtered levels at 22-25 m and 9-12 m bgl Maximum groundwater extraction rate: 3.6 m3/h
System design	4 boreholes 35 m deep, each well is a closed system where water recirculation and heat exchange occur in the same well

Figure 5: specs Spanish pilot

One of the main barriers for implementation of ATES systems in Spain is a legal barrier: in Spain it is prohibited to pump (ground) water back into the subsurface, once extracted from it. A dynamic closed loop system has been developed, to ensure that the water can stay in the subsoil without having to extract it; thereby bypassing the law.

ATES + PVT pilots – Belgium and NL-Delft



Building size	1.295.190 m3
Heat and cold demand	863 MWh th - 900 MWh fr
ATES peak power	650 kW th - 1300 kW fr
Aquifer characteristics	Depth 162.5 mbgl, filters between 80 and 160 mbgl Maximum groundwater extraction rate 80 m3/h
System design	1 hot well, 1 cold well, 2 monitoring wells

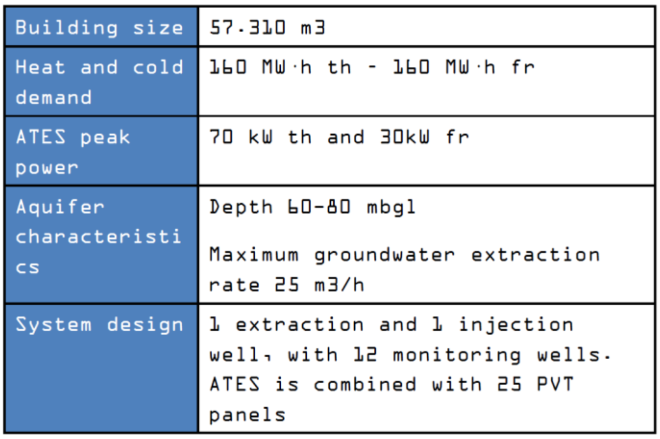
Figure 6: specs Belgian pilot

The Belgian pilot consists of the expansion of Nike's European Logistics Center at Ham, Belgium, with a new, versatile and flexible storage facility. Nike wants this new storage facility to be the new standard in the logistics landscape and an example on the European market.

The ATES system in this pilot consists of 2 groundwater wells that have been drilled into the subsurface at a depth of 162,5 m in a specific geological formation (Zanden van Diest consisting of fine sand containing glauconite). The filter for the extraction and infiltration of the groundwater is installed between 80 m and 160 m (ground level). Besides the 2 production wells, 2 measuring wells with level ducts have been drilled in the field, in order to confirm to the legislative requirements. The level ducts in the production and measurement wells were then equipped with glass fibres to monitor the evolution of underground temperatures.

A future imbalance between heating and cooling demand would lead to the depletion of the hot or cold well and a reduced heating/cooling capacity. Extra measures are necessary to create robustness against possible imbalance. Solar cogeneration is a rather innovative concept: solar heat is used to restore the imbalance between heating and cooling requirements while generating renewable electricity from the sun. To do so, photovoltaic solar thermal collectors are added to the ATES system. During summer, these panels produce hot water which is stored into the hot bulb of the ATES system, replenishing this bulb. When needed, this heat can be used to produce sanitary hot water, or in winter aid the heating of buildings. PV-electricity is produced simultaneously.

Control of the underground energy balance is possible by loading the hot bulb with solar generated heat when necessary, or by using the PVT-technology in reverse mode to release heat to the air by cooling down the panels at night. The PVT-system was chosen for its ability to load heat in the ATES system as in the Belgian pilot a dominant heating demand was expected.



Building size	57.310 m3
Heat and cold demand	160 MW·h th - 160 MW·h fr
ATES peak power	70 kW th and 30kW fr
Aquifer characteristics	Depth 60-80 mbgl Maximum groundwater extraction rate 25 m3/h
System design	1 extraction and 1 injection well, with 12 monitoring wells. ATES is combined with 25 PVT panels

Figure 7: specs Delft pilot

In the NL-Delft pilot, Virtu (developed by Naked Energy) integrates standard high efficiency photovoltaic cells within an evacuated tube solar thermal collector. For any given area more of the sun's energy is converted into heat and electricity than existing products with a commensurate impact on CO2 displacement.
In the NL-Delft pilot 120 PVT tubes were connected to an ATES system and provide additional heating to optimize the ATES systems performance.

Deltares has several buildings of which two are connected to an ATES system. One of the experimental lab buildings is not directly connected to the ATES system but has a very high heat demand, while the buildings with ATES have a heat surplus. Hence, solar heat from the PVT-panels and the surplus of heat from one of the buildings already connected to the ATES is stored in the ATES system and transferred to the building with a heating demand, which will decrease the overall energy use and would enlarge the available cooling capacity during summer for cooling for the building with a heat surplus. Also at this site high resolution temperature measurements with glass fibre technology was tested successfully.

NL-Utrecht pilot and Danish pilot

Within the E-USE(aq) project, in two of the pilots, ATES systems are combined with the remediation of groundwater. Anaerobic bacteria are cultivated injected in the soil.

The Utrecht installation is supplying thermally and cooling a sports building. The full ATES system encompasses 3 extraction wells and its intake of heat to being transferred to the aquifer comes directly from the temperature of the environment. This system could have an approximate lifetime of 30 years. In this project, the energy collection installation was already in operation for a long time. The bioremediation of the underground was added as a field test within the E-use(aq) project.

In the Danish pilot, the commissioner, Copenhagen municipality, had the principal aim of restoring the subsurface water of an industrial area. In order to enhance this process, a similar system to ATES was installed to increase the temperature of the target aquifer area. The water is pumped and heated on the surface and reinjected to being taken in again, thereby creating a heat-water cycle. The pilot was constructed to serve directly to the bioremediation. This system encompasses a well and a hot reservoir to complete the cycle. Also in order to improve the de-chlorination yield an electron-donor soup was injected. In this case an ATES-kind cycle is only used to enhance the bioremediation, however it is possible to rethink it as a potential economic income by reutilizing the heated water.

3. SWOT analysis

In the sections below, for each of the pilots or category of pilots, the outcome of the SWOT analysis is described. In 180267-D06 3.2.5 E-USE Final project results report more extensive analysis of the weaknesses and threaths for implementation of ATES systems is given, including an assessment of possible solutions to remove these weaknesses and threats.

Italian pilot

Strengths:	Weaknesses:
• Low cost and efficient thermal storage • Scalable • Easy to integrate in existing district heating and cooling networks	• Authorization/permits limitation (i.e. groundwater temperature increase) • Lack of know-how
Opportunities:	**Threats:**
• Balancing heating/cooling peak demand and centralized thermal energy production • Seasonal storage (in particular for district heating) • Integration with smart energy systems (i.e. power-to-heat) • Reducing operation cost of district heating	• Potential conflict with other groundwater use (i.e. drinking water) • Impact on groundwater characteristics • Clogging (if working at relatively high temperature, i.e. >25°C)

The most important strengths of applying ATES systems are that the technique is relatively low cost and efficient, it's scalable and it is easy to integrate with existing heating and cooling systems. The business case analysis of 2018 shows that payback times could be as low as 3 years. This proofs that ATES could be an economically feasible way for thermal energy storage. The fact that the technique is easy to integrate with existing networks, makes it even more attractive for site-owners. However, opposed to these strengths, there are also some drawbacks. First of all the authorization and permits in Italy are currently a major barrier for the construction of ATES systems. The authorization procedures are unclear and take up a very long time. In the E-USE(aq) project, it took multiple years to complete the authorization procedure. This is a major drawback for site-owners and it is to a large extent caused by the fact that there is uncertainty and lack of understanding in the decision-making process. The fact that the E-USE(aq) project delivered a successful pilot location where a lot of data have been generated by extensive monitoring helps to remove part of the uncertainty.

There is currently a lack of know-how in Italy; not only in the authorization procedure but there are also few parties that have the necessary knowledge to successfully construct an ATES system. This limits the potential for large scale implementation of ATES systems in Italy. The knowledge and experience generated in the E-USE(aq) project could help to solve this problem. Institutes such as Climate-KIC could help with disseminating the knowledge and bringing the right parties together to share the necessary know-how and raise awareness in Italy for this innovative technique. Other opportunities for ATES systems at power plants or industrial sites in general are more technical. Balancing heating and cooling peak demand could make ATES systems more efficient. Implementing ATES systems could reduce the operation costs for district heating. The main threats are also mainly technical, and can be tackled by developing a good understanding of the groundwater system and the soil. This gives insights in how the ATES system should be designed and the most suitable location for an ATES system.

All in all, the market potential for ATES systems at industrial sites in Italy is quite large. The suitability analysis for ATES systems based on soil characteristics (see chapter 1 of this deliverable) shows that especially in the northern part of Italy, the soil is very suitable. This pilot project showed that even the presence of high groundwater flow velocities does not have to be a problem and should not limit ATES performance. This enhances the market potential even more. The main barriers for implementation are the lack of knowledge and the authorization procedure. The Italian pilot tackles both barriers since specific knowledge of especially the underground is acquired and authorities are now acquainted with the technology. So, it is expected that the market will be opening up in the region Emilia-Romagna now.

Spanish pilot

Strengths:	Weaknesses:
• Integrates several renewable energy systems and technologies • ATES system which can reduce the overall investment	• Improve the current drilling knowhow • The system is still at an early stage and the perception from the market is still rather distorted: durability and terrain water availability and/or clogging in the long-term are complex issues. • Low value perception due to earlier geothermal systems made faulty or not working properly.
Opportunities:	**Threats:**
• The growing sustainability and energy demand reduction needs, and the growing building refurbishment market • The current trends as LEED and BREEAM seals and programs, plus the reduced heat demands due to PassivHaus • Economies of scale	• Long design, construction and commissioning time • Relationship with local and regional administrations which lack know how about ATES systems and geothermal technologies. • Competition with big investment projects is high due to bigger benefits associated

The main achievement of the Spanish pilot is the development of the DCL loop, which makes it easier to implement ATES systems. According to the legislative rules in Spain, groundwater has to be purified before it is allowed to be pumped back into the soil, even if the water itself is not contaminated. The development of the DCL-loop makes it possible to keep the groundwater in the soil, thereby bypassing the legislative barrier. Added to this, the Spanish pilot in the E-USE(aq) project shows that this technique is also economically very feasible (see deliverable 180267-D02 3.2.5 E-USE Validation of business cases). Unfortunately, there is still a world to win because the perception of the market is still much distorted in Spain. There is not enough knowledge present at the Spanish companies, universities and other stake- and shareholders and there is not a good knowledge infrastructure present in Spain. In general, there is a low value perception of ATES systems due to older geothermal systems that have been constructed poorly and are not working properly. This is bad advertisement for good functioning ATES systems. The opportunity to conquer the market in Spain is to improve the knowledge infrastructure in Spain. This is started in this project by sharing the success story of the E-USE(aq) project, and continues after the project is finished. It is work in progress; ITECON has already started up new projects in which ATES systems with DCL loops will be implemented, which all build on the pilot of the E-USE(aq) project. Hopefully, these new projects will help giving ATES systems in Spain a better position in the competition with large investment projects. Added to this, both ITECON and ITC will keep putting effort in bringing the right parties together to stimulate the implementation of ATES systems.

Because the DCL system makes it possible to use shallow water bearing layers, this enlarges the technical potential of ATES in Europe considerably and consequently the market potential also: the basis of the triangle in figure 3 becomes much wider and so the upper segment grows accordingly. In 2017 and 2018, ITECON already sold a number of DCL loops in Spain and even Malta and Portugal. An overview of these transactions and a thorough analysis of the related business case for the DCL loop is provided in Appendix 1.

Belgian and NL-Delft pilot – ATES and PVT

Strengths:	Weaknesses:
• PVT offers high energy density than separate PV and solar thermal panels, enabling higher capacity to be installed in a limited space • Vacuum tube insulation allows high thermal efficiency and higher temperatures in cold climates • Technology is readily scalable to larger installation sizes • Solar heat can be used both for storing heat in the aquifer in the summer and for directly heating buildings in the spring and autumn.	• Added complexity of system brings challenges in optimising performance through all seasons • Installation requires manpower with experience and skills in both electrical and hydronic technology • Combined technologies may not fit conventional product categories, with respect to renewable energy incentive schemes.
Opportunities:	Threats:
• Addition of solar heat into ATES system allows balancing of annual demand of heating and cooling, enabling long term inter-seasonal storage • Generation of solar PV electricity gives good synergy with heat pump electrical power requirements. • High energy density reduces costs associated with building or ground area • Increasing heat storage temperature increases COP of heat pump for heating supply • Solar energy reduces long-term energy costs and reduces CO2 emissions.	• If water flow is lost, high stagnation temperatures can result, causing risks of thermal damage to the collectors and the system installation • Long-term reliability of new technologies is less proven. • Lack of skilled trained installers • Solar heat can provide temperatures that are too high for injection into an aquifer, requiring automation methods to avoid this e.g. the ability to dump heat form the system.

In regions with a quite developed market, where these pilots were performed, the market potential is already very large and the challenge lies in how to benefit from this potential. The main strength of combining ATES and PVT is the fact that the problem of imbalances between heating and cooling demand can be solved. Also combinations with other renewable energy solutions are possible, to counteract imbalances, such as the addition of thermal energy from surface water and combining office and production buildings or working spaces with different energy demands. Combining different office buildings and connect them to the same ATES system has been demonstrated at the pilot location in Delft and in Delft there are also plans to test the addition of thermal energy from surface water to make the Deltares campus energy-neutral. The pilot in Ham, Belgium demonstrated that working spaces with different energy demands can be successfully combined. In the two pilots in Delft (NL) and Ham (BE), high resolution temperature measurements were demonstrated, which can be used for a better fit of systems close to each other in cities in developing markets where competition for underground space is heavy. Again, these findings enlarge the basis of the triangle in figure 3 (chapter 1) for the application of ATES, resulting in a growing market for this sustainable energy technology. Possible threats for the market uptake for combined ATES and PVT solutions is the political climate in the Netherlands. The government is currently in a transition phase and is not sure yet how to tackle challenges such as climate-change and energy transition. This might scare off parties to implement such systems.

NL-Utrecht and Danish pilots – bioremediation

Strengths:	Weaknesses:
• No need to remove contamination before ATES is installed • Removes building restriction in contaminated area • With proper design and monitoring, no spread of contamination	• Organization complexity • Costs and benefits are unequally distributed • Specific knowledge and experience is crucial • Limited number of existing plants • High competition with drinking water extraction
Opportunities:	**Threats:**
• Integrated use of space • Cost savings • Societal value is increased • Low-cost opportunity to tackle remediation together with ATES application	• Clogging • Spreading of contamination (only without proper design and monitoring)

Interest in the combination concept of ATES systems and bioremediation has recently risen due to the demand for both renewable energy technology and sustainable groundwater management in urban areas, which often face strong competition for space. One of the biggest opportunities for this technique is the fact that the combination of ATES and bioremediation in one single construction could be an effective solution to tackle both soil contamination and mitigate climate change at the same time and thereby provide a cost-effective solution for both problems within an integrated use of space. This is particularly applicable in industrial sites or municipal areas that are dealing with contaminated groundwater. Industries caused (especially in the past) many contaminated groundwater sites. Nowadays, industries are more cautious and legislation procedures have changed so less contamination enters the groundwater. However, there is still some contamination left in the soil. The big challenges of the present time are the energy transition and climate change. Both have an impact on land use. Industries often have a comparatively large energy demand, and ATES systems are a good alternative and/or additional energy source. The combination of ATES and bioremediation provides extra benefits, since multiple uses can be combined on the same area of land or volume of soil. In municipal areas there are still many contaminated sites left. Often, the municipalities are responsible to clean these sites. In our Utrecht pilot, we work with an ATES system below a public sports facility. In this case, since the contamination is spread over a larger area throughout the city centre of Utrecht, the Utrecht municipality pays for the remediation. In theory, combining ATES and bioremediation should be possible everywhere where there’s a good working ATES and specific types of contamination that could be degraded with micro-organisms. Wether this is indeed possible in practice or not highly depends on soil characteristics.

Since the results are very promising, the market potential for the specific application of ATES and Bioremediation combination systems is expected to increase in the coming years. Deltares currently discusses with the municipality of Zwolle (NL) about a possible application of a combined ATES and bioremediation construction on a former industrial site in an urban area.

However, more applied research and monitoring is needed before the method/product could be widely implemented; the method is not yet *business as usual* and still in the development phase. What is important here is that we keep raising awareness about this on conferences, in research articles and other publications. Added to that, we need to focus on governments and industries (because they are large stakeholders) and work with them in pilot locations to make the ATES+bioremediation business as usual.

4. Evaluation

The use of aquifers for thermal energy storage has large potential in Europe and can lead to relevant benefits from the environmental and economic points of view. On the next page, an overall SWOT analysis is provided, with the most important Strengths, Weaknesses, Opportunities and Threats defined for the application of ATES systems in Europe in general. The barriers for implementation that have been defined (see chapter 1) are still present, even after the finalization of the E-USE(aq) project and the pilots in this project. However, what our project does show is that to a large extent most of these barriers are solvable. The SWOT analysis on the next page gives some insights in the remaining barriers.

Strengths - Low cost and efficient thermal energy, economically feasible - Scalable - Easy to integrate with other land-uses and sustainable energy systems (this could also help balancing ATES systems) - Belowground, so not visible and therefore no visual amenity	Weaknesses - Extensive knowledge is vital for constructing successful ATES systems. Some measures can help with this (such as a good knowledge infrastructure), but they cannot remove this weakness completely. - Uneven distribution of costs and benefits - Risk of imbalance and interference - No visual amenity; ATES is easily overlooked as possible solution.
Opportunities - Spend enough €€ on extensive and innovative monitoring to - increase efficiency of ATES system - improve business case - help to ease legislative procedures - counteract possible interference with other ATES - Combine different land-uses	Threats - Misunderstanding related to performance and functionality of ATES, due to lack of correct information (shown in the Spanish pilot) - Legislative procedures; there procedures are difficult to change (shown in the Italian pilot).

In addition to the texts in the SWOT analyses tables, most important lessons learned about the possibilities of unlocking the market potential, compared to the outcomes of the Pathinder project, are in summary (see for pilot details Deliverable 1):

- Application maps can now be redrawn, since especially with the application of the system tested in the Spanish pilot, ATES is possible in much more regions then assumed before when figure 1 was drawn.
- Lack of adequate regulations can be counteracted by both technical measures (as shown in the Spanish pilot) as well as by establishing good contacts with authorities (as shown in the Italian pilot). However, especially the latter approach can take a long time. So, other communications are also important.
- In all of Europe, ATES attractiveness increases now we have shown that energy balance can be found by connecting rooms and buildings (as done in the Italian pilot, the Dutch pilot in Delft and the Belgian pilot) or add additional energy by solar panels (latter two pilots).
- A cost-effective combination of ATES with bioremediation (which was never tried on a full scale in practice before) is indeed possible, although more research is necessary, as shown in the Dutch pilot in Utrecht and in the Danish pilot.
- The audiences that were attracted to the events (see Deliverable 180267-D04 3.2.5 E-USE Local events - events report) and was reached by our communication efforts (see Deliverable 180267-D07 3.2.5 E-USE Report on communications and dissemination around ATES pilots) seems suitable to power the flywheel in figure 2. However they will have to be activated.

A future outlook based on these lessons learned is discussed in Deliverable 180267-D06 3.2.5 E-USE Final project results report, resulting in recommendations.

Appendix 1 - DCL® GEOTHERMAL PROBES BUSINESS ANAYLSIS (provided by ITECON)

Overview of systems sold

Itecon SL started developing the DCL® system in the early 2012, given the company's experience in geothermal open loop and closed loop systems, the earlier concept probes were designed to skip or reduce the usual technical barriers the company experienced in its projects.

The DCL® first commercial model was a 10 meter-long, 100cm diameter probe with a 26kW heat Exchange power, able to power from domestically heat pumps up to any peak power system by modular design.

The Spanish pilot system used three of these probes and a fourth one was tested with a metallic prototype able to Exchange up to 45kW, this making it an ideal testing site for the newly developed probe.

Thanks to the data analysis and the extensive testing, nowadays we have commercial 50kW modes which are being installed in several of our projects:

- A 200kW geothermal heat pump system in Polideportivo Nazareth (Valencia city) being a Valencia Council contract. It will empower an indoor swimming pool heating system, a hot water production system plus air conditioning for the sports facilities. Legal tender available.
- A 700kW geothermal heat pump system able to power a two heat pump-chiller system which Will power a district heating system for three public buildings which house a swimming pool, offices, a library, social halls and so on. The system comprises 17 50kW metallic DCL® probes. This is placed in the very center of Valencia city being a Valencia Council contract. Legal tender available
- A 100kW power geothermal system for an indoor swimming pool in sports facilities being constructed in Valencia, Poliesportiu Nou Moles, legal tender available.
- A public library and social hall building in Nules which will work with a single heat pump and a single DCL® probe, able to produce heating and cooling for the whole refurbished building, property of the Nules council. Legal tender available
- Two outdoors swimming pools (105m^2 and 20m^2) in Sant Joan (Alicante) for a housing complex. The system Powers a 100kW peak power heat pump which captures heat with two DCL® probes, thus providing the pools with renewable heat. Private contract availble
- A 240kW 4DCL® probes system in a hotel in Benicassim with hot water, heating and refrigeration with contract available. This Project has received public funds.
- A 26kW showroom HVAC system in onda. Contract available
- Two private single family houses 12 and 26kW power HVAC plus hot water geothermal systems. Contracts available.
- A showroom with 3 DCL® probes for testing and pilot private system in Gozo Island (Malta), construction on process. Contract and collaboration agreement available.
- A 4 DCL® probes geothermal HVAC and hot water with PV panel integration in Valencia for a housing block. Contract available.

Currently we have been able to reduce the boreholes and DCL® probes system costs from around 38.000€ for a single 100kW system (The spanish pilot early market value) to 27.600€ (in about

27%), given that we are nowadays able to make it with only two boreholes and two 50kW DCL® M3 probes (The metallic model).

This comprises the improvements which makes possible to install tow 40m deep boreholes and two 50kW metallic model instead of 4 32m deep boreholes with 4 P100 DCL® 26kW plastic probes, and the reduction in trenches, piping, control wiring, and so on.

Our contract volume for the DCL system is nowadays between 360.000€ and 600.000€ for the 2018-2019 years (in signed and foreseeable contracts) and a 40% growth in the following two years is foreseen.

Costs reduction survey

We have been improving the design and performance efficiency of our system thanks to the learnings we experienced with the E-Use porject, so that a similar installation can be done with a significant cost reduction, as well as the needed time to construct. This way, we can compare the estimated market value of the Nules system and compare it to a similar Project we have signed in Sant Joan, Alicante.

The Nules system cannot be valued from a market point of view, but it is possible to assign a market value to the installation by not including in the appraisal the pilot-site specifically installed monitoring systems; so that we can estimate the components and subsystems market value.

The engineering, design, management and legal grants costs are being ignored in this comparison due to that they would be similar in any case.

One of our projects presents a general similarity with the pilot system, being a geothermal 100kW heat pump system intended for swimming pool heating, placed in Sant Joan, Alicante.

The geothermal capturing system is comprised by two DCL® probes in 270mm drillings, 45m Deep each one. The heat pump is a Carrier unit, the same model, with integrated circulating pumps.

Similar to Nules Pilot site installation real market value estimation:

SUBSYSTEM	2016 SYSTEM	CURRENT SYSTEM	DIFFERENCE	COST REDUCTION	IMPROVEMENT
CONTROL AND ELECTRIC POWER	3.920,00 €	2.499,00 €	1.421,00 €	36,25%	Inverter system for DCL probes not necessary; less electrical components for less probes.
DRILLINGS AND CASING	11.361,00 €	10.111,00 €	1.250,00 €	11,00%	Only two drillings, bigger diameter (270mm Vs 220mm) and bigger PVC jacket, overall costs reduced.
PROBE AND CAPTURING SYSTEM	16.630,00 €	13.831,00 €	2.799,00 €	16,83%	Two 50kW probes instead of four 26kW probes. Metallic probes, more expensive each but reduced cost €/kW

HEAT PUMP	19.800,00 €	19.800,00 €	0,00 €	0,00%	The heat pump is the same model so that the comparison can be done about the geothermal system.
HEAT TRANSMISSION AND FLUID MECHANICAL & PUMPING SYSTEM	10.983,00 €	8.954,81 €	2.028,19 €	18,47%	Integrated circulating pumps in the heat pump as an optional, costs reduction reflected here.
OTHERS	62.694,00 €	55.195,81 €	7.498,19 €	11,96%	

GEOTHERMAL SYSTEM COSTS REDUCTION (Whole system except heat pump and engineering and legal tramits)	
TOTAL:	-17,48%

The overall cost reduction comprises too the reduced need of trenches, piping, auxiliary machinery such as generators and safety measures, although it is not feasible to estimate those indirect costs reduction with accuracy.