Combination of aquifer thermal energy storage (ATES) in district heating and cooling networks moving towards smart energy systems

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Previous and on-going activities

Project proposal
The **E-USE(aq) project**, financed by the EIT-Climate KIC, demonstrated how aquifer thermal energy storage (ATES) can be implemented in different European countries by showcasing innovative ATES systems tailored to local conditions at six demonstration sites in Italy, Spain, Denmark, Belgium and the Netherlands. These showcase projects showed how the obstacles in each country or region can be overcome, paving the way for the Europe-wide implementation of ATES systems. The project results show that ATES is a renewable energy solution that is economically feasible, and also that social and legislative difficulties can be overcome with innovative technologies, bridging the gap between science and practice.

The warm and cold ATES wells can be separated horizontally; each pair thus formed is then called a “doublet”. The well screens can also be installed vertically in a single borehole, forming a pair called a “monowell”. “Recirculation” systems always use the same wells for extraction and infiltration: water is extracted from the upstream well and injected into the downstream well (usually adopted if ambient groundwater flow velocity > 25 m/year).
Europe-wide use of sustainable energy from aquifers – E-USE(aq) (completed on 31st December 2018)

The Italian pilot plant (TRL-6) has the scheme of a «cold» low temperature district heating system, i.e. a system for distributing cold water in a temperature range between 10°C and 25°C to end-users’ substations where it is used to produce, also simultaneously, hot and cold water at different temperatures and for different purposes (space heating, cooling, domestic hot water production) via heat pumps and chillers.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° of production wells</td>
<td>3 + 3</td>
</tr>
<tr>
<td>N° of monitoring wells</td>
<td>4</td>
</tr>
<tr>
<td>Wells’ depth (m)</td>
<td>30</td>
</tr>
<tr>
<td>Max groundwater flowrate (m³/h)</td>
<td>19.4</td>
</tr>
<tr>
<td>Max cooling power (kW)</td>
<td>140</td>
</tr>
<tr>
<td>Max heating power (kW)</td>
<td>160</td>
</tr>
</tbody>
</table>

The pilot plant is now running since June 2019 with promising results!
Deep retrofit and decentralised low temperature energy generation and distribution at district scale – iEnergyDistrict
(completed on 31st December 2018)

The pathfinder project iEnergyDistrict, financed by the EIT-Climate KIC, aimed to
i) identify the relevant barriers that are limiting the adoption of low temperature
district heating (LTDH) networks in existing DH networks, ii) provide solutions to
overcome the specific barriers, iii) identify one or more sites for demonstrator(s)
realization, iv) realize a feasibility study and environmental impact of
demonstrator(s), and v) involve municipality and local government authorities.

Several potential sites have been identified, including:

- DH of Cesena (retrofitting)
- DH of Modena (retrofitting)
- DHC of Bologna Navile (retrofitting)
- DHC of Forlì production site (new)
Previous and on-going activities

Project proposal
The combination of ATES and low temperature DHC system can be seen as a promising solution for the implementation of a carbon-free heating and cooling strategy. In fact, ATES system can play a relevant role in the following fundamental topics:

1. **Increasing the efficiency of existing DHC networks**: ATES system can be effectively applied also in existing DHC networks. In fact, in the last years, the selling price of power dramatically dropped, and so the CHP business model is not sustainable anymore. Since the use of reversible heat pumps allow to self-consume a part or the whole power produced by CHP plant, ATES system can be seen as a way to free DHC networks economic from power selling price and increase the renewable energy share.

2. **Seasonal storage**: ATES system can represent a turn key element in the seasonal efficiency increase of DHC networks, since ATES system can allow to store in the groundwater warm water in summer to be used in winter, and to store cooled water in winter to be used in summer.
3. **Decentralized heating and cooling production**: ATES system can be used in cold LTDH and cooling networks as an effective local and decentralized temperature booster or sink. So, ATES system can play the role of temperature balancing of the distributing network. Moreover, ATES system can be used as decentralized heat/cold storage element.

4. **Power-to-heat and power-to-cool**: reversible heat pumps installation in DHC systems is a fundamental part in the design of a smart energy grid, i.e. a multi-source grid integrating together power grid, natural gas grid and DHC networks, since converting electricity into heat (power-to-heat) or cold water (power-to-cool) through reversible heat pumps can provide flexibility in the electricity system, since they can be operated when electricity prices are low or excess electricity is produced by renewable sources (i.e. photovoltaics and wind turbines). When the ATES concept is applied for power-to-heat and power-to-cool, there is the further benefits of using a renewable energy as heat source or heat sink and of allowing the storage of the heat and cold water produced.
BUT...

Expertise and concrete projects in the field is limited and there is currently a lack of reliable and adequate analysis tools and cost data to assess the technical-economic potential of ATES in combination with DHC networks. The realization of a **demo plant at a relevant scale** is **crucial** to demonstrate the sustainability of the concept and to promote the replication of the concept.

University of Bologna, in collaboration with CPL Concordia (DHC network designer, builder, manager and owner) and with the Municipality of Bologna have already identified the **Navile DHC network in Bologna** as a potential site for a demo realization of the combination of ATES in a DHC network. In particular, the project proposal would foresee: i) the retrofit of the existing DHC network moving towards a cold low temperature DHC, ii) the redesign of the substations, and iii) the redesign of the centralized heating/cooling plant. Both points i) and ii) include the installation of ATES systems.
Now 7,180 MWh of natural gas and 350 MWh of electrical energy are annually consumed to produce 3,820 MWh, 2,010 MWh and 1,650 MWh of warm water, cold water and electrical energy that is in part sold to the electrical national system. However, 995 MWh of heat (i.e. the 26% of the total) is thermally lost in the distributing network, while about **1,100 ton/year of equivalent CO₂ are produced**.
What is the innovative technology and key elements that need demonstration before commercialization? What are the products (final, intermediate or by-products)? What is the technological readiness level of the project and of its different distinct elements? How innovative is the project in comparison to the state-of-the-art?

The innovation lays in the combination of ATES systems in cold low temperature DHC networks. The key elements that need demonstration are:

i. the design of an ATES system in high groundwater velocity conditions (i.e. over 25 m/year),

ii. the development of effective technical and economic strategies for real time control of the DHC network,

iii. the test of new reversible heat pumps working with innovative refrigerants and with low quality groundwater (i.e. high concentration of some chemical components), tailored for shallow geothermal applications.

The final product of the project would be the optimized design of the combination between ATES and DHC. While TRL of both ATES and cold low temperature DHC systems is 9, the combination of both still requires demo testing at relevant industrial scale.
What are the capital expenditure, operational costs and benefits over 10-year period related to the innovative project? What is the level of certainty over envisaged costs and benefits? What are the key variables influencing them?

The uncertainty of the project is related to the characteristics of the aquifer, that need to be preliminary assessed and deeply investigated in order to properly design the ATES system. The capital expenditure has been evaluated in 1-2 million Euros with a pay-back time of 7-9 years. The pay-back time could be reduced if new users will connect to the Bologna-Navile DHC network.

What is the financing gap and how do you expect to address it?

The investment in the Bologna-Navile DHC network can be realized by the company (CPL Concordia) with own funds, but the investment is perceived as risky due to the uncertainty related with the innovative solution to be implemented. Reducing the investment through an external financing support (i.e. European funds) is fundamental to boost the realization of the project idea.
What is the GHG emission reduction potential of the project in comparison to a conventional project of the same scale?

The preliminary estimation evaluates a potential GHG emission reduction of about 790 ton/year of CO₂ emission, that is about 30% less than current emission, only due by the distributing temperature reduction in DH operation. The combination of ATES with the new low temperature DHC network can at least double this emission reduction.

What is the size of the potential market of the products (final, intermediate and by-products)?

The size of the potential market of the final product is wide, since most of the existing DH systems worldwide need retrofitting actions to increase efficiency and sustainability. Only in Italy, there are a total number of 236 DH networks, with a total pipelines installed of 4270 km, distributed in 193 cities.

What is the expected project development timeline? Has the project already done pre-/feasibility study, FEED study? What steps need to be taken/conditions met before Final Investment Decision?

The project would need 5 years to be implemented: 1 for the design, 1.5 for the construction and commissioning, 2.5 for the monitoring. A preliminary assessment of the aquifer characteristics need to be realized before final investment decision.

Is the project dependent on other projects, development of infrastructure or adoption/amendment of certain EU or national regulation?

No.