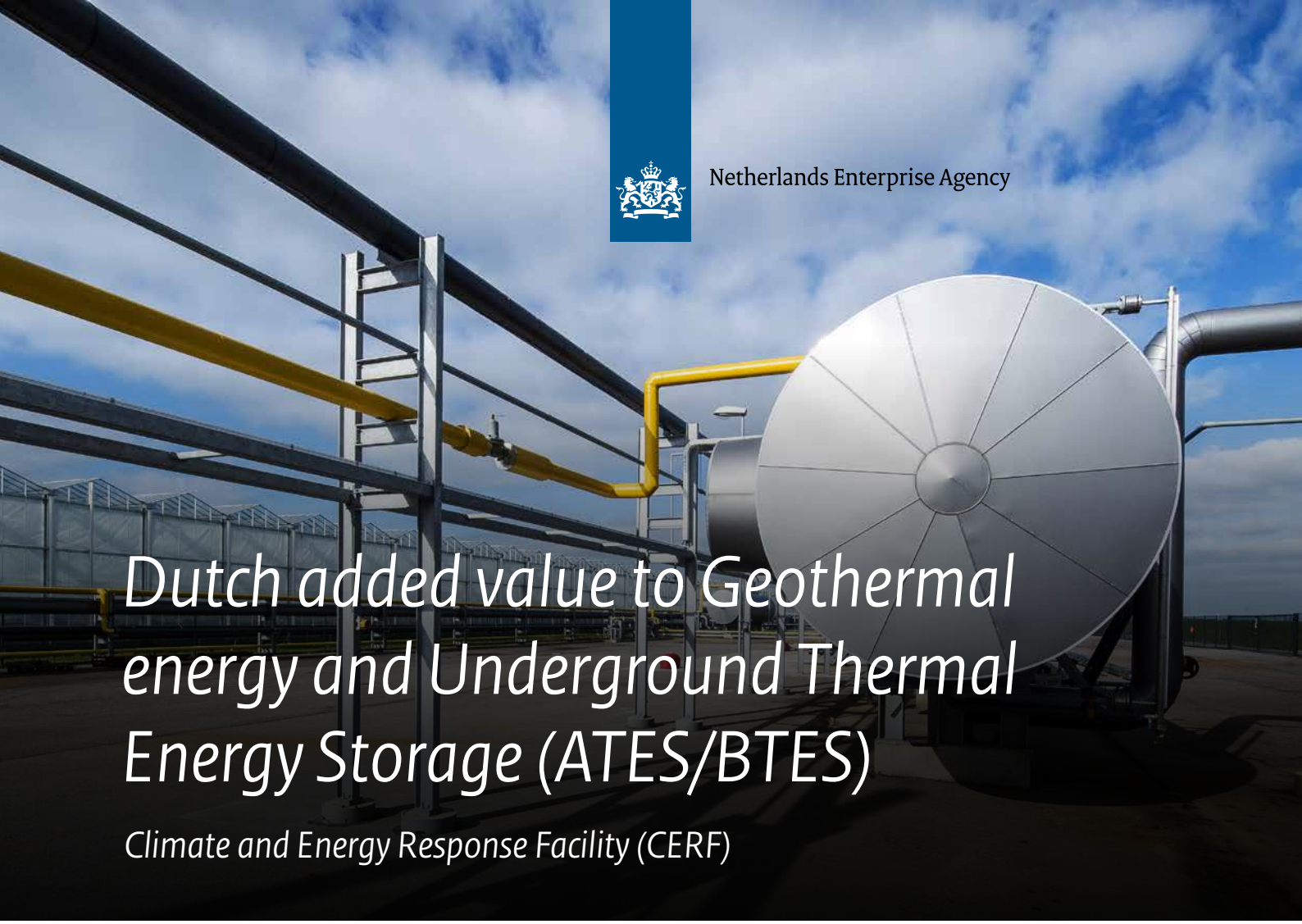

Netherlands Enterprise Agency

Dutch added value to Geothermal energy and Underground Thermal Energy Storage (ATES/BTES)

Climate and Energy Response Facility (CERF)

Potential for renewable energy and energy storage exists in the subsurface. In the Netherlands, geothermal energy and underground thermal energy storage are crucial in the energy transition. The Netherlands has the third largest number of geothermal district heating and cooling installations in operation or development, following France and Germany. Currently, the Netherlands is recognised as a leader in geothermal heat production due to its innovative and cost-effective methods.
The Netherlands has over 3,000 Aquifer Thermal Energy Storage (ATES) systems, the highest number in the world, along with more than 100,000 Borehole Thermal Energy Storage (BTES) systems. Additionally, a unique Underground Thermal Energy Storage (UTES) system is installed in the old galleries of a coal mine in the southern Netherlands.

Geothermal energy is a powerful and sustainable source of heating and cooling that utilises the earth's natural warmth. This heat originates from the earth itself and serves as an inexhaustible source of clean, sustainable energy. The deeper you go into the earth, the hotter it becomes, which is known as the geothermal gradient. Geothermal energy is generated by producing hot water or steam from beneath the Earth's surface. Geothermal energy is utilised for heating and cooling buildings, greenhouses, and industrial processes. Geothermal steam can also generate electricity through a turbine.

The efficiency, sustainability, reliability, and cost-effectiveness of heat sources, such as geothermal, waste heat, solar, or aquathermal, can be significantly improved when linked to an Underground Thermal Energy Storage (UTES) system. By storing excess energy underground and minimising reliance on conventional heating and cooling systems, these systems greatly reduce CO_2 emissions and energy costs. As the demand for sustainable energy solutions increases, UTES have become essential components of modern low-carbon energy strategies and a flexible energy system. In addition to a heat source and storage system, heat must be distributed to consumers. This distribution is achieved through a heat network or district heating and cooling (DHC) grid.

Underground Thermal Energy Storage (UTES) stores heat in the subsurface over extended periods, typically seasonal, for use during times when heat demand exceeds heat supply. For example, heat collected during the summer is stored for winter use. The subsurface can store vast volumes with minimal surface area. Various methods are available, including Aquifer Thermal Energy Storage (ATES), Borehole Thermal Energy Storage (BTES), Mine Thermal Energy Storage (MTES) and Pit Thermal Energy Storage (PTES). ATES utilises naturally occurring groundwater in deep aquifers as a medium to store thermal energy. BTES involves drilling a series of boreholes into the ground and installing heat-exchanging pipes in them. MTES stores heat from salt extraction in the galleries of old coal mines and caverns. PTES systems are found either at the surface or just below it.

Geothermal Energy – the Dutch Perspective

Geothermal technology is mainly utilised in greenhouse horticulture in the Netherlands. This is currently being expanded to include urban environments and district heating systems. In The Netherlands, geothermal energy production typically occurs at depths ranging from 1,500 meters to 4,000 meters below the surface. The Netherlands is unique because it focuses solely on producing heat from geothermal energy rather than electricity. In the Netherlands, approximately 50% of the final energy consumption is used for heating, 25% for electricity and 25% for transport fuels (KEV, 2021). Geothermal energy has the potential to supply over 25% of the heating demand in the Netherlands, significantly contributing to the country's energy transition.

UTES – the Dutch Perspective

The UTES systems have even broader applications and can be easily integrated with wind and solar energy technologies, for example, in fifth-generation district heating networks. Geothermal, aqua thermal, and medium-temperature storage technologies present significant opportunities. The Netherlands has the appropriate ocean climate and suitable subsurface for these techniques. Large-scale seasonal thermal energy storage is not yet implemented in the Netherlands, but smaller pits with shorter storage times (upxto several weeks) are present.

Project Examples of Geothermal Energy

- The geothermal system in The Hague (in Dutch) provides heat to around 4,000 households through the Eneco urban heating network. The city intends to develop 10 to 15 geothermal projectsfor urban heating.
- At Agriport A7 Middenmeer (in Dutch), ECW Energy operates three geothermal installations that provide heating for green-houses, saving 30 million m3 of natural gas each year. The first High-Temperature ATES (in Dutch) is designed to store excess heat from the geothermal wells during the summer, with a temperature of 85°C at a depth of approximately 370 meters.
- Greenbrothers has developed the first low-temperature geothermal system that produces 4 MWth in Zevenbergen. The wells are only 800 meters deep and yield water of approximately 30°C. When combined with a heat pump, this temperature can be upgraded to 70°C, making these shallow, cost-effective wells a viable solution for greenhouses, residential and utility buildings.
- Trias Westland (in Dutch) drilled the deepest geothermal exploration well in the Netherlands, reaching a depth of 4,000 meters. Although the quality of the reservoir at this depth was insufficient, a shallower geothermal reservoir was successfully developed. Currently, two geothermal systems have been established: A 20 MWth plant that provides heat to 100 hectares of greenhouses and a 15 MWth plant that will supply heat to the world's largest flower auction hall and 345 houses.
- The Minewater projects utilise former mine corridors that contain hot water to create an innovative circular energy network. This low-temperature water source provides both heating and cooling for homes, offices, shops and industrial facilities. Additionally, residual heat from the surrounding area is stored in existing underground corridors. As a result, the Minewater project is also the Netherlands' first MTES project.

Current Projects Under Development

- Delft (Geothermie Delft)
- TU Delft has drilled a geothermal doublet and will implement a high-temperature ATES system. Ultimately, the project will provide heat for the campus and several neighbourhoods in Delft.
- Tilburg (ELFO)
- Eavor loop technology will be utilised in a district heating project in Tilburg. This innovative system consists of 12 multilaterals drilled to a depth of 2,300 meters. The key distinction between the Eavor loop and traditional systems is that it operates as a closed-loop system.

Project Examples of UTES

- The office of insurance company A.S.R. has been renovated to operate completely independent of gas by utilising ATES a.s.r. becomes fully carbon neutral (asrnl.com)
- Wageningen University and Research has an ATES district heating network to connect all ATES systems on the campus. All buildings are connected to the ATES network Substantial energy savings thanks to aquifer thermal energy storage loop at Wageningen Campus - WUR
- The Hide Park, Hoofddorp residential area combines ATES with aqua thermal De grootste all-electric WKO in woningbouw - Eteck
- ATES provide heating and cooling for the office of the City of Utrecht and the public transport terminal (in Dutch 65.000 m2) WKO NS Utrecht
- Residential area Schoenmakershoek in Etten-leur has been independent of gas for 15 years using borehole thermal energy system (BTES) in combination with heat pumps (in Dutch) Wijk Schoenmakershoek: 1.500 woningen al 15 jaar gasloos met warmtepomp en bodemenergie | Bodemenergie
- ATES masterplan for new residential area Merwedekanaal at Utrecht providing heat and cold for 4,000 dwellings and 70,000 m² of commercial and social buildings. In Dutch: Utrecht krijgt grootste wko van Nederland - Stichting Warmtenetwerk

Current Project Under Development

- Utrecht Science Park will be heated using a high-temperature ATES system. The seasonal heat storage system will be heated using electricity from local PV panels. https://projecten.topsectorenergie.nl/projecten/acceleration-of-underground-thermal-energy-storage-38730

Research and Development

- The UDG Green Deal is a collaboration involving five different consortia that focus on ultra-deep geothermal energy pilot projects. In this context, ultra-deep geothermal energy refers to drilling deeper than 4 kilometres, which can produce temperatures exceeding 120 degrees Celsius. Currently, no drilling exceeds 4 kilometres in the Dutch geothermal energy sector, making this technology quite innovative even by international standards.
- WarmingUP: The WarmingUP collective is a collaboration of 38 participants (companies, governments and research organisations) that generates knowledge for sustainable, collective heat systems to make them reliable, sustainable and affordable for the heat transition. Research topics include intelligent heat networks and system integration, large-scale heat network deployment, aqua-thermal technology, geothermal technology, underground heat storage and societal integration. Several spin-off projects, such as WarmingUP GOO (in Dutch) or the Design Toolkit (in Dutch) for district heating and cooling networks, are currently running.
- GEOTHERMICA is a European research call which combines the financial resources and know-how of 20 owners and managers of geothermal energy research and innovation programmes from 16 countries and their regions. The Netherlands is represented by the Netherlands Enterprise Agency (RVO) by Paul Ramsak and Gerdi Breembroek. Ongoing projects with Dutch participants are HEATSTORE, CAGE, PERFORM, GECONNECT, GEOFOOD, RESULT, DEEP, GRE-GEO.

Dutch partners

The following list provides an overview of Dutch partners in subsurface thermal energy storage and their international experiences:

- Research organisations: Deltares, KWR Water, TNO, TU Delft, Utrecht University and WUR.
- Consultancy firms: DWA, Techniplan, Groen Holland, IF Technology (projects in Japan and South Korea, among others), KWA, Royal HaskoningDHV, Sweco, Van Harlingen Grondwater Management B.V. (VHGM) and Witteveen+Bos (projects in South Korea and Chile, among others) .
- Priva supplies control technology for subsurface thermal energy storage systems. Operational in China, among other countries.
- Melotte Pumptechnology | Submersible borehole pumps and submersible motors and injection valves for ATES operations.
- Boode supplies piping, screens and materials for wells in, for example, Japan.
- Haitjema is a highly experienced drilling company that has completed projects in Asia and the United Kingdom.
- Conrad Stanen (conrad-stanen.nl) is a Dutch manufacturer of specialised ATES/BTES drilling equipment. They are the first with an all-electric drilling rig.
- Bioclear Earth has developed the ATES+ or bio washing concept in cooperation with Brabant water, T&K Service, the municipalities of Den Bosch, Apeldoorn and Tilburg, the province of Noord-Brabant, Hydreco, IF Technology, Wageningen University and Rijkswaterstaat. This is a combination of ATES and an improvement in groundwater quality, making ATES possible in contaminated zones.
- KWR Water Research researched the possibility of UV technology in combination with ATES to clean up water pollution. WKO/UV: Energiek saneren - KWR (kwrwater.nl) (in Dutch)
- GreenSquare is a greenhouse builder focusing on Japan. Thecompany builds Dutch-style sustainable greenhouses and also wants to use Dutch subsurface energy technology.
- Dutch research institute Deltares https://www.deltares.nl/en collaborates with the EU project E-USE(aq) (EIT Climate-KIC) on the dissemination of ATES knowledge in the EU countries. ATES beyond the Dutch borders| Deltares https://www.deltares.nl/en/expertise/projects/europe-wide-use-soil-energy-ates

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These factsheets aim to provide an overview of Dutch added value for specific climate mitigation niches. The factsheets are the result of an analysis performed by the Climate and Energy Response Facility (CERF) in consultation with stakeholders from various ministries and/or field experts. The factsheets are prepared to the best of our knowledge, but are not necessarily complete and will be updated when relevant. This article is intended for internal use by the Dutch government. Suggestions for updates or improvements can be shared with cerf@rvo.nl.

Netherlands Enterprise Agency is a department of the Dutch ministry of Economic Affairs and Climate Policy that implements government policy for Agricultural, sustainability, innovation, and international business and cooperation. Netherlands Enterprise Agency is the contact point for businesses, educational institutions and government bodies for information and advice, financing, networking and regulatory matters.