Disclaimer HT-ATES potential maps in ESDL Mapeditor

The HT-ATES potential maps only provide a general regional indication of potential and are not suitable for local analyses or financial decision-making due to model and economic uncertainties.

The following disclaimer applies to the HT-ATES potential maps published in May 2025 (ThermoGIS release v2.4). The maps can also be found in the storymap at: https://www.thermogis.nl/en/high-temperature-aquifer-thermal-energy-storage

High Temperature Aquifer Thermal Energy Storage (HT-ATES)

Heat can be stored underground in various ways. High-Temperature Aquifer Thermal Energy Storage (HT-ATES) is one of them. This technique can be used to both store and produce heat (>60 °C). Storage usually takes place in the summer by injecting hot water into an aquifer. This heat can then be used again during colder periods (Figure 1).

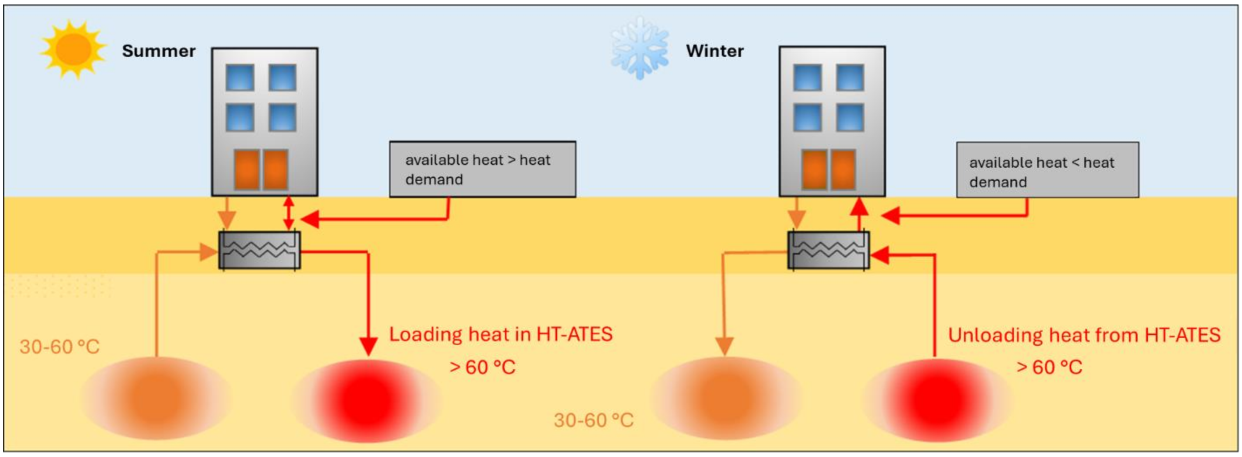

Figure 1 Working principle of an HT-ATES system. Left: In summer, water is pumped from the cold/lukewarm well (low temperature, orange), and heated with excess heat using a heat exchanger. The heated water is then injected into the warm well (red). In winter, the flow direction is reversed, and the heat is recovered from the warm well. The cooled water is pumped into the compensation well. Source: adapted from BodemenergieNL.

ThermoGIS-HT-ATES: purpose and method

In order to provide insight into the HT-ATES potential in the Netherlands, ThermoGIS has been expanded with an HT-ATES module. Calculations have been made to determine how suitable certain subsoil layers are for storing hot water. The calculations use:

- Maps (aquifer depth, thickness and properties)
- Constant values (technical and economic parameters, Tables 2 and 3)

The potential for HT-ATES depends heavily on the condition of the subsurface, but also on case-specific circumstances such as the temperature of the heat network. That is why assumptions for a generic heat network have been used in ThermoGIS-HT-ATES. This means that the suitability maps provide a general picture and are not suitable for detailed design.

Geological basis

The layers most suitable for HT-ATES are located at depths of 100 to 500 metres, such as the Maas-Sluis and Oosterhout formations. These layers have not yet been fully mapped using the ThermoGIS methodology. For this reason, the maps from REGIS II v2.2, a regional geohydrological model, have been used. Whereas ThermoGIS mainly uses 2D and 3D seismic data for the deeper layers, REGIS determines the depths and thicknesses of layers by interpolating between (shallow) borehole data. This leads to greater uncertainty, especially in areas with few boreholes.

For this reason, only the Brussels Sand Member is currently visible in the ThermoGIS-HT-ATES Map Viewer; this layer has been mapped using the ThermoGIS methodology. The ESDL Map Viewer does show potential maps for four aquifers in the Maassluis and Oosterhout Formations. The maps of these layers have been created in a different way than those in the ThermoGIS-HT-ATES Mapviewer. They do not yet meet the quality requirements for ThermoGIS and can only be viewed within ThermoGIS under the “New developments” tab.

ThermoGIS and WarmingUP GOO are working on improving the moderately deep (~100-500 m) regional hydrogeological models. These will eventually also be used for ThermoGIS-HT-ATES.

Uncertainty of economic parameters and calculations

There is currently only one operational HT-ATES project in the Netherlands. As a result, reliable estimates of economic parameters such as CAPEX (capital expenditure) and OPEX (operating expenditure) are limited. The economic maps in ThermoGIS-HT-ATES are therefore indicative and not suitable as a basis for financial decision-making.
Nevertheless, CAPEX and OPEX values are relevant to tools such as the DesignToolkit and MESIDO, which assess the affordability of a heating system using HT-ATES. To provide users with initial guidance, these maps are only shown as a general indication. Users must enter case-specific values themselves to obtain a more accurate estimate.
The economic model in ThermoGIS-HT-ATES is based on a net present value model (discounted cash flow) that has also been used for ThermoGIS geothermal. The NPV model has not been specifically adapted for HT-ATES, only input was changed. As a result, certain costs, such as the required pump energy, may be incorrectly estimated. In HT-ATES, for example, only one pump is usually in operation at a time, whereas in geothermal energy, both the ESP and the injection pump run simultaneously.
The OPEX is divided into:

- Fixed costs: partly a fixed amount per year (fixed OPEX, €), partly dependent on the size of the installation (variable OPEX, €/kW).
- Variable costs: dependent on the amount of energy produced (€/kWh).

The input values used are shown in Table 3, with an explanation in Vrijlandt et al. (2023). Table 1 shows the units used in the economic maps.
Table 1 Economic maps, incl. units.

Map	Unit
capex	M€
opex	M€ (OPEX in first year)
fixedopex	M€ (over total lifetime: 30 year)
varopex	M€ (over total lifetime: 30 year)
utc	€ct/kWh

Constant values input HT-ATES (technical and economic)

Tables 2 and 3 show the technical and economic constant values used to create the HT-ATES potential maps for the Maassluis and Oosterhout Fm.

Table 2 Technical parameters used in HT-ATES potential maps Maassluis and Oosterhout Fm.

Technical parameters	Value	Unit
aquifer top depth	from map REGIS II v2.2	m
aquifer thickness	from map REGIS II v2.2	m
aquifer net-to-gross	from map REGIS II v2.2	-
aquifer permeability	from map REGIS II v2.2	mDarcy
aquifer temperature	from 3D model ThermoGIS	°C
aquifer water salinity	salinity water [ppm] = 70000/1500 × depth [m]	ppm
aquifer anisotropy	8	-
injection temperature hot well	80	°C
cut-off temperature (minimal production temperature in hot well)	45	°C
injection temperature cold well (retour temperature heating network)	40	°C
injection/production period (max. 182 days)*	120	day
ROSIM simulation time (constant capacity after x years)	15	year
minimum depth**	100	m
maximum depth**	500	m
filter fraction (% from aquifer thickness)	25	-
kh cutoff **	1	m/year
filter length (% of total aquifer thickness)	0.9	s/l2
specific clogging verlocity (Vv)	0.3	-
Membrane Filter Index (MFI)	0.1	m
depth factor	0.01 (depth correction from 100m)	inch
distance between two wells at reservoir level	2x thermal radius	m
outer diameter (open production interval)	31	m
pump depth	150	m
put segment length	30	M

* when the number of production days is <20, the simulation stops
** for faster calculation

Table 2 Economic parameters used in HT-ATES potential maps Maassluis and Oosterhout Fm.

Economic parameters	Value	Unit
economic lifetime	30	year
drilling time	1	year
well costs	100.000 + 1000*depth + 0.3*depth^2	M€
CAPEX base costs (excl. wells)	1.1	M€
CAPEX variable costs (excl. wells)	25	€/kW

CAPEX contingency	25	%
annual OPEX base costs	70000	€
annual OPEX per unit power	6.8	€/kW
annual OPEX per unit produced energy	0	€ct/kWh
electricity purchase price for operations	8	€ct/kWh
tax rate	25	%
interest on loan	5	%
inflation	2	%
required return on equity	7	%
debt ratio	80	%