USES4HEAT

TRAINING MODULE

Seasonal heat storage for greenhouses

The Andel demonstrator (the Netherlands): from the ground to the greenhouse

Duration: about 60–90 minutes · Level: introductory to intermediate

What you will learn

By the end of this module you will be able to:

1. Explain why heat must be stored between seasons
2. Describe how an aquifer thermal energy storage (ATES) works
3. Name the three technologies of the Andel system and their roles
4. Read the key numbers: temperatures, wells, volumes, COP
5. Understand the permit and monitoring challenges





Agenda

MODULE 1

The case

Andel, the greenhouse, why storage

MODULE 2

The underground

Climate, aquifers, geology

MODULE 3

The storage (MT-ATES)

Wells, volumes, temperatures

MODULE 4

Heat pumps

Design, refrigerant, laboratory tests

MODULE 5

Solar PVT panels

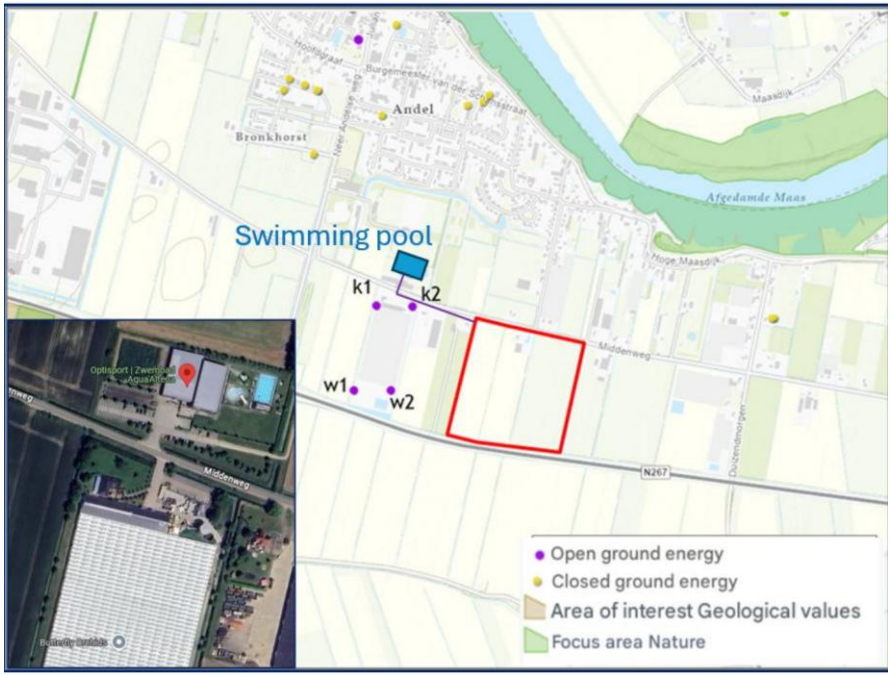
Electricity and heat from one panel

MODULE 6

Permit, risks, monitoring

And a knowledge check

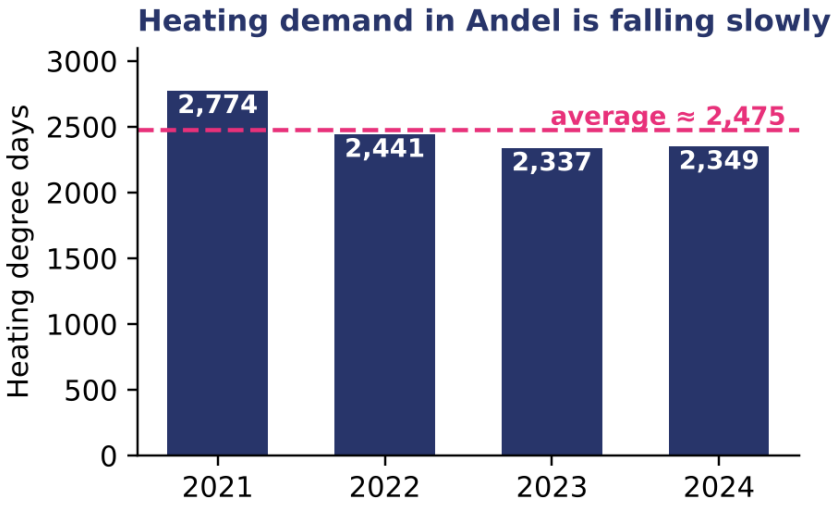
The case: a greenhouse that wants to stop using gas



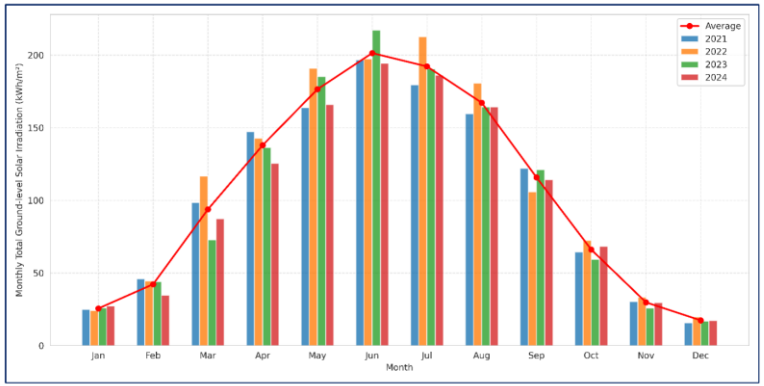
The demo area in Andel: new greenhouse (red), existing greenhouse, swimming pool.

- **Andel:** a village in the municipality of Altena, Noord-Brabant, close to the river Maas.
- **Host:** Butterfly Orchids, an existing 3.5 ha orchid greenhouse.
- **Expansion:** +12 ha with no gas connection, linked to the old greenhouse by a pipeline.
- **Neighbours:** a swimming pool connected to the energy system; the village is about 400 m away.
- **Today:** gas boilers, CHP, heat pumps and a low-temperature ATES (5–25 °C).

Why store heat? The seasonal mismatch



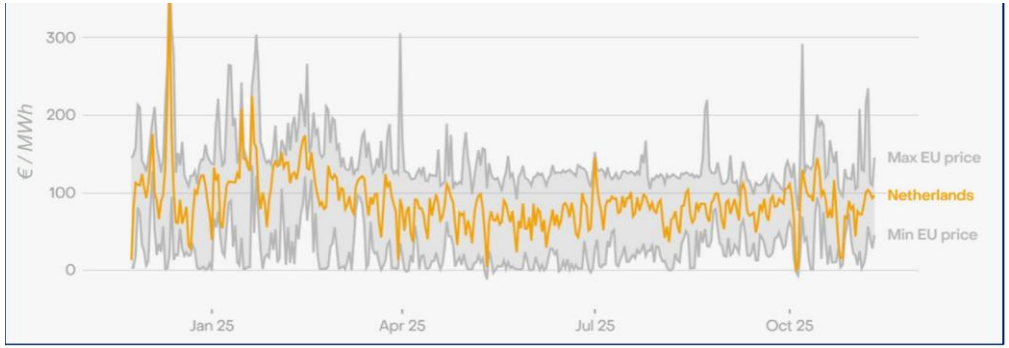
Heating degree days (heating demand), 2021–2024



Monthly solar irradiation: highest in May–July

Heat is needed in winter (October–April, below 15 °C). The sun and surplus heat are abundant in summer. Storage connects the two.

Why store heat? Electricity prices and the grid



Wholesale day-ahead electricity prices, Netherlands, Nov 2024 – Nov 2025

53%

renewable share of Dutch electricity in 2024

+100%

winter prices can be up to double summer prices

- Grid congestion makes winter electricity scarcer and more expensive.
- Idea: run the heat pumps in summer, when electricity is cheaper, and store the heat for winter.
- Gas taxes keep rising, which pushes users towards renewable heat.

The concept in one picture

Andel demo: seasonal underground heat storage

Surplus summer heat from the greenhouse

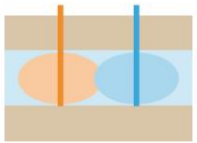
Surface water

PVT heat

Potential waste heat from nearby facilities

Cost-effective, large-scale, seasonal underground thermal energy storage

High Temperature ATES



Wells in the aquifer store heat from summer for use in winter

Groundwater heat pumps (GWHP)



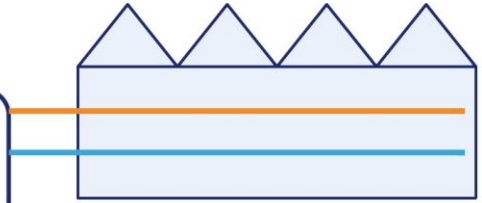
Upgrade the temperature of the collected heat before storage

PVT panels



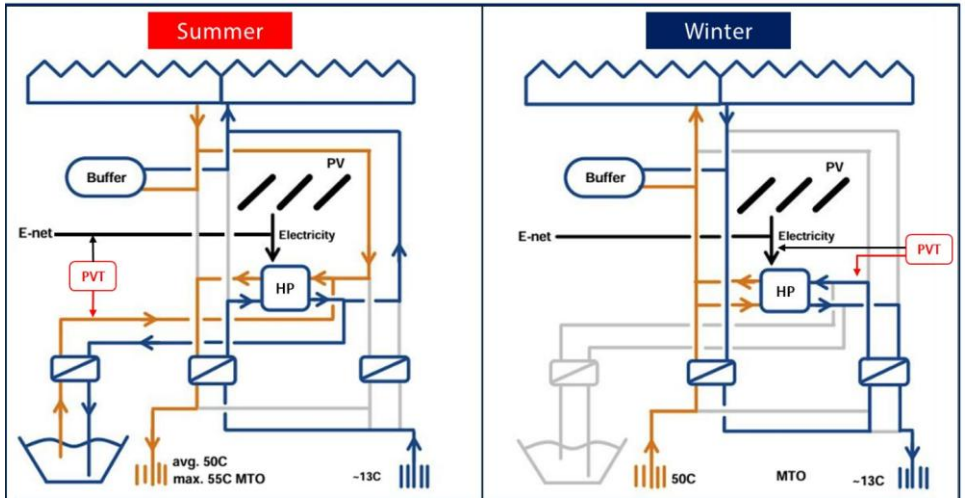
Produce electricity and heat from the same panel

Butterfly Orchids greenhouse: +12 ha, no natural gas connection



- **Seasonal storage: summer surplus heat is used in winter**
- **Flexibility: heat available in periods of high demand or high energy prices**
- **Projected saving of 2.4 million m³ of natural gas per year for the 12 ha**

How it works: summer charges, winter discharges



Energy system in summer (left) and winter (right)

SUMMER

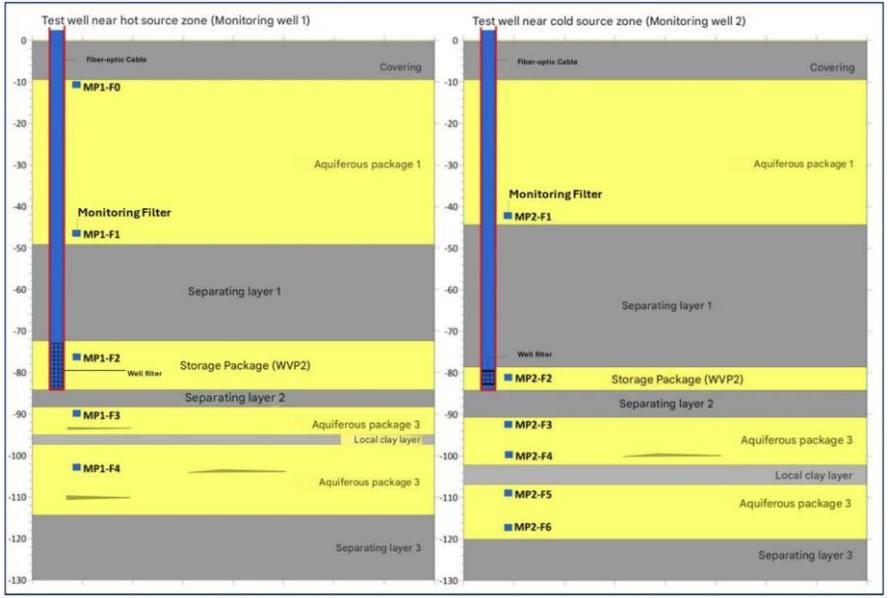
- Heat from the greenhouse (cooling) and surface water
- Heat pumps lift it to about 50 °C (up to 55 °C)
- PVT adds heat and electricity
- Hot water is injected into the warm wells

WINTER

- Warm wells supply the greenhouse, directly or through the heat pumps
- Heat is recovered down to a 25 °C cut-off
- Cooled water returns to the cold wells (about 13 °C)

CHARGE May → November | **DISCHARGE November → May**

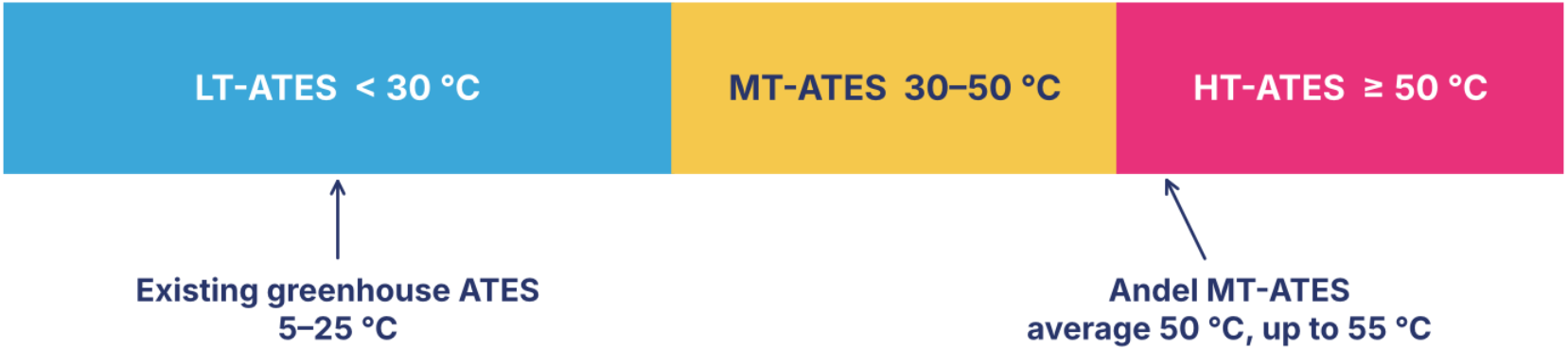
The underground: aquifers and clay layers



Layers at the two test wells (warm zone, left; cold zone, right)

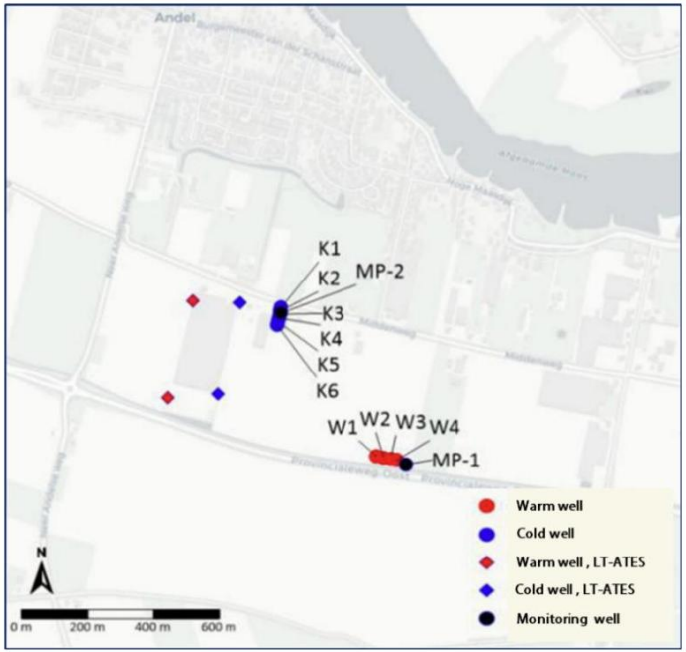
- **Aquifer:** a layer of sand that holds and lets water flow. Yellow in the picture.
- **Aquitard:** a clay layer that blocks the flow. Grey in the picture.
- **Storage package:** 72–84 m deep at the warm cluster (about 12 m thick); 79–84 m at the cold cluster (about 5 m).
- **Groundwater:** 12 °C, flowing southeast at about 18 m per year.
- **Test drillings:** two boreholes confirmed that the ground is suitable and gave the data for well design.

ATES temperature classes



- Low-temperature ATES usually needs a heat pump to raise the temperature before use; higher classes reduce or avoid that step.
- Only 6 medium-temperature and 1 high-temperature ATES systems are operational today: challenges are recovery efficiency, clogging, corrosion and permitting.

The storage design: four warm wells, six cold wells

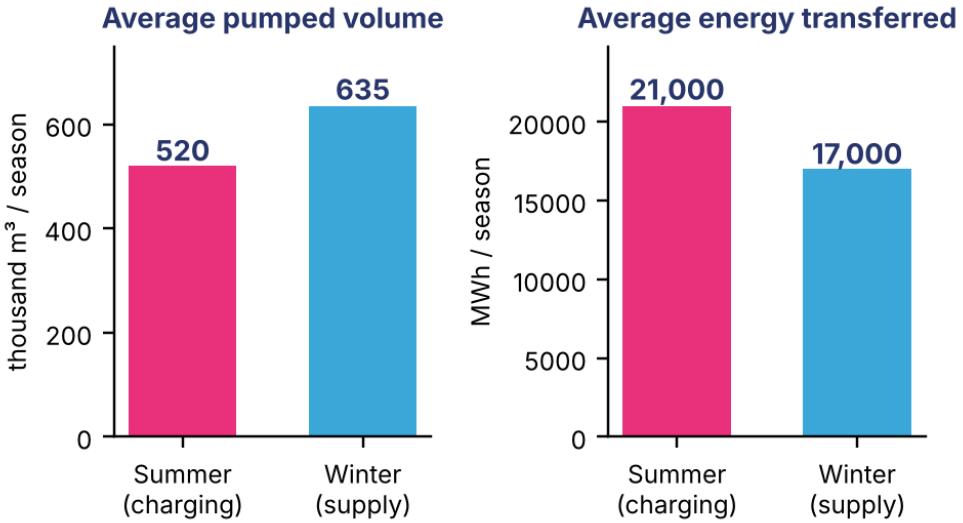


Warm (red), cold (blue) and monitoring (black) wells

Warm wells	4, about 20 m apart (southeast corner)
Cold wells	6, about 11 m apart (northwest corner)
Borehole	90 m deep, 500 mm wide
Warm well filter	Stainless steel, 73–83 m
Cold well filter	PVC, 80–83 m
Observation wells	3 per borehole
Max flow	390 m³/h

Clusters are kept about three times the radius of the heated zone apart to protect the cold source.

Storage numbers: volumes, energy and efficiency



50 °C
average injection (summer); up to 55 °C

13 °C
average injection (winter); down to 5 °C

25 °C
winter cut-off temperature

390 m³/h
maximum flow rate

Recovery efficiency: about 40% in the first five years while the aquifer warms up, rising to about 60% by the tenth cycle. Average heat supply with heat pump: about 18,500 MWh per winter.

Heat pumps: design

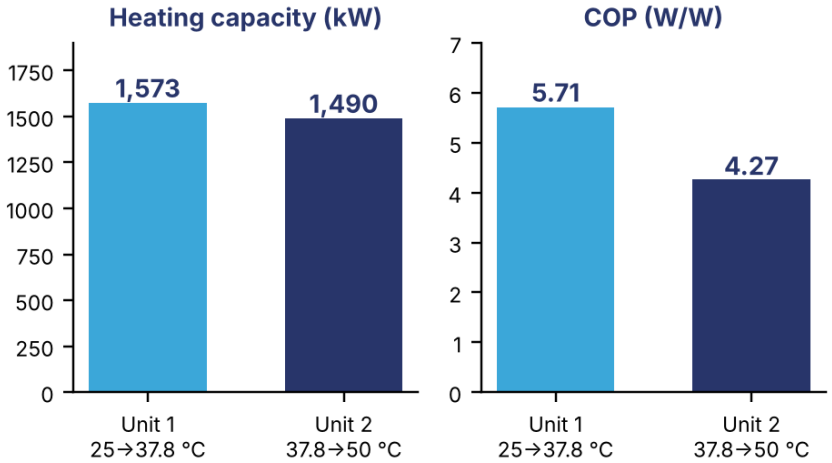




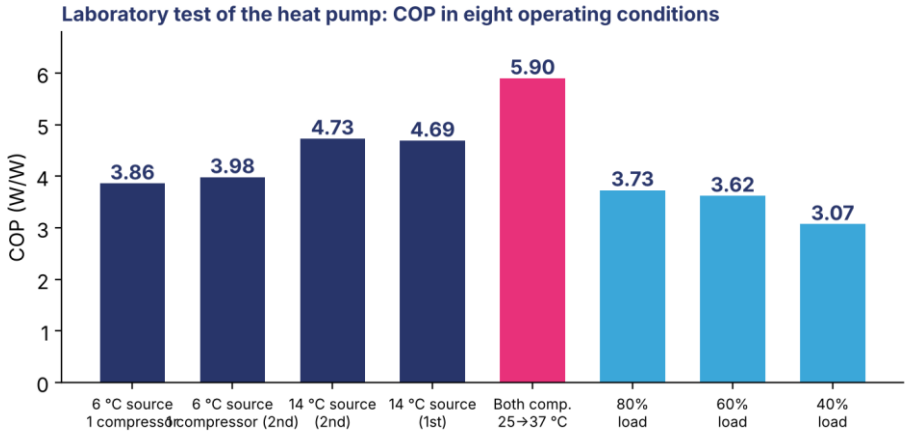
- **Unit:** HIREF XVA1281W DX, 1.5 MW heating capacity each.
- **Series pair:** two units in series on the user side and in parallel on the source side deliver 3 MW; two pairs give 6 MW.
- **Refrigerant:** R515B, GWP 299, non-toxic and non-flammable (class A1).
- **Heating and cooling:** cools the greenhouse in summer and sends the excess heat to storage.
- **Winter:** draws heat from the warm zone, which is much warmer than natural groundwater, so the COP improves.

COP (coefficient of performance) = heat delivered ÷ electricity used. A COP of 5 means 5 kWh of heat for each kWh of electricity.

Heat pumps: simulated and measured performance



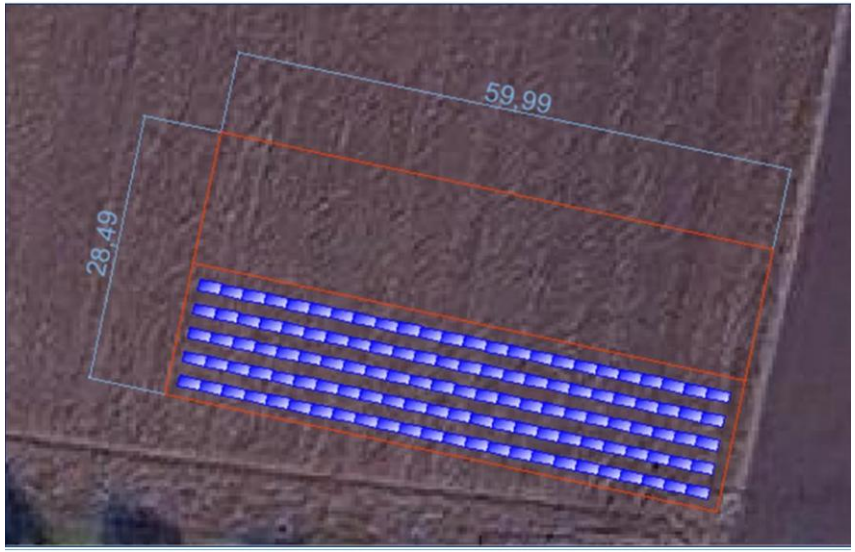
Design simulation: two units in series, worst-case winter



Laboratory tests (EN 14511-3)

- The first unit lifts water from 25 to 37.8 °C (COP 5.71), the second from 37.8 to 50 °C (COP 4.27).
- The higher the source temperature and the smaller the temperature lift, the better the COP. Partial loads were also tested.

Solar PVT panels: electricity and heat from one panel

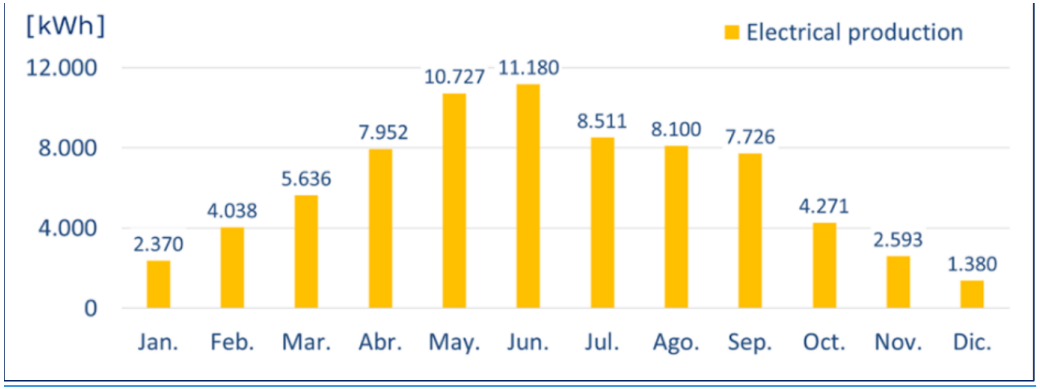


Planned PVT field on the roof of the technical room

120	72 kW	324 m²
collectors, 5 rows of 24	electrical peak power	solar area

- **Roof:** south side, 855 m² of a 1,710 m² roof.
- **Each collector:** 2.7 m² and 600 W; 30° structure for a 40° final tilt.
- **Spacing:** at least 4 hours of unshaded sun per winter day.
- **Weight:** 63.6 kg per collector, only 8.9 kg/m² extra roof load.
- **Prototypes:** three designs tested (harp, meander, meander-harp).

Solar PVT panels: how much do they produce?



Monthly electricity production of the planned field (kWh)

74,484 kWh

estimated electricity per year (first layout)

495 kWh

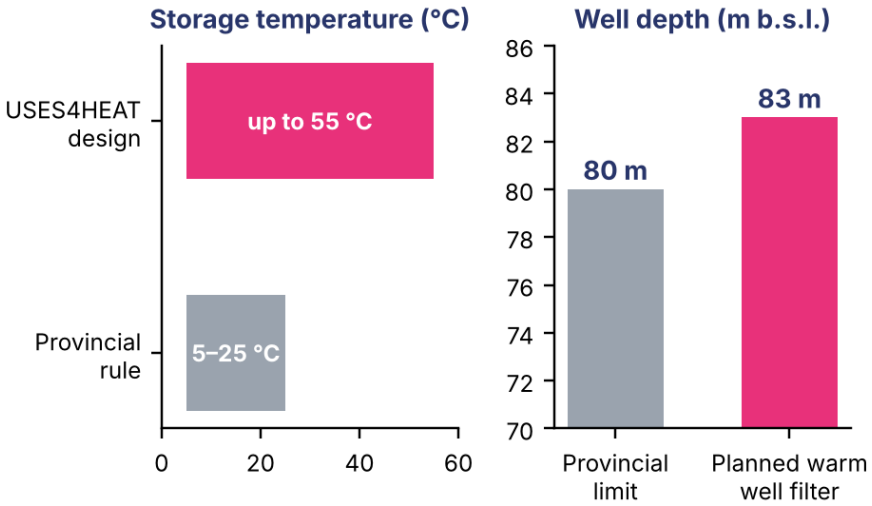
electricity per panel per year

542 kWh

heat per panel per year

- June is the peak month (11,180 kWh); December the lowest (1,380 kWh).
- Per-panel values come from the full prototype tests; the final number of panels is still being evaluated.

The permit: three deviations from the rules



Provincial limits vs the Andel design

- **1** Storage up to 55 °C (rules: 5–25 °C).
- **2** Full perforation of the storage layer below 80 m (rule: maximum 80 m).
- **3** A heat surplus in the first years: about 250% at first, about 170% after ten years.

Environmental impact and risk assessments and the monitoring plan were reported to the authority, with positive feedback. The demonstrator will inform policy for MT-ATES in the Netherlands and Europe.

Monitoring and risks

Monitoring wells

Extra wells and three observation wells in each borehole track temperature and groundwater above, below and in the storage aquifer.

Fibre-optic cable

Distributed temperature sensing along the monitoring wells follows the heat in the ground.

Risk review

Thirteen project risks (procurement, permits, performance, integration) were reviewed and rated low, each with a mitigation.

Modularity

The three technologies can work independently, so the concept can be demonstrated even if one underperforms.

Project targets: from prototype to proven system

TRL 8	TRL 8	TRL 7	TRL 8
MT-ATES	Heat pump	PVT panels	Energy management

- **TRL 7:** full-scale prototype demonstrated in a relevant operating environment.
- **TRL 8:** actual system completed and qualified through testing and demonstration.
- **TRL 9:** actual system proven through sustained operation.
- **Energy management:** an AI-based, predictive system will optimise operation and maintenance.

Knowledge check

1	At about what temperature is heat stored in the Andel MT-ATES?
2	Why do the heat pumps run in summer too?
3	How many warm wells and cold wells are planned?
4	Which technology produces electricity and heat at the same time?
5	Why does Andel need a special permit?
6	What does a COP of 5 mean?

Discuss in groups for 5 minutes. Answers on the next slide.

Answers

1 About 50 °C on average, with peaks of up to 55 °C.

2 Electricity is cheaper in summer; the heat is stored for winter, when demand and prices are higher.

3 Four warm wells and six cold wells.

4 The PVT (photovoltaic-thermal) panel.

5 Storage up to 55 °C, full perforation below 80 m and a heat surplus exceed the current rules (5–25 °C, 80 m).

6 5 kWh of heat for each 1 kWh of electricity used.

Key takeaways

1. Heat is needed in winter, but the sun and surplus heat come in summer: storage solves the mismatch.
2. An aquifer stores warm water between clay layers; 4 warm and 6 cold wells form the Andel system.
3. Heat pumps with a low-GWP refrigerant lift heat to about 50 °C; COP depends on the temperature lift.
4. PVT panels give electricity and heat from the same roof.
5. A special permit, monitoring and risk management make the demonstrator a model for future projects.

Thank you



Heat pump units with members of the project team.

Co-funded by the European Union

More information: www.uses4heat.eu

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