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Drivers to allow widespread adoption of ATES systems: a reflection on 40 years experience in The Netherlands

Martin Bloemendal[1,2,]*, Martin van der Schans[1,2] Stijn Beernink[1,2], Niels Hartog[2] and Philip J. Vardon[1]

[1] Delft University of Technology, Delft, The Netherlands
[2] KWR water research institute, Nieuwegein The Netherlands
* Corresponding author; e-mail j.m.bloemendal@tudelft.nl

Heating and cooling of buildings accounts for ~25% of the primary energy end use, hence is critical to decarbonize. In many climatic conditions heating and cooling systems can be decarbonized using seasonal thermal energy storage to overcome the mismatch in availability and demand [1], with Aquifer Thermal Energy Storage (ATES) being an example system (see Figure 1). ATES systems are relatively cheap, require limited above ground space, and can reduce primary energy use by ~50% and gas by 80-100%. In the Netherlands, adoption of ATES systems is high [2], with over 3000 systems in place. As an early adoptor, the Netherlands has around 40 years of experience. Since suitable conditions are present across the world [1], many other countries are making plans for large-scale adoption. ATES adoption in the Netherlands has been a great success story, which has developed due to key enabling policies. Depending on local conditions these policies could be simply adopted, but could also require adaptations. This paper provides an overview of key drivers for high adoption rate and successful exploitation of ATES in the Netherlands.

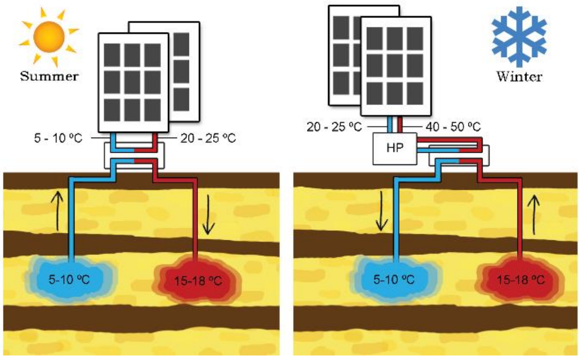

Figure 1: Basic working principle of ATES. In winter (right), buildings are heated with a heat pump which extracts heat from the warm well. This cools down the groundwater which is injected via the cold well. This cold groundwater is used in summer (left) for cooling. The extent of the changed temperature from the well is called the "thermal radius" [3].

Building energy performance standard sparked market demand, certification ensured quality: The Energy Performance Coefficient (EPC) regulation required building owners to make energy efficient buildings. From the early '90s, required EPC values became gradually stricter, until around 2022 where the net energy use of a new building needed to be 0 or smaller (i.e. energy positive building) [4]. This rule created a large demand for ATES. However, in the '90s and early '00s building owners simply applied ATES to get a building permit, resulting in many poorly performing or idle ATES systems [5]. An installation certification [6] created quality standards and banned "cowboys" from the market. Key elements are market standards for design, installation and operation, for both the wells and the surface plant, including communication protocols, as very few companies offered the whole market chain [7-9]. It was also defined that provinces can enforce optimal energy performance from building owners.

Planning of ATES wells: ATES development began with a first come–first served permitting principle. New systems required a minimal distance between new and already existing wells of at least 3 times the maximal thermal radius (Figure 1), leading to sub-optimal subsurface use. Studies showed that smaller distances between wells should be applied [10-12], and that similar well types

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can be placed together [10, 12] with negligible effects on individual performance [10]. Planning and coordination by the authorities helps optimization, where so called “areas of interference” are designated to ensure the integration of high density ATES systems.

Standardisation and simplification of surface plant design: Unlike for gas fired boilers, not only installed capacity matters when installing an ATES system. The total thermal energy stored and produced from an aquifer has a great impact on long term performance. Restoring energy balance in the Aquifer is a key element in this, making ATES also suitable for either heating or cooling dominated buildings/climates. Hence, the aquifer temperature follows from the building heating and cooling use, and inherent uncertain heating and cooling lifetime loads led to complex surface plant designs allowing flexibility to add or dump heat to/from the system in many ways. However, such designs were in practice too complex to build and operate. When the certification scheme was put in place in 2013 [6], basic designs were included in the market standards to ensure manageable systems [13]. The basic rule is to keep design simple.

Well standards: ATES specific well design standards were developed to ensure high quality wells, as ATES systems and wells need to perform for decades following buildings lifespans [14]. Key is to have the contractor responsible for maintenance, this provides an incentive to construct high quality and robust wells. Experience from drinking water wells in anoxic unconsolidated formations showed that wells were prone to mechanical clogging [15], hence limits to near well flow velocity to limit the transport of particles were part of the design standards. Alternating extraction and injection in ATES wells means they are less prone to mechanical clogging than water extraction wells [16, 17]. This resulted in balancing high production rates with a planned well rehabilitation every 10 years [9]. Wells in unconfined aquifers are prone to chemical clogging due to dissolved groundwater components, in particular from mixing the groundwater from reduced (anoxic) and oxic zones. In ATES systems, groundwater is mixed and are therefore more prone to chemical clogging than dedicated extraction wells. Therefore, the ATES design standards prohibit installation of ATES well screens across redox zones. Drinking water industry standards for sizing of gravel pack grain size and sealing of wells were adopted to prevent well intrusion of sand and aquifer short circuit flow. Since wells that are heavily clogged are difficult to rehabilitate, the standards also include timely maintenance. The standards have contributed to a longer lifetime of wells and pumps, with limited reported problems with wells.

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