TECHNOLOGY FACTSHEET

HEAT PUMP - GROUNDWATER TO WATER

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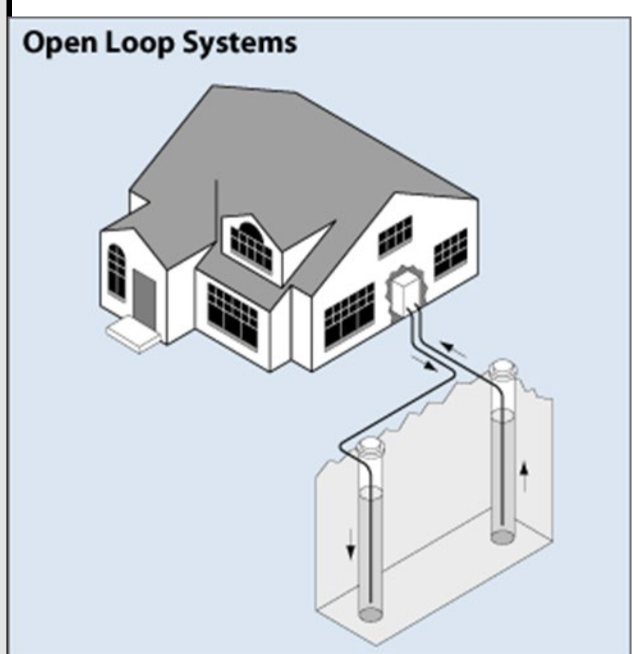
Sector	Trade, services and utilities
ETS / Non-ETS	Non-ETS
Type of Technology	Emission reduction

Description

Groundwater to water heat pumps
This type of system uses (ground) well water as the heat exchange fluid that circulates directly through the heat pump system. Once it has circulated through the system, the water returns to the ground through the (recharge) well. This option is obviously practical only where there is an adequate supply of relatively clean groundwater, and all local codes and regulations regarding groundwater discharge are met. Besides groundwater, the system could use surface body water as well.

This 'open system' often has a higher efficiency than the closed 'soil to water' system, but the cost of the installation is often higher as well because a second well needs to be drilled. The yield strongly depends on the type of soil where the installation is placed. This system has great advantages when the building has a high heat demand and/or the building also needs to be cooled.

Figure 1 illustrates the configurations for this type of heat pump.



(Source: Tidewater Mechanical, 2021)

A heating device must, among other things, be selected for its heating capacity. This capacity depends on (1) the degree of insulation of a building, (2) the desired interior temperature and (3) the size of the building. The largest houses are larger than the smallest buildings within the utility sector (and the other way around). This means that every heat pump that is placed in the residential sector, can also be found within the services sector. Within the latter sector however, there are also much larger buildings; this does create a different situation with a much larger heat demand. Such buildings are often equipped with several heating appliances, which are placed in a cascade arrangement. When the outside temperature drops further, an additional appliance will start operating. This way, electrical heat pumps are most often combined with gas fired boilers. The more efficient, but more expensive heat pump, for example, provides 80% of the heat demand, the gas boiler only assists on the coldest days in order to meet the "peak heat demand". The combination of an electric heat pumps with a gas-fired boiler can be considered as a 'hybrid cascade setup'. In a services building that reaches the level of 'nearly zero energy', a stand-alone heat pump could be sufficient, just as in a residential building.

TRL level 2020	TRL 9
	Commercial technology.

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	kWth		770 - 443								
					-			-			-
Potential	0	0	Current			2030			2050		
					-			-			-
			Min	-	Max	Min	-	Max	Min	-	Max
Market share	%	NL			0.05			-			-
			0.05	-	0.05	Min	-	Max	Min	-	Max

Capacity utlization factor	NA
Full-load running hours per year	961-1765
Unit of Activity	GJ/year — 2,975.97
Technical lifetime (years)	15-20
Progress ratio	-
Hourly profile	Yes

Explanation

Source for data: for the services sector, TNO Energy Transition Studies often use the investment costs from Arcadis. In order to calculate investments costs per m2 floor area, or per kWth, Arcadis distinguishes nine different building types as offices, schools, hospitals, etc. Within these types, three different building sizes have been distinguished. An assumption for the insulation level is used, which is related to new and existing buildings. These, together, determine the heat demand and therefore the needed capacity and investment costs in each situation.

Table 1 shows the typical needed heating capacity by building type and building size for new buildings:

		building size (m2)				heating capacity needed (kWth)			
Building type	**Heating demand (W/m2)**	**small**	**medium**	**large**	**average**	**small**	**medium**	**large**	**average**
Healthcare with beds; as hospital, nursing home	65	na	5.705	34.178	19.942	na	370	2.219	1.295
Healthcare centre without beds	65	877	na	na	877	57	na	na	57
Education (school)	58	2.022	7.610	15.729	8.454	118	445	919	494
Public buildings as theatre, museum	52	1.745	4.964	9.707	5.472	91	258	504	284
Office	52	1.681	4.383	24.553	10.206	87	228	1.275	530
Lodging, as hotel	52	na	3.678	na	3.678	na	191	na	191
Prison	45	na	15.854	na	15.854	na	721	na	721
Sport hall	45	158	2.910	8.468	3.845	7	132	385	175
Shop	32	158	1.460	20.907	7.508	5	47	679	244
Average	**52**	**1.107**	**5.821**	**18.924**	**8.426**	**61**	**299**	**997**	**443**

(Source: Own elaboration based on Arcadis, 2020)

Table 2 shows the same for existing buildings:

Building type	Heating demand (W/m2)	building size (m2) small	building size (m2) medium	building size (m2) large	building size (m2) average	heating capacity needed (kWth) small	heating capacity needed (kWth) medium	heating capacity needed (kWth) large	heating capacity needed (kWth) average
Healthcare with beds; as hospital, nursing home	100	1.850	4.200	15.950	7.333	185	420	1.595	733
Healthcare centre without beds	100	600	2.850	5.450	2.967	60	285	545	297
Education (school)	90	1.800	12.500	29.950	14.750	162	1.125	2.696	1.328
Public buildings as theatre, museum	80	1.150	4.350	11.400	5.633	92	348	912	451
Office	80	1.200	5.300	17.450	7.983	96	424	1.396	639
Lodging, as hotel	80	2.050	4.400	70.800	25.750	164	352	5.664	2.060
Prison	70	6.000	17.600	27.600	17.067	420	1.232	1.932	1.195
Sport hall	70	450	2.200	4.550	2.400	32	154	319	168
Shop	50	200	850	2.800	1.283	10	43	140	64
Average	**80**	**1.700**	**6.028**	**20.661**	**9.463**	**136**	**487**	**1.689**	**770**

(Source: Own elaboration based on Arcadis, 2020)

The non-weighted averages mentioned in the last rows of these tables have been entered as the final capacity range of this Factsheet: existing buildings with often a cascade configuration - new buildings with a stand-alone heat pump. The weighted averages would be much smaller since there are many more smaller buildings then there are larger once. Note the differences in individual building sizes within one table, and between the two tables that lead to a much larger range of needed capacities.

Capacity related:
Since, on average, the heating capacity of a heat pump within the services sector is larger compared to one in the residential sector, the installed thermal capacity is (on average) twice as large within the services sector.

Market share related:
When considering the air-, soil- and groundwater-to-water heat pumps within the services sector only, the penetration rate expressed as the installed heating capacity of the groundwater-to-water heat pump lies around 61% (CBS 2020). The penetration rate of electric heat pumps in general within offices with an energy label, lies at the moment around 9% (Dutch Energy Label database 2019, edited). If we take this as a very rough estimation for the whole services sector, then the market penetration of this type of heat pump is 9%*61%*=5,5%.

Running hours:
The first mentioned number represents a new buildings (heat pumps as a stand-alone device), the second an existing building (heat pump in a cascade configuration) (Warmtepomp-weetjes.nl, 2021).

COSTS

Year of Euro: 2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / kWth			1,407			1,990			-
		1,407	-	1,407	1,990	-	1,990	*Min*	-	*Max*
Other costs per year	mln. € / kWth			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Fixed operational costs per year (excl. fuel costs)	mln. € / kWth			50			-			-
		50	-	50	*Min*	-	*Max*	*Min*	-	*Max*
Variable costs per year	mln. € / kWth			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*

Costs explanation

Investment costs related:
- In this Factsheet the investment costs represent the situation whereby implementing the heat pump occurs at an ‘independent moment’. Another situation, distinguished by Arcadis, and called ‘a natural moment’. This would reduce the total costs since (1) there would be some mutual costs to share (among all measures taken; think of hiring a crane, for instance) and (2) the investment for new gas boilers had to be done anyway and are therefore subtracted. But, in case of implementing heat pumps, the difference is small; it would reduce the investment costs with only 2 until 7%.
- Besides the investment costs for the hardware, the costs above include as well wages, some direct costs as general execution costs and a contribution for risks.
- Costs that are not included are for example the internal costs of the project developer, subsidies, fees for the installation consultant.
- For existing buildings, additionally costs have been included to remove the ‘old heating system’ out of the building.

Table 3 shows Investment costs (€2015/kWth) for existing/new buildings, by building type and size, related to the previous mentioned needed heating capacity. As can be seen, not all combinations have been given investment costs by Arcadis (‘na’ = ‘not applicable/available’). When the heat demand and the 'groundwater to water' heat pump are not a logical combination ('not applicable'), then another heat pump type could have been chosen (see the other two related Factsheets). The non-weighted averages mentioned in the last rows of these tabels, have been entered as the final 2020 and 2030 investment costs. For 2020 this represents the cascading configuration in existing buildings; the number at 2030 represents the equivalent for a stand-alone heat pump in a new building. Note that for all new construction, both residential and non-residential construction, permit applications from 1 January 2021 must meet the requirements for Nearly Zero-Energy Buildings (in Dutch abbreviated as ‘BENG’).

	Investment costs (euro/kW) Existing buildings, cascade				Investment costs (euro/kW) New buildings, stand alone			
Building type	**small**	**medium**	**large**	**average**	**small**	**medium**	**large**	**average**
Healthcare with beds; as hospital, nursing home	na	1.643	1.834	1.738	na	2.940	1.208	2.074
Healthcare centre without beds	na	1.166	1.155	1.160	na	na	na	na
Education (school)	na	1.352	1.481	1.416	na	1.519	1.307	1.413
Public buildings as theatre, museum	na	1.136	1.396	1.266	na	3.596	1.669	2.632
Office	na	1.602	1.788	1.695	na	2.086	1.271	1.679
Lodging, as hotel	na	1.136	1.529	1.333	na	2.483	na	2.483
Prison	1.526	1.703	1.456	1.562	na	1.362	na	1.362
Sport hall	na	na	1.082	1.082	na	3.065	1.794	2.429
Shop	na	na	na	na	na	na	1.844	1.844
Average	**1.526**	**1.391**	**1.465**	**1.407**	**na**	**2.436**	**1.515**	**1.990**

(Source: Own elaboration based on Arcadis, 2020)

Observation:
- The costs expressed as euro/kWth lie higher in 2030 compared to 2020 (new compared to existing buildings). This means that, although there is less equipment needed in 2030 (no cascading system), the decrease in heating demand in 2030 dominates the investment costs each kWth.

Maintenance costs related:
The estimated cost of servicing a heat pump is, among others, dependent on the heat pump type, condition, size, age, location, brand and maintenance history of the unit; therefore it’s difficult to come up with an average number (CE Delft, 2021; Bloomquist, 2001).

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Heat	PJ			-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
	Ambient heat	PJ			-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
	Electricity	PJ			-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
	0	PJ			-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*

Energy in- and Outputs explanation	The efficiency of a heat pump is expressed as the Coefficient of Performance (COP). For example, a COP of 3 means that 1 unit of electricity is used to produce 3 units of heat, by using 2 units of ambient heat. The COP mainly depends on the difference between source temperature and delivery temperature. The higher the source temperature and the lower the delivery temperature the higher the COP. In winter, the temperature difference is larger, resulting in a lower COP. The annual average COP is called the seasonal coefficient of performance (SCOP), or the Seasonal Performance Factor (SPF). In a study whereby several heat pump have been monitored, the only one groundwater-to-water heat pump had an average SPF of 3,9 (bouw-energie). This SPF had been converted into the 'Energy in- and Outputs' mentioned in this Factsheet (stating the usage of 'ambient heat' as -1 MJ). Other sources make other assumptions: -NTA 8800 is a new determination method for the energy performance of buildings in the Netherlands that will be implemented in 2020 (NTA 8800, 2018). The mean COP of this type of heat pump is 4,3 - 4,8 in case of a delivery temperature of 35-40 ºC.

MATERIAL FLOWS (OPTIONAL)

	Material	Unit	Current			2030			2050		
Material flows					-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
					-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Material flows explanation											

EMISSIONS (Non-fuel/energy-related emissions or emissions reductions (e.g. CCS)

	Substance	Unit	Current			2030			2050		
Emissions					-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
					-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
					-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
					-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Emissions explanation											

OTHER

Parameter	Unit	Current			2030			2050		
Costs insulation measures (label E or D to A or A+)	euros2015			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Costs Low temperature heating - radiators	euros2015			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Costs Low temperature heating - floor heating	euros2015			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
	euros2015			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Explanation										

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