TECHNOLOGY FACTSHEET

TNO innovation for life

HEAT PUMP - SOIL TO WATER

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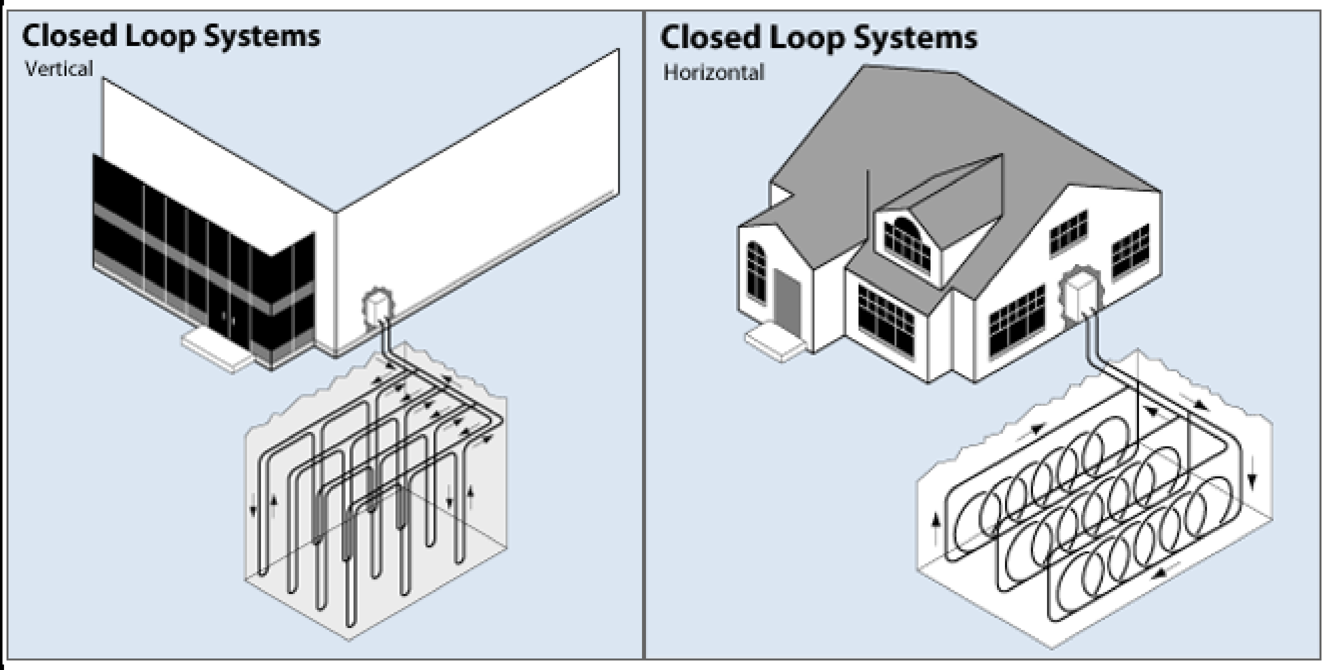
Author	Jeffrey Sipma
Sector	Trade, services and utilities
ETS / Non-ETS	Non-ETS
Type of Technology	Emission reduction
Description	Soil to water heat pumps

The heat source for the soil to water heat pump is the heat stored in the ground itself. But this could be a (combination with a) water source under the ground as well. Even open-water at the surface could function as the heat source. This is a 'closed' system, refering to the fact that, in case of (ground) water as the heat source, this water is not moved and remains at its location. With closed sources, a closed circuit of hoses or pipes (usually made of plastic tubing) is introduced into the heat source. This circuit contains a mixture of water and an anti-freeze such as glycol. The mixture is pumped around and takes over the heat from the source through a heat exchanger.

Figure 1 illustrates two 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 boilers 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		443 - 770								
					-		-				-
			Current			2030			2050		
Potential					-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Market share	%	NL			0.02			-			-
			0.02	-	0.02	*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 of 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. As well an assumption for the insulation level is used, related to new- and existing buildings. This together, determines 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 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	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 an 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 soil-to-water heat pump lies around 23% (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 is a very rough estimation for the whole services sector, then the market penetration of this type of heat pump is 9%*23%*=2,1%.

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			2,003			4,660			-
		2,003	-	2,003	4,660	-	4,660	*Min*	-	*Max*
Other costs per year	mln. € / kWth			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Fixed operational costs per year (excl. fuel costs)	mln. € / kWth			55			-			-
		55	-	55	*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 'soil-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	1.796	1.587	1.280	1.569	na	na	na	na
Healthcare centre without beds	4.001	1.840	1.399	2.413	4.259	na	na	4.259
Education (school)	2.542	1.209	1.209	1.653	3.461	na	na	3.461
Public buildings as theatre, museum	3.901	1.547	1.364	2.271	4.967	na	na	4.967
Office	3.901	1.547	1.248	2.232	5.145	na	na	5.145
Lodging, as hotel	2.625	1.547	1.248	1.807	na	na	na	na
Prison	1.473	1.188	1.188	1.283	na	na	na	na
Sport hall	na	2.500	1.709	2.104	na	na	na	na
Shop	na	na	2.692	2.692	na	5.467	na	5.467
Average	**2.898**	**1.621**	**1.482**	**2.003**	**4.458**	**5.467**	**na**	**4.660**

(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*
		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 6 soil-to-water heatpumps have been monitored, giving an average SPF of 4,1 (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 (2020) 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 3,6 - 4,25 in case of a delivery temperature of 35-40 °C.
-ETRI (2014) indicates COP = 3,6 for a 'ground source' heat pump in 2020, COP = 3,7 in 2030 and COP = 3,9 in 2050, in a commercial building.
-CE (2018) indicates the SCOP of 4,5 - 5,5 in case of a delivery temperature of 35 °C. For domestic hot tap water the SCOP is 2,75 - 3,75

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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