TECHNOLOGY FACTSHEET

GROUND SOURCE HEAT PUMP - HOUSEHOLDS

Date of factsheet	26-2-2019
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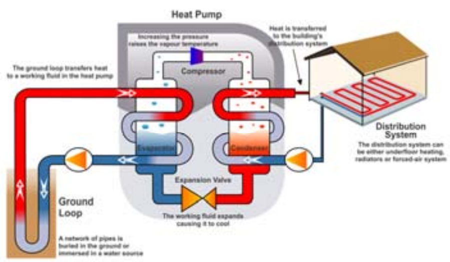
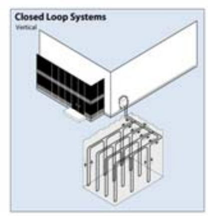
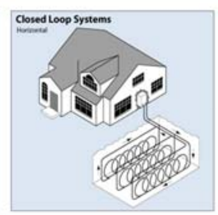
Sector	Households
ETS / Non-ETS	Non-ETS
Type of Technology	Emission reduction
Description	An electric heat pump with a ground heat source used for heating a dwelling. This type of heat pump extracts heat from the soil. The technology makes use of a soil heat exchanger (i.e. a long pipe) which can either be vertically or horizontally oriented (in a closed loop). Vertical pipe heat exchangers are more common in the Netherlands (CE, 2018). It is a closed system in which an antifreeze solution ('brine'), a mixture of water and antifreeze, is pumped through pipes in the subsoil. The heat pump has an evaporator (heat exchanger) where a refrigerant flows through that absorbs thermal energy from the antifreeze solution in the closed loop. An electric driven compressor increases the temperature, then the refrigerant condenses back to a liquid (in the condenser) and releases heat to a heat exchanger, an expander makes it ready for heat absorption (closing the cycle). Heat generated in the condensor is transferred to the central heating system. Water is used as medium for heat transport inside the dwelling, hence the name 'soil-water' heat pump. A ground source heat pump can also provide domestic hot water (sometimes with help of an electric heating element). The presence of a storage tank/buffer for hot water improves the performance of the heat pump over the year, because the number of times the heat pump is switched on and off will be reduced (CE, 2018). Furthermore a ground source heat pump can be used for space cooling in summer (Milieucentraal, 2018). The efficiency of a heat pump is expressed as the coefficient of performance (COP), the ratio between heat output and electricity input, and is mainly determined by the difference between delivery temperature and source temperature. The higher the source temperature and the lower the delivery temperature the higher the COP. A ground source heat pump uses the soil as a heat source which has a more or less constant temperature of 10-14ºC over the year which means it has little or no influence on the COP of the heat pump. As a consequence a ground source heat pump has a higher seasonal COP compared to a heat pump that extracts heat from the outside air (Greenhome, 2018; ETRI, 2014). A heat pump usually heats the water to 35 to 55ºC. At least once a week, the temperature of the hot tap water is increased with an electric heating element (such as an electric boiler) to 60ºC (and briefly to 70ºC) to prevent the risk of legionella contamination (Milieucentraal, 2018). For performance reasons a ground source heat pump should be used in combination with a low temperature heating system, which requires that the dwelling is sufficiently insulated. The minimum insulation level required corresponds to a dwelling with energy label C (CE, 2018). Usually the insulation level needed is label A or better. A low temperature heating system consists of under floor heating and/or low temperature radiators/wall heating. According to the Dutch Heat Pump Association ground source heat pumps are mostly installed in new buildings (DHPA, 2013). The amount of space required for the soil heat exchangers can be an issue for existing dwellings (Ecofys, 2015).







TRL level 2020	TRL 9
	Commercial technology. At the end of 2017 there were 30.355 ground source heat pumps (closed systems) used by households in the Netherlands (CBS, 2018). The share of households that uses a ground source heat pump in 2017 is 0,4% (based on 7,8 million dwellings in 2017 from CBS).

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range									
Capacity	kWth											10
					4		-					16
	kWth	NL	Current			2030			2050			
Potential					7,870,492			-			-	
			7,740,984	-	8,000,000	*Min*	-	*Max*	*Min*	-	*Max*	
Market share	%	Share of households			0.39			2.55			-	
			0.39	-	0.39	2.55	-	2.55	*Min*	-	*Max*	
Capacity utlization factor									-			
Full-load running hours per year									1,100			
Unit of Activity	GJ/year										39.60	
Technical lifetime (years)									20.00			
Progress ratio									-			
Hourly profile	Yes											

Explanation	The 'typical' thermal capacity of a ground source heat pump for a household is between 4 and 16 kWth (Milieucentraal, 2018). The required (max.) capacity of the heat pump depends on the transmission of the dwelling. The average thermal capacity of a residential air source heat pump according to CBS is 8,5 kWth (CBS, 2018). Average CBS capacity is obtained by dividing total capacity over number of heat pumps (closed systems for households). The average thermal capacity of a ground source heat pump in the ISDE subsidy requests of households is 12,2kWth (ISDE, 2018). Average ISDE capacity is obtained by dividing total capacity over number of heat pumps (soil heat pumps for households). At the end of 2017 there were 30.355 ground source heat pumps (closed systems) used in dwellings in the Netherlands (CBS, 2018). The share of households that uses a ground source heat pump in 2017 is 0,4% (based on 7,8 million dwellings in 2017 obtained from CBS). In 2017 about 4.400 ground source heat pumps were installed (added) in dwellings in the Netherlands (CBS, 2018). According to Nationaal Warmtepomp Trendrapport 2018 it is expected that in 2020 there will be more than 200,000 heat pumps in the Netherlands (all heat pump types), and in 2030 almost 1,300,000. This means the total number of heat pumps used in the built environment could multiply with a factor 6,5 compared to 2020 (Nationaal Warmtepomp Trendrapport, 2018). For ground source heat pump the same growth factor is assumed toward 2030. The future market share is very uncertain however, as it depends on a.o. technical and system innovations (possible cost reductions) and stimulation through energy policies. The current technical potential is estimated as follows. According to CBS there are 7,8 dwellings in the Netherlands in 2017. The minimum insulation level required corresponds to a building with label C. Based on extrapolation of the label registration of RVO 58% of total dwellings has label C or better and 14% has label A or better in 2017 (RVO, 2018). These buildings are assumed suitable for a ground source heat pump. However, for a large amount of existing dwellings soil heat exchangers can not be realised due to a.o. lack of space or no possibility to dig (Ecofys, 2015; CE, 2018). Based on the assumption that 10% of total dwellings is suitable for a ground source heat pump and a capacity of 10 kWth per heat pump the potential is estimated at 7,8 GWth. According to Nationaal Warmtepomp Trendrapport there is a potential of 8 GWth for ground source heat pumps for dwellings (Nationaal Warmtepomp Trendrapport, 2018). A mean value for the technical potential is then 7,9 GWth. In the future the amount of dwellings suitable for a heat pump can be expected to increase due to high insulation standards for new buildings and refurbishment of existing buildings. Typical full load hours for a ground source heat pump are 1.100 hours per year (ISDE, 2018). This number of full load hours is also used in 'Protocol Monitoring Hernieuwbare Energie' (CBS & RVO, 2015). ETRI (2014) indicates a technical lifetime of 20 years for a soil heat pump. CE indicates a ground source heat pump has a technical lifetime of about 15 years and 25-35 years for the soil heat exchanger (CE, 2018).

COSTS

	Euro per Functional Unit	Current			2030			2050		
Year of Euro	2015									
Investment costs	€2015 / kWth			1,145			967			930
		935	-	1,659	967	-	1,558	930	-	1,377
Other costs per year	€2015 / kWth			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Fixed operational costs per year (excl. fuel costs)	€2015 / kWth			10			10			-
		5	-	33	10	-	16	*Min*	-	*Max*
Variable costs per year	€2015 / kWth			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*

Costs explanation	Cost unit: euros2015/kWthermal In order to compute the costs per kW, we divided the reported costs as given by the source by the typical capacity of the heat pump (that is 10 kWth, which is an assumption see 'Capacity'). In ETRI report (ETRI, 2014) investment costs were already given in euros/kWth. However, which value was assumed for the capacity is not stated. The table above gives costs excluding VAT. In case VAT was included in the source, 21% VAT was subtracted. Ecofys (2015) investment costs for a ground source heat pump are 12.675 euros excluding VAT in 2020 (Ecofys, 2015). For 2030 investment costs reported are 11.175 euros excluding VAT. For 2050 investment costs reported are 9.300 euros excluding VAT. These costs consist of purshasing cost for the heat pump (it is not specified whether or not including installation costs). The report does not state fixed operational costs per year. In Startmotor (2018) the investment (purchasing) costs for a ground source heat pump are 13.500 euro including VAT at present, with a cost decrease of 10% in 2020 and 25% in 2030. Labor installation costs amount to 1.500 euro. Measurement and controlsystems costs are 1.050 euro in 2020, and expected to decrease to 788 euro in 2030. Fixed operational costs per year are 103 euros per year in 2020 and 97 euros per year in 2030. ETRI (2014) presents investment/CAPEX costs in euros2013/kWth (excluding VAT) for a residential ground source heat pump (ETRI, 2014). The CAPEX estimate takes into account the heat source system and the heat pump costs without considering the cost of the distribution system (ETRI, 2014). ETRI indicates the 'quality of CAPEX estimate' as 'medium'. In ETRI data, average costs of a ground source heat pump (CAPEXref) amount to 1.650 euros/kWth in 2020 (range: 1.260 - 1.940 euros/kWth) , 1.550 euros/kWth in 2030 (range: 1.190 - 1.830 euros/kWth) and 1.370 euros/kWth in 2050 (range: 1.050 - 1.620 euros/kWth). Fixed operational costs are 2% of the CAPEXref in 2020, and 1% of the CAPEXref in 2030 and 2050 (ETRI, 2014). Nationaal Warmtepomp Trendrapport 2018 indicates minimum investment costs of 12.000 euros including VAT (Nationaal Warmtepomp Trendrapport, 2018). These costs consist of purshasing cost for the heat pump including installation costs. The report does not state fixed operational costs per year. CE (2018) indicates investment costs of 8,500 to 16,500 euros including VAT for a vertical ground source heat pump (CE, 2018). These costs consist of purchasing cost for the heat pump including installation costs. Original source of these costs is Milieucentraal which reports a range of 8,500 to 19,500 euros (Milieucentraal, 2018). Maintenance costs amount to 50 euros per year (CE, 2018). Furthermore the grid connection costs (not included in table above) are as follows (CE, 2018): Adjustments electrical meter box: approximately 200 - 250 euros (one-time). Increased size of grid connection: annual cost depend on capacity of heat pump.

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:*	PJ			-1.00			-1.00			-1.00
	Heat		-1.00	-	-1.00	-1.00	-	-1.00	-1.00	-	-1.00
	Ambient heat	PJ			0.73			0.74			0.75
			0.73	-	0.80	0.74	-	0.83	0.75	-	0.75
	Electricity	PJ			0.27			0.26			0.25
			0.20	-	0.27	0.17	-	0.26	0.25	-	0.25
		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 and 2 units are 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). In the table energy in- and outputs associated with the mean COP / SCOP for space heating are given. Different assumptions from different sources are given below: 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 a ground source heat pump is 4,3 in case of a delivery temperature of 35-40°C (NTA 8800, 2018). ETRI (2014) indicates COP = 3,7 for a ground source heat pump in 2020, COP = 3,8 in 2030 and COP = 4 in 2050 (ETRI, 2014). Startmotor (2018) indicates a SCOP of 4 for space heating and an SCOP of 2,2 for domestic hot water in 2020 (Startmotor, 2018). Startmotor (2018) indicates a SCOP of 6 (times 1,5) for space heating and an SCOP of 3,3 (times 1,5) for domestic hot water in 2030 (Startmotor, 2018). CE (2018) indicates the SCOP of a ground source heat pump is 4,5 to 5,5 in case of a delivery temperature of 35ºC (CE, 2018). For domestic hot water the SCOP is 2,75 to 3,75 (CE, 2018).

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			16,361			13,907			11,453
		9,349	-	16,361	7,947	-	13,907	6,544	-	11,453
Costs Low temperature heating - radiators	euros2015			1,558			1,324			1,091
		1,558	-	1,558	1,324	-	1,324	1,091	-	1,091
Costs Low temperature heating - floor heating	euros2015			8,693			7,389			6,085
		8,693	-	8,693	7,389	-	7,389	6,085	-	6,085
				-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*

Explanation	In order to realise a low temperature heating system in a dwelling sufficient insulation and low temperature radiators (wall heating) and/or under floor heating are needed. Costs for insulation measures, under floor heating and low temperature radiators are taken from Startmotor (Startmotor, 2018). The table above gives costs excluding VAT. In case VAT was included in the source, 21% VAT was subtracted. For a terraced home with label E or D, insulation costs to achieve label A+ are around 21.000 euros including VAT. In case of label A costs are around 12.000 euros including VAT. Costs are expected to decrease with 15% in 2030 (Startmotor, 2018). For 2050 a costs decrease of 30% is assumed.

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