TECHNOLOGY FACTSHEET

INDUSTRIAL HIGH TEMPERATURE HEAT PUMP

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Sector	Industry: Generic
	According to (ECN, 2017), heat pumps will most likely be found in energy intensive process industries with heat demand at moderate temperatures (< 200°C). The most relevant sectors are: • Refining • (Petro)chemical industry • Food, drink & tobacco industry • Paper and printing
ETS / Non-ETS	ETS
Type of Technology	Electrification
Description	A heat pump transfers heat from a low temperature source to a higher temperature demand by applying additional power. The ratio heat output to power input is called the CoP (Coefficient of Performance). High Temperature (HT) heat pumps that provide heat well-above 130°C for industrial application are currently not available (Marina et al., 2017). The goal of current research is to develop heat pumps that can achieve output heat temperature levels of around 200°C, which will enable heat pumps to be used for a larger group of processes. Current developments focus on using either hydrocarbons or newly developed synthetic refrigerants to achieve sink temperatures of over 140°C (ECN, 2017). Reverse Rankine cycles heat pumps are compression heat pumps using a closed loop that are commercially available for sink temperatures up to 90°C. On request, they can even be adapted for sink temperatures of 120°C – 140°C (ECN, 2017). Although there are other types of heat pumps in development, the data in this factsheet refers to Reverse Rankine cycle heat pumps.
TRL level 2020	TRL 5
	For heat pumps up to 90°C, the TRL is 9, although there has not been a substantial roll-out (ECN, 2018). For skid-mounted compression heat pumps above 160°C of around 2 MWth-output, the TRL is about 4-5 (ECN, 2018). A pilot-scale installation (200 kW) was installed at the Dutch paper mill Smurfit Kappa Roermond by ECN. Siemens has developed a pilot-scale high temperature heat pump (Berenschot et al., 2017). Low pressure steam producing heat pumps are being demonstrated in Japan and are in pilot-scale development phase in the EU.

TECHNICAL DIMENSIONS

Capacity	Functional Unit		Value and Range								
	MWth-output		20								
			Min			-			Max		
Potential	MWth-output	0	Current			2030			2050		
			-			-			-		
			Min	-	Max	Min	-	Max	Min	-	Max
Market share	%		-			-			-		
			-	-	-	Min	-	Max	Min	-	Max
Capacity utlization factor	0.91										
Full-load running hours per year	8,000										
Unit of Activity	PJ/year	0.03									
Technical lifetime (years)	15										
Progress ratio											

Explanation	The current thermal power size of Reverse Rankine cycle heat pumps can go up to 20 MW per unit (ECN, 2017). According to ECN (2017), Reverse Rankine cycles have great application potential for processes in the refining, (petro)chemical, food, and paper industry that operate at <200°C (ECN, 2017). Geographically, these sectors are represented mostly in Rotterdam, Terneuzen, Moerdijk, Sittard and Delfzijl (ECN, 2018). High temperature heat pumps can potentially be used as either baseload or flex unit. In general, heat pumps are more suited to be used for baseload in order to make full use of their economic and energetic advantages (Berenschot et al., 2017; ECN, 2018). It is assumed that for baseload application the capacity utilisation is 8,000 hours per year (ECN, 2017). Heat pumps have an estimated lifetime of 15 years (Berenschot, et al., 2015) and require a major overhaul every 10 years according to VNP (2018).

COSTS

Year of Euro	2015									
	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / MWth-output	2.00			2.00			2.00		
		0.40	-	5.00	2.00	-	2.00	2.00	-	2.00
Other costs per year	mln. € / MWth-output	-			-			-		
		Min	-	Max	Min	-	Max	Min	-	Max
Fixed operational costs per year (excl. fuel costs)	mln. € / MWth-output	0.06			0.06			0.06		
		0.06	-	0.06	0.06	-	0.06	0.06	-	0.06
Variable costs per year	mln. € / MWth-output	-			-			-		
		Min	-	Max	Min	-	Max	Min	-	Max

Costs explanation	The study from Berenschot et al. (2015) provides cost data regarding compression heat pumps from Kobelco (size: 0.11 MWe to 0.25 MWe). The output is 2 to 5 bar steam (120 to 165°C). The technology can deliver a temperature lift of 55 to 95°C, with a COP of 2.5 to 3.5. The investment cost is estimated to be around 1,900 EUR/kWe, with a fixed OPEX of 15.4 EUR/kWe/yr. Blue Terra (2008) assumes a COP range of 3 to 5 for heat pumps. For a 1 MWth heat pump, Blue Terra (2008) estimates an investment cost for bare equipment of 100 to 250 EUR/kWth to provide up to 85°C heat and 300 to 900 EUR/kWth to provide up to 160°C heat. The study also indicates that the total investment cost (including installation cost and other costs such as grid connection costs) can be several times the investment cost. As an indication for the grid connection cost, according to Tennet, a 110 kV and 150 kV connection costs approximately 1.5 mln euros, and a 220 kV and 380 kV connection costs approx. 3 mln euros. The estimation for the total investment cost of a 10 MW heat pump by ECN (2017) was 400 EUR, with 200 EUR/kWth for equipment and 200 EUR/kWth for installation cost. O&M was estimated to be 3% of the CAPEX. The study by Navigant (Noothout et al. 2019) has a much higher estimated investment cost (including installation and connection to the grid) of 800 to 2,000 EUR/kWth for heat pumps up to 90°C and 2,000 to 5,000 EUR/kWth for heat pumps up to 140°C.

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Steam	PJ	-1.00			-1.00			-1.00		
			-1.00	-	-1.00	-1.00	-	-1.00	-1.00	-	-1.00
	Electricity	PJ	0.25			0.25			0.25		
			0.25	-	0.29	0.25	-	0.29	0.25	-	0.29
	Industrial waste heat	PJ	0.75			0.75			0.75		
			0.71	-	0.75	0.71	-	0.75	0.71	-	0.75
		PJ	-			-			-		
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*

Energy in- and Outputs explanation	Electricity is used to increase the temperature of a heat source (typically waste heat for industrial use of heat pumps). A typical performance of a heat pump is a COP of 4 (ECN, 2017). According to (Berenschot et al., 2017), the COP is 3.5 for a steam producing heat pump. The aforementioned COP are, however indicative, as the COP of a heat pump is situational and depends on the temperature levels and the temperature lift. The COP can be estimated using: • COP = fc x (Tsupply + 273)/(Tsupply – Tsource) • fc = 0.35 + 0.6/200 x (Tsupply – Tsource) Condition: • Tsource <Tsupply and 0°C< Tsupply, Tsource<200°C With: • Tsource = Source of heat (in °C) • Tsupply = heat sink (in °C) For a lift of 80°C to 130°C, as the current status of the Reverse Rankine cycle is, the COP is around 4.

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

	Substance	Unit	Current			2030			2050		
Emissions		0	-			-			-		
			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											

REFERENCES AND SOURCES

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