TECHNOLOGY FACTSHEET

INDUSTRIAL MECHANICAL VAPOUR RECOMPRESSION (MVR)

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Sector	Industry: Generic
ETS / Non-ETS	ETS
Type of Technology	Electrification
Description	A heat pump uses energy to transfer heat from a lower temperature (source) to a higher temperature demand (sink) using additional energy. For industrial heat pumps, the heat source is process waste heat. Mechanical vapour recompression (MVR) is an open heat pump system in which the pressure and temperature of the vapour, together with the corresponding saturation temperature, are increased by means of compression (Klop, 2015). Steam recompression is a specific variation of MVR. Low-pressure steam exhaust from industrial operations, such as evaporators or cookers, is usually vented to the atmosphere or condensed in a cooling tower, while other plant operations on the same site may require intermediate-pressure steam. Instead of expanding high pressure steam across a throttling valve to meet these needs, low-pressure waste steam can be mechanically compressed to a higher pressure so that it can be reused (US-DE, 2012). Steam recompression relies upon a mechanical compressor to increase the temperature of the latent heat in steam to render it usable for process duties (US-DE, 2012). The advantage lies in the fact that the required compression energy is very small compared to the amount of latent heat present in the recycled steam (Klop, 2015). The energetic performance of steam recompression is expressed in the coefficient of performance (COP). The COP gives the ratio of the net recovered heat and the energy used by the compressor. In this case, the net heat is the steam production including the additional steam yield by water injection. Typical economical and energy-efficient applications have a minimum COP of 3.5. Some applications of MVR have a COP of 10 or even higher (Klop, 2015). The key elements for a high COP are the following (Klop, 2015): • A low ratio of the absolute steam pressures. A guideline for the maximum ratio is 6, but in daily practice the ratio is about 3. • A minimum capacity. A guideline is a minimum of one tonne of steam per hour. • Water injection after compression. Technology suppliers (not exhaustive list): AtlasCopco, MAN-turbo, Howden, Siemens, Piller, Turbo Claw, SpiraxSarco, Spilling, Heliex.
TRL level 2020	TRL 9
	MVR is an established technology (Berenschot 2017).

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	MWth-output		8								
			4			-			20		
Potential	MWth-output	0	Current			2030			2050		
					-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Market share	%				-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*

Capacity utlization factor		0.91
Full-load running hours per year		8000
Unit of Activity	PJ/year	0.03
Technical lifetime (years)		10
Progress ratio		
Explanation	The unit size of an MVR unit can vary greatly, 4 to 20 MWth based on Navigant (2019). The average is 12 MWth. The lifetime of an MVR installation is 10 years (Walmsley et al. 2017). MVR is typically used as baseload, although flexible use is in some cases also possible (Klop, 2015).	

COSTS

Year of Euro	2015									
	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / MWth-output	0.481					-			-
		0.264	-	0.604	*Min*	-	*Max*	*Min*	-	*Max*
Other costs per year	mln. € / MWth-output			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
Fixed operational costs per year (excl. fuel costs)	mln. € / MWth-output	0.014					-			-
		0.008	-	0.018	*Min*	-	*Max*	*Min*	-	*Max*
Variable costs per year	mln. € / MWth-output			-			-			-
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*

Costs explanation	The investment costs vary from €132 per kWth-output for a larger heat pump (4.4 MWe-input, COP 9.8, 13 bar output) to €302 per kWth for a smaller installation (0.257 MWe, COP of 10.3, 3.2 output). It is assumed the investment cost of Klopt (2015) refer to the bare equipment cost. The installation cost is assumed to be twice the bare equipment cost (ECN, 2017; Blue Terra, 2018). The future developments in cost reduction are unknown. The total investment cost, including bare equipment and installation costs, but excluding all costs related to grid connection, ranges from €260 to €600 per kWth. Furthermore, the grid connection costs (both the one-time connection cost as well as the yearly connection tariffs) can be substantial. Grid connection costs can vary from a few thousand euros for lower voltage grids (Stedin, 2019) to several million to connect to the transmission grid (Tennet website) (depending on the distance to the substation). The OPEX is 1 to 4% of the investment cost (Navigant, 2019).

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Heat	PJ	-1.00			-1.00			-1.00		
			-1.00	-	-1.00	-1.00	-	-1.00	-1.00	-	-1.00
	Electricity	PJ	0.19			0.19			0.19		
			0.10	-	0.29	0.10	-	0.29	0.10	-	0.29
	Industrial waste heat	PJ	0.81			0.81			0.81		
			0.71	-	0.90	0.71	-	0.90	0.71	-	0.90
		PJ			-			-			-
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*

Energy in- and Outputs explanation	Steam pressures of up to 13 bar can be produced from low pressure steam (2.5 to 4.5 bar). The efficiency (COP) for steam recompression ranges from 3.5 to 10 (Klop, 2015).

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											

REFERENCES AND SOURCES
US DE (2012). Use vapor recompression to recover low-pressure waste steam
Klop (2015). Steaming ahead with MVR
ECN (2017). Dutch program for the acceleration of sustainable heat management in industry
Walmsley, T.G. Atkins, M.J., Ong, B.H.Y. (2017). Total Site Heat Integration of Multi-Effect Evaporators
Berenschot (2017). Electrification in the Dutch process industry
Navigant (2019). Verkenning uitbreiding SDE+ met industriele opties
Blue Terra (2018). Hoogtemperatuurwarmtepompen rentabiliteit warmtepompen