TECHNOLOGY FACTSHEET

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INDUSTRIAL NATURAL GAS CHP - GAS TURBINES WITH HEAT RECOVERY STEAM GENERATORS

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Sector	Industry: Generic
ETS / Non-ETS	ETS
Type of Technology	CHP
Description	Combined Heat and Power units (CHPs) are the most efficient way to convert fuels into useful energy (IEA-ETSAP, 2010). The most common conventional industrial CHPs are the natural gas-fired gas turbine with heat recovery steam generators (GT-HRSG), and the combined-cycle gas turbine (CCGT), which is a combination of a gas turbine and a steam turbine. The high temperature heat from the gas turbine exhaust can be used to produce high pressure steam of temperatures up to 593 °C (US EPA CHP Partnership, 2017). The hot exhaust from the gas turbine can be directed through a steam turbine to generate additional electricity, or can be used to provide steam for industrial processes. In the industry, CHPs are primarily deployed to provide the steam necessary for industrial processes (Energy Matters, 2015). This factsheet provides techno-economic data (costs and energy inputs and outputs) on gas turbines with heat recovery steam generators, although technical dimensions applied to the industry sector cover both GT and CCGT. Techno-economic data for CCGT can be consulted in Niessink (2019). The two main types of turbines used in gas turbine CHPs are aeroderivatives and heavy duty turbines. Aeroderivatives are derived from the airplane industry and provide up to 50MWe. They heat up relatively fast (15-45 minutes) and operate with 2-3 axes. Heavy Duties are especially designed for heavy industry, with capacities up to 150MWe, high reliability and long lifetimes. This type takes up to 1,5 hour to heat up and is less flexible in steam volume as it has only one turbine. It needs 60% of its full-load to function as a minimum (Energy Matters, 2015). According to CBS (2020) data, gas turbine CHP are deployed in all type of industries. CCGTs are mainly used in the chemical industry. Gas turbines are most common in chemical industry and refineries (CBS, 2020). The advantages of GT-CHPs over other types of CHP are high reliability, low emissions and the ability to produce high grade heat. Disadvantages include the required high pressure of input gas, and poor efficiency at low loading (US EPA CHP Partnership, 2017). A typical industrial CHP application for gas turbines is a chemical plant with a 25MW simple cycle gas turbine supplying base-load power to the plant with an unfired heat recovery system generator (HRSG) on the exhaust. This gas turbine CHP system will produce approximately 29MW thermal (MWth) of steam for process use within the plant.
TRL level 2020	TRL 9
	Gas turbine CHPs are a mature technology. Turbines have been in use for stationary electric power generation since the late 1930s. Turbine development was accelerated in the 1940s due to the demand for turbines for airplanes, and since the 1990s they have been a popular choice for new power generation plants (US EPA CHP Partnership, 2017).

TECHNICAL DIMENSIONS

	Functional Unit		Current			2030			2050		
Capacity	MWe		Value and Range: 20.00								
			1.00			-			500.00		
Potential	NL	MWe	2,000.00			2,000.00			-		
			2,000.00	–	2,808.00	2,000.00	–	2,000.00	Min	–	Max
Market share	Share of GT and CCGT installed capacity w.r.t. total CHP capacity in	%	93.00			-			-		
			93.00	–	93.00	Min	–	Max	Min	–	Max
Capacity utlization factor	0.35-0.8										
Full-load running hours per year						8,300.00					
Unit of Activity											
Technical lifetime (years)						25.00					
Progress ratio											
Hourly profile											

Explanation	Capacity: Energy Matters (2015) categorises industrial CHPs as small (<10 MWe), medium (10-25 MWe) and large (>25MWe). IEA-ETSAP (2010) reports capacity ranges of 5-25 MW for gas turbines with HRSG and 12-500 MW for CCGT. US EPA CHP partnership (2017) reports a range of 0,5-300 MW. Potential: As of 2015, there were 2,000 MWe of Industrial CHP capacity. There is a downward trend in capacity, with a large amount of capacity shut down in the early 2010s due to low electricity prices (Energy Matters, 2015). According to CBS (2020) there was an estimated 6,785 MWe installed CHP capacity from CCGT and GT CHPs in the Netherlands in 2017. Of this, 3,102 MWe were for decentralized production. About 91% of the decentralized capacity (2,808 MWe) was estimated to be in the industrial sector. According to ECN (2017) the industrial heat demand for temperatures between 100-200 is 5,050 MW. Besides CHPs, this heat demand can be delivered by a range of different technologies including steam boilers and heat pumps. Market share: a 2,808 MWe GT and CCGT installed capacity in the industry sector corresponds to 93% of total CHP installed capacity in the Dutch industry (3,029 MWe). Capacity utilization factor: EnergyMatters (2015) reports a factor of 1 for full load and 0,8 for partial load of a 6 MWe GT CHP. IEA-ETSAP (2010) reports lower factors: 0,7-0,8 for GT CHPs and 0,75-0,85 for CCGTs. The utilization rate of a given gas turbine or combined cycle gas turbine CHP unit depends on the economic conditions ("spark spread" between natural gas and electricity prices) in the country, as well as on the on-site heat and electricity demands, which can vary by sector and process. Full-load running hours: US EPA CHP Partnership (2010) reports an average number of 8,308 hours per year based on several figures ranging from 8,426 hours for <3MW CHPs to 8195 hours for >20MW CHPS. IEA-ETSAP reports availabilities between 90-95% (7,889-8,328 hours). Energy Matters (2015) explores multiple scenarios for flexible deployment of industrial CHPs. Their scenario with the lowest amount of running hours is one where the CHP is only used during daytime, which adds up to 3,000 hours. Technical lifetime: IEA-ETSAP (2010) reports 25 years for both GT and CCGT.

COSTS

Year of Euro	2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / MWe	0.60			0.56			-		
		0.59	–	2.06	0.56	–	0.56	Min	–	Max
Other costs per year	mln. € / MWe	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max
Fixed operational costs per year (excl. fuel costs)	mln. € / MWe	0.06			-			-		
		0.02	–	0.07	Min	–	Max	Min	–	Max
Variable costs per year	mln. € /	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max

Costs explanation	Investment costs: Energy Matters (2015) reports investment costs of 500, 600 and 700 Euro per kWe for GT CHPs of 6, 22 and 42 MWe respectively. IEA-ETSAP reports costs of 950 USD2008 (900 USD in 2030). US EPA CHP Partnership (2017) reports values from 3181 to 1248 USD2013 for CHPs from 3 to 44MW, including a full breakdown of these costs. US Dept. Of Energy (2017) reports significantly higher values of 1300-3300 USD/kW. Operational costs: O&M costs consist of routine inspections and scheduled overhauls of the turbine generator set. Operational costs were often reported in units of Euro/MWh. These were multiplied by the corresponding running hours per year to obtain the yearly operational costs per MW. Energy Matters (2015) reports values of 71/62/48 Euro per kWe for 6/22/42 MWe gas turbines. IEA-ETSAP reports 40 USD2008 for GTs. US EPA CHP Partnership (2017) reports 105 to 71 USD2013 for 3 MW to 44 MW gas turbines. US Dept. Of Energy (2017) reports 9 to 13 USD per MWh but doesn't specify the running hours.

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Electricity	PJ	-1.00			-1.00			-		
			-1.00	–	-1.00	-1.00	–	-1.00	*Min*	–	*Max*
	Natural gas	PJ	2.99			2.78			-		
			2.63	–	2.99	2.78	–	2.78	*Min*	–	*Max*
	Heat	PJ	-1.24			-0.74			-		
			-1.32	–	-1.11	-0.74	–	-0.74	*Min*	–	*Max*
		PJ	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Energy in- and Outputs explanation	Natural gas values are presented in LHV. Energy Matters (2015) reports electric efficiencies of 31,5% - 33,5% and thermal efficiencies of 41,5% - 42,5%. In a memo from 2013, Energy Matters presents 38%/42% electric/thermal efficiency for a gas turbine. IEA-ETSAP (2010) reports 32-37% electric efficiency and 48-43% thermal efficiency for GT CHPs, with 1,5% improvements towards higher electric efficiency projected for 2030. US EPA CHP Partnership (2017) reports lower values of 22-33% electric efficiencies for 3-44 MW CHPs By Dutch law, the minimum electric efficiency of an industrial CHP is 30%. In a scenario where CHPs are deployed in a more flexible matter, there will be more time that they work in partial load, which decreases the efficiency as a negative consequence. (Energy Matters, 2015)										

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		
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Explanation										

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