TECHNOLOGY FACTSHEET

COAL-FIRED POWER PLANT (CO-FIRING BIOMASS) - ELECTRICITY PRODUCTION AND DISTRICT HEATING

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Sector	Built environment
	Other sectors
ETS / Non-ETS	ETS
Type of Technology	CHP
Description	Working of the Technology A coal-fired power plant can be a combined heat and power plant (CHP). The fuel input consist of pulverized coal. In some cases biomass is cofired. Water is evaporated in a boiler to produce high pressure steam which is expanded in a turbine to generate electricity using a generator. Residual heat is cooled down by using a cooling technique, for instance cooling towers. From the drain of a steam turbine heat can be fed into a district heating network. Heat can be supplied to different sectors such as the built environment or industry. This factsheet focuses on a CHP plant that delivers heat to the built environment. A CHP plant without carbon capture and storage (CCS) is considered in this factsheet. Main components Components of a coal-fired power plant for the production of electricity and district heating typically consist of fuel storage/fuel feed, steam boiler, economiser/heat exchanger (i.e. feedwater heaters; commonly used as part of a heat recovery steam generator in a combined cycle power plant), turbine and generator, cooling technique, flue gas cleaning equipment and ash conveyor. Energy production related aspects The downside of utilizing heat for district heating is that the electrical efficiency of the CHP plant is lowered (loss of electricity production) (ECN, 2011). Loss of electricity production (GJe/GJth supplied) depend on the temperature of heat disconnection. Typical losses are included in this factsheet. Coal-fired CHP plants are equipped with flue gas cleaners to limit/prevent emissions of various harmful substances (such as particulate matter, NOx, SOx). The flue gas cleaner is included in the costs presented in this factsheet.
TRL level 2020	TRL 9
	The technology is already being applied on a large-scale and can therefore be considered to be mature. An example is the Amercentrale, a coal-fired CHP plant (cofiring biomass) located in Geertruidenberg (Noord-Brabant), supplying heat to the Amernet which is one of the large heat networks in the Netherlands (ECN, 2017).

TECHNICAL DIMENSIONS

	Functional Unit		Current			2030			2050		
Capacity	MWe		Value and Range: 900								
			200			-			1,600		
Potential	MWe	NL	-			-			-		
			Min	-	Max	Min	-	Max	Min	-	Max
Market share	%	Share of final heat demand	0.55			Phase out of coal Dutch climate agreement			Phase out of coal Dutch climate agreement		
			0.55	-	0.55	-	-	-	-	-	-

Capacity utlization factor		0.83
Full-load running hours per year		7,250
Unit of Activity	PJe/year	23.5
Technical lifetime (years)		30
Progress ratio		-
Hourly profile	Yes	
Explanation	Typical Electric and Heat Capacity Of Coal-fired Power Plants The electrical capacity of different supercritical pulverised coal power plants in OECD countries ranges between 200 and 1.600MWe (IEA, 2015; ETRI, 2014). Here 900 MWe is taken as an average. Full load hours per year depend on the marginal production costs (the merit order). A coal-fired CHP plant runs base load, because of its low marginal costs and relatively long start-up times; it typically has more than 7.000 full load hours per year for electricity production (Seebregts and van Dril, 2010; Energy Matters, 2012; IEA ETSAP, 2010). In case of 7.250 full loads hours this translates to a capacity utilitization factor of 83%. IEA (2010) indicates 75-85% as capacity utilization factor for a fluidised bed combustion coal-fired CHP (IEA ETSAP, 2010). A CHP plant with a capacity of 900 MWe and 7.250 full load hours produces 23 PJe per year. Full load hours for heat delivery are not the same. Indeed, heat demand peaks in winter and in other seasons there is a (much) lower heat demand. Heat is produced when the plant produces electricity, but due to limited overlap with the heat demand 30 to 45% of the available heat can be supplied per year (ECN, 2011). On average 25% heat losses can be assumed in a heat network (ECN, 2017). For example, in case of 2,6 PJth heat demand per year, a CHP plant needs to produce about 3,4 PJth per year. Assuming 4.500 full load hours (based on Energy Matters, 2012), the thermal output capacity for district heating would be about 210 MWth. Heat Supply by Coal-fired CHP In The Netherlands About 4% of heat demand in the built environment in the Netherlands is supplied with district heating in 2015 (ECN, 2017). Most of heat is supplied with large scale heat networks which have natural gas-fired CHP, municipal waste incinerators, biomass heat sources, and coal-fired CHP as heat sources (ECN, 2017). The Amernet supplied about 2,7 PJ of heat in 2015, out of which 95% was coming from the Amercentrale (ECN, 2017). The remaining 5% is supplied by other heat sources such as back up boilers. The final heat demand of the built environment is 463 PJ for dwellings and non-residential buildings in 2015 (ECN, 2017) which means the share of heat supplied by district heating using coal-fired power plants is 0,6%. In case half of fuel input in Amercentrale is coal, and the remainder biomass, the share would be 0,3%. The coal share will likely decrease further in coming years due to increased cofiring of biomass and a phase out of Dutch coal-fired CHP plants under the Dutch climate agreement. Technical Lifetime Coal-fired Power Plants ECN indicates a technical lifetime of 30 years for a coal-fired CHP (ECN, 2011). ETRI indicates a technical lifetime of 35 years for a Steam turbine coal supercritical CHP (ETRI, 2014).	

COSTS

Year of Euro: 2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / MWe	2.04			2.04			2.04		
		1.44	-	2.86	1.95	-	2.45	1.95	-	2.33
Other costs per year	mln. € / MWe	-			-			-		
		Min	-	Max	Min	-	Max	Min	-	Max
Fixed operational costs per year (excl. fuel costs)	mln. € / MWe	0.05			0.05			0.05		
		-	-	0.08	0.05	-	0.08	0.05	-	0.08
Variable costs per year	mln. € / MWe	0.04			0.04			0.04		
		0.04	-	0.07	0.04	-	0.04	0.04	-	0.04

Costs explanation

Overview
The ETRI (2014), Energy Matters (2012), IEA (2010) and PBL (2017) and ECN (2011) reports provide information on coal-fired CHP' investment costs/capital expense (CAPEX), fixed operational costs (FOM), and variable operational costs (VOM). Costs are described for different capacity levels expressed per unit of capacity.

Costs explanation per source

- ETRI (2014) presents the CAPEX per MWe of a steam turbine coal supercritical CHP (ETRI, 2014). ETRI indicates a CAPEX of 1940-2210 €/kWe for the plant in 2020, a CAPEX of 1940-2210 €/kWe for the plant in 2030 and a CAPEX of 1940-2210 €/kWe for the plant in 2050 (same values). The FOM costs per year in 2020, 2030 and 2050 amount to 2,5% of the CAPEX (ETRI, 2014). The VOM costs per year in 2020, 2030 and 2050 amount to 5,1 €/MWh (ETRI, 2014) and is converted to €/MWe assuming 7.250 full load hours per year. In the CAPEX the following cost components are included (ETRI, 2014): Civil and structural costs, Major equipment costs, Electrical and I&C supply and installation, Project indirect costs, Development costs and Interconnection costs. Costs excluded are (ETRI, 2014): Balance of plant costs and Insurance costs.

- Energy Matters (2012) indicates investment costs of a coal-fired CHP plant with capacity of 600MWe (Energy Matters, 2012). Energy Matters indicates 1.400 euros/kWe as total investment costs. CAPEX includes Civil and structural costs, Major equipment costs including heat disconnection costs. Fixed costs per year are zero (Energy Matters, 2012). Variable costs per year are 38,4 Million Euros per year (Energy Matters, 2012). Compared to the total costs of a coal-fired power plant, the extra investments in heat-disconnection are limited (Energy Matters, 2012). The plant is used for electricity production and disctrict heating.

- According to IEA (2010) the investment cost of a coal or biomass-fired fluidised bed combustion (FBC) CHP plant are in the range of $3000 to $4000/kWe, depending on the capacity of the plant (IEA ETSAP, 2010). Typical investment costs amount to $3250/kWe. The O&M costs, which are given as the total of fixed and variable, are in the range of $90/kWe to $120/kWe per year (typically $100/kWe). According to the IEA (2010) projection, incremental improvements and technology learning may lead to investment cost of $3000/kWe by 2020 and $2850/kWe by 2030 (IEA ETSAP, 2010).

When a CHP plant supplies heat to a heat network for the first time, there are additional investment costs for heat disconnection:

- PBL (2017) indicates an investment of 150-175 euros2017/kWth,output (PBL, 2017). The costs consist of the investment/CAPEX for heat disconnection (Dutch: 'kosten warmteuitkoppeling'). The fixed operational costs per year are 5% of the investment.
- D51ECN (2011) indicates investment costs of 300 euros2011/kWth,output (ECN, 2011). The costs indicated consist of the investment/CAPEX for heat disconnection (Dutch: 'kosten warmteuitkoppeling').

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	-	-1.00	-1.00	-	-1.00
	Coal	PJ	2.50			2.50			2.50		
			2.50	-	3.57	2.50	-	3.33	2.50	-	3.33
	Heat	PJ	-1.00			-0.38			-0.38		
			-2.18	-	-0.38	-1.97	-	-0.38	-1.97	-	-0.38
		PJ	-			-			-		
			Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*

Energy in- and Outputs explanation

Overview:
Different types of existing coal-fired power plants in different OECD countries have typical electrical efficiencies ranging between 40% and 46% (IEA, 2015). IEA (2015) indicates an electrical efficiency of 46% for existing ultra-supercritical coal power plant in the Netherlands (IEA, 2015).
The electrical efficiency of a CHP plant can only improve marginally due to further technical optimizations. The maximum possible efficiency of any heat engine is defined as the Carnot efficiency, which is not obtainable in practice. In case of CHP, a higher heat output lowers the electricity output and vice versa.

Ratios (used to determine min.-max. range in table above):
• ECN (2011) indicates a 46% electrical efficiency and (possible) thermal efficiency of 40% for a coal-fired CHP plant used for electricity production and district heating (ECN, 2011). Disconnecting 0,4GJth at 120+B66°C per GJ coal input results in a decrease of electricicity production from 0,46GJe to 0,4GJe (ECN, 2011). For 2020, 2030 and 2050 the same values are assumed.

• Energy Matters (2012) indicates a 15% thermal efficiency and a 40% electrical efficiency for a coal-fired CHP used for large scale district heating (Energy Matters, 2012). For 2020, 2030 and 2050 the same ratios are assumed.

• IEA ETSAP (2010) indicates an electrical efficiency of 24-28% for a fluidised-bed combustion (FBC) coal-fired industrial CHP and a thermal efficiency (steam) of 62-64% (IEA ETSAP, 2010). The 2020 projection is an electrical efficiency of 26-30% (28%) and a thermal efficiency of 60-62% (61%). The 2030 projection is an electrical efficiency of 28-32% (30%) and a thermal efficiency of 58-60% (59%) (IEA ETSAP, 2010). For 2050 the same efficiencies as 2030 are assumed.

Other ratios:
• ETRI (2014) indicates energy efficiencies of a Steam turbine coal supercritical CHP (ETRI, 2014). There are no thermal efficiencies given in the report, but only efficiencies at peak electrical load, which means that the plant maximizes its electricity output. In 2020, the max. elec. efficiency is 41% (ETRI, 2014). In 2030, the max. elec. efficiency is 42% (ETRI, 2014). In 2050, the max. elec. efficiency is 43% (ETRI, 2014).

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	Most of the non-CO2 emissions are prevented due to the flue gas cleaner.										

OTHER										
Parameter	**Unit**	**Current**			**2030**			**2050**		
Loss of electricity production per unit of heat supplied	GJe/GJth	0.18			0.18			0.18		
		0.09	-	0.18	0.09	-	0.18	0.09	-	0.18
Water consumption	liters/kWh	0.01			0.01			0.01		
		0.01	-	0.01	0.01	-	0.01	0.01	-	0.01
		-			-			-		
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*
		-			-			-		
		Min	-	*Max*	*Min*	-	*Max*	*Min*	-	*Max*

Explanation

• Downside of utilizing heat for district heating is that the electrical efficiency of the CHP plant is lowered (loss of electricity production). For each GJth of drain heat supplied to district heating there is 0,18 GJe loss of electricity production (ECN, 2011). The higher the temperature of the heat, the higher the losses. ECN (2011) indicates a loss of 0,18 GJe/GJth for drain heat at 120ºC and a loss of 0,09 GJe/GJth at 80 ºC (ECN, 2011).

• According to ETRI the water withdrawal is equal to 0,01 liters per kWhe and water consumption (i.e. water which is not returned to the water system) is 0,01 liters per kWhe (ETRI, 2014).

REFERENCES AND SOURCES

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