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Update of financial data for coal fired CHP plants in the technology catalog

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The note has been out in external review from May 11 to June 1 2017. Comments received in this process, comments found relevant has been incorporated.
The note will be incorporated in the energy technology catalogue for electricity and district heating production plants *https://ens.dk/sites/ens.dk/files/Analyser/technology_data_catalogue_for_energy_plants_-_aug_2016._update_june_2017.pdf* .

This note reviews financial data from the current data sheet of coal fired CHP plants in the Technology Catalogue for electricity and heat generation from The Danish Energy Agency. These data have last been updated in the years 2011-2012, and most sources of financial data in the sheet are from 2010-2011.

Method

In Denmark, most thermal units are combined heat and power plants (CHP). Most other countries do not have the demand for residential heating to utilize the waste heat from power plants, and are therefore using pure condensing plants. We assume that all new coal fired CHP units in Denmark will be extraction units.

The note follows the steps of (1) analysing the possible differences between CHP and condensing units which could impact the CAPEX and OPEX, then (2) analysing and comparing data of coal fired power plants from different sources. In this connection, OPEX is considered a total of fixed and variable O&M costs. Thereafter (3) an estimation of the split between fixed and variable O&M cost is performed.

The data is based upon the following publications and projects:

[1] The IEA World Energy Outlook 2014 coal fired Ultra-supercritical power plants in Europe. Values used are the projection for 2020.

[2] The IEA Projected Cost of Generating Electricity 2015 for coal fired power plants. Here both the 'world median' is used, and data from recently commissioned plants in the Netherlands. The three units in the Netherlands are chosen because of the proximity to Denmark, because the socio-economic parameters (labour cost etc) are assumed to be similar and because the units are new (all from 2015).

[3] EIA Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants 2013 for pulverizes coal fired advanced single units.[1]

[4] Aggregated data from different projects on existing units that Ea Energy Analyses have been working on since 2010. Data is used for estimating O&M costs.

All public tables used are shown in Appendix A. All prices in this analysis are in €2015. The cost from each source have been converted to its original value and currency, and then converted to €2015. All specific values are in MW electricity output. Due to economy-of-scale relationships, only larger power plants are considered, i.e. above 400 MW.

	Exchange rate to €2015	Used by source
€2011	1.059	DEA TC 2011
$2012	0.824	[1]
$2013	0.767	[2],[3]

Table 1: Exchange rates from currency used in source to €2015.

In the evaluation, European plants are weighted higher than overseas (USA) plants, and newer plants (2015-2020) are weighted higher than older (before 2015). And data from newer sources are weighted higher than older.

Differences between CHP and condensing units

The main difference between a condensing power plant and an extraction CHP plant, is that an extraction plant needs an additional heat exchanger compared to a condensing plant (see Figure 1). This additional district heating heat exchanger utilizes extracted intermedia steam from the turbines. From Danish experiences, the whole district heating installation is only around 5%

[1] In the report the costs estimates were based on information derived from actual or planned projects known to the consultant, when possible. When this information was not available, the project costs were estimated using costing models that account for the current labor and materials rates necessary to complete the construction of a generic facility as well as consistent assumptions for the contractual relationship between the project owner and the construction contractor. All costs were weighted average of the sources.

of the total CAPEX, which suggest only a small increase in the overall cost. There is therefore assumed 5 % higher costs of both CAPEX and OPEX on CHP compared to condensing power plants.

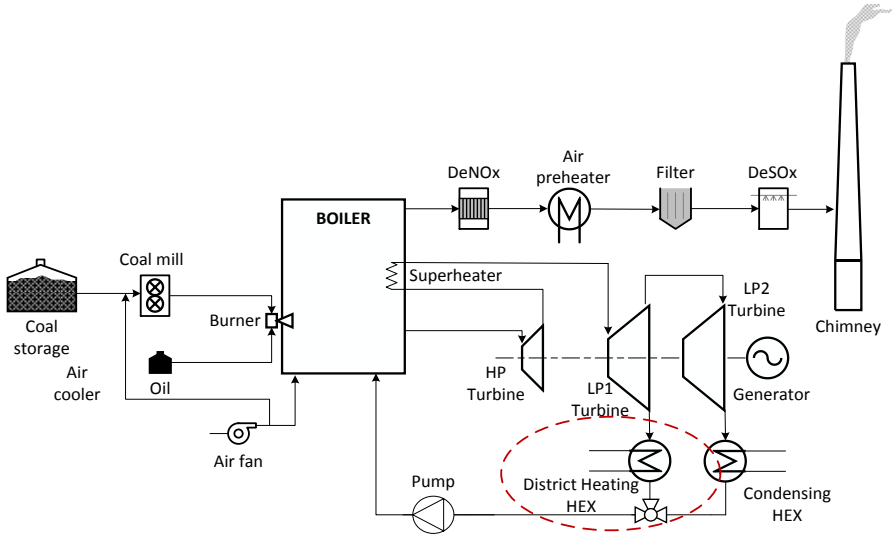

Figure 1: A schematic diagram of an extraction plant.

CAPEX and OPEX cost of new coal fired power plants

CAPEX

The data tables used is shown in Appendix A. All values compared are for new units (year 2020 is chosen when possible – assumed year of commissioning). The specific investment costs for the different sources are plotted in Figure 2 below. The MW is the unit's full load condensing power capacity. For condensing units, it is assumed that the costs are for a power plant cooling with sea water, which is known to be the case for the three units in the Netherlands.

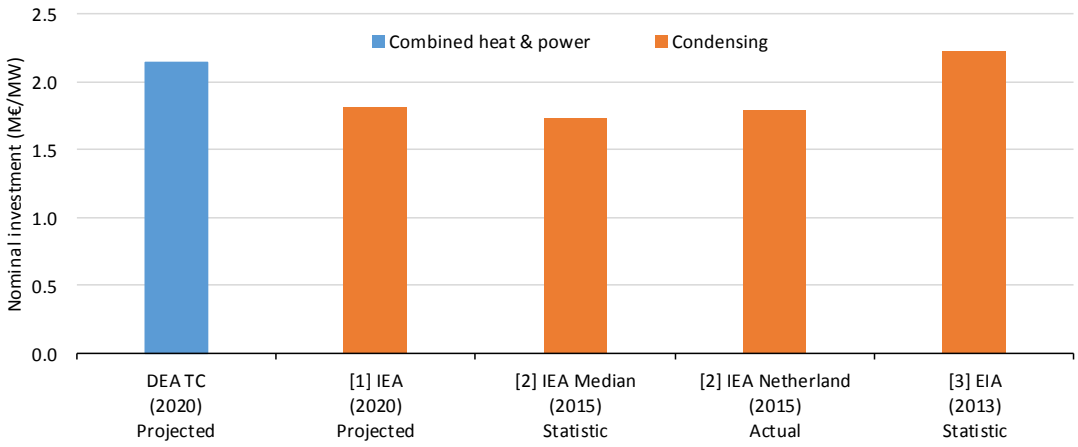

Figure 2: Nominal investment in coal fired power plants (2015M€/MW). The years in () indicate the year of the commission or statistic.

The investment cost from the European sources [1-2] is around 1.8 M€/MW, where the exception is the current value from the Technology Catalogue of 2.15 M€/MW, which is app. 20% higher. The cost listed by EIA for the USA is on the same level as the Technology Catalogue. According to the IEA the price of coal power is around 5 % higher in the USA compared to Europe. Under this assumption the EIA price for the USA can be translated to around 2 M€/MW for a European plant.

Weighting the newest projects and European sources highest, 1.8 M€/MW is proposed as the central estimate for condensing power plants. Assuming a 5% additional investment cost for adding the district heating units, we propose the 1.9 M€/MW for coal fired CHP plants.

OPEX

In the data sheet in the Technology Catalogue the OPEX is split into variable and fixed O&M costs. However, it is not always clear when a cost is going from fixed to variable and vice versa, and therefore different sources list O&M cost differently. To be sure that we can directly compare the costs we therefore look at O&M as a yearly sum (see Figure 3). And here used the amount of full load hours that each source assuming[2]. All sources assume a lifetime of 40 years.

Most sources project a decrease in the O&M cost for future plants (not shown in the figure), except the data in the current (before June 2017) Technology Catalogue, which surprisingly project an increase over time. The increase in the electrical efficiency over time is further increasing the O&M per input to the boiler, because the costs are given per MW and MWh electricity.

[2] For the current DEA TC and the data from Ea are assumed 4500 hours and for the IEA and EIA sources are assumed 7500 hours.

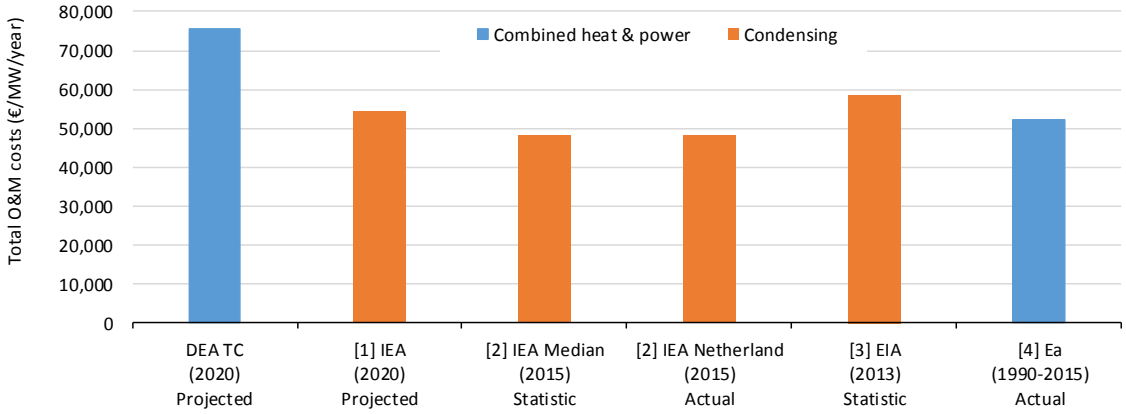

Figure 3: Total annual O&M costs for coal fired power plants (2015€/MW/year). The year in ( ) indicate the year of the projection or statistic.

The current data in the Technology Catalogue again list highest value, which is around 75,000 €/MW/year – i.e. 50% higher compared to the weighted average of the other sources of around 50,000 €/MW/year [1-4]. CHP plants are assumed to have a 5% higher O&M costs due to the extra heat element in the unit. So, the total O&M costs of a coal fired CHP unit are evaluated to be around 52,500 €/MW/year.

Split between variable and fixed O&M cost

As mentioned, it is not always clear when a cost is going from fixed to variable and vice versa. To evaluate the split, variable costs from the sources that list these are used (see Figure 4). The prices seem to be between 2-4 €/MWh.

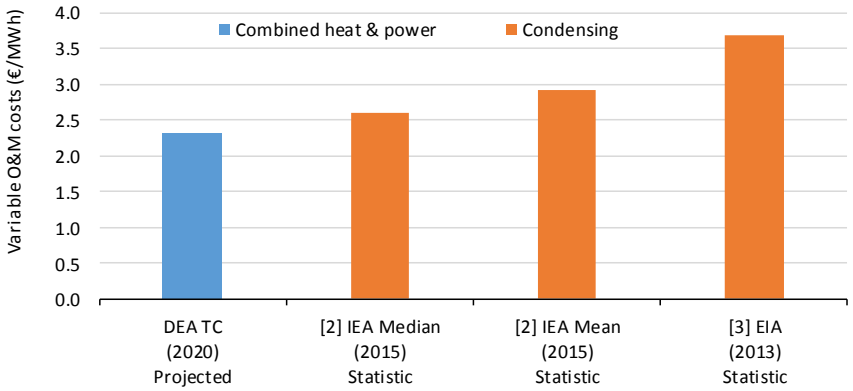

Figure 4: Variable O&M cost (2015€/MWh). The year in ( ) indicate the year of the projection or statistic.

Choosing 2.75 €/MWh as variable O&M cost for a condensing plant (weighting the newer sources highest) and adding 5% for the CHP part gives around 2.9 €/MWh. Using 7500 full load hours as used above, and 52,500 €/MW/year in total O&M costs, this yields a fixed O&M of 31,000 €/MW/year.

Updated financial numbers

The table below summarise the findings to a suggested update of the financial figures of coal power CHP plants in the Danish Technology Catalogue for commission year 2020. Newer and European data are weighted higher than older data and data from overseas.

Year 2020	Current numbers	Suggested update	Difference
Nominal investment (M€/MW)	2.15	1.9	-12%
Fixed O&M (€/MW/year)	65,000	31,000	-52%
Variable O&M (€/MWh)	2.3	2.9	+24%

Note: Data for plant with a max. capacity of 400-1000 MW. The costs are given in relation to the maximum electricity output, e.g. in condensing mode. The fixed and variable O&M are assumed to be independent of the amount of full load hours. The lifetime of the plant is 40 years. For a lifetime of 25 years roughly 6000 €/MW/year should be subtracted from the Fixed O&M (from DEA Technology Catalogue about LTE of coal fired CHP).

According to the NREL report[3] mature power plant costs are generally expected to follow the overall general inflation rate over the long term. And since the suggested prices listed in the table are in real 2015 prices, then no, or very little (annually 0% -1%), development is expected.

Prediction of the cost in 2030 and 2050

To predict the costs in 2030 and 2050, it is assumed that the cost is falling by 0.2 % p.a. This is based on an assumption of accumulation of capacity commissioned from 2020 to 2050 deduced from predictions of the future global installed electricity capacity in the 4D scenario in the Energy Technology Perspectives[4] [IEA,2016], and a assumed learning rate[5] of app. 8 % for coal technologies.

[3] Black & Veatch for NREL (2012), "Cost and performance data for power generation technologies"
[4] IEA(2016),Energy Technology Perspectives
[5] E.S. Rubin et al. / Energy Policy 86 (2015) page 198–218, A review of learning rates for electricity supply technologies

Appendix A: Data tables from sources

Table 3.3: Coal-fired generating technologies

Country	Technology	Net capacity[1] (MWe)	Electrical conversion efficiency (%)	Overnight cost[2] (USD/kWe)	Investment cost[3] (USD/kWe)		
					3%	7%	10%
Belgium	Ultra-supercritical	750	46	2 307	2 448	2 648	2 807
Germany[4]	Hard coal	700	46	1 643	1 744	1 887	1 999
	Lignite	900	43	2 054	2 180	2 358	2 499
Japan	Ultra-supercritical	704	41	2 496	2 649	2 866	3 037
Korea	Pulverised (PC 1000)	960	43	1 218	1 289	1 386	1 463
	Pulverised (PC 800)	766	41	1 252	1 317	1 407	1 477
Netherlands	Ultra-supercritical	1 070	46	1 620	1 720	1 860	1 971
	Ultra-supercritical	777	46	2 746	2 914	3 152	3 341
	Ultra-supercritical	1 554	46	2 660	2 823	3 054	3 237
Portugal	Pulverised	605	51	3 067	3 255	3 521	3 732
	Pulverised	605	46	2 533	2 689	2 909	3 083
United States	Supercritical pulverised	750	43	2 496	2 609	2 765	2 886
Non-OECD countries							
China	Ultra-supercritical	1 000	45	813	863	933	989
South Africa	Pulverised	4 693	40	2 222	2 588	3 157	3 652

1. Net capacity may refer to the unit capacity or to the combined capacity of multiple units on the same site.
2. Overnight cost includes pre-construction (owner's), construction (engineering, procurement and construction) and contingency costs, but not IDC.
3. Investment cost includes overnight cost (with contingency) as well as the implied IDC.
4. Data for the German coal plants were derived from publicly available sources. See references at the end of the chapter for complete details.

Source: IEA Projected Cost of Generating Electricity 2015. In $2013 prices.

Table 3.10: Levelised cost of electricity for coal plants

Country	Technology	Net capacity[1] (MWe)	Fuel cost (USD/MWh)	Carbon cost (USD/MWh)	O&M costs (USD/MWh)
Belgium	Ultra-supercritical	750	26.67	22.05	8.00
Germany	Hard coal	700	26.38	21.98	9.14
	Lignite	900	14.88	28.20	11.07
Japan	Ultra-supercritical	704	35.91	25.02	18.52
Korea	Pulverised (PC 800)	766	40.04	24.77	5.31
	Pulverised (PC 1000)	960	38.36	23.67	4.80
Netherlands	Ultra-supercritical	1 070	31.49	21.90	8.88
	Ultra-supercritical	777	31.49	21.90	8.88
	Ultra-supercritical	1 554	31.49	22.20	7.81
Portugal	Pulverised	605	31.47	22.21	6.16
	Pulverised	605	28.38	20.03	14.53
United States	Supercritical pulverised	750	28.42	25.20	11.12
Non-OECD countries					
China	Ultra-supercritical	1 000	35.67	28.88	4.07
South Africa	Pulverised	4 693	20.45	27.00	5.41

Source: IEA Projected Cost of Generating Electricity 2015. In $2013 prices.

	Capital costs ($2012 per kW)			O&M Costs ($2012 per kW)		
	2012	2020	2035	2012	2020	2035
Steam Coal - ULTRASUPERCRITICAL						
Europe	2200	2200	2200	66	66	66
United States	2300	2300	2300	69	69	69
Japan	2600	2600	2600	78	78	78
Russia	2200	2200	2200	66	66	66
China	800	800	800	32	32	32
India	1400	1400	1400	56	56	56
Middle East	1800	1800	1800	72	72	72
Africa	2000	2000	2000	70	70	70
Brazil	1800	1800	1800	72	72	72

Source: IEA World Energy Outlook 2014. In $2012 prices.

Table 6.2: Overview of data for coal generation					
MEDIAN CASE: COAL	Net capacity (MWe)	Electrical conversion efficiency (%)	Overnight cost (USD/kWe)	Fixed O&M costs[1] (USD/MWe)	Variable O&M costs[1] (USD/MWh)
Number of countries			9		
Count	14	14	14	14	14
Maximum	4 693	51%	3 067	92 123	12.7
Minimum	605	40%	813	0	0.0
Mean	1 131	44%	2 080	37 818	3.8
Median	**772**	**45%**	**2 264**	**34 542**	**3.4**
Delta	4 088	11%	2 254	92 123	12.7
1. Zero values for fixed and variable O&M cost do not refer to the same data point.					

Source: IEA Projected Cost of Generating Electricity 2015. In $2013 prices.

	Plant Characteristics		Plant Costs (2012$)			
	Nominal Capacity (MW)	Heat Rate (Btu/kWh)	Overnight Capital Cost ($/kW)	Fixed O&M Cost ($/kW-yr)	Variable O&M Cost ($/MWh)	NEMS Input
Coal						
Single Unit Advanced PC	650	8,800	$3,246	$37.80	$4.47	N
Dual Unit Advanced PC	1,300	8,800	$2,934	$31.18	$4.47	Y
Single Unit Advanced PC with CCS	650	12,000	$5,227	$80.53	$9.51	Y
Dual Unit Advanced PC with CCS	1,300	12,000	$4,724	$66.43	$9.51	N
Single Unit IGCC	600	8,700	$4,400	$62.25	$7.22	N
Dual Unit IGCC	1,200	8,700	$3,784	$51.39	$7.22	Y
Single Unit IGCC with CCS	520	10,700	$6,599	$72.83	$8.45	N

Source: EIA Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants 2013. In $2012 prices.