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Germany's Power Generation in 2022 and Beyond

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This white paper discusses a biomass fuel strategy for the German power generation sector that has the potential to reduce dependence on imported natural gas, mitigate grid reliability risk, solidify baseload generation, and significantly reduce carbon dioxide (CO_2) emissions.

The advantages of this strategic pathway are:

- ✓ Replace coal generation without increasing reliance on imported Russian natural gas.
- ✓ Sustain and create jobs in the fuel supply chain by extending the operation of coal fired power plants with renewable solid fuel.
- ✓ Produce significant reductions in net CO_2 emissions while generating on-demand or baseload power.
- ✓ Avoid the creation of costly stranded assets by keeping a cohort of power plants that were built to use coal operating.
- ✓ Lower the net cost of generation. Given recent coal prices and carbon prices in the European Trading System (ETS), pellet fuel's cost per megawatt-hour of electricity generated (MWhe) is lower than the cost per MWhe of coal.

The strategy that is explored in this white paper is to replace coal in selected power stations with sustainably sourced pellet fuel[1]. The replacement can be incremental over time by co-firing pellet fuel and coal with the goal of phasing out coal combustion completely in certain power stations.

For this white paper, FutureMetrics has selected 13 power stations in Germany with characteristics that makes them good candidates for the strategy described below. There are currently over 100 operating coal fueled power plants in Germany[2] , including additional power plants with potential for fuel change that have not been selected for analysis in this white paper.

This paper first describes the German power sector and then discusses the advantages of substituting pellet fuel for coal.

The reader is also invited to explore how this strategy can affect any of the 13 German power stations that are part of this analysis by opening and using the dashboard that complements this white paper. The next page shows the interactive dashboard with its default settings.

[1] FutureMetrics has published several white papers explaining how sustainably sourced pellet fuel is carbon neutral in the combustion process when compared to coal. Those papers are free to download from the FutureMetrics website.
[2] Interactive Google Map of German coal fueled power stations HERE. Data used to create the map is from "Global Coal Plant Tracker," Global Energy Monitor, January 2022.

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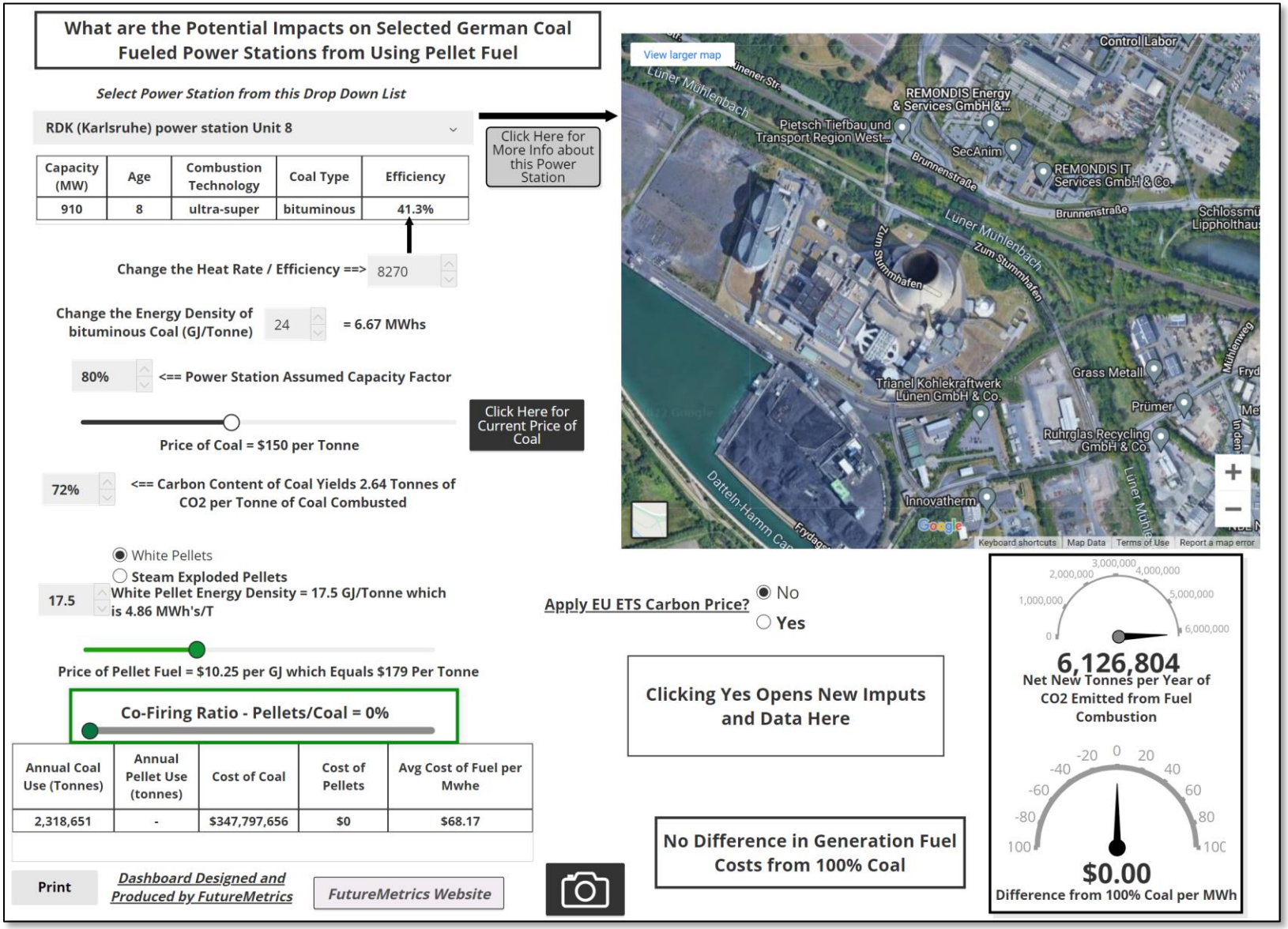

The user can select any of the 13 plants using the drop-down list in the upper left.

Once selected, certain plant specific parameters are displayed, and an interactive Google Map of the selected plant opens. The user can adjust a number of critical inputs that determine fuel consumption and CO_2 emissions.

The user can include the cost of CO_2 emissions based on the ETS carbon price by selecting "Yes".

The default setting for the "Co-Firing Ratio" is 0%. That is, the plant uses 100% coal. The slider control can change that up to 100% pellets and any ratio in between.

The dashboard shows annual fuel demand, and the average cost of fuel per MWhe.

It also shows the difference in the cost of fuel and the reduction in CO_2 emissions as the ratio of pellet fuel is increased.

Dashboard is HERE

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A techno-economic-geopolitical discussion of Germany's power sector

Recent geopolitical events in the European region have further highlighted that reliance on imported natural gas for heating and power generation introduces significant risk. 55% of Germany's current natural gas supply comes from Russia.

Recent events may motivate German policymakers and utilities to review and potentially re-visit options to reduce this dependence.

Germany had 30.5GW of installed natural gas-fueled power generation capacity in 2021; supplying 15.3% of Germany's power consumption.[3] Coal fired power plants provide nearly 28% of required electricity.

Germany's Installed Power Generation Capacity by Fuel Type (as of Nov 2021)

	Nuclear	Lignite	Hard Coal	Natural Gas	Oil	Onshore Wind	Offshore Wind	Solar PV	Hydro Power	Biomass	Total
GW	8.1	20.3	23.7	30.5	4.4	56.3	7.8	58.4	4.9	8.6	**223**
% of Total	3.6%	9.1%	10.6%	13.7%	2.0%	25.2%	3.5%	26.2%	2.2%	3.9%	
		44				136					
		19.7%				61.0%					

source: https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts, Analysis by FutureMetrics

Germany's Gross Power Generation by Source (2021 throught November)

	Nuclear	Lignite	Hard Coal	Natural Gas	Oil	Renewables	Other	Total
TWh	69	108.3	54.3	89	4.8	238	18.8	**582.2**
% of Total	11.9%	18.6%	9.3%	15.3%	0.8%	40.9%	3.2%	
		162.6						
		27.9%						

source: same as chart above, Analysis by FutureMetrics

These statistics illustrate the importance of baseload power generated by fossil fuel assets in maintaining grid reliability; especially coal which produced about 28% of Germany's power in 2021. With all nuclear power plants scheduled to go offline by end of 2022, another 69 TWh will have to be generated by other sources.

In addition to the nuclear power exit by the end of 2022, current Germany policy requires retirement of all coal-fired power plants by 2038 at the latest. But evolving policy by the new German Federal Government is expected to result in legislation that moves the coal exit forward to 2030. The expectation has been that baseload generation will be supplied by natural gas power plants, including new plants that perhaps can later switch to green hydrogen.

[3] https://energy-charts.info/charts/power/chart.htm?l=en&c=DE&stacking=stacked_absolute_area&interval=year&year=2021&download-format=text%2Fcsv

Coal power plant operators can bid into tenders by Germany's Bundesnetzagentur (Federal Grid Agency) for payments per MW of capacity to be retired. The first tender was conducted in September 2020 and the last tender is planned for 2026. For each tender, the agency has set a ceiling price. The actual price per plant is not published.

Tenders for German Coal Plant Decommissioning

Bid Deadline	Ceiling Price Euro/MW Net Nominal Capacity	Max Price USD/MW (@ $1.13 per Euro)	Total Capacity (MW)	Effective (Year)	Max Total Cost (USD)
1-Sep-20	165,000 €	$186,450	4,000	2021	$745,800,000
4-Jan-21	155,000 €	$175,150	1,500	2021	$262,725,000
30-Apr-21	155,000 €	$175,150	2,480,826	2022	$434,516,673,900
1-Oct-21	116,000 €	$131,080	433,016	2023	$56,759,737,280
1-Mar-22	107,000 €	$120,910	1,222,886	2024	$147,859,146,260
1-Aug-22	98,000 €	$110,740	TBD	2025	
1-Jun-23	89,000 €	$100,570	TBD	2026	
Total					**$640,144,082,440**

source: see footnote #4; Analysis by FutureMetrics

Given the cost of retiring coal assets, the current geopolitical situation and its impact on natural gas supply and prices, as well as the fact that sufficient green hydrogen supply is unlikely to be available for a decade or more, it is rational and pragmatic to now explore some scenarios for co-firing pellet fuel at newer coal plants and switching some stations to 100% pellet fuel.

The prerequisite for biomass-derived solid fuel that replaces coal in the EU markets is that it is produced from sustainable resources such as waste wood from sawmills and the lower grade portions of trees[5] harvested from certified sustainably managed forests. That is a necessary component in the supply chain that forms the foundation of pellet fuel's carbon emissions benefits.

The coal replacement biomass-based fuel must comply with the sustainability standards as defined by the EU Renewable Energy Directive III (RED III). If it certified to be produced from sustainable sources, then the carbon held in the managed forests supplying pellet manufacturing feedstock is not being depleted. Every molecule of CO_2 emitted from pellet fuel combustion is absorbed by contemporaneous replacement growth.

[4] https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Kohleausstieg/start.html (available in German only)

[5] The portion of a straight tree that goes to a sawmill (the sawlog) is typically between 30% and 50% of the tree stem. The some of the remaining tree stem may go to a pulp and paper mill, a plywood or oriented strand board mill, or to a pellet mill. Some of the small diameter stem and the tops and limbs may also be suitable as pellet factory feedstock.

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For this analysis, the German power stations in this small sample are a selection of plants that are:

- Considering switching from coal to sewage sludge but facing public pushback.
- Already considering switching to sustainably sourced wood pellet fuel.
- Less than 10 years old.

Discussion of the Power Plants that are highlighted in this White Paper

The operation of coal power plants in the European Union (EU), including those in Germany, not only face impacts from decarbonization policies, but also face high operating costs. Spot coal prices have averaged over $150/tonne for some time and, on March 2, 2022 at the time of this writing, have spiked to $435/tonne!

Source: https://markets.businessinsider.com/commodities/coal-price

Compounding high coal cost for German coal-fueled power stations is the cost of emitting carbon dioxide. The cost of CO_2 emissions in the EU has also risen steadily over the past few years and has recently been over $100 per tonne (see chart on next page)

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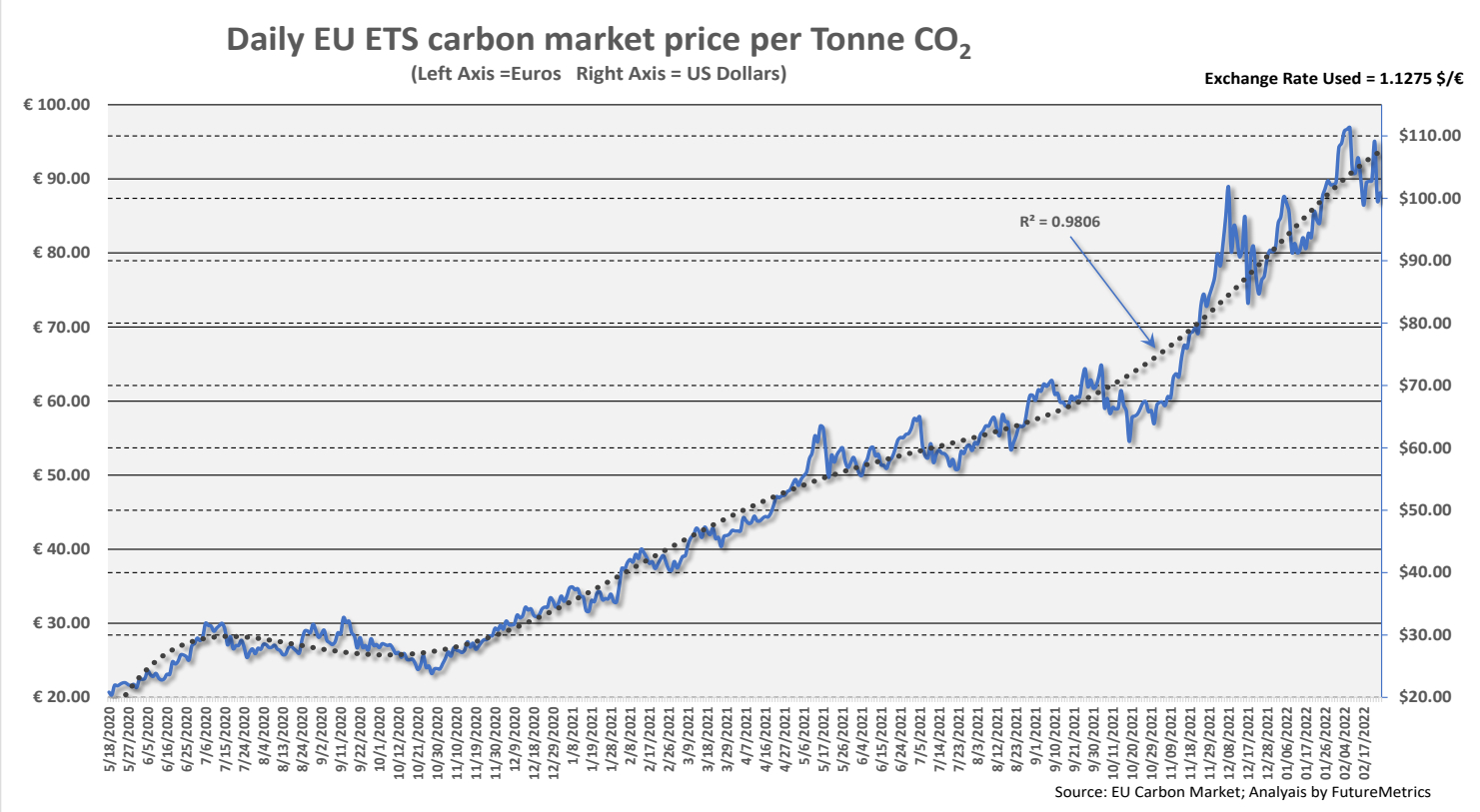

The combination of high coal prices and high carbon prices make coal fueled power generation in Germany very expensive.

The tables on the next page shows summaries of the 13 power plants that FutureMetrics has included in this analysis and in the interactive dashboard. The top table is based on 100% coal and the lower table is based on 100% pellets.

It is unlikely for all 13 plants to convert to 100% pellets in the near term. Co-firing pellets with coal, which can be explored in the dashboard, is a more likely scenario, at least in the near term. Some of the power plants may fully convert from coal to pellet fuel. Over the next decade it is more than feasible that sufficient pellet fuel production capacity can be developed to match demand at 100% pellet fuel. North America alone is estimated to be able to produce 74 million tonnes per year by 2031[6].

Using 100% coal, the weighted average cost of coal plus the cost of CO_2 emissions, using the inputs shown in the dashboard screenshot on page 2, is $218.51 per MWh. This cost does not include other power station operating costs (labor, maintenance, amortized capital costs, etc.). Using 100% pellets, and thus avoiding all of the CO_2 emissions cost from the fuel combustion, the weighted average cost is $89.86/MWh.

[6] Forisk's Research Quarterly

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Summary Date on the Coal-Fueled Power Stations Used in this Analysis

100% Coal Scenario

Station Name	Capacity (MW)	Age	Combustion Technology	Coal Type	Estimated Annual Coal Use (Tonnes)	Cost of Coal at $150 per Tonne	Avg Cost of Fuel per Mwhe	Annual MWhs Produced	Tonnes of CO2	Tonnes of CO2 per Mwhe	CO2 Cost per MWhs based on an ETS carbon price of €90 per Tonne	**Cost of Coal Plus the Cost of Carbon Emissions per MWhe**
RDK (Karlsruhe) power station Unit 8	910	8	ultra-super	bituminous	2,318,651	$347,797,656	$ 68.17	5,101,824	6,126,804	1.201	$121.44	**$189.61**
Walheim power station Unit 1	107	58	subcritical	bituminous	286,808	$43,021,226	$ 71.72	599,885	757,862	1.263	$127.75	**$199.47**
Walheim power station Unit 2	160	55	subcritical	bituminous	428,872	$64,330,805	$ 71.72	897,024	1,133,251	1.263	$127.75	**$199.47**
GKM Mannheim power station Unit 8	480	29	subcritical	bituminous	1,286,616	$192,992,414	$ 71.72	2,691,072	3,399,754	1.263	$127.75	**$199.47**
Datteln power station Unit 4	1100	2	ultra-super	bituminous	2,802,765	$420,414,749	$ 68.17	6,167,040	7,406,026	1.201	$121.44	**$189.61**
Merkenich (Nord) power station Unit 3	58.3	57	subcritical	lignite	227,302	$34,095,327	$ 104.31	326,853	600,623	1.838	$185.82	**$290.14**
Duisburg-Walsum power station Unit 10	790	9	ultra-super	bituminous	2,012,895	$301,934,229	$ 68.17	4,429,056	5,318,873	1.201	$121.44	**$189.61**
Wilhelmshaven Engie power station	830	7	ultra-super	bituminous	2,114,814	$317,222,038	$ 68.17	4,653,312	5,588,183	1.201	$121.44	**$189.61**
Neurath power station Unit F	1100	10	ultra-super	lignite	4,076,749	$611,512,363	$ 99.16	6,167,040	10,772,402	1.747	$176.64	**$275.80**
Neurath power station Unit G	1100	10	ultra-super	lignite	4,076,749	$611,512,363	$ 99.16	6,167,040	10,772,402	1.747	$176.64	**$275.80**
GKM (Mannheim) power station Unit 9	912	7	ultra-super	bituminous	2,323,747	$348,562,047	$ 68.17	5,113,037	6,140,269	1.201	$121.44	**$189.61**
Luenen-Stummhafen power station	810	9	ultra-super	bituminous	2,063,854	$309,578,134	$ 68.17	4,541,184	5,453,528	1.201	$121.44	**$189.61**
Boxberg power station Unit R	675	10	ultra-super	lignite	2,501,641	$375,246,223	$ 99.16	3,784,320	6,610,337	1.747	$176.64	**$275.80**
Totals or Weighted Averages ==>					26,521,464	$3,978,219,572	$ 78.56	50,638,687	70,080,316		$139.95	$218.51

100% Pellet Fuel Scenario

Station Name	Capacity (MW)	Age	Combustion Technology	Annual Pellet Use (tonnes)	Cost of Pellets	Avg Cost of Fuel per Mwhe	Cost of fuel /MWhe at 100% Coal	Annual MWhs Produced	Tonnes of CO2	CO2 Cost per MWhs based on an ETS carbon price of €90 per Tonne	**Cost of Fuel Plus the Cost of Carbon Emissions per MWhe**
RDK (Karlsruhe) power station Unit 8	910	8	ultra-super	2,543,891	$456,310,525	$ 89.44	$68.17	5,101,824	-	$0.00	**$89.44**
Walheim power station Unit 1	107	58	subcritical	314,670	$56,443,848	$ 94.09	$71.72	599,885	-	$0.00	**$94.09**
Walheim power station Unit 2	160	55	subcritical	470,534	$84,402,016	$ 94.09	$71.72	897,024	-	$0.00	**$94.09**
GKM Mannheim power station Unit 8	480	29	subcritical	1,411,602	$253,206,048	$ 94.09	$71.72	2,691,072	-	$0.00	**$94.09**
Datteln power station Unit 4	1100	2	ultra-super	3,075,034	$551,584,151	$ 89.44	$68.17	6,167,040	-	$0.00	**$89.44**
Merkenich (Nord) power station Unit 3	58.3	57	subcritical	171,451	$30,753,984	$ 94.09	$104.31	326,853	-	$0.00	**$94.09**
Duisburg-Walsum power station Unit 10	790	9	ultra-super	2,208,433	$396,137,708	$ 89.44	$68.17	4,429,056	-	$0.00	**$89.44**
Wilhelmshaven Engie power station	830	7	ultra-super	2,320,253	$416,195,314	$ 89.44	$68.17	4,653,312	-	$0.00	**$89.44**
Neurath power station Unit F	1100	10	ultra-super	3,075,034	$551,584,151	$ 89.44	$99.16	6,167,040	-	$0.00	**$89.44**
Neurath power station Unit G	1100	10	ultra-super	3,075,034	$551,584,151	$ 89.44	$99.16	6,167,040	-	$0.00	**$89.44**
GKM (Mannheim) power station Unit 9	912	7	ultra-super	2,549,482	$457,313,405	$ 89.44	$68.17	5,113,037	-	$0.00	**$89.44**
Luenen-Stummhafen power station	810	9	ultra-super	2,264,343	$406,166,511	$ 89.44	$68.17	4,541,184	-	$0.00	**$89.44**
Boxberg power station Unit R	675	10	ultra-super	1,886,952	$338,472,093	$ 89.44	$99.16	3,784,320	-	$0.00	**$89.44**
Totals or Weighted Averages ==>				25,366,712	$4,550,153,905	$ 89.86	$ 78.92	50,638,687	0	$0.00	$89.86

Generation from Pellets is Significantly Lower Cost and Significantly Lowers CO_2 Emissions

This scenario, in which 100% of the coal used by the 13 power plants is replaced by sustainably sourced pellet fuel, significantly lowers the cost of generation and eliminates the over 70 million tonnes per year of CO_2 emissions.

CO_2 emissions per MWhe vary amongst the 13 selected power plants due to coal type (bituminous or lignite), boiler design (subcritical or ultra-supercritical), and boiler efficiencies[7].

The reader is encouraged to open the dashboard and see what the impacts are for any one of the 13 power stations not only at 100% coal or 100% pellets, but at every ratio of pellets to coal in between, and for differing assumptions on fuel energy density and cost, ETS carbon pricing, boiler efficiencies, and other parameters.

The future cost of coal and carbon emission per tonne is unknown. However, this well-proven[8] strategy provides a hedge against that uncertainty.

Conclusion

Solid fuel that replaces coal in utility scale pulverized coal[9] power plants can provide a sustainable fuel option for baseload generation in existing power plants. The conversion from coal to pellet fuel requires only a modest capital investment. An added benefit is that the cost for scrubbing sulfur from the flue gasses will be greatly reduced or eliminated.

If the power plant uses an advanced pellet fuel[10] that can be stored outside in the existing coal yards, the conversion cost is very low. For lignite fueled plants, the modification cost may be zero, and the advanced pellet fuel's energy density will likely be higher than that of the lignite.

Advances in carbon capture and storage (CCS) are likely to lower the costs of refining CO_2 from the combustion process. Bioenergy CCS (BECCS[11]) is the only pathway to negative carbon emissions that also supplies reliable baseload power. If BECCS was to be deployed in any of the converted power stations the economics would be even more compelling.

But even without BECCS, in a world of high c carbon pricing and fossil fuel cost uncertainty, the economics are highly attractive.

Given the modest cost to modify a coal power station to use pellet fuel, balanced against the very significant benefits, one could argue that rather than only subsidizing the decommissioning of assets, it may be more beneficial in some cases to subsidize investments in the modifications needed to enable using sustainable pellet fuel instead of coal.

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[7] Critical inputs are based on data from "Global Coal Plant Tracker," Global Energy Monitor, January 2022, and analysis by FutureMetrics.
[8] In 2022 about 23 million metric tonnes of pellet fuel will be used in power stations to replace coal.
[9] More than 95% of utility scale power stations use pulverized coal technology.
https://en.wikipedia.org/wiki/Pulverized_coal-fired_boiler
[10] See the FutureMetrics white paper on this topic HERE.
[11] See the FutureMetrics white paper on this topic HERE.