The Global Coal Atlas: Techno-Economic Analysis of Converting the World's Coal-Fired Power Plants into Thermal Storage Power Plants

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Executive Summary
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Overview

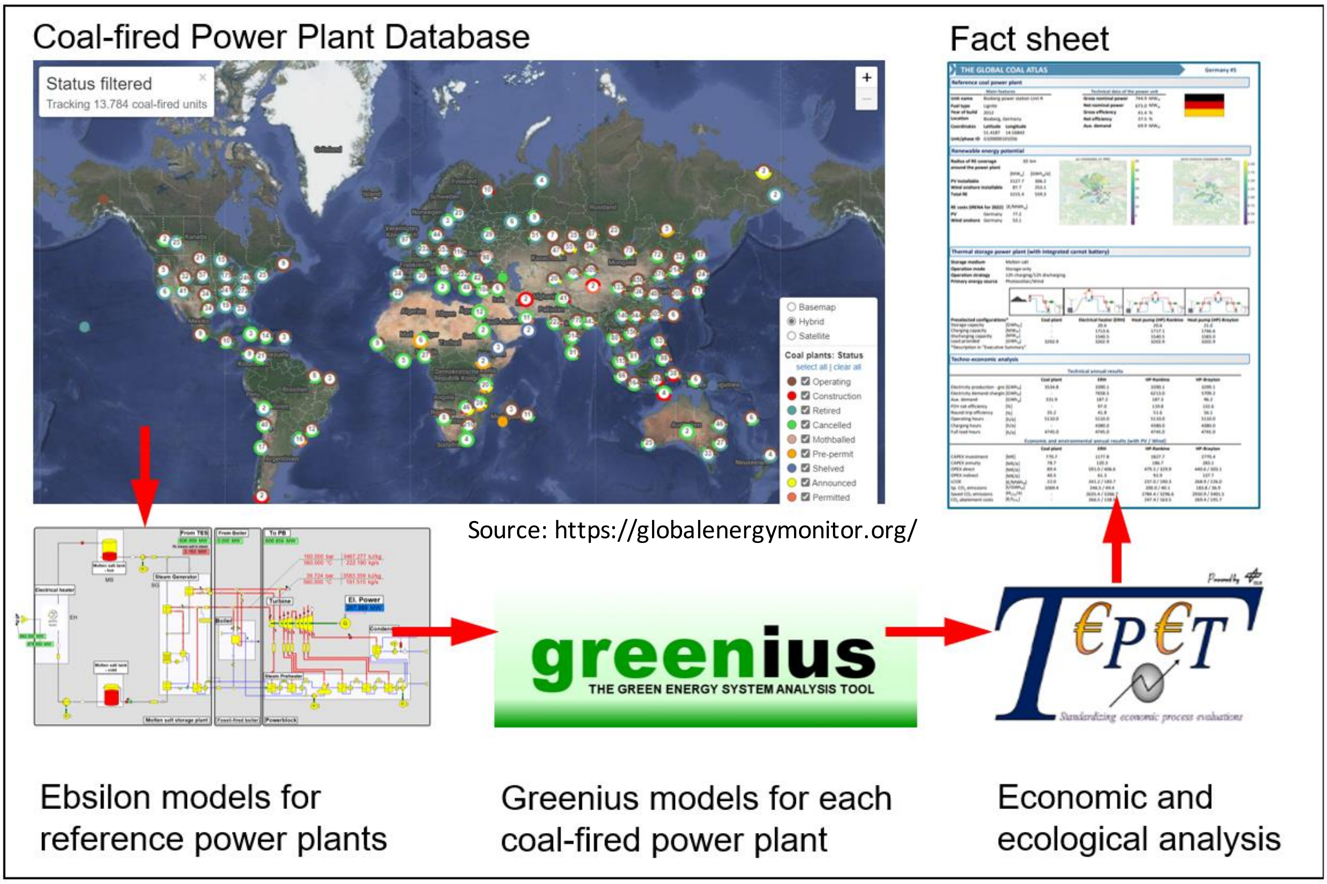
As part of the *Coal Atlas* project, technical concepts were developed and analyzed for converting existing grid-connected coal-fired power plants into CO_2-free thermal storage power plants (TSPP). The main goal of the analysis presented here is to create a collection of data that includes a forecast of decarbonization and CO_2 avoidance costs for each of the existing coal-fired power plants worldwide.

In a TSPP, a high-temperature thermal storage is charged using renewable energy (Power-To-Heat). Optionally, additional firing with CO_2-neutral fuels can be implemented. For discharging, the heat from the storage is converted into electricity and fed into the grid using the existing power block and grid connection (Heat-To-Power). This Power-To-Heat-To-Power storage is also known as a Carnot Battery. The storage converts fluctuating renewable electricity generation to power on demand.

The study examined configurations that combine high-temperature thermal energy storage with either electric heaters or high-temperature heat pumps for Power-To-Heat. While systems based on electric heaters represent a mature and cost-effective solution, heat pump–based systems can improve overall round-trip efficiency by upgrading low-temperature heat using electricity.

As shown in Fig. 1, a comprehensive global database of approximately 7,000 coal power plants served as the foundation for this analysis. Based on detailed technical data available for selected reference plants, two representative plant configurations were modeled in *Ebsilon Professional* [1] to obtain detailed thermodynamic and operational results. These *Ebsilon* reference models were then simplified and transferred into the DLR software *greenius* [2], enabling large-scale simulations for all approximately 7,000 coal power plants in the database. This allowed a consistent evaluation of the energy performance of each site under a typical daily operation profile (12 h charging / 12 h discharging). The technical results from these simulations were further processed in the DLR *TEPET* [3] tool to perform a techno-economic assessment.

This work provides the first global-scale techno-economic assessment of converting the existing coal power fleet into sustainable, dispatchable thermal storage systems. The results were summarized in a fact sheet that was created for each plant. It includes technical results such as i.a. round-trip efficiency and annual yield as well as those obtained from the economic evaluation like capital expenditure for conversion (CAPEX), operating costs (OPEX) and levelized cost of electricity (LCOE). In addition, the CO_2 avoidance potential and the associated costs were calculated. The data collection of these results is intended to serve decision-makers from industry and politics as an objective basis for a possible global conversion of existing coal-fired power plants into CO_2-free TSPP. These approx. 7000 fact sheets are provided as annex to this study.



Source: https://globalenergymonitor.org/

Figure 1. Methodology overview: Techno-economic analysis of converting coal-fired power plants worldwide to CO_2-free TSPP.

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[1] Iqony (2025) EBSILON® Professional. Available online: https://www.ebsilon.com/de/
[2] DLR (2025) greenius. Available online: http://freegreenius.dlr.de
[3] Albrecht et al. (2017), A standardized methodology for the techno-economic evaluation of alternative fuels.

Modelling of the Coal-Fired Power Plants

The techno-economic analysis of converting coal-fired power plants into thermal energy storage power plants requires, as a first step, the acquisition of reliable data describing the existing coal power fleet.

Several publicly accessible databases provide information on operational coal-fired power plants worldwide. These databases were carefully reviewed and compared in order to select the most suitable one for this study.

The *Global Coal Plant Tracker* from Global Energy Monitor (GEM) [4], January 2024 version, was selected as the primary data source. This database was chosen because it is publicly available, regularly updated, provides geographical coordinates of the plants, and includes key technical information such as installed capacity, year of commissioning, combustion technology, and an estimate of plant efficiency.

However, the use of this database also presents certain limitations. The efficiency estimation is based on stepwise rather than continuous dependencies, there is no information on potential cogeneration systems, and it is necessary to assume a boiler efficiency. The *Global Coal Plant Tracker* assigns a heat rate to each plant depending on the combustion type, as shown in Table 1. This heat rate is then corrected according to the age and capacity of the plant, as illustrated in Table 2, allowing the efficiency of each plant to be estimated.

For this study, the efficiency of the power block was required. Therefore, a boiler efficiency of 85% was assumed in order to derive the power block efficiency from the total plant efficiency provided in the database. It is important to note that these efficiencies are only estimates, and deviations from real plant performance are possible, particularly for plants whose parameters lie close to the step boundaries in the table, which may lead to under- or overestimation of their efficiency.

To calculate part-load efficiency, the power block of a reference system for which detailed technical data were available was modeled in *Ebsilon*. This allowed the creation of a characteristic map for the reference power block, which was subsequently integrated into *greenius* and then scaled to each individual plant using the corresponding parameters provided in the *Global Coal Plant Tracker*, enabling consistent large-scale simulations across all sites.

Table 1. Heat rate as a function of combustion technology.

Combustion Technology	Heat rate (Btu per kWh)
Subcritical	8702
Supercritical	8409
Ultra-supercritical	8272
CFB	8702
IGCC	7528
Unknown	8605
IGCC/CCS	10505
Ultra-supercritical/CCS	12534
Supercritical/CCS	12534
Subcritical/CCS	13724
Unknown/CCS	12534

Table 2. Efficiency correction factors for plant age and capacity.

	0 - 349 MW	350 - 449 MW	450+ MW
0 - 9 years	20%	10%	0%
10 - 19 years	30%	20%	10%
20 - 29 years	40%	30%	20%
30+ years	45%	35%	25%

The power plants were filtered according to capacity, considering only those with more than 50 MWe and with the operational status announced, under construction, operating, permitted, or pre-permit. After this filtering process, a total of 6,570 coal-fired power plants were included in the analysis.

The following data were extracted for each plant from the database:

- Name of the reference plant unit
- Fuel type
- Year of construction and retrofit
- Geographic location
- Capacity
- Efficiency

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[4] Global Energy Monitor (2025) Global Coal Plant Tracker. Available online: https://globalenergymonitor.org/projects/global-coal-plant-tracker/

Modelling of the Thermal storage power plants

Existing coal-fired power plants can be converted to thermal storage power plants by storing renewable energy in Carnot batteries and delivering the stored energy back to the grid using the former coal-plant existing power blocks and grid connections.

The conversion of coal-fired power plants into thermal storage power plants can be achieved through several technical configurations. In this study, three representative concepts with molten salt thermal storage were selected for detailed techno-economic analysis and compared with a coal-fired power plant:

- Coal Plant: Existing coal-fired power plant as basis for the conversion analysis.
- ERH: Electric heater + existing Rankine cycle: Integrates an electric heater, molten salt thermal storage, and steam generator with the existing steam cycle.
- HP-Rankine: Replaces the electric heater with a high-temperature heat pump, improving efficiency while retaining the existing Rankine power block.
- HP-Brayton: Combines a high-temperature heat pump with a newly designed Brayton power cycle.

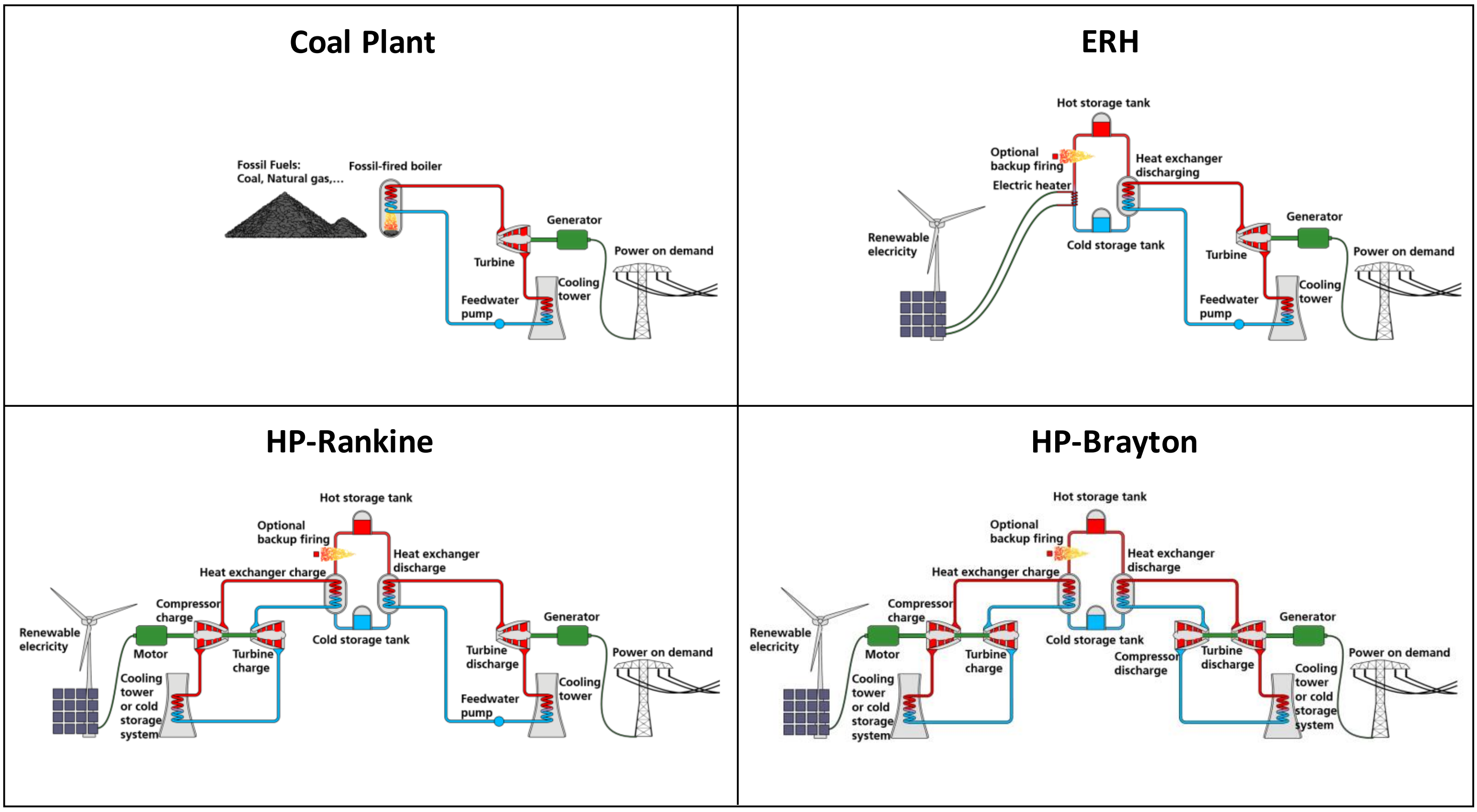

Figure 2. Compared concepts: coal-fired power plants and conversion concepts.

The annual energy performance of the thermal storage power plants was simulated using *greenius*. The Rankine power block models were based on performance maps calculated in a detailed *Ebsilon* model for different operating conditions of a reference power plant and subsequently integrated into *greenius*. This *greenius* model was then applied to approximately 7,000 power plants from the database by scaling according to plant capacity and efficiency.

An additional challenge arose in estimating the efficiency of the Brayton cycle and the high-temperature heat pump for concepts incorporating these components. Efficiency data for various gas turbine models from the GTW Handbook [5] were used to create a performance function for the Brayton cycle. Based on the known overall efficiency, the component efficiencies required to achieve this overall performance were determined using a detailed *Ebsilon* model of a Brayton cycle. These component efficiencies, identical to those of the heat pump, were then applied in the *Ebsilon* heat pump model to derive a performance function for the coefficient of performance (COP). These performance functions of the Brayton cycle and the heat pump were subsequently integrated into *greenius* to enable system-level simulations.

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[5] Gas Turbine World (2021) GTW Handbook

Modelling of the Thermal storage power plants

The simulations followed a fixed daily operating strategy of 12 hours of charging and 12 hours of discharging at nominal power. In addition, each discharge cycle included one hour of startup and one hour of cooldown, both operated at 50% part load. Consequently, the power block was in operation for a total of 14 hours per day. Hourly quasi-steady-state simulations were performed over the entire year, capturing all relevant operating modes and interdependencies between subsystems. Figure 3 shows this operating strategy. The same operating strategy was applied to the coal-fired power plants in the fact sheets to facilitate comparison.

The outputs of the simulation include annual energy production, internal consumption, overall efficiency, and part-load performance, enabling a consistent techno-economic evaluation across the global coal power fleet.

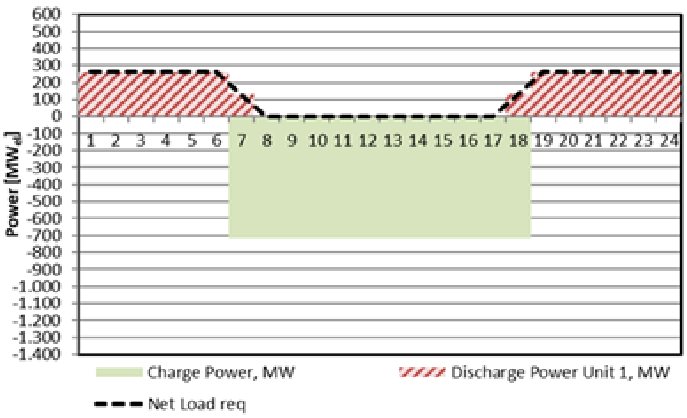

Figure 3. Daily operating strategy.

The following figures show the *Ebsilon* models of the thermal storage power plant concepts for the reference power plant on which the *greenius* models were based. For the economic assessment, a second reference plant was also used, from which the cost functions were derived. Figure 4 shows the model with an electric heater and a Rankine cycle, Figure 5 the model with a heat pump and a Rankine cycle, and Figure 6 the model with a heat pump and a Brayton cycle. The nomenclature of the components shown in the models is the same as that used in Table 3 to refer to the costs of these components.

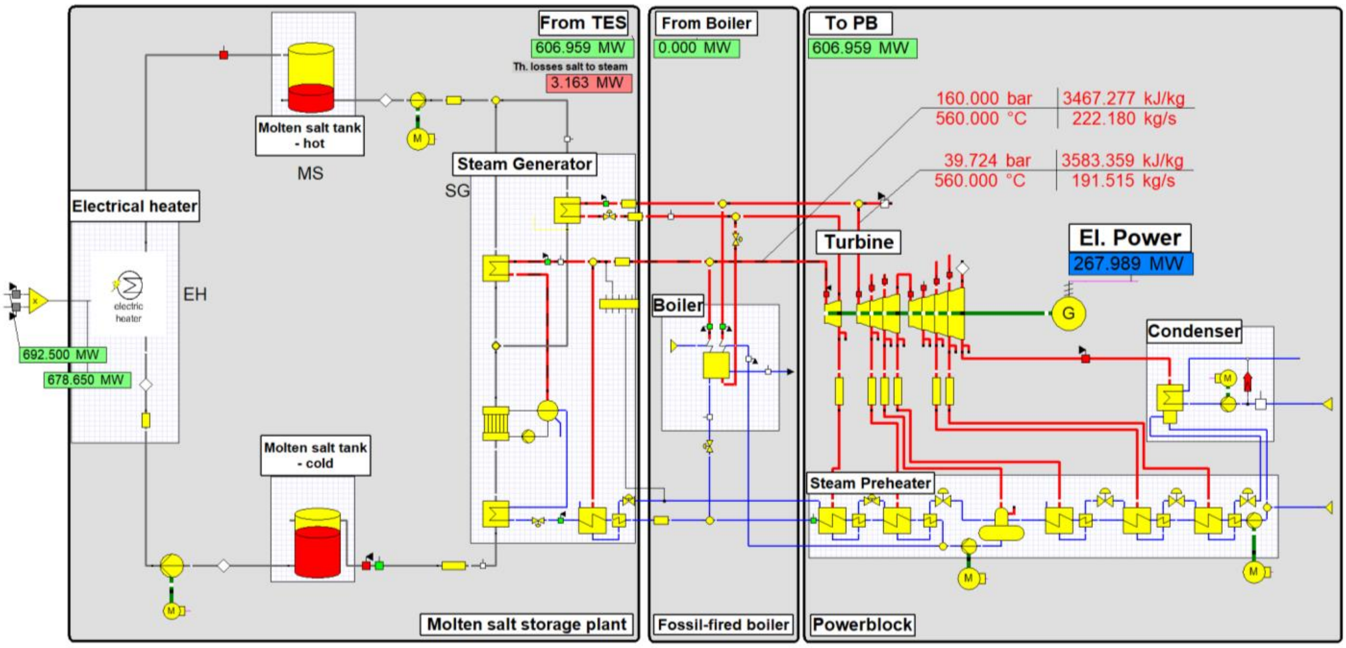

Figure 4. System model for a thermal storage power plant with electric heater and Rankine power cycle (concept ERH).

Thermal storage power plant concepts

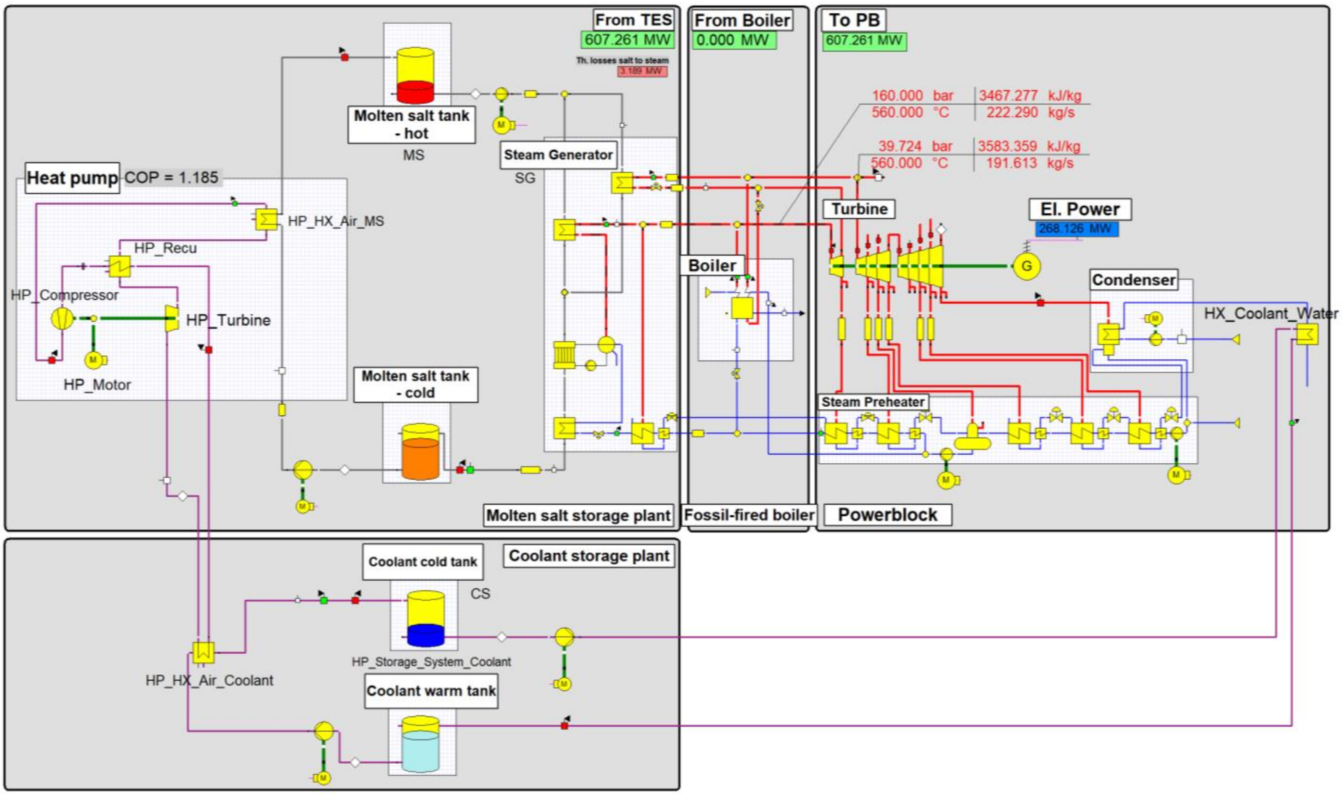

Figure 5. System model for a thermal storage power plant with heat pump and Rankine power cycle (concept HP-Rankine).

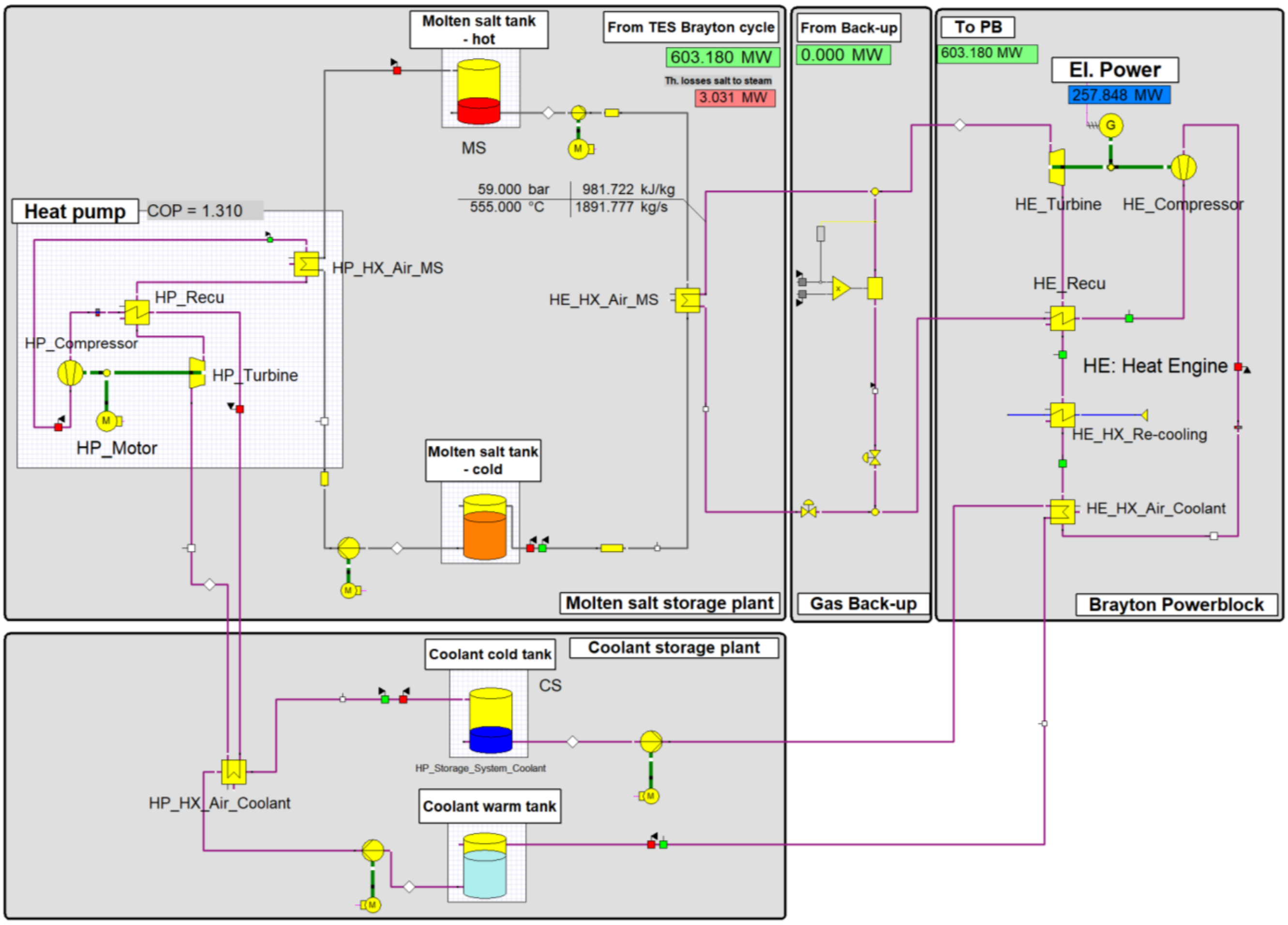

Figure 6. System model for a thermal storage power plant with heat pump and Brayton power cycle (concept HP-Brayton).

Potential of renewable energy sources (PV and wind)

As part of the fact sheets of this study the potential of renewable energy sources near the retrofitted power plant is presented. Renewable energy is the primary energy source for the thermal storage power plant concepts. In this study, two renewable energy sources are inspected: photovoltaic and wind energy. The potential of each energy source near the retrofitted power plant is depicted as a heat map in radius of either 10 km, 20 km, 30 km, and 50 km depending on a pre-defined site class (classification criteria according to the distance to the nearest power plant and population density). This site class reflects the accessibility of space for building-up renewable power generators next to a power plant's site. All results are processed with the DLR in-house tool REMix-EnDat which globally assesses renewable energy potentials in high spatial and as temporal resolution. However, not all existing power plants are analyzed due to data unavailability in the database.

Methods

1. Resource analysis: hourly wind speeds / solar radiation time series
2. Land cover analysis: excluded areas, suitability factors for usable areas → wind speeds / solar radiation on usable areas
3. Generator modelling: installation density, power curves for different power generation technologies

Results

1. Raster data: installable capacity, annual power generation potential, costs
2. For user defined regions and resource classes:
   - Time series of potential power generation
   - Capacity factor, Levelized Costs Of Electricity

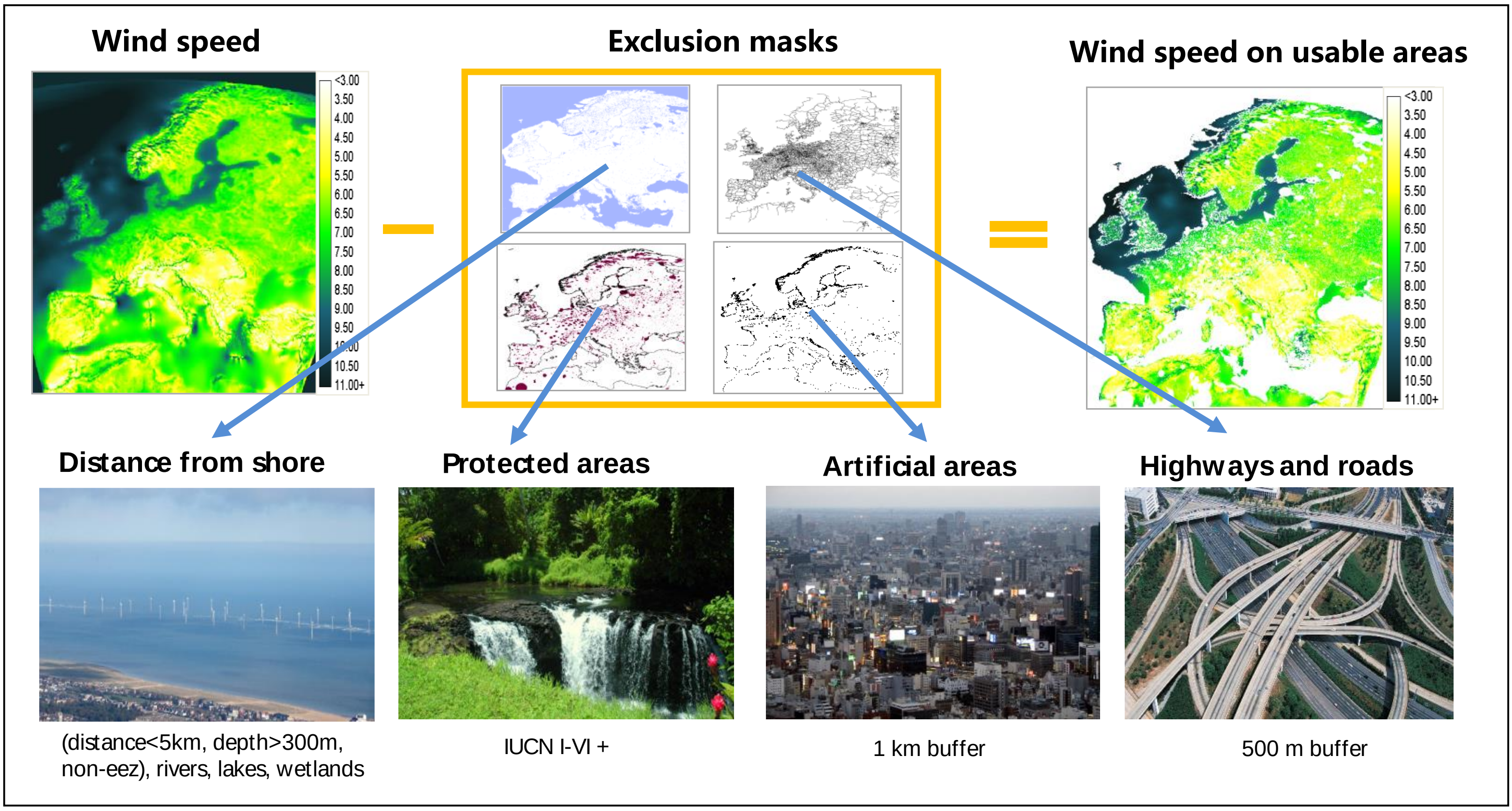

Figure 7. Potential assessment with EnDAT on the illustrative case of wind energy in Europe

Validity remarks

The analysis is based on raster maps with a resolution up to 1 km. The available area is filtered by exclusion masks, i.e. a minimal distance to settlement or shore. Additional filters are the elevation, protected areas, lands covered by salt or sand or ice, the slope and wetlands. For the remaining area a suitability factor based on the land cover type is defined which includes bare, crops, grass, forest, moss, shrub, and urban areas. The suitability factor depends on literature-based assumptions [6] taking possible conflicts of interest with harvests and other land-use into account. Therefore, potentials are to be understood as best estimates useful for globally providing orientation. However, they are not intended to exactly project the future power supply from building up specific renewable power generators in individual infrastructure projects since local regulations or land-ownership issues cannot be addressed.

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[6] https://elib.dlr.de/143360/

Techno-economic analysis

The implemented methodology is depicted in Figure 8. Based on the yield assessment of the power-plant performed using *Ebsilon* and *greenius*, the capital investment spending and operational costs can be estimated according to the plant/unit sizes as well as material and energy balance coming from the power plant simulation. The main result is in the end the LCOE of the plant. CO_2-abatement costs are also calculated considering the reference power plant, which influences the LCOE values.

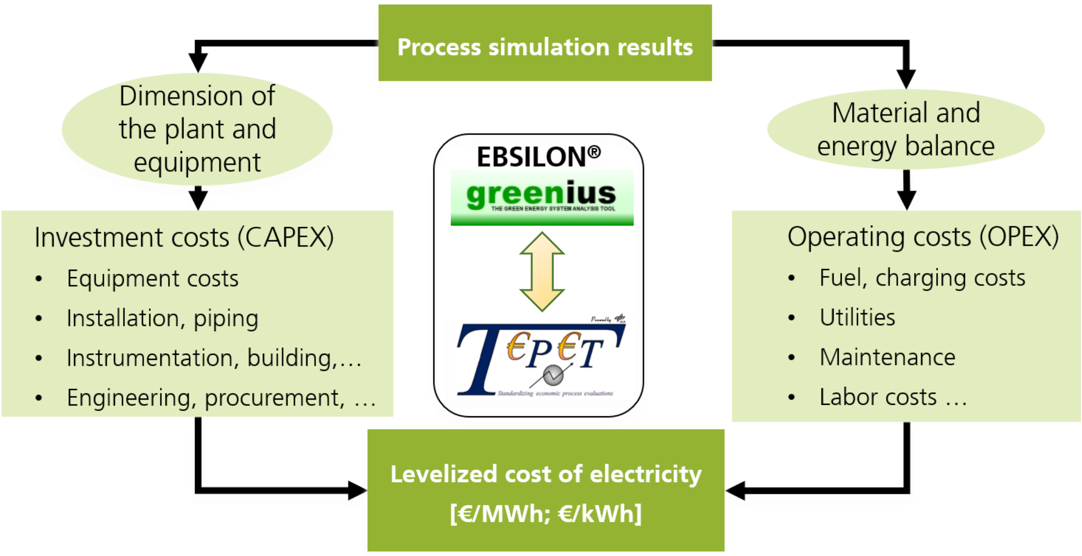

Figure 8. Methodology for economic analysis using DLR in-house Techno-Economic Process Evaluation Tool (TEPET) [3]

The methodology used for techno-economic analysis is a cash flow analysis [7]. Capital investment spending is approximated by summing all purchased equipment costs according to the cost function of each equipment. Supplementary factors are needed to approximate the spending for installation costs, piping system, electrical system, etc. This capital investment spending is then annualized to get the annuity for the cash flow analysis. Along with direct operational costs (raw materials and utilities) and indirect operational costs (labor costs, taxes, insurance, etc.), the annual electricity generation costs can be estimated. With this basis, the levelized costs of electricity (LCOE) can be estimated for the evaluated power plant.

For the basic level of evaluation (level 0), the assumed parameters for techno-economic analysis are following:

- Base year : 2022
- Operating time (y) : 20 years
- Full-load hours : 4,745 h/a
- Interest rate (IR) : 7 % [3,7]
- Working capital (WC) : 10 % of fixed capital investment (FCI) [3,7]
- Labor costs : 45.1 €/h [3]
- Labor-hours : 22,567 h/a [3,7]
- Other cost factors for are listed in Table 4 and Table 5.

The LCOE is calculated using Eq. (1), where it depends on the annuity, direct OPEX, indirect OPEX, operating labor (OL), and the electrical load provided by the power plant (P_{el}). Annuity is the annualized FCI of the equipment that depends on the plant operating time (y), interest rate (IR), and working capital (WC) as shown in Eq. (2). FCI itself (see Eq. 3) is calculated based on the multiplication of the equipment costs (EC) and the CAPEX cost factors as listed in Table 4. FCI is written as CAPEX investment in the fact sheets. Direct OPEX consists of raw material, i.e. the electricity for charging.

$$LCOE\left[\frac{€}{MWh_{el}}\right] = \frac{Annuity + \sum OPEX_{direct} + \sum OPEX_{indirect} + OL}{P_{el}} \qquad (1)$$

$$Annuity\left[\frac{€}{a}\right] = \sum FCI \times \left(\left(\frac{IR\,(1+IR)^{y}}{(1+IR)^{y}-1}\right) + \left(\frac{WC}{1-WC}\right) \times IR\right) \qquad (2)$$

$$FCI_i[€] = CAPEX = EC_i \times \sum CAPEX\ cost\ factors \qquad (3)$$

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[3] Albrecht et al. (2017), A standardized methodology for the techno-economic evaluation of alternative fuels.
[7] Peters, Timmerhaus and West (2002) Plant Design and Economics for Chemical Engineers

Techno-economic analysis

The calculation of equipment costs EC is based on reference and linear cost functions, derived from the methodology described below. Almost all equipment/components use the reference function ($EC_{i,ref}$, Eq. 4). Only molten salt storage system, coolant storage, HX molten salt, and HX condenser use the linear function ($EC_{i,linear}$, Eq. 5). These functions depend on the sizing of the equipment ($sizingi_i$) that can be the storage capacity [GWh_{th}], electrical power [MW_{el}], heat transfer area [m²], etc.

$$EC_{i,ref}\,[\text{M€}] = EC_{ref}\cdot a\cdot\left(\frac{sizing_i}{sizing_{i,ref}}\right)^b\cdot n \tag{4}$$

$$EC_{i,linear}\,[\text{M€}] = [a\cdot sizing_i + b]\cdot n \tag{5}$$

The reference function (Eq. 4) requires the sizing of a reference equipment ($sizing_{i,ref}$) and its EC (EC_{ref}) taken from the literature, while the linear function (Eq. 5) requires only the sizing of the equipment itself ($sizing_i$) without any data of reference equipment. The constants (a, b) are somewhat generalized constants that represent exponents and factors in both cost functions. Meanwhile, “n” is a factor representing the number of equipment needed, if only the maximum sizing of the equipment is reported in the literature.

As an example, the molten salt storage system has a reported maximum storage capacity of 2.72 GWh_{th} [7, 8]. If the molten salt storage system has a storage capacity of, for instance, 4 GWh_{th}, one must design it as 2 molten salt storage systems (n = 2), where each has 2 GWh_{th} capacity ($sizing_i$). Another example is the heat engine that is designed based on the state-of-the-art gas turbines, which have maximum power rating of 600 MW_{el} [5]. Should the thermal storage power plant require a heat engine with power rating of 700 MW_{el}, one must design it as 2 heat engines (n = 2), where each has 350 MW_{el} power rating ($sizing_i$). Likewise, all other equipment are designed and based on which their respective EC are estimated.

Table 3 summarizes all the required information and input data to calculate EC. All input data come from literature sources that were implemented firstly in the two reference coal-fired power plants in this study, i.e. Angamos, Chile (300 MW_{el}-class) and Jaenschwalde, Germany (500 MW_{el}-class). Based on the results from these two reference coal-fired power plants, the cost functions are either interpolated or extrapolated depending on the nominal power of each analyzed coal-fired power plant worldwide. Especially, the heat exchangers are designed based on the heat transfer coefficients (KAN values) of the heat exchangers in Angamos and Jänschwalde power plants.

Table 3. Implemented cost functions in this study adjusted to the base year 2022.[5] [7-9]

Equipment/component	Abbreviation	ERH	HP-Rankine	HP-Brayton	Eq.	a	b	EC_{ref} [M€]	$sizing_{i,ref}$	Max. $sizing_i$	Unit	Ref.
Molten salt storage system	MS	✓	✓	✓	(5)	11.305	2.123	-	-	2.72	[GWh_{th}]	[7, 8]
Electrical heater	EH	✓	—	—	(4)	1	1	80.64	1	-	[GW_{el}]	[9]
Heat pump ≥ 400 Mw_{el}	HP_Compressor + HP_Turbine + HP_Motor	—	✓	✓	(4)	1	0.604	3.25	1	800	[MW_{el}]	[5]
Heat pump < 400 MW_{el}	HP_Compressor + HP_Turbine + HP_Motor	—	✓	✓	(4)	1	0.604	1.70	1	400	[MW_{el}]	[5]
Heat engine	HE	—	—	✓	(4)	1	0.604	2.24	1	600	[MW_{el}]	[5]
Steam generator	SG	✓	✓	—	(4)	($sizing_i$)	-0.528	65.04	0.607	-	[GWh_{th}]	[7, 8]
Coolant storage	CS	—	✓	✓	(5)	0.016	0.169	-	-	13.29	[GWh_{th}]	[7]
Recuperator	HP_Recu HE_Recu	—	✓	✓	(4)	1	0.362	0.46	1	30	[1000 m²]	[7]
HX molten salt	HP_HX_Air_MS HE_HX_Air_MS	—	✓	✓	(5)	1.408	68.824	-	-	1	[1000 m²]	[7]
HX coolant	HP_HX_Air_Coolant HE_HX_Air_Coolant	—	✓	✓	(4)	1	0.362	0.46	1	30	[1000 m²]	[7]
HX condenser	HX_Coolant_Water	—	✓	—	(5)	0.394	7.542	-	-	1	[1000 m²]	[7]
HX re-cooling	HE_HX_Re-cooling	—	—	✓	(4)	1	0.362	0.46	1	30	[1000 m²]	[7]
Integration SG to PB	-	✓	✓	—	(4)	1	1	30.46	1	-	[GW_{th}]	[9]
HTF-system charging	-	✓	✓	✓	(4)	1	1	25.16	1	-	[GW_{th}]	[9]
HTF-system discharging	-	✓	✓	✓	(4)	1	1	25.16	1	-	[GW_{th}]	[9]

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[7] Peters, Timmerhaus and West (2002) Plant Design and Economics for Chemical Engineers
[8] Woods (2007) Rules of Thumb in Engineering Practices, Weinheim: WILEY-VCH Verlag GmbH & Co. KGaA.
[9] Arnold et al. (2022) “StoreToPower - Phase 1: Stromspeicherung in Hochtemperatur-Wärmespeicherkraftwerken“

Techno-economic analysis

Table 4 lists all CAPEX cost factors for the calculation of FCI or CAPEX from EC (see Eq. 3). Table 5 lists the costs factors for the estimation of indirect operating costs, where the summation of them results in the indirect OPEX which is required for the calculation of LCOE (see Eq. 1).

Table 4. CAPEX cost factors relative to the total equipment costs (EC).

CAPEX Cost Factors [10-12]		
Direct Costs	Installation Cost	26 % x EC
	Installed Instrumentation & Control	20 % x EC
	Installed Piping	7 % x EC
	Installed Electrical Systems	9 % x EC
	Buildings including Services	8 % x EC
	Yard improvements	2 % x EC
	Installed Service facilities	4 % x EC
Indirect Costs	Engineering & Supervision	6 % x EC
	Construction expenses	1 % x EC
	Legal expenses	5 % x EC
	Contractor's fee	6 % x EC
	Contigency	9 % x EC
	Sum	103 % x EC

Table 5. Cost factors for estimating the indirect operating costs (OPEX) relative to fixed capital investment costs (FCI), labor costs (LC), maintenance (M), overhead costs (OC).

Cost Factors for indirect OPEX estimation [7]		
Labor costs (LC)	Operating labor (OL)	Estimated as in [7]
	Operating supervision	15% x OL
Maintenance (M)	Maintenance labor	1% x FCI
	Maintenance materials	1% x FCI
	Operating supplies	15% x M
Indirect costs	Insurance and taxes	2% x FCI
	Interest rate (Financing)	7% x FCI
General expenses	Administrative costs	25% x OC
	Plant overhead costs (OC)	60% x LC
	Sum	$\text{OPEX}_{\text{indirect}}$

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[10] Pauschert (2009) ESMAP Technical Report 122/09
[11] U.S. Energy Information Administration (2020)
[12] U.S. National Energy Technology Laboratory (2015)

Techno-economic analysis

The dataset of the worldwide renewable electricity costs for charging the thermal storage power plant is required for the techno-economic analysis. In this case, the average levelized costs of electricity (LCOE) of photovoltaics (PV) and wind turbine are taken from the IRENA study [13] as listed in Table 6. The global average LCOE of either PV or Wind will be implemented, if a country does not have any LCOE data. As an example, Argentina has an average LCOE of Wind in the amount of 50.34 €/MWh$_{el}$, but no data of PV is reported by IRENA [13]. Hence, the LCOE of PV in Argentina is assumed to be the global average LCOE of PV in the amount of 46.50 €/MWh$_{el}$. Similarly, it applies to Portugal which has an average LCOE of PV of 57.34 €/MWh$_{el}$, but does not have any data of LCOE of Wind. In this case, the global average LCOE of Wind of 31.93 €/MWh$_{el}$ is assumed for Portugal. This approach applies to all countries in Table 6, as well as the other countries that are not listed.

Table 6. Average levelized costs of electricity (LCOE) of photovoltaics (PV) and wind turbine in 2022. [13]

Country	LCOE [€/MWh$_{el}$]	
	PV	Wind
Argentina	46.50*	50.34
Australia	39.25	31.77
Brazil	50.85	22.90
Canada	65.02	31.36
Chile	40.83	52.05
China	36.00	26.26
Denmark	88.12	40.69
Egypt	46.50*	43.09
Ethiopia	46.50*	47.68
Finland	46.50*	40.41
France	59.94	48.63
Germany	77.17	53.09
Global*	46.50*	31.93*
Greece	69.27	47.59
India	36.31	36.30
Ireland	46.50*	40.31
Italy	59.40	40.43
Japan	92.82	145.49

Country	LCOE [€/MWh$_{el}$]	
	PV	Wind
Mexico	64.2	44.68
Morocco	46.50*	50.24
Netherlands	86.54	44.27
Pakistan	46.50*	50.17
Poland	105.07	48.95
Portugal	57.34	31.93*
Russia	46.50*	39.65
Saudi Arabia	35.14	31.93*
South Africa	60.92	38.26
South Korea	71.5	79.08
Spain	44.53	31.76
Sweden	46.50*	35.90
Turkey	68.65	53.31
UAE	25.42	31.93*
United Kingdom	73.33	33.79
United States	56.00	27.61
Vietnam	46.50*	46.90

CO_2 avoidance cost is calculated using the formula from IRENA [13] (see Eq. 6). In this study, the LCOE of the coal power plants (LCOE$_{CPP}$) are considered with financing, where the CAPEX of the whole plant is considered to cost 1142 €/kW$_{el}$ which is still depreciating for the next 20 years with 7 % interest rate. The direct OPEX only comes from the coal consumption of the plant, where lignite and hard coal are assumed to cost 5.80 €/MWh$_{th}$ and 6.63 €/MWh$_{th}$, respectively, and the estimated net efficiency. The indirect OPEX is assumed to be 6 %/a of the plant's CAPEX.

$$CO_2\ avoidance\ cost\left[\frac{€}{t_{CO_2}}\right]=\frac{LCOE_{Retrofit}-LCOE_{CPP}}{GWP_{CPP}-GWP_{Retrofit}} \qquad (6)$$

The country-specific global warming potential (GWP) for photovoltaics (PV) and wind turbines are taken from ecoinvent 3.10 database [14]. If the data for the country is not available, the GWP value of the rest of the world (RoW) is taken for the calculation. As an example, Chile does not have GWP data for PV, hence the GWP data for PV in RoW (82.5 kg$_{CO_2}$/MWh$_{el}$) is assumed. The GWP for wind turbines in Chile amounts to 15.5 kg$_{CO_2}$/MWh$_{el}$, slightly lower than the RoW (15.6 kg$_{CO_2}$/MWh$_{el}$). In comparison, Germany has higher GWP values of 103.1 kg$_{CO_2}$/MWh$_{el}$ and 20.7 kg$_{CO_2}$/MWh$_{el}$ for PV and wind turbines, respectively. Due to the contractual agreement of the license, only 5 GWP data from the database can be reported here.

The GWP data for coal power plants in the ecoinvent 3.10 database [14] already includes the country-specific average net plant efficiency that does not align our methodology. Because a country, like China, India, or USA, could have thousands of coal power plants and the arithmetic average of the net plant efficiency would lead into huge uncertainty in the results. Hence, the specific GWP of coal are taken from another literature [9] to calculate the GWP of coal power plant (GWP$_{CPP}$) as follows:

- Brown coal/lignite : 410 kg$_{CO_2}$/MWh$_{th}$
- Hard coal : 390 kg$_{CO_2}$/MWh$_{th}$

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[9] Arnold et al. (2022) "StoreToPower - Phase 1: Stromspeicherung in Hochtemperatur-Wärmespeicherkraftwerken"
[13] IRENA (2023) Renewable power generation costs in 2022.
[14] Wernet et al. (2016) The ecoinvent database version 3 (Part I): Overview and methodology.

Glossary

Below are all the data entries included in the fact sheets together with their explanations:

- Unit name: Name of the power plant as listed in the Global Plant Tracker.
- Fuel type: The fuel type of the plants in the Global Plant Tracker is divided into lignite and hard coal to facilitate the calculation of specific CO_2 emissions. The Global Plant Tracker units have been classified according to their coal type as follows. Lignite plants are considered those whose coal type in the Global Plant Tracker is: lignite, subbituminous, waste coal, or unknown. Hard coal plants are considered those whose coal type in the Global Plant Tracker is: anthracite or bituminous.
- Year of build: Year of construction as listed in the Global Plant Tracker.
- Location: Location of the coal power plant as listed in the Global Plant Tracker.
- Coordinates: Coordinates of the power plant as listed in the Global Plant Tracker.
- Unit/phase ID: Identification used for the plant in the Global Plant Tracker.
- Gross nominal power: Gross nominal power of the coal power plant.
- Net nominal power: Net nominal power of the coal power plant.
- Gross efficiency: Gross efficiency of the coal power plant.
- Net efficiency: Net efficiency of the coal power plant.
- Aux. demand: Auxiliary demand of the coal power plant.
- Radius of RE coverage around the power plant: Radius around the power plant from which renewable electricity could be sourced for charging the thermal storage power plants.
- PV installable: Installable PV capacity around the power plant.
- Wind onshore installable: Installable onshore wind capacity around the power plant.
- Total RE: Total installable renewable capacity around the power plant.
- RE cost (IRENA for 2022): Cost of PV and wind electricity at the site.
- Storage medium: Storage medium of the thermal storage power plant; in all cases molten salts.
- Operation-mode: The operation mode is “storage only”; no hybridization with boiler operation.
- Operating strategy: Operating strategy of the energy concepts as described on page 5 of the executive summary.
- Primary energy source: Renewable energy sources used to supply the electricity charged into the thermal storage power plant concepts.
- Storage capacity: Thermal storage capacity of each thermal storage power plant concept.
- Charging capacity: Thermal input of the thermal storage power plant concepts resulting from charging via electric heater or heat pump.
- Discharging capacity: Thermal input to the power cycle resulting from discharging the thermal storage.
- Load provided: Annual load that must be provided and is delivered by the energy systems.
- Electricity production – gross: Annual gross electricity production of the plants.
- Electricity demand charging: Annual electricity required for charging by the thermal storage power plants.
- Aux. demand: Annual auxiliary energy demand of the plants.
- P2H net efficiency: Efficiency of the process from electrical charging to thermal storage.
- Round-trip efficiency: Round-trip efficiency of each concept, from power to heat to power.
- Operating hours: Annual hours in which electricity is generated in the system.
- Charging hours: Annual hours in which electrical charging occurs.
- Full load hours: Equivalent annual full-load operating hours at nominal power.
- CAPEX investment: Total CAPEX of each concept.
- CAPEX annuity: Annualized capital expenditure, calculated by spreading the total investment cost over the economic lifetime of the plant using an annuity factor.
- OPEX direct: Annual direct OPEX due to the purchase of electricity required for charging and for auxiliary demand.
- OPEX indirect: Annual indirect OPEX due to the factors listed in Table 5.
- LCOE: Levelized cost of electricity of each concept. First the LCOE using PV electricity is shown, followed by the LCOE using wind electricity.
- Sp. CO_2 emissions: Specific CO_2 emissions for each concept, assessed for PV and wind.
- Saved CO_2 emissions: CO_2 emissions avoided with the thermal storage power plant, assessed for PV and wind.
- CO_2 abatement costs: Cost associated with CO_2 savings compared to the coal power plant, assessed for PV and wind.