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Germany's electricity supply of the future

Second life for coal power plants

How old coal-fired power stations are used for an energy system based on renewable energies

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Zusammenarbeit (GIZ) GmbH

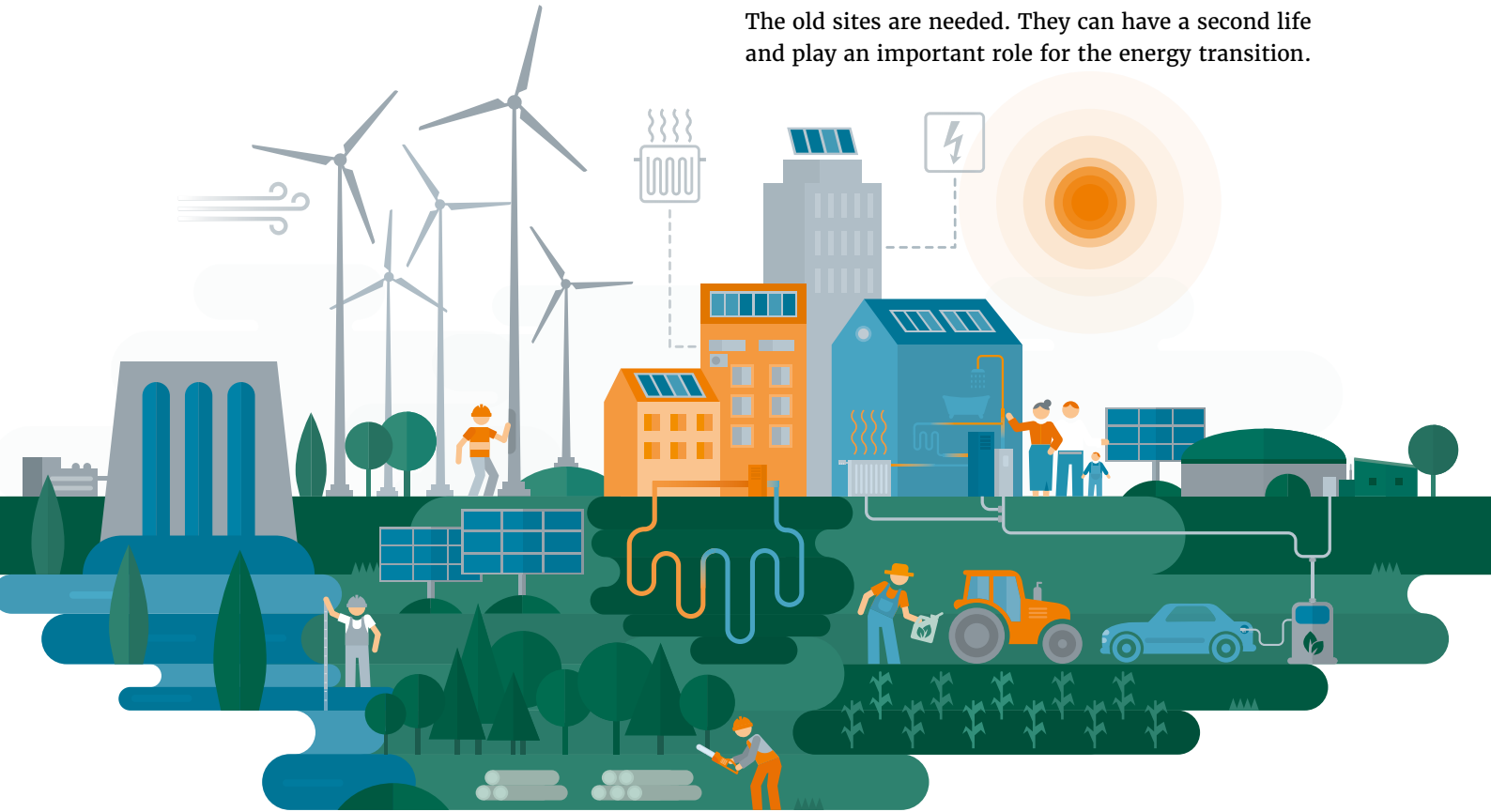
From coal to the climate neutrality

For more than a century, coal-fired power plants and blast furnaces played an important role for Germany's electricty and industry sector. From what was originally thousands of small-scale plants, about 100 larger power plants are still contributing a significant share to the electricity supply.

What happens at these sites when the plants stop operating? Law stipulates their shutdown by 2030 ideally and by 2038 the latest. But many sites remain. And they can contribute valuable infrastructure for the climate neutral energy supply of the future.

This brochure is intended to show how the sites of old lignite and coal-fired power plants will be used in an electricity grid run on 100 per cent renewable energies. Coal is often replaced by more climate-friendly gas; in the future it will be replaced by hydrogen. At some old sites large quantities of electricity can be fed in from renewables to produce green hydrogen or to power data centres. In Chile for instance, coal-fired power plants are being converted into solar thermal power plants using molten salt as a storage medium.

The old sites are needed. They can have a second life and play an important role for the energy transition.

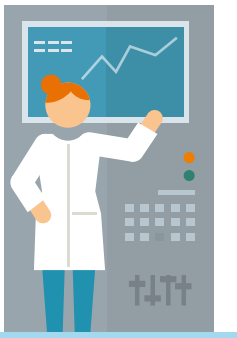


How to use old coal-fired power plants

Checkbox: Possibilities for re-using former coal-fired power plant sites

From fossil power plant to green energy plant

- Conversion to a gas-fired power plant with later conversion to green hydrogen
- Power transmission via the existing grid connection
- Use of costly desalination plants for chemical processes
- Conversion to biomass power plants, for example with short-rotation crops in tropical regions
- Further development of waste-to-energy sites
- Continued operation of the old heat exchangers in existing heating networks
- Use as a strategic reserve power plant



Energy storage

- Heat storage for medium periods of time, e.g. in molten salts (Carnot batteries), stone or steel storage tanks.
- Use grid connection for compressed-air energy storage
- Connection of battery storage systems to the high-voltage grid
- Conversion of green electricity into gas (P2G) and storage in accessible gas pipelines

Data centres

- Connection of server farms to the high-voltage grid
- Data centres supply heat for existing heating networks

Other options

- Landing of DC transmission lines in existing substation (converter stations)
- CO2 capture and storage (direct air capture) at the site

New life for old sites

The old sites of coal-fired power plants in Germany are in demand: for the production of green hydrogen, as gas-fired power plants, as storage facilities or as grid-serving plants such as syncronous condensers. Large parts of their infrastructure can be re-used. Even power sites that were abandoned a decade ago are being rediscovered.

Just a few years ago in 2015, politicians in Hamburg were proud of the new power plant: Marked by a big celebration, Swedish company Vattenfall commissioned its newest coal-fired power plant in Germany's second largest city. "Moorburg" was supposed to supply 800 megawatts (MW) of electricity and heat for district heating. Today, this has long been history.

Green hydrogen instead of coal is the new reality for Hamburg. The investment in coal never paid off. Low electricity prices were one of the reasons why Vattenfall decided to decommission the coal-fired power plant only five years after it began to operate, taking advantage of government tenders for decommissioning coal-fired power plants.

380 kV line supplies electricity for electrolysis

It is now rapidly becoming apparent that the old locations of coal-fired power plants are in demand. A "Green Hydrogen Hub" is to be created in Hamburg, combining green energy with electromobility, power plant processes and heat for industry and citizens. Vattenfall is planning to install an electrolyser with a capacity of 100 megawatts (MW) at the old site of the coal-fired power plant. "Moorburg is the ideal location," says Oliver Weinmann, Managing Director of Vattenfall Europe Innovation, "because electricity from the North Sea can be transported to Hamburg via the 380 kV line." The electricity could come from offshore wind farms that Vattenfall operates in the North Sea. Meanwhile, the quays where coal used to be unloaded will offer enough space for an import terminal for green gas.

Moorburg is not the only coal-fired power plant in the city of 1.8 million. Two smaller coal-fired power plants, many decades old, are still in operation. The "Wedel" plant has a thermal capacity of 400 MW and is to be shut down by 2025. A power-to-heat plant with 80 megawatts (MW) is now planned as a replacement to deliver district heating. Electricity from Hamburg's hinterland will be transported via the existing high voltage line, making use of several thousand wind turbines that have to be shut down when their electricity is not in demand regionally. In the future, the power-to-heat plant will use this electricity.

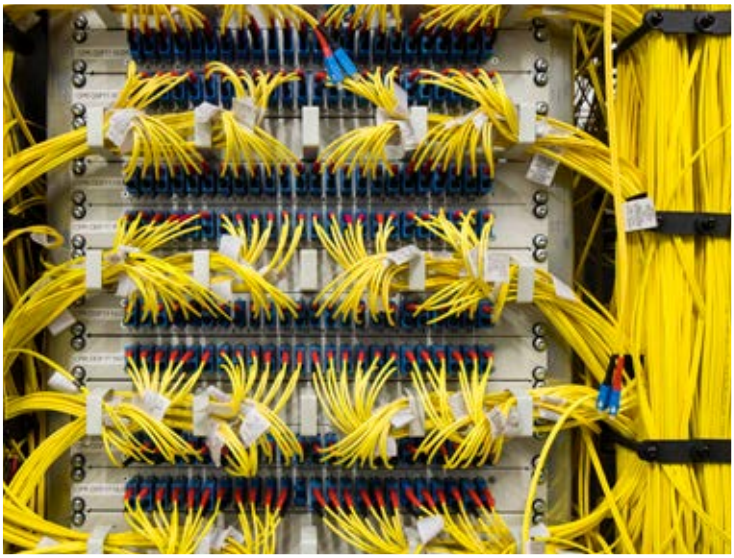
The rest of the heat from the old power plant is to be provided by a mix of different low-CO_2 sources: Waste heat from the heavy industry located in the port (copper, steel, aluminium), heat from waste incineration, deep geothermal energy and large heat pumps that use wastewater heat. In addition, Hamburg plans to build a natural gas-fired combined cycle power plant that will later be converted to green hydrogen.

Long forgotten sites rediscovered

In the course of the energy transition in Germany, former coal sites are being rediscovered. In the village of Thierbach, south of the eastern German metropolis of Leipzig, a lignite-fired power plant was shut down in 1999 and gradually dismantled since 2002. The high-voltage power lines in the area are almost the only reminder of the old days.

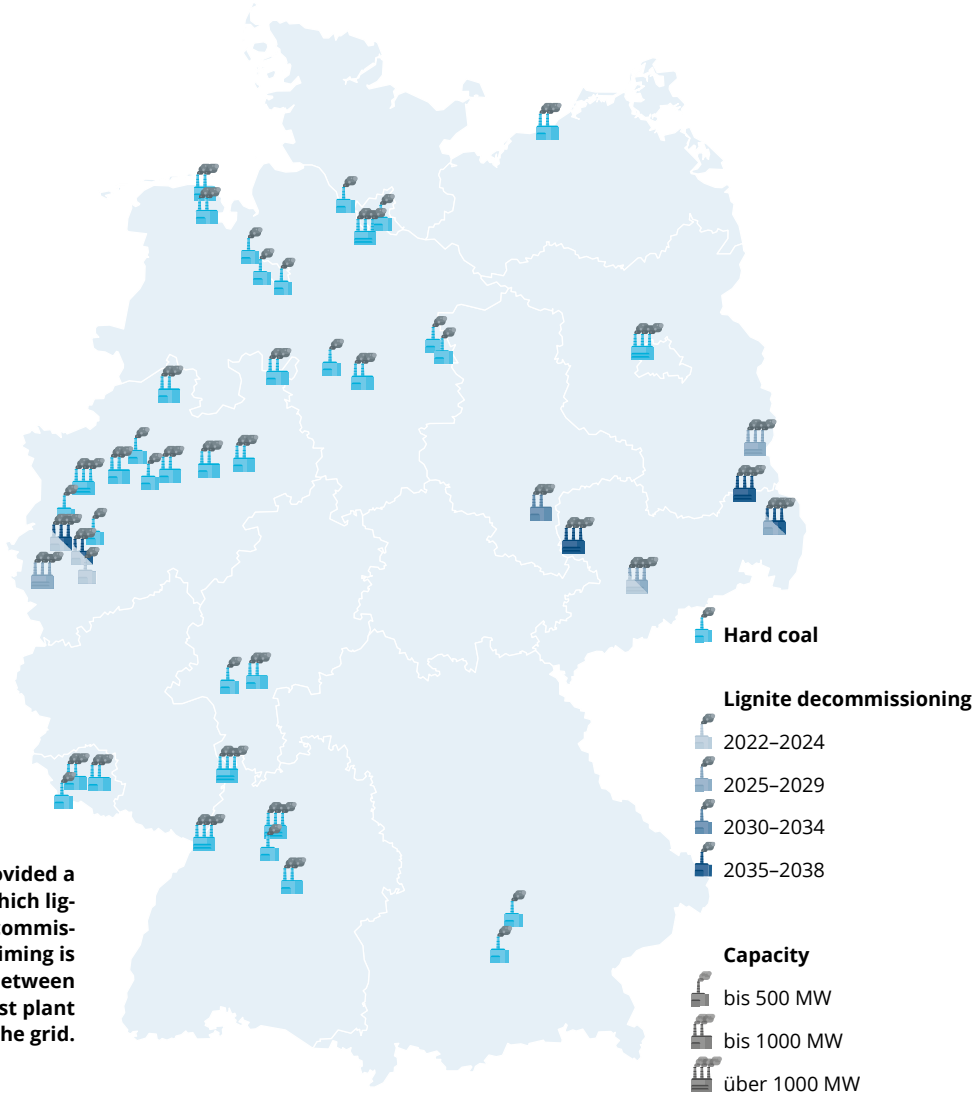
Now, 20 years later, the remaining infrastructure is exactly what makes the site interesting for new investors. "A site ready for construction and a connection on the electricity side with a transformer station - that's perfect for building a new and climate-neutral energy plant," explains Hanno Balzer, project developer at HH2E. The start-up specialises in using the legacies of the coal age in Germany.

In Thierbach, the company is planning an energy plant that will buy the abundant wind power via the electricity exchange during low-price phases. This electricity will then be converted into process steam via a



Reuseing the old coal-fired power plants: Lignite and hard coal can be replaced by fuels such as biomass, gas and green hydrogen. Data centres will be set up at some sites. And the former coal sites (and part of the power plant site) can be used for solar or wind energy.

A long farewell to lignite and hard coal



The Federal Government has provided a detailed timetable indicating which lignite-fired power plant will be decommissioned when. For hard coal, the timing is determined by tenders. Between 2030 and 2038, the last plant will be taken off the grid.

high-temperature storage tank and converted back into electricity when needed. The plant also includes an electrolyser for green hydrogen.

Balzer is sure that the new plant will be economically viable. Yet Thierbach is not an ideal location at all. "At other former coal-fired power plants, we can also use the old water desalination from the steam processes in addition to the substation," Balzer explains. In Thierbach the old desalination does not exist anymore. And unlike in Thierbach, many coal-fired power plants are located near cities or industries, so there often is also a great demand for hot steam. On such sites HH2E is currently developing four more energy plants in Germany and Poland.

First natural gas, then green hydrogen

Other coal-fired power plant sites are also planning their conversion. Take Herne in the Ruhr region, Germany's old coal and steel district, where the energy company Steag operates several coal-fired units. Despite the ongoing discussion on Germany's energy security after the war in Ukraine, "the power plant will be converted into a natural gas-fired boiler, which will secure the district heating supply for the soon to be completed highly efficient gas and steam power plant at the site," says Managing Director Ralf Schiele.

A prerequisite for conversion to natural gas is proximity to the pipeline network in order to reduce connection costs. The same applies to hydrogen, whose transport is a challenge due to its volatility outside pipelines.

Steag has other plans for two more coal-fired power plants with a combined capacity of 390 MW. The existing infrastructure will enable hydrogen to be produced at these sites via electrolysis, serving the German steel and French chemical industries.

Steag is also looking into the construction of large-scale battery storage facilities that can offer primary control power for the electricity

Rotating mass: Old solutions for new tasks

Grid development: Syncronous condensers with flywheels will be set up to help stabilise the grid which is increasingly dominated by fluctuating renewable energies. They had been largely replaced by power electronics and are now making a comeback.

grid. Good revenues can be achieved for such system services. The company is also pursuing such hydrogen and storage options at a decommissioned power plant unit (370 MW) in the city of Duisburg. A 15 MW battery storage system is already operating there, offering primary control power. The Essen-based company is considering expanding this to 150 MW in the near future.

Control power, storage and phase shifter

Storage facilities will become increasingly important in the electricity system to compensate for the volatile supply of renewable energies - i.e. to absorb electricity when production is high and to release it into the grid when it is low. In addition to new batteries, second-life batteries are also suitable for this purpose.

System services to stabilise the electricity grid: this is what electricity producer RWE is looking into for the decommissioned Westfalen coal-fired power plant (764 MW). The company is considering the construction of a syncronous condenser (or phase shifter) with flywheels for the grid operator Amprion. These transformers can actively control the flow of electricity in the grids and also provide reactive power. Both are important when large power plants are taken off the grid and many renewable power plants are connected. The prerequisite for the condenser is a connection to the 380 kV grid, which is given at the site. The conversion will find imitators in other grid areas.

Data centres and heat demand

Uniper is pursuing a different idea for the Staudinger coal-fired power plant (500 MW) near Frankfurt, which is scheduled for closure in 2023. In the future, the site could be reclassified as an industrial estate to locate data centres there. Data centres consume a lot of energy, which is why a connection to the transmission grid is advantageous. In addition, the waste heat from the data centres could serve as a substitute for the district heating that the power plant currently supplies.

The regional demand for heat is a key location factor: “For the future of former coal sites, a crucial question is whether the power plants were previously involved in combined heat and power generation,” says Christoph Pfister from energy consultants enervis. “Where this is the case, a commercial follow-up is likely.”

A special case are coal-fired power plants in industry, which will also have to be shut down in the next few years. These are important for process heat and process steam. In most cases known so far, the industrial companies are aiming for a conversion to natural gas and/or biomass.

“Win-win outcomes for the power system and the communities”

Juan Carlos Olmedo, President of the Board of Directors at “Coordinador Electrico Nacional”, Chile’s Independent Electric System Operator, speaks about the conversion of Chile’s coal-fired power plants on the way towards climate neutrality.

Mr. Olmedo, as the power grid coordinator, what is your opinion and recommendation for the conversion of thermal power plants in Chile?

Converting thermal power plants to zero emission energy sources may be a way to speed up decarbonisation at low cost.

Do you believe that there can be a win-win situation if coal-fired power plants are put to secondary use?

Yes, there are many win-win outcomes for the power system and the communities. And for Chile’s commitments to reach carbon neutrality by 2050.

Today 23 coal-fired power plants are still in operation in Chile. What role do these plants play in the country’s grid and electricity supply?

Thermal power plants provide a wide range of services to the electricity system, such as dispatchable and resilient generation, ancillary services, and power grid strength. Coal-based thermal generation has been a source of low cost and reliable energy for many years. However, the challenge of climate change mitigation requires a change of the primary energy source, implying that coal generation needs to be replaced.

Many of these power plants are less than 15 years old, meaning they are relatively new. Are they in danger of becoming stranded assets under the paradigm of decarbonisation and climate neutrality?

Decarbonisation of power generation facilities is a global challenge. Asset recycling is an alternative for extending the life of coal power plants and an opportunity to support carbon neutrality goals.

What concepts exist to use these plants beyond their original purpose?

Asset recycling is the main concept. The objective is to create a new use for these power plants, considering conversion alternatives such as synchronous condensers, conversion to a lower emission fuel, use of Carnot thermal batteries to replace boilers, and in the future the use of green hydrogen.

Why is it not possible to simply replace thermal power plants with renewable energies in a power grid system like Chile‘s?

It is necessary to understand that not all renewable generation technologies have the same performance and capacity. Today, most new power plants are solar photovoltaic and wind, known as variable energy resources. However, to effectively replace thermal power we need a technology mix that will be able to provide dispatchable energy, requiring storage capacity, network strength and system inertia.

What role is played by the fact that Chile operates an island grid that is not interconnected with neighbouring countries?

Operating as an island grid is a big challenge as the the power system has to be self-sufficient to supply reliable, secure and cost-effective electricity.

Chile has big mining operations with a high demand for energy. Has their stance towards coal-fired power plants changed? Are there examples of companies wanting to switch from coal power to renewables?

Mining companies have been very active in transforming their energy matrix to achieve their goal of

About

Juan Carlos Olmedo is President of the Board of Directors at Coordinador Electrico Nacional, the Chilean's Independent Electric System Operator. He has over 30 years of experience in the Chilean and Latin-American energy and infrastructure market with focus on power markets regulation and operation, generation and transmission project development, renewable energy and systems flexibility.

a green copper production. Among their actions, they are actively replacing fossil fuel based power purchase agreements (PPA) with agreements based on renewables.

Some towns in Chile depend on coal-fired power plants for their local economy. Could the repurposing of the power plants offer new prospects for local communities?

Certainly, repurposing the power plants will create value for communities and it is an opportunity for companies to achieve environmental, social, and governance (ESG) strategies and goals.

What ideas do operators of coal-fired power plants have, such as AES or ENGIE, when it comes dot repurposing coal fired powerplants in Chile?

The companies have been part of a study supported by GIZ to recycle coal-based assets using Carnot's thermal batteries to convert them into renewable sources.

Looking towards the future: What will the power grid in Chile look like in 2030?

Chile should have made the transition to a wholesale market based on binding bids, where new power capacity is 100% renewable, and most of the coal-based plants are decommissioned or converted into zero emission sources. The new high voltage DC-transmission system (HVDC) is allowing renewable power to be transferred from north to south, and the grid will be operated using a digital twin to improve system security. Finally, there will be new services and millions of new agents participating in more competitive power market.

Chile: Coal-fired power plants become renewable energy storage facilities

On behalf of the German ministries, GIZ has been supporting Chile in implementing a sustainable energy transition since 2014. In addition to the expansion of renewables, the 28 coal-fired power plants, which still generate around 40 percent of Chile's electricity, play a decisive role in this. By Rainer Schröer, GIZ Chile.

In 2018/19, a coal commission, in which GIZ was officially represented, met at the same time as a coal commission met in Germany. In Chile, the government and the power plant operators agreed to phase out coal-fired power generation by 2040 at the latest. No compensation or indemnities will be paid to the power plant operators.

More than 60 per cent of the coal-fired power plants are less than 15 years old. The coal commission therefore also considered the sustainable re-use of the decommissioned plants. An analysis by GIZ showed that the conversion of coal-fired power plants into thermal energy storage units is the most sensible alternative for Chile. They will be charged with variable renewable energies and thus ensure a continuous energy supply.

AES develops first project

Together with the German Aerospace Center (DLR), the Chilean Ministry of Energy, the national power grid coordinator and the power plant operators AES (USA) and ENGIE (France), feasibility studies and system simulations for conversion were carried out on several coal-fired power plants - with positive results.

The idea is attracting interest worldwide

A first project is currently being developed by the company AES. The coal-fired power plants are located at neuralgic points of the Chilean electricity grid and the conversion of the coal-fired power plants has several system-relevant advantages for electricity grid stability. The profitability of investments in renewable energy plants will be increased and investments in transmission lines will be avoided. In addition, jobs can be preserved at the power plant sites and high costs and negative environmental impacts of decommisionig can be avoided.

The idea is already attracting a great deal of interest in other countries. It can be assumed that after the successful implementation of the first project in Chile, further coal-fired power plants will be converted and thus make a significant contribution to climate protection.

Cerro Dominador Solar Power Plant: The first thermosolar plant in Latin America synchronizes the CSP plant with the chilean electrical system

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