0 Project title

Reference power plant –Lausitz

From a lignite-fired power plant site to an energy and industrial park for new technologies

Storage power plant with sector coupling

1 Responsible department and contact person

1.1 Responsible department

[open]

1.2 Contact person

Project coordination:

- Joint board of the industrial park Schwarze Pumpe
- CEBra - Centre of Energy Technology Brandenburg e.V.

Project participants:

- Joint board of the industrial park Schwarze Pumpe
- CEBra - Centre of Energy Technology Brandenburg e.V.
- Energiequelle GmbH
- Brandenburg University of Technology Cottbus-Senftenberg
- University of Rostock
- ONTRAS Gastransport GmbH
- Siemens AG

2 Description of the measure /contribution to structural change

2.1 Future challenges and general objective

The structural change to be expected and that has already started to take place in the coal regions, in particular in Lusatia, requires the conversion of large open-cast mining areas and power plant sites into industrial sites such as reference energy plants. The conversion of these sites into locations with CO_2-free energy technologies requires intensive, result- and implementation-oriented developments with the gradual introduction of new and supporting elements as pilot and demonstration plants.

This should be done gradually and initially in the context of the existing power plant structure or technology. This will enable a continuous restructuring without technological and social disruption through the use of existing synergies and the exploitation of new potential ones.

A key technology in the wake of the energy transition is the CO_2-free storage power plant, based on modern power electronics and hydrogen technology with a novel load angle-based power plant control function.

The transformation of value creation from the current lignite-based power plant technologies to the complete use of renewable energy sources in new concepts for energy and material flow provision (energy plants with sector coupling) is linked to this technological objective.

The loss of jobs in mining areas and coal-fired power stations will be compensated by the development and large-scale testing of new technologies and the establishment of small and medium-sized enterprises which might be active in this sector. The focus of this initiative is the transformation of the existing power plant locations: Boxberg, Jänschwalde and Schwarze Pumpe.

Even if these new individual pilot and demonstration plants will be initially tailored to a specific location, their development aims to create reference solutions for all of the locations mentioned, for other lignite regions and for the export sector.

2.2 Existing potential of Lusatia

The economic power of Lusatia has been characterized for decades by the extraction and conversion of local raw lignite into electricity. Over the decades, engineering has developed thanks to the geologists, energy and mining engineers, etc. who have gained a very high level of knowledge in the implementation of major projects in the field of plant construction, development of raw material sources and the associated areas - such as the implementation of maintenance projects, application, licensing and approval procedures.

The first essential pillar of this imminent transformation process is to understand this know-how, which has been developed in line with current energy and environmental policy objectives aiming technological leadership. Examples include the large-scale Fischer-Tropsch synthesis at the synthesis plant in Schwarzheide (1935), the BHT-coking and pressure reduction in Lauchhammer and Schwarze Pumpe (1949), the 30 MW oxyfuel plant at Schwarze Pumpe (2010), the hybrid wind-hydrogen power plant Prenzlau and the 50 bar pressure electrolyzer of the BTU Cottbus - Senftenberg (2010). More recent examples include the power plant Feldheim (10 MW) which started operations in 2017 and the future construction of a Li-ion storage with 60 ± 10 MW output by LEAG at the Schwarze Pumpe power plant site.

With the implementation and operation of such projects, valuable new experiences have been and will continue to be gathered, flowing into future project ideas.

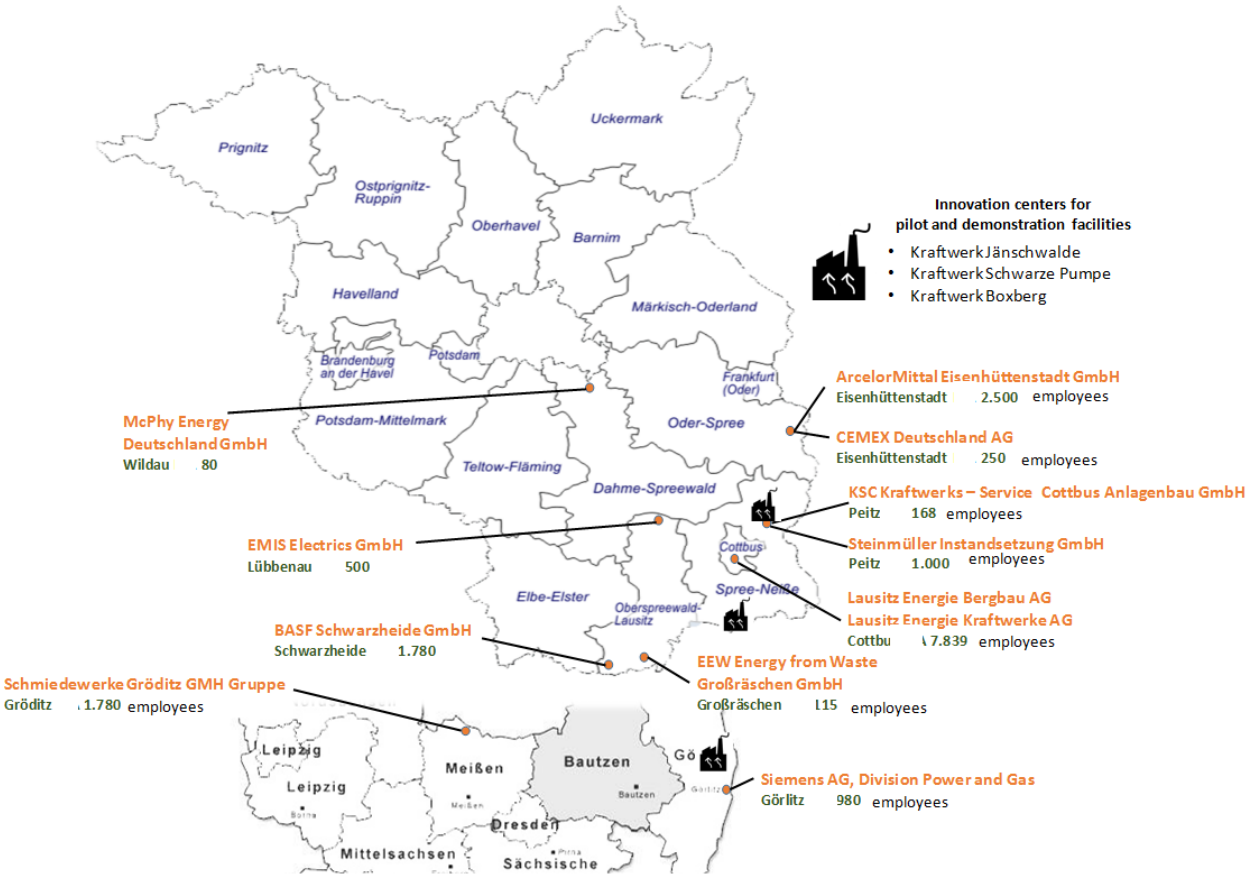

Figure 1: Company overview (energy technology and plant construction) in Lusatia

Figure 1 shows an overview of selected companies in the field of energy and plant construction that have settled in Lusatia in recent years:

- LEAG Cottbus (Power plant operation and open-cast mining)
- Siemens Görlitz (Steam turbines construction)
- Arcelor Mittal Eisenhüttenstadt (Integrated metallurgical plant)
- CEMEX Eisenhüttenstadt (Cement plant)
- McPhy Wildau (Electrolysis)
- BASF Schwarzheide (Chemical products)
- Schmiedewerk Gröditz (Electro-steel plant)
- EEW Energy from Waste Großräschen (Waste incineration)
- KSC Anlagenbau Cottbus/Peitz (Plant engineering and construction)
- Steinmüller Peitz (Plant engineering and construction)
- EMIS Electrics Lübbenau (Electrical engineering)

The second pillar is the Gigawatt-scale plant technology installed in Lusatia. Together, at the three power plant sites in Lusatia, there is a total of 7.2 GW of conventional lignite-based power plant capacity with its corresponding infrastructure connections (high-voltage networks, transport logistics, road and rail, efficient industry, water networks). Furthermore, all power plant locations, in particular Schwarze Pumpe, have high-performance connections to the high and medium pressure gas networks.

The third pillar is Brandenburg's and Lusatia's pioneering role in the expansion of renewable energies and innovative storage projects. In Brandenburg alone, 3,700 wind turbines have been built so far, with

an installed capacity of 6,800 MW. As a result, 9,500 jobs have already been created in the field of wind power. According to the Energy Strategy 2030, 2% of the country's area could be suitable for wind power in the future, which could lead to an increase in wind power to up to 10,500 MW and a significant increase in employment in the region. The installed capacity in the photovoltaic sector is currently 3,400 MW and is also expected to increase by 2030. In addition to these technologies, the generation of electricity from biomass and biogas still represents a noteworthy proportion. In Brandenburg, there are currently 20,000 employees in the entire renewable energy sector. The further expansion in the sector is expected to lead to a significant increase in employment opportunities.

The fourth pillar is the geology of Brandenburg and especially Lusatia, which has not yet been sufficiently considered, but which represents a decisive location advantage within the framework of the transformation process. Since the 1960s, drilling programs and seismic and gravimetric measurements have systematically investigated the deeper subsoil with regard to natural gas and oil deposits. The geological investigations (genesis model) are continuously refined. By 1995, more than 1.3 billion m^3 of natural gas and almost 1.0 billion tons of crude oil had been produced in Brandenburg. Based on the results of the geological investigations, the deposits could be further developed in order to serve as daily, weekly and seasonal reservoirs for renewable H_2 or methane in the future.

2.3 Objective and development of the project "Reference power plant Lausitz" - storage power plant with sector coupling

The objective of the project is **the development of the reference power plant Lausitz as a guiding concept for the transformation of the lignite-based energy industry. The phase development of the project over a staggered period will guarantee the continuous reduction of the specific CO_2 emissions of the Lusatian power plants, with constant installed capacity, security of supply, flexibility and added value, through the continuous replacement of the carbon-rich lignite by electrolysis hydrogen.**

The development of the reference power plant will focus less on fundamental research topics than on the application and qualification of innovative solutions and their integration into existing sites and technologies.

By connecting start-ups and other small and medium-sized companies with the local industry from the mining, energy and plant construction sectors, synergies can be tapped and additional added value can be generated locally.

The project development is to be divided into 4 thematic areas and includes the technical design, practical testing and upscaling of a 10 MW pilot storage power plant with sector coupling. The concept of the CO_2 - free storage power plant can be seen in Figure 3.

The first subject matter covers the technical design, construction and commissioning of the first large-scale storage power plant in Lusatia with a nominal capacity of approx. 10 MW including trial operation of all components. The reconversion parameters will be investigated by means of a power electronics-connected fuel cell and a pure H_2-fired gas turbine. In order to prepare the topics 2 and 3, it will be necessary to assess whether a renewable energy plant (preferably a wind turbine) in the vicinity of 10 km can be used or has to be built.

The second subject matter includes the operating phase for the setting and prequalification of the storage power plant Lausitz in accordance with the currently valid connection guidelines for large power plants. This subject area includes a sufficiently long phase of normal operation (at least 3 years) of the

storage power plant to pass through all operating states (normal operation, control power supply, fault mode and “dark doldrums” - times when solar and wind power is not available in sufficient amounts). These operating states should be experienced several times after the prequalification and their effects on the distribution network and the renewable energy plants in regular operation in close proximity should be examined.

Within the third subject matter the main technical innovation of the storage power plant, the load angle control-based operation, will be tested. For this purpose, the storage power plant Lausitz will be operated and tested on its own together with the renewable energy systems and sufficient power usage.

Figure 2 shows the development path of the future power plant "Reference power plant Lausitz".

		Plant engineering		Used storage	Potential
		Conventional	Renewable		
Status Quo		State-of-the-art plant technology for conventional power generation (steam cycle, boiler)	Renewable energy plants Wind, photovoltaic	Lignite in the open-cast mining operation	Natural gas deposits in the immediate vicinity (energy source and storage option)
Transformation phase		Technology refitting	Technology expansion and large-scale technical testing of storage power plants	Exploration and development of underground storage facilities	Substitution of lignite by renewable energy –based hydrogen with simultaneous compression of H_2
	Regional added value	H_2/O_2 Direct steam generation, upstream gas turbine etc.	Electrolysis technology	Research underground storage	Highly qualified skilled workers
		Development of steam turbines for coupling direct steam generation	Fuel cell development	Hydrogen storage metal hydride	Medium-sized specialized companies
		Hydrogen engine development (Wankel engine)	H_2-Gas turbine development	Methanization Feed-in of natural gas network	University research
Future		„Reference power plant Lausitz“ – Storage power plant with sector coupling			

Figure 2: Development path of the „Reference power plant Lausitz“– Storage power plant with sector coupling

The structuring of the transformation process by the region itself will enable the conversion of the power plant sites into future concepts (Reference power plant Lausitz) to take place without major performance deficits and loss of value added.

For this reason, the second step is to scale up the plant to an industrial scale, preferably with sector coupling.

The sector coupling and the associated digital networking will ensure the integration of the power plant sites into the local and regional industrial landscape.

This applies in particular to locations where significant industry has already been established. At locations such as the city of Spremberg, Cottbus, Weißwasser, Senftenberg, Forst and Guben in particular, "Smart City" concepts can also be applied to neighboring industrial and power plant parks. As a result, synergy effects can be expected at a higher level. In addition to process heat and heating supply, hydrogen technology also offers new possibilities for process coupling with the mobility sector, the chemical and the steel industries.

2.4 Pilot project „Reference power plant Lausitz“– Storage power plant with sector coupling

Gigawatt-scale power plants and storage facilities for the generation of electricity and seasonal storage of renewable hydrogen are to be built within the Reference power plant Lausitz as a long-term alternative. New technologies will be developed and tested on existing plants on a large scale and brought to operational maturity. The region's added value will be maintained and expanded through the use of pioneering technologies. Substantial synergies are expected to be created from the development of local geological structures for the storage of renewable hydrogen in the terawatt hour range.

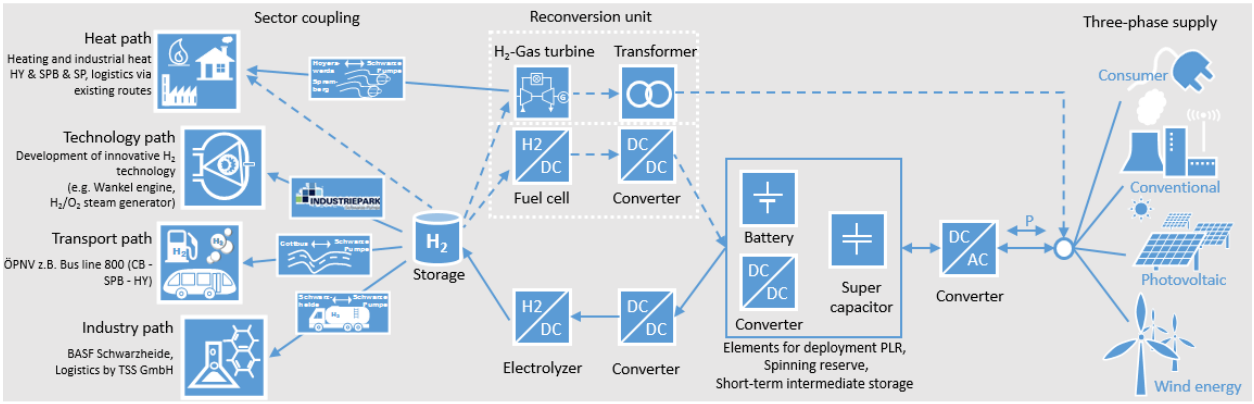

Figure 3: „Reference power plant Lausitz“– Storage power plant with sector coupling, digital networking and control functions

The main innovation of the storage power plant is that today's frequency-controlled power plant control will be replaced by "load angle-controlled power plant control".

The concept of the storage power plant is designed so that it can fulfill the tasks of conventional power plants completely CO_2-free and also automatically absorb, temporarily store and, if required, release the surplus electricity generated from renewable power plants. In this way, it makes an important economic contribution to minimize grid expansion driven by the Renewable Energy Act (*in German EEG: Erneuerbare-Energien-Gesetz*).

Hydrogen will be used as storage medium, will be produced from renewable electricity by electrolysis and could be either available for the transport sector, or converted back into electricity by means of a re-conversion unit (H_2 gas turbine or fuel cell).

The storage power plant will be able to provide novel control based on the assembly of well-known technological principles including: condenser (task: instantaneous reserve), battery (task: primary control power), electrolysis (task: H_2 generation) and H_2 gas turbine or fuel cell (task: power generation from H_2) (See Figure 3).

Due to the component switching, storage power plants are technically optimally suited to ensure the successive dismantling of conventional power plants while maintaining today's security of supply and system stability.

In addition to the innovative power plant control, the storage power plant offers the following major advantages:

- Highest possible operating range from 100% Pn in reference to 100% Pn – feed-in
- All the electrical properties of today's conventional power plants
- In case of dark doldrums automatically takes over the complete, reliable power supply
- Minimizes the grid expansion and thus reduces the economic costs of the energy transition
- Relieves renewable power plants from having to provide system services and creates financial savings potential
- High scalability (100 kW to 500 MW nominal power)

The partners (point 1.2) are interested to implement the storage power plant concept first in Lusatia because:

a) In perspective, the necessary electrical infrastructure for a large-scale project implementation (about 500 MW) already exists in the region

b) The storage power plant can already support conventional power plants with certain functions (black start capability) or replace (PRL)

c) The companies located in Lusatia have qualified professionals. In addition, suitable land for the construction and operation of the storage power plant is available

d) The storage power plant can make a significant contribution to the preservation of Lusatia as an energy region (power plant sites, hydrogen production, component manufacturing, infrastructure improvement in gas and telecommunications)

With the project "Reference power plant Lausitz" - storage power plant with sector coupling - described here, the partners plan the first large-scale implementation of this concept by the construction of a 10 MW pilot plant, which will be operated on the basis of the current technical guidelines as a power plant with sector coupling for at least 10 years and whose suitability as a must-run power plant of the present and future is to be proven.

The project focuses specifically on the topics 1 to 4 (see point 2.3 for details):

Subject matter 1 Planning, construction and commissioning of the Storage Power Plant -Lausitz (10 MW)

a) Construction and parameterization, certification of the storage power plant control system
b) Approval planning and detailed design for all individual technical components of the storage power plant including the H_2 storage facilities
c) Construction and commissioning of the storage power plant prototype/large-scale demonstrator
d) Assessment of the possibility to use an existing / or planning and constructing a new renewable energy plant in the vicinity (10 km) of the storage power plant

Subject matter 2 Network parallel operation with frequency control

e) Trial operation with proof that the storage power plant fully meets all electrical requirements (grid connection conditions) of an electric power plant, including prequalification for the control power market and the black start operation

f) Start of the normal operation and operation optimization of the storage power plant

g) Measuring campaign to quantify the efficiency with regard to optimization (savings) compared to grid expansion costs avoided by the storage function of the storage power plant

h) Measuring campaign to determine the technical and cost-saving potential of the renewable energy plant, as the storage power plant provides additional ancillary services

Subject matter 3 Island operation with load angle control

i) Planning and construction of an electrical island grid (10 MW), consisting of a renewable energy plant, controllable consumers and a storage power plant

j) Practical testing of load angle control in a converter-dominated electrical power network

Subject matter 4 Studies on long-term storage / Concept planning for industry storage power plant (up to 500 MW)

k) Comprehensive technical and economic evaluation as well as profitability analysis of the overall process

l) Concept planning of an industry storage power plant (up to 500 MW) based on the results of the pilot plant (Subject matter 1-3)

m) Studies on the long-term storage of renewable H_2 in potential underground storage facilities in Lusatia and the surrounding area (pore reservoirs, salt caverns)

3 Realization period

	2020					2025					2030
Subject matter 1: Planning, construction and commissioning of the large demonstrator Storage Power Plant -Lausitz											
Technical design, tendering and awarding of the control system and the storage power plant components											
Approval planning and approval of storage power plant prototype											
Construction and commissioning of storage power plant prototype											
Subject matter 2: Test of the network parallel operation with frequency control											
Completion of prequalification and start of regular operation											
Control operation of the storage power plant											
Optimization of the operation of the storage power plant											
Measuring campaign to quantify the efficiency with regard to optimization (savings) compared to grid expansion costs avoided by the storage function of the storage power plant											
Measuring campaign to determine the technical and cost-saving potential of the renewable energy plant, as the storage power plant provides additional ancillary services											
Subject matter 3: Test of the island operation with load angle control											
Planning of a 10 MW island grid											
Construction of an island consisting of a producer (EEA)-consumer storage power plant											

Practical testing of load angle control in a converter-dominated electrical power network											
Subject matter 4: Studies on long-term storage / Concept planning for industry storage power plant											
Technical and managerial evaluation as well as profitability analysis of the overall process											
Concept planning industry storage power plant (up to 500 MW)											
Investigation on long-term storage in the Lausitz / Brandenburg											
Investigation of alternative reconversion processes (H_2O_2 direct steam generation)											
Part 0: Experimental operation and scientific/technical support, project management											

4 Approximate estimated costs

Technological steps	Time frame	Costs
Part 1: Planning, construction and commissioning of the pilot Storage Power Plant 10 MW	**2020-2022**	**35 Mio. Euro**
Part 2: Test of the network parallel operation with frequency control	**2023-2024**	**5 Mio. Euro**
Part 3: Test of the island operation with load angle control	**2023-2026**	**10 Mio. Euro**
Part 4: Evaluation and concept planning industry storage power plant 200 MW. Investigations on long-term storage/ alternative power reconversion processes	**2028-2030** **2020-2030**	**16 Mio. Euro**
Part 0: Scientific/technical support (all 4 parts)	**2020-2028**	**6 Mio. Euro**
	Total:	**67,0 Mio. Euro**

5 Financing

Funding (EU, Federal Government, State) and own funds (will be provided by a consortium of stakeholders to be formed)

6 Open questions and need for action

- A prerequisite for the further project development is project start-up funding in 2018-2020 to prepare for project implementation in accordance with points 3/4 of 6.2 million Euros. This includes the basic engineering of the storage power plant with the power plant control including a separate consideration of the technical/technological implementation of the reconversion unit of the storage power plant (Figure 3).
- Business analysis with derived decisions and possible regulatory measures of pricing renewable energy
- Investigation of load angle control under practical conditions