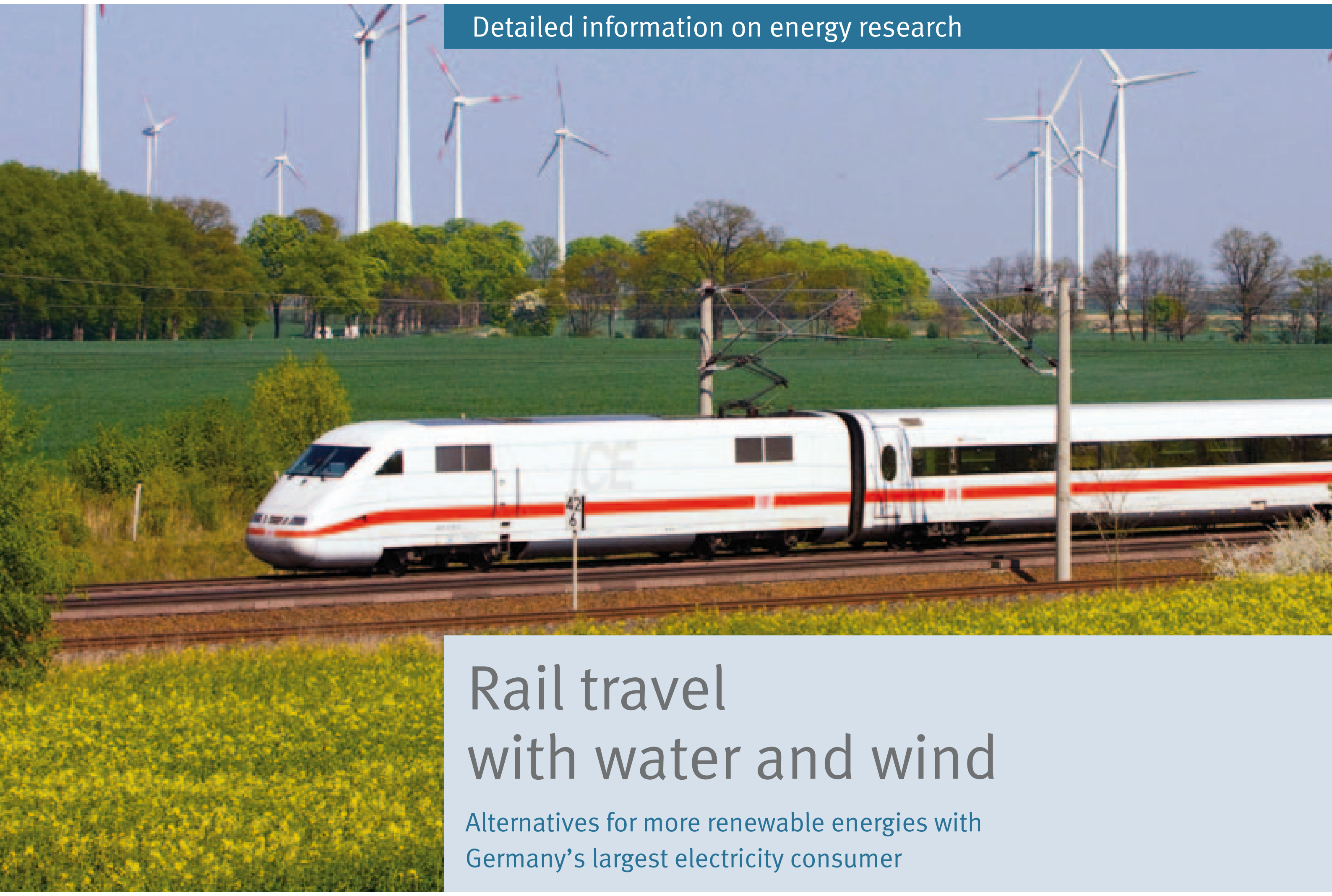
Detailed information on energy research



Rail travel with water and wind

Alternatives for more renewable energies with Germany's largest electricity consumer

BINE Information Service

It is a core problem of the energy revolution: the fluctuating yields from renewable energy sources have to be integrated into the electricity supply without endangering its safety and economic feasibility. Here the Deutsche Bahn railway company provides a prime example: by 2020, the company intends to draw more than one third of the 12 billion kilowatt-hours it consumes each year from green electricity. Researchers have calculated that doubling the green electricity used today will increase the electricity costs by around five per cent. The German railway power grid is distinguished, however, by many unique features.

The Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) in Kassel has researched how the proportion of renewable energies used for railway electricity can be increased. Right from the beginning it was clear that the special conditions with Deutsche Bahn had to be taken into consideration. In contrast to the public grid, the railway power grid is operated with a frequency of 16.7 Hertz (Hz). The 15,000-volt traction power systems are supplied from the railway company's own superimposed, overhead power line network that works with 110 kilovolts and 16.7 Hz.

The electricity fed into this central supply system comes from hydropower plants, thermal power plants and grid connections with the integrated 50-Hz public grid (via converters/ transformers). In addition, there is also a connection to the Austrian railway network and connection points to the Swiss national grid (Fig. 1).

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Because of the cost advantages, the researchers considered the possibility of directly feeding renewable energies into the 110-kV overhead rail cable network (in the case of wind energy and possibly with hydropower) and into the 15-kV level in the substations (in the case of photovoltaics and hydropower). Another possibility is to integrate renewable energies connected to the public grid with the rail electricity supply system via connection points linked to the 50-Hz grid. This concept has already been implemented by DB Energie in the case of three wind farms. As the energy manager for the Deutsche Bahn AG parent company, the DB Energie company procures and distributes the "traction electricity" with which the electric locomotives are powered.

Tight margins for green electricity

Deutsche Bahn (DB) competes with other transport service providers in the passenger and cargo sectors. Even though the energy costs only make up a tenth of the overall transport costs, the increased use of green electricity at an early point will have an impact on Deutsche Bahn's competitiveness as a result of possible cost increases. The green electricity must be distributed into the rail network as equally as possible and in accordance with the loads. This can be achieved by directly feeding the electricity into the 16.7-Hz network or by drawing 50-Hz electricity from the public grid. The limited transfer capacity reduces the potential for feeding into the 16.7-Hz network. For procuring 50-Hz electricity, on the other hand, Deutsche Bahn is not faced with any technical limits since the transmission network operators assume responsibility here. Although direct feeding offers economic benefits in terms of the avoided grid usage charges and fees, it requires increased network connection costs. For this reason, the researchers have assessed the suitability of direct feeding in comparison with drawing green electricity entirely from the 50-Hz grid.
Because the weather conditions mean that wind power and photovoltaics can only securely provide small generation capacities, the direct feeding of green electricity would require only slightly smaller volumes connected to the 50-Hz grid than would be the case when drawing 50-Hz electricity from all green electricity sources. However, if power plants that feed electricity directly into the rail cable network are displaced as a result of procuring green electricity, this will increase the costs for integrating green electricity. The high rail-specific load fluctuations between day and night (approx. 300 MW) mean that a relatively large proportion of the flexible capacities need to be drawn from the 50-Hz grid.
If fluctuating green electricity sources feed large amounts into the rail electricity supply, this will also mean that only part of these energy volumes can be used directly and surplus energy will have to be fed back into the public grid. The researchers have therefore accordingly evaluated the possible portion of fluctuating green electricity systems that can be integrated in the rail electricity supply. It has been shown that the optimum energy ratio is around 75 % for wind and 25 % for photovoltaics. If less priority is given to integrating hydropower for covering the basic rail electricity consumption loads, this will enable a higher portion (installed capacity) of fluctuating wind energy to be used in the range of electricity procured by DB Energie. By means of additional storage capacities, the relative share of PV can be optimised relative to wind energy.

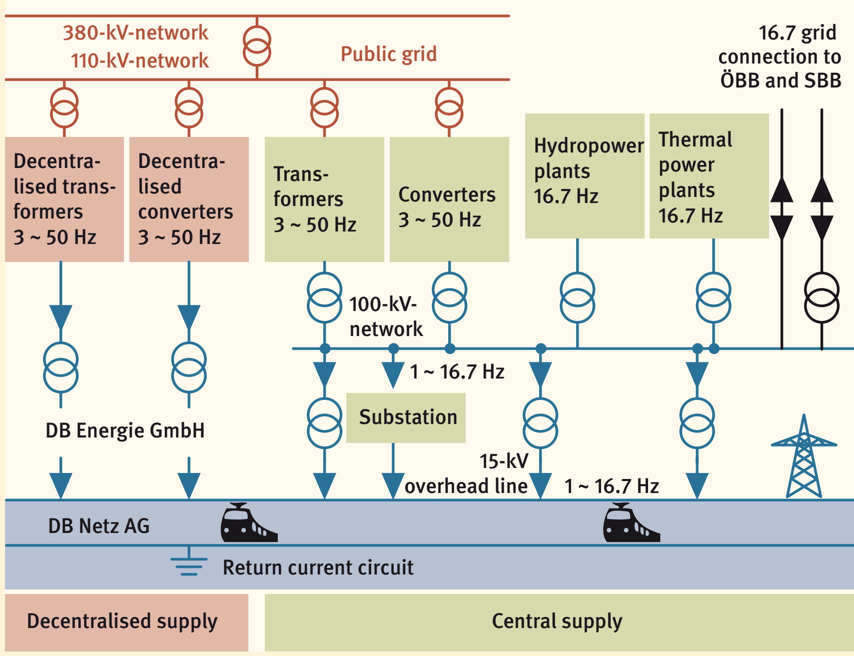

Fig. 1 *Basic concept behind the railway electricity supply system. Source: DB Energie GmbH*

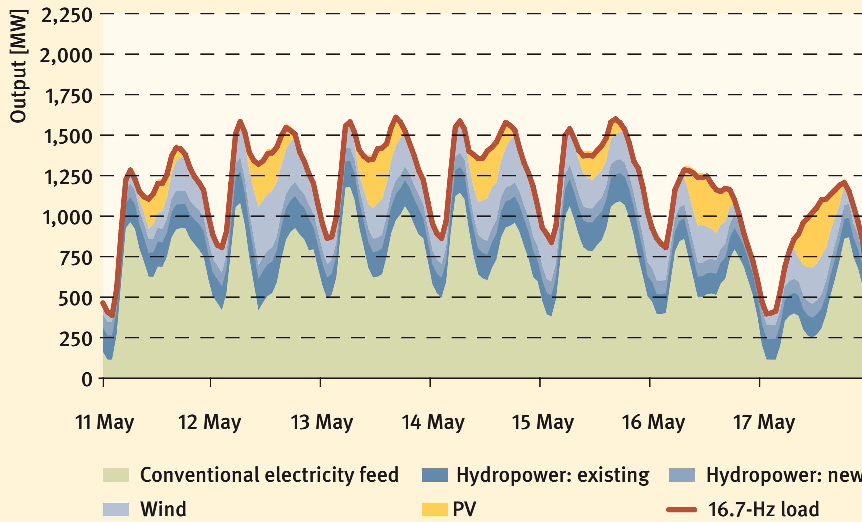

Fig. 2 *Early integration of power plants that feed green electricity directly into the central supply system – 2020 scenario with a high renewable proportion, example week for the 2000 weather year. Source: IWES*

Considered timescales and costs

Within this framework, the scientists from Kassel have assessed various renewable energy technologies: a special mix of onshore wind, solar energy, hydropower and biomass for flexibly procuring electricity. Offshore wind, on the other hand, does not meet the requirements for distributed generation along the main load points. The technical development of geothermal energy is currently not foreseeable. Onshore wind and solar energy will be integrated to a large amount, which will enable a high proportion of new plants, ensure a high degree of additionality and also provide considerable environmental benefits. However, this will also incur greater costs.
The study has considered three scenario years: 2012, 2020 and 2050. The scenario year 2012 has been chosen in order to be able to assess which additional costs can be expected today if the proportion of green electricity is increased. The 2020 scenario year will provide help in making practice-based

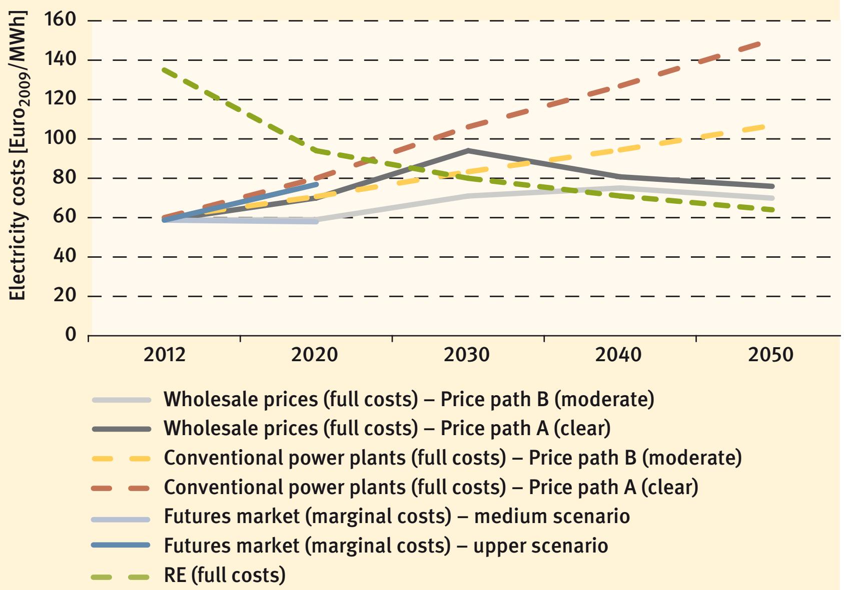

Fig. 3 *Forecasted electricity procurement costs until 2050. The cost developments from 2012 to 2020 when considering the full costs on the one hand (in accordance with the BMU Lead Study 2010) and the futures market on the other (in accordance with the estimates of DB Energie) are based on different assumptions and are not directly comparable with one another. Source: IWES*

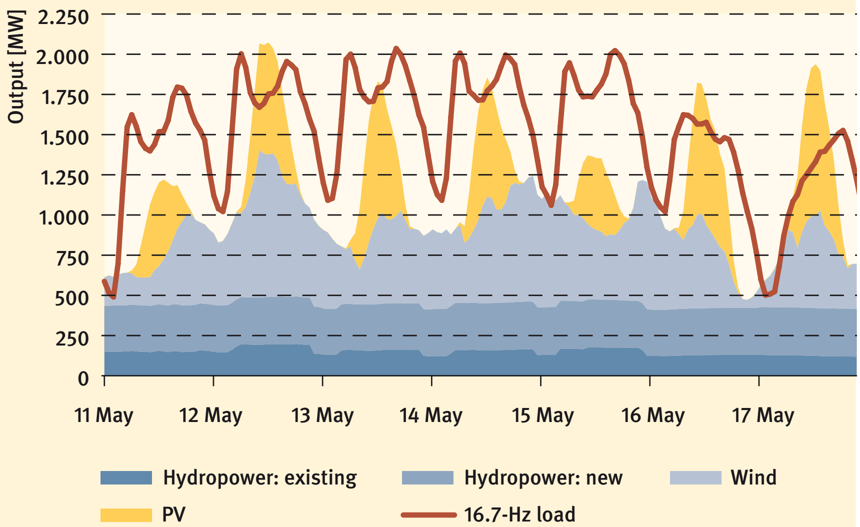

Fig. 4 *Early integration of power plants that feed green electricity directly into the central supply system – 2050 scenario with a high renewable proportion, example week for the 2009 weather year. Source: IWES*

The energy manager for German rail

At its headquarters, DB Energie monitors the energy supply for its electricity network and thus the electrical train operation for 20,000 train journeys in Germany every day. To ensure an optimum supply, coal, gas, nuclear power, hydropower plants as well as transformer and converter stations are available, which can be used in accordance with the “cost-effectiveness” and “supply security” criteria. At the click of a mouse, the headquarter controls the cables and power plants so that all trains belonging to the railway transport companies can be supplied with energy while underway on the roughly 19,800-km electrified rail network belonging to DB Netz AG.

decisions in the medium term, since the development within this timescale can be relatively well estimated. The 2050 scenario provides an overview in determining strategic policy directions.
The additional costs for increasing the renewable proportion of the rail electricity very much depend on the development of the wholesale prices (i.e. for the electricity mix from conventional and renewable generation). These are considered as reference costs for the 50-Hz procurement (from grey electricity – i.e. electricity without certifiable green characteristics), since the study assumes that only this electricity is replaced by a greater proportion of green electricity. This does not affect the quantities forecast for the conventional electricity directly procured by DB Energie.
For the scenario years 2012 and 2020, the marginal cost market provides the practice-related reference cost system, whereby the development of the CO_2 certificate costs and the fossil fuel costs are decisive for the wholesale price. In addition, the researchers expect increasing grid utilisation fees and slightly increasing Renewable Energy Sources Act (EEG) levies.
For the scenario year 2050, the calculations are done using a fictitious “full cost market”, since nobody currently knows how the market will function then. It is also assumed in this scenario that the EEG Act will be replaced with complete direct marketing of the green electricity generation plants. The 2020 scenario year provides a sensible addition in this regard in order to be able to depict the cost development until 2050.
Two versions are taken into account in the study: an upper price path that reduces the additional costs for procuring green electricity and a medium price path that leads to greater additional costs.
In contrast to conventional energy generation, considerable potential for cost savings is expected with renewable energies. This will mean that although an increase in electricity costs is expected in the medium term (until 2030/2040) in terms of the full costs (wholesale prices) including levies in the form of increased grid usage charges, EEG levies, etc., in the long term the electricity supply costs will be reduced as a result of the development of green electricity (Fig. 3).
Despite the additional costs caused by balancing out forecast errors or a falling relative market value for grid-fed wind and solar energy caused by the “merit order effect”, the researchers have established that the cost degression for the investment costs for green electricity generation systems will be a substantial factor for the market integration and competitiveness, particularly for wind energy. In the event of high fuel and CO_2 costs in 2020, wind power may even be equivalent to electricity from existing national hydropower sources (including in terms of the market value for the green electricity properties).
When the integration of green electricity via 16.7-Hz direct feeding is compared with 50-Hz procurement, it becomes clear that the costs avoided for the grid usage charges and fees in the case of direct feeding will be balanced out in the short and medium term by additional grid connection costs. In the long term, however, the increased costs for integrating green electricity combined with a sinking electricity consumption mean that considerably higher grid usage charges can be expected. In the long term, direct feeding may in economic terms be considerably better than procuring 50-Hz electricity. Not least because of this study, DB has decided to increase the proportion of green electricity it uses to 35 % by 2020 relative to the 50-Hz procurement.

Hydropower will fix it

When the lights go out during power cuts, the trains often continue travelling. This is because it is not just the diesel locomotives that are independent of the public grid – so are the electric locomotives. When Deutsche Bahn (DB) was electrified from 1910 onwards, it developed its own railway power grid. Today, the high-voltage rail electricity network is around 7,800 kilometres long and is connected with 110 kV/16.7 Hz to around 190 substations that are 80 % fed from fossil fuel-fired power plants. Hydropower, which initially provided an important energy source for rail electricity, currently only has a 10 % share. However, new hydropower plants are currently not realisable, even if there is existing potential. The only remaining possibility is to retrofit individual hydropower plants with new turbines in order to increase the efficiency.

One way of increasing the proportion of hydropower is provided by contracts with the energy sector: in 2011, Deutsche Bahn concluded an agreement with the RWE Group for the power company to provide 100 MW of energy from hydropower, particularly from the River Moselle, for a period from 2014 to 2028. This corresponds to 876 million kWh a year. The proportion of renewable energies relative to Deutsche Bahn's overall electricity requirements will therefore increase from 20 per cent at the moment to 28 per cent. Deutsche Bahn wants to achieve 35 per cent by 2020. Behind this lies the vision of completely converting the railway's electricity supply to renewable energies by 2050.

With an annual volume of 12 billion kWh, the railway network is one of the largest energy consumers in Germany. This amount corresponds to the consumption in the Berlin region. Deutsche Bahn currently procures wind energy for its electric locomotives from 33 wind turbines. This amounts to 104 million kWh a year – which is not even one per cent.

When rail electricity generators are renewed, they are replaced with 50-Hz generators, whereby converters placed nearby provide the rail electricity. When the power plant in Bremen, which is operated with blast furnace gas, is replaced in the new future with a 440-MW Combine-Cycle power plant, the rail electricity with an output rate of 200 MW will not come directly from the generator but via converters.

Deutsche Bahn is also banking on the capacity of the public grid in the future. The power companies are investing considerable sums in new power plants, including in neighbouring countries. In future, Deutsche Bahn also wants to procure electricity not only from Sweden but also in particular from Belgium, the Netherlands and probably Poland.

Project participants

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Links and literature

- www.iwes.fraunhofer.de | www.dbenergie.de

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