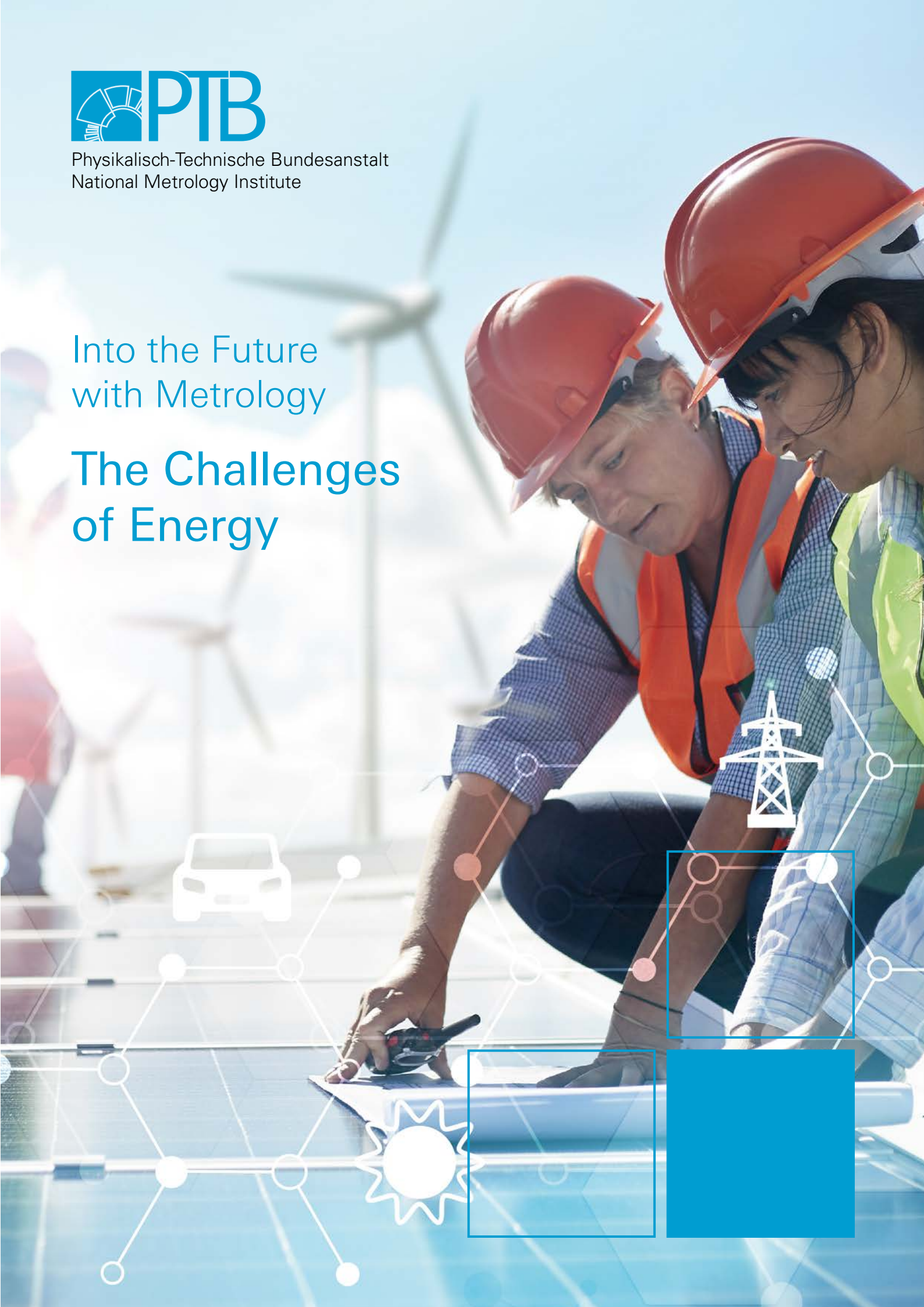
Physikalisch-Technische Bundesanstalt
National Metrology Institute

Into the Future
with Metrology

The Challenges of Energy



The Challenges of Energy

decentralized – efficient – regenerative – dynamic – safe – stable

With the energy transition, Germany has set itself the goal of creating – within a few decades – a fundamentally new, sustainable, decentralized energy system with hardly any CO_2 emissions. The change to this new system is one of the biggest challenges of our society. PTB, as the national metrology institute of Germany, wants to support all stakeholders – from the fields of industry and politics to consumers – in this endeavor. After all, reliable measurements are the prerequisite for safety, efficiency, and consumer protection.

PTB has already developed measurement and calibration capabilities in the fields of solar energy and wind power which, in part, are unique worldwide. However, a successful energy transition also requires powerful transmission and distribution grids, batteries and other storage elements, the development of hydrogen technologies as well as energy efficiency. Together with partners from industry, PTB's scientists are also developing suitable measuring methods and standards in these fields of work. The focus is, in particular, on the coupling of energy sectors, on the stabilization of the electricity grid, and on hydrogen as an energy carrier. All this will play a key role in the energy system of the future.

In addition to all the challenges, the energy transition gives us the chance of becoming the stage for climate-friendly technologies that are "made in Germany". This, however, can only succeed with excellent measurement technology. Excellent measurement technology is the key to protecting our environment and climate as well as to supplying energy that is secure, compatible with the environment, and cost-effective.

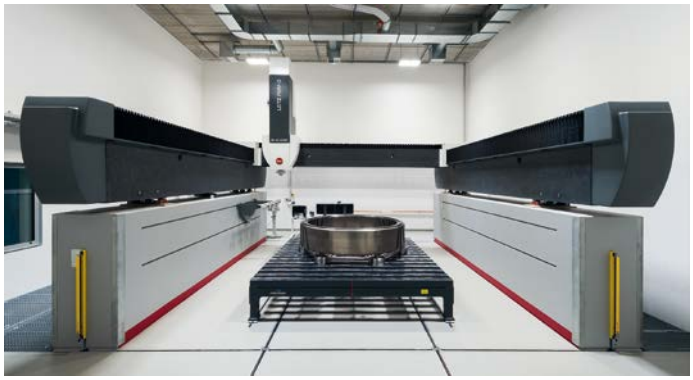
Metrology for renewable energies

Wind power and solar energy are the cornerstones of the energy transition. PTB's task is to support German industry in these fields with joint research projects and services. However, modern conventional gas and steam power plants will also play an important role in Germany's energy supply, at least in a transitional period. Here, too, PTB's measurement expertise – especially in the fields of pressure, volume flow and temperature measurement – will contribute to increasing the efficiency of these power plants and thus to reducing CO_2 emissions.

PTB's competence: wind energy

According to the German federal government's plans, 50 percent of the electrical energy required is to come from wind turbines in 2050. The technical requirements for powerful, high wind turbines with large rotor diameters are enormous, and the need for calibrations to operate the turbines reliably is great. Therefore, PTB has set up its Competence Center for Wind Energy. This center has a metrological infrastructure that is unique worldwide. PTB is thus the first national metrology institute that can offer reliable and comprehensive quality assurance to the wind energy industry. Our know-how comprises, among other things:

- A large coordinate measuring machine for the metrological traceability of large components (5 m × 4 m × 2 m measuring volume) such as gear components with the highest precision.
- The world's largest standard measuring facility for torques of up to 5 MNm, with the prospect of extending this facility to up to 20 MNm in the long term.
- State-of-the-art LIDAR (light detection and ranging) sensor techniques for wind potential analyses, including a wind tunnel for the calibration and precise determination of LIDAR systems.
- The development of a method to predict disturbances that arise from wind turbines and have an influence on facilities of air traffic control for flight safety. This method has been an official standard since June 2020 and is now part of the approval procedures.



The large coordinate measuring machine enables the metrological traceability of large components (5 m × 4 m × 2 m measuring volume) for the first time.

In addition, PTB and its European partners are, for the first time, developing guidelines which will make it possible to test the efficiency of wind turbines on a standardized basis.

PTB's competence: photovoltaics

By 2035, the share of photovoltaics (PV) could account for about 20 percent of the total electricity generated in Germany. To achieve this target, up to 100 billion euros would have to be invested in Germany. It must be remembered that every percent of measurement uncertainty in the efficiency of solar modules leads directly to a financial uncertainty of one billion euros. PTB has therefore set up the Competence Center for PV Metrology. This center offers a unique infrastructure of laboratory and free-field calibration procedures with the lowest measurement uncertainties worldwide. PTB is the only national metrology institute in Europe that is able to establish primary traceability of the measurement results for reference solar cells. About 50 percent of all systems installed worldwide are already traceable to PTB today.

Since 2019, the measurement infrastructure which is also needed to offer comprehensive calibrations for solar modules has been established at PTB. Such calibrations include the parameters that are necessary for a comprehensive, energy-based assessment of solar modules with regard to all influence quantities that are relevant to their output. Thereby, PTB's focus is on the quantities which are difficult to determine, i.e.: the performance under standard test conditions; the angle dependence; the dependence on the spectrum; and the dependence of the solar module temperature on wind velocity. Among other facilities, an LED-based sun simulator is the most important facility of the Competence Center. With this tool, the behavior of solar modules with a size of up to 2 m × 1 m can be simulated under various irradiation conditions found in the environment. This means that the standard annual output of solar modules (according to the Energy Rating Standard series IEC 61853) can now be determined.

The LED-based sun simulator is equipped with 16,320 high-power LEDs which are available in 18 different, individually controllable colors.

Metrology for energy carriers and energy storage

The aim of the German federal government is to ensure that in 2050, the share of renewable energies will amount to at least 80 percent of Germany's gross electricity consumption. The intention is to achieve this primarily by means of wind and solar energy. In order to balance out the fluctuations in the generation of electricity caused by varying weather conditions, large energy storage systems will be required in the future. If the energy transition is to be successful, energy carriers are required which will facilitate the use of the energy generated by renewables in different sectors, e.g. in the mobility sector and in the heat supply sector.

In close cooperation with partners from industry and with universities, research institutes and other national metrology institutes, PTB is not only carrying out basic research on the properties of new types of batteries, but also research on practical applications which are geared to the current needs of industry and society. This includes investigations in the fields of electromobility and stationary storage systems in private households. Since it is the gas grid in particular which is considered to be a potential storage facility for enormous amounts of energy – primarily in connection with hydrogen – PTB is also specifically extending its competence in the field of gas measurement technology.

PTB's competence: battery research

Ideally, a battery management system will, in the future, provide information about the state of charge of a battery, its state of health and its thermal load under operating conditions. This will, however, only be safely achieved if the interdisciplinary task of understanding the complex system of a battery is solved by investigating electrochemical parameters, battery aging, state variables and charging characteristics. Here, PTB is involved with a large number of measurement technique developments and research projects, for example:

- In the European "LiBforSecUse" research project, PTB is coordinating a consortium of partners from industry and from research and metrology institutes with the aim of developing a measuring method which can efficiently measure the residual capacity of lithium-ion batteries from electric vehicles for second-use applications. Although the life cycle of batteries used in electric vehicles ends when the batteries have reached a residual capacity of about 80 %, they can still be used for many years for other purposes, for example, as stationary energy storage systems for photovoltaic systems.
- Collaborations with the TU Braunschweig are dedicated to safety-engineering assessments of lithium-ion cells, modules and entire battery systems to be able to make safety-engineering statements in the event of faults such as overloading, overcharging and depth discharging.
- Participation in projects for fundamental research on lithium-sulfur batteries.

Due to its research activities, PTB can offer comprehensive services – from the SI-traceable description of the charge condition, the state of health and the safety conditions of lithium batteries to metrology for explosion protection.

PTB's competence: hydrogen technology

In the future, green hydrogen (H_2) will be a key player in the energy transition. Produced free of CO_2 with solar or wind power, green hydrogen is available as an energy carrier for numerous applications in three sectors, i.e. electricity, heat and mobility, and for its utilization as a chemical material in industry. To use green hydrogen comprehensively, many prerequisites will, however, have to be created. PTB is accompanying this process. It is promoting the technological development of the hydrogen economy in terms of metrology and safety engineering, and it is contributing to the setting up of a reliable infrastructure. To this end, PTB intends to build a demonstrator facility of its own on its premises in Braunschweig. PTB is already participating, together with other research partners from Lower Saxony, in the establishment of an innovation laboratory for hydrogen technology. In this laboratory, ideas are to be developed which are close to practical applications and can be implemented for research and transfer concepts.

The measurement competence for many H_2-relevant quantities is either already available at PTB or can be set up in the medium term. Besides density, efficiency, calorific value, heat quantity, viscosity and chemical composition, these quantities are as follows:

Pressure: PTB is one of only three metrology institutes worldwide that can measure high pressures in the range of 800 bar with very small uncertainties. In the near future, PTB will expand its measurement capabilities for gas pressures of up to 1000 bar (which may occur during the production, transport and storage of hydrogen).

Temperature: In the field of temperature measurement, PTB operates and develops a wide range of hydrogen-relevant measurement methods, for example, with regard to the thermal management of hydrogen cryogenic-pressure storage tanks.

Explosion protection

Hydrogen is an extremely ignitable gas when mixed with air. For a wide range of applications, maximum safety must be guaranteed at all times – whether these applications are close to the consumer (for example, at petrol filling stations) or in industrial processes. In close cooperation with BAM, PTB's main objective here is the development of test procedures for explosion-protected equipment, the standardization of these procedures and their implementation in the legally regulated conformity assessment procedures.

Synthetic fuels

PTB already engages in the analysis and characterization of synthetic hydrogen-based fuels for both aerospace and commercial vehicles. An optimization of tailor-made synthetic fuels for combustion with as few pollutants as possible will only be successful if, for example, the ignition behavior and the reaction kinetics are known.

PTB's competence: gas measurement technology

In the future, the natural gas grid will serve as a large storage facility for energy from renewable sources. Biogas can be fed into it just as well as hydrogen produced with surplus electricity or methane synthesized from it. If required, it is then converted back into electricity. But gases differ, for example, in their calorific value.

In the interest of fair billing for consumers, it must therefore be possible to determine the chemical and physical properties of the transported gas at any point in the grid as well as the behavior of the gas meters as a reaction to these properties. PTB has the competence to validate such measurement and assessment procedures and to check whether they comply with the requirements of the German Measures and Verification Act. The same applies to gas meters at hydrogen dispensers. In industry, hydrogen is also increasingly used as a gas to control production processes. If it is generated using solar and wind power, green hydrogen can contribute significantly to avoiding CO_2 emissions (for example, in steel production).

PTB and the company of *Salzgitter Flachstahl GmbH* have therefore agreed on a collaboration to develop a suitable hydrogen quantity measurement technology for industry. The accurate measurement of hydrogen is a prerequisite for the efficient control of production processes.

Metrology for extending the grid

In the future, power transmission and power distribution systems will have to fulfill completely new requirements: Instead of just a few centralized energy producers, there will be many decentralized ones; the electricity production from wind and solar energy will fluctuate over time; offshore wind power produced on the coast will have to be transported to conurbations in western and southern Germany; and for electromobility, a charging infrastructure will be required which extends all over the country. In addition to the creation of further transmission capacities through the construction of new grid components, intelligent information and communication technology is necessary in order to connect all energy producers and consumers in a suitable network and to coordinate the requirements in this regard.

PTB is engaging in the metrology for extending the grid and strengthening communication technology both in its own projects and, together with 18 international research partners, in the European Metrology Network (EMN) for smart grids. This joint project under the umbrella of EURAMET offers support for the standardization, testing, researching and developing of national strategies for the development and implementation of smart grids.

Smart meter gateways

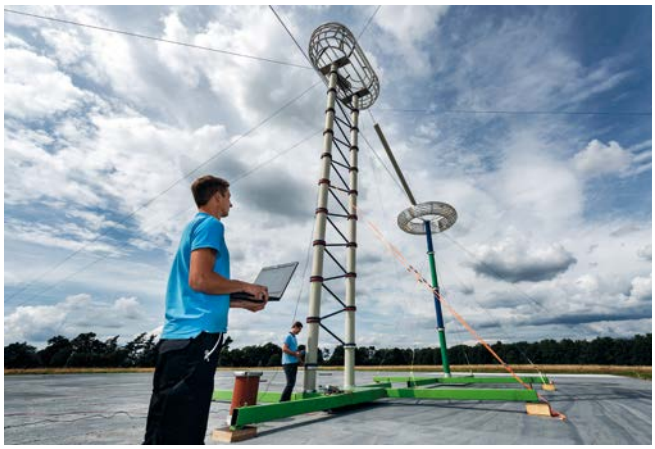
Together with modern electricity meters, smart meter gateways (SMGWs) make up an intelligent metering system that will play a key role in the energy industry in the future. In 2019, PTB started issuing type-examination certificates for smart meter gateways. In compliance with the highest data security and data protection requirements, the gateways not only make it possible to process the measured energy values right on location, but also to pass these values on to consumers, network operators, energy suppliers and energy service providers via public communication networks.

PTB's role in this is to contribute the requirements of legal metrology to this process in the interest of customer protection and fair competition. This is done by advising the authorities concerned and partners from industry, by participating in the respective standardization activities and finally by testing, assessing and certifying modern meters and smart meter gateways.

Advancement of the relevant measurement technology

In total, around 7,500 kilometers of the power grid will have to be optimized, reinforced or newly built over the next few years. The decentralization of the energy supply and the new energy generation methods will lead to new grid structures and may bring about new challenges for safe and reliable power supply, e.g. decreasing voltage quality. This will require new measurement methods. Another new issue is that ultra-high-voltage direct current transmission lines will play an important role in the future.

PTB wants to enable reliable and traceable measurements in the field of high-voltage measurement technology – both in three-phase and direct current transmission. To this end, it is already setting up the corresponding laboratory technology to further develop power generation and measuring equipment and to improve the measurement uncertainty for the realization of the relevant quantities.



PTB's high-voltage measurement facility.

One example of this is the high-voltage measuring facility set up in 2020. It can be used to generate and precisely measure direct voltages of up to 2000 kV. In the long run, PTB plans to offer calibration services for DC voltages above 1000 kV, which are important, for example, for high-voltage direct current transmission (HVDC). One of the aims of the research carried out here is to determine, among other things, the influence which the level and the quality of the DC voltage has on measuring instruments – because superimposed voltages have a considerable influence on the service life of components in the transmission grid. Ultimately, such measurements support the security and stability of the energy supply in the European electricity grid.

Charging devices for electric vehicles

In 2018, PTB started to issue type-examination certificates for charging devices for electric vehicles. These charging devices now comply with all the requirements of the measures and verification legislation. Furthermore, they not only guarantee exact measurements, but also a charging process that is transparent and exactly traceable for the customer – comparable to filling a car up with petrol at a petrol station. PTB is currently the only conformity assessment body for the field of electromobility that has developed an assessment procedure for charging equipment, and it is also actively supporting the German federal government's national development plan for electric mobility.

This plug is part of an in-cable measurement system developed by PTB. With this system, the amount of energy supplied to the vehicle during the charging process can be determined and compared with the amount of energy measured in the charging station. In addition to the correct energy measurement, other features (such as the trustworthy data storage and transmission of these measured values for the billing process) are also necessary for a charging point for electric vehicles to be certified by PTB as being compliant with the measures and verification legislation.

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The contents of this Info Sheet and further information can be found on the internet: www.ptb.de > Research & Development > Into the Future with Metrology > The Challenges of Energy

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