VDE-Study

Decentralized Energy Power Supply 2020

VDE

Title

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In addition to the present condensed version, the full study "VDE-Studie Dezentrale Energieversorgung 2020 " has also been published in German.

Contents

Foreword

The power industry is facing substantial changes all over the world. This phase is marked by the foreseeable scarcity of fossil fuels, and aggravated by the dramatic increase in power requirements for emerging countries, particularly China and India. The resulting increase in demand on the energy markets has already resulted in significant price increases. Recently it has once again become quite apparent just how much Europe depends on energy imports. Grid-bound energy transport in particular has been increasingly used as a means of applying pressure to assert certain economic or political interests. Furthermore, there is an urgent need for prompt action in view of the rapid rate of climate change.

Industrial countries such as Germany therefore give top priority to safeguarding a reliable, sustainable, environment-friendly and at the same time, low-cost energy supply. This includes a sensible energy mix and improvement in energy efficiency in generation, transmission and consumption. In particular, greater priority must be given in the long term to the renewable domestic energy sources, such as the sun, wind, water, biomass, geothermal energy systems etc. Together with covering the demand for electricity, a holistic, viable energy concept also has to take account of the energy demand for heating.

The use of fossil fuels, which cannot be renounced as a key element in our power supply for the foreseeable future, demands an approach which preserves resources and protects the environment. This includes the development of high-efficiency power plant technologies and procedures for CO_2 sequestration. But what seems particularly appropriate is the simultaneous extraction and use of power and heat from the energy conversion process in combined heat and power (CHP) units. This makes sense particularly for decentralized supply concepts, as heat distribution over large distances is not economically efficient. Although currently running on natural gas, in the long term CHP units can be converted to biogas or other biofuels. Decentralized supply concepts can also help to reduce grid losses by ensuring that as far as possible, electricity produced on a local scale is also used locally. However, a purely local supply is neither technically nor economically appropriate. Demand-oriented supply requires large storage capacities and efficient grids supplied from reliable sources in order to cope with the mostly fluctuating renewable energy sources which are not available in sufficient quantity all over the country.

On the consumer side too, more efficient processes and building construction can make a valuable contribution to saving energy. Suitable load management can be used to adapt consumption better to the currently available energy supply. Heat pumps making use of the thermal energy stored in the earth, and solar-thermal systems will replace fossil fuels in the heat market.

The quality of the energy supply is increasingly gaining significance. Recent widespread power failures have made this clear to us all. Here local supply concepts can help to sustain power supplies in such cases, particularly to important processes.

Local supply concepts therefore have an important contribution to make to future scenarios in addition to today's more-or-less centralized power supply systems. The study looks at the technical and economic aspects of decentralized power supply systems.

1 Introduction

In 2003 and 2004 a study of Germany's energy supply in 2020 was produced in the responsibility of the VDE. The aim of the paper was to evaluate the energetic, ecological and economical consequences to be expected from implementation of the existing energy policy.

Three scenarios were used to evaluate the effects on the power industry. The focus of the government-related scenario was on following corresponding political guidelines, while the alternative scenarios aimed for cost-optimized development and development with minimum CO_2 emissions. The results confirm that it is possible to achieve the Kyoto CO_2 targets, regardless of the chosen scenario. But the results of the alternative scenarios also reveal considerable advantages in terms of investment and energy costs. It also became clear that decentralized generation systems can be expected to make a greater contribution in future. This refers to the possibilities of combined heat and power supply (CHP) as well as using renewable energy sources in the form of wind energy, photovoltaic systems (PV) and biomass. CHP systems affect the heating market, so that alternative systems for heat supplies were included in the study in addition to power supplies. This includes in particular solar-thermal systems, but also heat pumps.

This study tries to describe and evaluate these developments and their impact on the supply structures. In the interests of comparability with the results of the above mentioned VDE study, the same approaches have been used, both relating to the growth in power demand and in terms of the presumed expansion of the power grid.

This study has been compiled in the context of an interdisciplinary working group by representatives from industry, authorities, associations, research and the power industry. This composition guarantees a sound, professional approach. It is the prerequisite for ensuring that this topic which is so important for society is given a balanced appraisal regardless of specific company interests.

2 Definitions, general conditions and system approach

The development of renewable energy sources and the most efficient possible use of fossil fuels will see decentralized (local) systems making a growing contribution to electricity generation over the next few years. According to the EU targets, by 2010 the share of renewable energy sources should account for 22%, with combined heat and power (CHP) units contributing 18%.

This study is restricted to units and systems that are integrated in distribution grids (0.4 … 30 kV). Purely islanding grid solutions are not included, on account of Germany's power grids that are available on a widespread basis. Nor does the study include onshore and offshore wind parks, although the high share already reached or currently expected must be taken into account in considering the overall system.

Alongside the supply-dependent and therefore fluctuating generation of energy from renewable sources, the study looks above all at adjustable power generation from CHP units. While the waste heat from large-scale thermal power plants cannot be used because of what is usually a large distance to the centres of demand, local systems are ideal for combined use and thus also permit a higher overall level of utilization.

Renewable energy sources also include biogas or biomass. Thanks to the relatively simple storage possibilities involved here, corresponding systems can be used as and when the need arises.

The complex nature of local supply with its many varied influences demands a system approach that takes account of all important components. This refers not only to the generation systems but also to the system as a whole with its widespread networks, and in the end also the consumer himself, with his behaviour also contributing to overall optimization.

Along the lines of a holistic approach to carefully managed, economic use of primary energy, the current study not only looks at the possibilities of generating electricity but also at different concepts for generating heat. This includes for example wood pellet heating systems, solar-thermal systems and heat pumps.

Grid-compatible, low-cost integration of decentralized generation units is featured in the study, together with energy-efficient operation that takes account of the general conditions of supply and demand.

The construction and operation of local systems is in principle open to all parties, thus permitting further liberalization of the market. This is supported by a relatively low investment risk compared to large power plants. Energy service providers are offered the opportunity of offering both power and heating supplies as a complete package.

3 Development in demand

As well as using renewable energy sources, local supply systems have the objective of improving the efficiency and reliability of the energy supply with systems erected close to the consumer. This entails rating the systems according to demand. In contrast to central power supplies, specific local knowledge of the local energy demand is thus a prerequisite for an optimum supply concept. Consumption behaviour is therefore a key variable, as it has a major influence on the rating and thus profitability of local systems.

3.1 Power demand

Today, decisions to purchase an appliance are based to a significant extent on the amount of energy that the appliance consumes, indicated by energy consumption labels. Electric and other appliances in all sectors show increasing levels of efficiency, with even further potential for energy saving becoming possible in future too.

On the other hand, it can be presumed that additional appliances altogether increase the power demand. Together with the growth in use of modern information and communication technology by both industry and private households, even here in our regions we are also witnessing a trend to use air-conditioning systems, whose negative impact on the power supply is already known particularly from the USA. Systems for forced ventilation with heat recovery, which could become a standard feature of modern buildings, have electric drive systems which can also cause an increase in power consumption. The same applies to heat pumps.

To summarize, it can be said that power consumption will continue to increase slightly in the next few years. An average growth in consumption of 0.5% p.a. can be expected by 2020.

3.2 Energy demand for room heating

In already existing buildings, for many years there has been a continuous decrease in energy demand for room heating, particularly for new buildings. This comes from various regulations in force on the execution of buildings which have resulted in successive improvements in the energetic quality (Fig. 1).

Subject to suitable general political conditions, it can also be presumed that older buildings will be refurbished so that in future a larger portion of existing buildings can be called "energy saving houses". As a result, today natural gas supplies are already not routed to many new housing estates because it is simply not profitable.

On the other hand, a more generous allocation of living space and the trend to single households also result in more living space per resident. But altogether it can be presumed that the corresponding greater demand for heating energy will be compensated for the most part by the decline in population development.

3.3 Energy demand for heating service water

The demand for service water has risen drastically in the past as a result of increased personal hygiene needs, whereby this demand scarcely shows any seasonal fluctuations. It amounts to a consumption rate of approx. 45 litres of hot water per person and day, with a 35°C heating-up range.

Contrary to consumption levels, greater efficiency in modern service water systems means that the primary energy demand will decrease. In particular solar-thermal hot

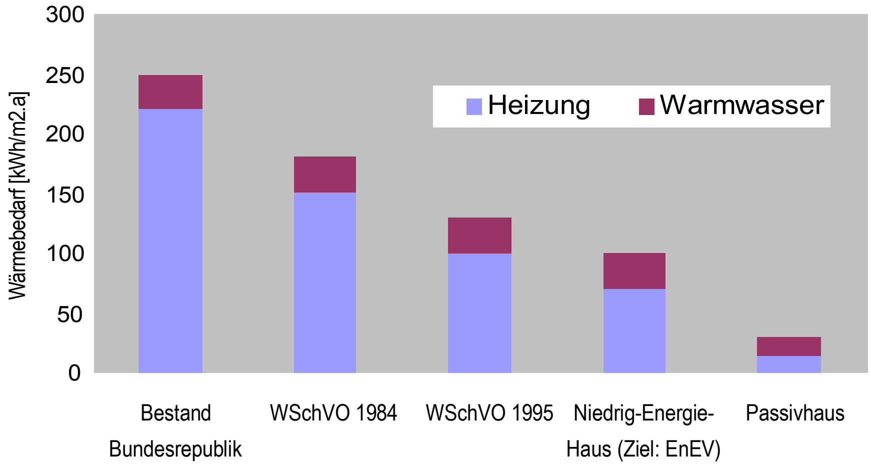

Fig. 1: Impact of the Heat Insulation Ordinances
Source: AGFW

water systems can be expected to make a growing contribution, and could contribute up to 60% to covering the energy demand for providing hot service water. This decrease in energy demand for providing hot service water could on the other hand result in a loss of base load supply for CHP units. The combination of a solar-thermal system with a CHP unit is therefore not appropriate in terms of economic efficiency.

3.4 Air-conditioning

Where air-conditioning systems in buildings are concerned, increasing priority is being given to the wish for comfort. There is a growing demand for air-conditioning systems even in the private sector. But it remains to be seen whether this development will take place on such a dramatic scale as in the automotive sector. Adapted building methods could at least partly counter this trend.

Notwithstanding general developments, increasing demand for air-conditioning can certainly be presumed where office buildings are concerned. The trend towards glass constructions, combined with increasing internal thermal loads (electronic appliances such as PCs) plays a crucial role here.

4 Description of local systems

It is important to optimize generation and demand when planning local supply systems, weighing up between economic and ecological objectives and demands for secure and reliable supplies. This latter aspect has become increasingly significant in Germany as a result of the recent widespread power failures.

Today the heat demand is usually covered by oil- or gas-fired central heating boilers installed in the house. Other conceivable alternatives could be based on renewable raw materials, such as wood pellets. Electricity demand is normally covered by power supplies from the public grid.

4.1 Operating methods

In local energy supply systems, the power demand can be covered to a certain extent by CHP units installed in the house. The heat generated at the same time is used preferably for the building's central heating system. Various different operating methods are possible:

- Heat-governed mode: this is based on the local heat demand. Electricity is produced as a side product and either consumed locally or fed into the grid, depending on the load situation. Heat demand is relatively static in contrast to the power demand, so that this type of operation has no special dynamic requirements.
- Power-governed mode: this is based on power demand (local demand or from the grid). Heat is the side product that should be utilized locally where possible. Given declining heat demand, systems with a high power/heat ratio are of an advantage here. In theory, excess heat can be fed to the environment by re-cooling systems, but this causes additional costs and is not appropriate along the lines of efficient operation.

For profitability reasons, CHP units are used primarily in the base load (e.g. heating service water). Supplementary peak load boilers are to be provided to cover peak heat demand (Fig. 2). The use of heat storage can be used to a certain extent to separate demand from generation.

4.2 Quality criteria for local CHP systems

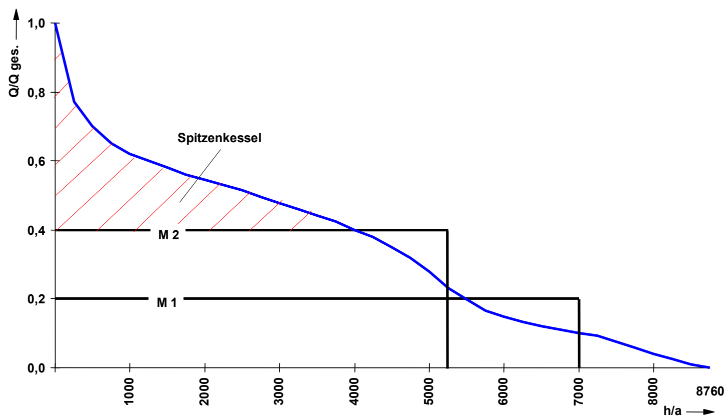

Fig. 2: Combination of CHP unit and peak load boiler

A concept for profitably covering demand at close proximity to the consumer presumes compliance with certain quality criteria. These include:

- Costs: the costs of generating electricity are crucial for acceptance by the customer. They are influenced by the amount of costs for investment, financing, maintenance, staffing and primary energy. The costs for the overall system can be far higher than the pure generation unit, as additional peripheral costs and expenditure have to be taken into consideration for the installation. These include among others fuel and heating system pipelines, but also noise control measures. Compared to large power plants, local CHP units with their modular design have the advantage that their capacity can be adapted to demand, thus avoiding surplus capacities. If there is a need to expand capacity, this is relatively simple. In spite of specifically higher costs, this results altogether in a lower investment risk.
- Efficiency factors: these describe the efficiency in converting the primary energy into power and heat. The electrical efficiency factor refers only to power, while the overall efficiency factor takes account of the sum of power and effective heat. In the electrical efficiency factor, it is important to distinguish between gross and net values. Only the net value also considers the power demand of internal consumption in a generation system, making it representative for the quality of the unit. Efficiency factors in the part load range of operation may be of interest for corresponding operation modes.
- Controllability/dynamic of CHP units: demand-oriented use asks for a fast reaction of the generation system as demand also changes rapidly.. Fast control processes can require load change speeds of even a few %/s. If this cannot be warranted by the generation system alone, then storage solutions have to be used in addition. In case of a fault, it must be possible to close the systems down quickly for safety reasons.
- Potential: availability of the primary energy sources is an important factor for the market penetration of local CHP units. Natural gas is available on a widespread basis and is thus currently the most frequently used fuel. In future, increased use of renewable energies (biomass and biogas) will also be possible. However, the question of the possible contribution and local availability of these energy sources is currently subject to highly controversial discussion.
- Emissions: the emissions depend on the primary energy source and technology being used. As a rule, innovative technologies such as fuel cell systems normally offer clear advantages compared to conventional technologies, with essentially negligible emissions of NO_x and SO_2. For all technologies, it applies that the higher the electrical efficiency factor, respectively the overall efficiency factor, the lower the specific emissions. However, not even fuel cells can avoid CO_2 emissions, as long as fossil carbonaceous fuels are used as primary energy source, such as natural gas. Only energy sources based on renewable raw materials can be considered to be CO_2 neutral.

5 Local supply structures

The definition of local supply structures covers a wide range. Starting from the smallest unit, a single family house, the system limits can be expanded to cover whole towns.

Designing local systems requires knowledge of the time-dependent demand for power and heat. Load curves are used for this purpose. They describe the energy demand of individual buildings or areas, depending on the individual time of day and year.

While the load curve for a single customer shows very high demand peaks for power and heat, superimposition of the individual load curves for several customers (e.g. in a housing block or on an estate) leads to a more constant demand. However, when it comes to heat demand, the morning peak is still clearly pronounced because of the simultaneity factory. Altogether, local supply of a large collective group, particularly a mixture of residential housing, office buildings and business properties, offers clear advantages over an individual supply. Load control possibilities can help to make demand even more constant or facilitate adaptation to the corresponding situation on the generation side.

The considered generation systems, for both power and heat, differ with regard to availability of the energy sources and thus predictability of use. While systems based on sun and wind have to follow the fluctuating supply, the use of other systems is geared extensively to the corresponding demand.

	Fluctuating supply	**Controllable**
Heat	Solar-thermal systems	Condensing boiler Biomass (e.g. wood pellets) Heat pumps
Power	Photovoltaic (PV) systems Wind turbines Small hydroelectric power plants	Geothermal systems
CHP		Combustion engines Micro-turbines Fuel cells Biogas systems

In both cases, storage systems are used to support the process and optimize the functioning of the units. But this current study only considers hot-water storage systems in the context of CHP units. Another ETG task force is currently examining the potential of different central and local storage systems: the study should be completed by the end of 2007.

The average annual consumption levels for thermal and electrical energy per accommodation unit differ fundamentally for different settlement areas. Where business properties are concerned, the total amount of energy consumption as well as the load curves vary according to the specific branch. Consumption is also estimated on the basis of the surface area being used. Various factors influence the level and the load curves for different time horizons (Fig. 3).

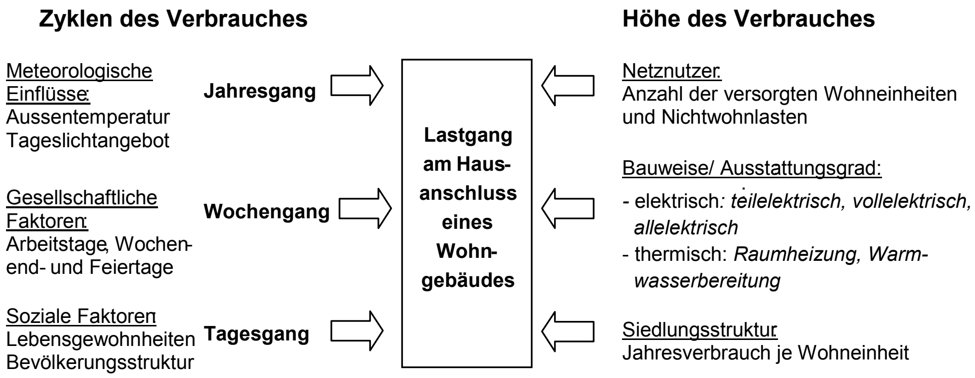

Fig. 3: Factors influencing the consumption of electricity and thermal energy in residential buildings

The potential for generating electricity and heat energy in settlement areas depends on a series of factors: if solar energy is to be exploited, then the building needs a suitable area for erecting the modules. In terms of economic efficiency, the suitability of the area depends among others on a minimum shadow and a south-east to south-west alignment. In residential buildings, these are usually parts of the roofs.

Within a residential estate, the effective solar potential is accumulated from all the buildings. Fluctuations in potential caused by the effects of clouds are superimposed in the same way, in contrast to fluctuations in energy consumption within the estate. In view of the fact that photovoltaic units in Germany are used primarily for feeding into the public electricity supply grid and thermal systems offer sufficient inertia, this local correlation is irrelevant in practice, although in weak electrical distribution systems it can cause considerable fluctuations of the supply voltage.

Just as with solar-thermal systems, heat-controlled CHP units also need simultaneous heat consumption. Intermittent decoupling from the heat demand requires the use of some form of heat storage. Storage solutions normally used in estates – a central tank for hot service water but no means of storing heating water in each building with partial electric supply – are currently restricted to the system limits "single family house" or "multi-family dwelling".

The integration of thermal loads to so-called local heating grids opens up the possibility of using a system of heat generators and storage units, optimized for the overall consumption of thermal energy (for heating the rooms and for hot water). In CHP units, the generation of power can be more or less freely controlled depending on the size of the heat storage unit. The generated power can be optimized for different objectives, such as minimizing peak load or grid losses within defined supply areas. However, with respect to pipeline losses, heat networks are only suitable in areas with relatively short connections between the consumers or in areas with high heat demand densities. The relatively high level of investment involved here makes it desirable to achieve the highest possible connection density.

5.1 Balancing groups

An arbitrary number of injection and/or withdrawal points are grouped together in a balancing group. The balancing group manager must ensure on the basis of predictions, which must be as accurate as possible, that the energy in his balan-cing group is balanced within every quarter of an hour. Deviations caused by prediction inaccuracies are billed to the balancing group manager by the responsible transmission system operator (TSO) in the case of insufficient injection, or remunerated for surplus injection. Billing is based on the costs incurred by the TSO in using control energy. If the balancing group manageer has contracted his own decentralized local generation unit (DG), then he can use these to minimize schedule deviations as far as possible. This can help to enhance the profitability of DGs.

5.2 Microgrids

Defined local supply areas, connected to the public grid in normal mode, can be operated independently of this grid when provided with corresponding technical equipment. They can be compared with conventional interconnected grids and are called microgrids.

Operators of microgrids are responsible for grid safety to the same extent as today's system operators. Normally the local generating units cover the corresponding demand. Connection to an overlying grid is a supplementary measure to ensure that the microgrid is still supplied even in the case of failure or non-availability of part of the decentralized generation unit (Fig. 4).

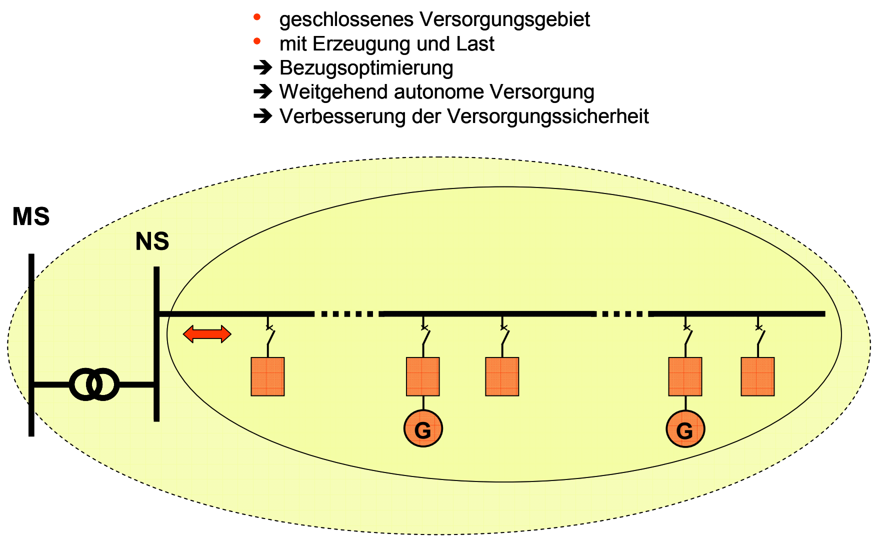

Fig. 4: Microgrid

On the other hand, this concept offers the possibility of disconnecting a microgrid from the remaining grid when there is a failure in the overlying grid, so that the microgrid can supply its own loads at least temporarily with the existing local generation units. Together with adequate generation capacity, this also demands highly dynamic control capability of the DG and new local control concepts, using modern information and communication systems.

5.3 Virtual power plant

Local power generators are currently not in a position to participate in power trading due to their low ratings. But an energy management system can pool such decentralized generation units, adding control and monitoring functions so that they form a virtual power plant (Fig. 5). They are comparable with large power plants and can participate in power trading, also making a grid-compatible contribution to the general energy supply. In addition, the pooling of DGs with a fluctuating supply and controllable DGs results in energy supplies on a more balanced basis.

The local equipment is controlled appropriately by an energy management system (EMS). The possibilities offered by modern information and communication technologies mean that this does not have to be limited to just local situations. A virtual power plant could also offer control energy on the market place, depending on the technical characteristics of the DGs.

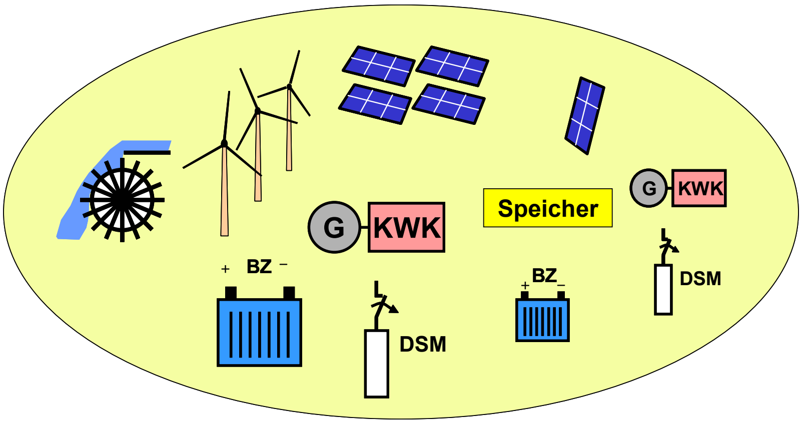

Fig. 5: Virtual power plant: many small units operate like a large power plant

Additional options consist in measures on the consumer side. Load shutdown or shift measures and, where applicable, also the use of storage facilities offer potential for further optimization.

5.4 Implementing local supply concepts

In principle there are no restrictions on implementing local supply concepts. Corresponding projects can be carried out by private persons, companies, energy and contracting companies, as well as established utility companies. The interest of the various market participants is geared to business optimization with exploitation of the leeway available in terms of legislation and prevailing market conditions (tariff systems, in-feed remuneration, tax exceptions or concessions, depreciation possibilities, subsidies, loan conditions, license fees, system usage fees, power trading, certificate trading, …). Supply via a contractor offers the chance of optimizing the supply task. By pooling demand, it is possible to make demand for electricity more constant in general, with lower specific demand from individual customers. As key account, the contractor also receives more favourable purchasing conditions for energy and equipment.

6 Support from information and telecommunication technologies

Widespread use of DGs in the distribution grid requires IT integration. This is a major challenge (Fig. 6). Up to now there are only very few communication systems for monitoring and control of distribution networks. Additionally innovation on the ICT sector takes place at far shorter cycles than on the energy sector. These aspects must be taken into account for a future efficient DG operation.

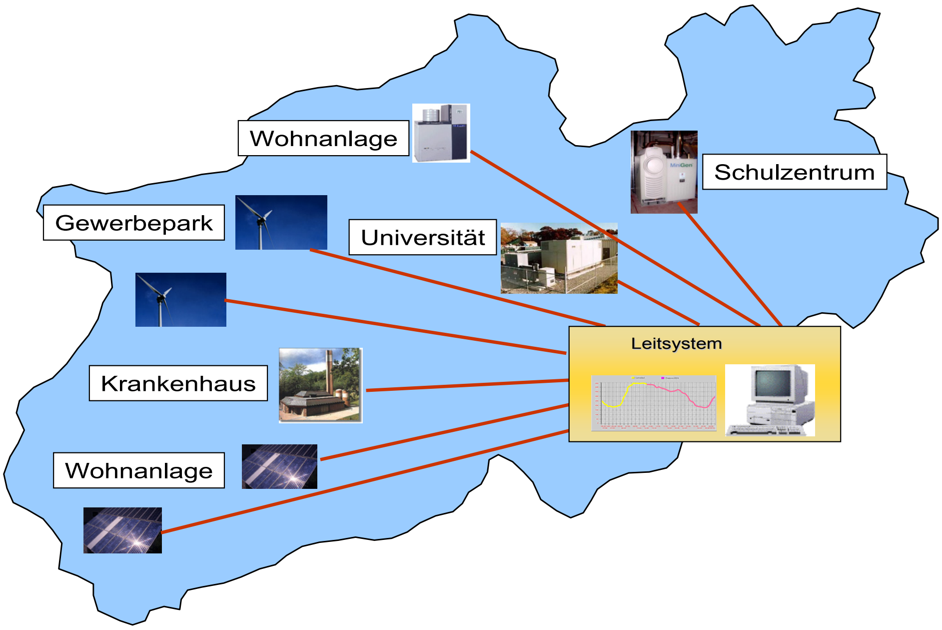

Fig. 6: IT network for DGs

The following variables have a significant influence on the requirements for DG optimization and communication systems:

- Widespread distribution in the grid
- Different generation characteristics
- Different manufacturers for the devices
- Different tasks of the units

Main tasks for communication will consist in:

- Supervision of the units
- Management of schedules
- Voltage and frequency control
- Emergency and disturbance management

6.1 Optimization systems

Optimized i.e. energy-efficient, minimum cost operation of the DGs requires energy management. A range of possibilities is available here, with differing levels of automation: from simple generation measurement via unit monitoring through to highly complex management systems.

The intelligence needed for this energy management task can be provided from a central system or also from a local source, each with differing impacts in terms of economic efficiency, availability and communication requirements. The decision-making strategies consider different business models for running the DGs, each with different demands on the communication systems. While simple low-cost local communication equipment is sufficient for local decisions, central solutions will need to meet higher communications requirements, but also offer more extensive scope for optimization.

For plants with larger capacity, the central decision strategy is usually more efficient. For smaller units on the other hand, there can be advantages in a local decision strategy where communication is limited to transmitting price and accounting data. An energy management system can facilitate both central and local decision strategies for the integration of different units.

The task of the energy management system (EMS) is to solve an economic optimization task under given boundary conditions. Even with intermittent renewable generation, energy management permits restricted planning of energy schedules. It takes account of generators, storage and consumer units together with existing contracts and options from the energy market. Optimization includes the following steps:

- Acquisition and prediction of the electric and thermal energy demand and of generation from renewable units.
- Calculation of schedules for controllable equipment (heat supply stations, CHP units such as fuel cell or gas turbine block-type thermal power plants, controllable loads, import/export contracts, storage facilities), taking account of general technical conditions.
- Online dispatch of the controllable equipment.

Energy management with a central decision strategy requires constant monitoring: if necessary, with short-term schedule adjustment, for example when using CHP units.

For smaller systems, local decision strategies are more appropriate in view of the disproportionate costs of communication. In this case, the central EMS provides a price indicator based on adapted current market power prices. This is then used for local calculation of an optimized schedule which can again be adapted in case of local events or by customer requirements. An efficient communication and trading system between the players on the power market is required for the integration of a large number of small scale units from independent customers.

The communication for energy management contains:

- Nominal values and switching commands for the generators and, where applicable, for the consumers (central decision strategy)
- Price indications and possibly temperature forecasts (local decision strategy)
- Measured and metered power values.

6.2 Communication systems

Fulfilling the energy management tasks requires a continuous data exchange between the particular equipment and the management system. However, at present there is only limited communication in distribution networks. On the other hand, due to an increasing share of local generation units and due to their increased integration in active network management larger quantities of data have to be communicated. A careful selection has to be made of which information is made available where and to what extent. The following sections look at some IT aspects for specific DG types.

DGs based on intermittent energy resources can normally be integrated in the system with unidirectional communication that does not need a permanent data link. Only the corresponding operating states and measured power values are transmitted. These data can be used for example to adapt predictions or as a database for coordinated operation of the DGs. Bidirectional communication is needed if a reduction of DG generation will be necessary in future due to congestion of overlaying transmission and distribution networks -as is already the case with wind energy - or for reactive power control.

DGs based on non-intermittent energy resources are influenceable in principle; limited however, if the network operator is not the owner of the unit. The communicational requirements depend on the control strategy selected. One possibility is the transmission of day ahead setpoints, which do not consider current operating conditions. In contrast to the advantage that no permanent data transmission is required, this approach allows no direct reaction in case of deviations from the schedule or to the behaviour of other units.

Coordinated operation of the DGs needs bidirectional data exchange in the monitoring and control direction. Setpoints are generated on the basis of the DG's current operating conditions, or in the case of a local decision strategy, depending on local parameters and the current price indication. It is possible to react to events at any time by adapting the behaviour of the units controlled accordingly, but, it also demands a mature communication system with high performance requirements concerning data throughput speed, error tolerance, availability and redundancy. While protection information has to be transmitted and processed within just a few milliseconds, the time for monitoring and control of DG can amount to seconds or minutes, or even hours in certain cases.

Different technologies are available for data transmission, depending on required performance, data volume and already existing communication infrastructure. However, the costs for operation and installation of the communication equipment must not exceed the management system's optimization potential.

7 Impact on the power grid

Today's transmission and distribution networks have been planned and erected on the basis of a unidirectional load flow from the power plants to the consumers. This could change with the increasing in-feed of electrical energy from DGs located close to the consumer. Power flow back into the overlying grid is conceivable. It must therefore be presumed that the DGs will have an impact on the overall network in all voltage levels (Fig. 7).

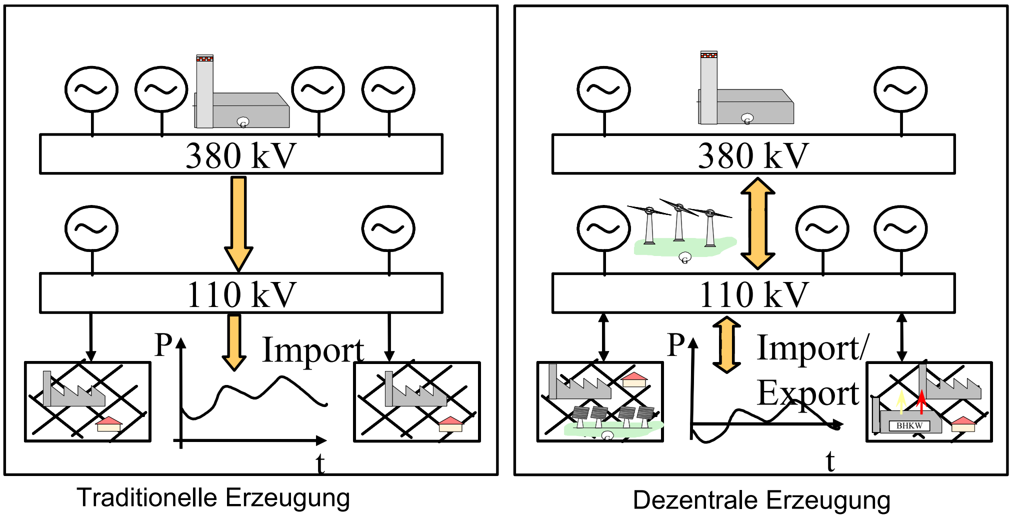

Fig. 7: Load flow with and without DG

Widespread use of DGs has impacts on the planning and operation of the electricity supply networks. The principles which had been used in the past have to be adapted to future requirements. While the impacts of individual DGs are known, hitherto there have been no verified planning principles or operating experience in the possible widespread use of DGs. The following aspects must be given particular consideration.

7.1 Short-circuit power

The short-circuit power present at a grid node is an important design criteria for the electrical and mechanical rating of the grid components. At the same time, it is an indicator for voltage stability and necessary for configuration of the protection systems.

DGs with conventional generators increase the short-circuit power; they can even bring existing grid components to their rating limits. On the other hand, DGs coupled to the distribution grid via power converters, e.g. PV units, only make a minimum contribution to the short-circuit power. This affects the protection concepts and can limit the possibilities for connecting high-power consumers and possibly other DGs.

7.2 Grid losses

DGs have a positive impact on grid losses, as the distances between generators and consumers are generally short. Grid losses are at a minimum when power generation

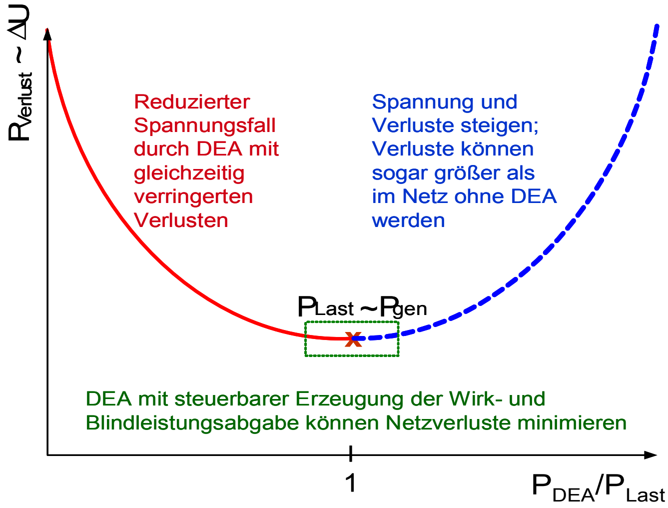

Fig. 8: Grid losses

and demand at a node are ideally exactly the same (Fig. 8). But the massive addition of DGs to a grid can cause power flow back into the transmission network with an increase in losses. In practice, the losses vary depending on the generation and load situation.

7.3 Plant and grid protection

Protection systems aim to eliminate or at least minimize damage to persons and equipment – including DGs – in the case of a fault. Fast, safe and selective fault clearing or disconnection of faulty grid sections or equipment must be warranted to this end. The simple safety systems used today are designed for unidirectional energy flow and adequately high short-circuit currents. Causes of faults are usually detected reliably with subsequent fast, selective disconnection.

Increased connection of DGs to the medium and low voltage grids has a profound, manifold impact on stationary and dynamic grid behaviour. New requirements therefore have to be set up for the grid protection concepts in terms of principles and parameters. This entails detailed studies of the performance limits of conventional protection concepts; where necessary, protection strategies and equipment have to be adapted to the changed generation structures.

In technological terms, a distinction has to be made between protection strategies with and without communication systems. Protection concepts without communication depend on new possibilities of analyzing grid information available at the location where the protection system is fitted in order to achieve enhanced sensitivity to changing generation conditions. Solutions with communication are based on protection principles with signal comparison. This entails adequately efficient, reliable and low-cost communication technology.

7.4 System services

The electricity supply areas are divided into control zones. System operators are responsible for grid control. The tasks include controlling frequency and voltage, reactive and short-circuit power, exchange of power with other supply areas and all other tasks involved in grid safety. These tasks are also referred to as system services.

With increasing grid penetration, DGs will also have to provide system services in the interests of safe grid operation. The following services are conceivable:

- Providing schedules and output smoothing
- Bottleneck management
- Maintaining voltage and voltage quality
- Providing reactive power
- Power control and maintaining frequency
- Providing reserves and reliability of supply
- Restoring the supply after faults

In technical terms, providing these system services makes great demands on the DGs. This refers in particular to dynamic power generation in order to satisfy the corresponding requirements.,In the future the integration in a suitable management system will be indispensable.

Last not least, it can be presumed that DGs will only provide system services if this is financially interesting for the DG operator. He must be able to achieve a greater yield than with the pure provision of real power or heat, taking account of the additional technical outlay involved.

7.5 Grid planning and investment

In theory it could be possible to operate a local supply area without connection to overlaying grids if the generation and the demand is locally and permanently balanced. But in fact in Europe there will always be a connection to a public supply grid as a redundant feature (apart from islands or remote individual supply solutions). This applies particularly to areas with a high level of fluctuating renewable energies. The question remains whether the grid equipment can be dimensioned for lower ratings.

Load removal in the grid is possible if the DGs contribute reliably to the local demand in due time. This can be supported by corresponding coordination of operations by means of an energy management system. If the location of grid connection and the operating mode of DGs can be selected in a suitable manner, it will be possible to prevent grid bottlenecks arising with local growth of the load. Thus the need for corresponding expansion of the grid may be avoided or delayed.

On the other hand, a high level of uncontrolled DG input can place a burden on the grid, with the need for grid expansion. It must be considered here that the grids generally have to be rated for the worst case, i.e. maximum load at minimum generation and maximum generation at minimum load. This also includes taking account of possible failures.

When evaluating potential for possible savings, consideration must be given to the long life-cycles of power supply equipment. Investment in new equipment is usually only made at the end of the life-cycle. It should be borne in mind that the investment costs for a transformer station do not decrease significantly by using a smaller transformer. Nor do smaller cable and line cross sections have a major impact on the investment costs, as the routing costs dominate. Altogether, it can therefore be presumed that the potential for savings is limited and only verifiable when looking at individual cases.

8 Operation of an overall system

When operating power supply systems, it is important with respect to an adequate quality of supply that power generation must comply with demand at every single moment. Together with adequate redundancy in generation, this also requires a sophisticated control system. While this used to be based on the outage of a large power plant, today it is wind energy which significantly affects the need for control. Inconstant wind levels result in fluctuating power generation with significant fluctuations in output. The grid operator has to compensate for the deviations between generation and demand, contracting suitable generation from power plants to this effect. Together with central power plants – including onshore and planned offshore wind parks – and various DG technologies, in future the grid management of an overall system will also have to consider controllable and switchable loads as well as storage systems. Furthermore the system operator has to respect existing contracts between the different parties involved (Fig. 9).

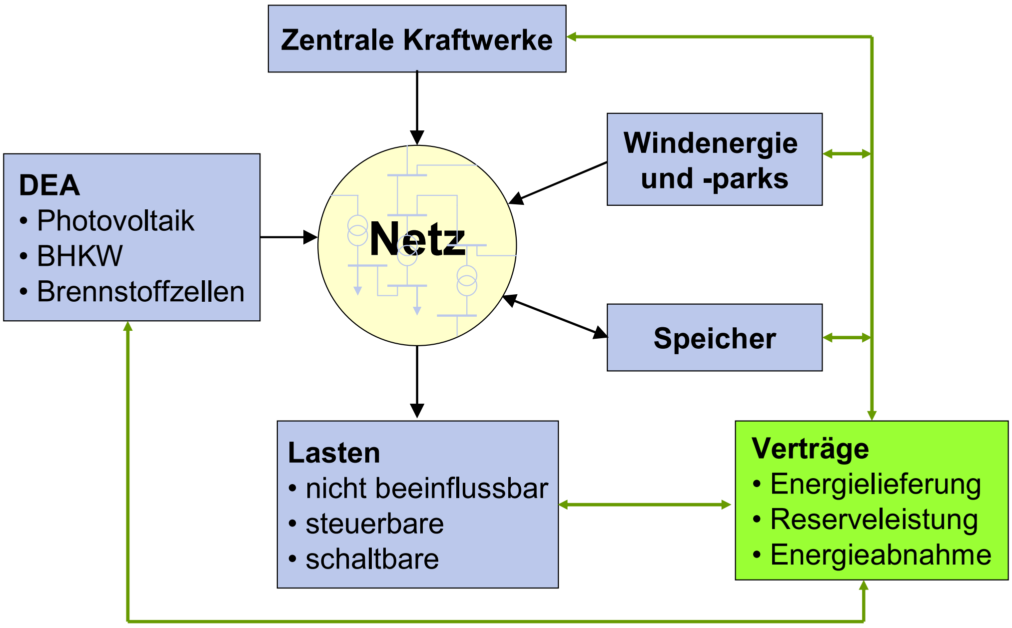

Fig. 9 Factors with an impact on grid management

Even under the most favourable conditions, the energy demand of a certain area will rarely be met by a corresponding local energy supply. In future it can therefore be expected that central and local supply systems will co-exist, with the widest possible use of the distributed renewable energy resources. Well developed power grids on all voltage levels are the prerequisite for a reliable power flow under the varying operation conditions.

In spite of improved prediction systems, it is indispensable to compensate for power deficits during the period in which renewable energy sources are not available. For this purpose controllable power plants are necessary. During the concerned time period of this study and in view of the dramatic expansion in wind energy, this role can only be played by conventional power plants, controllable DGs and storage systems.

Together with a control of the generation, in principle it is at least partly possible to adapt consumption to the available generation capacities by means of demand side management – DSM. This not only entails reducing consumption levels when there is insufficient generation but also shifting consumption demands, e.g. to cope with highly fluctuating generation.

DSM can be financially appropriate if it can help to avoid the need to build new conventional power plants. Heating/cooling systems are particularly appropriate here, which can be switched off for certain periods of time thanks to the relatively slow heat/cold flows and system-related availability of heat and cold storage capacities. This also includes heat pump systems.

Load management also includes recharging central energy storage facilities such as pumped hydro or compressed air reservoirs, or decentralized battery systems. A consideration of future hydrogen scenarios could also include suitable electrolysers in this control system.

The operation of an overall system therefore has to take account of the particular circumstances and requirements of the differing sub-systems, while at the same time meeting the customers' requirements. It must therefore be operated in such a way that it is possible to fulfil the demands for reliability, efficiency, ecology, sustainability, social compatibility, general economic considerations and a reduction in dependency on imports as far as possible in a European energy alliance.

8.1 Influence of distributed generation on the operation of large power plants

Power plants are planned for certain specific purposes, distinguishing between base load, medium load and peak load power plants. Their operation is geared primarily to the price of the corresponding prime energy being used, whether lignite, coal, oil, gas or nuclear fuel.

Today's power plants have been planned according to currently valid requirements. Up to now, no consideration has been given to the intensive use of fluctuating, renewable energy sources and to small, distributed generation. Development and expansion of the new technologies must be expected to have an impact on the efficiency factor and operation of thermal power plants. When planning to build a new power plant, it is therefore important to ensure that these aspects are taken into account by erecting suitable generation systems which are capable of operating at partial load and with fast-acting control systems.

8.2 Efficiency

Thermal power plants have their highest efficiency at the so-called best point, usually close to maximum output. The efficiency decreases rapidly with increasing partial load operation.

Fluctuating generation from renewable energy sources and the need to keep adequate power reserves available are modifying the operation of generation systems. Power plants are being used increasingly in ways which mean that they are not working on their optimum level. This results in an increased specific consumption of primary energy and higher specific CO_2 emissions.

8.3 Operations management

The increase in fluctuating energy and growth in local CHP generation means that power plants are increasingly being forced to frequently close down and start up again especially under low load conditions. This has consequences in the form of additional energy consumption, increased material aging, fewer full-load hours and therefore higher power generation costs.

These effects must be taken into account when evaluating the advantages of distributed generation. Appropriate consideration must also be given to the requirements for coping with distributed generation when building new power plants. Otherwise there will be an inevitable conflict in objectives between increased use of renewable energies, improving efficiency, decreasing emissions and reducing costs.

8.4 Significance of the grids in an overall system

The grids transmit or distribute the electricity generated in large power plants or small local units to the final consumer. The interconnected grid helps to optimize power generation in technical and economic terms and to fulfil the requirements for ecological and sustainable energy supply. An efficient grid covering all voltage levels is also a prerequisite to include some primary energy sources only available at remote sites. The resulting energy mix is the basis for more stable electricity prices.

Today's transmission grid was designed for consumption-oriented power generation: i.e. the power plants were built as close as possible to the load centres. But the liberalization of the power markets has brought about major changes in this respect. Large output quantities are meanwhile transported across large distances. The load flows from North to South as a result of wind energy input into the system are superimposed by load flows from East to West, or vice versa. Operational reserves in the grid are thus already today completely used up, to the detriment of safety, stability and grid losses in the interconnected system.

Global grid planning together with grid expansion and operation must therefore be geared to various different future generation scenarios. This also includes taking account of the general circumstances resulting from trading activities or extreme climatic conditions.

9 Economic efficiency of local systems

It is not appropriate to simply compare distributed energy systems with the existing structure, because of the manifold reciprocal effects. Such a comparison does not take account of the new supply options. In fact, an overall system is to be appraised which permits optimized energy supply, combining the possibilities and circumstances of both distributed energy systems and also central systems (including onshore and offshore wind parks). Alongside optimization in business management terms, such an appraisal must also bear in mind the consequences for the economy as a whole.

This latter aspect must evaluate how far the considered system meets the demands for ecology, sustainability, supply reliability, jobs and essential independence from energy imports. Consideration must also be given to the effect of incentive systems (subsidies for investment, in-feed remunerations, tax concessions, depreciation possibilities, emission certificates, …). While these are certainly important for a market launch, it is also interesting to see under which general conditions it is possible to dispense with financial support for the considered technologies.

9.1 Interests of the players

The players acting on the market have differing interests.

- The contribution made by the **manufacturer of the equipment** is limited just to his corresponding deliveries. His aim is to sell as many appliances as possible with high profit.
- The **owner of the equipment** and operator expects first and foremost to see a reduction in his energy costs, possible also an improvement of his supply reliability.
- The **contractor** acts as investor and operator. He sells power and heat to his customers to earn proceeds to finance his outlay.
- The **grid operator** is responsible for the grid connection and grid operation. DGs should not have a negative impact on grid operation, but possibly provide support.
- The **balancing group manager** is interested in optimizing his power procurement transactions. Controllable DGs could help him to reduce his procurement costs and decrease the outlay for balancing energy resulting from schedule deviations.
- The **customer** expects the operation of DGs to bring his energy costs down, without any detrimental effects on the accustomed energy quality and supply reliability.

9.2 General conditions

The state sponsors environment-friendly DG technologies in the market launch phase with tax concessions or financial incentives such as the Renewable Energy Act (EEG) and the Combined Heat and Power Act (KWKG). A further contribution is supposed to come from additional regulatory measures intended to boost energy savings, such as the tax on electricity, for example. The introduction of CO_2 certificates, currently restricted to power plants > 20 MW, is also supposed to result in environment-friendly power generation.

9.3 Business management variables

The costs involved in generating power and heat with distributed energy systems depends on various factors:

Investments: compared to large power plants, DGs are presumed to have specific higher investment, but the single investments are far lower for the individual. In addition, the far shorter implementation times are also beneficial, together with the usually minimum amount of formalities and permits required.

Economic efficiency is based on the system costs. Together with the costs for the power generating unit and a generally needed peak load boiler, additional costs for erection, connection and integration must also be considered. The costs include:

- Foundations and building
- Exhaust system
- Power and heat connection
- Fuel supply
- Noise protection and
- Planning and approval costs

As a general rule, the corresponding costs must be estimated to cater for at least 30% of the investment required for the power generation unit. Additional costs are incurred in the integration of a management system; however, technology and price developments on this sector will result in lower costs in future.

Operating costs: the operating costs refer to the expenditure not covered by interest payments and energy costs, for example maintenance costs or insurance. As far as operations management is concerned, it can be presumed that distributed energy systems essentially require no staffing. Support is usually provided by service agreements. Integration of the smaller DGs in a remote monitoring system warrants continuous monitoring of operations.

Influence of the utilization period (full-load utilization hours): the utilization period of DGs based on renewable energy sources depends on the local energy supply. Wind turbines are said to have values between 1,500 and 2,500 h/a, solar units between 800 and 1,200 h/a.

CHP units with heat-controlled operation usually reach 4,500 h/a if used only during the heating period. When used for heating service water outside the heating period, values of more than 5,000 h can be reached.

In power-controlled CHP operation, system utilization depends on the corresponding load profile. To achieve the highest possible utilization period, the unit should be rated for base load. The pooling of different consumer groups, such as private households, industrial companies and offices, results in a high share of base load, thus increasing the share of CHP power.

Influence of the operating procedure: DGs are intended to replace conventional power plants. This presumes that they can be integrated in grid control. This requires power-controlled operation, corresponding dynamic operation of the units and communication systems. The additional income resulting from this operating procedure is offset by higher unit wear and lower electrical efficiency during partial load operation. The units can be used for an uninterruptible power supply (UPS) if necessary, but this also causes additional costs.

On the other hand, when dimensioned correctly, CHP units in heat-controlled mode can be operated with a high utilization period in base load, while at the same time profiting from low wear. But power control is generally not possible in this mode.

Parallel operation of a peak load boiler with a CHP unit also results in changed operating behaviour patterns of the boiler, compared to a pure heating system. This must be taken into account when evaluating the heat generation costs.

Primary energy costs: DGs running on solar, wind or water energy do not incur any energy costs, but generation depends on the fluctuating natural delivery.

In CHP systems, including those based on biomass, the fuel costs are a major factor in the power and heat generation costs. Although biomass is generally available locally, the price is still stipulated on the market and based on the price for natural gas.

Metering and billing costs: for private customers, today simple meters are used to register the consumed or supplied energy (electricity, gas or heat). The meters are usually read once a year. In billing terms this is a simple procedure, but does not offer the customer any incentive to shift his consumption to off-peak times. Additional meters are required for customers using special tariffs, e.g. for operation of a heat pump. Separate meters are also needed to register input quantities being fed into the grid.

On the industrial sector (special contract customers), so-called load curve meters are used for the electricity and gas supply. The meters for electricity distinguish between active and reactive energy and also register the absorbed power.

The costs for metering and billing are usually charged by the grid operator and are therefore part of the grid usage fees.

A possible provision of system services by DGs results in increased metering effort, with transfer of the necessary data to a management and billing system. Where applicable, the data are provided online.

9.4 Grid investment and the costs for grid use

Decentralized generation units are generally operated in parallel with the grid where electricity is concerned. The operator of a DG bears the costs for connecting the unit to a suitable node point in the grid. The costs for the necessary measures within the grid are paid by the system operator. The grid costs are financed by system usage fees, for which the system operator has to obtain the regulator's consent. Additional costs for feeding energy into the grid are not incurred in Germany.

In particular, the connection of units based on renewable energies presumes that the grid is designed appropriately, frequently triggering investment in the grid. Possible savings from controllable DGs, due to less grid expansion and avoided grid losses, are offset by additional investment for new protection systems and for information and communication systems. In general economic terms, consideration must also be given to the external costs, such as the emission of greenhouse gases.

When planning gas and heat grids, consideration must be given to the fact that declining demand for heating energy also results in a lower utilization level of these grids.

9.5 Influence of tariffs

Today's price for energy supplies (electricity, gas, heat) is based on at least two components: an energy-related price for the delivered energy and the system usage (including license fees), together with a basic price for the provision of the necessary metering system and the related billing process. These are joined by taxes (tax on electricity and value added tax) together with levies as per EEG and KWKG. The statutory share in the electricity price already accounts for about 40 % today.

Political specifications intend to make a contribution to saving energy by implementing a reduced base price and a linear energy price. This results in a great discrepancy between costs and prices: although a power grid only generates practically energy-independent fixed costs, apart from the losses, the system usage fee has to be charged to a great extent on the basis of an energy-dependent price. This means that no grid usage fees are paid for self-generated and self-used electricity, although the costs for the grid are still incurred. In addition, this also results in revenue losses for license fees and taxation. Massive use of CHP units will have to result in a change in the tariff structure in the medium term. Industrial customers producing their own energy today already have special conditions for purchasing reserve power, because they generally do not keep redundant systems for cost reasons.

9.6 Proceeds

Fictive proceeds are generated today for CHP units particularly on consuming the self-generated electricity in substitution for expensive electricity from the grid. Surplus electricity is fed into the grid and remunerated according to the KWKG. In the case of electricity generated from renewable energy, the remuneration rates according to the EEG are generally so high that the total quantity is fed into the grid. These remuneration rates are constant for all load situations.

But in fact, the value of the generated power depends on the currently valid market price and on the corresponding situation in the grid, and is thus variable in time. Without EEG and KWKG, time-based metering and billing would play a crucial role in whether the equipment can be put to optimized use in a liberalized power market. This applies particularly as DGs are to participate in the provision of system services in order to support grid operation. Particularly DGs based on biomass as primary energy source could adapt their power production to demand by means of interim storage. Future remuneration models therefore have to take account of the type and the amount of the provided service (e.g. peak power or control power). The amount of remuneration is geared to the corresponding alternatives available on the market. Disconnectable loads are to be treated similarly to connectable generators.

Fictive proceeds also result from heat generation (heat credits) in contrast to the energy costs incurred in corresponding heat generation using conventional heating boilers (e.g. natural gas).

9.7 Competition situation on the electricity market

Business management advantages for CHP units result among others from today's structure of system usage fees and costs for balancing energy as compensation for the deficits in a balancing group. It is in particular the aspect of optimizing energy procurement and the possibility of generating balancing energy at low costs with decentralized generation units that will make local energy generation solutions interesting in future for local energy providers, such as municipal utility companies. But this presumes that there will be centrally controlled, grid-compatible energy in-feed according to the corresponding demand of a balancing group. On the other hand, uncontrolled in-feed could have negative effects on the grid.

These developments mean that the power grid is developing increasingly into a system services grid. Its primary task is no longer to transport energy but to provide balancing energy, reactive power and frequency stability. This requires the introduction of new tariff structures.

9.8 Competition situation on the heat market

CHP units produce heat as well as power. In district heating areas, corresponding poaching of customers can have a negative impact on the utilization and economic efficiency of the central systems. In addition, district heating systems need many customers to ensure that the heat power plants can run in an efficient base load mode particularly during the summer months.

This is detrimental to both business management and general economic objectives. From an overall economic and ecological point of view, it is therefore preferable for local CHP technology to be promoted in areas where it does not compete with existing district heating systems. These are primarily regions where the provision of district heating or construction of a completely new district heating grid is not envisaged for economic reasons.

CHPs also compete with renewable heat generation technologies such as solar-thermal systems and heat pumps. Although theoretically these systems could work well together – solar-thermal system in the summer, CHP in the winter – generally the solar-thermal systems have a negative impact on the economic efficiency of CHP units. This comes from the higher investment required for two systems, and the lower utilization period for the CHP, combined with lower proceeds on the power side.

Finally, the ever-improving thermal standard of buildings means that the use of available CHP units is not economically and energetically appropriate for example in low-energy houses, because the heat simply does not get used. To make use of this particular potential, new units need to be developed with lower ratings and larger power/heat ratio. Alternatively, heat pumps can be used.

10 Scenarios

The previous chapters have shown that as a result of technological developments and the changing energy markets, local supply systems can be expected to become increasingly competitive. In many cases, it should be possible for the supply tasks currently provided from a central source to be covered in future by local systems.

Prerequisite for positive developments in this context is that the local systems need to be competitive in energetic, ecological and economic terms compared to a central energy supply. The following sections will evaluate these aspects on the basis of fictive mixed settlement areas.

10.1 Description of the areas / supply concepts

The study areas each measure 1 km² in size. Two different settlement structures are considered:

- HV: inner city area, densely populated, building structures up to 4 storeys high.
- DB: suburban area, sparsely populated, building structures up to 2 storeys high.

Both study areas are presumed to have mixed use with 60% housing, 10% industry, 10% offices and 20% retail trade.

In the context of various scenarios, 5 different supply concepts are compared for each of the two areas:

A - E Supply with local heat grid and large generation units

A: Conventional supply with electricity from the grid and natural gas boilers
B: Heat-controlled block CHP units combined with natural gas peak boilers
C: Power-controlled block CHP units combined with natural gas peak boilers
D: Hot water provided by solar-thermal systems, natural gas boilers and power from the grid
E: All heat demands supplied by heat pumps, power from the grid

The following presumptions apply to the variants:

- Variant A: corresponds to a conventional supply structure.
- Variant B: rated for a CHP share of 30% heat output; the share of generated output is limited to 80%. Surplus electricity is fed into the public grid, remunerated at conditions negotiated as on the exchange.
- Variant C: the units are operated to essentially cover the local demand for power. Hot water tanks are used to store surplus heat.
- Variant D: 60% of heat required for service water is provided by solar-thermal systems. The corresponding solar-thermal heating capacity (investment) is estimated at around 10% of the installed heating capacity. Additional provision of heat by solar-thermal systems is neglected.
- Variant E: based on the presumption of heat supplied by electric heat pumps, monovalent operation with up to 2 hours interruption in the power supply.

Coupling into a local heating system allows for a solution with a smaller number of larger systems but running at specifically lower costs, compared to individual supply. But for redundancy reasons, at least 8 systems are chosen here each with at least 2 generation units, so that for the CPU systems operating in this interconnected fashion, there is no need to purchase reserve power from the public grid (Fig. 10).

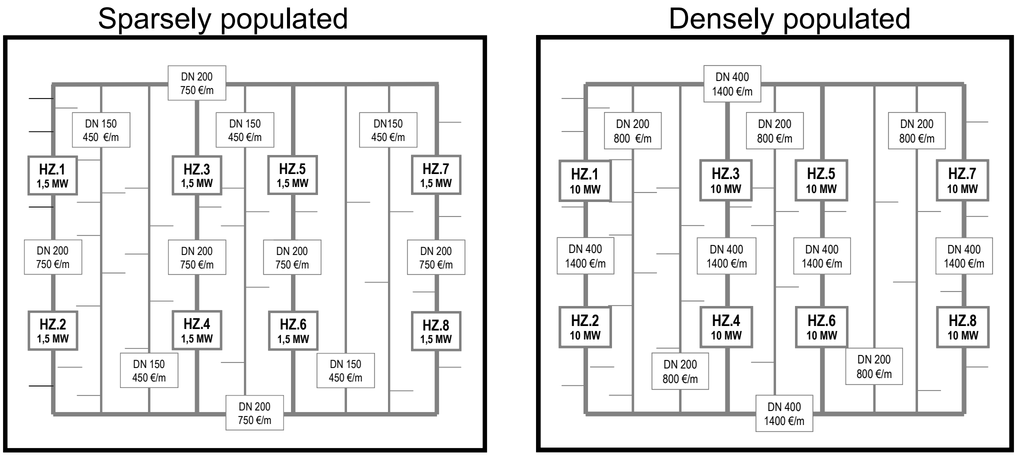

Fig. 10: Local heating scenario for the supply areas

Investment for the heating grid has been based on installation of the systems under the roads, differentiating between main transport pipes, distribution systems, building connection pipes and corresponding transfer stations. Line losses of the local heat distribution system are set at a flat rate of 5%.

All variants were also examined without integration in local heat grids (variants VA – VE). This is based on a correspondingly large number of smaller generation units; this is taken into account in specifically higher investment costs.

Therefore a total of 20 variants have been examined: 2 different supply areas each with 5 supply concepts, broken down again into versions with and without local heating grid. Power generation using renewable energies is only included indirectly by presuming that in future, natural gas will be replaced at least partly by biogas.

For power from the public grid, it is presumed in the reference year 2006 that there is an average generation efficiency factor of 38% and 5% grid losses.

The economic feasibility studies have not taken account of possible economic advantages from receiving subsidies, tax concessions or grants. This also applies to the electricity and natural gas prices: electricity is based on the net values (i.e. price for electricity without taxation and fees); natural gas does not take account of the advantages of being exempt from mineral oil tax.

A special tariff applies to power supply for heat pumps (WP), as currently offered by the power utility companies. This considers the supply via disconnectable power delivery contracts which justify a corresponding price discount.

Grid usage fees for the use of electricity are included in the electricity prices. Where areas are supplied by operating companies, consideration is given instead to the costs incurred when the operating companies provide the area with their own power line system. The capital costs are supplemented here by costs for maintenance of the grid and for power meters.

A profit margin of 10% has been estimated for the operating companies. This is already included in the electricity price for power taken from the public grid.

The studies have been based on 2006 as reference year. The effects for the year 2020 have been calculated by extrapolation. The study looks in detail at the effects of various different developments. Reductions of up to 50% in heat demand are considered possible by 2020 as a result of energy-saving measures. As far as CO_2 emissions from large power plants are concerned, it is presumed that this will be compensated at least in part by the effects of decommissioning nuclear power plants and constructing more efficient power plants.

The following is assumed for the year 2020 with regard to the results presented below, as felt to be probable by the members of the working group (changes relative to 2006):

	Development 2020
Heat demand	-50 %
Power demand	+10 %
Need for investment	-10 %
Gas price	+50 %
Electricity price	+30 %
Power plant efficiency factor	+10 %

10.2 Results

10.2.1 Consumption of primary energy

The results (Fig. 11) confirm that regardless of the settlement structure, local systems will provide energetic advantages compared to central supply. These advantages result on the one hand from combined heat and power supply, and on the other hand from the use of environmental energy, using either so-called solar-thermal heat systems or using heat pumps.

The energetic advantage is particularly clear for heat-controlled CHP units. The power generated locally in the CHP replaces corresponding quantities of electricity from large power plants with poorer energy utilization. However, this effect decreases with the fall in heat demand in 2020, with corresponding lower levels of power generated. The results also show that local heating grids only make energetic sense in combination with heat controlled CHP units.

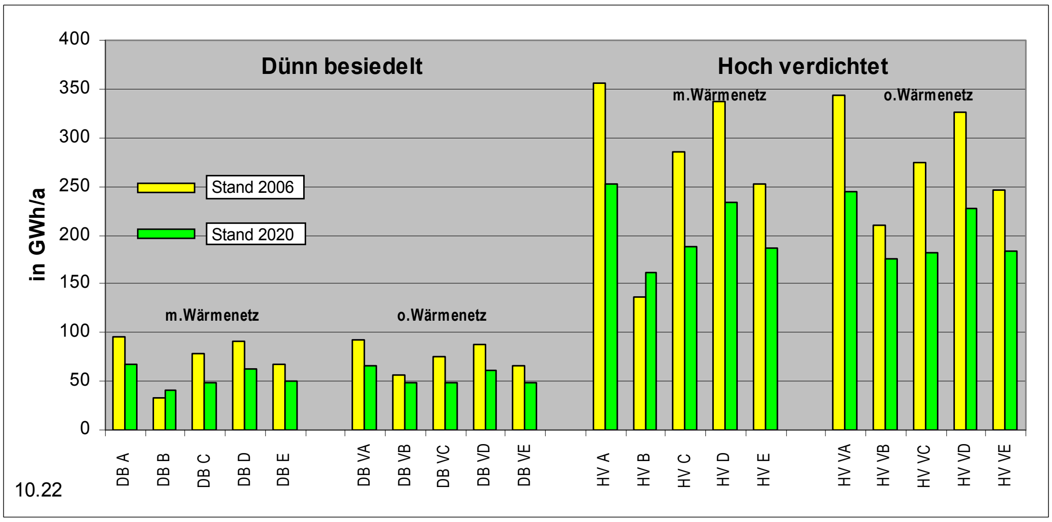

Fig. 11: Consumption of primary energy

10.2.2 CO_2 emission

Emissions are evaluated for 2006 on the basis of the average CO_2 emissions of the power plants. Together with the high energy utilization level in the CHPs, another advantage of local generation in terms of emissions is that natural gas is used, while central power generation is based primarily on lignite and coal. Similarly to primary energy consumption, here it is in particular the heat-controlled CHP units which profit (Fig. 12).

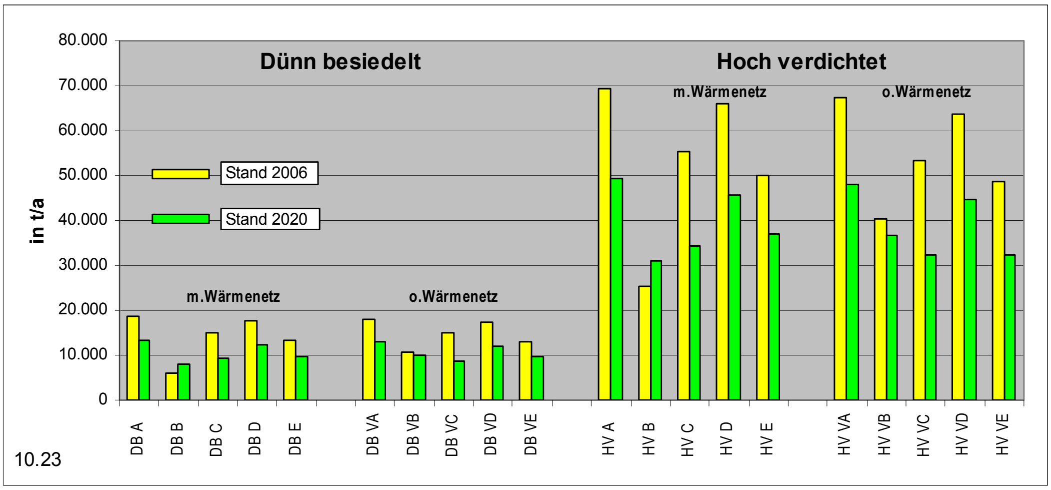

Fig. 12: CO_2 emissions

Decreasing heat demand produces a shift in this picture, with advantages for power-controlled CHP systems presumed for 2020.

10.2.3 Investment

Investment is the lowest for a conventional energy supply (variant A) for system inherent reasons (Fig. 13), as the expenses for local power generation do not apply here. For CHP units, the power generation share is the highest for heat-controlled systems, with total investment on a correspondingly high level.

Decreasing heat demand in 2020 results in correspondingly lower investment for all systems, in spite of the costs for heat pumps incurred with the heat probes in the earth. For densely populated areas, this investment can be reduced by heat-related grids but without any sustainable effect on the fundamentally high costs. Otherwise, local heat grids only bring advantages in terms of investment for power-controlled CHP systems and densely populated areas.

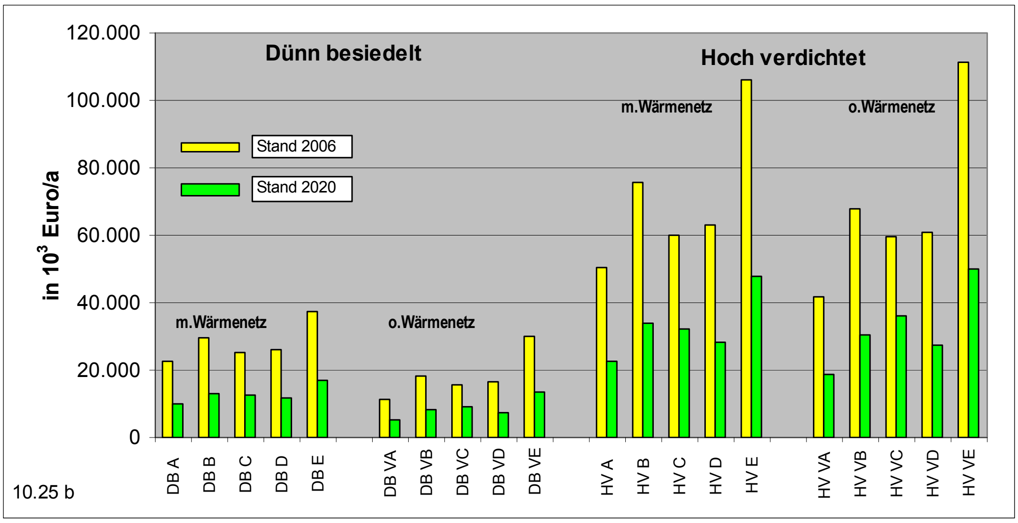

Fig. 13: Investment

10.2.4 Total costs

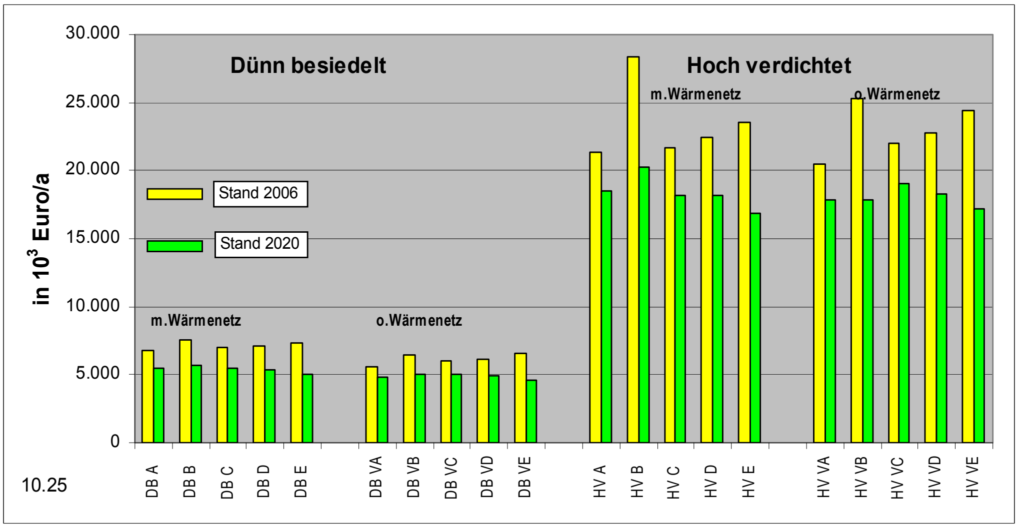

Fig. 14: Total costs

The total costs (Fig. 14) include not only investments but also energy and electricity prices, together with other operating costs. This once again confirms that the power-controlled operation of CHP systems currently offers economic advantages compared to heat-controlled procedures. As heat demand falls, as presumed for 2020, the costs for the CHP systems are expected to come closer together.

Although heat pumps are inferior to all other variants in terms of pure investment, the total costs show the advantages of using geothermal energy. Today already the heat pump is on about the same level as the other variants when it comes to supplying sparsely populated areas. By 2020 it can be expected to operate on a competitive scale under the assumptions made here.

The results confirm that local heating systems offer advantages at the most in densely populated areas. But this does not apply in every case: local heating systems cause higher costs particularly for conventional supply and heat-controlled CHP systems, although other results can be obtained in isolated cases.

The costs for CO_2 certificates have not been considered in the overall costs yet, as the price for CO_2 certificates is currently highly volatile and not used on a standard basis. When including this factor, conventional supply in particular will be faced with corresponding additional costs.

11 Summary and outlook

This study has examined the options for an increasingly local energy supply. The results show that the local energy supply can make a contribution not only to optimizing the supply situation on a local scale. In fact, exploitation of the technologies that will be available in the future will see local and central systems complementing each other with regard to generation and grid operation.

The main results are as follows:

- Central and local supply concepts must supplement each other in an appropriate manner. This is the only way to make best use of energy sources available at long distances (e.g. wind) while offering potential to compensate for fluctuations in the generation on a wide scale.
- A consideration of local supply concepts must take account of the heat demand and alternative concepts for providing heat.
- The use of renewable energies together with the highly efficient combined generation of power and heat in CHP units offers great potential for saving primary energy resources and CO_2 emissions.
- Local use of locally generated power reduces grid losses.
- Local heating systems offer advantages at the most in densely populated inner city areas.
- A more constant heat demand throughout the year is favoured by the installation of CHP units. A decrease in heat demand brings the investments down and favours economic efficiency. CHP systems with high power/heat ratio will offer more advantages in future.
- In the summer months, surplus heat could be used in absorption-operated refrigerating systems.
- Alternatives based on biomass can help to compensate for the dependency on gas imports and increasing gas prices in the long term.
- Different concepts for local energy supplies compete with each other.
- Electricity prices and their structure have a major influence on the competition position of differing supply concepts.
- Energy management systems can optimize the use of different systems with regard to corresponding demand and the attainable proceeds. Such concepts must include the possibilities for load control.
- The power supply grids are to be adapted to increasing in-feed from DGs. Possible savings are however offset by additional costs.
- DGs are expected to participate in the provision of system services. Suitable remuneration systems must be developed to this end.
- The operation and planning of large power plants must take increasing account of fluctuating energy generation (more control power instead of basic load).
- The role of storage systems and available technical possibilities have only been given marginal consideration. These issues are being dealt with in a new ETG task force.

- Local supply concepts open up possibilities for new business models. Contractors in particular are expected to see the greatest chances of participating in the market by providing energy services.
- In the current market launch phase, local supply systems are generally not competitive yet and need efficient support measures.

The VDE with 34,000 members, including 1,250 companies and 7,000 students, is one of Europe's largest technical/scientific associations. Its system is unique all over the world: the VDE combines science, standardization and product testing under one roof. The VDE's areas of activity are technical know-how transfer, research and promoting young researchers in the key technologies of electrical engineering, electronics and IT together with corresponding application. The VDE is committed to a better innovation climate, modern training and education in engineering and a high technical acceptance.

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