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Summary of the Position Paper

Centralized and decentralized components in the energy system

The right mix for ensuring a stable and sustainable supply

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A mix of centralized and decentralized technologies is the only way to ensure a climate-friendly, secure and economic energy supply. The challenge is to integrate the individual components to create a **functional overall system**. The "(De)centralized energy supply" working group of the Academies' Project "Energy Systems of the Future" makes the following proposals to this end:

- **All potential for expanding wind and photovoltaic systems** must be exploited if Germany is to be able to be greenhouse gas neutral by 2050. Photovoltaic systems on roofs and building surfaces, dual use such as wind or solar energy and agriculture, offshore wind energy and energy imports can alleviate the land-use conflicts which occur.
- In the absence of **transmission and distribution grid expansion,** the energy transition will fail, irrespective of whether the energy system has a more centralized or a more decentralized orientation. If grid expansion progress is slow due to a lack of acceptance, **decentralized approaches** can help to ensure that renewable energy expansion targets can nevertheless still be met in the short to medium term.
- **Digital applications** are essential for **efficient control** of the energy system. The more decentralized is the energy system, the more stakeholders shape it and the greater is the complexity. **Smart distribution grids** interconnect electricity generation plants, storage systems and consumers.
- A new, **streamlined regulatory system** can promote **innovation** and enable **system-beneficial prosumption**. Locating and operating renewable energy plants in a grid-beneficial way saves costs for additional grid expansion.
- The energy transition can only succeed if it is actively supported by the population. **Opportunities for political and economic participation** may be of assistance here.

Comprehensively expanding renewable energy plants and grids

Strengthening the expansion of renewable energy plants

Considerable time pressure applies to the transformation of the energy supply: the energy transition can only succeed if **renewable energy sources** are **expanded** distinctly faster than they have been so far. While costs for wind and solar energy plants have indeed fallen significantly, there is currently considerable local resistance to expansion of onshore wind energy and grid expansion. An **astute mix of centralized and decentralized technologies**, both onshore and offshore and in the north and the south, will be required if the power needs of the future are to be met climate-neutrally without intensifying conflict with nature conservation and residents. The following measures may be considered for **environmentally and socially responsible expansion** of renewable energy sources:

- **Decentralized photovoltaic systems in already built-up areas,** in particular on roofs and building surfaces, are accepted by the majority of the population and should therefore be further expanded.
- At the same time, large **solar farms** can help to generate electricity at low cost. "Agro-photovoltaic" systems could alleviate competition for land use with agriculture. These systems involve installing the solar systems higher above the ground so that agriculture can continue underneath.
- **Offshore wind energy** has the advantage that the plants have almost no impact on citizens' everyday lives. Major grid expansion is, however, required. Further research should be conducted into the environmental impact of offshore wind energy.
- **Energy imports** help to make use of synergies and also reduce the expansion of renewable energy plants in Germany. The European integrated grid here enables cross-border power trading and balancing of fluctuations.
- **Regionally differentiated market-based incentives or grid-fees** lead to regional expansion of renewable energy sources which is better coordinated with grid expansion.

Implementing grid expansion

Transmission and distribution grid expansion is essential to a successful energy transition and will still be required even with a highly decentralized energy system. If **transmission grid expansion** is delayed, decentralized solar systems in combination with storage systems and power-to-gas technologies can assist in nevertheless meeting climate targets. Decentralized battery banks operated by households can balance the fluctuating feed-in from wind and solar systems for a few hours. Calm spells with low light lasting several weeks can only be bridged with chemical energy carriers such as hydrogen or methane, which can only be produced in relatively large, more centralized plants. Since storage systems are still very costly, **research into reducing storage technology costs** should be intensified.

The higher the level of decentralized power feed-in, the greater is the need for power generation and consumption balancing in the **distribution grid,** something that, among other things, control of new flexible consumers such as electric vehicles and heat pumps can help with.

Digitally controlling and system-beneficially operating the energy system

Securing digitalization

An increasing proportion of decentralized components is making the energy system ever **more complex** and **interconnected:** the more generating plants, storage systems and flexible consumers there are in the system, the more difficult they are to coordinate. Increasing levels of **sector coupling** are also making a contribution.

Predominantly decentralized systems are more difficult to coordinate than centralized energy systems because there are more stakeholders. A high level of automation is indispensable if such systems are to be efficiently controlled. **Digital applications** such as artificial intelligence and autonomous and self-learning systems can make a major contribution here. Above all for small **prosumers** such as households, **low-threshold access** to secure information and communication technologies (ICT) is crucial. **Smart distribution grids** likewise play a major role in systems with a decentralized orientation.

Digitalized energy systems do, however, also involve **risks**: they offer greater scope for attack from cybercriminals, and the possibility of autonomous systems unintentionally acting against one another and potentially destabilizing the energy system cannot be ruled out. The emphasis should be on limiting harm in the event of attack or malfunction. Multilayer structures and decentralized cells which are capable of decoupling from the higher-level network and so maintaining a basic local supply boost energy system **resilience**.

Foresightedness is essential to digitalization because decentralized generating plants will in future have to make an ever greater contribution to stabilizing the overall system. Plants should therefore be equipped from the outset with the necessary **sensor and actuator systems,** so facilitating subsequent updates in response to changes to the regulatory framework. If, on the other hand, the appropriate hardware is not present, retrofitting is a highly complex, costly and protracted task.

System-beneficially expanding and operating plants and technologies

To ensure security of supply at all times and limit grid expansion, decentralized installations must be **operated system-beneficially**, so mitigating local grid congestion. This must on the one hand be enabled technically by providing suitable ICT for the plant and grid operators and on the other hand incentivized legally and economically by creating a regulatory framework for system-beneficial behaviour. **Local markets** for congestion management may accordingly counteract grid congestion. **Node-specific, time-variable pricing** furthermore make it possible to take account of grid congestion in the power price, but this does entail major power market reform.

At the same time, power generating plants and flexibility technologies should be **expanded grid-beneficially.** At present, renewable energy plants are in particular being constructed in northern and eastern Germany while their electricity is primarily required in the south and west of the country. **Regional components in the remuneration model** could ensure that greater account is taken of the grid situation during site selection.

Creating a stable regulatory framework for innovation and investment

Streamlining regulations

Stakeholders will only be prepared to invest in climate-friendly technologies if the right **legislative and economic framework** is in place. The regulatory system must therefore **promote innovation** and so create the foundation for environmentally responsible technologies, products and services. The current thicket of individual regulations should be replaced by a new, **slimmed down** regulatory system to allow the market to become a **"marketplace of ideas".**

Cross-sectoral CO_2 pricing as a key instrument for climate protection can contribute to achieving climate protection targets as inexpensively as possible. The CO_2 price must, however, be **sufficiently high** if it is to have a steering effect.

Supplementary instruments are furthermore required, for instance to allow modelling of external costs arising from land use-related conflicts. There is a need for measures such as **improved physical planning** which can boost acceptance of renewable energy and grid expansion projects.

Model calculations indicate that **more decentralized systems**, in which power is primarily generated and stored in small installations close to the point of consumption, will probably be somewhat **more expensive** than centralized systems, but the additional costs only amount to a few per cent. There has, however, so far been very little scientific investigation into long-term scenarios with comprehensively decentralized systems. **A broader range of energy scenarios** should be investigated and greater account taken of the **impacts on people and the environment** to permit a better comparison of centralized and decentralized systems. In addition, future studies must take greater account of distribution grids to ensure the cost comparison is meaningful.

Enabling system-beneficial prosumption

Solar systems on built-up areas enjoy the greatest public acceptance. Individual and collective self-consumption going as far as neighbourhood solutions could be facilitated in order to convince building owners to make their **roof areas** available for **photovoltaic expansion**. The European Union's Clean Energy Package offers some starting points here. In the long term, however, the focus on self-consumption is insufficiently ambitious because the aim should be to **make the most comprehensive use possible of existing roofs and building surfaces** for energy production, i.e. over and above own power requirements.

Prosumers should be able to use their self-generated power **system-beneficially.** The market should **enable various prosumption models** for this purpose without constantly creating new special arrangements or unnecessary hurdles for small stakeholders. At the same time the regulatory framework should be set up in such a way that **rapid intervention is possible** in the event of meteoric growth in prosumption having negative effects on the overall system. For instance, legislation could define a proportion of self-consumption installations beyond which the requirements for a **more system-beneficial mode of operation** become more stringent.

Enabling political and economic participation

Economic participation

The energy transition will stand or fall by the active support of citizens. **Local stakeholders'** participating financially in the wealth creation from renewable energy sources can have a positive impact on acceptance. A **countrywide Citizens' and Local Authority Investment Participation Act** could for example make a contribution, the advantage being that a level playing field is created for competition for all parties concerned across the country. Regulations specific to individual federal states, on the other hand, provide greater latitude for taking account of specific requirements at state level.

Further models of financial participation include **investment participation** by citizens and municipalities, an increase in business or property taxes and **special levies** payable by the operators to the affected local authorities.

Opportunities for political participation

Offering citizens opportunities for political participation at the various operational and decision-making levels will enable them to play an active part in shaping the energy transition. While public participation is already well established at a local and regional level, **participative processes** should be enhanced at **federal state and national levels**:

- The interests of the common good in physical planning can be represented in **citizens' assemblies by "lay planning assessors"** who are selected by sortition.
- A **debate about the energy transition spanning the whole of society** could elucidate the aims, systemic interrelationships and alternative solutions from various standpoints and so assist with developing socially acceptable and ethically responsible solutions for transforming the energy supply.
- Existing processes for participating in local planning and approval procedures could be improved by **better resourcing** and **skills development** for those involved.
- Informal formats such as **"round tables"** and **discussion platforms** can complement these measures.

There is furthermore a need for **new forms of initial and in-service training** for specialists because the increasing complexity of the energy system is presenting them with new challenges. For example, sector coupling is increasingly requiring **interdisciplinary knowledge** about energy production and consumption in the power, heat and transport sectors. **Data management** and **IT security** knowledge is also becoming increasingly important. Last but not least, knowledge in the social sciences and humanities, for instance in environmental psychology and political science, is becoming more significant for understanding and shaping the **social transformation process.**

A high level of **knowledge about the relevant systemic interrelationships** is required so all involved can participate appropriately. Scientists, planners and science journalists need to communicate their specialist knowledge still **more comprehensibly** in order to boost levels of public knowledge about climate protection and the energy system, because it is only if this knowledge is provided transparently and completely that all societal stakeholders will be able to make an active contribution to the success of the energy transition.

The Academies' Project "Energy Systems of the Future"

The Position Paper *Centralized and decentralized components in the energy system. The right mix for ensuring a stable and sustainable supply* evolved within the framework of the Academies' Project "Energy Systems of the Future". In interdisciplinary working groups, about 100 experts are working on different courses of action for the pathway to an environmentally sustainable, safe and affordable energy supply.

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