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Balancing Renewable Electricity

Energy Storage, Demand Side Management and Network Extension from an Interdisciplinary Perspective

Advance Publication of
Summary, Conclusions and Recommendations of the Correspondent Study of the Europäische Akademie GmbH

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Structure

Foreword

The design of future energy systems is currently strongly debated nationally and internationally. In Germany the debate was initiated by the government's Energy Concept published at the end of September 2010[1]. The discussion heated up again after the disaster in the nuclear power plant in Fukushima on March 11th 2011 occurred, leading again to significant changes in the concept. Hence, plans for producing a large share of electricity by using renewable energy sources gained in importance and urgency[2]. As a result of the recent discussions about future energy systems, large programmes have been launched to support research, development and demonstration of new energy technologies which may become relevant or deployable in the future. To a certain extent this development can be observed in nations all over the world.

At the beginning of 2009 the project "Energy Storages and Virtual Power Plants for the Integration of Renewable Energies into the Power Supply. Potentials, Innovation Barriers and Implementation Strategies" of the Europäische Akademie GmbH, funded by the German Aerospace Center (DLR), started. It concentrates on analysing new energy technologies like energy storage facilities, smart grid concepts, e-mobility and options for network extension. The final results will be published in a book entitled, "Balancing Renewable Electricity. Energy Storage, Demand Side Management and Network Extension from an Interdisciplinary Perspective" at the beginning of 2012. A public book presentation is planned for 2 February 2012 in Berlin (further information will soon be available on www.ea-aw.de).

In order to contribute to the political and scientific discussion occurring in 2011, the authors decided to publish parts of the study in advance. Accordingly, they present parts of the original summary and the chapter on conclusions and recommendations of the book that is in preparation. While the reader will be able to find the major results and messages of the study in the present excerpt, details on the analyses will be provided in the book.

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[1] See http://www.bmu.de/english/energy_efficiency/doc/46516.php ("The German government's Energy Concept").

[2] See http://www.bmwi.de/BMWi/Navigation/energie,did=405004.html ("Eckpunkte für ein energiepolitisches Konzept").

1 Background and Aim of the Study

An important aim behind the restructuring of Germany's and Europe's electricity systems is to reduce their environmental burden, especially with respect to greenhouse gas emissions. Emissions must be brought down to a level that is sustainable in the long-run and consistent with greenhouse gas emission reduction goals. Meeting these goals will require a system that will be able to cope simultaneously with the fundamental demands for economic efficiency, environmental sustainability and supply security. Making use of existing scenarios, this study sketches such a system. It focuses in particular on auxiliary systems for electricity production, such as energy storage methods and network extensions.

The study introduces technologies that can balance electricity in energy systems and that can serve as enabling technologies for the integration of large quantities of renewable energies in the power supply system. It begins with a discussion of normative aims for the future electricity system before continuing with a description of current policies and political developments and an overview of relevant existing energy system studies. These sections serve as background for the remainder of the study. They are followed by discussion and analysis of the growing demand for means to balance the fluctuations found in electricity generated in power systems with a high penetration of renewable energies, the potentials of diverse technologies, requirements for electrical networks, economic impacts and important legal issues. Finally, the main challenges to the achievement of developing balancing technologies and processes for renewable electricity-dominant systems are summarised and recommendations made. With respect to the legal regulations, the status quo as of April 2011 is assumed in the study.

This document is a condensed synopsis of the study to be published by Springer in February 2012 and consists of excerpts from the summary, the conclusions and the recommendations. Therefore, not all aspects are dealt with in-depth. The background and details of the analyses will be available in the final book.

2 Summary and Results

2.1 Aims for the Future and the Status Quo of Electricity Systems in Europe

The basic normative aims underlying this study of a future renewable electricity-dominated system are tied to the general economical principals of efficient allocation and just distribution. These principals are critical to characterising and evaluating policies and options that could become part of a future electricity system. Diverse economic discussions point to several trade-offs that exist among technical efficiency, low prices and environmental constraints. However, they also reveal that these trade-offs can be resolved by use of an action rule that is formulated on four priorities:

1. protection of the environment and, thus, society from unacceptable effects;
2. preservation of the total value of produced and natural capital;
3. maximisation of the intertemporal welfare of current and future generations under the restrictions of the first and second priorities; and,
4. just distribution of basics for meeting needs at present.

The action rule can be filled with content by applying indicators that evaluate technologies, policies and developments with respect to their environmental and societal aspects. The classification that was chosen for the evaluation of energy systems subdivides between protection of the environment, resource use and availability, and system characteristics with respect to society.

An analysis of the political processes in the last about twenty years shows the development and potential shortcomings of energy politics. Experts are worried about the potential unacceptable damage to the environment and society that could be caused by climate change. This has led to the establishment of limits on emissions of greenhouse gases. These limits have been defined politically by the international community. Experts' concerns are also the basis for the politically set quotas for energy produced from renewable technologies. Renewable energy's share of electricity production in Europe has shown large growth rates in recent years. This growth is expected to continue into the future. Still, there are many governance challenges ahead. For example, it will be necessary to encourage the international energy market, particularly in European countries, to strengthen technical infrastructure, and especially, electricity grids. It will also be important to assess to what extent Europe's rising competence in energy questions should be further extended. In addition, it will be necessary to find ways to address opposition to large-scale projects that may be acceptable from certain long-term environmental and societal normative perspectives, but may still encounter opposition among parts of society that object for various reasons to their development. This holds also for large-scale projects tied to technical systems that will be required for an expansion of renewable energy use. Adequate procedures for assuring stakeholder participation in decision-making processes will be essential.

Theoretical investigations about storing electricity as a means of storing economic value identify three options that can be followed to balance the demand for and supply of electricity in a system with a high amount of power produced from wind and solar radiation. First is to expand grid connections, particularly for transboundary transmissions, and to adjust the installation of wind and solar power to enable good potentials for the exchange of electricity in times of regional shortages. Second is to over-install conventional power plant capacity, for example, with natural gas-fired facilities, in order to be able to compensate a lack in supply. Third is to build options for energy storage and to introduce measures that can influence demand for electricity.

2.2 Existing Energy System Analyses

Continents are the appropriate scale for analyses of the technical and economical potentials for electricity systems that can balance electricity demand and supply at the regional level. Yet, in Europe, energy policy is still to a large extent seen as a matter of national sovereignty and competence. This means that for this interdisciplinary analysis, national energy scenarios and targets are primarily used. The case of Germany is taken as an example of a large nation in Europe with a strong economy and ambitious targets for the development of renewable energies.

A review of studies showed that two main methodological approaches are followed by policy-oriented analyses of electricity systems in Germany. For those analysing the time period of the next ten to twenty years, temporal exploratory scenarios building on economic optimisation mechanisms tend to be made. For scenarios that cover the present up to about 2050, a target system is typically defined and pathways for realising it are then analysed. Comparing the main scenarios calculated for Germany reveals the importance of being clear about the assumptions being used, using consistent parameters and carrying out further sensitivity analyses. This is crucial for purposes of interpretation and development of policy support based on the findings of the basically complementary studies.

The approach chosen for the system analyses in this study is: First, to investigate how a long-term viable energy system could be realised. This is to be done by analysing potential future scenarios where there is a high share of renewable energies in the system and low-carbon balancing strategies are employed. And second, to identify factors which can or should be adapted to realise adequate framework conditions for the innovation processes needed for achieving a long-term viable energy system.

It was beyond the scope of this study to develop completely new scenarios that include an energy conversion system. Instead, with the goal of concentrating attention on balancing technologies in systems with a high share of renewables, two existing scenarios have been selected as a starting point for analysis: the "lead scenario 2009" that follows a roadmapping approach (Nitsch and Wenzel 2009) and an explorative political scenario with ambitious environmental aims (scenario "III" from Lindenberger et al. 2008). Scenarios of the requirements for balancing electricity supply and demand are investigated for 2030 and "2040+"[3]. The analysis produced for 2040+ based on the outcome of the "lead scenario" shows that additional measures such as storage, peak load control or securing renewable energy imports will be required to realise a functioning power system.

2.3 Demand for Balancing Electrical Energy and Power when there is a High Penetration of Renewable Energies in the System

Looking in more detail into the technical characteristics of the two selected scenarios for representative days ("type days") in Germany with respect to the residual load, i.e., the load that could not be covered by the remaining controllable power generators in the system, reveals for the lead scenario a maximum temporal power deficiency in 2030 of 7 GW and in 2040+ of 18 GW. For 2030, the maximum temporal power surplus results are 13.7 GW and for 2040, 24 GW. Four TWh of electricity in 2030 (1.4 percent of annual total feed-in of renewables) and 21 TWh in 2040+ (4.7 percent of annual total feed-in of renewables) cannot be used in the system. These numbers show that there is a potential for using storage technologies.

The dimension that storage options should take is mainly determined by the additional power and energy required during wind calms. Analysing wind calms of several strengths and

[3] 2040+ represents a situation in a year around 2040 or later.

lengths shows that if these are to be covered only by storing electricity, storage power has to cover in total 18 GW in 2030 and 35 GW in 2040+. The energy capacity of the storage options in order to cope with the maximum energy demand has to amount in total to 600 GWh in 2030 and 1,700 GWh in 2040+. The dimension of the storage facilities is, in the 2030 scenario, determined by wind calms in which 5 percent of the installed power is not exceeded (in other words, at least 95 percent reduction) during 87 hours, and in 2040+ by long wind calms (218 hours) with at least 80 percent power reduction. The requirements could be lowered to the extent secured electricity can be imported. Assuming exemplary compressed air energy storages (CAES) and neglecting peak reductions in the calculation of generation costs, net-benefits from applying energy storage facilities can be calculated. The calculations show that reductions in generation costs, in the case of 15 GW additional storage power, exceed for the case of 2040+ the annuities of the investment, which means that using CAES with the assumed characteristics would be economical, even if the opportunity of getting peak prices is not considered.

Additional to this analysis of scenarios for Germany, a pan-European modelling approach was developed and realised during the study. It optimises the system of power production from wind and solar radiation, electricity network and energy storages on the basis of hourly meteorological data for seven years and technical and cost estimates for a future period around 2040 and beyond. Historical “burden”, in the form of already existing power plants, was neglected in order to analyse an optimised system without restrictions other than weather conditions, specific costs and available technologies. First model runs have been performed. The model mechanism relies on a genetic algorithm, optimising “individuals” specified by the various characteristics of the electricity system, expressed in cost values.

2.4 Technologies for Balancing Electrical Energy and Power

Looking at attributes of different technologies for balancing electrical energy and power reveals that the performance of a technology strongly depends on the specific situation for which it should be applied. Accordingly, technology options including storage technologies, as well as demand-side management and conventional power plants, can be categorised based on the following characteristics:

A) type and location of the systems,

B) duration and frequency of supply,

C) type of input and output energy.

Simulating the application for different typical cases allows the derivation of cost estimates, which can be projected to future years. According to the results of this analysis, the following can be said for the different analysed tasks. The assumed technical requirements are listed in brackets:

- *Long-term storage*

  (power:[4] 500 MW, available energy: 100 GWh, 1.5 cycles per month):

  For this task, costs of 10 €ct/kWh seem to be achievable using the option of storing electrical energy in the form of hydrogen, which is much lower than the estimated achievable costs for compressed air energy storage (CAES) (about 23 €ct/kWh). The potentials in Germany are high. In contrast, the option of pumped hydro is, with achievable costs of less than 5 €ct/kWh, much cheaper, but offers only small potential in Germany, and transferring electricity from outside Germany, e.g., from Scandinavia will prospectively require the expansion of transmission lines. In case an extra line has to be built for the storage option and the line is only used for this purpose, the total costs may reach the same level as those that could be achieved by hydrogen storage.

- *Load levelling in the transportation grid*

  (power: 1 GW, available energy: 8 GWh, 1 cycle per day):

  For this task pumped hydro plants are also interesting with the same cost values as for long-term storage. Additionally, compressed air storage technologies, especially the adiabatic variant with achievable costs also below 5 €ct/kWh, could become interesting alternatives. Furthermore, batteries can well be used for load levelling, although they are more expensive than the other two options. They show the advantage of being able to deliver also primary reserve.

- *Peak shaving in the distribution grids*

  (power: 100 kW, available energy: 250 kWh, 2 cycles per day):

  In this area, several battery systems, including zinc-bromine, vanadium redox-flow, lithium-ion, nickel-cadmium, lead-acid and sodium-sulphur or sodium-chloride are competing. The best guess, from today's point of view, would estimate the achievable costs for sodium systems to be the lowest, followed by the lead-acid technology, which is the cheapest variant at present.

[4] Charging/discharging power are set equal for the definition of tasks.

Additionally to the options that could be economical due to low specific costs, potentials from the double use of storage technologies, such as batteries for electric vehicles and small photovoltaic systems in houses, could also be relevant in the future. The total potential of demand-side management, including electric vehicles, combined heat and power plants, control of industrial load, heat pumps and white goods, is estimated to be around 16 to 23 GW theoretically and about 10 GW taking consumer acceptance into account.

Beyond the installation of storage options, the shutting-down of wind and solar power plants during extreme high supply peak events will still be necessary from technical, economical and legal points of view.

As for the future viability of storage systems, life cycle screenings of relevant technologies show that the expected large reductions of CO_2 in the energy system will lead to a higher importance of emissions generated in the production of materials. Due to high emissions of SO_2 in some important processes, ecosystem effects may gain interest.

With a much lower use of fossil energy resources projected for the future, the use and availability of mineral resources, particularly for the production and application of new energy technologies, including balancing technologies, will become increasingly important. An analysis of the availability of these mineral resources in terms of their reserve-to-production ratio, high regional concentration of reserves, and prices and price changes, shows that of the analysed substances only titanium is unproblematic. There are also only a few problems with availability for lithium, vanadium, arsenic, nickel and zircon oxide. Concerning mineral resources used in batteries, large-scale use of lithium type, lead-acid and vanadium batteries will require high recycling rates and potentially the development of substitutes in the long run.

Analysing a set of indicators gathered from relevant publications for system characteristics of balancing technologies with small modular systems provide a positive picture. In contrast, large central systems may be linked to problems of import dependency, may require large efforts to reach sufficient redundancy, and face acceptance issues in the local population. This suggests the importance of participatory decision-making processes. Additionally, adequate measures have to be implemented to keep the risk of accidents with sudden uncontrolled release of the stored energy low. In order not to hamper the development of options for balancing supply and demand of electricity at a high share of renewable energy use, implemented funding schemes have to be designed to be technologically neutral.

2.5 Electricity Network Aspects

Expanding the use of renewable resources for electricity production and using the balancing options discussed above also requires an extension of electricity grids. This concerns both the transmission and the distribution grid, nationally and internationally.

An investigation of technical restrictions in distribution grids shows that with the enabling of demand-side management, the capacities of distribution grids will soon be reached due to an increase in simultaneity of load. Breaching the operation boundaries can be avoided by coordinating load and generation in the distribution grid. In order to maximise demand-side management also with respect to maximal acceptance, automated procedures should be developed. The total costs of network reinforcements necessary with a penetration of decentralised controllable loads, which can be expected from 2020 onwards, are estimated to be about 1,000 € per household. These are high compared to the estimated annual generation cost savings of about 18 € per household.

Based on calculations for the transmission grid with typical days ("type days"), an extension of about 3,000 km or more is needed in the long run to cope with the regional shifting of feed-in towards substantial offshore expansion. However, this installation would be able to cope only with about 70 percent of the maximum installed wind capacity. In rare extreme situations in which wind power exceeds 70 percent of the maximal power, electricity generation will have to be curtailed to prevent damage to the grid infrastructure. Furthermore, extreme exchange of electricity with neighbouring countries is not accounted for in the assessment of required grid extension in this study. Other studies allowing extreme offshore feed-in and exchange result in a required expansion of about 3,500 km already in 2020.

Considering the current status and the anticipated advance of technology development, the most plausible technologies applied will be a combination of conventional overhead lines with high-voltage direct current (HVDC) lines. The investments in the long term (2040+) can thus be estimated, through calculations on the basis of type days, amounting to 6 to 8 billion €, or about 0.2 to 0.35 €ct/kWh of feed-in from wind power plants.

2.6 Economic Policy Options for the Use of Storage Systems

The theoretical analysis of potential problems in a market economy due to weather-dependent electricity supply and culturally caused demand fluctuations shows that several benefits can be gained from applying balancing options in the electricity system. An improvement of the cross-border infrastructure can help dampen the fluctuations caused by deliveries from regions with high supply/demand ratios to those with low supply/demand ratios. Suppliers as well as traders could be interested in operating storage systems. While suppliers will prospectively locate the systems close to the source, traders will tend to locate them close to customers. Grid operators ideally could locate storage facilities close to points in the network with high instability. However, the European Union's unbundling directive currently does not allow grid operators to operate energy storage systems to any significant extent.

The benefits for markets and society to be derived from energy storage facilities can justify policy intervention. With the use of storage systems, the stability of supply will be enhanced, environmental externalities – particularly those caused by climate change – will be reduced, monopoly power in times of scarce supply could be reduced by strengthening decentralised renewable energy systems, and the reliance on technologies with uninsurable uncertainty (nuclear power) can be reduced, or in the case of Germany, eliminated. For historical reasons, however, other technologies are being supported by governmental funding. Considering practical realities, funding beyond the currently provided support for research, development and demonstration projects is important.

2.7 Legal Analysis of Framework Conditions

There are several major legal issues with respect to installing strategies for balancing demand and supply of electricity which are brought to light by this study's legal analysis. The issues can be subdivided into: central storage systems and decentralised storage systems, including the options of demand-side management and smart grids, and the expansion of transmission networks.

With respect to central storage systems, in the cases of both current and pending laws, it is necessary to clarify whether the application of storage technologies applies to the supply layer or the grid layer. The legal classification influences how civil law applies to such issues as non-discriminating use and access as well as unbundling. Several disincentives and barriers to making investments into storage technologies can be identified in existing legislation. The actors most affected are the producers of electricity from renewable energies and the transmission system operators who are obliged by the German Renewable Energy Law (Erneuerbare-Energien-Gesetz (EEG)) to buy and market "renewable power". Additionally, a special planning regime for utilising underground resources could help to mitigate potential conflicts among the users themselves and between them and the respective landowners. In order to not hamper the development of energy storage technologies through legal regulation, disincentives should be abolished.

For decentralised storage systems, particularly e-mobility, smart grid and demand-side management, contractual issues related to the completely new actors and networks that will emerge will have to be defined. Such issues as duties of care, cooperation and information provision, as well as conditions of use will need to be addressed. The possibility that such technological systems could lead to the creation of far-reaching and extremely detailed individual mobility and energy use profiles requires consideration of the extent to which current legislation can deal with data protection concerns. This is especially the case considering the quantity and quality of data that will be collected as well as the new kinds of assessments, processing and use of that data which may occur. New solutions that could lie within or outside the existing legal framework for data protection will have to be assessed.

Current regulations covering procedures for the expansion of transmission grids are very diverse but also, in certain areas, dysfunctional. Most problematic appear to be the punctual investment duties of network operators tackled in civil court procedures, not adequately considering macroeconomic aspects (e.g., § 9 EEG). A more comprehensive and systematic approach is needed. For the national level, a fundamental reform model for strategic transmission investment projects could improve the situation. Some refinements and standardisation including, for instance, good practice guidelines for public hearing procedures may improve the handling of conflicts with the affected local population. The potentials for reforms on the EU level are limited. However, a better coordination on this level would be useful.

3 Discussion of Results and Conclusions

From the analysis, it is clear that various efforts must be made to change the current system. Expansion using renewable energy sources has to be supplemented by the further development and extensive implementation of auxiliary technologies. Following the assumptions of the scenarios with the highest penetration of renewable energies in the production of electrical power in Germany, in the period around 2040+ the power requirement for balancing supply and demand in the production of electrical power ranges up to about one-fourth of the peak power. According to different studies, an amount of up to about 1,700 GWh electrical energy is temporarily required to meet balancing needs. These gaps in the system have to be covered by CO_2-free or at least CO_2-poor options such as energy storage systems.

Peak power stations, various kinds of energy storage systems, load management as well as regional and transnational energy exchange are competing options to cover the demand of balancing power and energy. All of these options have pros and cons; there is no one solution that fits all requirements. There are various drawbacks to these technologies: peak power stations have low operation times making them costly, and they usually produce CO_2. Storage technologies are hard to predict for use in future scenarios, are typically quite expensive and their energy storage capability is limited. Load management is limited mainly to daily operations and will partly lead to restrictions of people's individual comfort, and the comparably low monetary benefits do not justify sophisticated control technologies. The balancing of electricity supply and demand throughout Europe will require huge extensions of transmission networks. The expansion of network infrastructure will require the acceptance of European society.

There are also many advantages to the various options: all of them are beneficial to a certain extent. Load management helps to lower peaks of residual power during the day, which means lowering the needed peak capacity and supporting a more constant operation of other production technologies. Peak power stations can easily be built and are flexible regarding their location. Storage facilities can use the peak production of renewable sources more or less for free, which means that less renewable energy is wasted. Regional and transnational balancing through transmission lines is an obvious option with moderate costs, which would in addition allow the building of plants to produce electricity from renewable sources at sites where they are most productive.

Technological progress will be needed in the following areas: First, load management could become feasible within the next decade through technologies such as smart metering. Load management has the potential to cover around one-third of the balancing power demand. A second option is inter-regionally compensating regional shortages of supply from renewable sources in Europe. This, however, is strongly dependent on the development of renewable energies in the different countries and of an adequate infrastructure. Around 10 percent of German peak power, i.e., one-third of the balancing power, could be covered under the condition that the transmission network will be extended throughout Europe. Third, storage capacities will need to be extended. Pump storage capabilities should be used wherever possible. Other storage technologies, such as hydrogen production without or with methanisation, could help to integrate the provision and usage of energy for different applications such as, for example, vehicles. The remaining capacity can be covered by peak power stations, primarily by existing fossil fuelled power stations that are granted a prolongation of their lifetime.

4 Challenges and Recommendations

The requirements for balancing electrical energy in the system will increase with the rising share of electricity produced from renewable energies. Several challenges arise with trying to use low CO_2 emission technologies such as energy storage systems to provide the stable electricity performance needed in different locations in Europe at different time scales from seconds to days and weeks.

In the following section, the major challenges identified in the study are listed and respective recommended actions derived from the analysis are presented. The section is subdivided into the aspect of technical infrastructure development (Section 4.1), framework conditions and organisational aspects (Section 4.2), including market conditions (Section 4.2.1) and support for the application of balancing technologies (Section 4.2.2).

4.1 Development of Technical Infrastructure

Challenge 1: Providing Sufficient Storage Capacity for Germany

The potential for extending storage capacity for use in the electricity system by expanding currently used technologies, and particularly pumped hydro, are very limited within Germany. They are likely to be insufficient to cover the needs of a future energy system with a high penetration of renewable energies in the electricity sector.

Recommendations:

Storage mix: Central storage technologies should be supported by applying demand side management (DSM), decentral storage structures and vehicle-to-grid systems where possible and economic. Network restrictions may require coordination of the different options.

Networking: Potentials in other countries, such as pumped hydro from Scandinavia, should be further developed, extended and used Europe-wide.

Over-installation: It should be analysed to what extent other measures, such as implementing overcapacities of plants using renewable energy for electricity production, together with larger exchange of electricity between regions, could be installed or wind and solar power plants could be shut down temporarily, as alternatives to applying energy storage.

Analysing further options: Alternative storage options should be further analysed. For instance, the gas network should be investigated for its storage potential, including the potential for hydrogen and methanised hydrogen production and usage.

Avoiding disincentives: The existing regulatory framework entails several disincentives or even legal barriers, both for producers of electricity from renewable sources and transmission system operators, which are obliged by the German EEG to buy and market "renewable power", to investing in storage facilities. Such legal disincentives must be abolished in order to convert power storage into an option to optimise the feed-in or marketing of "renewable power" according to market signals.

RD&D for cost reduction: Promising storage technologies should be developed further and their costs should be reduced in order to increase the storage potentials within Germany and Europe.

Challenge 2: Realising Technical Potentials of Decentralised Options

Load management or demand-side management respectively will have limited potential due to lack of user acceptance and low monetary incentives.

<u>Recommendations:</u>

Automation: Automated technical solutions to control loads without restriction of user comfort should be developed. The focus here will be heating and cooling systems and electric vehicles in the private sector.

Flexible tariffs: Flexible tariffs should be introduced to increase the awareness of the temporarily changing value of electrical energy from volatile renewable sources.

Minimising data requirements: The amount of required data about the electricity consumption of individuals depends strongly on the conceptual realisation. These data collection requirements should be minimised in order to prevent scepticism concerning data protection conflicts. Additionally, adequate data protection regimes should be installed.

RD&D – standardisation: Smart metering technology needs to be standardised, taking into consideration the mechanisms for automated load management including charging control of electric vehicles.

Challenge 3: Managing Environment and Resource Use

Mineral resource availabilities and the relevance of environmental aspects change over time and may hamper the development of the required balancing technologies and their long-term application. In particular, modular battery technologies are highly constrained by the need to use specific mineral resources, which may not be produced sustainably and for which some production processes show relatively high environmental effects.

<u>Recommendations:</u>

Green design: During the technology development phase, hindrances to large-scale application arising from resource use and environmental effects should be anticipated, bearing in mind the entire life cycle.

Monitoring resource use and market: The specific resource requirements of chosen technologies and the respective markets should be continuously monitored.

RD&D – mineral recycling and substitutes: If necessary, procedures for effective recycling of used materials should be developed and implemented as well as potential substitutes be investigated.

Challenge 4: Providing Sufficient Network Capacity for Electricity Transport

The lack of adequate transmission and distribution networks is a limiting factor for the integration of renewable energies. The capacity of existing distribution networks limit the load/supply management for the purpose of central balancing. Currently, there is insufficient communication and control infrastructure to make full use of decentralised balancing potential (e.g., demand-side management, including e-mobility). At present, the grid structure does not adequately link areas with potential renewable power generation with demand centres. Furthermore, existing transmission networks limit the access to storage locations and transnational balancing of electricity production from renewable energy resources.

<u>Recommendations:</u>

Accelerating planning procedures: Planning procedures should be accelerated through the use of more structured mechanisms that consider how to balance among competing interests, avoid double examinations of identical issues in subsequent procedures, prevent bad coordination between applicable regulations, pay attention to multi-level governance systems, and allow for flexible improvement.

Strengthening national and European interests: The regulation system should be reformed so as to strengthen national and European interests.

Intensifying R&D via adjusted regulation: In the network sector, the development of new transmission technologies has to be intensified. As a first step, the R&D costs for transmission and distribution companies should be accepted as costs by the regulator. A certain percentage for R&D should be defined by the regulator to foster the development and implementation of new technologies. At the distribution level, new planning guidelines have to be accepted by regulators in order to support the implementation of stronger distribution grids gradually to be prepared for foreseeable future requirements.

4.2 Framework Conditions and Organisational Aspects

4.2.1 Market Conditions for Balancing Technologies

Challenge 5: Adequate Implementation of Balancing Technologies in Regulations

Definitions and attributions in legal regulations are not sufficiently clear, particularly concerning central storage technologies to either grid management or power production level.

Recommendations:

Clarifying definitions and attributions: Respective definitions and attributions should be clarified and storage technologies adequately considered in relevant regulations.

Attributing storage facilities to grid management or at the power production level: The legislature should define whether energy storage facilities are to be attributed to the grid management level or the power production level.

Challenge 6: Designing a European Energy Market

The European energy market is still very nationally focussed. There is no harmonised energy strategy and the necessary institutions and legal framework for promoting a rapid development of a renewable electricity system are underdeveloped.

Recommendations:

International exchange of electricity: The transmission network should be strengthened, particularly with respect to international exchange of electricity.

Low-carbon policy framework: A comprehensive, long-term oriented and far-reaching/challenging European low-carbon energy policy framework that goes beyond 2020 should be implemented.

Integrating markets: Europe's generation markets should be further integrated.

Challenge 7: Removing the Historical Heritage of Subsidies and Taxes

Historically implemented subsidies and taxes, which are often technology specific, are disturbing the economic system and lead to inefficiency.

Recommendations:

Ideal framework conditions: Ideally, the old, out-dated system of subsidies and taxes should be taken back stepwise and economically sound and consistent measures such as demonstration projects and start-up subsidies for limited periods of time should be installed instead.

Intermediate framework conditions: As an intermediate practical solution, balancing technologies such as storage systems should be considered for temporary subsidies and tax arrangements. This is important to counter historically emerged drawbacks.

Challenge 8: Transforming Market Externalities to Costs and Earnings

Balancing technologies deliver several system services and externalities, but no market exists where the total benefits can be transferred in the form of earnings for storage operators.

Recommendations:

Internalising socio-economic benefits: Markets and compensation mechanisms should be established for balancing technologies and strategies according to revealed macro-economic/socio-economic benefits.

Internalising system service costs: Power generators should pay for the system services, including grids, which they require to operate properly, e.g., through extra payments.

Coordination: It should be reflected in how far new forms of coordination between different elements of the power supply system such as the production of electricity from renewables, grid management and using storage technologies may be valuable options to internalise benefits automatically via system optimisation.

Business cases for operating balancing technologies: Potential business cases should be analysed in detail.

System analysis – analysing potential benefits of balancing technologies: As a basis for political decisions, a detailed analysis of benefits from applying balancing technologies should be carried out.

Challenge 9: Handling New Complex Market Structures

Due to the use of smart grids and demand-side management, there will be a paradigmatic change from closed markets (with clearly defined roles, stakeholders and processes) to open markets (with a large number of small providers as well as cooperation between purchasers and providers); thus we will find highly complex and unclearly defined new contractual structures, regarding both network and individual aspects. The resulting regulatory barriers will be relevant for each specific business model to be established.

Recommendations:

Analysing contractual challenges in the new markets: Contractual problems and challenges should be analysed in detail with respect to duties and conditions of new or changed actors or the same actors with changed roles.

Developing general legal measures for the new markets: Legal measures need to safeguard an adequate level of data protection. With respect to network and individual contractual aspects, a definition of duties of care and spheres of risk may be a valuable option.

4.2.2 Specific Support for the Application of Balancing Technologies

Challenge 10: Strengthening Scientific Advice on Balancing Options

Current studies on energy system analysis are weak in terms of giving policy advice related to the design of framework conditions for a viable energy system with respect to the option of implementing storage technologies, e.g., expected market volume for balancing technologies.

Recommendations:

Extending energy system analysis: Intensive research should be carried out using full-scale scenario models, including coordinated cooperation of institutions using different, but often complementary model approaches. This continues to assume the same values for relevant parameters, sensitivity analysis with a consistent set of assumptions, model coupling, and model expansions to cover in total all relevant dimensions and aspects.

Large-scale projects and institutionalisation: Large-scale projects on energy system modelling should be funded. Furthermore, the potential of institutionalising energy system modelling, allowing regular updating and monitoring of system developments in Europe should be analysed. The activities of the International Panel on Climate Change (IPCC) can be taken as a procedural example.

Strengthening the European perspective: For an extended energy system, modelling the European perspective should be mandatory, considering the different national politics.

Assessing required installed power and energy capacity: As one major focus from the perspective of implementing technologies for balancing electricity demand and supply, the required installed storage power and capacity should be analysed in detail.

Challenge 11: Adequately Supporting the Application of New Technologies

New storage technologies are momentarily more expensive than existing alternative technologies due to their low scale economies.

Recommendations:

Implementing startup subsidies: Startup subsidies should be implemented in order to promote the application of technologies that result, in the long run, in lower total costs or allow the meeting of strategic goals concerning environmental impact or dependencies on energy imports. These should be phased out automatically to the level of externality compensations and be based on market mechanisms.

Investing in RD&D for storage systems: Investments in R&D and demonstration projects on storage systems should be increased.

Challenge 12: Adequately Supporting Long-Term Investments

Currently, state-promoted technologies such as demand-side management (DSM), decentralised storage systems and vehicle-to-grid will prospectively be strong competitors for technologies with long lifetimes, which require investment security to be built such as pumped hydro or compressed air.

Recommendations:

Reliable long-term conditions: Political decisions on boundary conditions on a national and an international level should be taken and conditions be reliably established for the long term.

Sound basis for decisions: Decisions on boundary conditions should be based on sound results from extended energy system analysis (see Challenge 10).

Challenge 13: Handling Opposition to Large-Scale Projects

Large-scale projects often lack public acceptance. Public acceptance issues related to the development of electricity networks as well as central storage systems, such as pumped hydro and underground hydrogen, will need to be addressed.

Recommendations:

Adequate participation mechanisms: Mechanisms for adequate participation of affected parties and the wider public should be implemented in planning and licensing procedures.

A special planning regime for underground resources: Especially for the usage of underground resources, it should be investigated in how far a special planning regime could help to mitigate potential conflicts of relevant interest groups.

Measures for conflict resolution: Specific conflicts and ways of finding solutions, such as the provision of adequate compensation measures, should be further analysed and respective measures applied.

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