DISTRIBUTION SYSTEM STUDY

RHINELAND-PALATINATE

Recommendations for Action & Summary

2030

energynautics
solutions for a sustainable development

Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

Bird & Bird

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Energynautics GmbH
Robert-Bosch-Straße 7
64293 Darmstadt, Germany

Contact: Dr. Thomas Ackermann
Phone: +49 (0) 151 - 22 66 19 55
t.ackermann@energynautics.com

Contact: Dipl. Wirt.-Ing. Sanem Untsch
Phone: +49 (0) 61 51 - 785 81 20
s.untsch@energynautics.com

Oeko-Institut e.V.
Merzhauser Straße 173
79100 Freiburg, Germany

Contact: Dr. Matthias Koch
Phone: +49 (0) 761 - 452 95 218
m.koch@oeko.de

Bird & Bird LLP
Maximiliansplatz 22
80333 Munich, Germany

Contact: Dr. Hermann Rothfuchs
Phone: +49 (0) 89 - 3581 6222
hermann.rothfuchs@twobirds.com

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RECOMMENDATIONS FOR ACTION

With a goal to supply 100 percent of its electricity demand from renewables by 2030, the German federal state of Rhineland-Palatinate is at the forefront of the expansion of renewable energies (RE) both in Germany and in Europe. This ambitious energy target poses new demands both on the corresponding expansion and restructuring of the distribution systems and on the use of innovative and intelligent technologies. A related question is to what extent local RE and load fluctuations can be balanced by utilising demand side management and storage.

In this study specific technology options for integrating renewables into distribution systems were evaluated by means of simulation models. In addition, an important part of this study was to identify the legal framework and the obstacles for grid integration as well as to develop approaches to improve the legal framework. The future role and authority of distribution system operators is discussed as well. The distribution system study arrives at the following recommendations for action:

Minimising network expansion costs

(1) Due to the dominance of wind energy in Rhineland-Palatinate's renewable strategy, we expect the technology options "Dynamic Line Rating" and "High-Temperature Conductors" to result in significantly reduced network expansion costs compared to traditional network expansion. In particular, existing routes of the 110 kV distribution system level can thus be used in a cost-efficient way to develop network capacity. The improved cooling of overhead lines in strong winds is especially advantageous for the effectiveness of dynamic line rating, since this effect coincides with peaks in wind energy production.

(2) In case of voltage maintenance issues – such as in rural areas with large amounts of solar power being fed into the grid – controllable medium voltage to low voltage transformers can be used to significantly reduce costs. These transformers effectively decouple the voltage in the low-voltage system from the voltage in the medium-voltage system by dynamically adjusting to feed-in conditions while maintaining the voltage within prescribed limits.

(3) The introduction of the technologies named in (1) and (2) is largely impeded by a lack of operational experience from the system operators and insufficient cost recognition within the framework of the incentive regulation. This leads to the recommendation to encourage pilot projects and the exchange of experience between system operators, which should allow for a better integration of these technology options into the planning processes of system operators. Recommendations regarding incentive regulation are provided below in a separate section.

(4) Intelligent feed-in management (curtailment of individual RE plants) can also substantially contribute to reduced network expansion costs. This applies particularly to situations in which short, very infrequent feed-in peaks would otherwise necessitate a substantial expansion of the network capacity. Here the recommendation would be to

introduce the legal possibility for long-term feed-in management (e.g. in terms of a maximum percentage of the annual energy fed into the grid), if the infrastructure expansion has progressed to a point where the attainment of energy policy goals is no longer in question.

Network expansion and flexibility

(5) From an efficiency perspective, it would be advantageous first to export excess RE power in Rhineland-Palatinate to cover the electricity demand in the rest of the German and European system, thus substituting fossil or nuclear power generation there. Only after exhausting this option do demand side management and storage options in Rhineland-Palatinate come into consideration, since unlike direct electricity consumption, they result in efficiency losses, which in turn increase the demand for RE expansion.

Prioritising flexibility options

(6) With an increasing RE share in the German-European system, flexibility options with low losses and low costs will take priority in Rhineland-Palatinate. This includes more flexibility of existing generation plants such as biogas CHP (gas storage and additional CHP capacity) and other co-generation plants with heat storage systems, as well as larger DSM players in the industrial and commercial sector.

(7) In the medium term, automated load management (demand side management, DSM) will become relevant for the provision of electrical heat and cooling; for Rhineland-Palatinate, the increasing use of heat pumps in the building sector will be of particular importance. Here, options for more flexibility regarding this technology should be taken into account early on. In addition, the two planned pumped-storage plants at Schweich and Heimbach are important in the medium term. They represent an already well-established technology option and constitute the only flexibility option in the order of several hundred megawatts in Rhineland-Palatinate with storage potential available throughout the year.

(8) PV battery storage systems in combination with feed-in restrictions will be important for the total system only in the medium to long term. In order to avoid energy-inefficient processes, power should not be stored to cover on-site demand at a later point unless the total system does not allow for any direct use somewhere else. Therefore, this study currently does not see any necessity to further promote PV battery storage systems beyond the existing support mechanisms.

(9) In a long-term perspective and in a power system with a very large RE share, power-to-heat and later also power-to-gas will play an important role. Both options interconnect the electricity system with other energy sectors, such as the heat, natural gas, hydrogen and traffic sectors. In these sectors, they only increase the portion of renewable energy usage if they are operated with excess renewable energies that cannot be used by the electricity system. For additional power consumption in further sectors, the corresponding amount of additional RE plants would have to be built. The recommendation would be then to promote research and development regarding projects that ensure long-term development requirements.

(10) It is recommended to work towards a situation where system operators can use commercial storage and demand side management in exceptional circumstances to help avoid network problems (for example by directly accessing the storage assets or via financial incentives).

(11) A wholesale support of specific technologies without taking account of the economic consequences for the whole system should be avoided. From the very start, the discussion of new legal frameworks and economic support measures should take into account the effect on the total economic system.

Further legal framework considerations

(12) In order to improve the legal framework for investments made by distribution system operators, the mechanism in the German Incentive Regulation Ordinance for re-financing via grid fees should be adjusted. On the one hand, the period of applying for the approval of investment measures should be shortened from nine to six months prior to the start of the respective calendar year. On the other hand, the incurred costs should be included to a larger extent during the on-going regulating period; thus, the costs should largely and without delay be reflected in the revenue cap of the calendar year (similar to a model of an annual cost of capital reconciliation).

(13) The “storage” operation and the access to third-party storage facilities by (distribution) system operators requires as a consequence of the unbundling a more detailed legal distinction of the purpose of such measures as grid- or market-related activities. As an alternative, specific circumstances have to be determined in order to define an event as grid-related or market-related storage activity.

(14) For demand side management measures, legislation has to provide clearer definitions of the cases where the measure has a grid-oriented goal that justifies system operator action for grid- or market-related demand side management measures.

(15) Regarding the reliable control of interruptible consumer facilities by system operators, the necessary planning and legal certainty makes it necessary to legally – not only via the provided regulatory measures – and promptly define in a more detailed way which facilities are affected and what specific kinds of access options there are.

(16) From an efficiency perspective, grid utilisation could be influenced by price incentives within the context of power grid fees. In particular, a legal description of additional groups of cases regarding individual power grid fees should be considered (e.g. flexibility of electricity procurement, what time during the day and/or night electricity procurement is mainly to be expected, and other non-discriminatory criteria).

SUMMARY

INTRODUCTION

The federal state of Rhineland-Palatinate aims to cover 100% of the state's gross electricity demand from renewable sources by the year 2030. This distribution system study for Rhineland-Palatinate was commissioned by the government of Rhineland-Palatinate to analyse the required prerequisites and options for action. The study has been prepared by Energynautics GmbH (calculation of the required network expansion), the Oeko-Institut e.V. (storage technologies and demand side management), and the law firm Bird & Bird LLP (legal framework).

The study is divided into six working packages. This report basically follows the structure of the working packages:

The section *Calculation of the Required Network Expansion* initially describes the results of Energynautics GmbH and summarizes working packages 1, 2, 4, and 5. The content of these working packages includes the energy economics analysis, the calculation of the required network expansion, the use of smart operating equipment and communication as technology options as well as the preparation of a cost-optimised technology use.

The section *Storage Technologies & Demand Side Management* separately describes the results of Oeko-Institut e.V. and presents the work done within working package 3. Data on demand side management and storage potentials in Rhineland-Palatine were individually collected; and a model-based analysis of their possible applications was carried out. From that, a storage concept for Rhineland-Palatinate was derived; and the flexibility options' priority order of use was established.

The section *Legal Framework* presents the results of Bird & Bird LLP prepared within working package 6. It comprises (i) the presentation of the legal framework and the obstacles resulting for grid integration, (ii) the identification of approaches for an improved legal framework, and (iii) a discussion of the future role and authority of distribution system operators.

CALCULATION OF THE REQUIRED NETWORK EXPANSION

This section presents the methods, structure and results of the network calculations.

Generation capacity in Rhineland-Palatinate until 2030

A prerequisite for a complete electricity supply from renewables is the strategic development of generating capacity in order to be able to cover the expected total yearly electricity consumption. In Rhineland-Palatinate, the two most important pillars of power supply from renewables are wind power and photovoltaics. By the year 2030, about 7,500 megawatts of wind power plants and 5,500 megawatts of photovoltaics are expected to be installed in the federal state of Rhineland-Palatinate; this represents a significant multiple of the currently installed capacities (in 2012: about 1,800 megawatts of wind power plants, and 1,600 megawatts of photovoltaics).

7,500 MW of wind 5,500 MW of PV in 2030

In addition to 2030 as the analysis horizon, the study analyses the year 2017 as an intermediary step of the development. The generation capacities in 2017 were interpolated between the values recorded for the base year 2012 and the perspective provided for 2030. Installed capacities in the scenarios of the study were not changed, unless this was necessary for keeping the 100 % RE strategy goal.

Network expansion and flexibility

In many networks, the expected continued large increase in the feed-in capacity from wind energy and photovoltaics substantially exceeds the current peak-load dimensioning and thus results in a required network expansion of the distribution systems up to the 110 kV level. Uncontrolled RE feed-in and local consumption offset each other only to a very limited extent; there is almost always regional excess or shortage. This means that also the highest voltage transmission system has to be adjusted. The expansion of distribution and transmission systems is very costly. Therefore, any option that contributes to reduced network expansion requirements are of interest. The distribution system study calculates the impact of different new technologies and quantifies the expansion requirements at all voltage levels for Rhineland-Palatinate.

In addition to the necessary network expansion as a prerequisite for balancing load and generation within and beyond the region, fluctuations of the residual load remaining in the system (the total sum of load and un-coordinated RE feed-in) have to be balanced. It has to be assumed that regions with load and generation that – according to current standards – are considered to be largely non-controllable will also have to make a contribution to balancing. Therefore, technologies and measures that have the potential to increase regional flexibility are of particular interest.

Determining network expansion: Methodology

Simulation models and load flow analyses are used to study the electricity supply system. According to the voltage level, different models are used:

The highest voltage level (380 kilovolt as well as 220 kilovolt) are modelled together with the high voltage level (110 kilovolt) in a joint load flow model. This model is based on real network data from Rhineland-Palatinate system operators that are combined into a joint model. In order to be able to include load flows beyond the region, this model is then integrated in a simplified model of the European transmission system which was developed by Energynautics. A complex procedure is used to predict for each network node (110 kV substation) in Rhineland-Palatinate the development of load and generation up to the year 2030 and to adjust it for the various analysed scenarios. In addition, the potentials of demand side management (DSM) and storage technologies determined by Oeko-Institut are included for the individual network nodes. To determine the network expansion, an algorithm was used for the highest and high voltage levels which minimises the network expansion according to capacity and line length and thus arrives at an optimal use of the existing flexibility. The model takes into account planning specifications of transmission and distribution system operators.

Highest voltage
High voltage

Reference networks are used to analyse the expansion requirement at the medium-voltage level (10-30 kilovolt). Initially, representative network areas are determined for specific network area classes; real network data of these areas are then generalised for the entire class. Based on the frequency distribution of the network area classes in Rhineland-Palatinate, the results of the reference networks can be extrapolated to the entire studied area. For the low-voltage level (0.4 kilovolt), we used model networks that do not constitute a representation of real network data, but – when combining the individual models – were already based on the analysis of “typical” circumstances such as network type, line length, and the number of residential and commercial connections. Also here, the distribution of network area frequencies is used to extrapolate the results of the model network analysis to the entire studied area. The expansion criteria for medium- and low-voltage systems were coordinated with distribution system operators.

Medium voltage

Low voltage

Similar to the expansion criteria for the individual voltage levels, the cost assumptions regarding the required lines and transformer capacities were also coordinated with the system operators in Rhineland-Palatinate. Based on this, the calculated required network expansion at the individual levels is used to calculate the corresponding costs.

Network expansion costs

For each network level, the models initially present the current state in the base year 2012. For the planning period until 2017, the system operators have already – to a large extent – scheduled the measures to be implemented. For high- and highest-voltage levels, system operators were interviewed regarding the measures planned until 2017 and beyond; these measures were then integrated into the simulation model. Based on this, the required network expansion is determined. The result of the calculations is thus the required network reinforcement at high- and highest-voltage levels that exceeds the system operators’ planning. For the medium- and low-voltage levels, data on planned measures are harder to collect and integrate into the models. The determined expansion on this voltage level therefore reflects total required expansion in relation to the current status.

The algorithms used for determining the minimum required network expansion analyse the reinforcement of existing lines. In addition, the connection of future wind power capacity will require new connection capacity. The costs of these lines depend on the geographical situation of each individual wind farm. In order to be able to estimate these costs without knowledge of specific projects, we developed an approximation procedure that takes into account both an assumed future geographical distribution of generation capacity (on the level of municipalities) and the location of existing substations. The study does not take into consideration how costs are split between plant operators and system operators, neither currently nor in the future. For a better cost allocation, the results provide connection costs and costs for the network reinforcement measures calculated in the simulations separately. As opposed to this, photovoltaic systems are continued to be connected to existing network structures; therefore connection costs are not separately calculated.

Wind farms

Analysed scenarios

A series of scenarios is used to analyse the required expansion of the electrical supply systems in Rhineland-Palatinate until 2017 and then until the year 2030. These scenarios include different technologies and measures in order to reduce network expansion: Initially, the reference scenario determines the network expansion requirements that would result if no new technologies were used and all generation capacity was accommodated (“business as usual”). Further scenarios include the use of demand side management (DSM), different variations of storage use, intelligent and modern network equipment as well as the option of restricting the capacity of generating facilities (curtailment). Due to the goal of a 100% power supply from renewables, the scenarios take into consideration losses from storage as well as curtailment and adjust the generating capacity of wind energy and photovoltaics accordingly.

The scenario “Intelligent Network Expansion” analyses the use of high-temperature conductors and dynamic line rating for the operation of overhead lines; regarding medium- and low-voltage, wide-area voltage control and controllable medium voltage to low voltage transformers are used.

The scenario “Smart Grids” investigates new measures based on the use of information and communication technology. The study uses a smart grid definition that aims at the activation and intelligent use of flexibility potentials at the medium- and low-voltage level. The individual technology options that are used in the simulation are batteries in photovoltaic systems, power-to-heat, demand side management as well as wide-area voltage control and controllable medium voltage to low voltage transformers.

The scenario “Intelligent RE Expansion” looks at options for curtailing generation plants in order to minimise the macroeconomic costs of network expansion. Energy losses due to curtailment are compensated by additionally installed capacity. The results can be used to evaluate whether the savings in network expansion costs exceed the additionally required generating capacity (and its costs) or not.

In addition to the scenarios already mentioned, further scenarios “DSM”, “storage (partially connected)” and “smart storage” analyse other variations of technology use. These vary from the initially mentioned scenarios regarding changes in the amount of available storage capacities and DSM or in diverging assumptions regarding operating details of the units. They do not constitute independent scenarios in the way of different technology classes; and we therefore do not include a more detailed presentation of them in this short version.

A technology selection is derived from the evaluation of all scenarios and is separately analysed; the corresponding results comprise a “system-optimised” scenario.

Results from the reference scenario

The simulations already include assumptions based on the system operators’ planning regarding the highest- and high-voltage system until 2017 and 2030; the calculated network expansion and its costs refer to the additionally required investments. The reference scenario determines the network expansion requirements that would result if no new technologies were used and all generation capacity was accommodated (“business as usual”).

Business as usual

The reference scenario exceeds the investment requirements for the network reinforcement determined by system operators by 1.8 billion Euro until the year 2030 for Rhineland-Palatinate (Figure 1). The largest cost portion of the determined network expansion (30 %) relates to the transformers from high to medium voltage. This concerns transformer costs for the wind power capacity expected to be installed by the year 2030. In addition the cost portions of high-voltage lines (19 %) and medium-voltage lines (9 %) include costs for wind farm connections. The second largest cost portion (20 %) originates in the low-voltage level that has to accommodate the capacity that PV systems feed in.

Network expansion costs 1.8 billion Euro

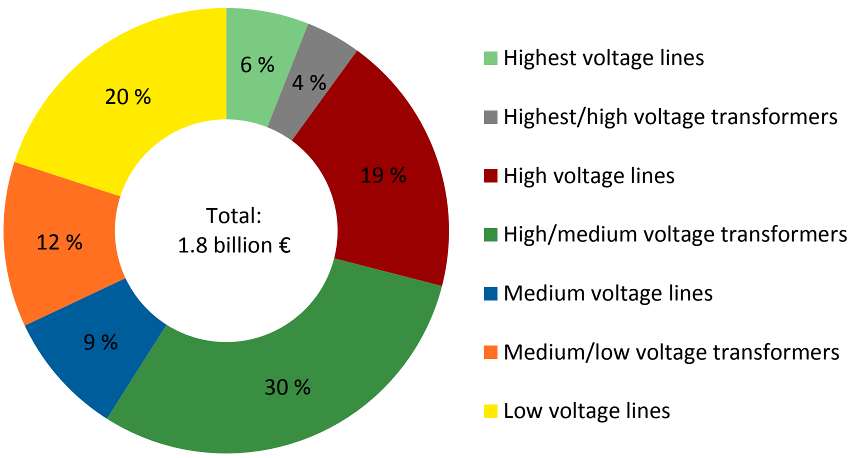

Figure 1: Distribution of network expansion costs between the voltage levels in the reference scenario 2030. Source: Own presentation (Energynautics GmbH)

Results from the Scenario Intelligent Network Expansion

It was determined that the network expansion costs for Rhineland-Palatinate up to the year 2030 can be reduced by up to 650 million Euro in relation to the reference scenario (1.8 billion Euro) if the technologies dynamic line rating, high-temperature conductors, controllable medium voltage to low voltage transformers (CMLT) as well as wide-area voltage control (WAVC) are included. The largest cost block (high-voltage/medium-voltage transformation) of the reference scenario does not show any significant change though. However, dynamic line rating can be used to substantially reduce the expansion requirements of existing high-voltage lines. In addition, at the low-voltage level there is a large saving potential from controllable transformers. Among the disadvantages of the analysed technologies at the highest- and high-voltage level are increased electrical losses and larger compensation requirements for reactive power.

Dynamic line rating (DLR)

High-temperature conductors (HTC)

Controllable MV/LV transformers (CMLT)

Wide-area voltage control (WAVC)

Results from the Scenario Smart Grid

In order to analyse the intelligent use of flexibility potentials at the medium- and low-voltage level, the simulations use the technology options: batteries in photovoltaic systems, power-to-heat, demand side management as well as wide-area voltage control and controllable medium to low voltage transformers. In the simulations the operation of storage and demand side management was controlled in such a way that their operation never leads to any increased network expansion, but can be used to reduce network loading at critical points. Apart from this restriction, we assume a market-led operation.

PV batteries, power-to-heat, demand side management

The results of the simulations show a possible reduction of network expansion costs in Rhineland-Palatinate by 350 million Euro until the year 2030 as compared to the reference scenario. Controllable medium to low voltage transformers account for the largest portion of these savings. Due to the losses related to the operation of battery storage and power-to-heat, a complete power supply from renewables would require a larger installed capacity; network connection costs for this additional capacity would partially eat up the grid-related benefits of these technologies.

Results Scenario Intelligent RE Expansion

The scenario "Intelligent RE Expansion" analyses the curtailment of generation facilities as an option for avoiding network expansion. This measure has a particularly large potential to be effective as it is always available at the critical network nodes. Regarding network expansion costs in Rhineland-Palatinate, this simulation shows a saving potential of up to 780 million Euro until the year 2030. However, curtailment causes energy losses that require an increased installed capacity in order to ensure a complete power supply from renewables. The costs of the additional generation facilities (that are not included in the network expansion costs) impair the total system costs of the analysed scenario, since the related costs exceed those in the reference scenario. A further, more restricted version of curtailment is analysed in the system optimisation.

Curtailment

System optimisation

Technology selection

The calculations of all scenarios were used to prepare a combined technology selection that includes requirements for both minimising network expansion costs and providing further flexibility options. In addition, two variations of the technology selection separately consider the impact of a specific storage technology (pumped-storage hydro plants) and analyse the effect of a narrowly restricted form of curtailment. Taking into account demand side management and storage use, the results show that network expansion costs can be reduced further compared to the results of the scenario "Intelligent Network Expansion" if the technologies are employed and utilised in an intelligent and coordinated fashion. In addition, since the feed-in peaks which cause network expansion happen very rarely, restricted curtailment measures can efficiently further reduce system costs.

In comparison to the reference scenario, the selected technology options can produce substantial savings at most network levels (Figure 2). In the system-optimised scenario, the sum total of the network expansion costs of all network levels amounts to 1.0 billion Euro until 2030 (reference scenario: 1.8 billion Euro). The cost share of the transformers between high and medium voltage increases to 50 %. At this level, the technology selection does not result in any substantial savings; the lower total costs of the network levels therefore leads to a relative increase of this level. The transformation between medium and low voltage is the other network level with a substantially larger portion of network expansion costs as compared to the reference scenario (increase from 12 % to 23 %). In this case, due to controllable medium to low voltage transformers, this increase is actually caused by higher costs.

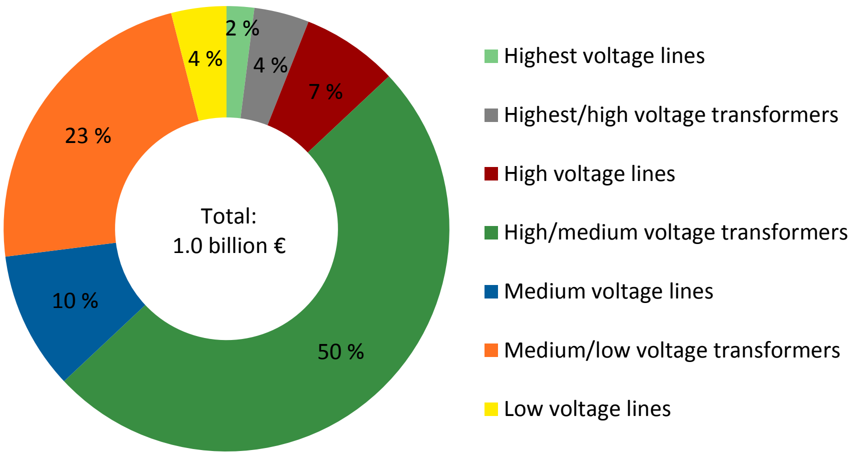

Figure 2: Distribution of network expansion costs between the voltage levels in the system-optimised scenario 2030. Source: Own presentation (Energynautics GmbH)

Cost comparison of the scenarios

Both the calculated network expansion costs and total costs are used to evaluate the scenarios. In addition to network expansion costs, total costs also include the costs for the wind power and PV generation capacity required until the year 2030. Table 1 shows the resulting cost-based order of the scenarios. For the listed technologies, it should be noted particularly for storage and demand side management (DSM) that there are substantial differences between the scenarios regarding the assumed available capacities as well as the operating mode. Storage can be found both in the scenarios with the highest and in the scenarios with the lowest costs.

Table 1: Comparison of scenarios in terms of network expansion costs and total costs for the year 2030. Source: Own presentation (Energynautics GmbH)

Scenario	Network expansion cost relative to reference scenario	Total cost [1] relative to reference scenario	Technology selection [2]
Storage (partially connected)	1.18	1.26	Storage
Smart Storage	1.00	1.12	Storage
Smart Grids	0.80	1.06	Storage, DSM, CMLT, WAVC
Reference Scenario	1.00	1.00	Conventional Network Expansion
DSM	0.96	1.00	Demand Side Management
Intelligent RE Expansion	0.56	0.98	Curtailment
Optimised Scenario + PSH	0.61	0.97	DLR, HTC, CMLT, Storage, DSM, PSH
Optimised Scenario	0.58	0.95	DLR, HTC, CMLT, Storage, DSM
Intelligent Network Expansion	0.63	0.95	DLR, HTC, CMLT, WAVC
Optimised Scenario + Curtailment	0.49	0.94	DLR, HTC, CMLT, Storage, DSM, Curtailment

The order of the scenarios shows that costs can only be minimised through a favourable combination of technology options. If we take a closer look at the differences between the scenarios, the results can provide conclusions both regarding the technologies that produce the largest cost minimisations and advantageous operating modes of storage and demand side management.

Key findings of the network calculations

The presented scenarios use the example of the intended development in the federal state of Rhineland-Palatinate up to the year 2030 in order to show the possible impact of specific technology options on the network expansion costs of a region. It becomes obvious that measures with a high potential to decrease network expansion costs often only have a small impact on providing flexibility (for compensating fluctuations from loads as well as wind power and PV fed into the grid) in a German and European context and vice versa. The long-term goal of a complete, secure and efficient power supply from renewables therefore requires the balanced use of all available technology options at the individual points where they are most efficient. Even if all new technologies are applied, all scenarios show reinforcement requirements for the high- and highest-voltage grid that exceed system operator planning. This result confirms that the planned

Activating all options

[1] The applied total costs include network expansion costs as well as costs for wind power and PV plants; storage costs are not included.

[2] DSM: demand side management (load management); DLR: dynamic line rating; HTC: high-temperature conductors; CMLT: controllable medium voltage to low voltage transformers; PSH: pumped storage hydro plants; WAVC: wide-area voltage control

system operator measures are necessary for implementing the expansion goals within the framework of the planned development.

For the planned expansion goals of wind and PV capacity fed into the grid, the required network expansion is mainly determined by the periods of the highest primary energy supply. This means that the maximum required network expansion is only needed for a limited number of comparatively short periods of time. At the highest- and high-voltage level, the most efficient measures for reducing network expansion costs are the technologies of dynamic line rating and high-temperature conductors. Particularly for dynamic line rating, an increased transmission capacity of overhead lines would be available exactly during the times with high feed-in capacity, i.e. during periods of high wind speeds.

Dynamic line rating

High-temperature conductors

Regarding the low voltage level, controllable medium to low voltage transformers (CMLT) are often an appropriate tool for avoiding line expansion in case of voltage issues; therefore they are potentially highly beneficial for the reduction of network expansion costs.

Controllable MV/LV transformers

The results of one of the variations of the system-optimised scenario show that a limited form of curtailment not only significantly contributes to the reduction of network expansion costs, but also is efficient at a total system cost level – even after compensating the corresponding losses through additional installed capacity from renewable energy plants in the context of the 100 % RE strategy. As curtailment measures are only necessary during the very few times of maximum supply, they cause only small energy losses. Unlike DSM and storage, curtailment is always available in exactly the regions where feed-in peaks would otherwise necessitate further network reinforcement.

Limited curtailment

Regarding reduced network expansion costs, the use of demand side management and storage technologies did not show any substantial benefits. These technologies mainly prove advantageous for compensating RE and load fluctuations in the electrical supply system. However, they are not significantly beneficial for limiting network expansion costs in the context of a complete power supply from renewables by the year 2030 in Rhineland-Palatinate. Storage, in particular, would potentially increase network expansion requirements, unless they are compensated by additional restrictions, i.e. taking into account at least the local grid utilisation during normal operation. However, if a purely grid-led storage operation is neither desired nor possible, the site selection would already need to take into account the network capacity available for accommodating the capacity. An operating mode oriented towards covering the user’s own consumption that does not specifically and reliably reduce capacity peaks of load and power fed into the grid, does not comply with any of the conditions set out above.

Demand side management, storage

Generally, the results of the network calculations confirm that the expansion or reinforcement of the power grid would be the most significant measure for compensating regional power fluctuations from the load and RE power fed into the grid. With intelligent network planning that takes into account modern technologies and new possibilities, provided for within the current or possible future legal framework, there are options for action that would be highly economically beneficial in comparison to “business as usual”.

Priority network expansion

STORAGE TECHNOLOGIES & DEMAND SIDE MANAGEMENT (WORK PACKAGE 3)

In work package 3, storage technologies and demand side management in the German federal state of Rhineland-Palatinate are reviewed and the potentials determined for the scenario years of 2017 and 2030. On this basis, modelling is used to derive a storage concept for Rhineland-Palatinate. The technology options considered are load management, biogas CHP gensets with gas storage, CHP plants with heat storage, pumped storage power plants, PV battery systems and power-to-heat and power-to-gas. For the scenario year of 2030 a distinction is made in the case of some flexibility options between potentials that are partly tapped and those that are fully tapped.

Determination of potentials

The demand side management (DSM) potential in Rhineland-Palatinate is composed of manual load management, heat pumps and electric boilers in households, of processes with interval operation or thermal storage in the commercial sector[3] and the DSM potential in industry (chlorine electrolysis, cement plants and the paper industry).

Potential available all year round

The storage and flexibility options in Rhineland-Palatinate are shown in Table 2 with their partially tapped potentials in the scenario year of 2030 and their efficiencies and losses during the storage period. The storage potential of approx. 1,700 MW – which is not dependent on load patterns and thus available all year round – is chiefly derived from pumped storage power plants (1,450 MW, of which the 850 MW of the Vianden pumped storage power plant are already available in the reference scenario and 300 MW each come from the pumped storage power plants planned in Schweich and Heimbach respectively), followed by power-to-gas (200 MW) and biogas CHP gensets with gas storage (50 MW). The power-to-gas potential is derived from electrolysis and the hydrogen feed-in to the natural gas network (possible all year round) and the electrolysis and catalytic methanation with renewable CO_2 from biogas plants.

Potential which fluctuates in the course of the year

A minimum of 470 MW and a maximum of approx. 4,350 MW of flexible load and flexible production capacity – which is dependent on load patterns and thus fluctuates in the course of the year – are available to integrate renewable energies in the electricity system. The largest component of this maximum potential is power-to-heat with approx. 3,000 MW.

3 Greenhouses, waste water treatment plants, waterworks, cold storage facilities, food retailing, food production and air-conditioning.

Table 2: Potentials and efficiency merit order for storage and flexibility options in Rhineland-Palatinate in the scenario year of 2030 (partly tapped potential). Source: Own presentation (Oeko-Institut e.V.)

Option	Potential	Dependent on load patterns	Efficiency	Storage duration	Storage losses
Biogas CHP gensets with gas storage	40 – 50 MW	No	100 %	< 12 h	0 %/h
Load management	300 – 450 MW	Yes	100 %	< 2 h	0.5 %/h in case of cooling or heat
CHP plants with heat storage	20 – 540 MW	Yes	100 %	< 4 h	0.5 %/h
PV battery systems	0 – 350 MW	Yes	85 %	< 2 h	0.01 %/h
Pumped storage power plants	1,450 – 1,900 MW	No	75 – 80 %	< 5 h	0 %
Power-to-heat	150 – 3,100 MW	Yes	50 %	“unlimited”	0.5 %/h in case of heat storage
Power-to-gas	200 MW	No	25 – 35 %	“unlimited”	0 %

Methodology for modelling DSM and storage use

Perspective to be modelled

In principle the use of DSM and storage can be modelled from different perspectives. The decision to use flexibility and storage can be made from a network perspective (e.g. to avoid grid bottlenecks), an overall economic perspective (e.g. to minimise total system costs) or a business perspective (e.g. to maximise individual profit). Rhineland-Palatinate can also be modelled in isolation, effectively as if it were an island, or as integrated in the German and European electricity systems.

In order to answer the question of the extent to which Rhineland-Palatinate can use storage and flexibility options available in Rhineland-Palatinate to smooth out its renewable and load fluctuations, a storage concept is derived from an overall economic perspective and isolated for Rhineland-Palatinate using Oeko-Institut’s electricity market model PowerFlex.

Electricity market model PowerFlex

Oeko-Institut’s PowerFlex model applies the specific flexibility options according to lowest cost and taking into account technical and economic restrictions (side conditions) to meet Rhineland-Palatinate’s electricity demand. The use patterns of the different technology options and the local gap remaining to meet the electricity demand and the remaining local renewable surplus lead to the residual load. The residual load is shown as a load duration curve.

Germany and Rhineland-Palatinate

Considering Rhineland-Palatinate in isolation distorts the resulting use patterns when compared to modelling Germany as a whole since a uniform electricity price is generated in Germany rather than a specific price for Rhineland-Palatinate. When Germany is considered as a whole, the use patterns of the flexibility providers in Rhineland-Palatinate, which are often located on the distribution system level (e.g. load management, CHP gensets, power-to-heat), are heavily influenced by the expansion of renewable energies, flexibility and storage assumed for Germany. As a result, the interactions between Germany and Rhineland-Palatinate become more prominent and the question of the influence of DSM and storage in Rhineland-Palatinate becomes less relevant. In this context power-to-heat and power-to-gas gain in significance, mainly because they shift the energy flows between the electricity, heat and gas sectors, and make a purely electricity-based evaluation more difficult.

Rhineland-Palatinate modelled in isolation

By focusing on the balancing out of fluctuating renewable load within Rhineland-Palatinate the electricity deficit and the renewable surpluses are minimised, thereby bringing about a minimisation of the “interconnector capacity” between Rhineland-Palatinate and Germany. At the same time this can, under other circumstances, also result in a greater network expansion in Rhineland-Palatinate. This question is examined in more detail in Work Package 5 in which the use of storage and flexibility options for both “market-driven” and “grid-driven” reasons is analysed.

Reference scenario for isolated consideration of Rhineland-Palatinate and balancing with Germany

Two node model

With the help of a two node model (Germany and Rhineland-Palatinate), the renewable surpluses in Rhineland-Palatinate and the necessary electricity imports from Germany are determined for the scenario years of 2017 and 2030 according to a geographical balancing of load and renewable fluctuations between Rhineland-Palatinate and Germany and the use of existing pumped storage power plants (all German pumped storage power plants and the Vianden pumped storage power plant). Renewable surpluses arising in Rhineland-Palatinate and – as far as possible – in Germany are thus utilised to fulfil the electricity demand or are stored in the pumped storage power plants. In turn the power plant fleet in Germany is also utilised to help meet Rhineland-Palatinate’s electricity demand. In Figure 3 the remaining renewable surpluses in Rhineland-Palatinate (negative section of the curve) and electricity imports to Rhineland-Palatinate (positive section of the curve) are shown in comparison with the renewable surpluses and the electricity deficit in Rhineland-Palatinate when the federal state is modelled in isolation.

In the scenario year of 2017 renewable surpluses only arise in selective cases in Rhineland-Palatinate due to the geographical balancing of fluctuations with Germany. In 2017 there is not yet a need for electricity storage and flexibilisation to help the integration of renewable energies in the electricity system. In the scenario year of 2030 up to approx. 60 % of the local renewable surpluses in Rhineland-Palatinate can be used outside of the federal state to meet the electricity demand or be stored in pumped storage power plants. The remaining renewable surpluses amounting to 3.7 TWh can only be utilised with the help of additional flexibility and storage options or they must be curtailed.

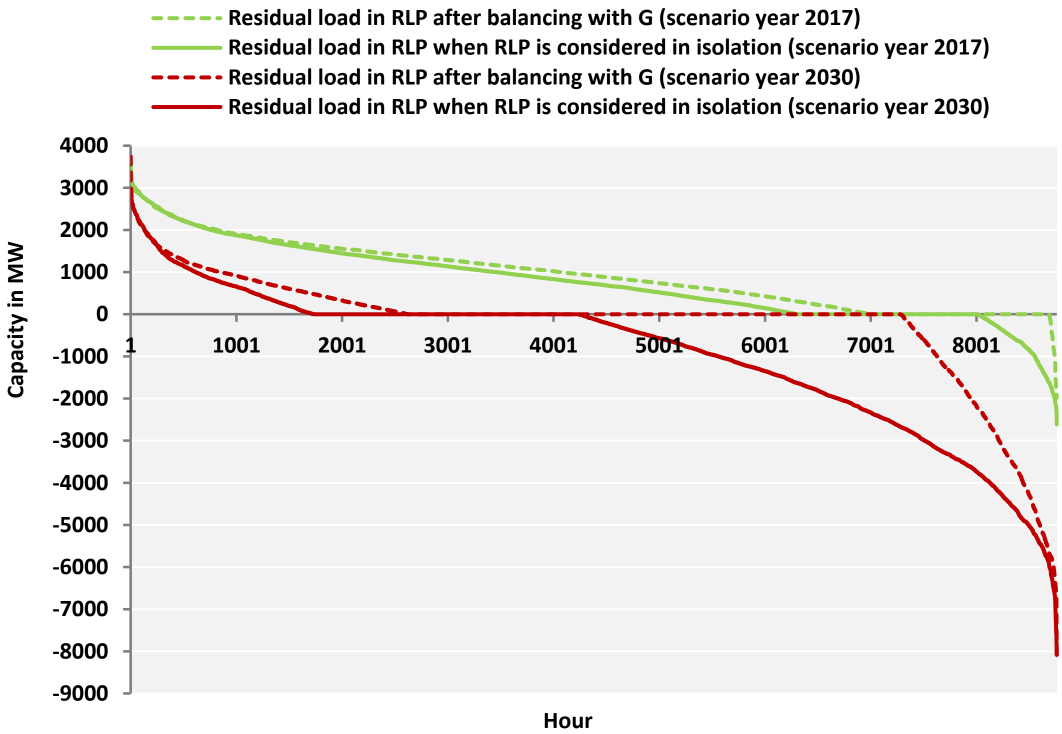

Figure 3: Residual load of Rhineland-Palatinate (RLP) in the scenario years of 2017 and 2030 when interconnected with Germany (G) (two-node model) and when considered in isolation (only RLP). Source: Own Presentation (Oeko-Institut e.V.)

Effects of flexibility use in Rhineland-Palatinate

Additional integration of renewable energies

The use of flexibility to minimise the overall system costs has an effect on the electricity balance at various points. With flexibility options there is the incentive in times of low marginal costs to increase electricity consumption and to reduce the electricity production and, in turn, in times of high marginal costs to reduce electricity consumption and increase electricity production. If this occurs when there are local renewable surpluses (minimum marginal costs), additional quantities of renewable electricity are integrated in the electricity system. The minimum specific cost per megawatt hour is thus achieved when local renewable surpluses can be shifted in times of local electricity deficits (maximum marginal costs). However, the overall system costs are reduced when the merit order of the electricity production mix is optimised without there being local renewable surpluses. In Table 3 flexible electricity consumption, storage use and flexible electricity production in the scenario year of 2030 are summarised and compared to the reduction of local renewable surpluses and electricity deficits. As can be seen, approx. 2,000 GWh of electricity are consumed, produced or stored flexibly by means of load management and electricity storage (without power-to-heat and power-to-gas) in the scenario year of 2030, of which only 600 GWh is attributable to the effect of the additional integration of renewable energies in the electricity system. This underlines that load management and storage act as market agents in the model and thus only indirectly or with corresponding price signals have the maximum integration of renewable energies in the electricity system as an objective.

Table 3: Flexible electricity consumption, storage use and flexible electricity production in the scenario year of 2030. Source: Own presentation (Oeko-Institut e.V.)

DSM and storage scenario (partially tapped)	Load increase, storage charge, reduction of electricity production	Reduction of local RES surpluses	Load reduction, storage discharge, increase of electricity production	Reduction of local electricity deficit
Load management	+190 GWh	-80 GWh	-180 GWh	-80 GWh
Biogas CHP gensets with gas storage	-120 GWh		+120 GWh	
CHP plants with heat storage	-210 GWh		+110 GWh	
PV battery systems	+160 GWh		-140 GWh	
Pumped storage power plants	+1,300 GWh		-1,100 GWh	
Power-to-heat	+6,000 GWh	-6,000 GWh		
Power-to-gas	+400 GWh	-400 GWh		

Reasons for the partial integration of renewable energies in the electricity system should be seen in conjunction with the times of renewable surplus and an available flexibility potential. In particular renewable surplus peaks that are higher than 2,000 MW and renewable surplus plateaus of 2 to 5 hours can no longer be absorbed by flexibility potentials available all year round since the installed production capacity and the installed storage capacity are limited.

Derivation of a storage concept for Rhineland-Palatinate

With its goal of having 100 % of its electricity produced from renewable energies by 2030, Rhineland-Palatinate is a pioneer in terms of the expansion of renewable electricity production in Germany and Europe. For this reason accelerating the expansion of load management and storage to stabilise local renewable and load fluctuations in Rhineland-Palatinate also seems reasonable.

However, from the perspective of efficiency it would be expedient to first use the local renewable electricity surpluses in Rhineland-Palatinate to help meet the electricity demand in Germany and Europe and thereby replace fossil or nuclear electricity production. Only when this possibility is exhausted do load management and storage options come into consideration. In contrast to immediate use, load management and above all storage options have higher efficiency losses, which in turn lead to the need for a greater expansion of renewable energies.

Immediate use of renewable electricity surplus

When the use of load management and storage options increases depends on the expansion of renewable energies and the development of electricity consumption in Germany and Europe. With the planned Germany-wide expansion of renewable energies above all load management can soon be used more substantially, especially to smooth out load peaks.

Load management and storage are generally market agents and are not part of the network infrastructure. The decision to utilise these options, which rely on sufficient network expansion, is primarily market-driven. In addition system operators can sometimes also use storage and DSM for the purpose of network capacity management.

When Rhineland-Palatinate is considered in isolation the local renewable surpluses of up to 8-9 GW exceed the flexibility potential available all year round in Rhineland-Palatinate (amounting to 2.2 GW of partially tapped potential) by approx. a factor of 4 in the scenario year of 2030. If the maximum renewable surpluses and maximum flexibility potential including the potential dependent on load patterns arise at the same time, the renewable surpluses can be used in Rhineland-Palatinate, at least in the short term, and can be almost fully exhausted. However, as a result of the predominance of power-to-heat this is only the case in the winter months. In our assessment it becomes clear that all flexibility options available in Rhineland-Palatinate are needed in the course of the transformation process in the electricity system. This is an extreme case, particularly when the German federal state is modelled in isolation, but also when the increasing expansion of renewable energies outside of Rhineland-Palatinate is considered.

Flexibilisation of existing production plants

In the development of tapping the storage and DSM potentials in Rhineland-Palatinate over time, those flexibility options are prioritised which show low losses, are inexpensive to use and can balance out at least short-term fluctuations. This is the case, for example, with the flexibilisation of existing production plants like biogas CHP gensets (gas storage and additional CHP plant capacity) and CHP plants (heat storage). Load management can also be used to attenuate load peaks and, in some cases, to utilise local renewable surpluses. Large DSM market agents in industry and the commercial sector seem to be particularly suitable for this purpose since they are either already available via the corresponding infrastructure (e.g. when they provide balancing capacity to smooth out fluctuations) or the infrastructure can be upgraded at short notice for this purpose.

Demand side management

In the medium term automated load management for the electrical heat and cooling supply also plays a significant role. At the same time the increasing use of heat pumps in the building sector is significant in Rhineland-Palatinate and the possibility of flexibilising this technology should be considered at an early stage.

Pumped storage power plants

The two pumped storage power plants planned in Schweich and Heimbach respectively are also significant in the medium term. This technology option is already well-established and the two power plants are the only flexibility option in the size category of several hundred megawatts in Rhineland-Palatinate (large centralised storage). Furthermore the storage potential is available consistently all year round and does not depend on demand or production patterns (unlike, for example, DSM or CHP plants). These options have, after a lengthy planning and construction phase, a long technical lifetime.

PV battery storage

Only in the medium and long term does PV battery storage combined with limits on feed-in play a role in balancing out feed-in and load fluctuations in the overall system. What is problematic in this regard is that the decision to use this local storage option is made individually by the PV battery owners. As a result the electricity for self-consumption is sometimes stored when immediate use would have been possible in the overall system. In energy terms, this is inefficient due to the storage losses of the overall electricity system. In addition PV batteries are currently still relatively expensive, although cost reduction potentials are likely in the future.

Power-to-heat and power-to-gas

In the long term and in an electricity system with a very high share of renewables, power-to-heat and later also power-to-gas are important technologies. Both options interlink the electricity system with other energy sectors, e.g. the heat, natural gas, hydrogen and transport sectors. However, power-to-heat and power-to-gas only increase the share of renewable energy sources in these sectors when they are themselves operated using surplus renewable energies that can no longer be utilised by the electricity system. For the additional electricity consumption in the other sectors additional renewable power plants have to be built accordingly.

Compared to the other flexibility options power-to-heat and power-to-gas have, as full electricity storage (i.e. including re-conversion to electricity), by far the lowest efficiencies. At the same time power-to-heat – with virtual natural gas storage and an efficiency of approx. 50 % for the conversion of natural gas to electricity – still has a significant advantage over power-to-gas with an efficiency of approx. 25 % for the process chain of power-to-gas-to-power. In addition the specific investments for power-to-heat are significantly lower than for power-to-gas.

Overall the different options will contribute to the expansion of a renewable energy system in the various development steps over time. In principle all options can play a role in a future electricity system (and also the overall energy system) based on renewable energies, at different points of and in different phases of the transformation process. Research and development and demonstration and pilot plants are therefore appropriate in the case of all options, especially those which only begin to play an extensive role in the medium to long term. Figure 4 shows the time-related sequence of different flexibility potentials for utilising local renewable surpluses in Rhineland-Palatinate.

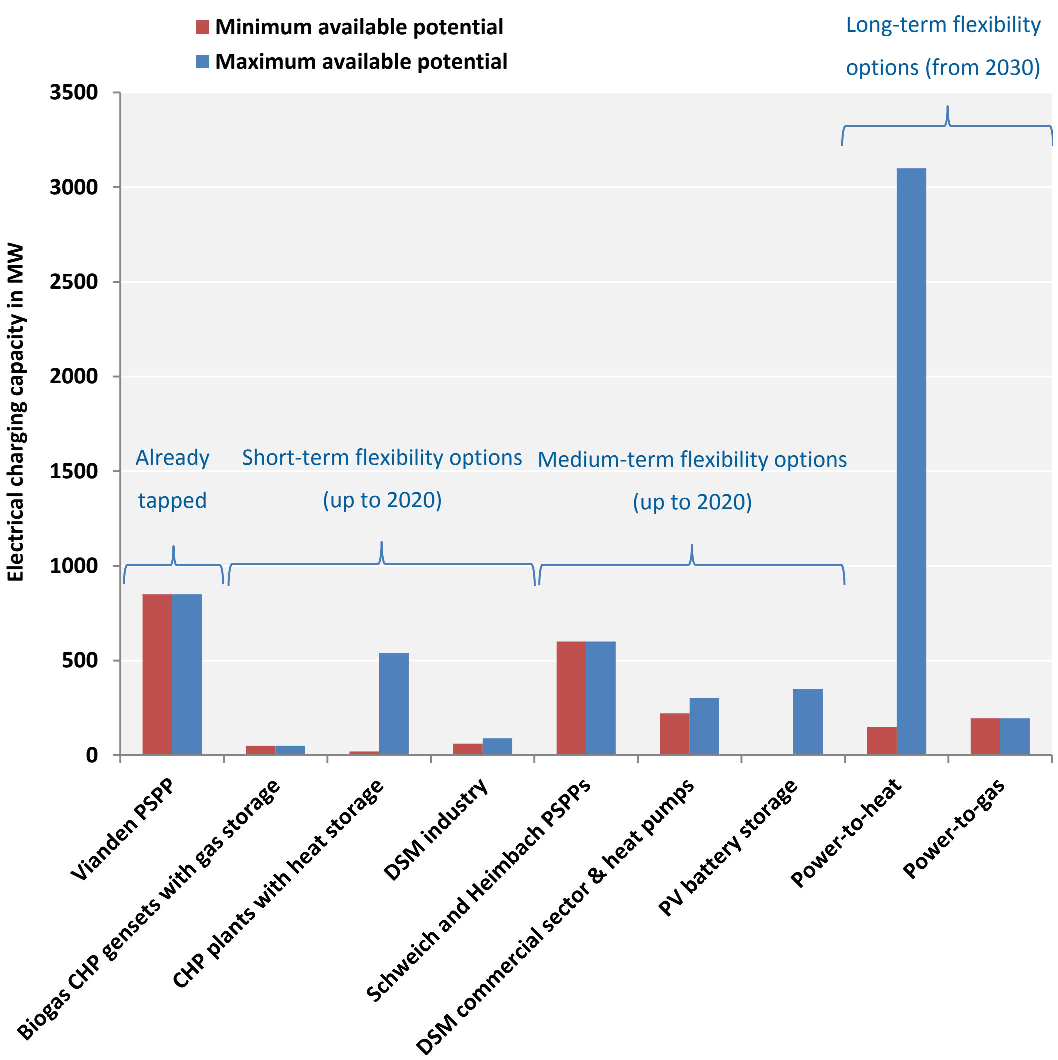

Figure 4: Incorporation of partially tapped flexibility potentials for utilizing local renewable surpluses over the course of the transformation process towards 100 % renewable energies in Rhineland-Palatinate. Source: Own presentation (Oeko-Institut e.V.)

LEGAL FRAMEWORK (WORK PACKAGE 6)

The legal framework (work package 6) is organized into a total of three steps: The first step illustrates the legal framework and the obstacles to grid integration resulting therefrom (29 issues in total, task 6.1 below). A second step identifies approaches for improving the legal framework (16 approaches overall, more details below, task 6.2). The third step finally discusses the future role and competence of the distribution system operators (task 6.3 below). In detail:

Legal framework and obstacles (task 6.1)

Grid expansion (regarding: issues 1 to 9)

- Important core laws pertaining to planning approvals are the German Grid Expansion Acceleration Act (NABEG), the German Power Grid Expansion Act (EnLAG) as well as the German Energy Industry Act (EnWG), each in combination with the German Administrative Procedures Act (VwVfG). Their scope of application comprises in particular high-voltage overhead power lines with a line voltage of 110 kilovolt or more. Power lines that have a smaller voltage are not subject to the requirements of a planning approval. However, their allowability may be hindered by certain individual regulations. Key laws
- If grids for integrating renewable energy are to be put in place, it is decisive what kind of "grid" is qualified as the "power line" by the EnWG. This has consequences for the unbundling as required by law. The distinction between the general supply system, the closed distribution system, the customer facility and the customer facility for self-supply of undertakings is of particular relevance. Quality of power line
- If a plant operator wants to connect plants with each other and to the grid, the operator must first of all consider the consequences of unbundling. The operator runs the particular risk of establishing an energy supply system or a closed distribution system through the connection of the plants. In the alternative the customer facility, the customer facility for self-supply of undertakings or the direct power line may be considered. System and unbundling
- The grid connection costs are borne by the plant operator, the costs for the reinforcement and expansion of the grid are borne by the system operator. The grid capacity's load or overload is, as a rule, no argument for the system operator to refuse expanding the grid capacity and, in particular, carrying out the connection to the grid. Costs (grid connection/ capacity)
- A system operator must not make the fulfillment of its duties to connect the plant as well as to accept, transmit and distribute the electricity subject to the conclusion of a contract. Instead, there is a statutory duty between the system operator and the (future) plant operator. Legal duty

- When determining the revenue cap, the system operator's costs for "research and development" are taken into account as a premium in the amount of 50 percent of the costs that have been defined as eligible within the scope of the state's energy research promotion. Such costs that were estimated when determining the base level of the revenue cap or as part of an investment measure are not taken into account. Moreover, the fact remains that costs for research and development are not included in the determination of the revenue cap.

Research and development

- As a rule, the distribution system operators' investments can only be authorized if they involve "considerable" costs. Other than that, investments in the expansion and restructuring of high-voltage power lines can be authorized if said investments are necessary for the stability of the overall system, for the integration into the national or international interconnected grid or for a needs-based expansion of the energy supply system. The approval procedures for the recognition of costs in the revenue cap are time-intensive. The current mechanism of the German Incentive Regulation Ordinance (ARegV) results in distribution system operators having to wait for up to seven years for their money depending on the respective case.

System operators' investments

- Plant operators do not share the costs for grid expansion or grid reinforcement. If this statutory regulation is deviated from at the disadvantage of the plant operator, the agreement deviating from it might be void.

Plant operator and grid expansion/ reinforcement

- The transmission systems are constructed according to the (n-1) criterion. Furthermore, supra-regional electricity distribution systems are operated according to the n-1 criterion to the effect that high-voltage distribution systems are also included. The (n-1) criterion is usually used as generally recognized rule of technology for medium-voltage lines.

Technical conditions

<u>Smart Grid (regarding: issues 10 to 12)</u>

- A distribution system operator may perform those responsibilities of the Smart Grid that relate to the grid's focus. Insofar as actions on the market side become the focus of attention, an enquiry may, as the case may be, be made as to the focus of the measure. In any case, activities that are mostly or purely market-related are inadmissible.

Distribution system operator and grid's focus

- The law enables electricity distribution system operators to charge their customers a reduced grid fee if they are in turn allowed to control fully interruptible consumer facilities.

Interruptible consumer facilities

- The provisions pertaining to the informative unbundling set boundaries for the distribution system operator in the operation of a Smart Grid. In any case, the passing on of information by the system operator, which it has received while operating the Smart Grid, is sensitive. The consumption data obtained while operating the meter point comprises personal data that is subject to protection by the German Federal Data Protection Act (BDSG). The collection, processing and use of such data are only admissible insofar as the BDSG or any other

Use of personal data

regulation has permitted it or if the person concerned has expressed its consent. The principle of certainty applies for the interpretation of statutory enabling provisions.

Storage (regarding: issues 13 to 20)

- The EnWG permits distribution system operators to operate storage facilities on the grid's side, which they are exclusively reserved to for the performance of their responsibilities (storage-like facilities). The operation of further storage facilities on the market side in a narrower sense by distribution system operators is inadmissible. The central control of storage facilities on the market side in a narrower sense by a distribution system operator is not admissible, either.

Operation by distribution system operators

- The measurement of the specific feed-in payment, which is important for a decentralized electricity generation and feed-in into the distribution system, is guaranteed by individual measurement installations. The different electricity quantities are identified by means of the management (German *Bilanzkreis-management*) whereby allocation is ensured.

Specific feed-in payment

- What is important for the acceptance of the storing of electricity is that the storage medium benefits from statutory privileges. Biogas and storage gas benefit from far-reaching privileges.

Statutory privileges

- Electricity, which is delivered to a storage facility for interim storage purposes, is exempt from the renewable energy levy if the electricity is only retrieved from the storage facility for feeding back electricity into the same grid.

Interim storage

- To the extent that storage facilities as storage-like facilities are exclusively reserved to system operators for the performance of their responsibilities, being part of the supply system, they are subject to the relevant statutory liability restrictions on the regulation of contractual or other legal relations.

Liability

- Storage facility operators must grant other companies access to their storage facilities according to adequate and non-discriminatory technical and economic conditions if said access is technically or economically necessary for an efficient system access with regard to the supplying of customers.

Third party access

- A system operator must not unilaterally demand the plant operator to store the generated electricity as an alternative to feeding it into the distribution system, for example in order to prevent the grid capacity's expansion. Agreements by mutual consent deviating from the above are effective under certain conditions. Storage and conversion losses lie in the plant operator's sphere of risk.

No storage instead of feeding in

- Financial funding programs play an important role in making storage technology more attractive, e.g. the KfW Renewable Energy Storage Program; program number 275. Comparable market incentive programs are also conceivable for other specific issues in order to make storing in particular more attractive or to increase the grid integration of electricity from renewable energy in general.

Funding programs

Load management (regarding: issues 21 to 25)

- Distribution system operators are entitled and obligated to remove threats or disruptions to the security or reliability of the electricity distribution system through grid- or market-related measures. Special provisions are redispatch and feed-in management. Furthermore, the preliminary or final decommissioning of plants or partial capacities may be considered. The respective measures by the system operators correspond to rights and obligations on the part of the plant operators. Measures
- A system responsibility comparable to that of the transmission system operators applies to the operators of electricity distribution systems within the scope of their distribution responsibilities. System responsibility
- If the threat or disruption is based on an overload of the grid capacity, feed-in management provides for the payment of compensation to the plant operator (German Härtefallregelung). A statutory modification of the compensation to be paid upon commissioning of new plants in due course would in principle be reconcilable with Art. 14 and Art. 12 German Constitution (GG) (property, profession). Feed-in management
- The system operator always requires a specific authorization in order to take system- or market-related measures or other adjustment measures. The control of plants beyond the above is not allowable. It is true that an at least partial and permanent throttling of new plants in particular would in principle conform with the GG if there is a respective statutory basis, insofar as that seems necessary due to an otherwise overloaded grid capacity. However, the current legal framework does not provide for the above. Authorization
- The system operator can control energy by shutting down plants. This requires that there is a contractual agreement between the plant operator and the system operator. Control energy

Overlapping issues (regarding: issues 26 to 29)

- Individual grid fees could create incentives for an effective loading of the grid. Separate (fixed) or variable grid fees may be particularly suitable. A variable grid fee may in particular contribute to the grid user adapting its electricity consumption to the requirements of the distribution system. The statutory limits must be observed. Individual grid fees
- Privileges in the renewable energy levy provide incentives for the generation and consumption of electricity from renewable energy plants. Besides the special provision for exemption from the renewable energy levy during storage (issue 16 above) and besides the reduction of the renewable energy levy, the internal consumption is above all relevant. Energy levy

- The direct marketing mechanism provides a fundamental incentive for an alternative to the statutory feed-in remuneration. Direct marketing is the alternative to returning the electricity to the system operator at the feed-in rate associated therewith (two alternatives).

Direct marketing

- Incentives can also be provided through tax relief, for example for electricity that is exclusively made from renewable energy (hydro energy, wind energy, solar energy, geothermal energy, landfill gas, sewage gas or biomass) or for particular plant sizes and spatial connection.

Tax

Approaches for improvement (task 6.2)

Within the scope of the legislative influence of the Land (federal state) of Rhineland-Palatinate on the law of the *Bund* the following is to be considered by taking suitable measures and initiatives above all in the German *Bundesrat*:

Grid expansion (regarding: approaches 1 to 4)

- in due time in the future and following the sufficient expansion of the infra-structure for generating and distributing electricity from renewable energy, making the statutory requirements for site approval for energy generating plants more dependent on a previous loading of the grid capacity, in order to avoid an otherwise necessary expansion of the grid capacity;

Site approval and grid capacity

- either (i) at least shortening the period from nine to six months by which the motion for approval of the investment has to be filed prior to the beginning of the respective calendar year, sec. 23 (3) sentence 1 ARegV or (ii) giving greater consideration to the costs incurred by the operators of the electricity supply systems also during the course of the regulation period and reflecting the costs in this regard to a large extent without a time offset in the calendar year's revenue cap (on the basis of the suggestion by the circle of Länder regarding the yearly balancing of capital costs);

Costs and incentive regulation

Smart Grid (regarding: approaches 5 to 6)

- determining the fully interruptible consumer facilities in order to establish planning certainty in using the creative scope for action and then specifying which kind of possibilities for intervention the system operator may have;

Determining rights and duties

- defining the rights and obligations of the distribution system operator in the scope of metering point operations as well as purpose and scope of collecting and using personal data in more detail;

Storage (regarding: approaches 7 to 12)

- categorizing the objective of storage operations in consideration of the requirements for unbundling as a grid- or market-related activity, in the alternative determining specific preconditions of fact that, if met, constitute a case of grid-related or market-related storage activity; *Distinguish between grid- or market-related activity*
- carrying out a sharing of the lower remuneration suffered due to losses from storage and/or transformation of energy between the parties involved (sharing between plant operator and system operator and, as the case may be, third parties); *Sharing of lower remuneration*
- specifying the legal terms not defined by statute for third-party access to storage facilities in order to contribute to an increased legal and planning certainty; *Specifying third party access*
- if specific preconditions are at hand, granting the system operator the right to offer storage of the generated electricity instead of primarily feeding it in and purchasing it. The result of the distribution system survey on the relevance of increased use of storage facilities for the grid expansion is, however, to be appropriately considered. Subsequently, in accordance with the target that grid expansion is to be reduced to a justifiable extent in future, the appeal of storage is not to be unconditionally increased beyond the present scope and therefore to be assessed with reservations; *Storage instead of feeding in*

Load management (regarding: approaches 13 to 15)

- to define in more detail in which cases a grid-oriented target justifying system operators to act with regard to grid- or market-related measures of load management is at hand, as opposed to market-oriented targets that do usually not justify the above; *Distinguish between market and grid*
- in due time in the future and subsequent to the sufficient expansion of the infrastructure for generating and distributing electricity from renewable energy, to limit the automatism of the claim for compensation to the effect that the claim for compensation does not apply in any case and regardless of any behavior by the system operator. In the alternative it is to be considered to grant the system operator against which claims have been raised a certain transitional period (for example one calendar year), before the duty for expanding the grid capacity in combination with the claim for compensation of the plant operator becomes applicable; *Modify claim for compensation*
- in due time in the future and subsequent to the sufficient expansion of the infrastructure for generating and distributing electricity from renewable energy, to allow for a permanent throttling of energy generating plants in the amount of a maximum percentage of the power capacity (energy generation management), if this would prevent an expansion of grid capacity that would otherwise become necessary;

Overlapping issues (regarding: approach 16)

- describing additional case groups for individual electricity grid fees (e.g. flexibility in power consumption, the day and/or night time of preliminarily expected power consumption and other non-discriminatory criteria).

Individual grid fees

Discussion on roll and competence of the distribution system operators (task 6.3)

- The role of distribution system operators in the context of the integration of renewable energy-electricity is defined by their statutory tasks. Distribution system operators have the duty to guarantee for an as safe, economical, customer-friendly, efficient and sustainable as possible system-bound supply of the public with electricity and gas that is increasingly based on renewable energy sources. This is the basis on which distribution system operators perform their task of distributing electricity. As a specification of this duty the distribution system operators are obligated to operate, maintain and optimize according to needs a reliable and efficient energy-supply grid free from discrimination. The limit is economic appropriateness, sec. 11 (1) EnWG. Moreover, the distribution system operators assume respective tasks pertaining to load management, grid development planning and system responsibility. Furthermore, they are the addressees of the reporting requirements on grid condition and grid expansion plans as well as of the duty to provide support for measures by the system operator in the grid of which they are directly or indirectly technically integrated and the standards by an upstream grid operator justified thereby.

Role

- The description of responsibilities implies the statutory foundations and limits to the distribution system operators‘ competence for contributing to the integration of electricity from renewable energy. The essential key element for the distribution system operators to exercise their competence in conformity with the law is their capacity and reliability, since the operation of an electricity supply system requires authorization from the authority in charge , cf. sec. 4 (1) sentence 1 EnWG. Furthermore the distribution system operator must consider different underlying circumstances. On the one hand, it may be envisaged that a certain outline condition is observed by a plurality of individual measures by the distribution system operator and is to be adequately considered in each case (category 1, e.g. unbundling). On the other hand, it is conceivable that the law provides for certain circumstances for particular individual activities by the distribution system operator that have to be considered when implementing this specific single measure (category 2, e.g. conclusion and implementation of concession agreements). Finally, underlying circumstances regarding competence may result from the respective state of the distribution system operator in terms of corporate and local laws (category 3, e.g. involvement of a local authority).

Competence

Current and future activities based on a dynamic understanding

- On the basis of the described role and competence it was the traditional role of the distribution system operators to obtain energy quantities from the upper voltage lines and to distribute them to the end consumers. However, the energy reform opens up and requires a much larger field of responsibility for the distribution system operators. For in particular the expansion of electricity generation from renewable energy and the decentralized feed-in associated therewith is progressing continuously. The current legal framework already provides starting points for an increased or at least dynamic scope of responsibilities of the distribution system operators. The duties to operate and to maintain an "effective" electricity supply system and to optimize, reinforce and expand the latter "according to needs", implies a dynamic element which is aimed at developments of the demand. In addition, broadening the distribution system operators' scope of responsibility is above all to be supported by two measures: Improvement of innovation and investments by distribution system operators as well as improvement of the legal framework in the described key areas (grid expansion, storage operation, load management, Smart Grid). In order to realize considerations regarding the future role of the distribution system operators, specific legal key points must be observed that are hardly optional (from a political point of view) (e.g. unbundling, exercise of influence in case of local participation etc.) Instead, the future role and competence of the distribution system operators must be modified selectively and therefore productively. Approaches can be found in step 6.2 of this study.