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Research Report

The electricity market reinvention by regional renewal

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EIKV-Schriftenreihe zum
Wissens- und Wertemanagement

The electricity market reinvention by
regional renewal

Sebastian Fontaine

IMPRESSUM

EIKV-Schriftenreihe zum Wissens- und Wertemanagement

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Motivation

The reconstruction of the energy system affects large sections of the population because many house owners suddenly become energy producers. The distinction between the producer and the consumer becomes unclear. The insight that electricity is a uniform product, and consequently competition is impossible by quality variance, leads to the question: How would co-existence of all power plants be possible within one market, in which there is such a variety of preconditions, but with an identical product? The marginal cost of written-off photovoltaic systems revert to zero for the rest of their lifetime, as is the case with wind turbines. How can other systems compete after the time of fixed feed-in remuneration?

Der Umbau des Energiesystems betrifft breite Bevölkerungsschichten ganz unmittelbar, weil viele Hauseigentümer plötzlich Energieerzeuger werden. Die Grenze zwischen Erzeugern und Verbrauchern verschwimmt. Aus der Erkenntnis, dass Strom ein uniformes Produkt ist und somit keine qualitative Konkurrenz erlaubt, kristallisierte sich eine Frage: Wie können die verschiedenen Anlagen zur Energiegewinnung überhaupt nebeneinander im Markt bestehen, mit so unterschiedlichen Voraussetzungen aber einem identischen Produkt? Die Grenzkosten abgeschriebener PV-Systeme tendieren für die Restlebensdauer stark gegen Null, die der Windenergie ebenso. Wie können nach der Zeit der festen Einspeisevergütung dann andere Systeme überhaupt noch konkurrieren?

La transformation du système d'énergie concerne larges couches de la population vu que beaucoup de propriétaires de maisons deviennent producteurs d'énergie. Les barrières entre les producteurs et les consommateurs tombent de plus en plus. Le fait que l'électricité est un produit uniforme et ne permet pas de concurrence au niveau de la qualité soulève la question suivante: Comment tous les systèmes de génération d'énergie différents peuvent-ils coexister dans le même marché lorsqu'ils sont soumis à des conditions différentes bien qu'ils concernent le même produit? Les coûts marginaux ont un impact voisin de zéro pour les systèmes photovoltaïques qui font l'objet d'amortissements fiscaux comme les éoliennes. Comment les autres systèmes peuvent-ils rivaliser du tout après la période des tarifs de rachat fixé?

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Abstract

The ubiquity of electrical devices in our daily life is not something we think about anymore in the industrialised world. It has become as normal as breathing. Yet unlike air, power has to be obtained and distributed. The constant availability of current is therefore not a given thing, but something that involves ongoing hard work. Just one hundred years ago, electricity was classified as a luxury good.

Since renewable energies entered the German market 25 years ago, they slowly started to change some fundamental conditions, the basis begins to quake now. The market thus far had seen some transitions from local power plants within the cities to huge power plants beyond the gates of the cities. Later, the co-generation of power and heat was invented and power plants came back, again closer to the consumers. No such changes ever impacted on more than one fourth of the overall market, which is the case for renewable energies today.

In the coming years, more and more photovoltaic systems will cease to have contracts with fixed remuneration. Whilst they are in good condition they will produce energy at almost no cost. How this will impact on the overall market is hard to predict. Therefore, the study inspects the market conditions given by the special character of the uniform product “electricity”. Based on Germany’s leading role in terms of renewable energy, the scope includes the bigger, integrated European market. Some input comes from inspection of other industrialised areas with emerging renewable energy markets, such as the US.

New technologies can turn every house owner into an energy producer, making the distinction between supply and demand unclear. This regionalisation is considered to be the main game changer in a liberalised market. Due to the fragmentation into many small market participants, there is no major player that could take the lead in the evolution. In any case, it is the role of the government to ensure services for the public as well as public security. The increasing number of single directives of regulating authorities has to be substituted by a major act in describing the market framework, where the freedom of the forces can develop their potential.

Finally, this work gives an insight into further possibilities resulting from the main decision to look at power in terms of provision of services instead of a physical good.

Scope

The overall energy market usually means all primary energy, including oil, all other liquid fuels and also gas, coal, etc. Within this study, the energy market is understood to mean the market for electricity only. Since renewable energies are used to produce electricity, this market begins to move. The primary objective of this work is to investigate this movement. There are five different renewable energies with some remarkable features in terms of the economy:

Type of energy	Remarkable characteristic
Wind (kinetic)	Instant consumption with no possibility to store. It is a rival good for wind turbines that are standing together.
Sun (radiation)	The use of radiation for energy production turns a public good into a private one. On what legislation is this based?
Water (potential or kinetic)	The right to water is one of the oldest rights known to man. The very first generators were also based on watermills. Could this be used as generic blueprint?
Biogas (chemical)	Two-step energy conversion, as the gas drives a generator, can therefore independently store the energy. Is this service billable somehow?
Geothermal	Can extract the energy when required, but is some mining right required for the usage?

Finally, all of the above turn a public good into a private good to be sold on the energy market. For some, the legal basis to do this seems questionable. Investigation into the legal basis of electricity leads to this question: which kind of product is power, i.e. is it a private or a public good or maybe there is even a third variation?

In the coming years, the period of fixed remuneration will expire for the first systems of renewable energy. The producers have to sell their energy on a free, liberalized market. Their marginal cost of power is very different compared to fossil power plants, as those renewable energy systems do not normally have much costs associated with fuel.

This work is a study of potential implications for the energy market in Germany. As Germany is part of the pan-European power grid, this is also part of the extended objective. A possible concept for energy market evolution will be described, whereas a detailed elaboration of a proposition that will be ready to use is beyond the scope of this work.

List of abbreviations

AC/DC	Alternating current / direct current
BAU	Business as usual
BBergG	Bundesberggesetz – Federal Mining Act (law)
BC	Before Christ
BKV	Bilanzkreisverantwortlicher – person responsible for balancing group
EE	Erneuerbare Energien – renewable energies
EEG	Erneuerbare-Energien-Gesetz – law for renewable energies
EMVG	Gesetz über die elektromagnetische Verträglichkeit von Betriebsmitteln Law about the electromagnetic compatibility of supplies
GHI	Global Horizontal Irradiance
GuD	Gas und Dampf – gas and steam
KMU	Kleine und mittelständische Unternehmen – small and midterm enterprises
LTE	Long Term Evolution, standard for mobile communication
MR	Momentanreserve – instant reserve based on inertia
MRL	Minutenreserve – minutes reserve (control)
NEV	Netz-Entgelt-Verordnung – regulation for the grid fee
OTC	Over the counter
PRL	Primärregelung – primary control
PV	Photovoltaic
RAAS	Real-time awareness and alarming system
RES	Renewable energy sources
SAIDI	System Average Interruption Duration Index
SRL	Sekundärreserve – secondary reserve (control)
UCTE	Union for the co-ordination of transmission of electricity
ÜNB	Übertragungs-Netz-Betreiber - operator of highest level of power grid
UPS	uninterruptible power supply
US	United States
VAT	value added tax
VLS	Volllaststunden – full load hours
WTO	World trade organisation

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1. Introduction

With the introduction of the German law, “Stromeinspeisungsgesetz”¹, the renewable energy market was born on 1 January 1991. Only in the last 5 years has the capacity of renewable power plants doubled. Originally the law was intended by Hermann Scheer² to open a door to the traditional energy market for this new technology.

With 25% of the market share, a threshold is reached now that underlines: The time of its infancy ends, especially if we look at the long-term planning and consider that “G7 leaders agree to phase out fossil fuel use by end of century”³. While Germany is ahead in this regard and therefore in the focus of this study, US think-tanks are also investigating this area and have drawn up a timetable to illustrate the competition.

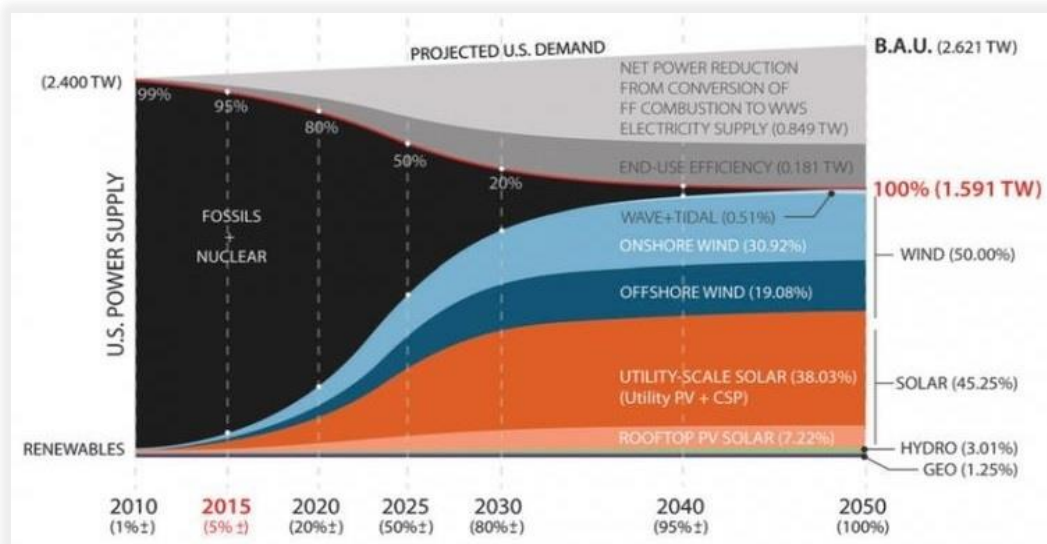


Figure 1: Timetable proposition to reach the G7 purpose to phase out fossil fuel⁴

To reach that goal, investors need to be very sure about how to invest and in which technologies to invest. The current pubescent phase with quick and frequent changes is a dangerous one for stability of the energy supply. To make it ready for the future, three major steps are required.

1 Leuschner, Udo, Stromeinspeisungsgesetz, <http://www.udo-leuschner.de/energie-chronik/energierecht/stromesp.htm> (18.03.2014)

2 Jochimsen, Ulrich, Wie das Stromeinspeisungsgesetz entstand und sich die erneuerbaren Energien in Deutschland durchsetzten, <http://www.ulrich-jochimsen.de/files/Stromeinspeisungsgesetz.pdf>

3 Connolly, Kate, G7 leaders agree to phase out fossil fuel use by end of century, <http://www.theguardian.com/world/2015/jun/08/g7-leaders-agree-phase-out-fossil-fuel-use-end-of-century>

4 Vox: Here's what it would take for the US to run on 100% renewable energy - The Solutions Project, <http://thesolutionsproject.org/vox-heres-what-it-would-take-for-the-us-to-run-on-100-renewable-energy/> (28.08.2015)

1.1. Game-changer regionalisation replaces centralism

Energy consumption is not uniform all over the landscape. There are conglomerates of industrial centres that consume considerably more electricity than rural areas. In the past, huge centralised power plants were established close to these centres. Therefore, the distance of power transmission was kept to a minimum. The power grid is designed to suit these few, huge power plants.

With the success of PV, many roofs have become small power plants. The production is getting more and more regional. Any farmer could even build his own biomass power plant. The location of power production becomes more and more decoupled from the concentrated locations of industrial consumption. Therefore, there is increased importance attached to the distribution grid.

This topic becomes more urgent when taking into account the fact that the technical network stabilisation can nowadays only be done by traditional power plants. The company that controls the grid is authorised to disconnect producers in case of overcapacities to guarantee the stability of energy supply. If producers of renewable energy are disconnected from the grid, they have the right to compensation for their outage.⁵ In contrast, where there is poor availability of power, they are allowed to disconnect consumers or even districts. The question is, how can both scenarios be best prevented.

One idea is to integrate the ability for stabilisation work into all the small distributed power generators that are typical for the renewable energy. After distributing the production it is logical to distribute the remainder that is essential for a stable electricity supply. Actions to stabilise the power grid are prescribed today. How would a market design to support stabilization as service agreement look?

5 Oberlandesgericht Hamm, Entschädigungsanspruch aus § 12 Abs. 1 EEG (2012), http://www.justiz.nrw.de/JM/Presse/presse_weitere/PresseOLGs/archiv/2015_01_Archiv/10_03_2015_/index.php (10.03.2015)

1.2. A strong state conducts better than it prescribes

The energy market is anything but free. The regulation has reached a high level, too high maybe. If it becomes all-encompassing, the market gets strangled. The legislation would better reduce the influence to a level to design the rules of the game only.

Nevertheless, German legislation has long known the word “Daseinsvorsorge”⁶ (services of general interest), not be confused with well-fare (“Fürsorge”). The origin of this word is based on the writings of Ernst Forsthoff (1902 – 1974), but the origin of the concept comes from 1793 (constitution of Gironde, Nr. 24 „Les secours publics sont une dette sacrée de la société ; et c'est à la Loi à en déterminer l'étendue et l'application.”^{7,8}). Forsthoff's work started before the seizure of power of the National Socialists and continued after it. He continuously published writings on legislative and constitutional topics. Without doubt, some of them use wording that is grounded in this time. Nevertheless, he could continue working even after the liberation of Germany. Some topics have their origin in the period of National Socialism, but without sharing its negative ideology.

The current study partly goes back far in time and therefore also connects with citations from this time. One word that will appear several times is “Lebensraum”. It was often used at this time to argue in terms of expansion wars. There is a second meaning of “living areas” which is intended in this work only. Any proximity to the ideology of National Socialism is hereby denied.

History is also responsible for the fundamental difference of the European philosophy underlying the law procedures, compared to those in the US. The welfare state is something positive and acceptable for Europeans. It takes responsibilities on which the inhabitants rely.

6 Forsthoff, Ernst, Die Verwaltung als Leistungsträger, Königsberger rechtswissenschaftliche Forschungen, Stuttgart und Berlin, W. Kohlhammer Verlag, 1938

7 cp. Forsthoff, Ernst, Rechtsstaat im Wandel, Verfassungsrechtliche Abhandlungen 1950-1964, Stuttgart, W. Kohlhammer Verlag, 1964, pp. 29–30

8 Maury, Jean-Pierre, Constitution française de 1793, projet de Constitution girondin, Plan de Constitution présenté à la Convention nationale les 15 et 16 février 1793, l'an II de la République, <http://mjp.univ-perp.fr/france/co1793pr.htm> (03.06.2010)

In fact, the availability of power is so important nowadays, that it has to be considered almost as common property. In this case there are in principle two options:

1. The government takes complete responsibility for power supply, as it does for education, peace and streets. Private companies would be subcontractors only.
2. The government ensures that only private companies can do the job, as for public transport, telecommunications, healthcare, etc.

The second option seems to be the preferred one nowadays, as the European Commission is proposing an Energy Union now “to encourage renewable energy producers to better integrate in the wider electricity market.”⁹

The laws of the European Union member states will have to be adapted accordingly for this new role to be fulfilled. The state should concentrate on its role as conductor of the orchestra of specialised enterprises and market participants.

1.3. Redesign of the market instead of price-tuning

The German law “Stromeinspeisungsgesetz”, which subsequently became known as “EEG”, continuously pushes renewable energies as if they were still emerging technologies. The old pricing model is becoming unhinged. Strong examples are regulating authorities prohibiting the disablement of power plants that have become uneconomical. If the technical need to stabilise the network is no longer covered by market price, then further growth is obviously not possible with the current model.¹⁰ That is why the German authorities started to consider a revision of the energy market design.¹¹

The traditional, centralised energy market deals with only one product: energy measured in wattage (MWh).

The regional, renewable energy market has to deal with more:

- Demand (service of energy transformation)
- Reliable availability (service to provide reserve, transportation)
- Level of quality (service to equilibrate any disturbances)

9 European Commission, Energy Union Factsheet, Why do we need an Energy Union?, http://europa.eu/rapid/press-release_MEMO-15-4485_en.htm (25.02.2015)

10 Rösing, Justin, The renewable energy usage in industries, interviewed by Fontaine, Sebastian (04.06.2015)

11 BMWi, Zentrale Vorhaben Energiewende für die 18. Legislaturperiode, <https://www.bmwi.de/BMWi/Redaktion/PDF/0-9/10-punkte-energie-agenda-fortschreibung,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf>, p. 6

Nowadays, the last two points above are ensured by regulatory authorities establishing a framework of laws, standards and specifications. Market participants are very creative and many new business cases are currently designed, tried out and invested in. The provider of the power grid is just bringing together the consumer and the producer of electricity. If the need on one side is not in balance with the tender on the other, than the grid operator has little option to intervene. But if he has to take the financial burden and cannot transfer it to the renewable energy producer, then only two participants are left: the consumer and the traditional energy producer. Who must foot the bill for the additional efforts?

This question could be answered by a political decision, or by implementing a market mechanism that balances benefit and cost. All the services around power production must be provided, regardless of technology or location. Today the effort to ensure availability and quality of power cannot be billed directly. The costs are hidden in the price of an MWh. It is time to make these costs visible and accountable by trading such services independently as discrete items, or at least by letting them have direct and considerable influence on the overall price.

2. State of the art

Electricity is a product, which has been available on the market for more than 100 years. The technological specifications are mainly unchanged, as they belong to the principle of natural law. Today, electrical power is a natural part of our daily lives. Few people reflect on what would be missing or not working without it.

- Illumination immediately ends as well as trains, lifts and machines.
- Phones, even cell-phones will stop to work after a few hours of battery life.
- Fridges and freezer start to heat up – content might spoil after a few hours.
- Water pumps stop working and as soon as the reservoirs are empty, there is no more water to flush toilets.
- The above applies also in the case of the gas station used to refuel cars.
- Even oil-driven heating is controlled by small electronics, so homes become cold, or hot in areas where people rely on air conditioning.

All the above examples show that every consumer trusts in wire-based power delivery by the network at every single second. In fact, electricity is a very special product with the need to instantaneously balance production and consumption. Only with tremendous effort involved, can it be stored directly in capacitors.

Our daily lives are therefore founded by a tiny power grid that links all consumers with the producers. This balance has been consistent over the last two centuries. What we are now seeing with the increase in renewable energy is just another change. It seems to be more standard evolution than surprising revolution.

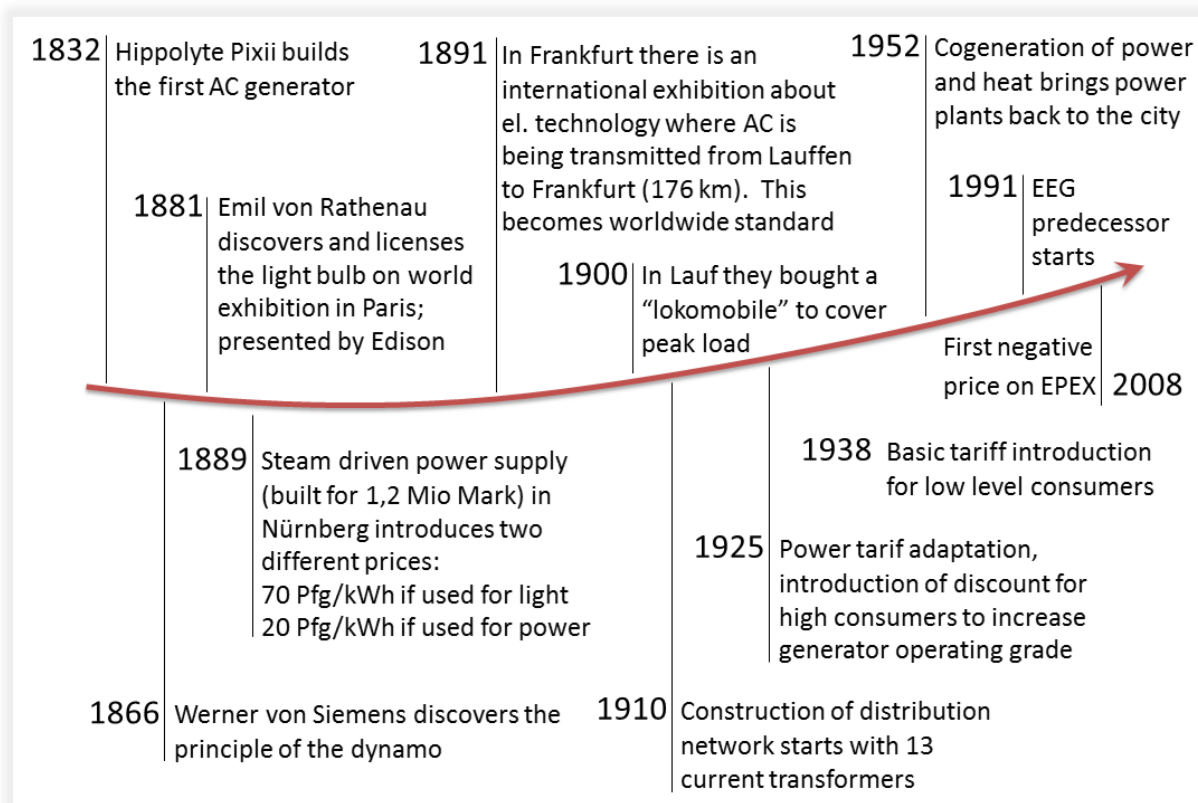


Figure 2: History of the energy market

(data taken and reproduced from ^{12, 13, 14})

As power plants became bigger and more powerful, they were built outside cities due to pollution issues. One of the earliest indications for increased sensitivity for environmental questions in the electricity sector is the installation of the first permanent measurement of flue gas, 1903 in Tullnau.¹⁵

¹² Wikipedia, Elektrischer Generator, <http://de.wikipedia.org/w/index.php?oldid=143028367> (12.06.2015)

¹³ Negative Strompreise werden häufiger, <http://energyviews.de/3965/negative-strompreise-werden-haeufiger> (13.08.2014)

¹⁴ cp.Hahn, Manfred, 100 Jahre Strom in Franken, von der Kaiserzeit bis zur Energiewende, Treuchtlingen-Berlin, wek-Verlag, 2014, p. 16

¹⁵ cp.Hahn, 100 Jahre Strom in Franken, p. 28

At the same time, the development of the landscape began. More and more villages became connected to the new centralised power plants. They worked as crystal nucleuses from where the meshed network started its expansion.

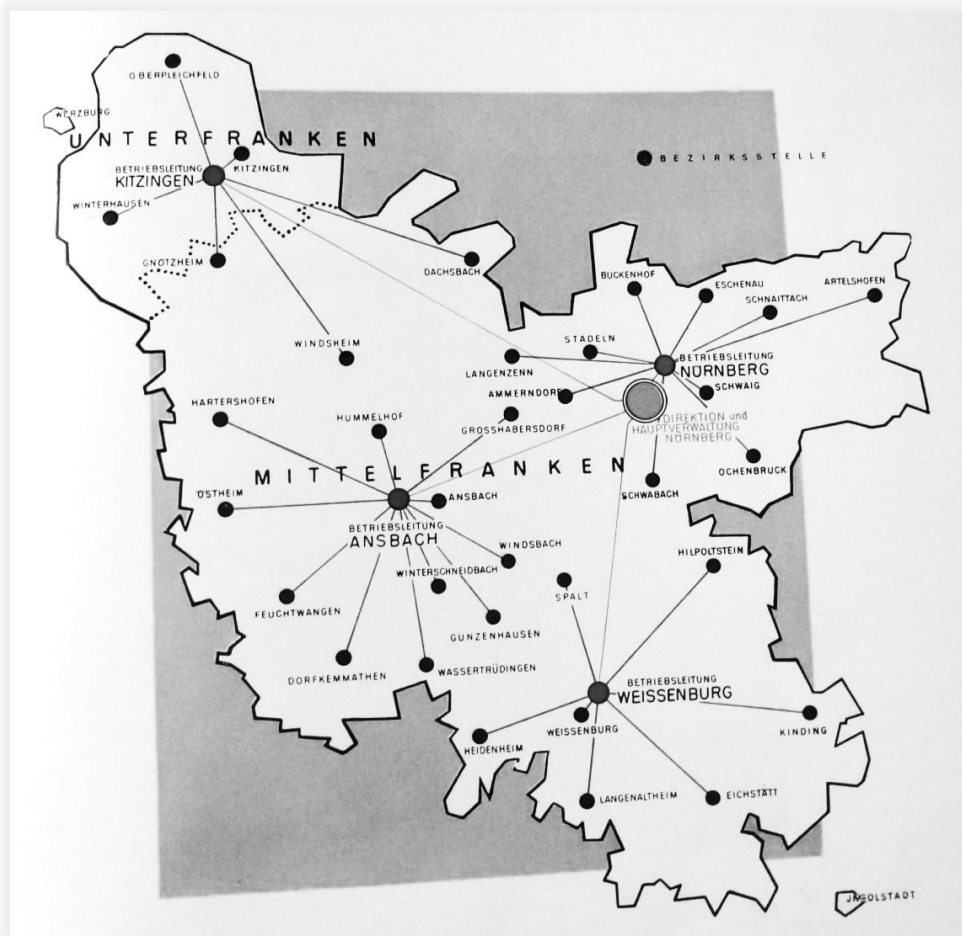


Figure 3: Power grid organisation in Nürnberg¹⁶

The early pictures of power distribution grids have some similarity with nerve cells that start to grow and interconnect. The problems of meshed networks are similar in several subjects such as biology, electricity and communication networks. “Linear statical and dynamical system models are often used to predict a system’s future state given the current and past state(s)”¹⁷

Statistical methods can therefore also be an option for future energy market enhancements. Such a paradigm change in how to view to power grids is happening in Germany right now.¹⁸

¹⁶ Hahn, 100 Jahre Strom in Franken, p. 84

¹⁷ Farkas, Károly, Hossmann, Theus, Legendre, Franck, Plattner, Bernhard and Das, Sajal K., Link quality prediction in mesh networks, computer communications doi:10.1016/j.comcom.2008, <http://people.ee.ethz.ch/~lfranck/link-prediction.pdf>, p. 3 (2008)

¹⁸ KoRiSim - Kooperatives Informations- und Risikomanagement in Zukunftsfähigen Netzen, Eine Simulationsstudie, <http://forschung-stromnetze.info/projekte/kooperatives-informations-und-risikomanagement/> (28.08.2015)

2.1. Hierarchical top-down distribution

The evolution of the power distribution grid is explained in its design. First, power had to be distributed within the cities. Later, when power had also to be delivered to rural areas, bigger power plants were built outside the cities. Through time, four layers of power distribution emerged (1,3,5,7) with three transforming levels (2,4,6).

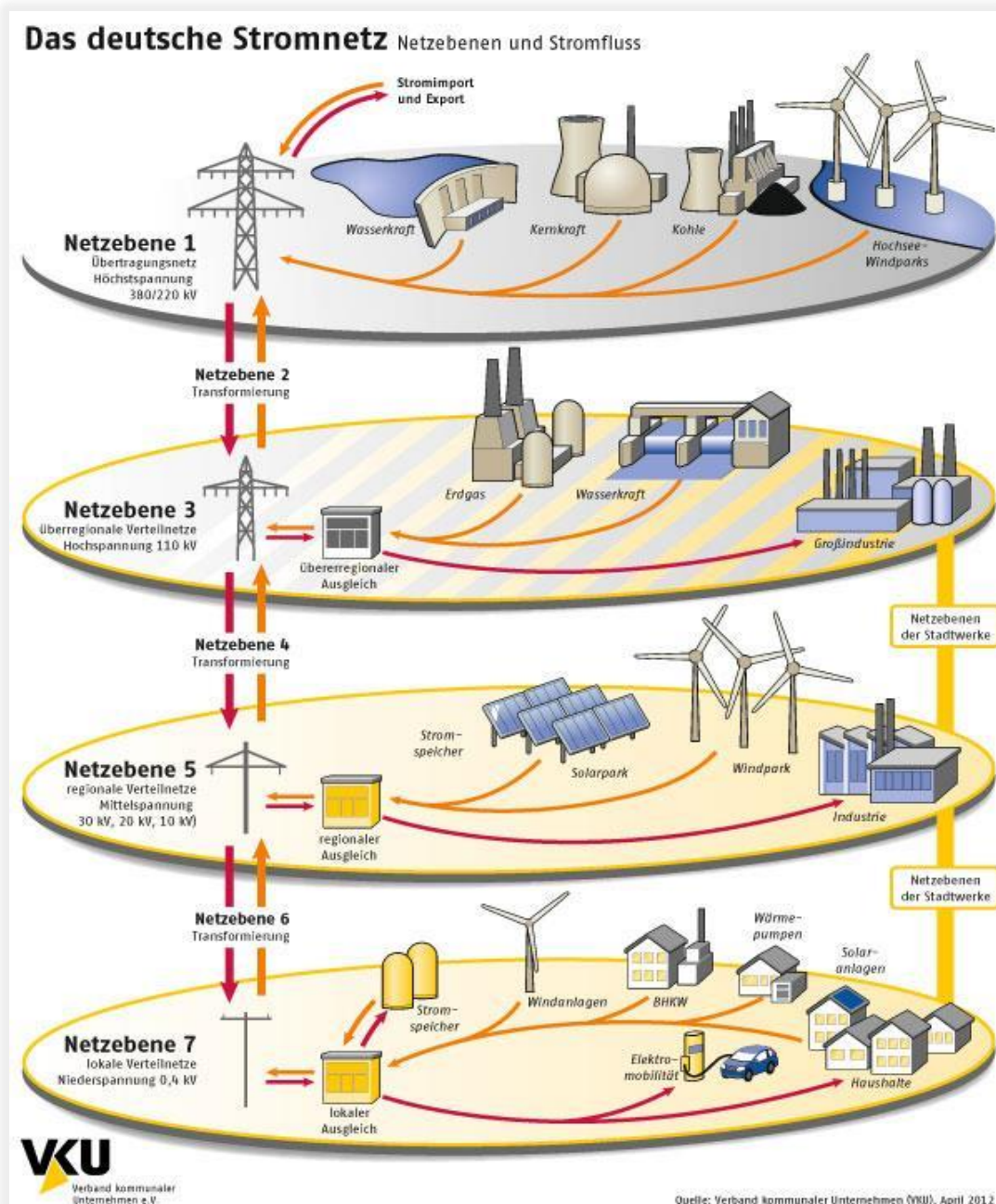


Figure 4: Power distribution grid, voltage and organisational levels

(taken from ¹⁹)

¹⁹ Stadtwerke Flensburg GmbH, <http://stadtwerke-flensburg.de/FAQ.1078.0.html>

The higher in the hierarchy a power plant is located, the more powerful it is, the less it can be influenced by switching actions on the lower voltage-levels. Stabilisation of the power grid is leveraged, which is a natural characteristic of the system.

Solar panels producing more power on the lowest voltage-level than demanded within this layer can reverse the direction of the energy flow up to a higher level. The historical network design is not made to suit these needs; it always works top-down. The best scenario would be if local production could be balanced with the need of local consumers through mutual compensation.²⁰

The “Energiewende” will impact all infrastructures that exist today on all the levels. Therefore German environment secretary even compared the project with the rebuild of the nation after World War II.²¹

2.2. Support for new market participants

Some well-known products required government support to enter the mass market. One famous example is the catalytic converter used in cars. Their usage had been dictated by legislation (USA: 1974 and Germany: 1984).²²

The highest level German power grid is owned and driven by four major companies called “Übertragungs-Netz-Betreiber” (ÜNB). As these four are subsidiary companies of the biggest players in the energy market, they had some power to avoid the market entrance of new power producers. They just had to make the connection to the grid very slow or expensive to obstruct the competition.

20 Erneuerbare Energien, Das Magazin, Solarstrom im Netz - Lastmanagement statt Regelenergie, <http://www.erneuerbareenergien.de/lastmanagement-statt-regelenergie/150/436/54783/> (08.08.2012)

21 Hammer, Benjamin and Altmaier, Peter, Energiewende "größte Herausforderung seit dem Wiederaufbau in der Nachkriegszeit", http://www.deutschlandfunk.de/energiewende-groesste-herausforderung-seit-dem-wiederaufbau.697.de.html?dram:article_id=215620 (18.07.2012)

22 Wikipedia, Fahrzeugkatalysator, <https://de.wikipedia.org/w/index.php?oldid=143109295> (22.06.2015)

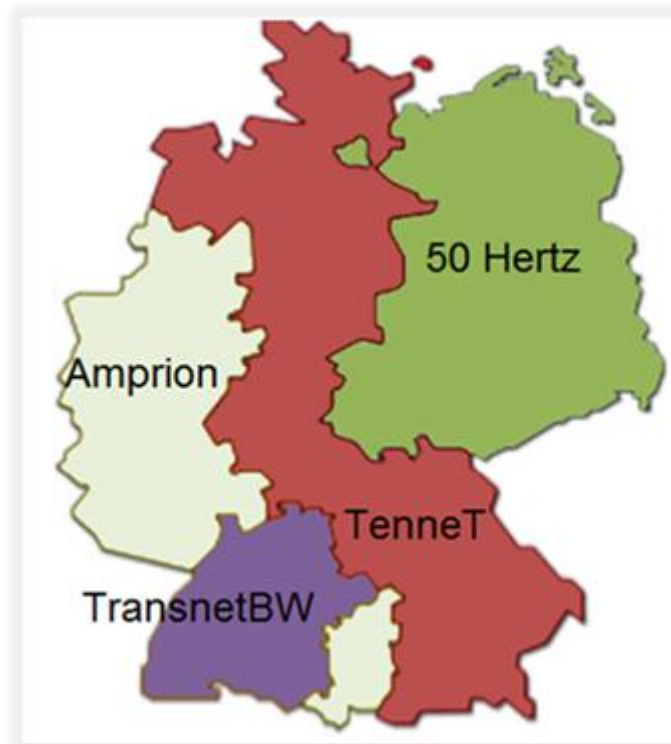


Figure 5: Map showing operators of the high level power grid.²³

To limit the power of the ÜNBs, the law called “Stromeinspeisegesetz” of 1991 forced the grid operators to accept power from all renewable power generators. In addition, some minimal price for the renewable energy had been guaranteed. This was the start of the feed-in remuneration.

From the outset, it was visible that the renewable energy sources produce power at different prices. The initial level of apportionment by this law was only sufficient to cover the production cost for some very good wind regions, but definitely not for photovoltaic.

Soon it became evident that connectivity alone is insufficient to let the new technology enter the mass market. Some price subsidies will also be required to support the technologies, depending on their individual prime costs.

²³ Brems, Wibke, Fragen und Antworten zur Stromversorgung und Stromnetzen, <http://wibke-brems.de/fragen-und-antworten-zur-stromversorgung-und-stromnetzen-2/> (19.02.2014)

2.2.1. Legislation adapts price structure

Subsidies for power production are all but a new invention for renewable energies. The so-called “Kohlepfennig” (1970-2012) promoted the stone coal with €177 billion and brown coal with €65 billion. Even atomic energy was stimulated by €187 billion. Subsidies for renewable energies have reached just €54 billion so far.²⁴

The first adaptation of the “Stromeinspeisegesetz” happened in 2000, and was driven by Hermann Scheer.²⁵ Since then, it has been known as “Erneuerbare Energien Gesetz” EEG. Now there are several regulations for the different technologies, such as photovoltaic on roofs or in the landscape, those for biogas and biodiesel, for wind turbines and for all others, including heat production by solar panels. So the problem is not limited to electrical power, but includes heat energy as well, including power-heat-coupling.

The number of different rules that attempt to serve all the different needs of technologies is too extensive to be listed here. Moreover, it changes quite quickly as the technology in this field evolves quickly. The regulation can scarcely keep up with that pace of change. It is also clear that not all technically useful evolution is made, because investors are waiting for regulations to become more appealing.

As the topic of renewable energy is close to the topic of general environment protection and pollution, it might be more than just a coincidence that the German law “Verbandsklage” (comparable with class action) grew in importance at the same time.²⁶ This allowed the associations to go to court and sue in name of their members or in name of nature. If the impact on a single person is small, then the individual’s will to start a lawsuit may not be strong enough to really do it. However, as the association can bundle such interests, the big players in the energy market obtained a serious counterpart.²⁷ Thus many small associations were founded. The number of enterprises being active in the energy market continuously increased as well. The competition

24 Wirth, Harry Dr., Aktuelle Fakten zur Photovoltaik in Deutschland, <http://www.ise.fraunhofer.de/de/veroeffentlichungen/veroeffentlichungen-pdf-dateien/studien-und-konzeptpapiere/aktuelle-fakten-zur-photovoltaik-in-deutschland.pdf>, p. 23 (19.05.2015)

25 Jochimsen, Wie das Stromeinspeisungsgesetz entstand und sich die erneuerbaren Energien in Deutschland durchsetzten, <http://www.ulrich-jochimsen.de/files/Stromeinspeisungsgesetz.pdf>, p. 1

26 Säcker, Franz Jürgen, Die Einordnung der Verbandsklage in das System des Privatrechts, München, Beck, 2006, pp. 45–46

27 Schaumburg, Ellen, Die Verbandsklage im Verbraucherschutz- und Wettbewerbsrecht, Ansprüche auf Unterlassung, Widerruf, Beseitigung und Gewinnabschöpfung, Baden-Baden, Nomos, 2006, p. 20

in electricity production increased, apart from naturally monopolised structures of the power distribution grid.²⁸

The balance of power changed and with it the structure of the energy market.

2.2.2. Market adaptation by intention

The government has three main possibilities to influence the price of a product.

1. Direct Taxes (e.g. “Sektsteuer” or electricity & insurance tax)
2. Subsidies (direct or indirect)
3. Instructions (e.g. “Buchpreisbindung”, sold by pharmacies only)

With the EEG some fix prices (option 3) were introduced for the producer of renewable energy, the so called feed-in remuneration. To refund the financial guarantee a mathematical model was defined:²⁹

$$C_a = \left(P_{rp} \frac{\text{€}}{\text{MWh}} - E_{ep} \frac{\text{€}}{\text{MWh}} \right) \cdot \frac{R_e}{S_p}$$

C_a : Cost allocation of apportionment

P_{rp} : Price promised to the producers of renewable energy

E_{ep} : Price for the power that is achievable on stock exchange EPEX

R_e : Amount of renewable energies sold

S_p : Total power sold

There are some exceptions for high level energy consumers and enterprises competing on an international level (2834 in 2014).³⁰ Apart from these few particular cases, power consumers must participate in this mechanism.

28 cp.Schulte-Beckhausen, Sabine Dr., Stromspeicherung: Markt oder Regulierung?, Kölner Gespräche zum Energierecht, http://www.energierecht.uni-koeln.de/downloads/presentation_koelner_gespr_022013.pptx, p. 25 (21.02.1013)

29 cp.Prognose der EEG-Umlage 2015 nach AusGlMechV, Berechnung der Übertragungsnetzbetreiber, <https://www.netztransparenz.de/de/file/20141015-Veroeffentlichung-EEG-Umlage-2015.pdf> (15.10.2014)

30 cp.Bundesamt für Wirtschaft und Ausfuhrkontrolle BAFA, Statistische Auswertungen zur „Besonderen Ausgleichsregelung“ des Bundesamtes für Wirtschaft und Ausfuhrkontrolle (BAFA), http://www.bafa.de/bafa/de/energie/besondere_ausgleichsregelung_eeg/publikationen/statistische_auswertungen/ (26.08.2014)

This compensation cannot be seen as a traditional subsidy, as the government does not provide any money to it. It is more an equalisation burden than subsidies, and therefore the concept has to be compared with the burden to compensate war-based losses after World War II, which is where the idea of a redistributing welfare state has its origin.

Die Not der Kriegsfolgen drängte den Staat in eine Umverteilungsaufgabe. Die Besteuerungsgewalt wurde enthemmt und die Steuerintervention ermutigt.³¹

2.3. Welfare state consuming reserve assets

The idea of a state that influences the market is even older than the abovementioned redistributing burden after World War II. In that regard, there is a clear distinction between European and US law. By 1938, the idea of services for the public (“Daseinsvorsorge”) and welfare (“Fürsorge”) had been clearly separated. The historical frame conditions have been influenced by the Nazis, and so are the words being used in the original source. It should be outlined that one must carefully separate the concept of public service from the ideological fault and the lust to conquer. Unfortunately, the German word “Lebensraum” cannot distinguish between the landscape to be conquered and the generic area where a single human being lives. As described in detail in Chapter 1.2 (p. 3) it will also be used in this study, without any intended negative connotations.

The area where a single human lived changed dramatically during the time of industrialisation. Previously, people could survive on their own property. After industrialisation and migration into cities, the survival of people was coupled to public services, such as water supply, disposal of waste, public transport capabilities, and even electricity supply.

„Der Lebensraum des Menschen, in dem er sein Dasein verbringt, läßt sich scheiden in den effektiven und den beherrschten Raum. Als beherrschter Raum soll derjenige bezeichnet werden, der dem Menschen in so intensiver Weise zugeordnet ist, daß er ihn als ihm allein gehörend, als sein Eigen betrachten, sich als sein Herr bezeichnen darf. Es ist der Hof, der Acker, der ihm gehört, das Haus, in dem er lebt. Der effektive Raum ist derjenige, in dem sich das Leben, über den beherrschten Bereich hinaus, tatsächlich vollzieht. Die industriell-technische Entwicklung des 19. und 20. Jahrhunderts hat es nun

31 cp.Kirchhof, Paul, Der sanfte Verlust der Freiheit, Für ein neues Steuerrecht - klar, verständlich, gerecht, München, Carl Hanser, 2004, p. 91

mit sich gebracht, daß sich der effektive Lebensraum vermöge der Ausbildung des modernen Verkehrswesens außerordentlich vergrößert hat und auch jetzt noch in der Zunahme begriffen ist, während der beherrschte Lebensraum sich stark verringerte, bei immer breiteren Schichten ganz verschwand. An die Stelle des Hauses ist die Etage, das möblierte Zimmer, die Schlafstelle getreten. Die bis zur Minimalisierung gehende Verengung des beherrschten Lebensraumes kennzeichnet die städtische, zumal die großstädtische Lebensweise.“³²

It is common in German and European legislation to socialise duties as well as risks. Sometimes this approach causes the economy to “forget” the principle that everyone should carry their own risk, wherever possible.³³

In the renewable energy market, the focus of legislation seems to be more on the production side than on the consumer`s or grid side. One fourth of power production has already been switched to renewable sources, while much less of the power-grid has been adjusted. This situation is caused by the political will to change the source of the production while, at the same time, pinning the grid operator down to efficiency only. We live today with the benefit of the great far-sightedness of previous investments, but there is a limit of optimisation reached, and more investments to the grid are inevitable.³⁴

Sometimes, the stock exchange offers a negative price for power which is quite a good indication of an unhinged market. Nonetheless, to ensure the stability of the energy supply, regulation authorities already prohibit the disabling of power plants that have become unprofitable. The EEG has been designed as a start-up promotion, but it is not the technology that needs further support, but the market design.³⁵

32 Forsthoff, Die Verwaltung als Leistungsträger, pp. 4–5

33 Kirchhof, Paul, Deutschland im Schuldensog, Der Weg vom Bürgen zurück zum Bürger, München, Beck, C H, 2012, p. 131

34 Küster, Michael, Grid operator view to the renewable energy market, pp. 7–8, interviewed by Fontaine, Sebastian (29.06.2015)

35 Rösing, Justin, The renewable energy usage in industries, p. 1

3. The clash between the ancient and the modern

The first nuclear power plant in Germany was built in 1960 with a capacity of just 15 Megawatts (Karlstein am Main). Today, even some wind turbines can produce this amount of energy.³⁶ In 1981, a nuclear power plant started operation with a maximum capacity of 1.345 Megawatts (Grafenrheinfeld). The evolution of atomic energy performance was breathtaking at that time, but on 27 June 2015, the time of Grafenrheinfeld ended again. The power plant was shut down due to Germany's intention to exit the nuclear power industry.³⁷

A direct comparison between wind and nuclear energy shows some similarity during start-up time, but wind turbines will probably remain for a longer period than will nuclear power plants.

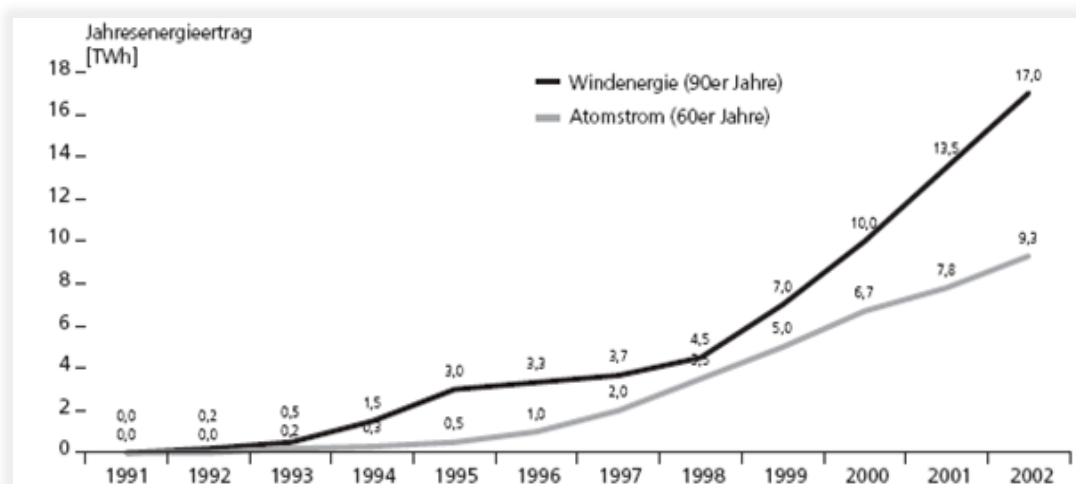


Figure 6: Comparison of the emerging phases of wind and nuclear power plants³⁸

Comparing the absolute figures, wind turbines entering the market even outperform the nuclear power plant evolution. If production was to be mutually compared in relation to the total market, it would be seen to be different, since the overall energy market was more than twice as large in 1990 as it was in 1961.³⁹

Rotating wind turbines have a different quality to the rotating masses in traditional generators. Wind speed is variable, whereas a traditional power generator spin is stable and reflects the 50 Hz of the power grid. Their imminent inertia effect is a system built-in stabilization for fluctuation on the grid level. Most of the renewable energy power plants convert the AC by power

³⁶ Hahn, 100 Jahre Strom in Franken, p. 157

³⁷ cp.Hahn, 100 Jahre Strom in Franken, p. 163

³⁸ Geitmann, Sven, Erneuerbare Energien, Mit neuer Energie in die Zukunft, Oberkrämer, Hydrogeit-Verlag, 2009

³⁹ Statistisches Bundesamt, Wiesbaden, Statistisches Bundesamt Deutschland - GENESIS-Online, <https://www-genesis.destatis.de/genesis/online/> (11.07.2015)

electronics. This allows the wind turbines to deal with the changing wind speed, but without any inertia effect.⁴⁰

The only mechanism today that can deal with a fluctuating load is the market for load-frequency control and performance, the so-called “Regelenergie-Markt”. The call for tender of this market happens in Germany, via an online platform.⁴¹

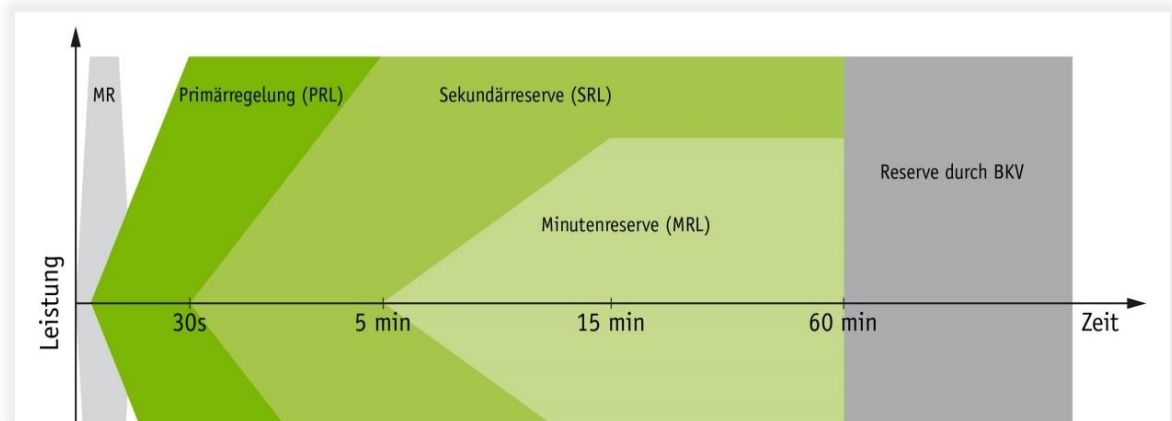


Figure 7: Time slices of different energy regulation scenarios⁴²

In the very short term (milliseconds), the inertia effect (MR) can smooth out disturbances within the power grid without human interaction. To align supply and demand there are three main levels of control (green in the graphic):

PRL: The primary regulation

SRL: The secondary control or reserve

MRL: The minutes reserve

The last responsibility to match production and consumption demand is taken by the local balancing group (BKV). Previously, power source, distribution and disposal was organised by the dispatcher. This single role is prohibited today. Since the market has been liberalised, such a central position would be a violation and would be subject to judgment by the federal network agency.⁴³

40 Ulbig, Andreas, *Operational Flexibility in Electric Power Systems*, ETH Zürich, 2014, p. 67

41 regelleistung.net, <https://www.regelleistung.net/ext/static/market-information>

42 Was sind Sekundärreserve & Sekundärregelleistung?, <https://www.next-kraftwerke.de/wissen/regelenergie/sekundaerreserve>

43 Küster, Michael, *Grid operator view to the renewable energy market*, p. 7

3.1. High market share causes deformation

The original objective behind the feed-in remuneration (“Einspeisevergütung”) was to lower the entry barrier for the renewable energy technology. Fluctuating demand has long been a reality, and renewable energies offer few options to deal with it. Usually their supply varies with weather conditions. One big question of the German “Energiewende” is how the fixed remuneration might match with these two variable items. It seems to be obvious that such a fixed price for production effort cannot drive a 100% renewable energy market. In fact, on 25 July 2015, already 78% of the day’s energy demand was produced by renewable energy.⁴⁴ In perfect weather conditions, the complete coverage of energy demand by renewable sources is no longer so far from being a reality.

Pricing on the stock exchange follows the Merit-Order effect. The technology that produces energy for the lowest price serves the market first, followed by the technology that has the second best pricing, and so on. The EEG changed all that, as renewable energy has to be taken by the grid provider in any case. Therefore, this energy is the first that is sold, regardless of the price, which in any case is fixed by remuneration.

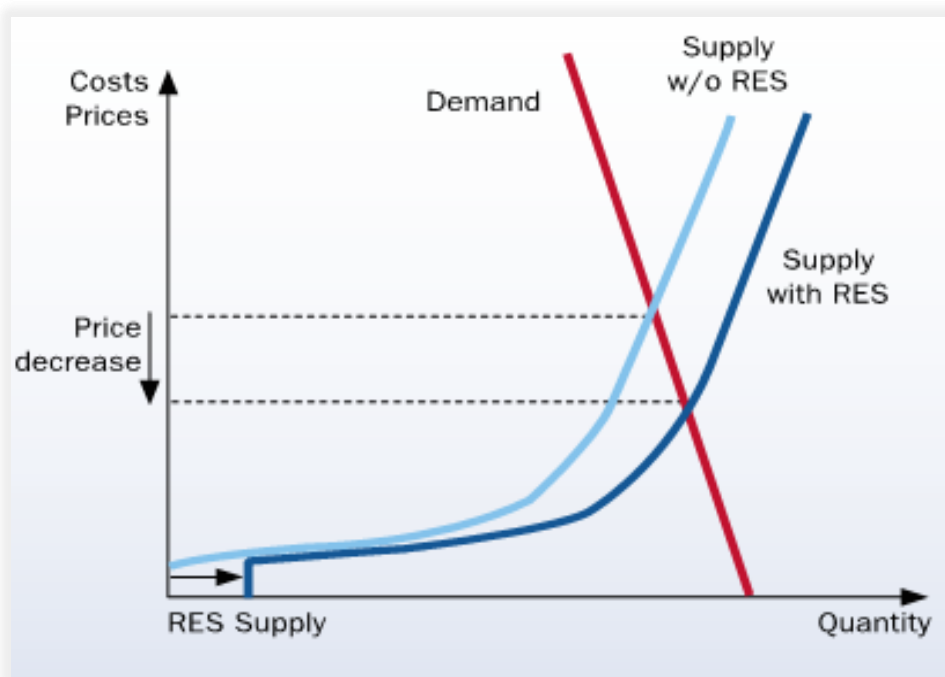


Figure 8: Merit-Order effect of renewable sources of generation (RES).⁴⁵

44 Gertz, Emily J., Germany Breaks a Renewable Energy Record, Europe’s industrial powerhouse shows how other fossil-fuel nations can kick their coal habit., <http://www.takepart.com/article/2015/07/28/germany-sets-renewable-energy-record> (28.07.2015)

45 Istituto per gli studi di politica internazionale, The British capacity market: a hidden déjà vu?, <http://www.ispionline.it/it/energy-watch/british-capacity-market-hidden-deja-vu-11981> (12.01.2015)

The preferential use of renewable energy causes a shift in market harmony. The most expensive traditional producers are edged out first.

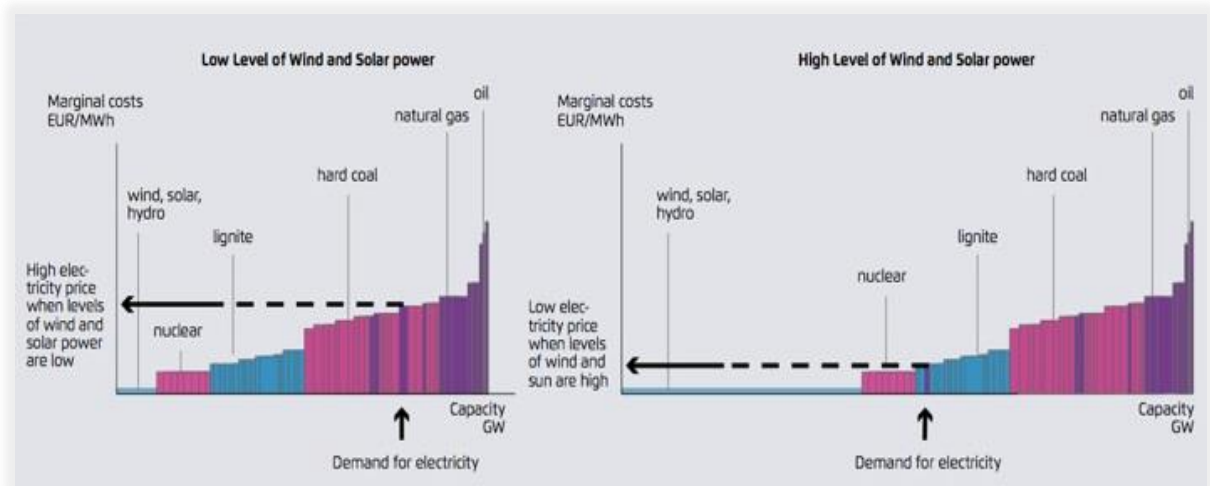


Figure 9: Electricity price depends on availability of renewable energy.⁴⁶

As described in Chapter 2.2.2 (p. 12), the difference between the fixed price of renewable energy on one hand, and the variable price paid on the stock exchange on the other, has to be compensated. When the overall price of energy decreases, the gap to the guaranteed fixed price escalates. The dictate to deal renewable energy first leads to the paradox situation that the fee for its usage rises.

Due to the Merit-Order effect the most expensive offer that is just sold marks the margin for all others that manage cheaper production.⁴⁷

Also, the price on the stock exchange is only relevant with regard to traditional energy sources. The more renewable energy there is in the market, the less traditional energy can be traded, as it becomes displaced. Lower trading volume usually goes in line with higher price amplitudes. Lower demand on traditional power sources means that the competition between the generation operators also increases. Investment in new non-renewable energy equipment becomes more and more unattractive, up to the point where it becomes more economical to switch off and dismantle some old and written-off power plants. These dismantled power plants may be greatly missed in times of low renewable energy production due to weather anomalies.

From a technical point of view, gas-based power plants are most suitable for renewable energy, because they can easily follow the demand from fluctuating production. Unfortunately, this

⁴⁶ America's Power Plan, Postcard from the Future: Texas, <http://americaspowerplan.com/texas/>

⁴⁷ Wirth, Aktuelle Fakten zur Photovoltaik in Deutschland, p. 13

technology is one of the more expensive and therefore becomes uneconomic first. In addition, the cheapest traditional power plants are nuclear ones, which are also the most inflexible.

The higher the market share that renewable energy has, this contradiction will become more acute. In the electricity market, the overall goal is reliability of supply. No market participant can have an interest in a collapsing market.⁴⁸ The price melting on the stock exchange with the negative effect to the most flexible gas power plants clashes directly with the need to compensate the unpredictable, weather-based production of renewable energy systems.

3.2. Wider distribution means more transportation

In the physical goods market, the final price is the sum of the product itself plus its transportation fee. If a product has been made far from the selling point, it must beat the price of the competitor plus the additional price to bridge the distance. In other words, if two products with the same price are in competition, the one produced closer to the market will win.

Renewable energy production is carried out by many small power plants throughout the country, which results in the need to bring the power to the traditional centres of consumption.⁴⁹ But this is not the only reason for wider distribution.

„Anders als zu Zeiten regionaler Monopole können sie [Verbraucher] ihren Stromlieferanten heute frei wählen. Als Folge ist die Zahl der Anbieter auf dem Markt in den vergangenen Jahren deutlich gestiegen. Strom wird mehr und mehr zu einem auch international handelbaren Gut. Geschäftsbeziehungen erstrecken sich über große Distanzen.“⁵⁰

The liberalization of the power market allows the consumer to make a contract with any producer. Power becomes more and more a product which is internationally traded.

48 Küster, Michael, Grid operator view to the renewable energy market

49 cp.Rösing, Justin, The renewable energy usage in industries

50 Hahn, 100 Jahre Strom in Franken, p. 201

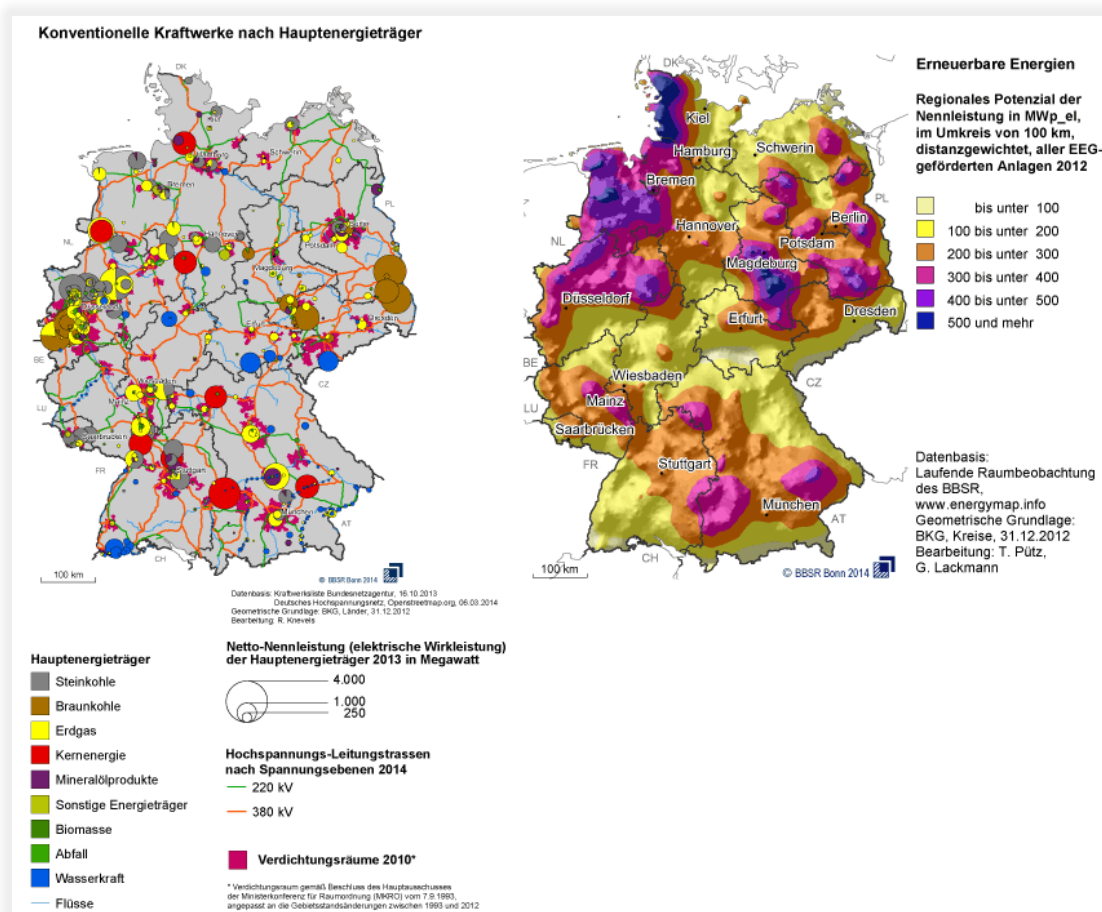


Figure 10: Topology of power plants, consumers and renewable energy capability⁵¹

Fortunately, electricity is the same everywhere. Therefore, it will not be physically transmitted from a power plant in the south to a consumer in the north, while at the same time another power plant from the north serves a consumer in the south. In such a case only the net discrepancy will be transmitted in one or the other direction.

Nevertheless, the need of transportation capacities rises. The market subsection of the grid increases as well and so the risk evaluation in case of a line failure becomes more and more important. The rising utilisation average consumes the free resources. In any emergency situation, such free resources are essential to be able to bridge temporary outages. Reduced reserve capacity therefore reduces the resilience of the system to deal with faults.

⁵¹ Pütz, Thomas, Netzausbau - warum?, http://www.bbsr.bund.de/BBSR/DE/Raumentwicklung/EnergieKlimaschutzpolitik/Projekte/Netzausbau/01_Start.html?nn=1037332 (June 2014)

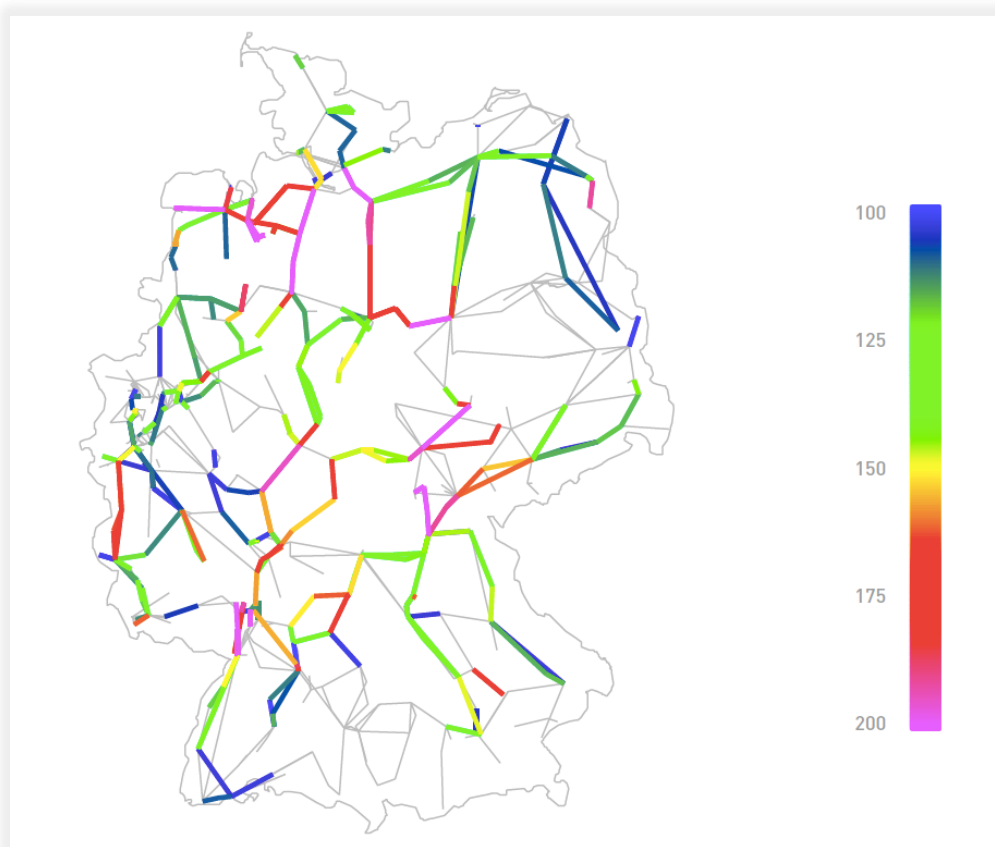


Figure 11: Simulation of Grid load in % if a broken line has to be compensated⁵²

Due to the temporal and regional fluctuations of renewable energy production, overcapacities are not only required in production, but also in transportation facilities.

Traditional power plants have to buy their fuel, including fuel for transport. Longer distances to a harbour or mine could be considered as a comparable disadvantage to a less windy location, or one with less hours of sunshine per year. In both cases, the return on the investment is more difficult to generate.

It is difficult to understand that the remuneration for one MWh produced by any wind turbine is the same, regardless of whether there is a consumer nearby, or the power has to be transported over a long distance. High local demand should increase the remuneration to increase the will to invest, whereas low demand should result in lower remuneration. Such an effect could be achieved by simply sharing the remuneration between the producer and the grid operator.

The higher the distance of electricity transportation, the higher the loss by natural resistor of the wire. Therefore, it might be better to share the overall remuneration between the power grid

⁵² Feix, Oliver, Obermann, Ruth, Strecker, Marius and König, Regina, Netzentwicklungsplan Strom 2014, zweiter Entwurf, http://www.netzentwicklungsplan.de/_NEP_file_transfer/NEP_2014_2_Entwurf_Teil1.pdf, p. 63 (04.11.2014)

provider and the producer. This could also help to build renewable power plants in regions where the yield rate is maybe lower than elsewhere, due to natural disadvantages of the location. The disadvantage of the lower yield rate might be more than outweighed by the advantage of physical proximity to the consumer and therefore reduced transmission loss. As a positive side effect the overall transmission losses would decline.

In any case, it is the political will in Germany to have solidarity in price for the transmission costs. Every market member has to pay the same amount. It only differs in terms of the dimension of the connectivity, but the distance is irrelevant.⁵³ That price solidarity is comparable to phone and internet connectivity. The bandwidth drives the price, but not the distance to the next distribution panel. Ultimately, however, distance limits the possible speed in any case. Even willingness to pay the higher price of a wider connectivity bandwidth is of no help.

⁵³ cp.Küster, Michael, Grid operator view to the renewable energy market, p. 6

3.3. Price mending and modelling

The prime costs per kWh electricity differ by technology. In general, each technology has a range, as the dedicated production cost also depends on location and frame conditions:

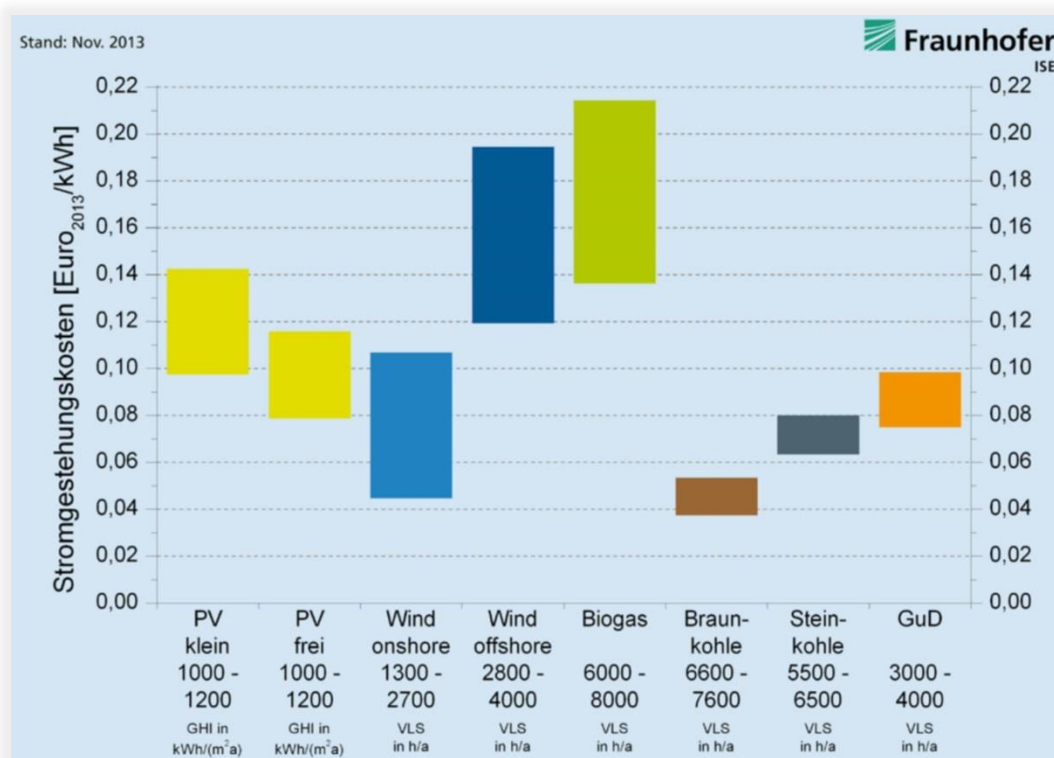


Figure 12: Prime cost of electricity production by technology⁵⁴

PV: photovoltaic amount of radiation received in MWh/(m²a)

GHI: The total amount of radiation received by a surface horizontal to the ground.

VLS: "Volllaststunden" if the system could run on full load its yearly amount of production would be fulfilled within this timeframe (max. 8760 h/a).

GuD: Gas and Steam power plants combine both technologies.

It is apparent that the best onshore wind systems can already compete with the most expensive brown-coal engines. It is, however, recognised that competition in terms of price only would exclude some technologies that might have other merits. They could possibly provide special services that are essential for the supply guarantee.

⁵⁴ Weber, Eicke R Prof. Dr., Stromgestehungskosten Erneuerbare Energien, <http://www.ise.fraunhofer.de/de/veroeffentlichungen/veroeffentlichungen-pdf-dateien/studien-und-konzeptpapiere/studie-stromgestehungskosten-erneuerbare-energien.pdf>, pp. Abs2:2 (Nov. 2013)

Nevertheless, the traditionally tradable asset is the power demand measured in MWh. For this market a stock exchange exists in Germany and other European Countries, but does not in most areas of the world:

- EPEX SPOT: Germany, France, Austria, Switzerland
- Nord Pool: Norway, Sweden, Finland
- USA: no central energy stock exchange since the collapse of Enron⁵⁵
- Asean: mostly controlled by governmental enterprises, not privatised

There is an entrance barrier in order to deal on the stock exchange. On the EEX for example, the day-ahead trade has to be bigger than 100kWh in order to participate.⁵⁶ Several companies are starting to operate with very diverse business models. For example, they try to bundle producers whose single output is too small to overcome the obstacle.

3.3.1. Cooperative virtual power and balancing service

The “virtual power station” is a concept that tries to combine many small and varying energy producing stations so that they act like a big traditional one. Most of the private photovoltaic enclosures are below the volume that enables stock exchange trading (100kWh), even in their Watt peak capacity, not to mention standard delivery on a cloudy winter day with a covering of snow. Even big wind turbines might be affected in still conditions. Bundling those small power stations could possibly grant access to the stock exchange.

In a perfect scenario, the members of the virtual power station complement each other. This could be a biogas system that is able to store its gas during daytime, when the photovoltaic is active. During the night, without power from the photovoltaic, the biogas engine can produce energy from the stored gas and bridge the time. Together, both can act as a “virtual power station”.

In principle, there are two possibilities to deal with oversupply of energy. Production can be throttled, or consumption promoted. Increasing the production on demand is called positive regulation market. Decreasing the production or increasing the consumption is called negative

⁵⁵ InformationWeek, Energy Exchanges Should Survive Enron Collapse,
<http://www.informationweek.com/energy-exchanges-should-survive-enron-collapse/d/d-id/1012983?>
 (12.07.2001)

⁵⁶ NEXT Kraftwerke, Was ist Day-Ahead-Handel?, <https://www.next-kraftwerke.de/wissen/strommarkt/day-ahead-handel>

regulation market. If these negative prices last for a short time only, they cause even higher energy consumption, because the power plants are too inert to reduce their output quickly. It is cheaper than to pay others to “burn” the energy. Power to heat conversion is a concept where power is simply turned into heat, for example in swimming pools. Such systems can reach a capacity of 10 MWh and can react within minutes. Therefore, they could even be used in the secondary regulation market.⁵⁷ If the negative price lasts longer, or the price stays too low, then it is clearly more beneficial to disable some power plants to reduce the overall offer.

3.3.2. Levelling by valuable green-washing

Another interesting way to generate income is the so-called “greenwashing”.⁵⁸ During periods where there is less demand than offer of power, and as a consequence, there are low or even negative prices, water is pumped upwards into a reservoir. In the mountainous areas of Switzerland, this is made using cheap nuclear power from France, for example. When the price rises again, the reservoir is used to produce power. This power is now sold coming from hydrodynamic water. A traditionally produced power became a renewable energy simply by a reforming action. The “conversion” is a profitable action due to the positive price difference for energy delivered at specific times of demand and for the now “greenwashed” type of energy.⁵⁹ Such a price modelling is so far one of a few possibilities to generate income by stabilising the power grid. Consuming power while the overall consumption is low and reverting the electricity into the potential energy of water is a very effective storage technique. When the overall consumption rises again, the storage can be used for additional power supply and so help to bring demand and supply into balance.

Such a hidden service is difficult to quantify and therefore difficult to bill directly. But it is very clear that such market participants are producing much more than just power in terms of MWh. The negative connotation of the word “greenwashing” is not justified in this situation, as they fabricate real added value by performance smoothing in the energy market.

⁵⁷ cp.Küster, Michael, Grid operator view to the renewable energy market, p. 2

⁵⁸ Marquis, Christopher, Toffel, Michael W. and Zhou, Yanhua, Scrutiny, Norms, and Selective Disclosure: A Global Study of Greenwashing, <http://www.hbs.edu/faculty/Pages/item.aspx?num=50187>, p. 3 (13.05.2015)

⁵⁹ Schweizerische Energie Stiftung, Wasserkraft ist nicht gleich Wasserkraft, Fakten zur Pumpspeicherung, <http://www.energiestiftung.ch/files/textdateien/aktuell/publikationen/h2o-ist-nicht-h2o.pdf>, p. 2 (17.06.2009)

3.3.3. Buyback program for power, instead of shares as usual

Another peculiarity of the renewable energy market is the fact that some energy producers feed in all the self-produced electricity instead of direct local consumption. Selling renewable energy and feeding it into the grid is a refund by a fixed price. Had this power been used for personal consumption, it would have reduced the need to obtain the current from the grid for their daily requirement. It would offload the grid to have a bypass behind the counter (self-consuming) but trading over the counter is more profitable today. If the figures of apportionment and standard price were to be equal, the self-consumption would also become interesting in an economic sense. This status is called grid parity (“Netzparität”). The saved buy-price is then the standard price for electricity.

This happens, for example, when an old heating system is replaced by cogeneration of heat and power to increase overall efficiency. If the electricity, being produced as a by-product in this case, is injected into the public power grid, then it can be billed as part of the EEG remuneration with high fixed price. Hence it becomes easier to assess the investment of the cogeneration, even if the original interest was only the generation of heat. The investment has been triggered by the need to replace the heating while the power generator is an added value by principle. The electricity could be used only to reduce the personal consumption to be otherwise purchased via the grid. Carrying out the investment appraisal by looking at the electricity part considers the saved heat only as a plus. Due to the fixed figures on the electricity side, it is easier to calculate this way than the reverted point of view. A comparable method of approach would be to build a retaining dam for electricity production only, while the flood protection is a nice added value for the national economy down the river⁶⁰, but this value is not taken into account for the dam planning. However, for thousands of years dams have been built to protect. If these dams are now equipped with turbines, then the biggest investment of the dam could be considered as written-off by the value of flood protection.

The perspective of accounting has a direct impact on the prime cost of the produced energy.

If multiple benefits are combined (e.g. cogeneration of heat and power) then it becomes even more important to split the investment figures and the benefit figures to get a clear view. For some reason this is often not done today.⁶¹ If one part of the income is able to carry the whole investment, then the added value of the other part is taken as a gift. This approach of hidden

60 The Three Gorges Dam Project, <https://www.mtholyoke.edu/~lpohara/>

61 cp. Rösing, Justin, The renewable energy usage in industries, p. 2

costs and hidden gains is problematic as it avoids a clear impression of the effects. On the other hand the effect of certain predictability is gladly taken to become able to calculate and argue a project. The hidden part only can make it more profitable. To come back to the dam example: The positive effect for the national economy to be saved of flood risks is hard to calculate directly. Insurance companies make their business by dealing with such probabilities. Therefore such contracts could be used to get an indication of the expected positive effect. If the project could become profitable by energy production only, then it is simpler and much easier to argue for it in public parliaments. The same is valid for the directorate in a private company. As a result, the power price carries burdens today that are not completely linked to it.

3.3.4. New technology tightens an old problem

The physic of electricity requires some production constraints. Reactive power has to be produced to stabilize the grid, but it cannot be consumed by customers. Nevertheless, both producers and consumers need it in terms of having a stable grid. Therefore this topic is a good example to explain the overall principle.

On the production side, the provision of reactive power can substantially increase the costs, whereas it has been caused on the consumption side. Modern electronic devices have hardware that reduces the negative effect on the grid. On the other hand, the producers of photovoltaic and other renewable energies are compelled by law to use technology that can deal with reactive power.⁶² There is considerable effort to also allow the grid provider to deal in this power. If the consumer is big enough and the reactive power is also expected to be huge, then OTC contracts are usually made.⁶³ As an alternative, the consumer can setup a compensation for the reactive power. Handling reactive power is another service that cannot be dealt today in the normal way, such as is the case with active power.

On the contrary, the type of load is changing. Switching power supplies of mobile devices and personal computers can disturb the quality of the net. The technical details are out of the scope of this work, but the sheer number of these devices has a measurable impact on the power quality itself. Not only are consumer electronics changing, there is also a rushed evolution on the producing side. The old physical generators with a lot of copper inside and rotating masses

62 cp.Geoplex, Neue Vorschriften für Photovoltaikanlagen ab 1. Januar 2012, http://www.geoplex.de/fileadmin/user_upload/PDF_PV/Gesetzgebung_Photovoltaik_seit_2012.pdf, p. 4 (march 2012)

63 cp.Küster, Michael, Grid operator view to the renewable energy market, p. 3

are substituted more and more by AC/DC converters based on power electronics. There is no more physical inertia that can smooth such aberrances. On the other hand, legal regulations now force photovoltaic to be able to bridge short power outages (Low Voltage Ride Through).⁶⁴

The change of power production technology can therefore open the market for services that were not required in the past. In this case smart-metering would not only be an option for consumers, but also allow to measure all services provided on producer side, too.

3.3.5. Measurement as a precondition for commerce

Another characteristic of electricity that is not merchandisable today is availability. We are accustomed to having power available through a plug, as and when we need it. The situation is totally different in other countries, e.g. in India.⁶⁵ What we take for granted is, in fact, the result of considerable effort on the part of the power grid provider and producer.

Photovoltaic delivers power during sunshine hours only. If we imagine that someone needs power only then and is disconnected at other times, they would then be entitled to a lower price for their power than the person who needs a totally reliable supply. In former times, power plants had to be sized for maximum load and were partly idle at ancillary times. Today the situation is partly reversed. In very windy conditions, or when there is unbroken sunshine, there is too much energy. At the same time reserve power plants have to be on standby for the time where there is less renewable energy available. During such times, some consumers could simply be cut off the grid, which could help to stabilize the situation because consumption could be adjusted to the fluctuating production. But as there is no price for alternating energy availability today, there are no market players. The market for negative balancing power (“negative Regelleistung”) is an attempt to fix this, but it is not exactly the same.

The new technology for renewable energy splinters the production into thousands of production locations. The old technology that solved many problems by innate effects fades off slowly. A measurement of these intrinsic values was never necessary, now it becomes essential for grid stability.

64 SMA Solar Technology AG, TechnikKompendium 3.4 - PV-Netzintegration, Hintergründe, Anforderungen und SMA Lösungen, <http://files.sma.de/dl/10040/PV-Netzint-ADE123016w.pdf>, p. 10 (april 2012)

65 R. Gokul, Power outage affects normal life in Trichy - The Times of India, <http://timesofindia.indiatimes.com/city/trichy/Power-outage-affects-normal-life-in-Trichy/articleshow/32441705.cms> (22.03.2014)

3.4. Redesign by instruction is failing

The introduction of the EEG dramatically changed the German energy market. Similar effects can also be observed in the US. “Curtailments of wind generation on the Texas electric grid have steadily dropped since 2011 as more than 3,500 miles of transmission lines have been built, largely as a result of the state's Competitive Renewable Energy Zones (CREZ) program”⁶⁶

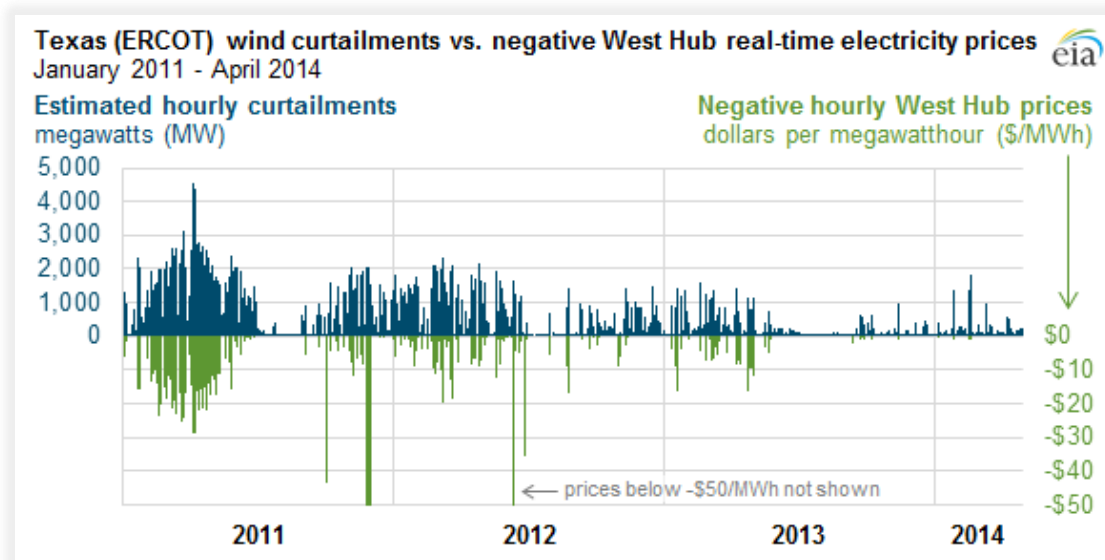


Figure 13: Negative electricity prices in Texas in relation to grid curtailments⁶⁷

The US is known as a country that promotes a free and liberalized market, but if the reliability of power supply is harmed, intervention is necessary. The negative prices in the abovementioned example vanished as new power transmission lines were planned, built and came into use. The increased ability to distribute the power reduced the local surplus.

⁶⁶ U.S. Energy Information Administration (EIA), Fewer wind curtailments and negative power prices seen in Texas after major grid expansion - Today in Energy, <http://www.eia.gov/todayinenergy/detail.cfm?id=16831> (24.06.2014)

⁶⁷ Ibid.

In Germany, a regulatory agency was introduced during market liberation. This agency is producing more and more instructions. These cannot all be mentioned in this study, but below is a brief overview:

- Biogas systems are forced to use biodiesel instead of petroleum, even though it is more expensive and technically difficult, due to different chemical characteristics.⁶⁸
- Photovoltaic systems have to be able to deal with reactive power, which increases the basic investment.⁶⁹
- Disconnection of uneconomic power plants can be prohibited, which is a massive intervention on a liberalised market.⁷⁰

Those working in the energy market have long been saying that there is a common understanding between all market participants, and no-one has any interest in harming the market by increasing their personal profit. In any case, it is obvious that regulatory actions increase the willingness to find alternatives. The current activities of the regulating authority cause pressure and counter pressure. Finally, it forces the market players to act primarily in their own interest and have less respect for the greater common interest. A continuation of this will inevitably lead to failure.⁷¹ A better instrument to organise cooperation is required.

Stand together is not only more efficient, it is a prerequisite in a market where consumption and production must be balanced at all times. While the energy market turns more and more regional and renewable, it exposes further the unvarnished nature of this inimitable product.

⁶⁸ AC²T research GmbH, Determination of the Impact of Biogas on the Engine Oil Condition Using a Sensor Based on Corrosiveness, <http://cdn.intechopen.com/pdfs-wm/20076.pdf>, p. 1

⁶⁹ cp.Geoplex, Neue Vorschriften für Photovoltaikanlagen ab 1. Januar 2012, p. 4

⁷⁰ manager magazin, Unrentable Kraftwerke: EnBW will gegen Abschaltverbot klagen, <http://www.manager-magazin.de/unternehmen/energie/a-944475.html> (20.01.2014)

⁷¹ cp.Küster, Michael, Grid operator view to the renewable energy market

4. Reality check questionnaire

The development of technology is so fast that it overtakes the market adaptations. Regulations cannot be conceived, argued and decided with the same speed. To evaluate how real market participants rate their engagement in this environment, the decision was taken to interview a representative selection of them. Four major groups were defined in the beginning:

- | | |
|-------------|--|
| 1. Producer | 3. Grid operator |
| 2. Consumer | 4. Politics (legislation and regulatory authority) |

The first idea was to follow the label “Energie-Kommune”⁷² and contact the municipal persons responsible. This should include all groups, and it should even be possible for public utilities to include the grid operator view. An online questionnaire (in the Annex) has been designed to make a comparison between the responses. As there are five main renewable energies (wind, water, photovoltaic, biomass and geothermal) the corresponding municipality has been selected to cover all of them (also listed in the Annex). By calling the contact persons, it became clear quite quickly that there was virtually no interest in giving an interview or filling in the questionnaire. In fact, no-one was willing to answer the questions, neither by phone, nor in written form.

The second option therefore was to contact the personal network. Here the experience was similar. Everyone was interested in the subject matter, and willing to listen, but not to talk and deliver any information. Market participants all fear coming out from under cover and prefer to wait for the regulatory authority or legislative to take the lead. The need for a strong leader was blatantly obvious.

In fact only seven usable sets of data remained. Statistically relevant evaluation could not be made from this data pool. When this became evident the possibility of extending the group of participants to single, private operators of photovoltaic systems was looked at, in order to get more answers. However, the decision was made to focus on selected protagonists to have fewer answers with a high individual value. Nevertheless a tendency is apparent and worth presenting.

⁷² Agentur für Erneuerbare Energien e. V, Kommunalatlas, <http://www.kommunal-erneuerbar.de/de/energie-kommunen/kommunalatlas.html> (22.10.2014)

4.1. Reasons to enter the renewable energy market

With the renewable energy evolving so quickly, as in Germany at the moment, it can be considered to be a booming market. In this case, it is interesting to understand why investors take the decision to invest in renewable energy, instead of in traditional energies. In the questionnaire, several questions have been asked to gauge individual motivations.

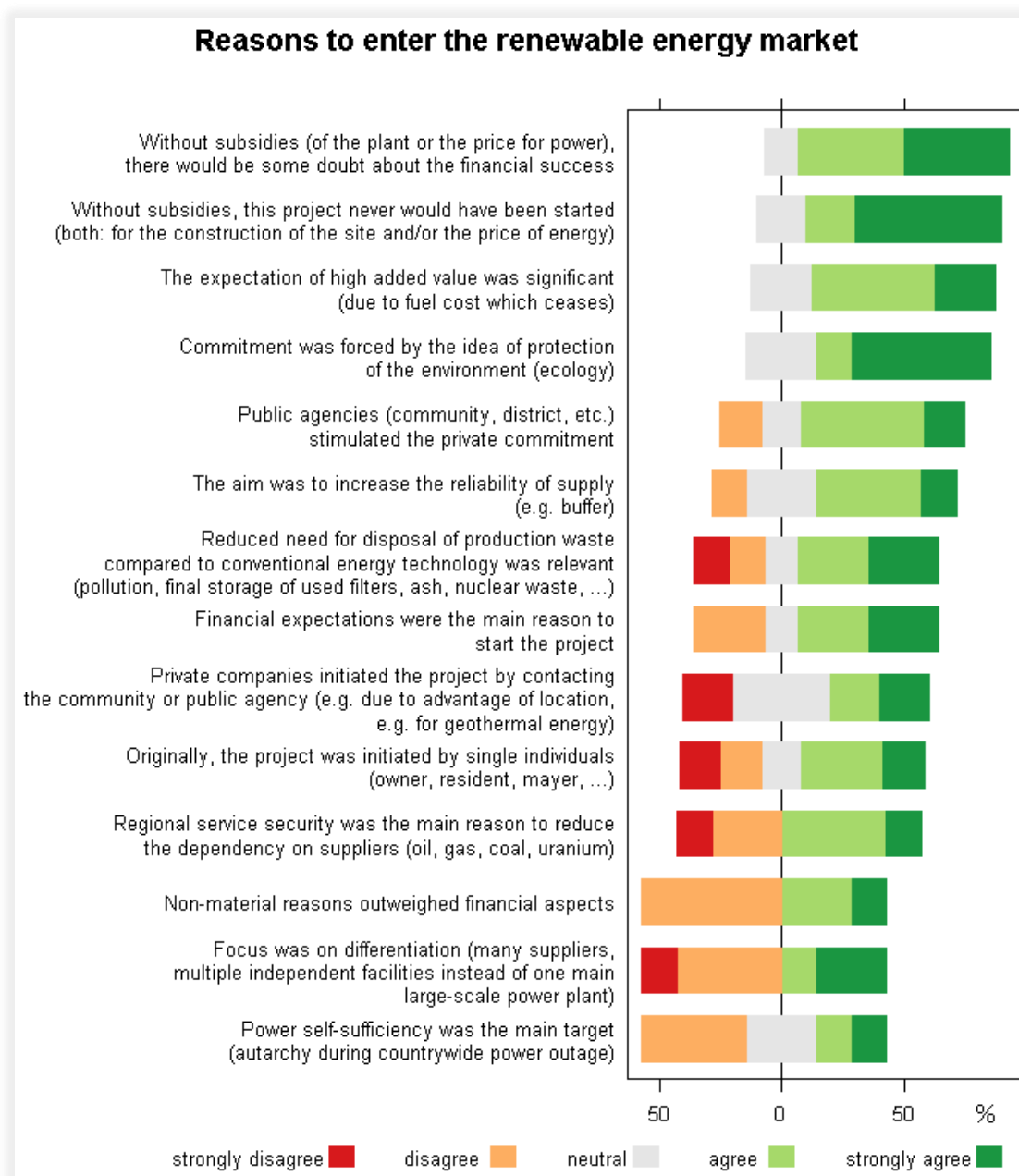


Figure 14: Motivation for investing in renewable energies

(own drawing based on questionnaire results)

The first eye-catching detail is that non-material reasons do not play a major role; in fact they are the lowest ranked of all. At a second glance, that seems to be logical, because ecological enthusiasm for an idea can hardly drive 1/4th of the overall energy market.

The answers clearly illustrate that subsidies are driving the market. Not a single participant of the questionnaire would have started its investment without them. Even the second most agreed-on question is all about subsidies and their importance.

It is also interesting that power self-sufficiency is ranked much lower than the aim to increase the reliability of supply. Even if one question was directed at politicians and the other at consumers, it is clear in any case that reliability of energy is a very important factor, whilst where the energy comes from is of less importance.

4.2. Problems while entering the market

The introduction into the renewable energy market obviously has an impact on the individual concerned, but also on the market as a whole. If the new power plant is relatively small, then the impact may not be considerable, but with many combined smaller actions, the impact may be noticeable. In any case, projects are usually hampered by various problems and risks for all involved parties.

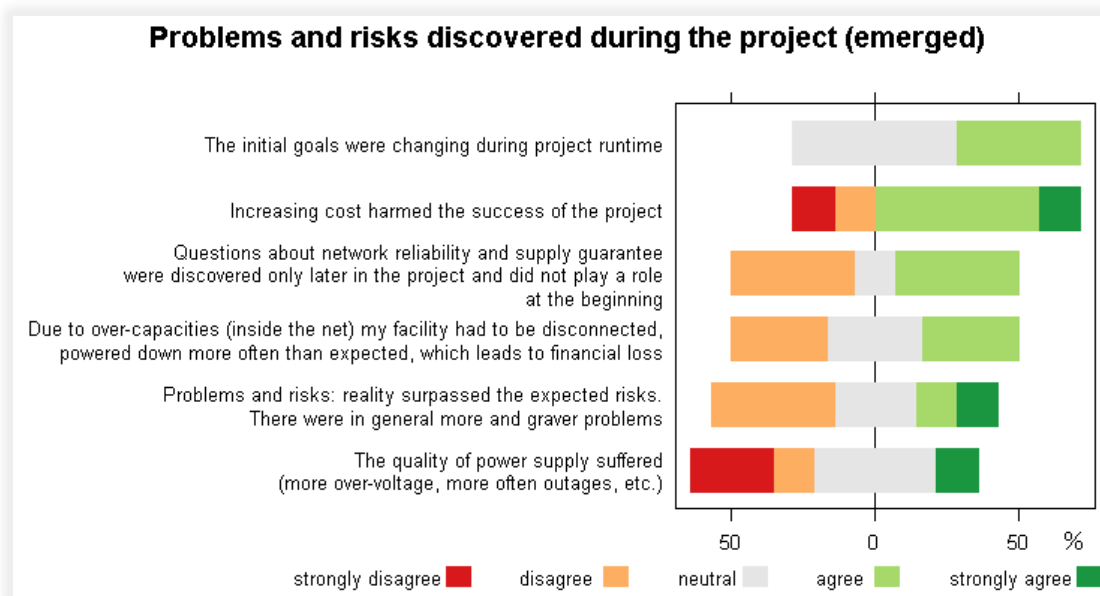


Figure 15: Problems and risks during entry into the market
(own drawing based on questionnaire results)

The biggest problem reported is the classical one in each project: changing goals or requirements during the runtime. This causes the second most generic one, higher costs than were initially calculated.

By contrast, the quality of power seems to be regarded neither as a problem nor a risk. In general, the importance of the quality of electricity and the vulnerability of the availability can be

demonstrated by the introduction of the real-time awareness and alarming system (RAAS) for central Europe.⁷³ As most of the participants denied any negative impact on the quality of the power through their own actions, this can suggest two different directions:

- Either the Union for the Coordination of the Transmission of Electricity (UCTE) makes a great job
- Or the impact is really low

There are sources that hint to rising problems that are below the tick mark to become relevant for statistics. If the statistically measured power failures with a minimum length of one minute (SAIDI value) decline, the number of very short interruptions could theoretically rise dramatically at the same time, without statistical impact.⁷⁴ Indeed there are two opposing effects:

- The official SAIDI continuously decreased by about ¼ between 2006 and 2013⁷⁵
- The number of monitoring systems of the UCTE and the warnings about power quality increased.

This allows just two conclusions, both of which indicate a strong need to adapt, either the layout of the energy market design or of the statistics itself. Either the statistics that are taken today do not reflect the real risks and should therefore be adjusted quickly, or there is a powerful lobby focussing on subsidy management.

A closer look at the statistics reveals that first impressions can be misleading.

73 TENNET, TSO Security Cooperation launches Real-time Awareness and Alarming system (RAAS) for Central Europe, <http://www.tennet.eu/de/de/news-presse/article/tso-security-cooperation-launches-real-time-awareness-and-alarming-system-raas-for-central-europe.html> (29.07.2009)

74 cp. Zaunmüller, Christine Dr.; Laurent, Pascal, The consumer perspective of the energy market, p.4, interviewed by Fontaine, Sebastian (30.07.2015)

75 Bundesnetzagentur, Bundesnetzagentur - Stromnetze - Versorgungsqualität - SAIDI-Wert 2006-2013, http://www.bundesnetzagentur.de/cln_1912/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Stromnetze/Versorgungsqualitaet/Versorgungsqualitaet%20C3%A4t/Versorgungsqualitaet%20C3%A4t.html

On the lowest level of the voltage grid, the number of disruptions is stable, whereas on the higher levels the number of disruptions is declining. The level where most of the renewable energy systems are connected does not appear to be part of the positive evolution.

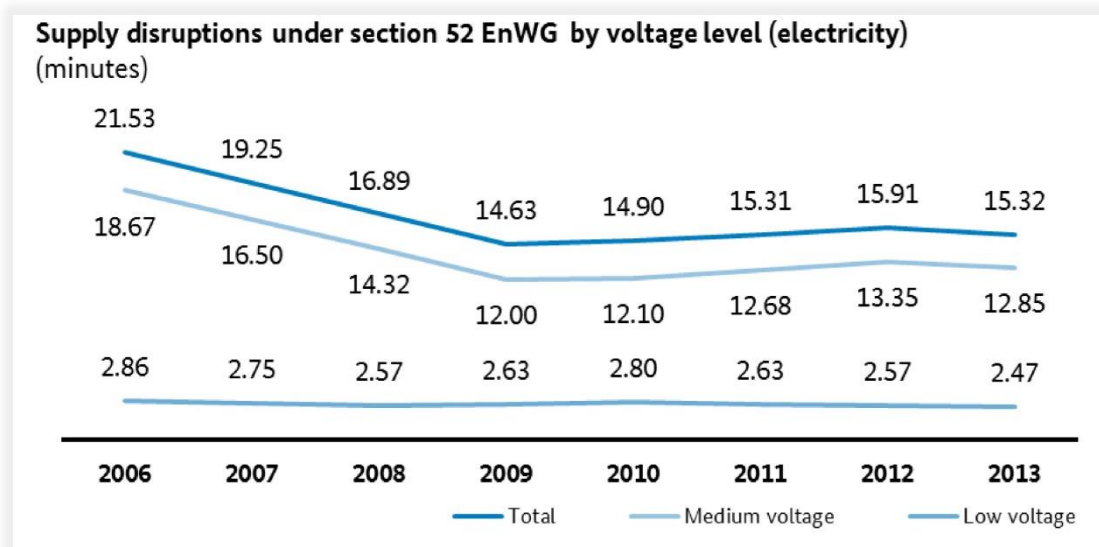


Figure 16: Supply disruptions by voltage level⁷⁶

The powering up or down of generators to follow the fluctuating demand are known as dispatch actions and are planned by the forecasting of the regulation market (Chapter 3.3.1, p. 24). In the case that the forecast was wrong, some unplanned dispatch actions become necessary. Such a short term emergency intervention is called a “redispatch” action. Unfortunately, there is only data available for redispatch activities since 2013; therefore it is impossible to compare the same period in time with the supply disruptions. But as the overall trendline of these activities is climbing several further interpretations are possible.

⁷⁶ Bundesnetzagentur, Monitoring report 2014,
http://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/BNetzA/PressSection/ReportsPublications/2014/MonitoringReport_2014.pdf?__blob=publicationFile&v=2

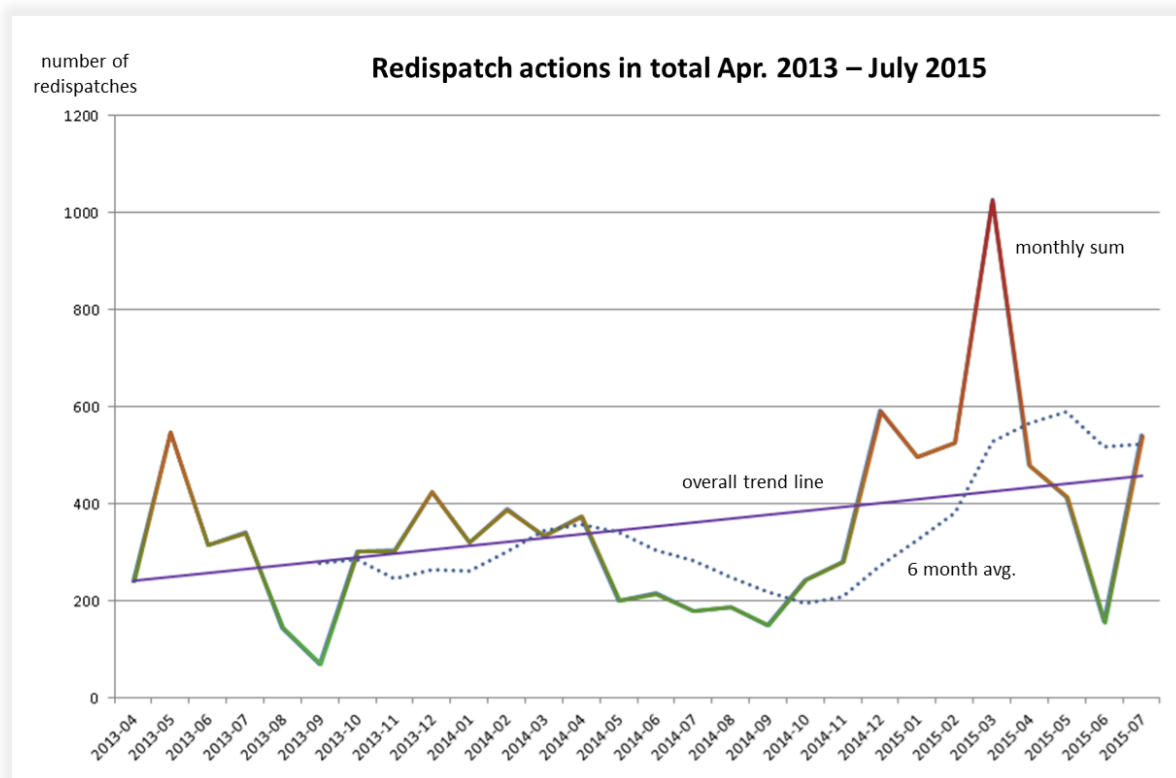


Figure 17: Raising number of redispatch actions
(own drawing by figures of ⁷⁷)

The six-month average trend curve is unsteady, which might be an indication of an overall erratic topic. Without having a longer period in time, any conclusion is purely conjecture.

It seems logical that distributed power generation results in a kind of risk-spreading for big impacts and therefore reduces the interruptions. The loss of one small generator, for whatever reason, has a lower relative impact than the loss of a giant fossil or nuclear power plant. In return, the overall number of switching actions (planned & unplanned) will increase greatly due to the higher number of individual systems. Increasing the regional autonomous active power control can be one solution to offload the ÜNB redispatch demands.

The official statistics agree with the result of the questionnaire. For the investors, the installation of renewable energies did not noticeably impact on the quality of power.

⁷⁷ Informationsplattform der deutschen Übertragungsnetzbetreiber, Redispatch-Maßnahmen, <http://www.netztransparenz.de/de/Redispatch.htm>

4.3. Individual consequences of the engagement

To get an impression of whether investment in the renewable energy market could be considered as a success and would be repeated or regretted, the consequences of the investment were evaluated.

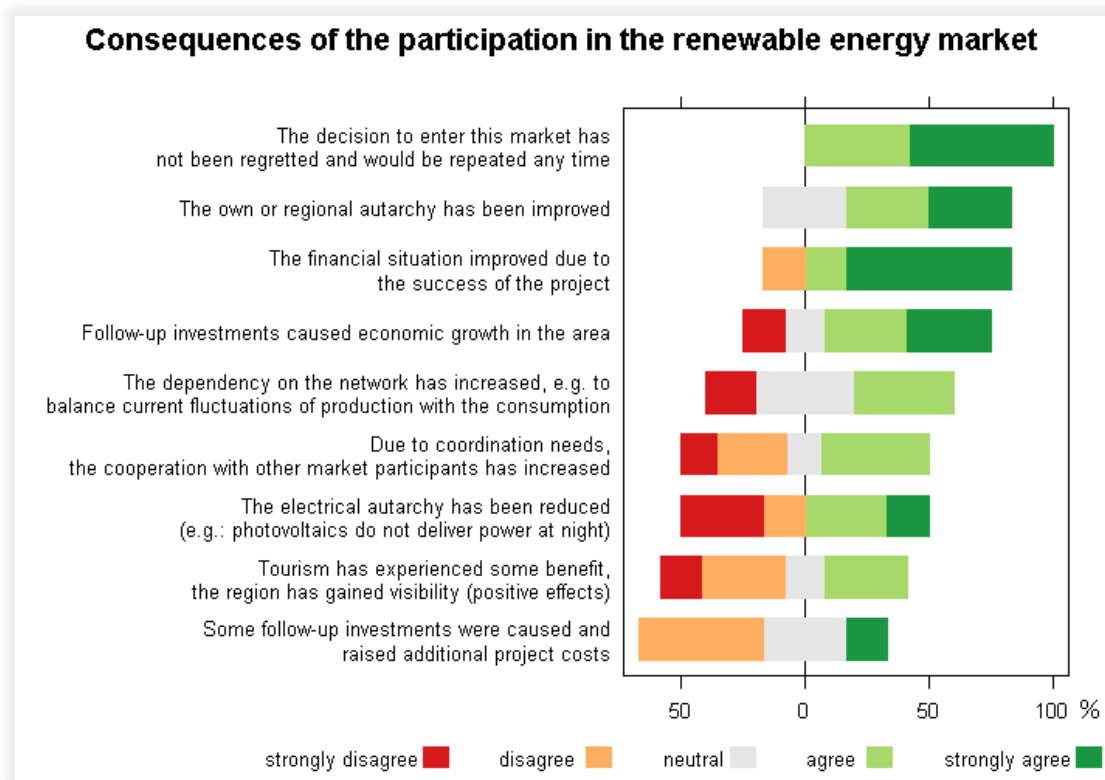


Figure 18: Individual consequences of engagement
(own drawing based on questionnaire results)

Even if we have seen that the costs during the project became higher than expected, the project did eventually become financially successful for almost every participant. No-one had any regrets.

From the point of view of public domain, it is a pity that this initial investment did not cause some follow up projects that might even further increase the local tax income, increase the employment or have other positive side effects. Together with the fact that subsidies have been considered as essential for the decision to enter the renewable energy market, one consequence could be to try to strengthen follow-up investments to maximise the effect of state assistance. It is a fact that, despite unexpected increased costs, strong financial success was still possible, and from this it could be deduced that the slight annual reduction in subsidies by the EEG can still keep the generation of income on a satisfactory level.

4.4. Participants conclusion of their investment

The dedicated interviews with an engineer, a grid operator and a consumer clearly showed that the switch towards renewable energies makes all of them sceptical about the technological competition. The majority of the participants of the questionnaire were autonomous operators of the power generating facility and their bottom line is clear.

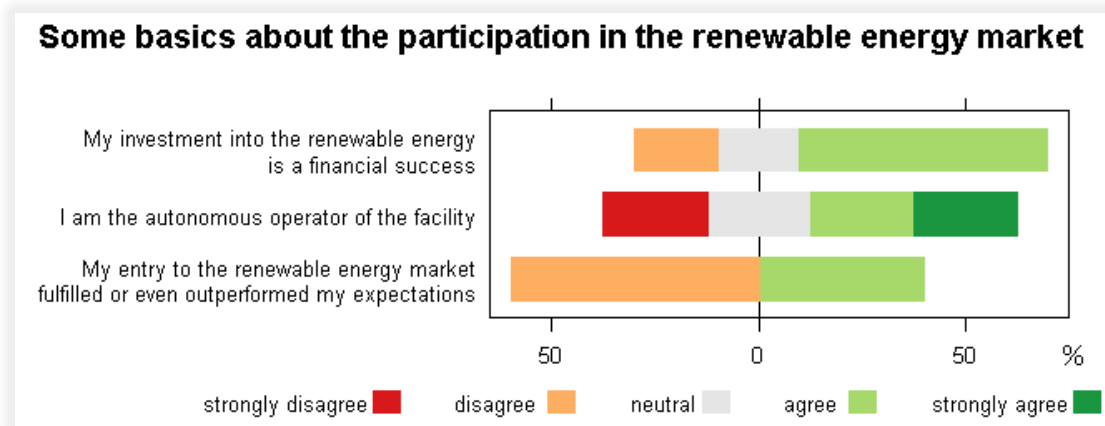


Figure 19: Conclusion of the participation

(own drawing based on questionnaire results)

An overall majority considered the investment to be a financial success. About 30% did not manage to fulfil their expectations, but it is unclear if this has been caused by exaggerated forecasts, by costs that increased during project realisation or by any other negative effect. Nevertheless, more than double this percentage of participants are satisfied.

The transformation of the energy system in Germany is ongoing, as it is in most European countries. The operators of generator systems seem to be content with their investment. It looks like further expansion of renewable energies will continue as forecasted.

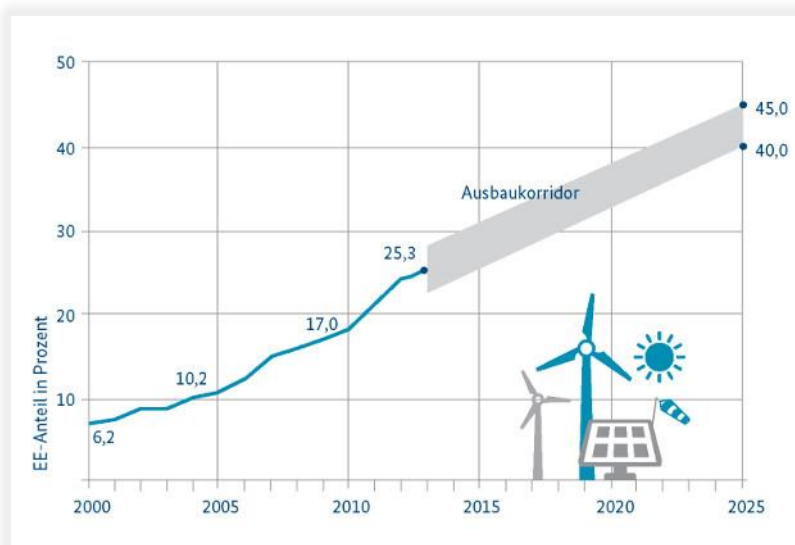


Figure 20: Renewable energy growth 2000 - 2014 and extension plan till 2025 ⁷⁸

Since the renewable energy market is responsible for more than a quarter of the overall energy market and the plan is to continuously evolve its market share further, the time of start-up co-financing must end. It is time to rebuild this market to play a major role.

5. Unrivalled market for an inimitable good

Consumers have no choice in terms of product features. Either you consume electricity or you do not. It is possible to make contracts that target the character of production, but it has absolutely no influence on the power that is finally consumed. The consumer cannot even prove where the power comes from. It is only a matter of the contract. It is impossible to determine whether the actual physical product comes from the company to which the price is paid, or if it comes from another company. It is all mixed thoroughly on grid level. In fact, it makes no technical difference.

⁷⁸ AGEE-Stat, EEG-Reform, Informationsportal Erneuerbare Energien, <http://www.erneuerbare-energien.de/EE/Redaktion/DE/Standardartikel/Infografiken/infografik-anteil-ee-am-bruttostromverbrauch.html>

Electricity from the plug is AC Power at a frequency of 50 Hz and in Europe 230 Volts, regardless of how it is produced. It is really unrivalled, and it is uniform. None of the producers can compete in terms of quality or characteristics, not even in terms of the packaging. The difference is basically a promise to be proven or simply believed in.

In addition, there is no way to store electricity directly without conversion. Voltage can be stored in capacitors, but this is a very restricted method. It is invisible and elusive and almost ubiquitous, but no warehouse exists. No other product exists with comparable characteristics. The power-grid is very large and can distribute the power to almost everywhere. In Germany, there is a marketing strategy that sells yellow⁷⁹ power, but the colour of power that comes out of your plug cannot be evaluated; it is marketing alone. The same can be said for green electricity.

5.1. Unique selling point of current as a commodity

The energy market encompasses all the sources, renewables and fossils, plus all their forms, such as solids, fluids, gas, electric or pure heat in the form of steam. The gas market and the power market are closely related, but the technologies are very different in terms of their physical basics. As gas is a physical good, it can be stored in a so-called “gasometer”, even for long periods and almost without any energetic loss. Apart from this fundamental difference, they share a lot of similarities. Since the grids are organised in levels, the energy flow is normally organised top-down, and a blackout is difficult to recover.

79 Willkommen bei Yello Strom: Ihr günstiger Stromanbieter, <http://www.yellostrom.de/>

Due to the similarity and the distinguishing fact that gas can be stored, both products can complement each other. In principle, it is possible to convert one product into the other.

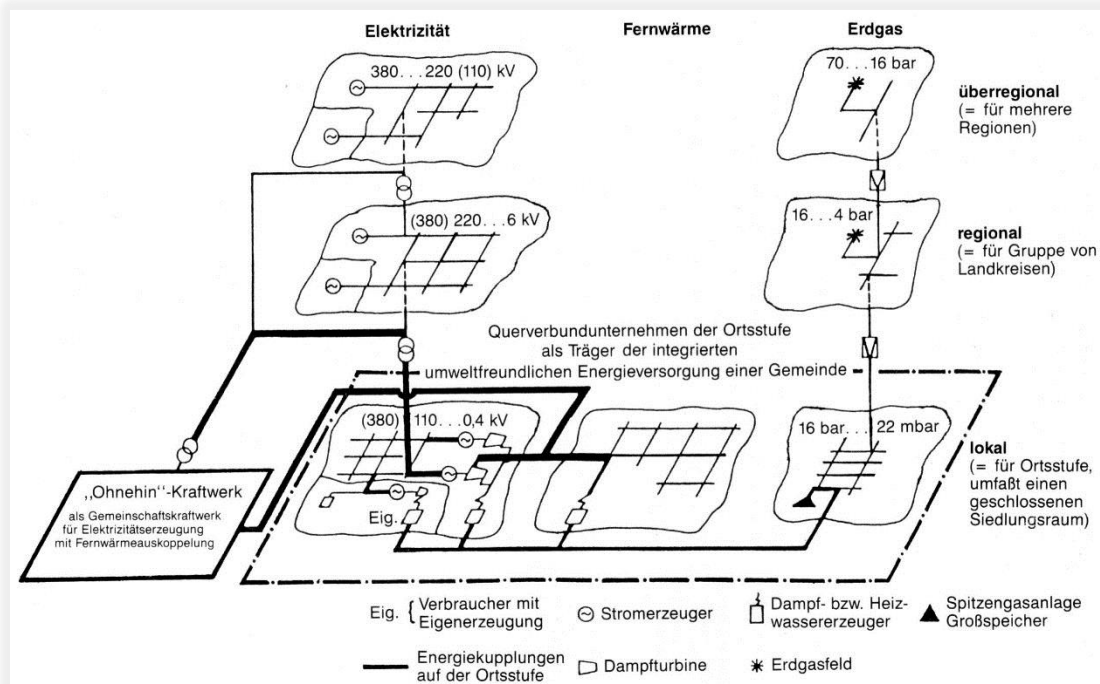


Figure 21: Comparison of gas- and electricity-grid based supply⁸⁰

Burning gas to produce electricity is common practice in power plants. Power-to-Gas (hydrogen) research is currently subsidised by the German state of Baden-Württemberg.⁸¹ In a second phase, the hydrogen can be converted to standard domestic gas which is in fact the link that has the potential to couple both markets.⁸²

The economical application of transformation is determined mainly by two factors: marginal costs of electricity in relation to the price of gas in combination with the transformation losses.

80 Leonhardt, Willy, Klopffleisch, Reinhard, Jochum, Gerhard, Kommunales Energie-Handbuch, Vom Saarbrücker Energiekonzept zu kommunalen Handlungsstrategien, Karlsruhe, Müller, 1989, p. 85

81 Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), Erneuerbarer Wasserstoff für die Mobilität der Zukunft, <http://www.zsw-bw.de/infoportal/presseinformationen/presse-detail/erneuerbarer-wasserstoff-fuer-die-mobilitaet-der-zukunft.html> (24.06.2015)

82 Strategieplattform Power-to-Gas, Stellungnahme zum Netzentwicklungsplan Gas, http://www.powertogas.info/power-to-gas/aktuelle-meldungen/detail/news/stellungnahme-zum-netzentwicklungsplan-gas/?tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail&cHash=1af6c0ffa46f2c4e2af25da5f9642fd9 (12.06.2015)

Despite many similarities, there are fundamental differences in both markets. The electricity market already knows two different prices. One depends on the actual consumption, the performance price, and the other depends on the maximum capacity (technical limitation of access point) that might be consumed, the contract price. In the gas market, there is one price only.

The amount of electricity produced overall, and the consumed power must always be in balance. There can be some reserve of production capacity, but never a real overproduction, as this would immediately crash the physical network in between. There is no stock. It is simply not possible that one producer floods the market by bad quality low price entities. Electricity is uniform everywhere in the grid. Any producer is interconnected with any consumer, at all times and instantly. Any action influences all of them. To ensure the defined quality, the ÜNBs measure continuously, proof and re-adjust if required. One possibility for producers to compete could be the ability to produce on time when requested, as a service to follow the market demand.

5.1.1. Many producers – one single product

At a first glance it looks like a contradiction to the standard model of product lifecycle that power is unchanged for so long, but is merchandised as always. It is another example of the uniqueness of power that the lifecycle happens on the production side. Consolidation phases in terms of production companies could be recognized and lead to a concentration phase.

„Die zunehmende Verbreitung von Fernwärme führt in den späten fünfziger Jahren dazu, dass Kraftwerke in die Innenstädte zurückkehren.“⁸³

For some time the German power market has been split into four parts, namely the following companies:

- RWE
- EnBW
- E.ON
- Vattenfall

Today, there is again a big transformation, as with the rise of the EEG. Thousands of house owners enter the market as new producers of photovoltaic electricity.

⁸³ Hahn, 100 Jahre Strom in Franken, p. 164

However, the influence of the big 4 is still visible in the grid-responsibility (see Figure 5, p. 10). On the other hand, the wind turbine market is more capital intensive and therefore has seen some concentration, fusion of firms and even bankruptcy.⁸⁴

In any case, the entirety of producers is interconnected by one single grid. Power has the technical feature to interact. Once injected to the grid, any production-based deviation in terms of any thinkable characteristic is leveraged. They all have to cooperate to keep the quality on the required high level.

As the power grid is harmonised throughout Europe, the logical consequence is to use the specific capacities of some countries to actively balance between the different producers, e.g. by “Implicit Intraday Allocation”.⁸⁵ The French nuclear industry cannot compete with the Swiss water-based power generation via the properties of the product itself. But they definitely do compete via the method of production, with specific costs and conditions.

All the different technologies of traditional and renewable energy production have dedicated capabilities to interact with the market demand. Some are inert and others agile. In fact, all the differentiating factors in the various production methods can be clustered in principle into two groups:

1. Prime costs (including capabilities to constantly produce 24/7 respectively to be able to regulate and therefore follow market demand)
2. Location (transport distance = higher installation effort and enduring energy loss)

84 Balser, Markus, Prokon-Insolvenz ist Teil einer Krise der Windkraft-Branche,
<http://www.sueddeutsche.de/wirtschaft/nach-prokon-insolvenz-gegen-wind-1.1948031> (02.05.2014)

85 Swissgrid, Swissgrid - Schweiz - Frankreich,
http://www.swissgrid.ch/swissgrid/de/home/experts/topics/congestion_management/ch-fr.html

5.1.2. Without alternatives consumers can hardly select

On consumers' side of the grid, all the input to the grid is mixed and cannot be resorted again. Only the contract has a minor influence in the power market, but the finally distributed product does not necessarily have anything to do with the ordered product. Incoming good inspection or tests to compare the delivery with the order is pointless.

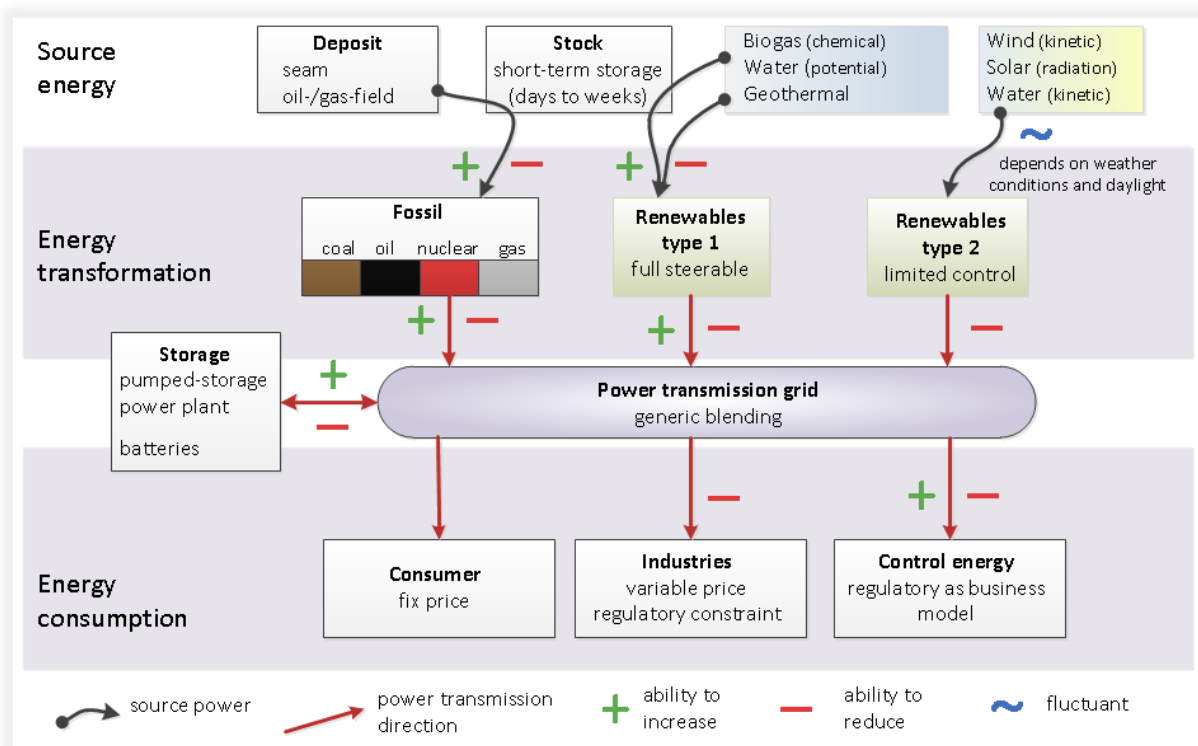


Figure 22: Energy flows and their capacity of control

(own illustration inspired by ⁸⁶)

The only way to be sure which kind of energy is being consumed, is to use energy that has been self-produced. Independence of the grid is the only real choice that the consumer has.

„Als E.on-Chef Johannes Teyssen jüngst die Aufspaltung seines Konzerns verkündete, nannte er ausdrücklich den Selbstversorgungsdrang der Kunden als bedeutende Ursache für die Krise von E.ons klassischem Geschäftsmodell mit Großkraftwerken. Die im Konzern verbleibenden Einheiten sollen wiederum von genau diesem Trend profitieren.“

87

86 Ulbig, *Operational Flexibility in Electric Power Systems*, p. 36

87 Sorge, Niels-Viktor, Trend zur Energie-Autarkie: Familie Schmitt macht es sich selbst, <http://www.spiegel.de/wirtschaft/service/strom-selber-erzeugen-selbstversorgung-liegt-im-trend-a-1010782.html> (01.01.2015)

The German steel company “Saarstahl” started cooperation with the owner of a coal power plant in Ensdorf. In this area of the German state “Saarland”, the cooperation between coal and steel has a long tradition, as well as in the coproduction of power and heat.⁸⁸ Both energies are heavily used in this process of the steel industry. In this case, the company had an interest in preserving the traditional power plant to guarantee their own supply and not to be dependent on any weather conditions.⁸⁹

Even the big players of Silicon Valley decided to produce their own electricity due to hard economic facts. If they build their own photovoltaic power supply, the investment is clearly calculable. There is no uncertainty due to fuel costs, and the risk of other incidents like natural phenomenon that possibly could destroy the plant can be assured. Apple fixes their energy prices at today’s rates for the next 30 years.⁹⁰ Amazon seems to follow that strategy by building North Carolina’s First Utility-Scale Wind Farm⁹¹ to increase the percentage of renewable energy produced.

5.1.3. Power as a co-product

First of all, electricity is a type of raw material. Consumers buy power to have light, to drive machines (force) or to convert it into heat. There are only some rare cases where electricity is useful without conversion. These are medical uses, electrical fences on farms and in some chemical processes for electrolysis.

Any power conversion is accompanied by loss as an unwelcome side effect. The classical steam driven power generators produce a lot of heat as a co-product. When this waste-heat has been used in cogeneration of heat and power, then it becomes less clear whether the electricity or the heat is the product or the co-product.

Renewable energy systems also produce some waste energy. Photovoltaic requires converters which have losses, and as such, waste heat. Big wind turbines have the same need and, therefore, require coolers. Due to the dependency of these technologies on weather conditions, they

88 Leonhardt, Klopffleisch, Jochum, Kommunales Energie-Handbuch, p. 48

89 cp.Zaunmüller, Christine Dr.; Laurent, Pascal, The consumer perspective of the energy market, p.1

90 Simerson, Matt, Apple data centers on 100% renewable power, <https://matt.simerson.net/news/2015/05/06/apple-renewable-power> (06.05.2015)

91 Amazon Web Services Announces Its Largest Renewable Energy Project to Date, <http://phx.corporate-ir.net/phoenix.zhtml?c=176060&p=irol-newsArticle&ID=2067354> (13.07.2015)

are less suitable for cogeneration of heat and power. Therefore, the heat is treated in those circumstances as waste power only. From an overall perspective, this seems to be a step backwards.

On the consumers' side, the usage of electricity is again combined with the release of heat. Sometimes it is the co-product of heat that is dominant, and the primary use becomes minimal in terms of energy percentage. Light is such an example, and consequently this caused the EU to prohibit standard light bulbs.⁹²

The concept of the co-product is also valid on a higher level of abstraction. We have seen already that the regulatory authority can prohibit the disablement of a non-profitable power plant to ensure security of supply.⁹³ Such a stand-by generator has costs involved, because it has to remain manned and operational at all times. It does not produce power if it is not needed, but it delivers a guarantee of supply and to be able to serve even extreme demands. The second service is a kind of redundancy in case any other power plant goes offline. Mostly this requirement is argued by unreliable renewable energies, but it is valid also for planned maintenance or an unplanned failure of a fossil fuel driven or nuclear device. The bigger the device, the more reserve capacity is required to substitute its production output if it cannot provide it itself.

Standby power plants can therefore be seen as “producers” of precaution and supply guarantee, co-products in this point of view. In a service society goods are no longer related to physical goods only. Services can also be treated as any other commodity.

At a first glance it seems a strange concept, but even the consumer can deliver services. In the traditional view, a consumer of electricity is at the opposite end of the supply chain from the producer. In the unique world of energy, both play a role to keep the market stable. A fluctuating consumption is traditionally balanced by production being able to follow. As nowadays the production is even more fluctuating than the consumption, it might be worth investigating whether the consumption might follow the production instead. A consumer being able to swing the consumption capacity around an average can deliver both consumption and waiver as a service to stabilise the grid. In Chapter 3.3.1 (p. 24), the concept of power to heat is introduced. Its main intention is consumption on demand, which is bundled with a flexibility to follow oversupply. Offering this flexibility as a network stabilisation service can be treated as a co-

92 Kommission der Europäischen Gemeinschaften, Amtsblatt der Europäischen Union L 76/3, VERORDNUNG (EG) Nr. 244/2009, <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:076:0003:0016:DE:PDF> (24.03.2009)

93 cp.manager magazin, Unrentable Kraftwerke: EnBW will gegen Abschaltverbot klagen

product of the overall consumption, and therefore turns the customer into a service provider, one might even say: producer.

Both roles are interconnected.

If the point of view is broadened from pure power only towards the services belonging to the network stability too, than it becomes apparent that each power production method differs, not only in technology or ecological footprint, but also in its capability to stabilize the network. The service delivery is very different, depending on the production equipment and the power source.

Any producer of power and any consumer of power, which can adapt to the other's need, is able to deliver stabilisation services as a co-product, which has to be treated as considerable added value for the overall electricity grid.

5.2. Energy as a mix of private, public and merit goods

Wherever electricity is generated, power transformation processes are involved. Fossil and renewable energy production differs mainly in the fact that the source energy of renewables is mainly on site, whereas fossil energy carriers have to be transported to the power plant. The often-used expression “neither sun nor wind does send an invoice” cannot be used to compare, as neither coal seam nor oil deposit asks for money.⁹⁴ Digging, lifting and any other kind of extraction involves costs, but this argument already compares the overall process line, which is more than just the source of the energy.

The more interesting question is: Where on the chain of transaction processes does the source energy cease to be a public good and become a private good? Or is even the outcome, the electricity itself to be in fact treated as a private good?

94 Douglas, Holger, Die Sonne stellt keine Rechnung? Welch ein Irrtum!,
http://www.deutscherarbeitgeberverband.de/aktuelles/2014/dav_aktuelles_2014-03-26_sonne.html
 (08.07.2015)

5.2.1. Transform public to private by digging deeper

The status of natural resources is clearly defined as a public good. If human action is required (mining, prospecting, filling up, water, for example) to be able to bring them to the market, these goods are called “Immobile Allmendegüter”.⁹⁵

Coal can be treated after mining and be transported towards the energy plant where it is burned and finally transformed into electricity. After mining, the former public good is turned into a private good, because the owner of the mine holds a licence that grants him the right to do so. Therefore, the power companies that have been generating power for more than a hundred years are used to dealing with private goods and not with public ones. Therefore, it seems logical that renewable energy systems sell electricity as a private good, even if driven by a public good.

Neither wind nor sun radiation can be mined and sold in bags or lorries. Their conversion into power could therefore be considered as a one-step transformation, including the activity of “mining”. While licenses to dig are widespread in international law, there seem to be a lot fewer regulations for the use of energy that has its origin above ground. There are many rules for aviation⁹⁶, for example, but not for the exploitation of the energy.

In the Netherlands, there exists the concept of “Windrecht”.⁹⁷ With this law, obligations in terms of windmill usage are clarified, for example, the feudal lord has to ensure that trees surrounding the windmill are not getting too big to “outshine” the windmill. Both types of mills, water and wind, are bound by a similar kind of right in that country. But the concept of regulating wind is uncommon on an international level, unlike the use of water, which is a separate topic in legislation and is one of the oldest rights. It might have its origin when mankind settled down, but in any case it can be traced back to King Hammurabi I. in 1700 BC in Babylon.⁹⁸

The right to turn a public good into a private one and sell it afterwards is usually bound to a usufruct. It is awarded for a special period in time and mostly coupled with restrictions. None of these concepts could be found for the renewable energies of wind and photovoltaic. Geothermal energy usage and corresponding terms are not clearly defined in the law “BBergG” as this law focuses on material items, but not on energy. In 1980 the geothermal energy got the status

95 Maring, Matthias, *Globale öffentliche Güter in interdisziplinären Perspektiven*, Karlsruhe, KIT Scientific Publishing, 2012, p. 203

96 International Civil Aviation Organization (ICAO) UN specialized agency, *Freedoms of the Air*, <http://www.icao.int/Pages/freedomsAir.aspx>

97 Wikipedia, Windrecht - Wikipedia, <https://nl.wikipedia.org/w/index.php?oldid=40781019> (15.06.2015)

98 cp. Winckler, Hugo, *Der Codex Hammurabi in deutscher Übersetzung*, Dogma, 2013, pp. 23–25

“bergfrei” which means the usage does not require special licenses.⁹⁹ Biogas plants use only private goods as input and therefore are not involved, except one takes into account the oxygen of the air used to burn the gas. To compare the full cost of traditional and renewable energy, the sourcing of energy has to be included as well as the pollution.

This point of view considerably shifts the discussion about subsidies for renewable energies, as traditional coal mining has seen huge subsidies in the past decades, or even over centuries. Factors such as providing job securities and maintaining the potential for self-sufficiency can also potentially transfer to other technologies. The decision to invest in any technology depends on the total costs involved. This also includes any political decision about subsidies.¹⁰⁰

Another political decision that could be seen as a long-term subsidies action is the agreement that nuclear waste disposal is treated by the public domain.¹⁰¹ The source material is mined, turned into a private good and money is generated by it. Later, the remaining waste is sold back and again turned into a public good when buried again.¹⁰² Afterwards, the risk and the associated dangers are definitely different than before the initial mining. The pollution caused by traditional coal, oil or gas-based power generation also becomes public again. In the traditional economy, the conversion of public into private goods and back again is regulated by several laws. In the market of renewable energy there are many rules, but not regarding property conversion, and the old regulations are no longer relevant.

Therefore, one could say that the transformation of physical energy by wind or solar radiation into electricity does not change the character of being a public good, due to the missing legal basis.^{103, 104} If this point of view is held, then the service of transformation is the only billable added value.

99 cp.Ehrlich, Heike, Erbas, Kemal and Huenges, Ernst, 3. Geothermie Scientific Technical Report, Angebotspotential der Erdwärme sowie rechtliche und wirtschaftliche Aspekte der Nutzung hydrothormaler Ressourcen, <http://gfzpublic.gfz-potsdam.de/pubman/item/escidoc:8467:4/component/escidoc:10068/9809.pdf>, pp. 29–30 (08.04.2010)

100 cp.Kirchhof, Der sanfte Verlust der Freiheit, pp. 83–87

101 BGBl. I S. 434, Atomgesetz, Gesetz über die friedliche Verwendung der Kernenergie und den Schutz gegen ihre Gefahren, <http://www.gesetze-im-internet.de/bundesrecht/atg/gesamt.pdf>, p. 12 (01.04.2015)

102 cp.Hecking, Claus, Pinzler, Petra, “Wir sind dann mal weg, Kernkraftwerke zu verschrotten kostet Milliarden. Stiehlt sich die Industrie aus ihrer Verantwortung?”, *die Zeit*, Vol. 2015, No. 36, p. 19, 03.09.2015, https://premium.zeit.de/system/files/DZ/2015/36/epaper/DZ_36_15_019.pdf

103 cp.Rexer, Tobias, The renewable energy with open topics in jurisdiction, p. 1, interviewed by Fontaine, Sebastian (21.07.2015)

104 cp.Raczek, Karl-Heinz, The renewable energy as public good, p. 1, interviewed by Fontaine, Sebastian (21.07.2015)

5.2.2. Securing livelihoods by electricity as public good

Since the age of industrialisation, the environment of people has changed dramatically. In former days, people lived on their farm in a natural environment with everything necessary to survive at hand. Since industrialisation, some technical assets have become essential to live and even to survive and cannot be provided by the individuals. Such assets have to be delivered and ensured by the state.

„Die durch die Industrialisierung ausgelöste räumliche Verschiebung der Bevölkerung hat dazu geführt, daß sich der beherrschte Lebensraum des einzelnen mehr und mehr verringert (von Haus, Hof und Werkstatt zur Mietwohnung und dem Arbeitsplatz in der Fabrik), während die Technik den effektiven Lebensraum außerordentlich erweiterte. Mit dem beherrschten Lebensraum gingen dem einzelnen die Sicherungen verloren, die seinem Dasein eine gewisse Eigenständigkeit verleihen. Nun war er auf Vorkehrungen angewiesen, die seiner sozialen Bedürftigkeit zu Hilfe kommen und die Daseinsführung ohne beherrschten Lebensraum erst möglich machen: Gas, Wasser, elektrische Energie, Abwasserableitung, Verkehrsmittel usw. Die soziale Bedürftigkeit ist also unabhängig vom Vermögen. Sie trifft für jeden, dessen Dasein nicht durch einen beherrschten Lebensraum abgesichert ist, in eminentem Maße zu. Sie trifft heute sogar für jedermann zu, da es in dem sekundären System, der Lebensform hochindustrialisierter Völker, wie Hans Freyer überzeugend dargelegt hat, autonome und autarke Daseinsformen nicht mehr gibt.

Dieser Bedürftigkeit zu Hilfe zu kommen, ist staatliche Aufgabe geworden, wobei Staat im weiteren, auch die Gemeinden umfassenden Sinne verstanden sein soll. Was in Erfüllung dieser Aufgabe geschieht, ist Daseinsvorsorge.“¹⁰⁵

Today it is almost impossible that people are completely disconnected from the electricity supply. If bills are not paid, in general, the grid operator has the option to turn off the power, in principle, with the exception being in the case of financial hardship. Nonetheless, this disconnection of supply unfortunately happened in Saarbrücken in 2012. As a result four children died in a fire caused by candle usage. That prompted a discussion about competences. Firstly, it was not clear whether the energy supply company had the right to disconnect the family or not. Finally, the actual power cut had been caused by a lack of communication due to a gap in the

105 Forsthoff, Ernst, Der Staat der Industriegesellschaft, Dargestellt am Beisp. d. Bundesrepublik Deutschland, München, Beck, 1971, p. 76

jurisprudence.¹⁰⁶ The unemployment office would have paid the bill had they been informed, so the power supply should not have been interrupted.

The concept of security of supply ensures that there is enough capacity to serve the whole demand for electricity. So there is no rivalry about a short good on the consumer side. Moreover, suspension is prohibited by the law in case of hardship.

Finally, all preconditions are fulfilled to name electricity as a public good for citizens.

The situation is different for the industries. Supply guarantee avoids rivalry, too, but there is no case of hardship and power therefore can be disconnected in case of default of payment. Both electricity markets (private & industries) differ in this respect.

5.2.3. Promotion turns power into a (de-)merit good

With the exception of some indigenous people and some individuals living in isolation, such as the Lykov family (1978)¹⁰⁷ there is no full choice to consume energy or not. Nowadays electricity is as natural and common as nutrition and clothing. For people being part of the modern society there is no option to not use power in their daily lives. The only decision they can take is which kind of power production they wish to have and which one they refuse by signing a corresponding contract.

This reveals a paradox. It is possible to sign a contract for consumption of renewable energy only, but there is no contract to use, for example, nuclear energy only. The only existing choices are which kind of renewables, renewables only, or a combination of energies. Exclusion of renewables is not possible.

Renewable energy has to be firstly dealt on the stock exchange, as described in Chapter 3.1 (p. 17). It is irrelevant whether or not a client is interested in signing contracts to consume renewable energy. Even if they did not sign any contract, some of the energy consumed will have been produced by renewable technologies. One can say there is a compulsion to consume renewable energy.

106 Jungmann, Michael, “Ämter wussten nichts von Stromsperre, Burbacher Brandunglück”, Saarbrücker Zeitung, 28.08.2012, <http://www.saarbruecker-zeitung.de/leben-in-saarbruecken/topartikel/art297097,4417691>

107 Wikipedia, Lykov family, <https://en.wikipedia.org/w/index.php?oldid=663180221> (20.07.2015)

The fee to balance the difference in stock-price and guaranteed revenue for the producer is called “EEG-Umlage”, a remuneration. It is funded by payment of energy consumption. In general, there is no chance to escape the fee to be paid, or the usage of the energy, meaning that all the conditions are fulfilled to have the renewable energy considered as a merit good.

Photovoltaic is a particular case, as the output can be restricted by the grid operator. He has the right and the access to directly steer the photovoltaic in the case of oversupply.¹⁰⁸ Even if he is obliged to pay compensation in this case, the characteristic is similar to a demerit good, as the usage can be interdicted, at least for a while. But on the other hand there is an obligation to contract (§ 8 Abs. 4 EEG)¹⁰⁹, so the photovoltaic energy can be treated as a merit good, even with this exceptional possibility to restrict.

The obligation to be connected to a regulatory system for restriction is not limited to photovoltaic production; something similar exists for the consumption part as well. There are two main concepts:

1. Load-shedding to stabilize the grid based on Frequency Thresholds¹¹⁰
2. Load-shedding based on contract, mostly used for major consumers (steel industries, for example)

The earlier mentioned technology of power to heat conversion¹¹¹ is something different. The participation in the market of balancing energy is something based on free will, whereas the load-shedding for major consumers is a prerequisite for getting connected to the grid.

Neither the source energy is a private good, nor is the resulting electricity. The only thing that really can be treated as merchandise is the service of transformation. As seen earlier, there are even more services required to stabilise the network as a whole. One must rethink the key of payment and give up the focus on a physical good (product MWh) for a broader consideration of the service idea.

108 Oberlandesgericht Hamm, Entschädigungsanspruch aus § 12 Abs. 1 EEG (2012)

109 cp.EEG 2014 - Einzelnorm, http://www.gesetze-im-internet.de/eeg_2014/__1.html (25.11.2014)

110 Stefanidou, Ifigeneia, Zerva, Maria, Control Strategies for Under-frequency Load Shedding, Interaction of Distributed Generation with Load Shedding Decentralized Under-Frequency Load Shedding of Household Loads, ETH Zürich, 03.09.2009, p. 13

111 cp.Küster, Michael, Grid operator view to the renewable energy market, p. 2

5.3. Key of payment for electrical power

The current layout of the EEG, the impact of the Merit-Order effect and the unequal treatment of renewable and traditional energy production gives the impression of start-up financing. While the share of renewable energy in the total energy market is already more than 25% in Germany, one could argue that this start-up financing was hugely successful. By now, however, renewable energies have become a major pillar of the economy and therefore can no longer be seen as a start-up.

The price for electricity in the last 16 years has been more and more determined by governmental action.



Figure 23: Governmental special charges to the electricity price 1998-2014¹¹²

There is no single price of a MWh. Even in the early stages of the power market, there was a separation made. Two prices existed to influence the consumption and to support the business.

112 BDEW Bundesverband der Energie- und Wasserwirtschaft e.V., Preise - Grafiken,
<https://www.bdew.de/internet.nsf/id/preise-de> (13.11.2014)

The general objective function and the restrictions are looming already in this example:

01.05.1896 Einweihungsfeier des Dampfkraftwerkes mit Kohlebefeuerung im Nürnberger Stadtteil Tullnau. Für Lichtzwecke wird ein Strompreis von 70Pf/kWh, für Kraftzwecke von 20Pf/kWh festgelegt. Für größere Verbrauchsmengen werden gestaffelte Nachlässe gewährt. Eingesetzt werden drei Einphasenwechselstrom Maschinen mit je 230 kW. Die Baukosten betragen 1,2 Mio Mark.¹¹³

Nowadays the situation is more widespread; a wider variety of circumstances have to be taken into consideration. The number of items influencing the overall price is continuously growing and they cannot be listed here in total, although the picture above already gives a good indication.

5.3.1. Technical restrictions and odds

The cogeneration of power and heat couples both markets together. The reduction on one side can hardly be in correlation with an expansion on the other side.

Es wird nicht funktionieren, die Strom- und die Wärmeerzeugung aus der Kraft-Wärme-Kopplung zu verdoppeln, wenn gleichzeitig der Wärmebedarf von Gebäuden um 30 Prozent sinken soll.¹¹⁴

The different governmental programs therefore have to match. A goal to increase building insulation will reduce their consumption of heat. If at the same time there is another program to extend the co-generation of power and heat, the effects are opposed.

A purely photovoltaic system can never provide electricity around the clock. It would rely on a mechanism to store the power produced during daylight hours for the night. On a longer cycle, a similar point of view applies to wind turbines. The strength of the wind can be forecasted, but not influenced. In still conditions, the demand has to be fulfilled in another way.

There are two different kinds of generators: One can autonomously produce current with good quality, without being connected to a grid. The other one needs the grid to follow the frequency. In the case of a nationwide blackout, it is a difficult task to re-enable all producers and reconnect the network participants. Producers that are able to do a so-called “black start” have to be first

¹¹³ cp.Hahn, 100 Jahre Strom in Franken, pp. 26–27

¹¹⁴ Dorsch, Hans, "In der Gesamtheit nicht realisierbar", Interview mit Ulrich Wagner, Vorstand Energie&Verkehr beim Deutschen Zentrum für Luft- und Raumfahrt, <http://www.heise.de/tr/artikel/In-der-Gesamtheit-nicht-realisierbar-2556458.html> (23.02.2015)

to produce. Later, the producers that have to follow must be reconnected one by one. In this case, it is also important not to overload the capability of the main generator to keep the system in synchronisation. When the power-grid is split into pieces, for whatever reason, (e.g. overload of some major lines due to ship traverse “Papenburg”)¹¹⁵, then the reassembly will be very difficult as production and consumption must also always be balanced. Such cases are considered as force majeure¹¹⁶ and therefore not part of the standard economic consideration.

The most important prerequisite for the industry is to have reliable availability of electricity. A short outage of a few seconds can harm the assembly line in such a way that production outage lasting several days is caused.¹¹⁷ For some high level consumers it is not an option to install an uninterruptible power supply UPS, as such devices are limited in size and capacity. UPS’s are therefore in use where the overall consumption is clustered, for example, in data centres.

A second example of the use of UPS is to assure the quality of power. Switching power supplies of computers, for example, are very sensitive and poor power quality can impact on their proper functioning. The quality of the power grid is defined by a couple of technological specifications, such as voltage, frequency, harmonics, distortion factors, reactive power, to name a few. Each consumer is more or less sensitive for any kind of deviation. Therefore, the stability of these key-figures is a sign for the good level of quality of the power-grid. The list of constraints due to technical restrictions is long and cannot be listed here in total. Therefore only the major ones have been named.

115 Kurth, Matthias, Stromausfall Pressekonferenz 17. November 2006,
<http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Allgemeines/Presse/Reden/2006/StromausfallNov06Kurth061117Id7966pdf.pdf> (17.11.2006)

116 cp.UCTE, Final Report System Disturbance on 4 November 2006,
https://www.entsoe.eu/fileadmin/user_upload/_library/publications/ce/otherreports/Final-Report-20070130.pdf, p. 18

117 cp.Zaunmüller, Christine Dr.; Laurent, Pascal, The consumer perspective of the energy market, p. 2

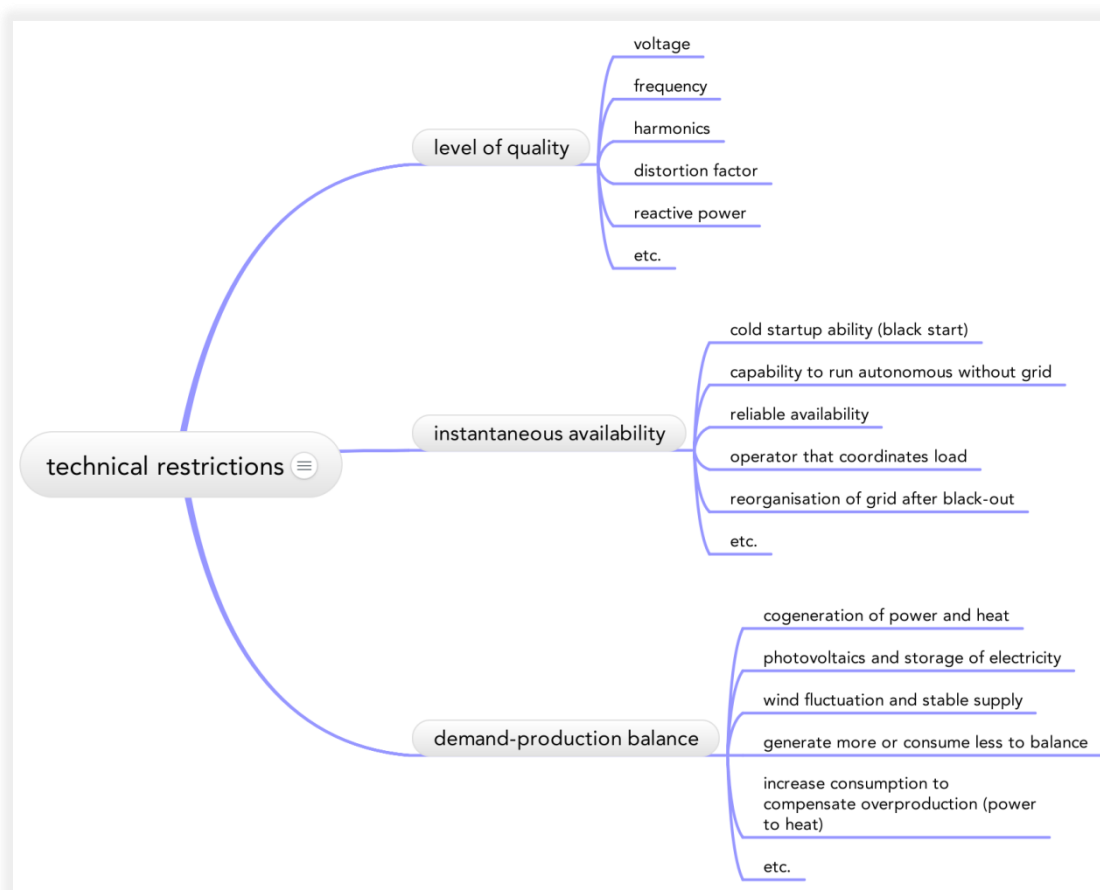


Figure 24: Technical restrictions of the energy market

(own drawing)

On the other hand, the technology is evolving very quickly and some interesting topics are coming to the fore, especially with regard to the energy market.

One tool to bring demand and supply in balance is the timetable. Market participants, consumers and producers, have to announce their forecast to the grid operator. This behaviour makes it possible to avoid imbalance by being prepared in advance. Participation in this tool usually results in a lower power price. However, taking part is risky, as any deviation from the forecast is penalised. Even if less power is consumed, the penalty payment would increase the overall price. This is valid for all members in the accounting grid or balancing group (“Bilanzkreis”). Today the price of a deviation is determined up to six weeks after the forecasted event happened. Therefore, it is impossible to estimate how expensive the error of the forecast will be.¹¹⁸ There is a high, double risk in the participation of this mechanism.

Communication evolution - like the internet - allows faster information flow, up to real-time communication. In principle, this can possibly reduce the importance of the forecast as well as the timeframe to get the feedback about the real happenings.

Electricity is just a part of the whole primary energy consumption. Another big part is the transport sector being based on fuel.¹¹⁹ With the evolution of the electric car, there might be a shift towards the electricity market. Since these vehicles are driven by rechargeable batteries, their charging mechanism could have a large impact on the course of the overall consumption curve. There are ideas to use electricity-driven vehicles as power banks or even as controllable sinks for times when there is an oversupply expected. It is probably easier to control the charging current and keep the direction of power instead of using the vehicle accumulator as power-source. In any case, this technological evolution potentially has the ability to impact on the energy market as well.

5.3.2. Legal and political variables

The abovementioned electric cars are also a good example of the impact of politics on the energy market. Power delivery for free is either a big subsidisation or another indicator for the public good character of power, or both:

Die Osloer City-Maut von 3,30 Euro gilt nur für Benziner und Diesel. Außerdem können E-Auto-Besitzer kostenlos Strom zapfen: Da in Norwegen wegen des Überangebots an Wind- und Wasserkraft die Kilowattstunde nur rund fünf Cent kostet, wäre eine individuelle Abrechnung teurer als dieses „Geschenk“.¹²⁰

¹¹⁹ Geitmann, Erneuerbare Energien, p. 29

¹²⁰ Wirtschafts Woche, In Norwegen wird das Elektroauto zum Problem, <http://www.wiwo.de/unternehmen/auto/fragwuerdige-foerderung-in-norwegen-wird-das-elektroauto-zum-problem/10636304-all.html> (01.09.2014)

The components of today's power price are mainly determined by governmental influence. More than $\frac{3}{4}$ of the overall price belongs to regulation, tax, fee, levy and subsidies.

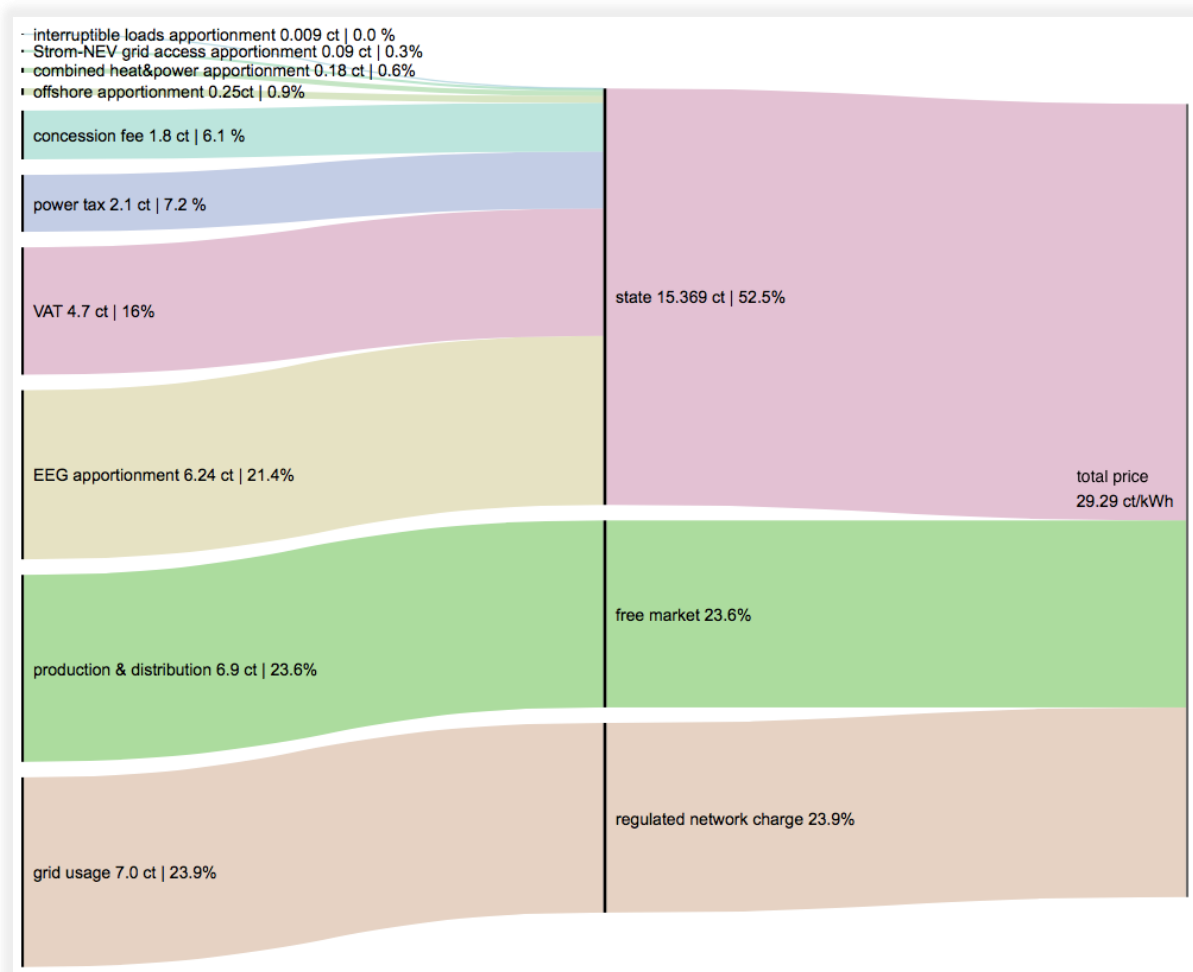


Figure 25: Private Household's power price components

(own drawing based on figures from 2014 ^{121,122})

With the liberalisation of the energy market, it became necessary that the regulatory authority took over the role of a conductor or even sheriff. As seen earlier, the list of technical restrictions is long. Single power generators with a relatively small capacity compared to the total market have little influence on its overall performance. If their specifications do not fulfil all of the technical specifications, the impact on the overall system might be negligible. The situation, however, becomes problematic when the sum of all those small systems reaches a size that becomes considerably important to the overall system. Each single operator might not be big enough to have an impact, but together they do have an impact.

121 Wirth, Aktuelle Fakten zur Photovoltaik in Deutschland, p. 24

122 BDEW Bundesverband der Energie- und Wasserwirtschaft e.V., Preise - Grafiken

This leads to a paradoxical situation. On the one hand the state wants to push the renewable energy generation. Therefore, technological requirements are reduced to safe costs, compared to traditional power plants. On the other hand several preconditions have to be fulfilled. The sinking share of traditional power generators cannot carry an increasing need to take-over the requirement fulfilment. This balancing act leads to an increasing number of legal restrictions since the market liberation has started. The core idea of the EEG is therefore a shift in costs in favour of the new power market participants. There is no reason for this apportionment other than political will.

The change in technology reveals more and more new technological competitions. Since the market is a shared medium, a single actor with the will to invent a new technology relies on the will of the others to cooperate. As a logical consequence, there are requests to the regulatory authorities to define answers for each single technology driven new problem. As a further step, the amount of taxes, subsidies, levies and legal constraints rises.

„Die Gesetzgebungshistorie weist seit Einführung des EEG-Umlageprivilegs 2003 eine Tendenz zu dessen ständiger Ausweitung hinsichtlich Umfang und Begünstigtenkreis auf.“¹²³

As a crazy side-effect of this behaviour, the legal and political restrictions do not only help to leverage single technology problems, but increases at the same time the political restrictions to the market participants in general. This is in contrast to the original idea to liberalise the market.

„Ein klassisch liberales Staatsverständnis fordert die strikte Trennung von Staat und Wirtschaft, verlangt also eine »Neutralität« der Besteuerung. Staatsaufgaben und Steuerlasten sollten möglichst vermindert, vor allem aber die Steuern so ausgestaltet werden, dass sie so wenig wie möglich den eigengesetzlichen Ablauf der wirtschaftlichen Prozesse und ihrer Ergebnisse beeinflussen.“¹²⁴

The governmental impact increasingly limits the free play of market forces. If the business risk is completely covered by regulation, finally the risk is socialized. In that case, society should also take part in the odds and profits.¹²⁵

123 Klassert, Christian and Gawel, Erik, Wie weiter mit der Besonderen Ausgleichregelung im EEG?, https://www.ufz.de/export/data/global/50127_9_2013_Gawel_Klassert_Bes_Ausgleichsregelung_EEG_gesamt.pdf, p. 2 (June 2013)

124 Kirchhof, Der sanfte Verlust der Freiheit, p. 54

125 Merz, Friedrich, Nur wer sich ändert, wird bestehen, Vom Ende der Wohlstandsillusion, Kursbestimmung für unsere Zukunft, Freiburg im Breisgau, Herder, 2004, p. 111

5.3.3. Production efforts

Each operation in the energy market requires production equipment, and as such, investments. Facilities to produce power vary, depending on the sector. Each sector is covered by individual legal requirements. Coal burning systems have to install a flue gas desulfurization plant, which is obviously obsolete for wind turbines. The initial investment is therefore very dependent on all the environmental rules.

The calculation of the return of investment also depends on the depreciation period. The lifetime of the power plant and its durability influence the total cost of ownership.

Nach Ende der Amortisationszeit ist Strom aus PV-Kraftwerken wegen niedriger Betriebskosten und fehlender Brennstoffkosten („Grenzkosten“) günstiger als jeder andere Strom. Fossil-nukleare Kraftwerke hingegen müssen auch nach vollständiger Abschreibung der Investition für die Stromerzeugung laufend Brennmaterial zukaufen und Brennfälle entsorgen.¹²⁶

126 Wirth, Aktuelle Fakten zur Photovoltaik in Deutschland, p. 9



Figure 26: Production efforts for the whole lifecycle
(own drawing)

The total list of production efforts is very individual, even within the renewable energy market only. The market design knows just one figure to calculate the revenue today; the price per kWh. Even a brief glance at the figure above shows that most of the costs are not bound to a single item and, therefore, do not scale with it. Especially where the fuel cost and waste disposal is not required in the on-going costs, the one-off costs are leading.

5.3.4. Distribution efforts

As soon as electricity is generated, it must instantaneously be consumed, therefore the distribution grid has a hauled out position. The importance of the grid connection is so high, that even investors of wind farms make their commitment depending on the availability of a network connection.

„Die Windparkbauer sagen also, ohne einen garantierten Anschluss können wir nicht finanzieren. Aber der Netzbetreiber sagt, ohne eine garantierte Finanzierung wollen wir keinen Anschluss zur Verfügung stellen. Das ist eine klassische Situation für die regulierende Hand des Staates. Eigentlich könnten die Firmen das Problem lösen. Sie müssten kooperieren und Konsortien bilden. Wenn die Wirklichkeit wie das Lehrbuch der Ökonomen geschrieben wäre, würden sie ihr spieltheoretisches Dilemma überwinden, aus eigenem Gewinninteresse. Sie tun es aber nicht. Aus Angst, Misstrauen, Trägheit. Hier ist der Staat gefordert.“ ¹²⁷

Rebuilding the energy landscape from the traditional centralized system to a localised, regional and renewable energy generation system requires a conceptual change of the grid infrastructure itself. If the huge fossil power plants on Level 1 and 3 (see Figure 4, p 8) will be substituted by many small power generating items on Level 5 or 7, one could assume that transmission layer 1 and 3 become obsolete. Sometimes the power has to be distributed over long distances to balance local production drop downs. For such scenarios the high-level power grid layers are predestined by principle. For the transmission of power the direction is important and cannot simply be reverted. For this upcoming need the infrastructure has to be upgraded to support transport in both directions. It may also be that the elder power lines are incorrectly localised. The transportation need of renewable energies differs from the former fossil production due to its regionalisation. Local weather conditions do not necessarily fit the demand of power. To cover such imbalances, a complete rebuild of the highest level of the power distribution grid has to be evaluated and eventually financed.

Due to transportation, there is a considerable energy loss and, as such more energy input to the grid than output. The fraction of loss also depends on the technology, distance and many other factors. For a public utility with short distances and almost perfect conditions it can already

¹²⁷ Augstein, Jakob, *Sabotage, Warum wir uns zwischen Demokratie und Kapitalismus entscheiden müssen*, München, Hanser, 2013, pp. 69–70

easily be over 2%.¹²⁸ Maintenance investments have also to be considered as a normal part of the price for electricity, not only for the power plant itself, but for the distribution grid as well.

These costs are socialised, the alpine hut does not have to pay more than a detached house in a village, nor do the producers have to pay the real costs of connectivity.¹²⁹

5.3.5. Pay per levy or reward

The key of payment shows clearly that nowadays the main part of the costs has the character of levy. Taking into account that the source energy of electricity is always a public good, and that the renewable energy product is characterised by high share of fixed costs (initial investment compared to fuel or other ongoing costs), it seems logical to opt for a levy based price model. The awareness that power is a public service, and supply guarantee is a part of the welfare state, supports the conclusion to cover at least the basic supply (the minimum power required by average household) by levy.

This thought is also opposed by the need to increase power efficiency. For national accounts, it can be economically beneficial to invest in power efficiency instead of more production.¹³⁰ Pay per levy would thwart this request, as levies do not give any incentive to do so. The reward price per kWh works much better to reach that goal.

„Amerikanische Energieversorgungsunternehmen haben es längst erkannt: Selbst Zuschüsse oder billige Kredite für Sparmaßnahmen kommen in der Regel billiger als der Bau immer neuer Kraftwerkskapazitäten. Richtig gerechnet, lohnt es sich für ein kommunales Energieversorgungsunternehmen gar nicht mehr, den Strom- und Wärmeverkauf unbegrenzt auszuweiten.“¹³¹

Moreover, only the reward price offers the flexibility needed to balance supply and demand. Finally, the transmission of power should have an influence on the price, which is hardly possible by the levy model.

128 Stadtwerke Tübingen GmbH, Daten und Fakten zum Stromnetz,
<http://www.swtue.de/netze/netzinformationen/netzstrukturdaten/strom.html>

129 cp.Küster, Michael, Grid operator view to the renewable energy market, p. 6

130 Bundesministerium für Wirtschaft und Energie (BMWi), Ein Strommarkt für die Energiewende, Ergebnispapier des Bundesministeriums für Wirtschaft und Energie (Weißbuch),
<http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/weissbuch,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf>, p. 85 (July 2015)

131 Leonhardt, Klopffleisch, Jochum, Kommunales Energie-Handbuch, p. 23

The main idea is indeed to let the government describe the main frame, instead of organising the details. A conductor does not influence each single instrument in the orchestra; the players follow his advice. If he were to try, the result would be failure due to overload. In Germany, there is a corresponding discussion about the tax-system in general. There are those asking the state to focus on its core business only.

„Das Haushaltsrecht, das Steuerrecht und das Finanzrecht gewinnen [...] an rechtsstaatlicher Qualität, wenn sie darauf verzichten, durch steuerrechtliche Ausnahmetatbestände zu lenken. [...] Ist die steuerliche Lenkung völlig entfallen, wird die Wirtschaft des Gedankens entwöhnt, Risiken und Verluste auf die Staatskasse zu verschieben.“¹³²

The same applies to the design of the energy market. Focussing on prescribing the framework and letting market forces act within it is probably more efficient than trying to regulate each item inside. In fact, regulating arouses the interest to exploit the weak point of the rules.¹³³

In summary, over-regulation shifts the focus. It becomes less interesting to develop the best solution for a problem, but more interesting to benefit by the specialities of the artificial rules, regardless of whether or not they are still related to the ongoing evolution of the market.

Regulating can encourage start-up technologies, but can also impede evolution. Therefore, the energy market should be composed of a small levy part (1/4) and a bigger reward part (3/4), the reverse ratio of today (see Figure 25, p. 58). Such a shift from levy to reward could be established by creating a market for all the services about network stabilization and quality, services, which are built-in today and where the financing is hidden.

There are some obvious parallels to the telecommunication market (fixed lines that can operate autonomous without external power, not mobile).

- Basic fee of telecommunication is called contract price and connectivity is socialised as the standard price is the same for everyone, same for electricity.
- Both markets have an regulating authority.
- With the liberalization the number of companies in this market increased a lot.
- ISDN as digital phone and the older analogue one are uniform products as is power.

The difference is that the phone market knows the flat-rate model. One price for unlimited phone calls exists, whereas one price for unlimited power does not.

¹³² Kirchhof, Deutschland im Schuldensog, p. 131

¹³³ cf. Küster, Michael, Grid operator view to the renewable energy market, p. 6

5.4. Growth increases responsibility as well

With the growing quote of energy with its origin in renewable sources, there is less and less justification to continuously treat it as an emerging market. Emerging is still the right word in a sense that the growth goes on, but not in a sense that the technology is young, weak and needing support. The majority has to preserve minorities; this is one of the basic principles of our political system.

Consistently this means for the renewable energy market that it is time to stand on its own feet. When the turnover point is reached, the minority will not even be able to iron out all the privileges that have been granted to the start-up technology. The EEG is by principle made as a knock-on financing. The special conditions of a world of renewable energy must now be served by rules that come from inside the renewable environment and cannot be delivered from the outside much longer.

5.4.1. Edicts causing costs

The more complex a product becomes, the more development work has to be done and the more costly the production becomes. This is true for the energy market and there has long been an aim of having a grid without disturbance. One of the first examples where edicts caused the introduction of more complex technology to ensure stability of the grid goes back to 1952-53 and concerns the radio.¹³⁴

With the EMVG (a law concerning electromagnetic compatibility) in Germany, all the regulations about electromagnetic compatibility are standardised in one law. The legislator defines rules and the participants have to carry the costs involved as a consequence of this rule.

As regards renewable energy regulation, there are some special edicts that are worth taking a closer look at. The paradoxical effect that a sinking price in general causes a rising EEG apportionment has been described in Chapter 3.1 (p. 17), as well as the Merit-Order effect. Where there is an oversupply of energy and only renewable energy may be available for regulation, then there is another speciality.

¹³⁴ cp. Stiftung Radiomuseum Luzern,
http://www.radiomuseum.org/forumdata/users/133/PDF/TFK_Umbau_UKW.pdf, p. 20

The grid provider is allowed to disconnect the generator to save the grid, but the supplier has to be paid as if he had delivered the power (§ 12 Abs. 1 Satz 1 EEG 2009¹³⁵). In fact, it is irrelevant whether or not the power has been delivered, because the supplier is being paid.

The underlying idea is to make the investment risk predictable and to ensure that renewable energy is the preferred one. Of course it is in the interest of any grid operator to avoid such conditions, where possible. Not only would they have to pay for all the power distributed, plus the normal loss, but also for all the power that may have been produced, but was not. If this idea is carried too far, then one could build up unlimited capacity of renewable energy plants, which would never deliver anything. Oversizing would, at least for the investor, be quite lucrative.

This example makes it very clear that the expected service (a stable network for all) is paid by the grid operator and the consumer, whereas the one causing the problem is rewarded (i.e. gets money for no delivery).

Another example where cost and profit fall apart is the offshore apportionment. Where an offshore wind farm cannot be connected to the grid for reasons that are neither caused by the grid provider nor by the wind farm provider, this apportionment is used to pay the wind farm owner as if he had already delivered the power. In other words, neither the grid provider nor the wind farm owner is under any pressure to have the connection physically done.

The positive effect of the edicts is that some market participants gain planning security, which is a prerequisite for them to enter the market. Unfortunately, in this case the consumer has to pay for things that still do not deliver any added value.

135 BDEW, VKU and BEE, BWE, BDW, Fachverband Biogas, Ermittlung von Entschädigungszahlungen nach § 12 Abs. 1 EEG 2009, [https://www.bdew.de/internet.nsf/res/722468E70B908CBAC1257BEA005244E0/\\$file/165_neu_2012-01-13_Verbaendeempfehlung-Entschaedigungszahlungen-Par12EEG2009.pdf](https://www.bdew.de/internet.nsf/res/722468E70B908CBAC1257BEA005244E0/$file/165_neu_2012-01-13_Verbaendeempfehlung-Entschaedigungszahlungen-Par12EEG2009.pdf), p. 5 (13.01.2012)

5.4.1. Unpleasant consequence of market regulations

A well-known side effect of special funding of renewable energies is the preference of power feed-in instead of personal consumption (Chapter 3.3.3, p. 26). In the past, the market price for electricity was usually lower than the fixed price for renewable energy production, grid parity (“Netzparität”) that has not yet been achieved. Therefore, the incentive of the market to the producer is to deliver any produced power to the grid in the first instance, and to buy it back later.

„Biogasanlagen speisten aufgrund der über diesen Zeitraum [2000 - 2012] geltenden Vergütungsregelungen den produzierten Strom nahezu konstant und unabhängig vom (residualen) Strombedarf ins Stromnetz ein. [...] Biogasanlagen wären allerdings mithilfe zusätzlicher Gasspeicher und durch den Zubau elektrischer Erzeugungskapazitäten verhältnismäßig einfach in der Lage, auf Lastschwankungen [...] zu reagieren“¹³⁶

To promote the consumption of self-generated power, people do not only save money from not buying power, but in addition they receive income to balance the difference they would have earned by selling the renewable energy. “The additional costs associated with the promotion of renewable energies are passed on to electricity consumers via the renewable energy surcharge.”¹³⁷

There was a debate on charging for the personal consumption of energy in power plants with the EEG apportionment. This power never leaves the building, but the debate was about whether it should be charged anyway. However, the measurement of this power is difficult, and ultimately these difficulties were behind the decision to abandon the idea.¹³⁸

As a result of regulation (see Figure 23, p. 53), more and more special cases have to be treated. In the end the competition happens less on the market or the product, but in the taking advantage of some gaps in the regulations.¹³⁹

136 Fachverband Biogas e.V., “Sonderheft Direktvermarktung, Das Fachmagazin der Biogas-Branche”, *BIOGAS*, März 2015, p. 7, 2015

137 Jägemann, Cosima, Hagspiel, Simeon, Lindenberger, Dietmar, The economic inefficiency of grid parity: The case of German photovoltaics, Köln, Dec. 2013, p. 2

138 Graichen, Patrick Dr., EEG-Ausnahmen für Industrie und Eigenverbrauch sinnvoll fortentwickeln, Vorschlag für eine europarechtskonforme Reform der EEG-Ausnahmeregelungen zum Ausgleich der Interessen von Energie-, Industrie- und Verbraucher-Seite, http://www.agora-energiewende.de/fileadmin/Projekte/2013/EEG-20/Impulse_Zusammenfassung_Reform_des_EEG-Umlagemechanismus.pdf, p. 7 (Jan. 2014)

139 cf. Küster, Michael, Grid operator view to the renewable energy market, p. 6

In the general energy market, the coverage of load-peaks is expensive as it results in idle production capacities for the remainder of the time. In this case, market intervention can be beneficial, because incentives to avoid the peak load are more rational than promotion of power use in the idle time.

„Es ist allemal vernünftiger, vorhandene Lastspitzen beim Stromverbrauch mit technischen und tarifpolitischen Mitteln zu kappen, anstatt die Lasttäler mit Elektroheizungen aufzufüllen, die ökologisch und ökonomisch unsinnig sind, nur um die gegenwärtigen Überkapazitäten bei Kraftwerken und Leitungssystemen besser auszulasten.“¹⁴⁰

First attempts to align the load curve exist. For some big consumers it is already interesting to deal with their loads.¹⁴¹ There is no revenue for a balancing service. Only the better price per MWh that is offered in case of predicated consumption being announced in forehand makes them dealing. The sector is starting to move.

5.4.2. Service-idea creates added value instead

The regulating authority tries to conduct the market through stipulation. Compensation of costs is attempted by apportionments which require reciprocal financing. The reward of the desired service can instead create added value. The negative effect of inflexible rules can be best illustrated by the standard price for household electricity. There is no flexibility required to react on a fluctuating energy offer, as special tariffs, according to the time of usage, are known in Germany, but rarely used.

Die Mehrheit der Stromnachfrager richtet ihre Nachfrage nach Durchschnittspreisen aus und hat nicht die Möglichkeit, kurzfristig auf stündliche Preisspitzen zu reagieren. Wenn es zu Knappheiten kommt, bleibt die Stromnachfrage mangels Preissignale folglich hoch – letztlich muss der Netzbetreiber mit kontrollierten Abschaltungen reagieren. In diesem Fall wird Versorgungssicherheit zu einem öffentlichen Gut, weil typischerweise ganze Netzgebiete abgeschaltet würden - individuelles Verhalten oder Zahlungsbereitschaften spielen keine Rolle.¹⁴²

140 Leonhardt, Klopffleisch, Jochum, Kommunales Energie-Handbuch, p. 175

141 cp.Zaunmüller, Christine Dr.; Laurent, Pascal, The consumer perspective of the energy market, p. 3

142 Elberg, Christina, Growitsch, Christian, Höffler, Felix, Richter, Jan, [Untersuchungen zu einem zukunftsfähigen Strommarktdesign](#), Köln, März 2015, p. 8

Measuring instruments that can measure the consumption for every single timeframe are called “Smart Meters” and should be used for those consumers having usage above 6.000 MW/a.¹⁴³ In Switzerland, such price models are already very common.

In the worst-case scenario, the grid provider has to disconnect areas to reduce consumption and to bring it into balance with the generation again. Regulating by switching is an extreme measure compared to the offer of regulating fees. The possibility to regulate greatly depends on the system’s technology. If all plant operators were not only to be paid for the good wattage itself, but also for the regulatory service, then the competition between the plants would, in all likelihood, be quite different.

„Für Betreiber von Biogasanlagen sind Anschaffung und Betrieb eines eigenen Optimierungssystems zur Ermittlung marktoptimaler, anlagenindividueller Fahrpläne zu aufwendig und kostenintensiv. Stromhändler wiederum haben nicht die Möglichkeit, sämtliche Details komplexer Anlagenkonfigurationen in ihren Systemen abzubilden und bei Fahrplanberechnungen so zu berücksichtigen, dass der maximal mögliche Erlös für die einzelne Anlage im Vordergrund steht.“¹⁴⁴

The basic characteristics of the different types of source energy have a direct impact on the capability to regulate.

143 Bundesministerium für Wirtschaft und Energie, Das Stromnetz wird intelligent, BMWi veröffentlicht Eckpunkte für den künftigen Einsatz intelligenter Messsysteme und Zähler ("Smart Meter"), <http://www.bmwi-energiewende.de/EWD/Redaktion/Newsletter/2015/3/Meldung/topthema-stromnetz-wird-intelligent.html> (17.02.2015)

144 Fachverband Biogas e.V., Sonderheft Direktvermarktung, p. 41

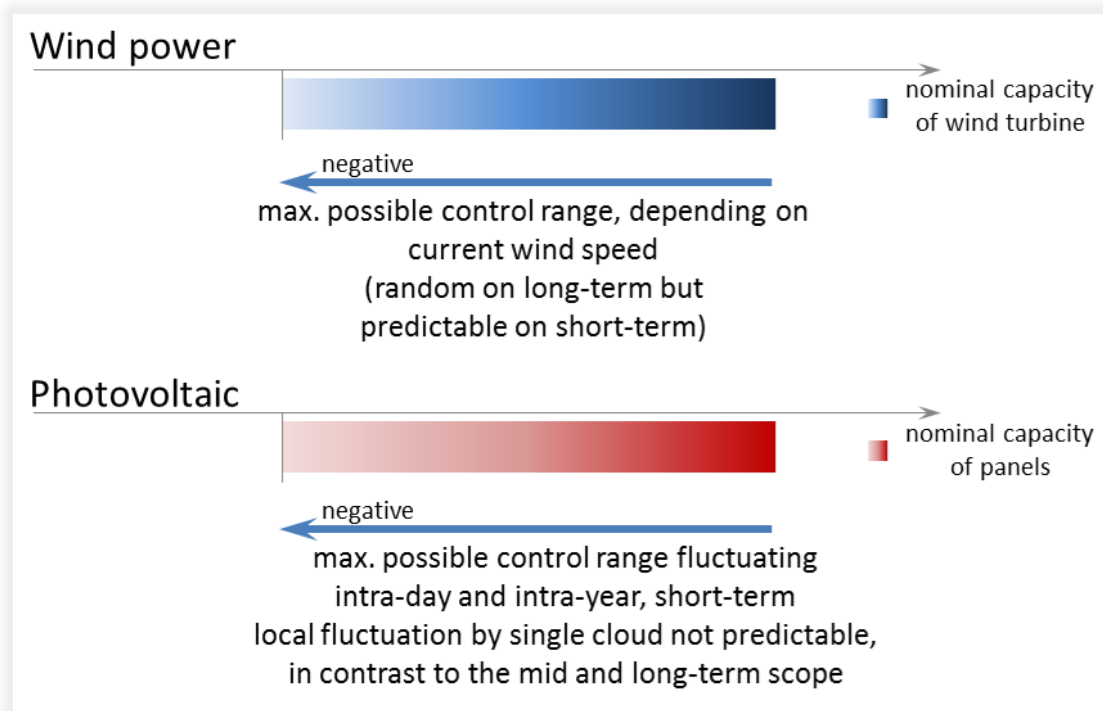


Figure 27: Balancing capacity of wind and photovoltaic
(own drawing)

This means that photovoltaic and wind based systems can only reduce their performance. The current maximal power heavily depends on weather conditions. This has the effect that the produced power in the yearly average is far below the theoretical maximum.

Most of the time the systems run at a very low percentage range of its maximum capacity.

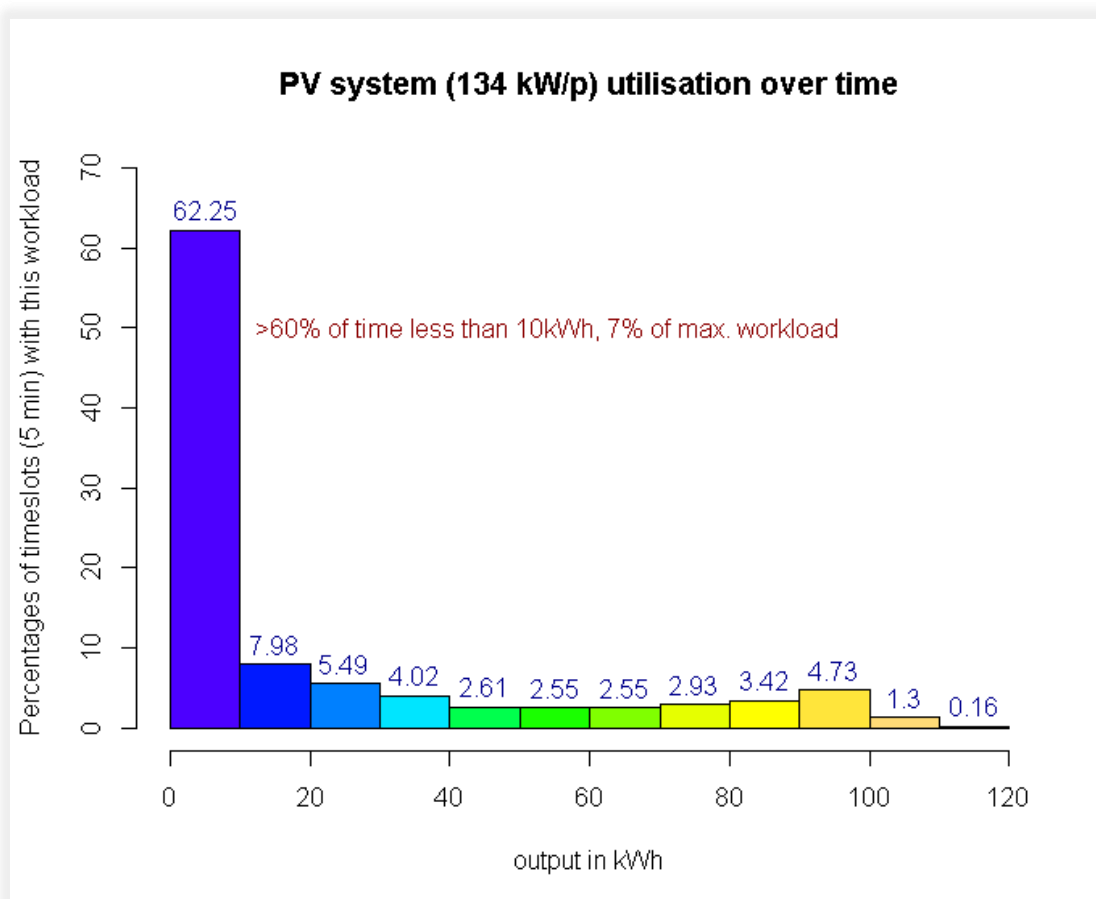


Figure 28: Dispersion of load of a photovoltaic system

(own drawing based on data from 09.07. – 13.07.2015 ¹⁴⁵)

Figure 28 is based on data taken in summer time during a very sunny period, in almost ideal weather circumstances. The maximum rate of usage in the yearly average is 860-1200 h/full load equivalent in Germany. The exact figure depends on the location. As the year has 8760 hours, the expectable production rate is max. 13,7% of the theoretical maximum. The possibilities to regulate are correlatively limited. Wind energy struggles with the same principle restrictions.

¹⁴⁵ cp.Fontaine, Josef, The renewable energy, producer's point of view, interviewed by Fontaine, Sebastian (26.07.2015)

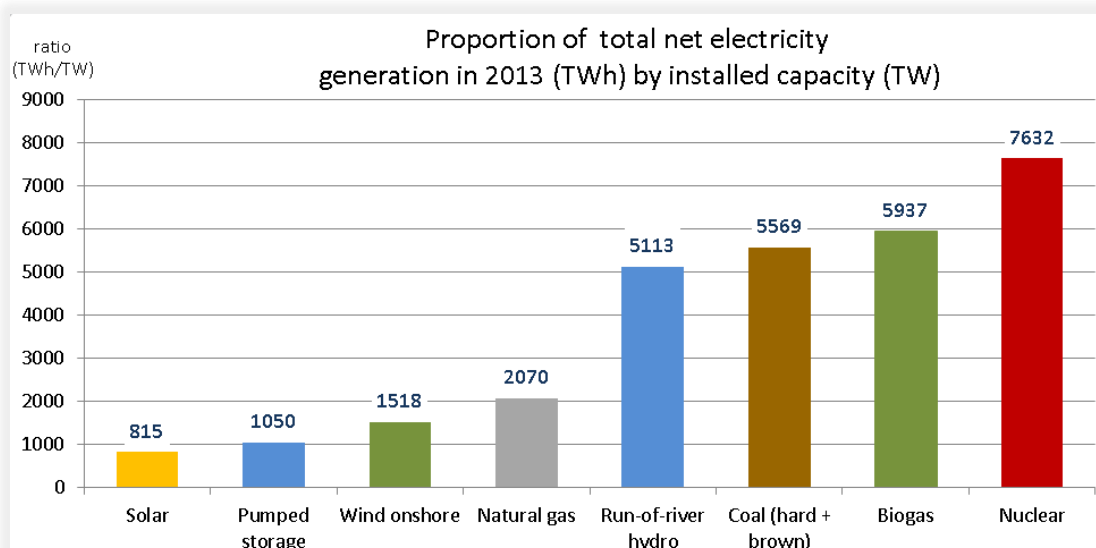


Figure 29: Proportion of generation by installed capacity

(own drawing by ¹⁴⁶)

Pumped storage and natural gas have a relatively low ratio (full load equivalent per year), because they are mainly used as reserve energy systems. Here it becomes obvious that one must separate the technical and organizational reasons. Biomass has the highest usage ratio of all renewable energies, and even its ability to regulate is significant.

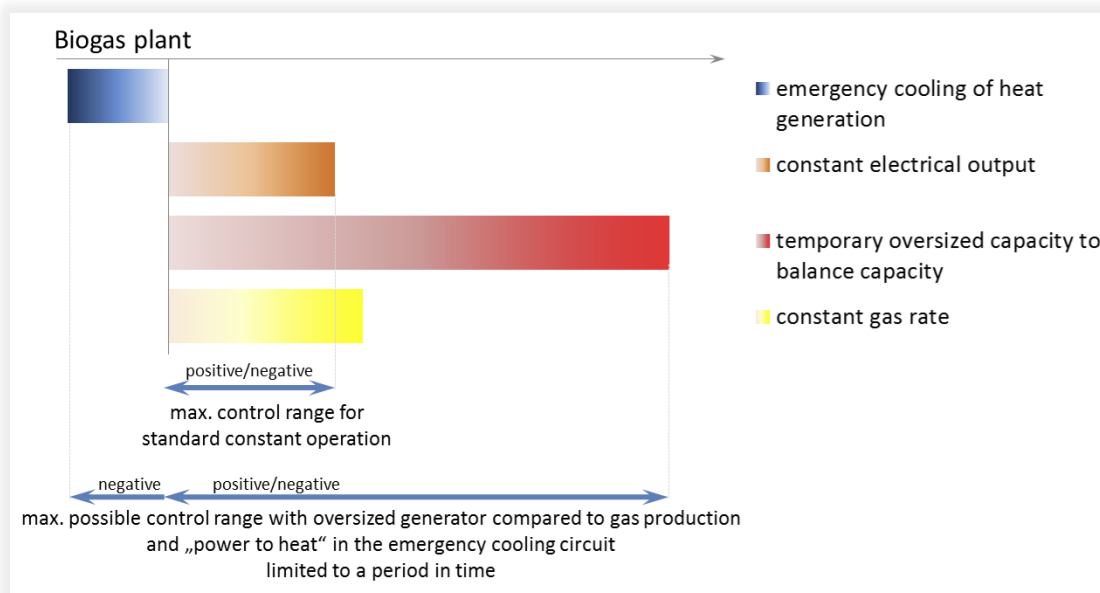


Figure 30: Balancing capabilities of biogas

(own drawing)

The average capacity of a biogas plant is determined by the primary gas production. As some energy has to be used to heat the fermenter, there is some self-consumption of the energy.

Therefore, less than 100% of the gas production is available for constant electrical output. If the capacity of the engine is oversized, then it can produce more power in shorter time. The average production is still limited to the amount of gas production, but regulating becomes possible on a wider range. Each biogas plant with a generator has a system for emergency cooling, in case the heat cannot be used for district heating. If this system is not in use for a certain timespan, it could be applied with a power-to-heat system and could even consume energy while the oversized engine is in idle mode. The overall balancing capacity is then a lot wider than the average maximum capacity.

Therefore, the incentive to provide services such as regulating energy capacities could force the owner of such systems to refocus. The main intention of such plants could switch from constant output to regulating a unit.

5.5. Government as warrantor and conductor

Since the market for electricity has been liberalised, the role of the regulating authority has gained on importance. The number of rules with impact on the price continuously rises (Figure 23, p. 53). Therefore the legislative is all but dispensable. The need of the market participants to cooperate puts the authorities in a central role. In Europe the solicitous state is a normal idea, in contrary to the USA, where the individual forces are expected not be disturbed by central power, wherever possible.

„Da es in den USA - anders als in Deutschland - nur in begrenztem Umfang sektorspezifische Fachbehörden gibt, die zur Durchsetzung der Gesetze bundesweit zuständig sind, setzen die USA traditionell auf das private enforcement“¹⁴⁷

Even the European law enforcement area is all but homogeneous, but with the European Court of Justice, a central instance does exist. Nevertheless, the following considerations focus on German law. The transferability of the described concepts to other countries therefore must be considered as limited.

147 Säcker, Die Einordnung der Verbandsklage in das System des Privatrechts, p. 78

5.5.1. Electrical power as a service of general interest

Since mankind started to live in artificial habitats, the individual was no longer able to survive by his own means. Everyone relies on services of general interest, also called public services, “Daseinsvorsorge” in German (Chapter 2.3, p. 13).

„Der Mensch ohne beherrschten Lebensraum, der nicht mehr das Wasser aus dem Brunnen, das Holz zur Feuerung aus dem Wald, Nahrungsmittel vom Acker oder aus dem Stall holen kann, lebt in einem Zustande weitgehender Bedürftigkeit. Er bedarf der organisierten Vorkehrungen, umfangreicher Versorgungsapparaturen, um in den Genuß dessen zu kommen, was er lebensnotwendig braucht.“¹⁴⁸

The concept of public services should not be confused with social welfare (“Fürsorge”). Every member of society is dependent on the existence of such services, regardless of their income.

„Jedenfalls wird sich die Daseinsvorsorge als ein eigenständiger Begriff neben der Fürsorge behaupten müssen. Fürsorge wird demjenigen zuteil, der sich in einer individuellen Notlage befindet. Es muß wohl beachtet werden, daß die Daseinsvorsorge zwar die Fürsorge in sich schließt, aber nicht in ihr aufgeht. [...] Auch der sozial verhältnismäßig Hochgestellte, sagen wir der vermögende Betriebsführer eines großen Unternehmens, ist auf die hier erörterten Leistungen der Daseinsvorsorge in gleichem Maße angewiesen wie jedes Glied seiner Gefolgschaft. Die Bedingungen freilich, unter denen dem einzelnen die Leistungen der Daseinsvorsorge zugänglich gemacht werden, unterliegen den sozialpolitischen Anforderungen, die zum Teil fürsorgerischer Art sind.“¹⁴⁹

Electricity drives the main part of daily life today. Therefore, the classification of electricity as a public service seems to be beyond doubt.

But there must be some distinguishing features to differentiate this model from socialism, as the public service has a depoliticising effect.

„Gegen die Einordnung der Daseinsvorsorge in das Verfassungsrecht sprechen auch politische Erwägungen. Daseinsvorsorge ist Bedarfsbefriedigung. Ihre Notwendigkeit

148 Forsthoff, Ernst, Verfassungsprobleme des Sozialstaates, Münster Westfalen, Aschendorffsche Verlagsbuchhandlung, 1954, p. 7

149 Forsthoff, Die Verwaltung als Leistungsträger, p. 47

nimmt in dem Maße zu, in dem die Daseinsführung an technische Vorkehrungen gebunden ist. [...] Die Daseinsvorsorge steht im Widerspruch zur politisch verstandenen Verfassung. Sie wirkt entpolitisierend.“¹⁵⁰

Therefore, we must be careful how we use this concept of public service. It is not advisable to simply hand over all the responsibility for power supply to the public domain. The state, whilst being responsible to ensure a power supply, should not have to do it by itself. It is a permissible political decision to have the job be done by private enterprises. In this case the state automatically takes the leading role, to ensure that private partnerships work. To avoid a cacophony of lone wolves and to facilitate musical harmony, there is an obvious need for a conductor.

5.5.2. Market liberalization is no contradiction

There are several examples that show how liberalisation can harmonise with the national supply mandate. The telecommunication market is an ideal example of the clash between public and private interest. In cities with a high population density, the cable based infrastructure for communication services is, in general, better than in rural areas. When some frequencies for fast mobile internet access were sold in 2010 by auction (by government to private enterprises), a new mechanism was introduced. The purchasers have an interest to see a return on investment in a shorter time, thus this is a strong incentive to install the technology first in areas with a high population density. Many users usually means much turnover, which makes it easier to generate income.

The public interest, in contrast, was to serve rural areas first, where there is a lack of fast access to electronic communication platforms. Therefore the prerequisite for the bidder was made clear. The landscape was cut into four types of regions. Only if more than 90% of the inhabitants were connected in the regions with the lowest population density, then the installation within the next level of regions was allowed. This made the restrictions for the overall grid setup calculable for the bidder and covered the interest of the auctioneer.¹⁵¹

150 Forsthoff, *Der Staat der Industriegesellschaft*, pp. 78–79

151 cp.Infos zum LTE-Ausbau auf dem Land, <http://www.lte-anbieter.info/verfuegbarkeit/lte-netzaufbau-land.php>

The concept reveals that control of the guidelines is essential. This is one reason for being in favour of the regulating authority. The authority does not only take care of the telecommunication market, but also electricity and gas, post and railway traffic.

The liberalized electricity market is somewhat special, as the grid operator companies are still major players, while the power producers increase in number by all the small renewable power systems. There is considerable risk that an individual provider reduces the quality of his equipment to increase the return on investment. At least he has almost no interest to invest in better equipment and curtail his margin. The impact of one damaging party to the complete system would remain so small that probably nobody would notice it. This makes it alluring to profit by unfair behaviour.

Putting rules in place and ensuring that they are respected is a natural mission for the state and the police. Examining offices help to ensure that all market participants follow the rules. Deviants are not harmful as long as they are few in number, and therefore they must be revealed quickly.

5.5.3. State-run ventures with bad reputation

With the WTO Agreement on Basic Telecommunications on 1 January, 1998, the liberalisation of the telecommunication market started. It was followed by a very quick evolution of technologies that all tried to get the maximum out of the existing grid equipment. The fibre optics expansion started in the eastern part of Germany in 1990 after reunification, but the advanced modernisation was stopped quickly as soon as the focus shifted towards profit.¹⁵² The liberalisation of the market created competition and thus caused the end of the costly infrastructure update. Since then, the discussion about the broadband expansion became stagnant, with Germany having the worst fibre optic connectivity in Europe.¹⁵³

152 Sietmann, Richard and c't, 25 Jahre TK-Liberalisierung – warum die Breitband-Politik in der Sackgasse steckt, <http://www.heise.de/ct/ausgabe/2012-11-25-Jahre-TK-Liberalisierung-warum-die-Breitband-Politik-in-der-Sackgasse-steckt-2346330.html> (04.09.2014)

153 Süddeutsche.de GmbH, Munich, Germany, “Breitbandausbau in Deutschland - Das dauert, Wenn das Internet aus der Leitung tröpfelt”, Süddeutsche, 23.12.2014, <http://www.sueddeutsche.de/digital/breitbandausbau-in-deutschland-wenn-das-internet-aus-der-leitung-troepfelt-1.2278326>

With this example in mind it is debatable whether state-run facilities are more innovative than private ones. Without doubt the respective focus is very different. Public services rely on political decisions. Such decisions are characterised by discussions in parliaments and are attended by lobbying activities as well as journalistic reports. Therefore, they usually take longer than decisions within the closed environment of enterprises. In addition, enterprises have an extrinsic competition by business rivalry. This rivalry also exists in politics, known as opposition. The same effect, confrontation with the opponent, speeds up decisions in the private economy and slows down decisions in politics. This might explain the different perception of speed in both cases.

The question whether the longer discussions in politics leads to a reduced error rate or if the trial and error principle of the private market leads to bolder attempts cannot be answered in the scope of this work.

In general, public driven large-scale projects are on average 73% more expensive than planned.¹⁵⁴

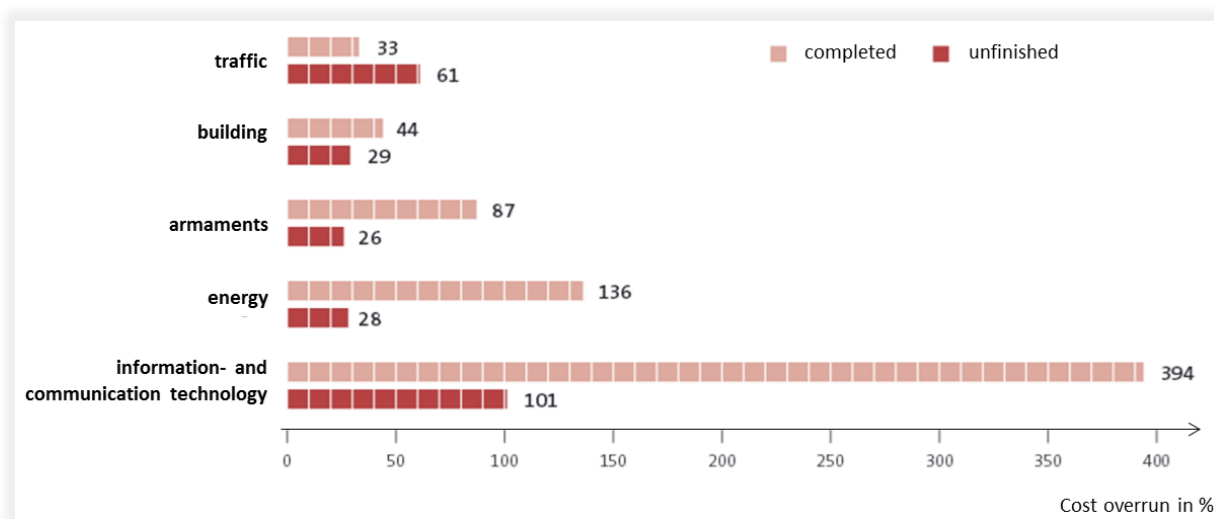


Figure 31: Cost overrun by public projects per sector¹⁵⁵

Such deviations from the plan are sometimes deliberately caused by the companies involved. They have discovered that change requests and time lag due to decelerations can be lucrative. The latest example of such a presumable fraud has just happened in Germany while this study is being written. The company called “Imtech” made use of the different requirements of the public and private sector. They try to win the tender with unrealistic figures. Once in the project

¹⁵⁴ Kostka, Genia, Großprojekte in Deutschland | Hertie School of Governance, <https://www.hertie-school.org/de/infrastruktur/> (May 2015)

¹⁵⁵ Ibid.

they expand it with subsequent additional charges. Making money with no progress was probably their illegal business.¹⁵⁶

The idea to have the business run by public authorities only can be considered as a failure. The best negative example is the former DDR, before the reunification of Germany.

„Die frühere DDR konnte als Staatshandelsland nicht bestehen, obwohl sie mit nur wenigen Steuern und geringen Steuersätzen ausgekommen ist, weil dieser Steuerverzicht mit der staatlichen Herrschaft über die Produktionsfaktoren Arbeit und Kapital erkaufte werden musste. Berufs- und Eigentümerfreiheit haben sich letztlich gegen den staatlichen Großproduzenten und Arbeitgeber durchgesetzt.“¹⁵⁷

When the public sector limits its actions to only the boundaries of a market, without acting as principal, the participants all stay within the same sector. The renewable energy market can be a good example. There are municipal facilities involved, but they are organised like the private sector.

5.5.4. Frame of statistical dealing to be organized by legislation

So far we have seen that the good “electricity” is reliant on three major attributes:

1. Power consumption (measured in MWh, the product itself is considered as a public asset, only the transformation service is billable)
2. Quality (measured by several of characteristics, such as frequency, voltage, etc. to be ensured by services that are valuable)
3. Transportation (comparable with the traditional service of commerce)

Availability can only be measured by time of unavailability. In fact, it is a result or logic consequence of the three other attributes being present. Therefore, the availability will not be treated as a part of a generic price model. Taxes and other appropriations are only dependent on political interests and therefore will not be treated here either. Today, it is the duty of the grid providers (transportation) to ensure the quality of the electricity. They act as gatekeeper. As this is the most sensitive topic, it should stay as a central point.

156 Fuchs, Christian, Lebert, Stephan, Müller, Daniel, “Imtech: Die unheimliche Firma, Einblicke in ein kriminelles Geschäftsmodell”, *die Zeit*, 29/2015, 20.07.2015, <http://www.zeit.de/2015/29/imtech-flughafen-berlin-ber-verzoegerung>

157 Kirchhof, Der sanfte Verlust der Freiheit, p. 53

The ability to balance the amount of power on consumer and production side is one of the key features in the system.

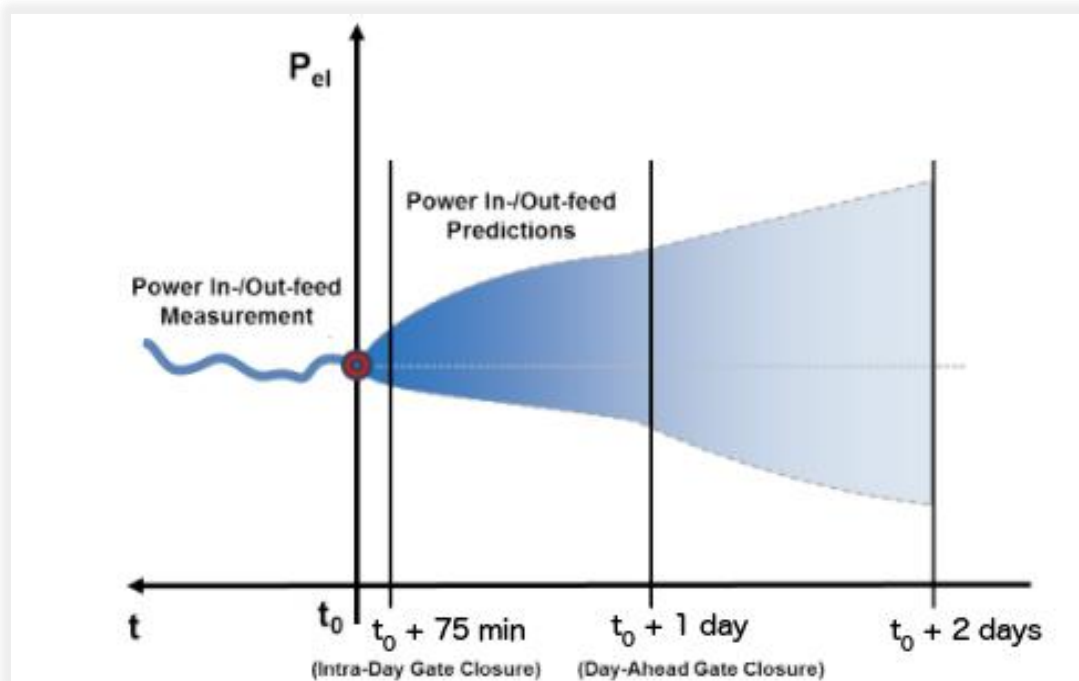


Figure 32: Probability range of power requirement prediction

(own adaptation by ¹⁵⁸)

Therefore, both the ability of power supply to follow demand on one side and the flexibility to adjust the demand regarding the availability of delivery on the other, are worth pricing.

With such a price mechanism, the current EEG system of subsidies would become virtually unnecessary. This would push all participants to refocus their activities on the technological needs, instead of competing by regulation exceptions.

„Die Aufgabe auf Subventionen zu verzichten, ist schwer, aber dringlich. Sie ist wesentlicher Teil strukturellen Sparens, weil sie dem Unternehmer die Vorstellung nimmt, die Sanierung und Erhaltung seines Unternehmens müsse von anderen - den Steuerzahlern - finanziert werden.“¹⁵⁹

On the stock exchange today, the price of power varies greatly over time, going even to negative prices (Figure 13, p.29). In fact, the fluctuation of price on the exchange looks like statistic values with a dedicated mean value (which of course changes over time) variance and a standard deviation.

¹⁵⁸ Ulbig, *Operational Flexibility in Electric Power Systems*, p. 63

¹⁵⁹ Kirchhof, *Deutschland im Schuldensog*, pp. 125 f.

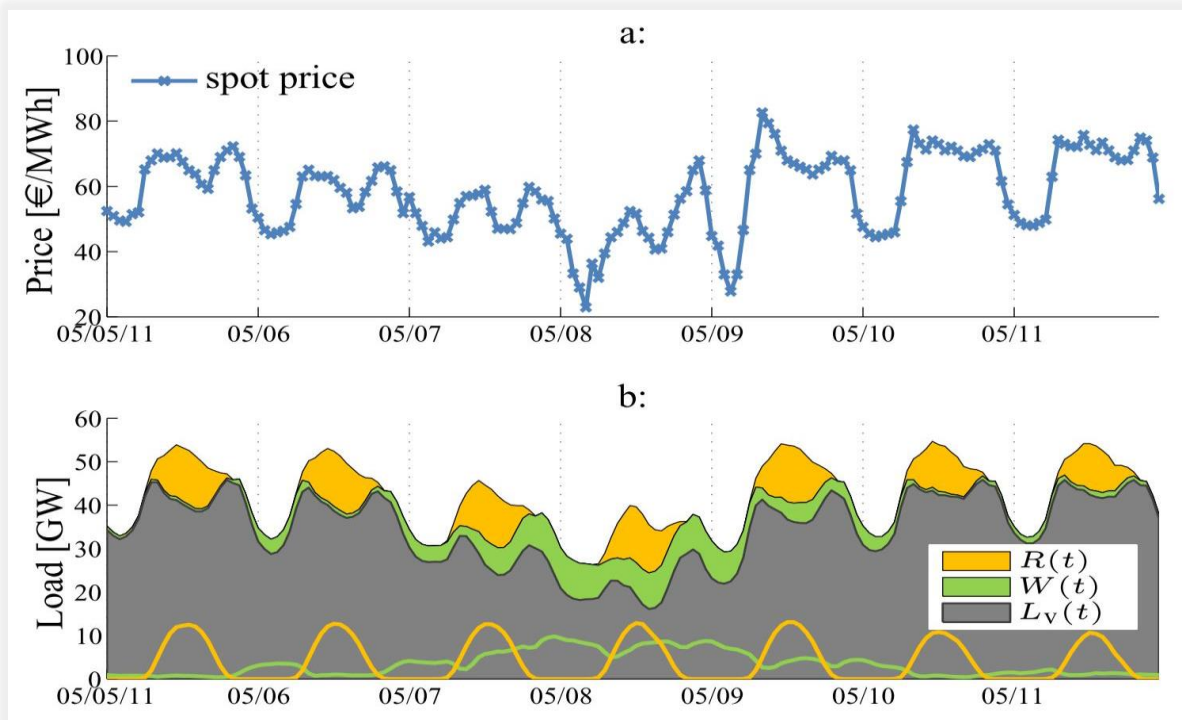


Figure 33: Exchange spot price follows load, predictable with stochastic tools¹⁶⁰

(Solar feed in $R(t)$, Wind feed in: $R(t)$, vertical Load $L_v(t)$)

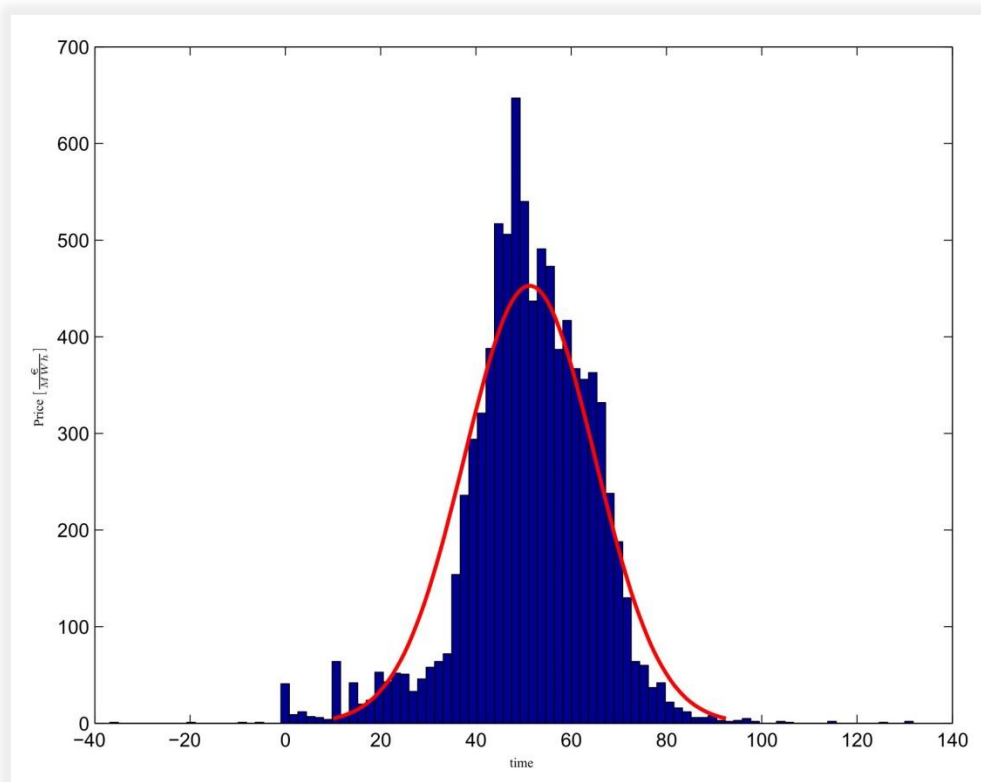


Figure 34: Histogram of day-ahead prices¹⁶¹

¹⁶⁰ Hildmann, Marcus Christoph, *Quantitative methods for the economic analysis of liberalized power markets*, ETH Zürich, 2014, p. 29

¹⁶¹ Hildmann, *Quantitative methods for the economic analysis of liberalized power markets*, p. 80

The price fluctuations are therefore a clear indication that there is a need to determine the price structure of ability to balance production and consumption. But the production itself can also be described by stochastic elements.

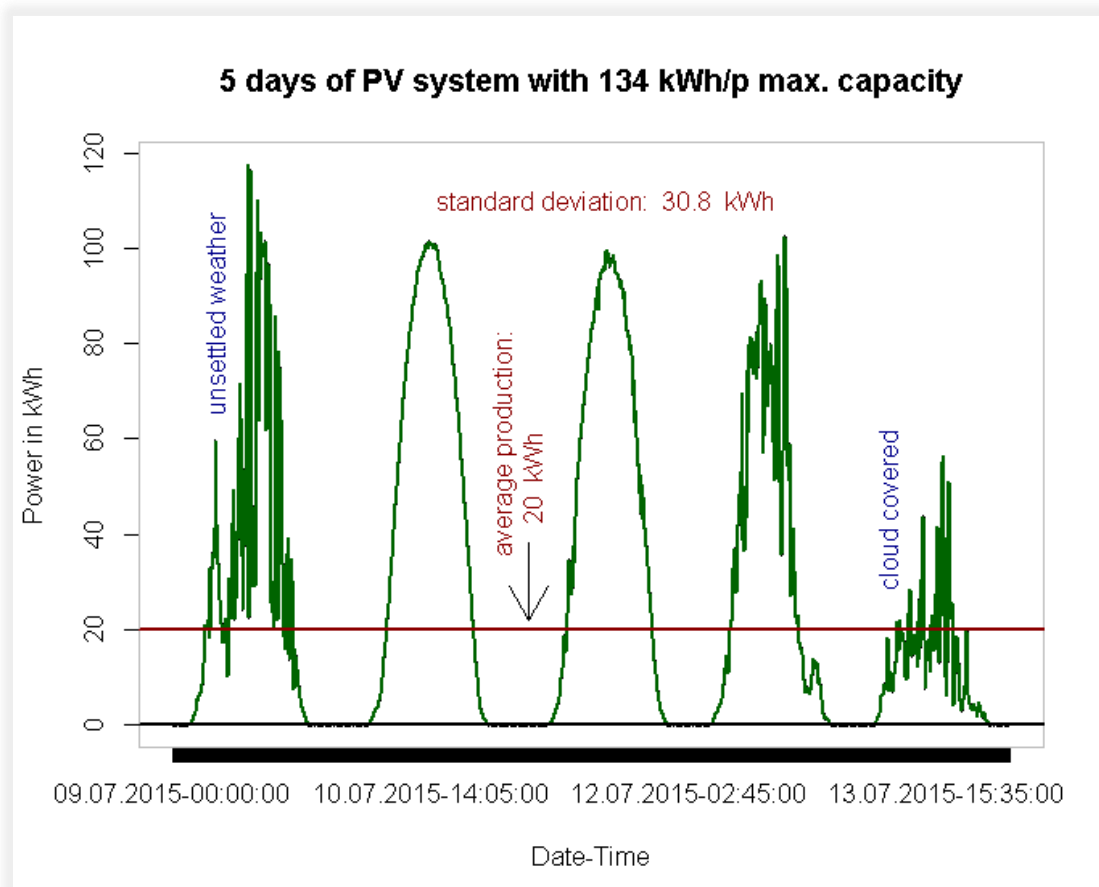


Figure 35: Stochastic view to workload of a photovoltaic system

(own drawing based on data from 09.07. – 13.07.2015¹⁶²)

Using the weather forecast and some empirical values, the average production to be expected can be forecasted as well as the standard deviation during that time. The quality of the forecast depends of the type of the system. A wind turbine will have a different characteristic to photovoltaic. Systems that do not depend on the weather will be more or less deterministic, as is the case with, for example, barrages (apart from long dry periods), biogas and geothermal power systems.

¹⁶² Fontaine, Josef, The renewable energy, producer's point of view

If power is treated as public good, one could say that it should be free. Unfortunately this would misjudge the rebound effect¹⁶³ as well as the need to finance the basic infrastructure of the power plants, and there is still a correlation of the size of the building to the capacity to produce.

Today there is a price for wattage only, which hardly takes into consideration the services to stabilise and guarantee supply. It is the government mission to define what is treated on the energy exchange and how, but the energy itself should play an inferior role to define the price as it has to be considered a public good in principle. To illustrate a possible scenario respecting all the main three factors of power (wattage, quality & transport, including taxes and levies), some possible formulas are set out below:

$$P_s = P_{ge} \times F_{gr} \times F_{gt} + (T + L)$$

P_s Price on the Stock

P_{ge} Basis Price for electricity generator

F_{gr} Factor for the ability to regulate the generation

F_t Factor for the transport requirements of this generator, compared to the average

T Taxes

L Levy

The regulation factor is comparable to the standard deviation of the consumption. To become able to balance it would make more sense to buy, for example, 100 MW within the next three hours, without exact determination of point in time when they will have to be produced. The result might be that power is required for only one hour, but with full load, or during all three hours but with just 1/3 of the load in average, etc. The number of variations is unlimited, but can be described by statistical figures.

These figures can then be taken to calculate the factors.

$$F_{gr} = 1 + \sigma_g$$

σ_g : Maximal possible standard deviation of the generator

¹⁶³ cp.Madlener, Reinhard and Alcott, Blake, Herausforderungen für eine technisch-ökonomische Entkopplung von Naturverbrauch und Wirtschaftswachstum, unter besonderer Berücksichtigung der Systematisierung von Rebound-Effekten und Problemverschiebungen, <http://webarchiv.bundestag.de/archive/2013/0510/bundestag/gremien/enquete/wachstum/gutachten/m17-26-13.pdf>, p. 20 (07.12.2011)

If a constant energy delivery is demanded, then this factor becomes 1. If any fluctuating power is required, the price rises quite quickly with the need to regulate. Of course there must be a communication mechanism. Today, this is solved via communication networks, but an outlook to an alternative will be given at the end of this work.

Another possibility to determine the price is the capability of a generator to follow the demand. In other words, if the overall demand at a point x in time is y GWh and at the time $x+1$ it is $(y+z)$ GWh, then z could be positive or negative, depending on whether the overall demand raises or decreases. The capability of the generator to swing in phase with the demand is important.

$$F_{gr(x+1)} = \frac{\frac{y}{y+z}}{\frac{C_x}{C_{x+1}}}$$

x : Point in time

$x+1$: Subsequent point in time

y : Demand of power in GWh

z : Difference of demand of power in GWh at the subsequent point in time compared to before

C_x : Capacity of generator at point in time

C_{x+1} : Capacity of generator in the subsequent point in time

If the adaptation of the own capacity to generate power (C_x, C_{x+1}) is able to follow the ratio of the market demand change, then this factor will be 1. This is the aspired condition. If the system could do even more, i.e. help to compensate the disability of other power generators, then it would earn more. In the case that it would do less, this would result in a factor smaller than 1 and would therefore reduce the revenue.

The same is valid for the grid requirements to transport the power. If the distance to the consumer is lower than the nationwide average, the factor F_t should decrease the power-price; if it is higher, the power becomes more expensive.

$$F_t = \frac{D_{pc}}{D_{na}}$$

F_t : Factor for transmission of the power

D_{pc} : Actual Distance between producer and consumer

D_{na} : Nationwide average of the Distance

This calculation also takes nationwide imbalances into account, if, for example, the major consumption would be in the south, while production would be in the north.

On the consumer side, the formula for the price would be similar:

$$P_c = P_s \times F_{cr} \times F_t$$

P_c Price the consumer has to pay

P_s Price of power on the stock exchange

F_{cr} Factor for the ability to regulate and predict the consumption

F_t Factor for the transport requirements of this consumer, compared to the average

As the grid operator still has the duty to stabilize the network, he is the only one that can deal either with consumers or with producers. A direct deal of consumer and producer would jeopardise the role of the grid operator as guarantor for stability.

If the consumer is able to predict his consumption, then the purchasing of the energy becomes easier for the grid operator, therefore this behaviour can principally be rewarded by a reducing factor.

$$F_{cr} = \frac{\sigma_{cc}}{\sigma_{ca}}$$

F_{cr} Factor for the ability to regulate the consumption

σ_{cc} : Standard deviation of the difference between the forecast of consumption and the actual consumption of the current consumer.

σ_{ca} : Average standard deviation of all comparable consumers

The factor F_{cr} therefore is the division of the consumers' standard deviation compared to its prediction by the overall average deviation of this group of consumers. Of course, this implies that groups have to be defined by the grid operators. In Chapter 6 (p. 87) these groups are called "hubs". If no prediction is given, then the factor could be set to a fixed value.

The above-mentioned formulas are only auxiliary means to illustrate the overall idea to make the statistic qualities the main factor with major influence on the energy market price. In any case, this would open the door to differentiate all the power plant types by their individual capabilities to offer services. As the technical specifications of power are fixed, the capability to influence the statistical bias has to become a major part of the price. The service is the major distinctive feature, not the energy itself.

5.5.5. Public safety as a header brick of supply guarantee

The importance of the state also appears in another topic that has been considered as normal behaviour in the past - public safety. The protection of the infrastructure causes additional cost, as the ambient defence equipment of nuclear power stations shows. The attack on such a building would not only pose a danger of radiation due to the nuclear material, but any outage of these power plants would have a huge impact on the overall power supply, as their amount of production is considerable.

The power production capability of an offshore wind farm is comparable to that of a single nuclear reactor, such as the one previously mentioned, at Grafenreinfeld (1,3GW)¹⁶⁴. “The consent of the 2.4 GW Dogger Bank Teesside A&B development allows for two separate 1.2 GW projects, each with up to 200 turbines installed across an area of around 600 km² and located 165 kilometres from the UK coast at the closest point.”¹⁶⁵

An offshore wind farm is protected by the rough surrounding environment; it is difficult to reach the site. On the other hand, this makes it harder to monitor the surroundings and to intervene when required. It is untrue that the greater number of wind farm units means it is more difficult for a generic failure to happen, because there is normally just one single transformer substation.

The impact of a loss of such a farm is indeed comparable to the outage of a nuclear power station, except for the risk of radioactive contamination. Talking about the stability of the power grid, it definitely is comparable. Therefore, it is not surprising that the government is willing to take quite drastic actions to ensure their safe operation. In the event of an attack, there are plans to activate emergency laws.¹⁶⁶

164 Wikipedia, Kernkraftwerk Grafenreinfeld, <https://de.wikipedia.org/w/index.php?oldid=144804961> (07.08.2015)

165 windfair, UK: Forewind secures consent for another 2.4 GW of offshore wind, <http://w3.windfair.net/wind-energy/news/19191-uk-forewind-secures-consent-for-another-2-4-gw-of-offshore-wind> (10.08.2015)

166 Jehle, Christoph, Offshore-Windparks durch Terrorismus gefährdet, Bundesregierung will im Gefahrenfall mit Notstandsgesetzen reagieren, <http://www.heise.de/tp/artikel/45/45387/1.html> (12.07.2015)

Today, the balancing mechanism between production and consumption to stabilize the power grid depends more and more on the communication networks. The combination of dependencies increases the risk of failure by principle as it decreases the ruggedness.

Die Kommunikation ist meist auch das schwierigste und größte Thema bei der Anbindung eines neuen Partners.¹⁶⁷

In the various discussions during research for this study, this topic arose quite frequently. The solutions offered mostly rely on the fixed line phone, which works without external power. This technology is due to expire by 2018.

Anders als bei bisherigen Analoganschlüssen oder ISDN-Anschlüssen, an denen ein ISDN-Telefon mit Notspeisung betrieben wurde, funktioniert ein IP-Anschluss allerdings nicht mehr, wenn der Strom ausfällt.¹⁶⁸

It is interesting that, at the same time, the battery capacities of the telecommunication equipment are in the discussion to be used as a buffer for the electricity grid.

Für die Notstromversorgung stehen an 8000 Standorten zirka 20 Mega-Amperestunden in Form von Bleibatterien bereit. Da diese Reserve sehr großzügig ausgelegt ist, wären die Batterien Lehmann zufolge hervorragend geeignet, um Schwankungen im Netz abzufangen — ohne den Betrieb der Telekommunikations-Infrastruktur zu gefährden.

Erste Tests verliefen erfolgreich, der unternehmensinternen Markt erwies sich aus ökonomischer Sicht aber als zu klein, um Einnahmen zu erzielen.¹⁶⁹

The consolidation of technologies on the telecommunication market reduces the overall resilience, of course. As this concurs with the progressive complexity of the energy regulations, the overall risk has to be considered as incalculable. It seems that government, as major stock holder of the telecommunication market, does not look upon both topics as one.

As renewable technology goes along with regionalisation, the communication overhead becomes system-relevant if no other possibility to interact can be found.

¹⁶⁷ cp.Küster, Michael, Grid operator view to the renewable energy market

¹⁶⁸ IP-Umstellung: Fragen & Antworten, <http://europe.telekom.com/netz-blog/article/24> (27.02.2015)

¹⁶⁹ heise online, Die T-Batterie: Strom von der Telekom, <http://www.heise.de/newsticker/meldung/Die-T-Batterie-Strom-von-der-Tekom-2557767.html> (25.02.2015)

6. Future prospects (outlook)

This study focussed on evaluating whether or not an adaptation of the energy market mechanism is required. It draws up a very first sketch of the future journey, without the details. The proof of all possibilities offered by this way goes beyond the scope of this study.

Referring to the overall awareness that the energy market participants cannot compete via the product itself but via the capability of provision, some very first formulas have been presented to better describe the overall idea. These formulas obviously have to be developed further and their effect should be simulated to evaluate their effect.

To increase the resilience of the overall system, it is worth considering reducing the combination of all the grids. Today the grid of electricity is combined with the gas distribution network via gas based power plants. Moreover, the heat distribution grid is linked due to the cogeneration of power and heat. The third interconnection to the communication grid is a weak point as this grid is itself in the reconstruction phase. The dependency of the telecommunication grid can be reduced by fundamentally changing its application changes.

6.1. One big transition instead of scuttling

Today, the settlement of energy flows is managed by so-called control areas (“Regelzone”), which require online communication.

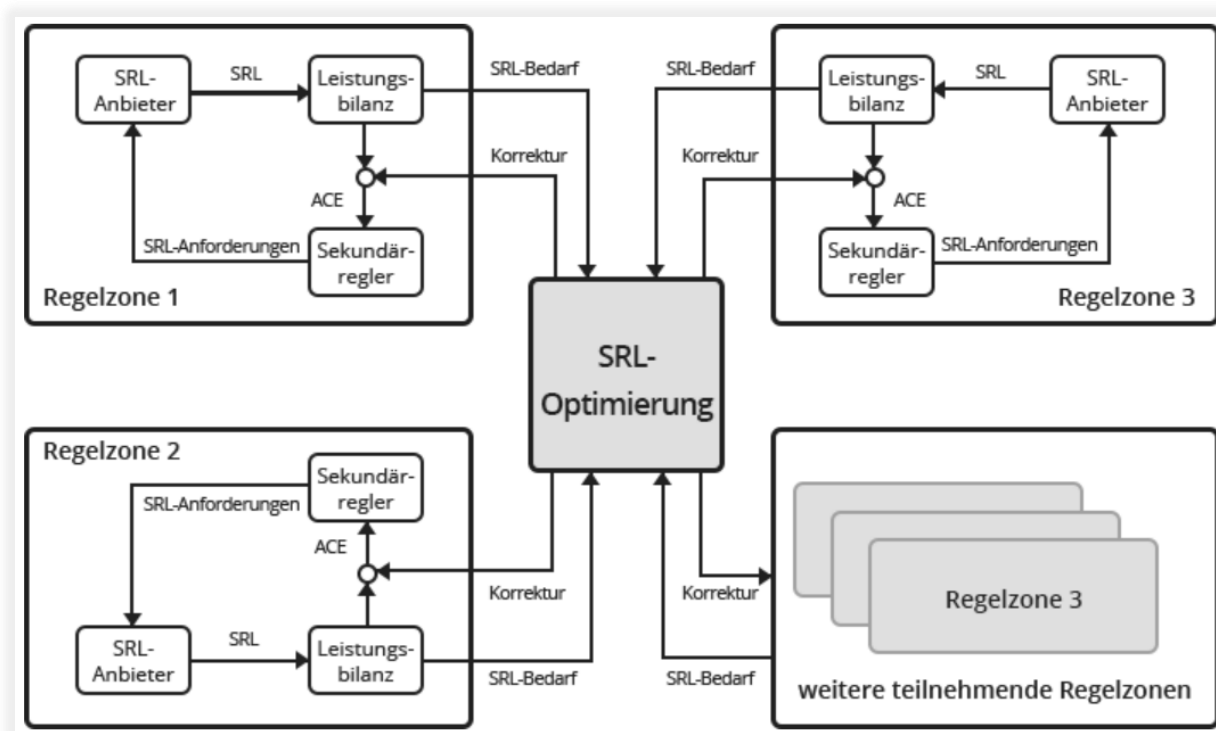


Figure 36: Current principle of secondary control (SRL) by areas¹⁷⁰

But there already exists a successor model, the so-called energy-hub¹⁷¹ concept. (Figure next page)

¹⁷⁰ regelleistung.net, <https://www.regelleistung.net/ext/static/gcc>

¹⁷¹ Berger, Matthias, Validierung des Energy Hub Konzepts mittels einer Fallstudie in Baden-Dättwil, ETH Zürich, 2011

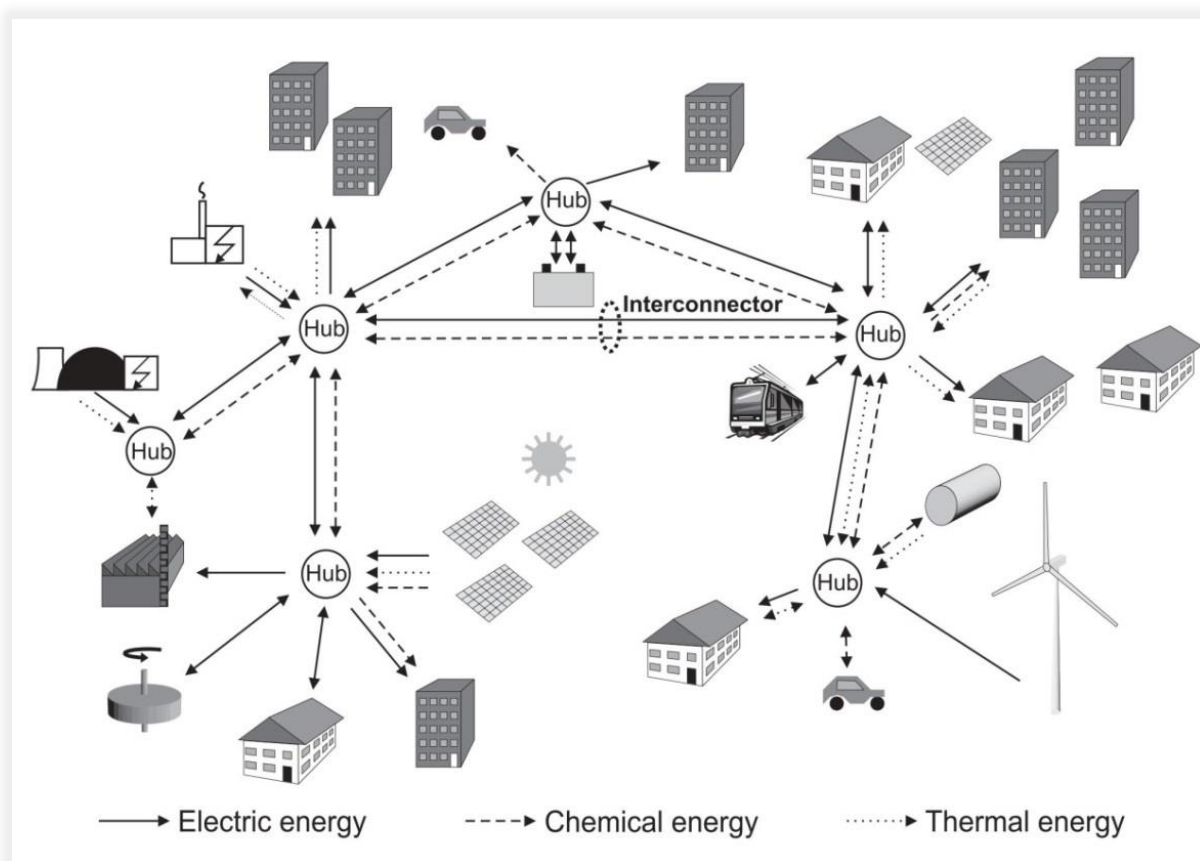


Figure 37: Control areas being substituted by hub-concept¹⁷²

The increasing number of participants increases the number of nodes as well as the number of interconnections in the network. By splitting the meshed net into hubs, the complexity per hub is reduced, and only the flows that enter and leave the system have to be zero in sum. Nevertheless the inter-node communication is becoming essential for the operation.

Instead of having more and more adjusting screws that make the system so complex that it is not manageable anymore, it is time to consider a radically new idea.

Let the energy net organise itself with a build-in swarm logic or so-called collective intelligence. The swarm logic is similar to the hub concept, as small individual entities are grouped. Together they act as a collective, but are based on individual decisions. In this scenario, the communication network is only required to collect the individual measured data for invoicing and monitoring to avoid abuse, but no longer for online control. One self-organising swarm, consisting of all the distributed tiny energy generators succeeds millions of assets with the need for active control.

¹⁷² Favre-Perrod, Patrick, *Hybrid Energy Transmission for Multi-Energy Networks*, ETH Zürich, 2008, p.15

This idea would have to overcome many hurdles, such as:

- Measurement of network quality must be done on each single generator to become autonomous – the technology exists, but has to become affordable. That might happen automatically in terms of entering mass production.
- Resilience for all the possible disturbances must be guaranteed. In fact, the problem of verification hindered further evaluation on swarm and neutral networks thus far.¹⁷³ Maybe it could be done by integrating the new concept into the old one and keeping the relative dimensions of the participants small, compared to the rest of the system. After a few months, or even years, the behaviour of the participants compared to the overall market can be investigated. This approach can be accompanied by simulations to double check the theory.¹⁷⁴
- Safety for any kind of attack. As any swarm needs communication between the members (inline), this communication could be used to send harmful signals. This has to be avoided with the same determination as the communication networks are secured today.
- Ability to collapse without danger and resurrection after a major, unforeseeable impact. The swarm must be able to split into parts and re-sync again.

The net is finally the big melting pot where everything comes together and where the theory is proven by reality. The application of such a system must be more useful than the current concept, which means more stability and economic profitability, combined with the versatility to adapt for future changes in the renewable energy market.

173 cp. Warrington, Joseph, Robust and distributed approaches to power system optimization, ETH Zürich, 2013, pp. 16–17

174 Sunbeam GmbH, Forschung für Energieeffizienz: Projekt: Kommunale Strom- und Wärmenetze integriert planen und optimieren, Oktober 2014 - März 2018, <http://www.eneff-stadt.info/de/planungsinstrumente/projekt/details/hybrides-planungsverfahren-zur-energieeffizienten-waerme-und-stromversorgung-von-staedtischen-verte/>

6.2. Simulation of swarm performance

Within a swarm, some participants might act selfishly. To avoid that, or to be at least able to recognise it, a conducted swarm is the concept that will be examined here. In this case, the overall indication comes from transformation stations that connect the different levels of the power grid. If it recognises a need in the higher level, it would ask its participants within this level to deliver more. If the demand drops, it would ask to throttle. Inside the hub there would only be an intra-swarm trading¹⁷⁵ in a scalable model. This hierarchical approach would also enable splitting into groups and subgroups, as well as to join such groups by adding a superior level. In total, all the generator of power will act as a collective organism.¹⁷⁶

The overall idea is to have five signals to be sent via the normal power wire:

1. Increase supply
2. Reduce supply
3. Control signal as keep alive to let the system fall back in emergency mode in case of trouble and lost connection -> alert via communication network, for example
4. Reduce load (demand)
5. Increase load (demand)

With these five signal states, all the grid participants could be informed about the required action. This would be possible without the need of an extra communication grid. There is a technology, called “ripple control”, which is used to switch on and off street lights, for example. Of course there has to be a link to the agreement that has been made on the stock exchange. There, the price and the ability to react has to be agreed earlier. Each of the participants in this system can then decide, based on the contract and the measured values, if they are able to react according to the signal and, in that case, how to react. The detailed action of each member must include a whit of randomness. If the very first signal would cause all suppliers to reduce their production at once, that would lead to catastrophe. However, they should react by probability. The more subsequent signals of the same value are received, the higher the probability to follow can be.

¹⁷⁵ cp.Eidenbenz, Raphael Paul, *Coping with Selfishness in Distributed Systems: Mechanism Design in Multi-Core and Peer-to-Peer Systems*, ETH Zürich, 2012

¹⁷⁶ cp.Gisi, Lucas Marco, Horn, Eva, *Schwärme - Kollektive ohne Zentrum, Eine Wissensgeschichte zwischen Leben und Information*, Bielefeld, transcript, 2009, p. 216

The communication logic can even go further. If the antagonist signals are sent alternately (increase supply, reduce load or reverse), then all the participants know that it is really important to react and do this by higher probability. This all is an analogue technique to the path-finding logic of ants.

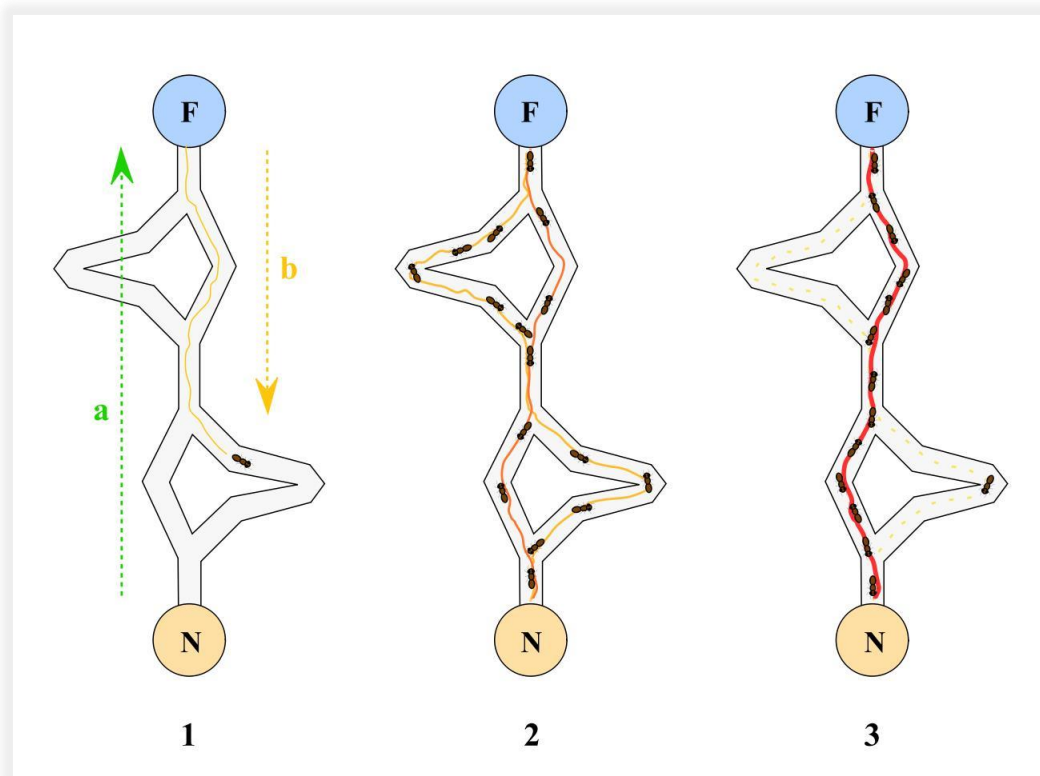


Figure 38: Swarm path finding, self-enforcing¹⁷⁷

The ants are running from their nest to the food and back again. During their walk they leave pheromones. The subsequent ant will most probably follow the trail of pheromones. Ants are more likely to take the shortest path, because it takes less time (if all ants run at same speed, of course). Therefore, the shortest path is self-enforcing. A comparable logic can be implemented in the logic of the power generators. As more subsequent signals with the same parity are received, the probability will increase that the system will follow the advice, if that is possible.

In any case, the power measurement system sends back the real result via normal communication lines. This is used for accounting, but even more importantly to decide in the transformation station on how to proceed, and to know which of the systems have reached their limits already. In case the external line is broken, the data could be stored locally and resent later. The two independent directions of communications should increase the resilience of the overall system.

¹⁷⁷ Krause, Christian, Dynamic Adaptation in Ant Colonies and Robot Swarms, <http://www.ckrause.org/2013/04/dynamic-adaptation-in-ant-colonies-and.html> (09.04.2013)

As each communication is just a push, there is also little probability that a single device will be attacked and compromised.

The access to the physical grid has to be monitored in any case. This is already the case today to avoid electricity theft, and will become more important to avoid injection of wrong command signals. In any case, the command signals can be monitored and compared to the intention. If there is a deviation an alarm can be raised.

Additionally, each system with some considerable power could measure the network quality itself and react autonomously. This option would again change the overall behaviour.

The impact on a complex system such as the energy market has to be simulated with thousands of members and several variances. Unfortunately, this surpasses the resources of this study, but hopefully can be done in a subsequent dissertation.

It would be great to convert this swarm-approach to a mathematic formula, model it in software and be able to compare the results and evaluate the economic impact such a system would have. Best would be to check both restrictions in parallel, the technological and the economical ones. They are mutually dependent.

7. Conclusion

The overall energy market relies on an infrastructure that was conceptually designed around 100 years ago. Within the last 25 years, this basis has started to quake. This is caused by the game changing impact of all the technologies that have been invented following the EEG apportionments. At the time of market entrance of the renewable energy, it was impossible to predict the evolution it would cause.

Paradigms are changing, and are partly switching completely:

- Law of large numbers was understood as big plants with huge capacity, but now it has to be seen as various regionalised plants, each with small capacity.
- In the beginning of the 19th century, electricity was a luxury good, whereas nowadays it is considered more as a common property.
- Production costs are determined more by regulating authority provisions than by technical or environmental framework conditions - but it is called a “liberalised” market.
- The line between producer and consumer dissolves; roles are mixed as are the interests.

For the final consumer it makes no difference where the power has been produced, it simply comes out of the plug. The grid infrastructure mixes up all the service differences that are required to ensure a stable network.

The preferential treatment of renewable energy causes a Merit-Order Effect on the stock exchange. This drives out technologies that could possibly produce electricity more cheaply than the renewable energies, but are the most expensive of the fossil energy carriers. The price difference is paid by the remaining traditional energy sources via apportionment.

It is foreseeable that the current concept is anything but sustainable. The G7 have decided to fade out fossil energy sources for all industries, not only for the electricity market. When this goal is achieved, there will be no depositor left to pay for this apportionment. Therefore, the development of an alternative market mechanism is imperative. The nervousness of today's players about the future energy landscape became obvious in this study during interviews and requests to answer the questionnaire. The need for change is beyond dispute, but everyone fears to see their hopes dashed.

In the fragmented environment of the liberalised energy market, there is no player big enough to lead the way. In addition, the services of general interest (“Daseinsvorsorge”) are clearly the responsibility of the state. If it changes the current rule set too much, then there is a risk that

system-critical enterprises will go bankrupt, in the worst case scenario. However, fear of the consequences is a poor counsellor. In any case, all the circumstances that influence the market have to be taken into consideration:

- Communication is a key technology to balance supply and demand, but this market is in a situation of upheaval itself.
- Computer assistance is not only changing the energy demand (inductive load), but can help by the growing ability to simulate even very complex environments.
- The rising power injection on lower grid level possibly increases the chance to organise local hubs with less reliance on the higher levels with impact to the supply guarantee.
- The less fuel has to be imported, the more money stays and circulates within the local market.

All in all, the product electricity has remained mainly unchanged in the last 100 years and will most probably stay that way into the future. Therefore, the competition of the market participants cannot be done via product properties. There can, however, be a big competition in the capability to provide electricity as the different types of energy heavily vary in their ability to do so. All that is missing is a pricing model that reflects this difference.

Describing a dedicated pricing model that suits all needs of the energy market is far out of the scope of this study, but one potential approach is outlined to indicate a possible future direction. It becomes very clear that future energy business will be based on services and not so much on wattage. Electricity is not good for commodity, as it is more a public good.

The services to make electricity available create the added value and therefore they have to be invoiced at cost.

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