



Brandenburgische
Technische Universität
Cottbus - Senftenberg

10th EEEIC

International Conference on Environment and Electrical Engineering – Student Edition

Wrocław-Ostrava-Cottbus
17th – 21st of May 2011

Harald Schwarz, Przemysław Janik,
Radomir Gono , Dirk Lehmann

module at BTU: 35-4-52

ISBN 978-3-940471-31-4

organiser / veranstalter

Wroclaw University of Technology
Department of Electrical Engineering
pl. Grundwaldzki 13
PL 50 – 377 Wroclaw

Technical University of Cottbus
Department of Power Distribution and High Voltage Technology
Walther-Pauer-Straße 5
D – 03046 Cottbus

VŠB - Technical University of Ostrava
Department of Electrical Power Engineering
17. Listopadu
CZ - 15 Ostrava - Poruba

The German National Library – CIP

One of this publication is by the German National Library.

ISBN 978-3-940471-31-4

copyright

Dieses Werk einschließlich aller seiner Teile ist urheberrechtlich geschützt.
Alle Rechte, insbesondere die der Vervielfältigung, Verbreitung und Übersetzung liegen beim Verlage. Kein Teil des Werkes darf ohne Genehmigung des Verlages, auch nicht für Unterrichtszwecke, fotografiert oder auch durch andere Verfahren reproduziert und verbreitet werden. Ebenfalls ist eine Einspeicherung und Verarbeitung in EDV-Anlagen ohne Genehmigung des Verlages strafbar.

publisher / verlag

© 2015, Technical University of Cottbus, Informations-, Kommunikations- und Medienzentrum (IKMZ)

printing / druck

Technical University of Cottbus, Reprografie

Table of contents

dena grid study II (dena Netzstudie 2) – options of grid extension and their socio-scientific validation	1
Hydropower - Yesterday, today, tomorrow	7
Energy policy development in Germany	10
Nuclear Power Systems and Economy	13
Entwicklung der Atombewegung	19
Model Home 2020 innovative energy draught	21
Carbon Capture and Storage	25
Hydroelectricity in Poland and Germany	31
The sun as a source of energy	37
Methods of obtaining energy in Poland and Germany	43
Upcoming challenges to German energy politics caused by the change from conventional to renewable energy sources	46

dena grid study II (dena Netzstudie 2) – options of grid extension and their socio-scientific validation

Selected issues concerning part II of the study

Franziska Flachsbarth
University of Technology, Cottbus
franziska.flachsbarth@tu-cottbus.de

Josephine Sindermann
University of Technology, Cottbus
josephine.sindermann@tu-cottbus.de

Adrian Krug
University of Technology, Cottbus
adrian.krug@tu-cottbus.de

Abstract— The following paper concentrates on the German grid study 2 (dena 2), that was published in November 2010. The study consists of three parts: the forecast of the infeed of renewable energies (RE) by generating time rows and analyzing weather model data, the description of effects on the grid with regard on possible technologies for grid extension and the analysis of options to increase the grid's flexibility. The paper focuses on the second part of the study and identifies three major options of grid extension as well as possible effects on society caused by dena 1 and dena 2. It is aimed to reflect the need of grid extension, to sum up the option's technical and economical aspects and to grasp effects on society.

Germany aspires to have installed an amount of at least 30% of RE up to year 2020 [1]. To reach this goal, energy infrastructure has to be developed. A centre of excellence, Deutsche Energie-Agentur GmbH (dena), was established to concentrate on such issues. In 2005 dena 1 was published to give advice of integration of wind energy in Germany [2].

Keywords: dena 2, grid extension, wind infeed, TAL, FLM, Renewable Energy, german grid

I. INTRODUCTION

The grid extension plans derived from dena 1 and fixed in the German grid extension law (Enlag) [3] brought about a strongly negative attitude within the general public, and this has been causing significant delays in carrying out the project. Until 2015, an extension of 850 km was planned, but so far, only 80 km could be built [4]. Committees have been formed that aim at promoting a better understanding between the energy companies and the general public [5]. As pursuing the idea of grid optimization instead of simply extending the grid is one of the main points to come to an agreement, dena was asked to concentrate on fathoming measures to boost efficiency such as the integration of high-temperature-conductors (TAL) and monitoring of overhead-lines (FLM) [6]. It has to be figured out that dena 2 fails to fulfill the requirements. Although it tries to deal with social acceptance, the study itself does not contain any directives or concrete suggestions, yet it asks politics to take a stand in regards to the ethnology of choice and to provide financial support [7].

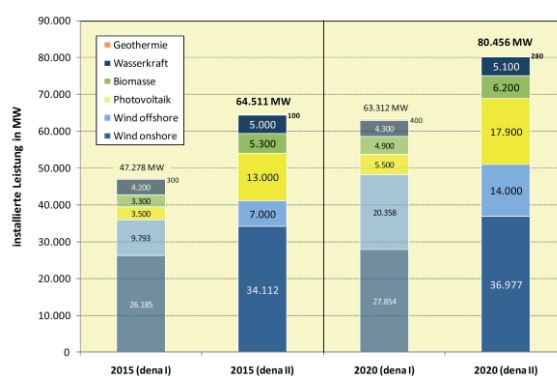


Figure 1, renewable energies up to 2020 , dena II Page. 47

II. THE NEED OF GRID EXTENSION

Dena 2 assumes a rate of 39 % of RE up to 2020. Especially the infeed of wind power and the shift of power supply to the coastal area makes grid extension indispensable. Figure 1 shows the forecast of the amount of RE in 2020: 80.46 GW will be installed. Compared to the rate of RE in 2010 there will be an increase of at about 35 to 40 GW.

To visualize the difficulties coming along with the integration of RE and to prevent power failure, dena 2 has forecasted the energy infeed of wind and solar energy for the year 2020. Using the installed performances and weather model data of the years of 2004 to 2007, time rows representing the power infeed have been generated.

Regarding the gathered material, dena 2 determines possible effects on the German grid [8]. Important criteria for the effects on the grid are the temperature of conductors and the transmission capacities. These criteria again depend on local conditions such as orientation, shading of the conductor, running of cables as well as on the wind direction [9]. With reference to the forecasted infeed of wind energy transgressions of the conductor's potentials can be identified. Preventive options can be seen in the installation High-temperature-Conductors (TAL) and in the flexible line management (FLM).

Both, the data used as well as the resulting calculations, are strongly influenced by subjective assumptions made by dena 2,

such as the nuclear phaseout, a modified grid plan based on dena 1 and the need of a nationwide installation of TAL and FLM. It is obvious that any sort of assumption has an effect on the result of the whole study.

III. TECHNOLOGIES

Apart from the option of the extension of the German grid, there are two other remarkable technologies to enhance the overhead lines: TAL and FLM.

High-temperature-Conductors (TAL) are conductors used for operation temperatures over 80°C. TAL conductors operating between 80°C and 150°C are known as conventional high-temperature-conductors. This type of TAL is state of the art and already used in some small erection plans. The other type of TAL is planned to operate over 150°C, but it is still in the early phase of development. Implementing any sort of TAL, it can be achieved to raise the electrical current limit climbs up to 150%. Unfortunately, the electric losses are also increased due to the rising resistance of the heating of the material. The construction is mainly comparable to standard conductors, but differently, a very pure aluminium mixed in a composition with zirconium is used. To increase the heat dissipation, the conductors could be coloured black.

Ordinary overhead lines (DIN EN 50182) are designed for standard climate conditions (35°C ambient temperature, 900 W/m² solar irradiation and 0.6 m/s wind speed). But to reach exactly these parameters is quite rare. Usually, there are still significant reserve capacities. By knowing the exact weather conditions at the track of the power line, the capacities could be implicated in the grid operation. That is the idea of FLM: The operation temperature of the overhead lines is monitored. There are several systems to be chosen. First, there are on-line measuring systems, which do only detect the temperature at one certain point of the overhead line. Another option is the utilization of fiber optics cable integrated in the conductors. They detect the temperature of the entire section using the Raman effect. A third honourable option is to install a force meter between the mast and the conductors to monitor the tensile strength.

But of course, there are some basic conditions which have to be considered: economic efficiency, an increase of electric losses, effects on grid stability, a decrease of distance between ground and conductors, abundance of emission regulations, mast statics and adequate experience of the technical devices.

In regard to the options mentioned, dena 2 only recommends the development of pilot projects concerning TAL. Although it is possible to apply FLM in its essentials during peak and low wind load situations, there is still the need of further scientific experience [10].

Dena 2 examines appropriate technologies to transmit wind energy by using a value benefit analysis. The technologies using overhead lines can be identified as the favourite technologies. For longer distances, high voltage DC-transmission (HGÜ) seems to be advantageous [11].

Concerning offshore wind parks, multicore cables for short distances and voltage source conductor (VSC)- HGÜ lines for long distances are preferred [12].

After discussing overload situations and possible technologies, dena 2 presents the non-transferable power and interprets the possible options of grid extension (onshore).

Using a model of 20 regions, power situations can be described [13]. With the help of time rows and forecasted power-infeed, it is possible to develop this power-balance, which shows that some regions lack of power and others have a surplus of power (fig. 2).

The used regional model is an attempt to represent the German grid system [14]. As there was no national need of load distribution, the grid system is grown regionally. The place of generation of electrical energy was chosen by the demand. Because of the high amount of energy produced by wind turbines, this concept changed. Wind energy is mostly produced in the northern part of Germany while industry settled down in the south. As a result, there is such a high need in grid extension. In difference to dena 1, dena 2 only defines regional borders to be extended, but no energy lines in special. At the red borders seen in figure 3 are the bottlenecks of the German grid system. To extend or enhance these sections are the challenges for the future published in dena 2.

Solutions can be seen in adopting technologies, such as TAL, FLM or a basic option (BAS) that regards standard transmission. These options are examined to three variants, which describe the use of storages: Variant 000 (0% storage), variant 050 (50% storage) and variant 100 (100% of non-transferable power are stored) [15].

To define the toughening of the region's conductors, dena 2 uses a method based on the power interexchange between two knots, which is called Power Transfer Distribution Factor (PTDF)-method. It is formed of proportion of power-flow and the interexchange of power between two knots. Several knots are combined to one region. The power flows for the region's frontiers are determined by multiplying the PTDF-matrix and the infeed-matrix (Power-flow software INTEGRAL is used) [16].

The needed power adjustment can be examined by dividing the nontransferable power by PTDF. Now it is possible to collect the required number of systems and the need of grid extension for each region.

According to the results of dena 2, grid extension cannot be dropped despite storage- technologies are used. That is why dena 2 only examines potentials of the use of pumped-storage plants by using a sensitivity-version focused on a variation of performances on the efficiency.

Figure 4 shows the costs and the defined need of grid extension of all recommended technologies. Dena 2 recommends the option BAS 000. The main reason has to be seen in the comparably low costs of one billion € per year (fig. 4). Although the implementation of TAL would avoid at about 100 km of grid extension, dena 2 concludes that the doubling of the costs (appr. 1.6 billion €) cannot be justified by the optimization achieved. On the first view, the high costs of TAL

are amazing and can be questioned. But equivalent to the assumptions of dena 2 – (e.g. dena 2 assumes TAL investment for the entire grid) – the implementation of the new techniques as TAL and FLM causes also mast reinforcements. The planned grid-extension and the conclusion of dena 2 (prefer BAS 000) causes a lot of public complaints and protests.

Dena 2 does state that the examined data including the results cannot be used in general. For a detailed calculation of grid extension it is necessary to apply current values and grid models. The actual benefit of the study in terms of a quantified need of grid extension has to be denied. Dena 2 drops the less economical, but socially much more preferred option of TAL in favour of the most cost-effective one. As a consequence, the social dispute concerning grid extension could not be settled/calmed down. The following paragraph is aimed to discuss the social effects caused by dena 2.

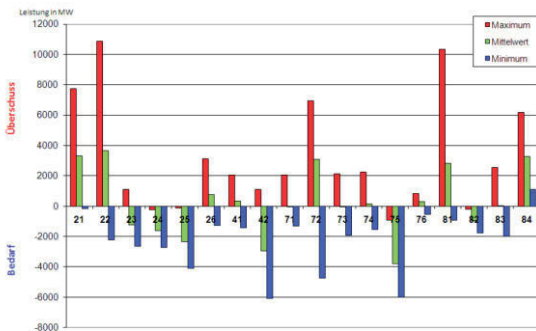


Figure 2, region model overage / demand dena II P. 263

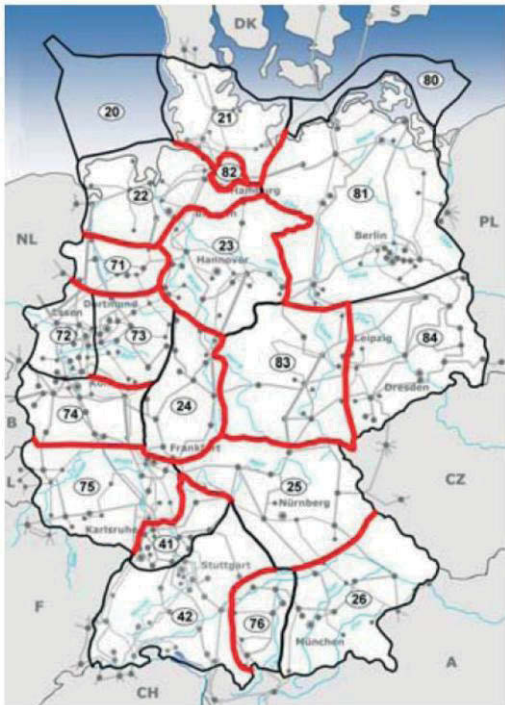


Figure 3, required grid extension systems for each region dena II P. 293

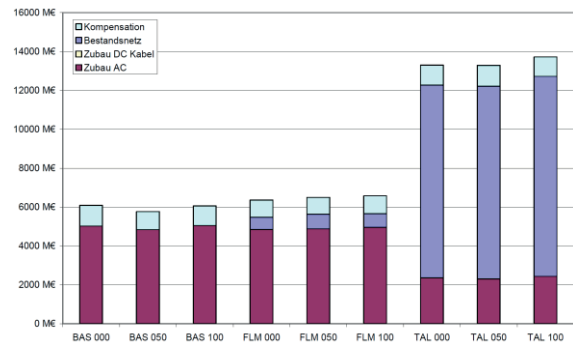


Figure 3, Overview of investment costs dena II S. 304

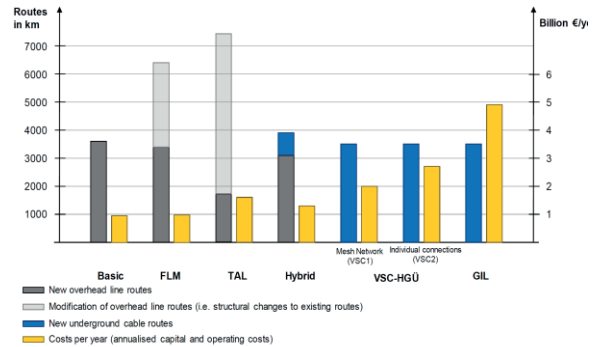


Figure 4, Summary of the main results dena II P. 15

IV. ACCEPTANCE WITHIN SOCIETY

Currently, Germany shows more civil protest than it has for the longest time. Due to the presumption that the companies would solely be interested in an optimization of their profits whereas they ignore the concerns of the general public in regards to matters of health, social aspects and environmental issues, all protests similarly ask for higher participation and show a general scepticism towards big companies especially of the energy sector [17].

As described, dena knew that it had to handle this conflictive situation in dena 2. To provide valuable insights in the social demands which are voiced in regards to dena 2, some results of a recent study in environmental psychology which examines the factors which influence the grid erection, will be depicted first. [18]

When regarding the participants of the study as a representative group of those affected by the grid extension, it shows that at least the minimum requirements for the acceptance of new power lines are met: 87.3% of the participants stated they would support the utilization of renewable energies (RE) and would not be interested in hindering their development. But still, the necessity for a grid extension as it is outlined by the grid operators is questioned [19]. One of the reasons for this is that grid overload has no visible effect on people’s daily life and therefore, it is beyond their understanding. Another reason is that the data which serves as a base to calculate the grid load is not open to the

public and therefore, the information is challenged.

In terms of acceptance of the new power grid, the fairness and transparency transported by the actors within the process planning plays a decisive role [20]. 55.6% claim balancing of the incongruity between regional costs (landscape alteration, health risks, decrease of tourism) and regional benefits as a minimum requirement. Furthermore, the majority of study participants would be willing to support a grid extension only after exploiting all other alternative options (e.g. Smart, Grid, grid optimization) [21]. Laying earth cables is highly preferred over overhead lines, as it is presumed that landscape alteration as well as the negative impact on man and nature would be significantly lower.

There is potential for a compromise: Overhead lines should be running next to already existing infrastructure lines, otherwise below the surface. By guaranteeing stable power prices and a visible support of the RE, the willingness of the people to support the grid extension could be raised significantly.

The study gives out one final recommendation to the players in the energy market: „ For future planning, a well-balanced proportioning of the criteria in the decision-making process is highly advisable, economical, ecological and social criteria should be treated equally. From the viewpoint of the study participants, so far, this has not always been the case, it was perceived that economic matters were dominant. Technical potential as well as the chance of exploring options within the planning process should be completely exploited to guarantee the highest amount possible of nature protection and protection of human health.“[22]

If you take this as a basis for creating a strategy for the German energy supply grid, dena 2 deviates in three significant aspects from the outlined compromise:

A. Objectivity

The study dena 2 has been carried out by a party whose credibility is being remarkably contested as the general public would suspect the energy companies would pursue their own economical interests with the study. The consultant Christian von Hirschhausen points out that the energy companies' advantage of possessing more information than the general public would weaken the credibility of the study[23]. The majority of the major German newspapers as well as politicians doubt the need of investment identified in the study exactly because of this reason.[24] Therefore, this already destroys dena 2's chance of convincing the population for Germany of the necessity of the grid extension.

B. Transparency

Hirschhausen states a need for heightened transparency in the energy sector to provide better grounds for discussion within government agencies and to enable these agencies to make better judgement calls. This in turn could raise acceptance for larger infrastructure projects [25]. According to the WWF, dena 2 and the data it is based on is not comprehensible for external parties [26]. Specialists also voice the concern of a lack of transparency of dena 2 [27]. Several universities had

asked for insight in the grid data to reassess the calculation of the power flow balance yet their request was denied. The same applies to the ‚cost comparison‘: When illegitimately putting together investment and cost, a comparison of operating costs is not possible, neither can the investment be rated (in regards to amortization, net present value etc.). A comparison of options of the cost therefore loses its credibility and is not comprehensible anymore.

Dena 2 fails in to show its objectivity by letting external parties reassess its calculations both regarding technical as well as economical aspects. As the basis for calculation is not disclosed, sufficient transparency for creating acceptance for the grid extension is missing.

C. Potential for optimization of the existing energy grid

In discouraging the optimization measures for the existing grid mainly because of cost issues, Dena 2 defies the favored premise of minimizing the overhead lines. This finding of dena 2 is widely questioned. One main aspect in this process is the criticizing of the presumptions that the study is based on. Presuming that the grid extension called for in dena 1 [28] and the nuclear power phase-out have been fully conducted and executed is not only unrealistic but false, and if taken as a basis for calculation, significantly changes the load factor of the infeed points and therefore changes fundamental conditions for the study itself [29]. To ensure validity of its results, the study would have needed to be revised also concerning the extension potential for RE which had been predicted too prudent [30].

The federal association of wind power (BWE) criticizes a number of presumptions of the study – fuel prices to remain constant, prices for CO2 certificates which according to the BWE are calculated too low, an inflation rate supposedly calculated too low also. The BWE states that all these factors would lead to a negative rating of RE [31]. Jarass points out that assuming the necessity of a constant use of FLM and TAL [32] would be just as absurd as the proposition of not reducing wind turbines at all.[33] He even calls the result of dena 2 inappropriate as he considers it to be based on false presumptions [34].

Another approach of criticism of dena 2's result is criticizing the methodology which had been selected for the study. This approach points out a fundamental problem of the study. Hirschhausen criticizes the lack of a cost-utility analysis implicating the long-term effects of the reduction of CO2 and the integration of RE. He recommends to change the structure of objectives from a conventional microeconomic view to a more holistic approach which takes into consideration the overall economy as well as matters of climate change and protection and the whole energy system [35].

V. FINAL REMARKS

Expectations were high that dena 2 would ease the conflict between energy companies and the various critical parties opposing them. By introducing another criteria which is concerned with the long term benefits of the CO2 reduction, the acceptance within society or the optimization of the grid, dena 2 would have signaled a willingness to work on finding

consensus [47]. But judging dena 2 is as difficult as judging energy companies at large.

The three objectives of ensuring a constant supply, nature protection and economic efficiency are not easily combined, yet all of them need to be met by the energy companies. It is understandable that companies would focus on economic efficiency, but if you consider the greater good of all of society, it cannot be accepted. Making use of capital budgeting and carrying out a cost-benefit analysis will always lead to results which neglect aspects like the acceptance within society and the consideration of the impact on nature. These aspects are bound to be almost ignored, if at all, they would be considered in terms of financial benefits only. This leads to the question whether it is actually even sensitive to have the grid operation sector be handled by private investors and companies and therefore, a solution to the continuing problems might need to be looked for on a completely different level.

Another fundamental aspect of the criticism voiced is that dena 2 did announce in its introduction that the study would take a European viewpoint into consideration, but this is nowhere to be found. Several parties point out that an energy concept which would not heed to political boundaries would significantly reduce the need for grid extension. According to the newspaper ‚Handelsblatt‘, dena 2 does by no means meet the requirements announced by the EU commission shortly before the study was published [48]. The EU commission’s report highlights the need for a European perspective in regards to grid extension. In the report, a need for 45000 km of new electric lines and an investment volume of € 200 billion is stated. The commission outlined where the grid should run and furthermore, it suggested to shorten the approval process to 5 years only to speed up the grid extension. Final decisions about the measures for grid extension shall, according to the report, still be made individually on a national level [49].

When dena 2 was published, Oettinger pointed out that planning the grid extension on a European level and not on a national level, the need for grid extension identified by dena 2 would have been a lot lower [50]. The BWE agrees with this statement insofar as remarking that dena 2 would have come to different results had the basis for calculation been a European perspective [51].

Briefly said, a Europe growing together more closely could enhance the efficiency of the grid operation and would help in working towards achieving the common European goals of climate protection.

ACKNOWLEDGMENT

At the first place we would like to record contribute to Mr. Dirk Lehmann. He guidance our work from the very early stage of the research and gave us always advice and provide us by new ideas. Furthermore many thanks go to Przemyslaw Janik, he gave us an very personally impression in the polish history and way of life.

REFERENCES

- [1] Renewable Energy Sources Act (EEG) 2009 § 1,I
- [2] dena (2005) : Präsentation zu Netzstudie, Page 8, in: dena Netzstudie 1, URL:http://www.dena.de/fileadmin/user_upload/Download/Dokumente/Projekte/ESD/netzstudie1/dena-Netzstudie_1_praesentation.pdf, 22.12.2010
- [3] c.f Hirschhausen (2010), p.11
- [4] dena Grid Study I ,Summary Page 9
- [5] e.g. go to www.forum-netzintegration.de (last called on 14.01.2011)
- [6] see also Plan N, chapter 5
- [7] see dena 2, p. 240 and dena 2, p. 395 as it can be cited: “Die Bauzeit für einen solch großen Infrastrukturausbau (...) hängt von vielen Faktoren ab, wie z.B. der Bereitschaft, dieses Projekt zu starten und zu realisieren, der politischen Unterstützung und Förderung, dem Finanzierungsplan, dem Genehmigungsverfahren, dem Bauplan usw. und nicht zuletzt von der öffentlichen Akzeptanz eines Netzausbaus. “
- [8] dena Grid Study II, Summary Page 6
- [9] dena Grid Study II Page 138
- [10] dena Grid Study II Page 159, 160
- [11] dena Grid Study II Page 163
- [12] dena Grid Study II Page 176-177, 193-196, 202
- [13] dena Grid Study II Page 262
- [14] Übersicht über die installierte Kraftwerksleistung und die Leistungsflüsse in den Netzgebieten der deutschen Übertragungsnetzbetreiber (Regionenmodell) „Stromtransport 2009“ URL:http://www.50hertz-transmission.net/cps/rde/xchg/trm_de/hs.xsl/1388.htm 22.12.2010
- [15] dena Grid Study II Page 255
- [16] by use of : $P_{\text{Preal-P}} = P = 3 \frac{1}{2} * 0,7 * U * I$ (active power) , The factor 0,7 ensures the n-1 criteria flatly.
- [17] see Schweitzer-Ries, Petra (2010), Page. 24f
- [18] Schweitzer-Ries (2010)
- [19] see Schweitzer-Ries (2010), p. 9f
- [20] see Schweitzer-Ries (2010), p. 10f
- [21] see Schweitzer-Ries, Petra (2010), Page. 24f
- [22] see Schweitzer-Ries, Petra (2010), Page. 30f
- [23] see dena (2010), p. 3 and Hirschhausen (2010), p. iii as it can be cited: “Diese Vorgehensweise (that government is dependend on the opinions of dena working as a coordinator (remark)) wird der Infrastrukturverantwortung des Staates nur unzureichend gerecht. Diese Informationsasymmetrie könnte zu einer überhöhten Informations“rente“ für die Übertragungsnetzbetreiber führen; auch wird die Glaubwürdigkeit des Prozesses geschwächt und somit die Akzeptanz größerer Infrastrukturprojekte reduziert.“
- [24] see Handelsblatt, Süddeutsche Zeitung, FAZ, Financial Times Deutschland (all dated 23.11.2010); see also Nestle (15.12.2010)WWF, 23.11.2010
- [25] see Hirschhausen (2010), p. 21
- [26] WWF, 23.11.2010, go to: http://www.wwf.de/presse/details/news/maengel_im_netzausbausenari_o/ (last called on 14.01.2011)Zimmermann, 12/2010 in neue energie, S. 17; einige Atommeiler liegen am Einspeisepunkt für geplante Regenerativprojekte
- [27] Zimmermann in: neue energie (12/2010), p.18
- [28] see Nestle (15.12.2010)
- [29] see Zimmermann in: neue energie (12/2010), p.17
- [30] see Zimmermann in: neue energie (12/2010), p.17
- [31] see Albers (23.12.2010), go to www.wind-energie.de (last called on 14.01.2011)
- [32] see Jarass (2010), p.14
- [33] see Jarass (2010), p.30-32 and dena2: ("vollständige Integration erneuerbarer Energien")

- [34] see Jarass (2010), p.1
- [35] see Hirschhausen (2010), p. iv
- [36] To be able to decide between the alternatives depicted, the dena study used a scoring model. The three factors economic efficiency, system compatibility and the impact on nature are considered equally strong and as the main factors for a decision whereas technical properties are not weighted that strongly. (remark)
- [37] see e.g. Handelsblatt, (23.11.2010), financial times deutschland (23.11.2010)
- [38] see Zimmermann in: neue energie (12/2010), p. 17f
- [39] see Ehrlich in Financial Times Deutschland (09.11.2010)
- [40] see Gerder (23.11.2010)
- [41] see Jarass (2010), p.30f
- [42] see dena 2, p. X ("vollständige Integration erneuerbarer Energien")
- [43] see Jarass, p. 14
- [44] see dena 2, p. 15
- [45] see Deutsche Umwelthilfe (2010), p. 48
- [46] see „Zusammenfassung der dena 2“, S. 13 (pdf, S. 15)
- [47] Gerder, Ulf (23.11.2010): „Falsche Grundannahmen der dena-Netzstudie“
- [48] Ehrlich, Peter (09.11.2010): „Europa braucht 1000 Mrd. Euro für Energienetze“ go to <http://www.ftd.de/wissen/:energiewirtschaft-europa-braucht-1000-mrd-euro-fuer-energienetze/50192705.html> (last called on 14.01.2011)
- [49] Financial Times Deutschland (23.11.2010): „Netzausbau soll Verbraucher wenig kosten“ go to <http://www.ftd.de/politik/deutschland/:dena-studie-netzausbau-soll-verbraucher-wenig-kosten/50197737.html> (last called on 14.01.2011)
- [50] Deutsche Umwelthilfe e.V. (Hrsg.): „Plan N. Handlungsempfehlungen an die Politik.“ (Nov. 2010), go to [http://www.forum-netzintegration.de/detailansicht-netzintegration/?tx_ttnews\[tt_news\]=36&tx_ttnews\[backPid\]=35&cHash=1e0aa2702c](http://www.forum-netzintegration.de/detailansicht-netzintegration/?tx_ttnews[tt_news]=36&tx_ttnews[backPid]=35&cHash=1e0aa2702c) (last called on 14.01.2011)
- [51] Gerder, Ulf (23.11.2010): „dena-Netzstudie II springt zu kurz“, go to www.wind-energie.de (last called on 14.01.2011)
- [52] Stratmann, Klaus (23.11.2010): „Für Ökostrom fehlen Tausende Kilometer Leitungen“, go to http://www.handelsblatt.com/technologie/energie_technik/dena-fuer-oekostrom-fehlen-tausende-kilometer-leitungen;2698491 (last called on 14.01.2011).
- [53] Hirschhausen, Christian von: „Bewertung der dena Netzstudie 2 und des europäischen Infrastrukturprogramms. Gutachten im Auftrag des WWF“ (23.11.2010), go to <http://www.wip.tu-berlin.de/typo3/index.php?id=201> (last called on 14.01.2011)
- [54] Jarass, Lorenz (07.12.2010): „Dena Netzstudie II: Annahmen rechtswidrig, Ergebnis sachwidrig“, go to http://www.jarass.com/home/index.php?option=com_content&view=frontpage&lang=de&Itemid=88 (last called on 27.12.2010).
- [55] Nestle, Ingrid: „Dena II - Netzbetreiber lassen Bundesregierung im Dunkeln tappen“ (15.12.2010), go to <http://ingrid-nestle.de/presse/detail/nachricht/dena-ii-netzbetreiber-lassen-bundesregierung-im-dunkeln-tappen.html> (last called on 14.01.2011)
- [56] Schweitzer-Ries, Petra: „Umweltpsychologische Untersuchungen der Akzeptanz von Maßnahmen zur Netzintegration Erneuerbarer Energien in der Region Walle - Mecklar (Niedersachsen und Hessen)“ vom 30.06.2010, go to: www.forum-netzintegration.de/.../Abschlussbericht_Akzeptanz_Netzausbau_Juni2010.pdf (last called on 14.01.2011)
- [57] Süddeutsche Zeitung
- [58] WWF, 23.11.2010, go to: [http://www.wwf.de/presse/details/news/maengel_im_netzausbauenario/Zimmermann: „Fokus Dena 2 Studie“ in: „neue energie. Das Magazin für erneuerbare Energien“, \(12/2010\), p.17-18, hrsg. von Albers, Hermann in Berlin.](http://www.wwf.de/presse/details/news/maengel_im_netzausbauenario/Zimmermann: „Fokus Dena 2 Studie“ in: „neue energie. Das Magazin für erneuerbare Energien“, (12/2010), p.17-18, hrsg. von Albers, Hermann in Berlin.)

Hydropower

Yesterday, today, tomorrow

Bo Zhang

Lehrstuhl Energieverteilung und Hochspannungstechnik
Brandenburgische Technische Universität Cottbus
Cottbus, Germany

Bianca Räßle

Lehrstuhl Energieverteilung und Hochspannungstechnik
Brandenburgische Technische Universität Cottbus
Cottbus, Germany

Abstract—This electronic document is a “live” template. The various components of your paper [title, text, heads, etc.] are already defined on the style sheet, as illustrated by the portions given in this document. (Abstract)

Keywords-component; formatting; style; styling; insert (key words)

I. INTRODUCTION (HEADING 1)

Using water for power generation, people have worked with nature to achieve a better lifestyle. The mechanical power of falling water is an age-old tool [1]. As early as the 900's, the Chinese recognized the advantages of mechanical hydropower and used it extensively for milling, pumping and forging. At almost the same time the hydropower was also extensively used in European.

Since the invention of generators and electrical appliances, hydropower has been used to drive the generator. Today, electricity generation from hydropower makes a substantial contribution to meeting the increasing world electricity demands. Especially after the oil shocks of the 1970s people showed a renewed interest in hydropower [1]. In the mid 1990s hydropower plants accounted for some 19% (or approx. 2500 TWh/a) of total electricity production worldwide. The installed capacity amounted to 22% (or approx. 700 GW) of the total installed capacity for electricity generation [2]. Worldwide average growth rates of hydroelectricity generation in the future are estimated from about 2.4% to 3.6% per year between 1990 and 2010 or 2020 respectively [2].

Now there are many new forms of hydropower generation such as sea current energy, tidal energy, wave energy etc.. Due to the zero-emission of CO₂ and high efficiency, hydroelectric power plays an important role in the application of renewable energy.

II. HYDROPOWER—AN OVERVIEW

A. The hydrologic cycle

Hydropower is energy that comes from the force of moving water. The fall and movement of water is part of a continuous natural cycle called the water cycle [3]. Energy

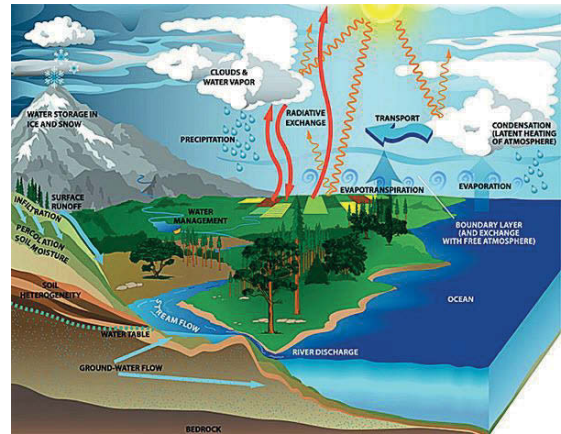


Figure 1. The hydrologic cycle [source].

from the sun evaporates water in the earth’s oceans and rivers and draws it upward as water vapor. When the water vapor reaches the cooler air in the atmosphere, it condenses and forms clouds. The moisture eventually falls to the earth as rain or snow, replenishing the water in the oceans and rivers. Gravity drives the water, moving it from high ground to low ground. The force of moving water can be extremely powerful [3].

Hydropower is called a renewable energy source because the water on the earth is continuously replenished by precipitation. As long as the water cycle continues, we won’t run out of this energy source [3].

B. Hydropower generation

To generate electricity, water must be in motion. This is kinetic energy. When flowing water turns blades in a turbine, the form is changed to mechanical energy. The turbine turns the generator rotor which then converts this mechanical energy into another energy form—electricity (Fig. 2). Since water is the initial source of energy, we call this hydroelectric power or hydropower [1].

At facilities called hydroelectric power plants, hydropower is generated. Some power plants are located on rivers, streams, and canals, but for a reliable water supply, dams are needed.

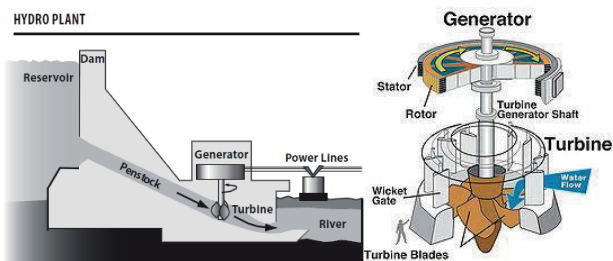


Figure 2. Hydro plant and turbine-generator [3].

Dams store water for later release for such purposes as irrigation, domestic and industrial use, and power generation. The reservoir acts much like a battery, storing water to be released as needed to generate power. Then the electricity is transported via huge transmission lines to a local utility company [3].

C. Turbines

Depending on the discharge of water and the available height of fall different turbines can be applied (Fig. 3). The specific type of turbine to be used in a power plant is not selected until all operational studies and cost estimates are complete. The turbine selected depends largely on the site conditions [1].

D. Types of hydropower plants

Each power plant must be adapted specifically to the local conditions. In accordance with different criteria the power plants can be divided into different categories. The three most common hydroelectric power plants are:

- Run-of-the-river hydroelectricity

Run-of-the-river hydroelectricity is the hydroelectric generation whereby the natural flow and elevation drop of a river are used to generate electricity. The amount of those hydro plants are determined by two factors: head and flow. Head is how far the water drops. It is the distance from the highest level of the dammed water to the point where it goes through the power-producing turbine.

Flow is how much water moves through the system—the more water that moves through a system, the higher the flow. Generally, a high-head plant needs less water flow than a low-head plant to produce the same amount of electricity.

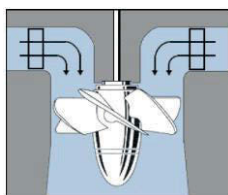


Figure 3. a) Kaplan-turbine.... [3].

- Storing power plant

One of the biggest advantages of a hydropower plant is its ability to store energy. The water in a reservoir is, after all, stored energy. Water can be stored in a reservoir and released when needed for electricity production. During the day when people use more electricity, water can flow through a plant to generate electricity. Then, during the night when people use less electricity, water can be held back in the reservoir. This is why the hydropower is more responsive than most other energy sources for meeting peak demands.

Storage also makes it possible to save water from winter rains for summer generating power, or to save water from wet years for generating electricity during dry years.

- Pumped storage power plants

Some hydro plants use pumped storage systems. A pumped storage system operates much as a public fountain does. The same water is used again and again.

At a pumped storage hydro plant, flowing water is used to make electricity and then stored in a lower pool. Depending on how much electricity is needed, the water may be pumped back to an upper pool. Pumping water to the upper pool requires electricity so hydro plants usually use pumped storage systems only when there is peak demand for electricity.

Pumped storage is water pumped to a storage pool above the power plant at a time when customer demand for energy is low, such as during the middle of the night. The water is then allowed to flow back through the turbine-generators at times when demand is high and a heavy load is placed on the system.

E. The hydropower debate

According to a summary by Bartle (2002) hydropower provides a proven and well-advanced technology with which experience could be gained over centuries. It has long been applied for reasons such as flood control, improved navigation or the supply of irrigation and drinking water. In today's climate debate, hydropower is further promoted as a CO₂-neutral and renewable energy supply. However, recent studies revealed that some large hydroelectric or multiple-use reservoirs, especially in the tropics but also in boreal regions, potentially represent significant sources of CO₂ and CH₄ (e.g. Abril et al. 2005; Duchemin et al. 1995; Tremblay et al. 2004; WCD 2000). The phenomenon is caused mainly by the large amount of biomass that is flooded and the resulting microbial decomposition, whereas the exact processes (especially considering the longer-term) are still in the focus of current research.

Due to the fact that resources are geographically widely spread (Bartle, 2002) dependencies on other countries are fewer than for other energy sources, such as oil or gas. Yet conflicts may still arise, in particular at transborder rivers where cooperation between upstream and downstream countries or provinces is lacking for diverse reasons (source).

In contrast, also joint resource development projects were launched, as for instance the Kariba hydroelectric power plant in the Zambezi river bordering Zambia and Zimbabwe in Africa or the Yacyretá power plant in the Parana river initiated by Argentina and Paraguay.

Rising environmental awareness led to conflicting policies within the environmental sector, including climate protection and conservation goals for freshwater ecosystems (Bunge et al. 2001, p. 2). The various ecological implications of dams and other transverse structures used for the generation of hydropower comprise modifications in stream or river morphology, natural functions, processes and structures (Jungwirth, 2003a). Changes in flow conditions from lotic to almost lentic, entailing changes in chemical and physical characteristics such as temperature and hydrologic regime, may alter ecosystems significantly (e.g. Hütte 2000; Jungwirth 2003b). Representing a disruption in the longitudinal connectivity, transverse structures generally impede active migration and passive drift of aquatic organisms.

Alongside the direct ecological implications also geomorphological changes can be triggered by the impoundment of a strip of running water. Considered problematic is the fact that the natural sediment regime of a stream or river is disrupted, entailing the deposition of material upstream of the transverse structure and a lack of material in the downstream section. The latter ultimately leads to erosion even in the far deltaic regions and therefore indirectly to salt water intrusion in the long run. This may affect drinking water supplies and destroy arable land. The deposition of fine materials in the upstream part of the river brings up the problem of clogging and turbidity, which have an impact both on organisms and the so-called self-purification potential of the ecosystem (Hütte 2000; International Rivers 2009; WCD 2000). Moreover, a rising risk of geological events such as erosion, landslides or seismic events may potentially be associated to fluctuating water levels in a reservoir (International Rivers 2009).

Further limitations to the use of hydropower are mainly associated with large dams which require the restructuring of vast landscapes and imply social consequences. Large resettlement projects, among them the world's largest, e.g. in the Yangtze valley in China where 1.3 million people were displaced, cause the loss of homes, jobs and often a future perspective since compensation is frequently not sufficient (International Rivers 2009). The affects of impoundments on fisheries can be substantial since ... (WCD 2000). Loss of cultural heritage...

III. THE POTENTIAL OF HYDROPOWER

A. Europe

With the implementation of the EU Water Framework Directive (WFD) and the Flora-Fauna-Habitat Directive (FFH-

directive) and international legislation including the Kyoto Protocol, the European Union pursues both climate protection and freshwater conservation.

In Germany approximately 75 % of the feasible hydropower potential is already utilized. The future focus will mainly be on potential by optimisation of existing HEPPs, the replacement of transverse structures, which cannot be removed for reasons of, by hydroelectric structures, and small hydropower plants.

B. China

C. Moveable HEPP

The Hydro-Roth Ltd.

IV. CONCLUSIONS

After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

ACKNOWLEDGMENT (HEADING 5)

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression, "One of us (R. B. G.) thanks . . ." Instead, try "R. B. G. thanks". Put sponsor acknowledgments in the unnumbered footnote on the first page.

REFERENCES

- [1] G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," *Phil. Trans. Roy. Soc. London*, vol. A247, pp. 529–551, April 1955. (references)
- [2] J. Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
- [3] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in *Magnetism*, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
- [4] K. Elissa, "Title of paper if known," unpublished.
- [5] R. Nicole, "Title of paper with only first word capitalized," *J. Name Stand. Abbrev.*, in press.
- [6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," *IEEE Transl. J. Magn. Japan*, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetism Japan, p. 301, 1982].
- [7] M. Young, *The Technical Writer's Handbook*. Mill Valley, CA: University Science, 1989.

Energy policy development in Germany

Current Situation and Forecast

Xiaoyu Tong

Environmental Sciences and Process Engineering
Brandenburg University of Technology Cottbus
Cottbus, Germany
aimartong@googlemail.com

Abstract—this article generally introduces the basic knowledge of energy policy, German environment and energy policy. In addition, it indicates the tendency and prediction of energy policy in future.

Keywords—component; energy policy; environment; germany; prediction

I. FUNDAMENTALS OF ENERGY POLICY

A. *what is energy policy*

Energy policy is the manner in which a given entity (often governmental) has decided to address issues of energy development including energy production, distribution and consumption. The attributes of energy policy may include legislation, international treaties, incentives to investment, guidelines for energy conservation, taxation and other public policy techniques..

B. *What raw materials (energy) can be used*

Apart from petroleum which is used as motor and heating fuel, other types of energy, such as coal, natural gas and thermal energy, can also serve as energy resources. As member of nuclear family, Uranium can be used to generate electricity. Yet, all the above-mentioned materials share one thing in common: they're all non-renewable in the short term, the renewal of which might span over centuries or million years. However, we could still resort to alternative renewable energy resources as optional plan.

C. *Objectives of energy policy*

The framework of energy policy relies on three pillar objectives of economic efficiency, the stability of supply, and environmental protection. Hence, national energy policy is designed to achieve the goal of sustainability.

The objective of economic efficiency implies that the energy we use should be as cost-effective as possible so that we could offer more competitive quality products with lower production cost that could be afforded by more consumers

The goal of stability means that the supply of energy, such as non-stop power supply for hospitals and sufficient petrol provision for vehicles, should be guaranteed effectively

In terms of the last objective, we need to stop climate change for we need clean air and water to keep human bodies, animals and plants growing healthily.[1]

II. ENVIRONMENT AND ENERGY POLICY IN GERMANY

A. *Energy situation in Germany*

The energy mix of Germany is mainly consisted of fossil fuels like petrol, coal and natural gas. According to the latest report by the Federal Statistical Office, the focus on consuming raw energy materials led to the uneven energy resource consumption structure in 2005, in which petroleum played a leading role of 35.9% in proportion, anthracite and brown coal altogether 24.2%, natural gas 22.7%, nuclear energy 12.5%, while renewable energy resource taking up just 5%.

Currently, the major application of nuclear energy concentrates on power generation rather than on heating or driving motors. In 2005, it has already shown great potential in power industry, taking up a total of 26.3%. Brown coal in the same year reported a proportion of 25%, showing a downward trend compared to its share of 29.3% in 1991. More drastic change can be found in the use of anthracite coal, the share in electricity generation of which has declined from 27.8% to 21.7% in 14 years of time. The Federal Statistical Office has reported that, in power industry, the proportion by renewable resources increased from 3.2% in 1991 to 10.2%, and is estimated to grow to 11% by next year and a more promising future of 20% by 2020 hopefully. In this growing sector, wind power reports a share of 4.3% in 2005 (compared to 0.02% in 1991), hydraulic power 3.4%, and other forms of renewable energy resources taking up the rest, such as biological, geothermal and solar power, etc..

B. *Environmental Protection in Germany*

In Germany, environmental protection is under the joint charge of BMU (Federal ministry of environmental and natural conservation and nuclear security) and the Federal environmental statistical office. At state level, it is taken care of by many local branch offices. BMU and the Federal environmental statistical office generate a public report on environmental status quo on yearly basis.

Meanwhile, the Federal government has set up a long term plan to enforce enterprises to cut down their poisonous gas and CO₂ emissions while treating the discharges properly

The mass application of latest research breakthroughs and technological innovation has been greatly downsized our

negative influence in the environment either in corporate production or in daily life

At the same time, more and more people have become aware of the need of energy conservation and environmental protection, and responded actively in terms of waste disposal and classification.

C. CO₂ Emission

Since the first day of 2005, the regulation over greenhouse gas emission has become effective within the 15 nations in the European Union. In the first stage of allocation, no serious effective has been shown. The emission quota set by National Allocation Plan (NAP) and the arrangement on ways to cut down the emission provide a buffer zone for the economies, leaving the household, centralized heating and vehicle emissions unattended. In this primary stage, Germany has set a relatively low level of charges of below 10 Euros per ton within the permitted emission quota, which is estimated to grow in the long run to around 15 Euros by 2030.

In 2009, the direct and indirect emissions by German households were totaled 618 million tons, the average emission per capita being 7.5 tons

III. ORIENTATION OF FUTURE ENERGY POLICY

Reference forecast

1) Economy development and population expansion in Germany.

While German economy is increasing at an annual growth rate of 1.4%, conditions are getting worse in terms of negative population growth and ageing problem.

2) Technical development on demand

Technological innovation has greatly influenced the use and cycle of energy resource, and the application of latest high-techs will lead to a longer cycle period.

3) Total energy consumption

Daily consumption of underground energy will see a decline by 2030, while the use of power and natural gas will be increased relatively

4) Energy consumption by home, industry and public transportation.

By 2030, household energy consumption will decrease by 14% from the level of 2002. The popularization of power saving appliances will also contribute to the first decline in electricity consumption in year 2020.

5) Electricity generation and District heating.

In the future, the electricity generation in Germany will focus on the use of natural gas, leading to the downward trend in the use of coal. In the predictable future, it will take up 38% of total electricity generated by renewable resource and 26% of total power production. Energy consumed for centralized heating is going to decline due to the adoption of heating conservation plan. On the whole, the leading roles of coal, brown coal and fuel oil in the field of centralized heating will be replaced by recycled waste and bio-energy resource like natural gas.

6) Utility of renewable energy in Germany.

The total proportion taken up by renewable energy resources as primary energy will be increased from 3.4% in 2002 to 11.5% by 2030, over half of which is consumed to generate electricity. And over a quarter of power will be generated by the consumption of new energy by 2030, by which time renewable energy resources will take up to 8% of total demand of fuels.

7) Primary energy consumption.

The consumption of primary energy is declining in the long run in Germany, which is a distinct trend compared to what happened in the past

8) Structure of primary energy consumption.

In the estimated period, great changes will be seen to restructure primary energy consumption, marked by increasing proportions of natural gas and renewable energy resources and diminishing significance attached to coal and petroleum.[2]

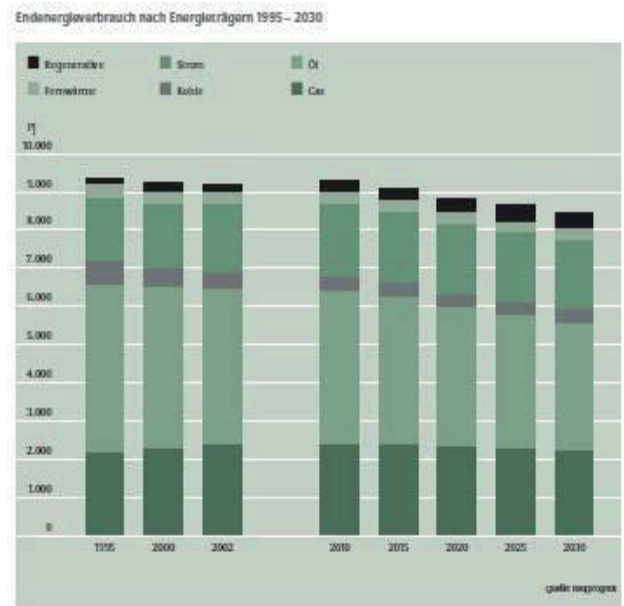


Abb1. Energy demand 1995-2030

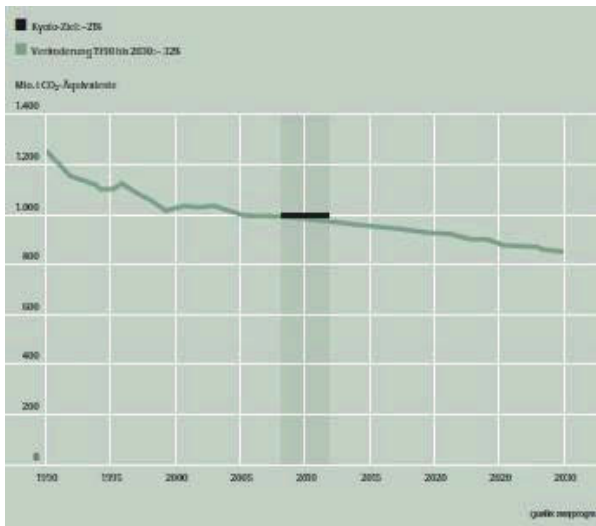


Abb2. CO₂ Emission 1990-2030

REFERENCES

It is necessary to introduce policies to encourage the use of renewable energy resources so as to reduce the dependence on petroleum and coal. The upgrading of technologies of electricity generation by using wind, solar and bio-energy joins the increase in life span of nuclear power station to improve

effectively the status quo of energy resources in Germany in terms of reduce the greenhouse gas emission and hence the pressure and risk onto the environment..

- [1] <http://www.kernfragen.de/kernfragen/gesellschaft/02-Grundlagen-der-Energiepolitik/2-1-Worum-geht-es.php>
- [2] EWI/Prognos-Studie Die Entwicklung der Energiemärkte bis zum Jahr 2030, Energiewirtschaftliche Referenzprognose Energiereport IV-Kurzfassung.

Nuclear Power Systems and Economy

B.Sc. Jonas Richter, Susann Römig, Falko Richter
Chair of Power Distribution and High Voltage Engineering
Brandenburg University of Technology
Cottbus, Germany

This document is a general introduction to nuclear power systems and economy. Jonas Richter describes the various types of existing and technically feasible reactor designs. Susann Römig and Falko Richter reveal the basic principles of nuclear power plant economy and its challenges.

Nuclear Power Plant Technologies, Generations of Reactor Types, Nuclear Industries and Economics

I. INTRODUCTION

By taking into account that the actual production of electricity will not full fill the increasing global future demand over the next century, this paper will gain a simplified understanding about the potential to satisfy this demand. Nuclear power plants have both the hazard of radioactivity as well as the ability to support the transition to renewable energies.

II. REACTOR DESIGN

A. General Reactor Types

By fading away specified and adapted nuclear power systems, three basic reactor designs were established. These are the Water Cooled Reactor, Metal Cooled Reactor and the Gas Cooled Reactor. This grouping is based on technology and differs from the classification which deals with the temporal development of nuclear power plants, which separates four generations. The first generation class includes only early prototypes of nuclear reactors. Because the modulus functions of reactor design are connected among one the others a series of different names of reactor systems can be summarised as sub-groups or crossbreeds.

To obtain an idea about specified reactors, names used are the Advanced Pressurized Heavy Water Reactor, High Power Channel Reactor, Aqueous Homogeneous Reactor, Supercritical Water Cooled Reactor, Advanced Gas Cooled Reactor, Liquid Metal Fast Breeder Reactor (Sodium Cooled Fast Reactor, Lead Cooled Breeder Reactor), Very High Temperature Reactor, Pebble Bed Reactor and Molten Salt Reactor. [1][4]

B. Turbine Generator and Reactor Vessel

All larger power plants operate with turbines to drive generators. This is also true for solar power plants that take advantage of radiation to produce steam to turn a turbine. Oil-fired, coal-fired, wood-fired and other traditional power plants utilize a combustion chamber to engender steam at high pressure, except power plants that operate with liquid biomass or direct electricity producing systems like fuel cells, photovoltaic and hydroelectric plants. Instead of a combustion chamber, nuclear

power plants have a reactor vessel. For this reason, they are categorised the easiest way over their reactor design and function.

III. COMPONENTS AND FUNCTION

Main similarities and differences of the basic components and functions will be explained in the following section.

A. Fuel Rods

Before spreading the differences, major similarities of the reactor types will be summarised. Lowly enriched uranium-235 (2-3 %) pellets are filled into long fuel rods (5 m). These are clustered into blocks. Fuel rod material consists of zirconium (Zr), zircaloy®, steel or ceramics. The reactor core is built by setting these blocks together. [1][8][10]

B. Fission of Uranium

The energy production process begins with the fission of uranium atoms. Free neutrons split uranium atoms. Each fission releases around two or three new neutrons and enables a chain reaction. Many of these neutrons have high kinetic energy. It is possible to utilize them for enriching thorium-232 to U-233 (natural uranium) inside the reactor core. But for this transition an extra amount of neutrons is needed (Fast Breeder Reactor). Very fast neutrons are not able to split many atoms and the heat production is therefore deficient. [2][5]

C. Moderator and Coolant

For two purposes water is pumped through the fuel rods. First, it acts as moderator to thermalize the neutrons. By deceleration they are brought to the average speed of the surrounding uranium atoms (thermal neutron reactor design). This increases the fission rate (and neutron flux) and transfers the chain reaction into service conditions. Heat is then produced permanently. The second function of water is to absorb this heat and carry it to the steam generator. In this example only one material (water) acts as moderator and coolant simultaneously. Other reactor vessel design contain two materials for these purposes. These are helium, carbon dioxide, sodium, lead, molten salt as coolant and graphite, light or heavy water as moderator. [5]

D. Core Structure

The hot radioactive water that leaves the pressure vessel is looped through a steam generator, which in turn heats a non-radioactive (secondary) loop of water. Some reactors operate with a high number of small pressurized-tubes instead of a vessel (High Power Channel Reactor), which contain the fuel,

moderator and coolant. The possibility of series production of the components has the effort to scale the dimension of this reactor easily, but the complex core structure creates difficulties in regulation of the core and exalts the requirements for maintenance and nuclear knowledge (Chernobyl; Type: RMBK - Reactor Bolshoy Moschnosti Kanalniy considered to be one of the most dangerous reactor design). The idea of apportion the core (like fuel cells) into simultaneous operating units has potential, but it is not researched any longer. One economic reason is the volume consumed of this system. That makes the containment buildings expensive. [2][4][9][10]

E. Control Rods

To control or stop the reaction control rods are set between the fuel rods (or pressure tubes). Other fuel rod blocks include them. In the quantity they are driven into the core they assimilate neutrons and slow down the fission and heat production. If control rods were installed above the core, they can drop in the core by gravity in the event of a power blackout. Control materials are boron (B), cadmium (Cd), boron carbide (B₄C) as well as hafnium (Hf), indium (In) and silver (Ag) or ceramics. Control rods are made of an alloy of aluminium (Al) and boron carbide (= boral®). [4][5][6]

F. Steam Generator

The steam generator extracts the heat and utilises it to convert its medium (usually light water, H₂O) into steam. The core (or primary) circuit and turbine (or secondary) circuit are generally separated (otherwise it is a boiled water reactor, BWR), only heat transmission occurs. The coolant is set under pressure so that it cannot boil inside the vessel (pressurised water reactor otherwise it is a BWR). If water usually at 155 bar is used (BWR have lower pressure level) then it has around 330 °C when entering the steam generator. Inside the turbine circuit water shifts into steam due to the remarkably lower pressure level (70 bar). Other coolants like gases or liquid metals reach higher temperatures (Very High Temperature Reactors) and have better thermal efficiencies. [1][10]

IV. WATER REACTOR

A. Pressurised Water Reactor

Ordinary PWR (pressurized water reactor) operate with light or heavy water or graphite as moderator. Heavy water (D₂O) is less reactive, not as corrosive and does not absorb as many neutrons as light water. That is why the enrichment of uranium can be lower or natural uranium can be used, which decreases the cost for enrichment as a benefit for the running costs. Light water reactors require enrichment of U-235. An increased neutron flux does intensify the requirements for the core materials. PHWR can be refuelled while at full power, which makes them very efficient by allowing a precise flux control in the core (neutron economy) and optimal use of uranium (fuel management). Nation with own uranium reserves and no expensive enrichment plant prefer heavy water. [7][8]

PWRs represent the current majority of installed nuclear power plants worldwide. They are considered to hold the second place in safety and reliable technology. This is the state of

the art. The newest designs are the Advanced Pressurized Water Reactor and the European Pressurized Reactor; all belong to generation class III or III+. [1][4]

B. Boiled Water Reactor

Instead of two circuits a BWR (boiled water reactor) has only one and feeds the turbine directly. It has no steam generator and its coolant boils inside the pressure vessel. This why the construction cost are considerably lower compared to a PWR. But maintenance, resistant materials against radioactivity and the contamination of the turbine and other devices raise the service operation costs. Also, the waste disposal of activated systems is directed against sustainability (Kyshtym disaster, INES 6, 1957). The thermal efficiency of these reactors can be higher. They are simpler, and even potentially more stable and safe (Fukushima-Daiichi, INES 7, 2011). Circulation pumps and a positive void coefficient enhance the system-related interior risk for a meltdown, especially when graphite acts as moderator (Chernobyl, INES 7, 1986). This type belongs to generation II. The boiled and pressurised water reactors are the most common nuclear power systems. The first reactor to have a core meltdown (NRX-Reactor, INES 5, 1952) was light water cooled and heavy water moderated. BWR is a thermal neutron reactor design, the newest of which are the Advanced Boiling Water Reactor and the Economic Simplified Boiling Water Reactor. [1][2]

C. Aqueous Homogeneous Reactor

Aqueous Homogeneous Reactor (AHR) uses soluble nuclear salts dissolved in water and mixed with a coolant and a neutron moderator. In the quantity water is mixed with nuclear salt this type equals with the molten-salt technology. [1][4]

D. Distinctive features of Water Reactor

The differences in design of water reactors are determined essentially over their coolant, second by moderator, and in detail about modulus function and structure:

- Structure: vessel, pressure-tubes, circuits one/two, steam generator no/yes, fuel rods (or balls)
- Function: pressure high/low, boiled/liquid, reaction thermal (or fast)
- Moderator: water, graphite
- Coolant: water (gas/liquid metal = other reactor types)

V. LIQUID METAL REACTOR

A. Molten Salt Reactor

Molten Salt Reactors (MSR) dissolve the fuel in sodium, zirconium, and uranium fluoride salts, or use fluoride salts as coolant. One remarkable safety feature is that they have no high pressure or flammable components in the core is. In combination with high efficiency and high power density MSR are suitable for vehicles. The prototype produces only 0.1 % of the radioactive waste of standard reactors. This technology is a candidate for another type (No. 4) of nuclear power system classified by core liquid. If molten uranium (fissile material) is cooled by a working gas this system should be added to gas reactors. [1]

B. Sodium or Lead Cooled Reactor

A LMR or LMFBR (Liquid Metal Fast Breeder Reactor) uses sodium or lead as coolant and graphite as moderator or is completely unmoderated. Liquid metals provide excellent radiation shielding and for example, sodium does not harm the fuel rod material (here steel). It prevents corrosion, is mostly transparent to neutrons (sodium is not getting radioactive easily) and boils not until around 900°C. No huge pressurized atmosphere inside the containment is required, even at very high temperatures. Most LMFBRs are of this type. A great disadvantage of sodium is that it explodes violently when exposed to water. Large quantities of lead (or lead-bismuth eutectic mixtures) may be problematic from toxicology and disposal points of view. Sodium and lead are inert and possess higher densities why the circulation pump capacity must be greater to carry heat away. LMR can operate at high temperature efficiency. [1][2][4][10]

C. Fast Reactor or Breeder

Breeder or fast reactors (fast neutron design) usually perform at overcritical conditions. They produce more fissionable fuel than they consume, because of neutron capture, which means that they enrich existing natural thorium or uranium themselves. The exterior fuel rods inside the core stand in the incubation zone. It is possible to generate radio nuclides (radioactive elements) for medical and technical application or plutonium for nuclear bombs. [2][10]

D. Nuclear Power Module

Another liquid core uses uranium hydride (H_3U) as fuel and is hydrogen (H) moderated. It is a completely industrial fabricated "nuclear battery" or nuclear power module (HPM) with an electrical power up to 550 MW. It is possible to cluster the module to scale the power individually or add capacity over time. A 25 MW scaled module (~ 50 Mio. USD) would produce electricity for around 20,000 homes up to 30 years and would need to be refuelled every two years (for 10 days) at full power and reconditioned every seven to ten years. The module having a turbine generator and no pumps, is independent and the manufacturer is responsible for the waste management. The Hyperion Power Generation® is a self contained, automated, liquid metal nuclear reactor that can substitute the function of larger fuel cells as long as they are uneconomically and technologically immature. A worldwide demand is given. Questions about terrorism and administration were discussed. For this reason the series production has not started (maybe 2014). [3]

VI. GAS REACTOR

A. Gas Cooled Reactors

Built GCR or High Temperature Gas Cooled Reactors (HTGCR) and AGR (Advanced Gas Cooled Reactor) operate with helium (He) or carbon dioxide (CO_2) as coolant and generally graphite as moderator. While some reactor cores have graphite blocks others are filled with uranium and thorium (Thorium High Temperature Reactor, THTR) that is sheathed with graphite in the shape of balls. The containment only embodies this fuel moulded into ceramic balls (Pebble Bed Modular Reactor, PBMR). The fuel-balls actually form the core's

mechanism, and are replaced one-by-one as they age. Gas is circulating through the balls. Thorium-232 is converted into U-233 (Breeder or Fast Reactor). The result is a high thermal efficiency compared to PWRs, low-maintenance, "very" safe reactor with inexpensive standardized fuel. A huge advantage is that thorium-232 is more plentiful on earth than uranium. U-233 is also believed to have favourable nuclear properties when compared to traditionally used U-235, including better neutron economy and lower production of long live transuranic waste. The incubation zone can be devoted to deliver fuel for other nuclear reactor types, for example light or boiled water reactors. Several reactors were especially designed to unify all these purposes. The decommissioning costs can be high due to the implemented large volume of the reactor core and fuel design which makes fuel reprocessing expensive. [1][2][4][7][8][9][10]

B. Helium

Helium has a lower capacity of heat transport than water, but helium can reach high temperature (800 °C – 1,000 °C) under relatively low pressure (39 bar). This extra amount of process heat enables the manufacture of hydrogen for fuel cells or direct use in the petrochemical industry. Helium has a high thermal conductivity, is non-reactive, non-corrosive, incombustible, inert, stable and transparent to neutrons. It is not getting radioactive in contrast to CO_2 . Because of a small atomic size, the reactor and loop have to be very leak proof. It does not dissolve contaminants inside the interior machinery that become radioactive as water or sodium. Typical designs have more layers (up to 7) of passive containment than light water reactors (usually 3). [1][4][9]

C. Gaseous Uranium Hexafluoride

The future development and projects to evolve generation IV also address the direct use of gaseous uranium hexafluoride (UF_6) inside the core. UF_6 is an intermediate in the production of uranium (particularly U-235) which engenders pellets at high costs. In theory, it would mean lower processing costs, and smaller reactors. In practice, running a reactor at such high power densities would probably produce uncontrollable neutron flux. New studies are testing options to push gases directly on the turbine. [1][8]

VII. ECONOMY

A. Revenues

As a matter of fact, the responsible power companies and power plant operators do not provide appropriate information. The power plant operators' income is derived from the traded spot price for electricity of the European Energy Exchange in Leipzig (EEX). This constitutes the price at which each MWh is sold. In 2009, the average electricity price for one single base-load MWh was 39 €, the price for one single peak-load MWh was 51 €. Thus the price was 40 % lower than in the previous year. This drop in prices can be attributed to lower fuel costs as well as emission allocations. Also the increase of renewable energies and the resulting fluctuations in the electricity supply influenced the prices [11].

B. Fixed Costs

Cost analysis for nuclear power plants is very complex, compared to revenue estimation. In terms of costs, nuclear power plants that vary in their performance, reactor types and locations are very difficult to compare. For each type of cost substantial differences can occur for different parameters. Fixed costs include investment for the plant and its equipment, interest, depreciation and insurance premiums [12]. Thus, the level of fixed costs depends on various factors such as interest rates, depreciation methods, financing, utilisation time of the plant and insurance rates [12]. In general, the fixed costs of nuclear power plants are still very high in comparison to other traditional power plants even after 50 years of experience with the technology [12][13]. Eventually, they amount to estimated 70,000 €/MW a year [14].

C. Variable Costs

The variable costs of nuclear power plants consist primarily of the energy costs itself (transportation, storage, disposal) and the expenses for the power plants' operation, maintenance and repair [12][13]. The estimated amount of nuclear power plants' variable costs adds up to 7.5 €/MWh [14]. Based on the aforementioned values for a modern plant with an electricity production of 10 TWh and a capacity of 1,350 MW, electricity generation costs total 1.695 €/kWh [14].

D. Real Costs

The real costs of nuclear power include not only fixed and variable costs but also additional costs. The additional costs have mainly to be met by government and society [13]. The real construction costs and time hardly can be estimated exactly in advance [13]. Furthermore, there is no private insurance for nuclear power plants that could cover the consequences of a nuclear accident [13]. The estimated damage of such a severe event in Germany amounts to about 5,000 billion € [13]. The German Atomic Energy Act regulates that the damage caused by nuclear power plants has only to be covered up to 2.5 billion € (§ 13 AtG) [13]. Thus the society would take on almost all the damage. If the whole risk was insured, costs would have resulted in between 0.215 €/kWh and 1.84 €/kWh [13][14]. The high standard of safety requires extensive upgrades and renovations [13]. After 40 years of operation an investment of 500 €/kW is needed to ensure a safe operation for the next 20 years [14]. Life times over 60 years would still be uneconomic due to the higher costs for upgrade in the range of 1,200 €/kW to 1,600 €/kW [14].

The actual costs for the deconstruction of nuclear power plants and the safe storage of radioactive waste are not yet predicted [13]. It appears that the applied liability reserves are probably not sufficient. Moreover, nuclear power plant operators can reduce their income tax to generate liability reserves [15]. In Germany, the operators use their deconstruction and disposal reserves for other business activities like reduction of debt financing [15]. Further tax benefits resulted from the non-taxation of nuclear fuel until the end of 2010 [15]. In addition, the Federal Government guarantees for exports of nuclear technology [13], funds nuclear research projects and the police security of nuclear waste transports [15]. What the total costs include and what the additional costs of nuclear power actu-

ally are, can hardly be evaluated. Based on the amount of costs which are often not considered in calculations, it is questionable whether nuclear power truly is economical. Therefore, recent discussions on energy policy necessitate the presentation of various studies that have dealt with this issue.

E. Results of international studies

As high capital costs and low marginal operating costs are representative features of a nuclear power plant, its energy will compete with alternative electricity generation sources for base load operation, such as coal and gas. But, in opposition to facilities using these fossil-fuels, all of the nuclear power plants operating today have been constructed within non-competitive markets under public ownership or governmental regulation [17][18].

Many industrial nations' electricity markets are currently at advanced stage of transformation into competitive electricity industry structures. This implicates that new nuclear power plants will have to be developed and constructed as merchant plants. Thus, they provide electricity supply in the short and long run on the basis of contracts. Add to this, operators will have to consider the permission progress, design, development and construction cost and operating performance risks of a new facility. However, by competitively negotiated and termed contracts, at least some of the risks might be transferred to customers as distribution corporations and consumers on the wholesale and retail markets. Nevertheless, uncertainties and large contingencies associated with permission, construction and operation of a nuclear power plant within a competitive electricity generation market remain. Investors and generators must bear and consider such risks due to their significant effects onto the cost of capital for investors. According to this situation, potential investors prefer less capital-intensive and shorter construction projects.

Another problem is the development of historical construction cost experiences, which were expected to decrease due to economies of scale. Instead of this, many regulatory admission delays, demands for redesign, construction and quality control problems have accrued [17]. Besides, only few new nuclear power plants have been under construction or completion in the last two decades anywhere in the world, a situation that additionally limits technical progress, scale economies and available information about construction cost. In addition to the high costs and risk uncertainties of construction, the lack of representative construction performance minimises incentives to credible investment in new plants. This suppresses the demand for erection of new nuclear power plants [18]. In addition to the 443 plants in operation throughout the world in January of 2010, there have been 55 new reactors under construction. For instance, China started work on 15 plants in 2008/09. The European main power plant vendors, Westinghouse and Areva NP, are only involved in two projects outside from China. Olkiluoto in Finland and Flamanville in France are Generation III/III+ reactor construction sites of Areva NP [17][18].

According to the recent PSIRU study of May, 2010, there are key determinants of overall electricity costs of nuclear power plants as follows. For comparison purposes generally

the overnight cost is quoted, which contains the first load of fuel, but excludes the interest during construction. Moreover, this cost data is given per installed kW. Eventually, there are some challenging aspects of construction [16][17]:

- unreliable data:

Prognoses of construction costs have often been inaccurate and strongly underestimated. In opposition to combined-cycle gas turbine plants including fixed contract prices, nuclear power plants are not sold by turnkey contracts. These Gas turbine plants are manufactured in large numbers and require little on-site work. In contrast, the on-site engineering of nuclear facilities represents approximately 60 % of the overall construction cost because of complicated cost control and administration. Contrary, the main components that are procured on turnkey terms like the steam generators, reactor vessel and turbine, add less to the total cost. Furthermore, particularities at specific sites require consideration such as type of water cooling [16].

- forecasting difficulties:

Adding to the points given above, subsequent design changes or completely new designs might become necessary due to safety regulatory requirements or inefficient construction designs. This often introduces unexpected problems within the construction process [16][17].

- learning, scale economies, and technical progress:

As mentioned before, there was expected a significant decrease in the development of construction costs by economies of number and learning effects. But with the technological progress, costs have risen, too. Another cause often quoted is increased regulatory requirement. In the 1970s, the main vendors were receiving up to 10 construction orders a year. This made the production of the main plant components more efficient and allowed them to assemble skilled workgroups. But cost reduction by multiple processing is still difficult to estimate. The study states a report of the Nuclear Energy Agency, which figures out the economies of scale not being extensive: „The ordering of additional units in the same series will not lead to significantly more cost savings. The standardisation effect for more than two units of identical design is expected to be negligibly low“ [22].

There have been only few new orders for western vendors in the last 20 years. That caused retraction within production lines and project teams. Within the last 25 years before getting the order for Chinese plants in 2008, Westinghouse had achieved one single contract. Furthermore, the construction site in Finland means Areva’s first project by 15 years. Add to this, large equipment items generally need to be subcontracted to specialised companies on the basis of expensive unique contracts. Major shortage in component manufacturing is expected. For instance, only Japan Steel Works is able to cast important items for certain reactor pressure vessels [16]. Furthermore, the shortage of skilled labour becomes urgent, as the German Environment Ministry stated: „The number of nuclear graduates and technicians is insufficient and many graduates do not enter or quickly leave the nuclear sector“ [19].

- construction time:

An extension of the construction time can have severe impact on the facility, especially if the electricity output is already contracted and it will tend to increase interest during construction. Such a situation forces the utility to buy “replacement power” to supply its customers with the power they had contracted from wholesale electricity market until the plant has been erected. In every case, the long overall lead time and its possibility for delays result in many risks as failure or cost escalation for the generating utility. As the Sizewell B reactor in Britain eventually entered commercial service in 1995, it had taken 16 years until the vendor finally handed over the plant’s operation [16][17][18].

- cost of capital:

Large projects are financed through a combination of debt and equity. The costs of debt depend on the “risk-free” interest and the risk of the project. Moreover, the cost of equity is influenced by the additional interest the company has to pay to compensate its shareholders for the delay of dividend payout. Thus, the cost of equity is nearly always higher than the cost of debt. Nevertheless the company needs to be prepared to risk its own money [16][17]. Due to the large significance of the capital charges, the required rate of return severely impacts the economics of nuclear power plants. The real cost of capital vary regarding to the electricity market characteristics, the specific risk of the country, the utility credit rating and the structure of public or private ownership. They are assumed to be about 5 to 8% within a regulated monopoly and more than 15% in a competitive electricity market. In such efficient competitive markets the generation company bears the risk of investment, not the consumers. The cost of capital could be decreased by risk reduction through government guarantees and state aid. Thus, Vattenfall benefits from high credit rating as a Swedish state-owned utility and consequently benefits from lower capital cost and less shareholder pressure compared to the two main German utilities, E.ON and RWE, which are partly or wholly owned by private shareholders [16].

In the United States the government provides financial security for companies using technologies that avoid emissions of greenhouse gases. These companies are enabled to cover their borrowings by federal loan guarantees which pay lenders if the borrowers fail on their debts. In 2007 six of the largest US investment banks at that time demanded financial support from the government. The investment banks justified their requirements on “the higher capital costs and longer construction schedules of nuclear plants as compared to other generation facilities” [20]. Moreover, they are “concerned about a number of political, regulatory and litigation-related risks that are unique to nuclear power, including the possibility of delays” [20]. They stated that the DOE should assure 100 percent of the loans as one of the “minimum conditions necessary to secure project financing from lenders and from investors in the fixed income markets” [20].

- operating performance:

Particularly for capital-intensive technologies and base-load power plants a high utilisation is essential. Contrary to the construction costs, the load factors are precisely measured and

regularly published by the press. They measure the plants' reliability and display a wide spread of utilisation. For instance, in Germany the observed overall lifetime load factors are distributed between 53,7 % and 93,3 % to the end of 2008 [21].

These operating numbers indicate further potential for unexpected risk, as their impact on the cost of power is very large, too. According to the PSIRU-study, only the top 100 out of the 414 operating plants have a lifetime load factor of more than 80 % [16]. New reactor designs increase the level of reliability, but also emerging performance problems in the first years of operation are likely to occur among them. Because of the discounting Cash Flow method of an economic analysis, such "teething problems" of the early years have more impact on the cost of power than the improvement requirements and replacement of worn equipment within later years [16].

REFERENCES

- [1] A Technology Roadmap for Generation IV Nuclear Energy Systems, issued by the US DOE Nuclear Energy Research Advisory Committee and the Generation IV International Forum (GIF), Dec. 2002, download: <http://gif.inel.gov/roadmap>, 2010.11.30, 01:44
- [2] Matrin Volkmer, "Kernenergie Basiswissen", revised edition, Berlin: eds. Informationskreis KernEnergie, kernenergie.de, kernfragen.de, ed. Winfried Koelzer, Volker Wasgindt, press. UbiaDruckKöln, ISBN 3-926956-44-5, Juni 2007, pp. 20 – 51
- [3] Jan Bornebusch, "Kernkraftwerk für jedermann" about Hyperion Power Module, spektrumdirekt [08.11.2010], download: <http://www.wissenschaft-online.de/artikel/1053834>, 2011.01.24, 23:11
- [4] Wikipedia.org, writ. many authors, ed. Wikipedia – The Free Encyclopedia: articles [Nov. 2010 – Jan. 2011]: "Generation IV-Reaktor", "Generation IV International Forum", "Boiled Water Reactor", "Pressurized Water Reactor", "Thorium High Temperature Reactor", "Molten-Salt Reactor", "Pebble Bed Modular Reactor", "Very High Temperature Reactors", "Gas Cooled Reactor", "Reaktor Bolshoy Moschnosti Kanalniy", "High Power Channel Reactor", "Fast Reactor", "Helium", "Zirconium", "Silver", "Hafnium", "Uranium", "Cadmium", "Thorium", "Sodium", "Lead", "Boron", "Indium", "neutron" "radioactivity", "steam generator", "Kernreakortechnologie", "Nuclear Reactor Technology", "Liste der Unfälle in kerntechnischen Anlagen", "Internationale Bewertungsskala für nukleare Ereignisse", 2010/11
- [5] AREVA – In the heart of a Pressurized Water Reactor, Movie: EPR – Olkiluoto 3 (Finland) : [eng., 6 min 2sec., mpg, 150,447 KB], AREVA Corporate Communication +33(0)147 962 987, Image & Process +33(0)478 221 075, Copyright © AREVA – Image & Process, 2004
- [6] Lisa Kampert, "Das Ende des Atomzeitalters – oder sind neue Reaktoren sicherer?", Münster-Hiltrup, Immanuel-Kant-Gymnasium, school year 2008/09, LK Physik 12.2, Herr Tüllmann, März 2009
- [7] Patent, "Cores für Hochtemperatur-Kernreaktoren", inventors: Kugeler, Kurt, Prof. Dr.-Ing.; Phlippen, Peter-W., Dr.-Ing.; Schmidlein, Peter, Dr.-Ing., 4100 Duisburg; Mühlensiep, Jutta, Dipl.-Ing., 4000 Düsseldorf, Fricke, Ulrich, Dipl.-Ing., 4100 Duisburg; representative: Bauer, H., Dipl.-Ing., Pat.-Anw., 5100 Aachen, Applicant Forschungszentrum Jülich GmbH, 5170 Jülich; document identification DE3519934C2, filing date 04.06.1985, Certificate 3519934, disclosure day 04.12.1986, publication day of patent grant 17.01.1991, publication day of patent journal: 17.01.1991, IPC-Main Class G21C 5/00, IPC-Subsidiary Class G21C 1/07 G21C 9/00; 17.01.1991
- [8] Martin Faessler, "Kernreaktoren" about nuclear energy, Department für Physik, LMU, Vortrag 23.10.06 im Rahmen der Ringvorlesungen "Das Energieproblem" download: http://www.physik.uni-muenchen.de/lehre/vorlesungen/wise_06_07/ep1/vorlesung/skript26_5_2.pdf, 23.01.2011, 04:11
- [9] n.p., "Aufbau und Funktionsprinzip von AKW's", download: http://www.w.cgg.at/htdocs/chemie/schuelerdaten_alt/referate_alt/12.htm, 2011.01.24, 00:19
- [10] n.p., "Überblick über Reaktortypen, die zur Stromerzeugung eingesetzt werden", Reaktorschule Paul Scherrer Institut CH-5232 Villigen-PSI, download: <http://www.ensi.ch/fileadmin/deutsch/files/Reaktortypen.pdf>, 23.01.2011, 20:54
- [11] RWE annual Report 2009 http://rwecom-online-report-2009.production.investis.com/lagebericht/wirtschaftliche-rahmenbedingungen/strompreis_e.aspx
- [12] Grosse Niels: Ökonomie der Kernenergie, Kyklos – Verlag Basel (1963) Seiten 68 -69 sowie 96 – 97
- [13] EUROSOLAR – Info (April 2006) „Die Kosten der Kernenergie“, EUROSOLAR Europäische Vereinigung für Erneuerbare Energien e. V.
- [14] "Kernenergie im energiepolitischen Zieldreieck von Klimaschutz, Versorgungssicherheit und Wirtschaftlichkeit." – Wuppertal Institut für Klima, Umwelt, Energie GmbH RWE annual Report 2009
- [15] "Staatliche Förderung der Atomenergie" Studien vom Forum ökologisch-sozialer Marktwirtschaft im Auftrag von Greenpace
- [16] S. Thomas, "The economics of nuclear power: an update," Public Services International Research Unit, University of Greenwich, pp. 13–29, March 2010.
- [17] S. Ansolabhere et al., "The future of nuclear power", Massachusetts Institute of Technology, 2003
- [18] Y. Du, J.E.Parsons, "Update on the cost of nuclear power", MIT Center for Energy and Environmental Policy Research, May 2009
- [19] "World nuclear industry status report 2009", German Federal Ministry of Environment, Nature Conservation and Reactor Safety, 2009
- [20] "Investors' comments in response to DOE notice of proposed rulemaking on loan guarantees for projects that employ innovative technologies, July 2007
- [21] IAEA, <http://www.iaea.or.at/programmes/a2/>
- [22] Nuclear Energy Agency, Reduction of Capital Costs of Nuclear Power Plants (Paris: OECD, 2000), p. 90

Gliederung Entwicklung der Atombewegung (Fokus Deutschland)

Philipp Wahle
Lehrstuhl Energieverteilung und Hochspannungstechnik
Brandenburgische Technische Universität Cottbus
Cottbus, Germany
philipp.wahle@hotmail.de

Markus Strauß
Lehrstuhl Energieverteilung und Hochspannungstechnik
Brandenburgische Technische Universität Cottbus
Cottbus, Germany
smarkus2007@yahoo.de

Keywords-component; formatting; style; styling; insert (key words)

I. INTRODUCTION (HEADING 1)

In this paper the development of anti-nuclear movement in Germany is examined in more detail. This begins in the 70s, and develops in the 80s for most citizens' initiative in Germany. There were anti-nuclear demonstrations, with over 100,000 participants. However, beginning in the mid-80s and the decline of the movement, since it loses much traction. Today the focus has changed the resistance. The central issue today is the problem of waste storage and waste transport resistance.

There was the first significant opposition to nuclear power plants in the Federal Republic of Germany in '72 - '73rd This is a year or two later than in France and Sweden.

Besides the question of why have the people committed to nuclear power plants, and still do, it is interesting to know what kind of people that. It can be said that there were many different currents, whose only common denominator the rejection of nuclear power plants was. In other political issues was to be irreconcilable. In the beginning there were many in the movement of bourgeois and conservative tendencies. Over the following years the movement was more anti-capitalist and anti-state trains. This is not least due to the hard access to the police against demonstrators back. Now it also looks at why there is opposition to nuclear energy at all. First, here are the fear of the destructive potential of nuclear energy is mentioned. The people and have had prior to the issue of nuclear power Hiroshima, Chernobyl eyes or later. Second, the fear of Radioktivität and their effects is mentioned. This refers to the normal operation of power plants, and even more problems with breakdowns and malfunctions. Furthermore, there were protests because of the structure, in which it is possible to build nuclear power plants. Of nuclear energy is a major technology that is beyond social and political

control processes. To use this technology you need the appropriate support of the political system, and in the opinion of the motion it follows the formation of a surveillance state in order to make the same power plants without disabilities.

Important events:

In February 1975, 28 000 protesters stormed and occupied the site of the NPP Wyhl. were protests against the construction projects it before, and it escalated into this form of protest. In the further course was before the administration court Freiburg obtained a building freeze. This event can be seen as the start of the anti-nuclear movement because it has triggered media interest, but it also represents a victory against the nuclear industry. After the incident in Wyhl exacerbated the police actions against the demonstrators. To acts of demonstrators, the police responded by also changing behavior. As an example, eye Distinct trenches or teach new fences were mentioned. At the time it came to separate the initial mass described. Overall, the movement was in the time a radical left-wing influence what is in the above-described motivation of the movement (head note: police state) is editorial. In conclusion we can say that the knowledge of the nuclear mid to late 70s in the anti-nuclear movement was very poorly marked, and the demonstrators to demonstrate aunts (especially the non-regionally-based) also had other motivations.

1979 demonstration in the Wendland (Gorleben). This should be upfront reprocessing plant. Exploration wells to prevent violent protesters. On March 28, it is the first MCA in the United States (Harrisburg), with the result that demonstrate the 100,000 people in Hanover against nuclear power, reprocessing and the building project is abandoned. In 1980, a drilling site in Gorleben for 2 months of protesters occupied. The goal is the prevention of interim and final storage plans for Gorleben. This plan is deemed to have failed.

Excursion: The Green party.

At this point a little excursion follows in the history of the Greens. There were two lines of development that led to today's party. In the former GDR was one line of development. The focus here was the civil rights movement. End of 1989, "Initiative Frieden, Menschenrechte", "Demokratie Jetzt", together, and parts of the "Neuen Forums" for the "Bündnis" in 1990 and moved to the fall in the Bundestag. The Greens in East Germany merged in 1990. In 1993, joined together, the Greens and Alliance 90. In 1994, the "Bündnis" 90/Die Grünen in the Bundestag, and again between 1998 and 2005 they were at the red-green coalition for the first time participated in the federal government.

The line of development which is more interesting for this paper is available in West Germany around 1980. In the creation story it is said that the party has been transformed from social initiatives of the 70s, and especially from the anti-nuclear movement. The reason is discussed why it is because of the history of this party can easily read a transformation of society from 1980 to 2010. At the beginning of the party its members and voters as environmentalists and querulous were insulted that knit their own sweaters, and eat only organic products. In the first elections the party was far below the 5% hurdle. First successes came during one of the time, but until the mid-90's image was preserved in the Green voter. Today, yields a very different picture. It is now relatively widespread, that the population concerned with the origin of food, and that value is placed on organic farming. Issues such as sustainability or renewable energy sources are now being discussed by the general public through it. This can be clearly seen in the development of choice shares of the Open, because this party is on track to develop into a popular party in Germany. Currently, she would receive about 20% of the vote, and a level just behind the Social Democrats. In the anti-nuclear movement, the founding of the party was perceived more critical or hostile. The idea to shift the discussion from the roads in the parliaments did not like. It was also felt that this party would not be able to achieve anything against the construction of nuclear plants, and they would legitimize quasi-democratic. Furthermore, there was concern that the party would distance itself from militant action, and it would cause an increased criminalization of the left, extra-parliamentary wing. When it came to first state government interests, the agreements were designated as a betrayal of the principles and the anti-nuclear

movement. Even the withdrawal from nuclear energy in 2000 was not far enough for many.

1985 Wacker (Bayern) was identified as the site to build a reprocessing plant. Again, there are massive protests and occupations of construction sites. In the course of clearing operations a demonstrator killed by a CS gas attack by the police.

Drives the 1986 nuclear disaster at Chernobyl, the anti-nuclear movement to new members. These come mostly from middle-class background. However, the "new" and "old" members have little in common, so that actions are more in parallel. This is above all safe to the very different worldviews of the two groups. It is, however, again to protest against nuclear energy with more than 100,000 demonstrators in various German cities. In the same year, a demonstration against the NPP Brokdorf was already prevented in advance. This power plant was the first nuclear power plant, which has gone after the reactor accident at Chernobyl in the network. This was also the time when the anti-nuclear movement lost much of its attraction. This can be explained by the fact that it is not as spectacular successes such as could be enforced in Wyhl. In particular, that the commissioning of nuclear power could be Brokdorf prevent the movement was frozen in despair. Success no longer be perceived, neither the media nor in the movement itself.

With the beginning of the 90s shifted the nature of the protest. From the anti-nuclear movement is an anti-nuclear movement. There is more content and with promotions trying to draw attention to the intractable problem of waste storage. From 1995 keeps trying to stop Castor transports. The goal of these actions is to cause as high cost of transport to make it clear that there is still a nuclear hostility in the country. The goals to create the highest possible cost, and do a great media interest in the subject, works very well with great regularity. Most recently, a Castor transport on 6-7. November 2010 has held up, which required a large police operation, and causes another very high costs.

REFERENCES

- [1] ...und auch nicht anderswo!
Bernd-M. Beyer, ed. Von der Red. Atom-Express.
Die Geschichte der Anti-AKW-Bewegung
Verlag die Werkstatt
- [2] Aufstieg und Krise der deutschen Atomwirtschaft 1945-1975

Verdrängte Alternativen in der Kerntechnik und der Ursprung der nuklearen Kontroverse

Joachim Radkau

rororo sachbuch 1980

[3] Risiken der Kernenergie

Fakten und Zusammenhänge im Lichte des Tschernobyl-Unfalls

Jürgen Rassow

VCH Verlagsgesellschaft mbH, 1988

[4] Kernenergie und die zukünftige Energieversorgung

A. Voß, A. Schatz

Verlag TÜV Rheinland

[5] Handbuch der Kernenergie Band 1 und 2

Hans Michaelis

Deutscher Taschenbuch Verlag,

Model Home 2020 innovative energy draught

Daniela Ehnert Olga Schäfer

Abstract: In this article the experimental project „Model Home 2020“ is presented. With an innovative energy concept. The window producer VELUX take a step to the future energy efficient building. The energy concept is introduced and explained in the following parts of the text.

I. The building

In November 2010, in Hamburg an established building are equipped with an modern energy-, daylight-, and climate system. The building is a semidetached house from the 1950's with an base area of 8x8m. The building has also an adjoining building. The structure of the main building should preserved. Also the adjoining building have to take in consideration and should be modernized. During the modernization the building have to be amplified to get more living space. A lot of value have to set on an attractive architecture with a high residential value an comfort. [4;3]



Fig. 1 Active light house in Hamburg-Wilhelmsburg

II. The energy concept

3 aims there persecuted:

3.1 The building should be modernized with smart devices, to get maximum energy

efficiency and a minimum CO2 emissions.[1]

3.2 A future architecture which takes the materials and the environment in consideration. Thus healthy and comfortable conditions are produced [1]

3.3 The use of renewable energies, in particular solar heat as an integrated part of the building, made the building independent from fossil fuels. The required energy is completely covered also the electrical current by renewable energy. [1]

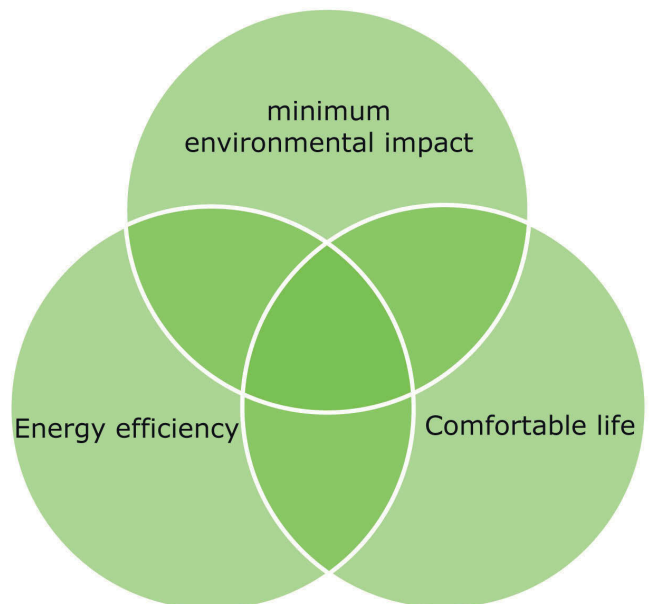


Fig. 2 The concept

III. The building technology

The building was equipped with a solar energy arrangement. By this the heat pump feed in the warm water in the heating circle. Thus the losses of the accumulator will be minimized. The energy consumption of this device is more less than the energy consumption of an normal heating device. Only the spill-over of the heating energy is stored in an accumulator. The heat pump use both solar power and environment heat for energy extraction. This device can nearly cover the demand of warm water and heating. In the process an ventilator to absorb the outside air

and leads them by the external unit. The heat is delivered directly to the pump. The living rooms are tempered about an under-floor heating. [2]

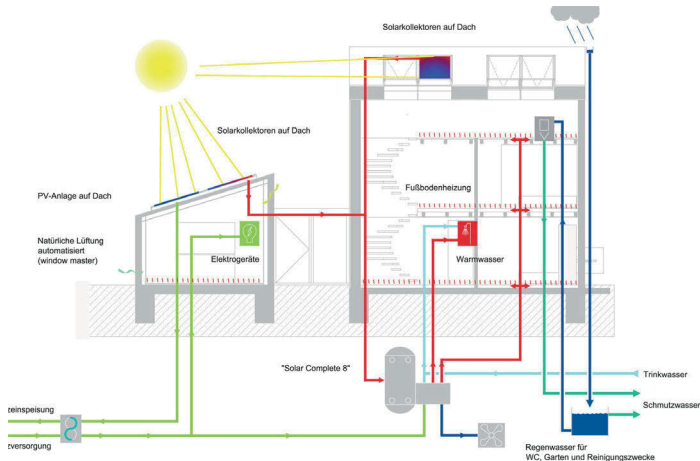


Fig. 3 The energy draught

The required remaining quantity in energy for electric current, electric lightning and help current for the warm pump are produced by photovoltaic cells. The heat energy, the heat requirement and the current demand of 108,5 kWh/m² in the year to get balanced by the own generating system combined with the solar - air/water- warm pump and the photovoltaic cells. [2] Every produced flotation is completely neutralized by regenerative energy production.

CO₂-Bilanz

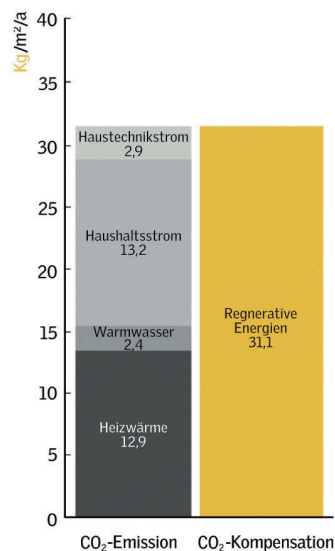


Fig. 5 CO₂-balance

Very important for the house was the air ventilation and the ventilation. It should avoid to fitting ventilation shafts. Therefore the necessary minimum air change to be effected by automatically roof lights and facade lights. Because of wind pressure and differences of temperature between inside and outside only the nature to arrange a good fresh air supply. A chimney effect is generated by differently highly build windows, therefore a naturally air ventilation is supported from top to the bottom. By an intelligent teamwork of shutters steered dependent on light and dependent on temperature and solar protection elements with the windows, the system works like a natural air-conditioning. By the high number of the window elements "the light active house" get a high effect of daylight. Thus the application of electric lightning was reduced considerable and another conservation of electric is possible. [4]

Nutzungs-Energiebilanz

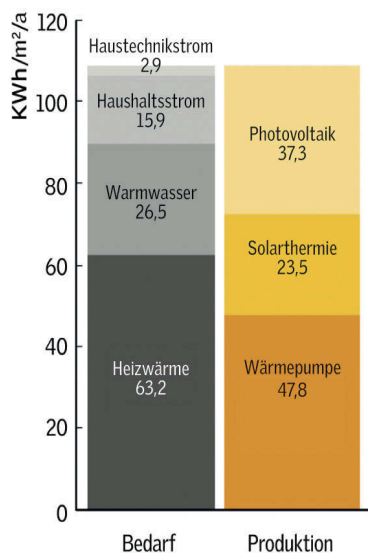


Fig. 4 use energy balance

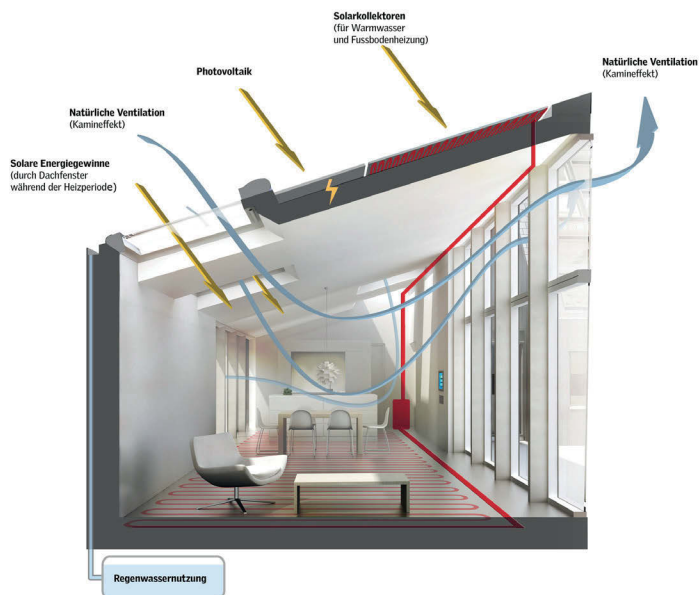


Fig. 6 The annex: Solar collectors for Solarthermie and Photovoltaik on the roof of the cultivation are essential elements for the energetic care of the light active of house.

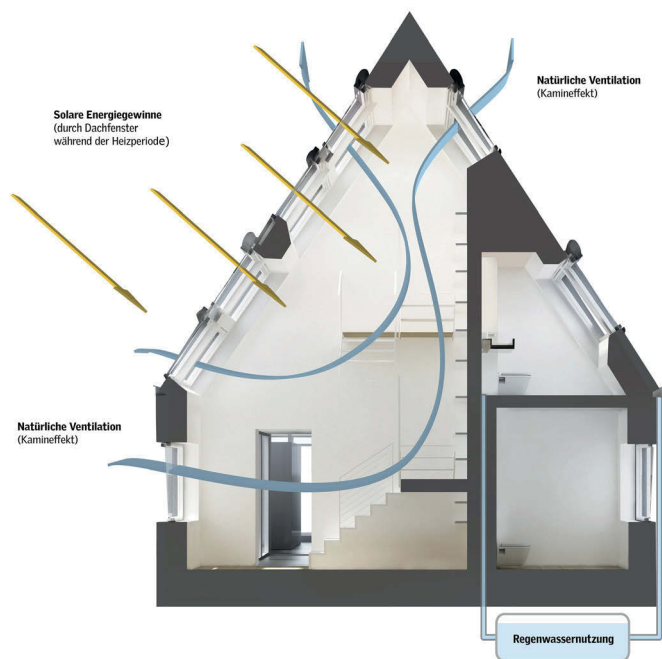


Fig. 7 Regenerative energy covers the complete power demand of the light active of house. Therefore the modernised colonist's house can reach CO2 neutrality in the company.

IV. The rebuilding

The demanding architecture which is obliged to the energetic sighting creates absolutely new stay surfaces and public thoroughfares. An open stairwell has studied from the ground floor up to the roof. This area with much natural light is flowed through the roof windows. It was seen

to an especially bright interior creation whereby the light effects elevated. The highly glazed facade allows a specific constriction to the nature. In the ground floor insert two children's rooms and a bathroom. The parents' bedroom, a dressing room and another bathroom were arranged in the upper floor. The attic floor was also covered in the modernization. This area is actual now light- flooded because of generous roof-lights and accommodates additive living space. After the modernization and the rebuilding of the adjoining building the building services room, a pantry and another guest's bathroom were provided in this area. Finally there is a roofed terrace which creates a connection between inside and outside. [1]

V. summary result

The building was dammed by the most modern knowledge. For the whole building a primary energy demands because of the geometry and other boundary conditions a result to EnEV of 42.28 kWh / m². This value equates to 24.6% for the EnEV reference building of allowed energy demand. The roof constructional systems and ground constructional systems reprove to U-values between 0.12 and 0.14 W / (m²K). In the „Light active house“ rising energy prices do not play any role. The technical arrangements, the sun and the environmental energy make it possible to cover the total power consumption for the whole year. [2]

References

- [1] <http://www.maisonairtelumiere.fr/index.php/lichtaktiv-haus> (16.01.2011)
- [2] http://www.velux.at/ueber_velux/sunlighthouse/6experimente/lichtaktivhaus.aspx (16.01.2011) © 2001, 2010 VELUX Gruppe“
- [3] Institut für internationale Architektur - Dokumentation: Leichte Konstruktionen, Detail, Heft 11/2010, Nr: 50, S. 1224
- [4] <http://www.velux.de> „© 2001, 2010 VELUX Gruppe“

Carbon Capture and Storage

The situation in Germany

Ludwig Zech

Student in Bachelor of Science in
Business Administration and
Engineering

Michael Gutsche

Student in Bachelor of Science in
Business Administration and
Engineering

Richard Klaucke

Student in Bachelor of Science in
Business Administration and
Engineering

CCS captures huge amounts of carbon dioxide (CO₂) in the power plant process. It is probably the most promising alternative to counteract the greenhouse effect in the short term. It basically consists of 3 processes: Capture, Transport and Storage. Currently 3 methods are tested for the deposition. Experiences from the U.S. can be used for the transport. Between the CO₂ producer and the storage is a pipeline network, which guarantees a safe transport. The storage is the most critical process of CCS. There must be a secure solution for several centuries. Currently depleted natural gas reservoir and saline aquifers meet the requirements and are being intensively investigated. CCS does not only split CO₂ – it also splits opinions.

I. INTRODUCTION

“Coal has a future – not the CO₂ emissions from it“ [1] Tuomo Hatakka, CEO of Vattenfall Europe, picks up one of the biggest challenges of energy. Global warming requires active action to reduce greenhouse gas emissions. Climate research proves that the emissions worldwide not only have to be stabilized, they have to be halved by mid-century.

The worldwide growing demand for energy also impedes the achievements of climate protection (Kyoto-protocol). In the World Energy Outlook 2010 the International Energy Agency (IEA) expects an increase in energy demand by 36 percent until 2035 [2]. The protocol of the World Energy Council bases on an increase between 70 and 100 percent up 2050. The reasons for this are the increase in world population and the growing demand from emerging and developing countries [3].

Because of the climate targets and the growing energy needs a low carbon dioxide or better a CO₂-free energy supply is essential. To reach this aim innovations developed by research are necessary. Prof. Dr. Robert Socolow, Co-Director of the Carbon Mitigation Initiative at the University of Princeton, has written in an article in the WirtschaftsReport: “As the Mount Everest, the complex climate problem can only be solved through stages” [3].

One of these stages is the Carbon Capture and Storage (CCS).

The CCS technology provides the possibility of rapidly and significantly reducing CO₂ emissions. It should serve as a bridge until a sustainable supply of energy based on renewable sources is reliably available, at that at calculable prices.

In essence, the CCS technology can be divided into three processes: CO₂ capture, CO₂ transport and storage of CO₂ [4].

Exactly in this order the topics are treated and a conclusion is drawn in the end.

II. CAPTURE OF CO₂

Currently, three methods for the capture of CO₂ are pursued which all have to be more matured and improved.

The important legal basis for CCS was given by the European Council in March 2007, this Council announced the construction up to 12 CCS demonstration power plants as a next step towards the introduction of this technology. The federal government supported this approach vigorously at its summer meeting in Meseberg 2007. “Two up to three of the 12 EU planned demonstration power plants in Germany should be realized“ [5].

The situation in Germany is currently difficult. Companies like RWE and Vattenfall would like to begin the construction of a demonstration power plant, but without the legal basis the necessary security is not given. Without “the adoption of carbon storage law (KSpG) as well as the creation of acceptance for CCS technology by politics“ RWE is forced to “stop the first steps towards an implementation of the IGCC project in Hurth and to take out the momentum of the planning activities of the power plant“ [6]. The planned demonstration power plant of RWE in Hurth uses the pre combustion capture technology. Vattenfall is planning a demonstration power plant in Jänschwalde to embrace technologies of oxyfuel and post combustion capture.

In the following we want to give you details about technologies.

A. Pre Combustion Capture

The Pre Combustion Capture process takes place in IGCC power plants (Integrated Gasification Combined Cycle). IGCC power plants are gas and steam turbine power plants, which have a segment for coal gasification. The CO₂ is separated before the combustion of the fuel source. At first air is decomposed in nitrogen (N) and oxygen (O) and the oxygen will pass into the carburetor. There, the carbon reacts under high pressure and high temperatures with the initiated oxygen. To complete the reaction, hydrogen (H) must be injected. This process is known as coal gasification and the resulting synthesis gas consists mainly of CO₂, carbon monoxide (CO) and H₂. Because of the addition of water vapor in the Shift-Reaction CO is converted into CO₂ and another H₂ is formed. Now, the synthesis gas consists mainly of CO₂ and H₂. After the desulfurization 90-95 percent [7] of the CO₂ will be separated under high pressure (20-30 bar [8]) by physical

absorption. After oxidation with air, the remaining synthesis gas becomes a fuel gas with good calorific value, which is then burned in the gas turbine to generate electricity [9]. By using the waste heat from the gas turbine by an attached steam turbine, system efficiencies can be achieved by 40-45 percent [8].

Advantages of the pre combustion capture process are the relatively high efficiency, low total emission and the high air purity. Furthermore, it is the most advanced method. However it is also important to note that the efficiency of an IGCC power plant with CCS is 10 percentage points worse than it would be without CCS. In addition to that, already existing systems cannot be extended to allow the CO₂ separation [10].

B. Oxyfuel

No conventional combustion with air, but combustion with 95 percent pure oxygen happens in this process [11]. This pure oxygen has to be produced in an air separation plant, which requires additional energy. This additional demand for energy leads a decrease of net efficiency by about 45 percent to 35 percent. To compensate this loss of 10 percent an increased demand for primary energy of about 29 percent would be necessary [11].

The combustion happens with 1.15 fold excess of oxygen to keep the building of carbon monoxide at its lowest level. In addition to the pure oxygen, the flue gas will be recycled to the boiler. By the repeated recirculation a large density of CO₂ in the flue gas will be obtained. In addition it avoids an excessive combustion of the main materials, which consequently has a reduced burning power [12].

Then the recycled flue gas volume contains about 89 percent CO₂. By the conventional combustion the concentration of CO₂ in the flue gas volume is about 20 percent [11]. The other components of the flue gas, for example resulting sulfur compounds are separated as by-products. After the separation of the other components the flue gas only consists of nearly pure CO₂. By increasing the pressure and simultaneously reducing the temperature of the flue gas it becomes a liquid-like state [12].

The strengths of this process lie in the modification of conventional power plants and the relatively small space necessary. An increased energy demand because of the air separation and their relatively low CO₂ purity are the weak spots in this process [13].

C. Post Combustion Capture

This process begins after the conventional combustion. This means the combustion process itself will not be changed, only the processing of the flue gas is a new one. After the combustion the flue gas will be separated with the help of a washing process.

The essential feature of this method is an additional CO₂ – scrubber. In this boiler, the flue gas is cooled by a scrubbing solution, for example Monoethanolamine (MEA). With this amine the CO₂ will be bound. MEA: “Monoethanolamine are often used amine to capture CO₂, where you can reach a reliability of 98 percent and product purities of over 99 percent“ [14].

The uncombined CO₂ – depleted flue gas is emitted into the atmosphere. The CO₂ – saturated scrubbing solution comes into the desorber, a kind of boiler, where the solution is broken down into pure CO₂ and free amine at about 120 degrees. The obtained amine will be recycled into the process operation, where it can bind new CO₂.

One of the best advantages of Post Combustion Capture is the high purity of CO₂ with nearly 99 percent. Also there are users who develop this process to achieve technical optimization and to exploit the potential more and more [15].

On the other hand post combustion capture upgrades the conventional power plants in an uncomplicated way, which has a worldwide application potential for these power plants. It is also assumed that by 2020 the commercial availability of this variant will be reached.

But the upgrading of power plants is only useful for new conventional power plants, because of the loss of efficiency. In old conventional power plants the efficiency is already low enough without CCS. A huge amount of chemicals is also needed, which is a danger in itself. Additionally the process needs a large demand for cooling water.

IMPROVING THE EFFICIENCY

As mentioned above, the CCS technology has an additional need for energy, which reduces the efficiency by 8-14 percent [16]. To compensate this loss, there are numerous inventions, for example the use of new materials. They can withstand steam temperatures of 700°C and pressures up to 350 bar [17].

Furthermore, the drying of the coal improves efficiency by about 5 percent [18]. Moreover, the energy consumption can be reduced by improvements in the gasification process [19] and the use of new gas purification processes such as membrane processes [20].

Like CCS technology all these technologies are still in the maturing process, but it is already clear that the initial loss of efficiency is more than compensated.

III. TRANSPORT OF CO₂

After the capture of CO₂ the liquefied carbon dioxide must be transported from the power plants to suitable storage sites. But the storage sites are only in very few cases in the vicinity of power plants, so that the transport is usually over long distances. For this reason an effective transportation is necessary. To ensure this effective transport underground pipelines are the best alternative. Much experience with the transport of various gases and liquids through pipelines have been gained.

For over 100 years, natural gas has been transported worldwide through pipes. Today there are 40.000 km of gas pipelines in Germany [21].

In the U.S. there is already a 5.000 km-long CO₂ pipeline network which has been in operation for over 30 years [22]. Distributed pumping and compression stations prevent the falling of pressure on long distances during transport.

However, if it still comes to a leakage of the pipeline, transportation will be interrupted by automatic shutters. The CO₂ flammable nor explosive converts immediately into dry

ice and can be disposed [23]. The exit point is closed by the dry ice and air drifts ensure that the vaporized CO₂ concentration is not dangerous [24].

IV. STORAGE OF CO₂

There are two decisive criteria for the storage of liquid CO₂: the legal basis and the technology.

In January 2008 the EU Commission presented a directive on CCS. In this directive we find the legal framework for the implementation of CCS and simultaneously binding rules for exploration, monitoring and long – term care for CO₂ - storages [25]. In June 2009 the EU Commission passes the directive of CCS. Since this day, the EU member states have had 2 years to implement the directive into their national laws [26].

In Germany three dates to implement this directive were already postponed. Apart from the legal basis, the research to storage the CO₂ makes progress.

REQUIREMENTS OF THE STORAGES

To find a qualified storage location for the liquid CO₂, the location has to meet certain aspects. An important aspect is the capacity of the location.

The storage formation has to have the necessary porosity and has to guarantee the necessary storage volume for the project.

Furthermore, the injection rate is not negligible. It has to be assured, that the storage formation can receive injection rates, which are higher than the production of the source. The injection rate must not endanger the integrity of the storage.

Another request is storage security. The CO₂ is stored in a supercritical state, therefore the cap rock has to be completely impermeable to prevent a migration of the CO₂ or saline waters outside the storage complex.

It is also necessary that as little drilling holes as possible exist. These holes are big potential dangers, because impenetrability is not guaranteed.

Socio – economic conditions have to be also considered. The storage must be accessible easily for the pipelines and the storage activity does not interfere with other uses of the subsurface, like geothermal for example. Furthermore, the public must be informed and tolerate the operation [27].

A NUMBER OF STORAGE FACILITIES

For the storage of CO₂, there are some options, but these highly depend on the national geological deposits. The following is a list of potential storage options and a view of the possible use at an international level as well as in Germany.

A. *Storage on the seabed*

In this method, ships would drain the CO₂ into deep ocean layers. Form a sea depth of 3000 m there is such a high pressure that the density of CO₂ increases so strongly, so that the CO₂ is deposited on the seabed. Thus, the bound CO₂ would dissolve slowly in the overlying water layer, and finally escape.

Conclusion: This option is not pursued and excluded worldwide [28].

B. *Salt caverns*

The underground mining of potassium salts in a potash mine develops voids in the rock. Also known as salt caverns because they are usually surrounded by nearly impermeable rock salt. Now such salt caverns are used as gas storage.

In principle, these salt caverns for storage of CO₂ would be useful, but they pose security risks. Furthermore, in Germany there are only two free unused potash mines available.

Conclusion: There are significant security risks and a low storage potential – this option was discarded [28].

C. *Unused coal fields*

For economic reasons, the energy companies refrain from promoting coal deposits, which are below 1500m. Technically, the CO₂ could be fed into the coal seams. The majority would bind strongly with the coal. In the binding process, the coal would swell. This creates a loss of storage potential and the permeability of the seams.

Conclusion: For Germany, this option is not suitable [28].

D. *Empty oil fields*

During the so-called Enhanced – Oil – Recovery – Procedure (EOR) CO₂ is pumped into oil fields. Through this CO₂ the pressure in the oil camps and the flow of oil increase, so that dwindling deposits can be used longer. The CO₂ replaces also gradually the mineral and remains trapped in the reservoirs, provided the holes are sealed. This method of increasing oil yield, while storing CO₂, is already industrial practice. In Germany, this variant is not very promising because it requires a large effort to seal the holes and there are only small capacities in Germany available.

Conclusion: This option is internationally perceived as attractive, however in Germany rather rejected because of the low storage potential [28].

E. *Gas deposits*

Also in gas fields CO₂ is used to increase the supply pressure. This procedure is called Enhanced – Gas – Recovery – Procedure (EGR). These gas fields are well suited for storing the CO₂ because they have saved the natural gas for millions of years. This means the storage security is given. In Germany, large storage capacities exist. Another advantage of this option is the existing infrastructure that can be used to transport the CO₂. But you need to seal old holes accordingly, which is complicated and expensive.

Conclusion: Both, storage and existing research results and experience with this storage process can make the option attractive for Germany [28].

F. *Saline aquifers*

Here, the CO₂ is introduced into pores of salt-water-bearing rocks, called saline aquifers. In such porous rock formation, the CO₂ is taken up almost like water in a sponge. With progressive injection it is spreading there. The geological features are not yet fully understood, but saline aquifers offer

by their extending the greatest storage potential for carbon dioxide. Beside the gas deposits they are the most promising option for storing CO₂. Further research is carried out for several years in that procedure.

Conclusion: The world's large capacity and promising research make this option very attractive [28].

SUMMARY OF STORAGE FACILITIES

For the German area mainly the saline aquifers and depleted gas fields are of great importance. These meet the requirements explained above and are currently subject of intensive research. By international comparison, the storage capacity of the natural gas deposits in Germany is rather low.

Until 2005, about 2.18 gigatons of natural gas from 39 gas fields were promoted [4]. These cavities are in deviation of about 18 percent of the capacity for CO₂ – migration in Germany. In addition, the BGR assumes that the storage capacity increases by 30 percent, if the potential amount of the natural gas is used [29].

The capacity of the aquifers is “estimated by the BGR to about 20 ± 8 gigatons of CO₂. Thereof about three quarters are located in northern Germany. The basin shares in the German sector of the North Sea or the Baltic Sea have not been taken into account. Including these storages, the capacity increases significantly” [29].

According to Johannes Peter Gerling of the Federal Institute for Geosciences and Natural Resources (BGR) in an interview with Focus Online the “CCS – era [...] last about 40 years” [30].

Specified by the BGR, the storages would annually be claimed by 0.3 to 0.35 gigatons of CO₂. Since April 2008, the BGR have developed a nationwide register of storage capacities. However, they need to be explored before.

EXPLORATION OF STORAGE FACILITIES

To explore possible storages different models are used. By using 3D seismic it is possible to create two and three dimensional profiles of the storages. Artificial sound waves are generated on the surface, which are reflected by each layer of rock in different ways. These echoes are recorded by highly sensitive equipment and processed by the computer. Experts can use these data to create three dimensional models, which represent the length, width and depth of each layer of rock. These models show the geological stratigraphy and point the places, where the CO₂ could leak out. Another model shows how the CO₂ would spread in the rock layers. Therefore, the results of 3D seismic are of great importance. They give information about the quality and disorders of the rock (gas permeable layers).

If the investigated potential storages meet the requirements (see IV. REQUIREMENTS OF THE STORAGES) geological and geochemical investigations of the rock layers must be carried out by exploratory boreholes.

These provide information about how the storages react under normal conditions and how much CO₂ they can probably absorb.

The exploration of the storages sites is time and labor intensive and can take, depending on the nature and size of the testing storage, several months to several years. Only when no risk factors are seen, the storage can be approved. The approval processes for natural gas storage serve as models, which have successfully been used for many years [31].

FACTS ABOUT THE STORAGE

The CO₂ is stored in deep geologic formations at depths of 800 meters. Impermeable cap rock has to prevent the CO₂ from reaching the surface again. Four different trapping processes are distinguished, which are intended to ensure that the CO₂ gradually binds to the rock and can be locked safely.

After the injection of CO₂ into saline aquifers, the CO₂ molecules and water molecules move uncombined in the rock layer. After a few years, the proportion of free bonds will be only at about 20 percent [32]. The outer layers prevent the CO₂ from exiting. In the same way natural gas is kept in the ground for millions of years.

The second process is seen as residual saturation or as a capillary bond. This is the CO₂-water mixture in the pores of sedimentary rocks laid in the saline aquifer thereby preventing that the gas moves. The result is a so-called immobile phase.

In the third process, many of the CO₂ molecules of the mixture have a close bond with the molecules of the salt water. The resulting mixture is heavier than water and sinks.

The bond between the elements will remain stable until the pressure on the mixture is reduced.

In the final process a part of the resulting mixture mineralizes and becomes a fixed deposit in the rock. But this happens only after many years. After that the CO₂ in these minerals, however, is permanently combined.

These four processes only occur under appropriate conditions. They complement each other and provide an increasing fixation of CO₂ in the subsurface [33].

MONITORING IS ESSENTIAL

To ensure safety and environmental impact transport and storage should be regulated by the state and be monitored by the authorities. Various technologies have to be combined for reliable monitoring. Therefore different monitoring systems are used, partly underground, but also at the surface and may be in the atmosphere.

Micro seismicity can measure small movements of rock strata already while discharging CO₂ into the earth, to prevent that the outer layers are destroyed by taking an excessive pressure loss.

Furthermore, the changes of the rock layers are monitored by 3D seismic. Special bore holes are drilled to check the spread and concentration of CO₂. Fluid samples from the boreholes provide information about the chemical reactions. The monitoring of gas concentration in the ground and the analysis of the mineral content continue to contribute to better control of the storage [34]. In addition to that minimal elevations, caused by the pressing, can be recorded by radar satellites.

These images can be evaluated and judged. It is not yet clear whether examination procedures can be used more cost-effectively on the surface [35].

THE DISCUSSION ABOUT CCS

Society is divided on the subject of CCS. On the one side are the supporters, who consist of parts of the economy and science. On the other side are the critics primarily from conservationists.

There have already been established numerous studies by the proponents and the critics. Here some discrepancies in significant main points of the arguments appear.

In a study by the Association for the Environment and Earth Germany, shortly BUND, Dr. Krupp has left unconsidered competing usages for the storage facilities in Germany. These competing usages are for example the mining of ore and the use of renewable energy (geothermal energy).

According to calculations the German storage capacities will be used up in only 25 years [36]. Contrary to these calculations, the energy companies are talking about 40 years and beyond - that is at least one generation of power plants.

This discrepancy will probably be solved with the detailed and reliable data of the national land registry, which the Federal Institute for Geosciences and Natural Resources collects at the moment.

One argument against CCS is that it is in contrast to renewable energies. The CCS critics see the use and development of geothermal energy threatened. Supporters counter this argument with the idea of using different regions. Only 10 of 180 geothermal projects are planned in northern Germany [37]. The storage of CO₂ is only possible in the North German Basin.

Furthermore, the correlations of earthquakes through the drilling of geothermal energy projects remains unclear and the subject of current research. An earthquake measuring 3.4 in Basel is the trigger for this discussion [38]. Nevertheless, hopes are for the common use of geothermal energy and CO₂ storage.

The energy companies are confident that the future belongs to renewable energies - as soon as they can be used for base load and will be just as reliable as conventional fuels.

Another criticism is that this technology requires an additional demand for energy about 30 percent. Therefore the demand for coal and the environmental damage would increase caused by the consumption of landscape, groundwater lowering or acidification of groundwater.

Furthermore the CCS critics point to the undetectable leaks of CO₂ disposals. It argues that the natural gas fields are charged with numerous boreholes and the already filled old boreholes have to be proved as being tight [39]. The possible consequences in terms of the corrosion behavior in a CO₂ pipeline and exit options were not disclosed.

Proponents counter these statements with the findings of current research projects and the experience gained in the world for CO₂.

It is interesting to consider the risk assessment. While CCS critics call the safety of CO₂-Storage into question, the proponents point out that the risk "to store CO₂ underground

has to be compared with the risk" to let the "gas into atmosphere" [40]. CO₂ storage is an alternative which can minimize the real risk of climate change. "This compares with the manageable risk of a possible leakage of CO₂ from an underground storage site" [40].

V. CONCLUSION

We consider the development of CCS technology as positive because it shows that our society treats the problem of climate change actively and research is being done "to solve the complex climate problem" [3].

We believe that the technology needs for further development on the one hand a single register, as it is currently collected by the BGR. On the other hand the activities in research have to be improved. So, the next steps for the advancement of technology would be guaranteed.

Overall it is a positive sign, that the issue is such a lively discussion on the subject of CCS and a direct exchange between critics and supporters. The increased demand inside the debate will improve the dealing with the subject and the stronger the research on technology, the less likely it is that errors can happen.

Finally, one can say that CCS technology can serve as a bridge - to develop renewable energy to such a point as to accomplish the basic load completely. Renewable energies are the future - and CCS as well.

- [1] Vattenfall Europe AG: CCS – Wissen 03, August 2008, 2nd ed. , Berlin p.1.
- [2] http://www.worldenergyoutlook.org/docs/weo2010/weo2010_london_no_v9.pdf Date: 22nd December 2010 09:12.
- [3] Der WirtschaftsReport: Braunkohle hat große Zukunft, January 2009, p. 28, article by Prof. Dr. Robert Socolow.
- [4] IZ Klima - Informationszentrum für CO₂-Technologie e.V. : CCS – Speicherung von CO₂, Technologie für den Klimaschutz, November 2010, 4th ed. , Berlin, p. 10.
- [5] Entwicklungsstand und Perspektiven von CCS-Technologien in Deutschland, gemeinsamer Bericht des BMWI, BMU und BMWF für die Bundesregierung, 19th September 2007, p. 25.
- [6] <http://www.rwe.com/web/cms/de/2688/rwe/innovationen/stromerzeugung/clean-coal/igcc-ccs-kraftwerk/> Date: 19th December 2010 17:53.
- [7] Vattenfall Europe AG: CCS – Wissen 03, August 2008, 2nd ed. , Berlin, p. 7.
- [8] http://www.kraftwerkforschung.info/fileadmin/user_upload/Bilder/Publikationen/projekt_0906-KWmitKohlevergas.pdf Date: 20th December 2010 09:18.
- [9] <http://www.ea-nrw.de/ccs-tagung/page.asp?TopCatID=&CatID=&RubrikID=11795> Date: 20th December 2010 10:35.
- [10] <http://www.eon.com/de/businessareas/35243.jsp> Date: 20th December 2010 11:54.
- [11] Dr. habil Krupp: Geologische Kurzstudie zu den Bedingungen und möglichen Auswirkungen der dauerhaften Lagerung von CO₂ im Untergrund, Auftraggeber: Bund für Umwelt und Naturschutz Deutschland e.V., 18th November 2010, Berlin, p. 10.
- [12] <http://www.vattenfall.de/de/oxyfuel-prozess.htm> Date: 20th December 2010 15:19.
- [13] <http://www.eon.com/de/businessareas/35242.jsp> Date: 20th December 2010 17:43.

- [14] Dr. habil Krupp: Geologische Kurzstudie zu den Bedingungen und möglichen Auswirkungen der dauerhaften Lagerung von CO₂ im Untergrund, Auftraggeber: Bund für Umwelt und Naturschutz Deutschland e.V., 18th November 2010, Berlin, p. 8.
- [15] <http://www.eon.com/de/businessareas/35245.jsp>
Date: 21st December 2010 10:22.
- [16] Entwicklungsstand und Perspektiven von CCS-Technologien in Deutschland, gemeinsamer Bericht des BMWI, BMU und BMWF für die Bundesregierung, 19th September 2007, p. 6.
- [17] <http://www.kraftwerkforschung.info/werkstoffe-fuer-ueber-700-c-dampftemperatur/>
Date: 21st December 2010 13:53.
- [18] <http://www.kraftwerkforschung.info/quickinfo/dampfkraftwerke/trocken-e-braunkohle-bringt-mehr/>
Date: 21st December 2010 14:29.
- [19] http://www.kraftwerkforschung.info/fileadmin/user_upload/Bilder/Publikationen/projekt_0906-KWmitKohlevergas.pdf
Date: 21st December 2010 15:48.
- [20] http://www.kraftwerkforschung.info/fileadmin/user_upload/Bilder/Publikationen/projekt_0906-KWmitKohlevergas.pdf
Date: 21st December 2010 16:47.
- [21] BTU Cottbus: Wechselwirkungen zwischen CO₂ Abscheidung, Pipelinetransport und Injektion in Saline Aquifere, 16th September 2010, Michael Nimitz, p. 7.
- [22] <http://www.iz-klima.de/ccs-prozess/transport/co2-pipeline/>
Date: 22nd December 2010 14:45.
- [23] Vattenfall Europe AG: Fragen und Antworten zu Abscheidung, Transport und Speicherung von CO₂, June 2009, questions 24 - 25, p. 7.
- [24] IZ Klima - Informationszentrum für CO₂-Technologie e.V. : CCS – Speicherung von CO₂, Technologie für den Klimaschutz, November 2010, 4th ed. , Berlin, p. 18.
- [25] IZ Klima - Informationszentrum für CO₂-Technologie e.V. : CCS – Speicherung von CO₂, Technologie für den Klimaschutz, November 2010, 4th ed. , Berlin, p. 18.
- [26] EU-Richtlinie zu CCS: Richtlinie 2009/31/EG des Europäischen Parlaments und des Rates vom 23.4.2009 über die geologische Speicherung von Kohlendioxid und zur Änderung der Richtlinie 85/337/EWG des Rates sowie der Richtlinien 2000/60/EG, 2001/80/EG, 2004/35/EG, 2006/12/EG und 2008/1/EG des Europäischen Parlaments und des Rates sowie der Verordnung (EG) Nr. 1013/2006.
- [27] Bundesantalt für Geowissenschaften und Rohstoffe: Stability – CO₂ Storage, Abschlussbericht August 2010, Hannover, p. 14.
- [28] IZ Klima - Informationszentrum für CO₂-Technologie e.V. : CCS – Speicherung von CO₂, Technologie für den Klimaschutz, November 2010, 4th ed. , Berlin, pp. 6 - 7.
- [29] Entwicklungsstand und Perspektiven von CCS-Technologien in Deutschland, gemeinsamer Bericht des BMWI, BMU und BMWF für die Bundesregierung, 19th September 2007, p. 10.
- [30] http://www.focus.de/wissen/wissenschaft/klima/tid-13853/co2-speicherwenig-platz-fuer-sehr-viel-gas_aid_386531.html
Date: 23rd December 2010 11:34.
- [31] IZ Klima - Informationszentrum für CO₂-Technologie e.V. : CCS – Speicherung von CO₂, Technologie für den Klimaschutz, November 2010, 4th ed. , Berlin, pp. 14 - 15.
- [32] http://www.eon.com/de/downloads/090921_CCS_Broschuere_DE.pdf (p. 13)
Date: 23rd December 2010 10:19.
- [33] IZ Klima - Informationszentrum für CO₂-Technologie e.V. : CCS – Speicherung von CO₂, Technologie für den Klimaschutz, November 2010, 4th ed. , Berlin, pp. 10 - 11.
- [34] http://www.tuevsued.de/anlagen_bau_industrietechnik/aktuelles/co2_wirtschaftlich_abscheiden_transportieren_speichern
Date: 20th December 2010 09:36.
- [35] http://www.eon.com/de/downloads/090921_CCS_Broschuere_DE.pdf (p. 9)
Date: 27th December 2010 17:11.
- [36] Dr. habil Krupp: Geologische Kurzstudie zu den Bedingungen und möglichen Auswirkungen der dauerhaften Lagerung von CO₂ im Untergrund, Auftraggeber: Bund für Umwelt und Naturschutz Deutschland e.V., 18th November 2010, Berlin, p. 51.
- [37] Bericht der Bundesregierung über ein Konzept zur Förderung, Entwicklung und Markteinführung von geothermischer Stromerzeugung und Wärmenutzung, 17th March 2009, Berlin, p. 10.
- [38] Bericht der Bundesregierung über ein Konzept zur Förderung, Entwicklung und Markteinführung von geothermischer Stromerzeugung und Wärmenutzung, 17th March 2009, Berlin, p. 13.
- [39] Dr. habil Krupp: Geologische Kurzstudie zu den Bedingungen und möglichen Auswirkungen der dauerhaften Lagerung von CO₂ im Untergrund, Auftraggeber: Bund für Umwelt und Naturschutz Deutschland e.V., 18th November 2010, Berlin, p. 26.
- [40] Vattenfall Europe AG, division communication: "Zwölf Irrtümer über CCS", News 12nd August 2010, 4th stanza.

Cottbus, 21st January 2011

Hydroelectricity in Poland and Germany

Philipp Schwanbeck, Jonas Krenz
Faculty 3 of Mechanical, Electrical and Industrial Engineering
University of Technology Cottbus
Cottbus, Germany
schwaphi@tu-cottbus.de
krenzjon@tu-cottbus.de

Abstract—The paper deals with the most spread currently enlarged renewable energy source hydro power. We are referring to Poland's and Germany's situation of usage and give a look at present problems and future prospects regarding this technology. By reference to several facts about other European states it will give an impression of how Poland and Germany are placed within this topic.

Keywords— (small) hydro power plants, hydroelectricity, renewable energy

I. INTRODUCTION

The technical requirements of hydro power plants are not an obstacle for the industry and research. There are huge differences between Poland and Germany in the expansion. In spite of European efforts and good economical conditions the expansion of the most efficient renewable energy source is hindered by politics and regional planning borders. Despite beneficial geographical terms and big commitment, the realization often fails because of the existing law concerning water power, official regulatory procedures and environmentalism. Poland still has an average of 80 percent unused hydro power potential and Germany about 20 percent. To fill Germany's gap and parts of Poland's as well, the Technical University of Munich develops a new generation of hydro power plant, which can be utilized especially for creeks and smaller streams beginning with a drop height of only 1.2 meters.

II. DEVELOPMENT AND UTILIZATION AND THEIR BACKGROUNDS

The era of hydropower by means of turbines started in France in 1832. But the real development of hydropower began around 1900 with the invention of three-phase electricity, although from the 1950s until about 1980, small hydro power plants had a negative development in the European Union. Many small hydro power plants were shut down because of age and competition from newer, larger plants. When some European Union countries decided to reduce their dependence on imported energy, small hydro power was given economic

support and the number of hydro power plants gradually started to increase again.

III. OVERVIEW ABOUT USAGE OF HYDRO POWER IN EUROPE

In 2006 there were nearly 21,000 small hydro power plants in all European Union member states from January 1st 2007 and if candidate countries as well as Norway, Switzerland and other countries are included, it where nearly 23000. [1]

The installed capacity of all European Union member states from January 1st 2007 was more than 13,000 Mega Watt, or more than 15,000 Mega Watt if candidate countries, Norway, Switzerland and other countries are included. In 2006 the total electricity generation from small hydro power plants in all European Union member states from January 1st 2007 was more than 41,000 Giga Watt hours and if including candidate countries, Norway, Switzerland and other countries nearly 52,000 Giga Watt hours.

On average, a small hydro power plant in the all European member states from January 1st 2007 had a capacity of 0.6 Mega Watt and produced about 2.0 Giga Watt hours in 2006.

More than 90 percent is concentrated in the following 6 countries; Austria, France, Germany, Italy, Spain and Sweden. In addition, Switzerland and Norway have a high hydro power capacity, while Bulgaria, the Czech Republic, Poland and Romania account for nearly 80 percent of the total capacity of the European Union member states from may 1st 2004.

IV. AGE AND RESULTING PROBLEMS OF HYDRO POWER PLANTS

Most of the small hydro power plants in the European Union are quite old. Only 45 percent are less than 60 years old and only 32 percent are less than 40 years old. The Eastern European countries have the highest share of young plants (about 38 percent are less than 20 years old). The two non-European Union western countries (Norway and Switzerland) are in an intermediate position, with a

slightly lower percentage of young power plants (34 percent are less than 20 years old), but the highest percentage of plants less than 40 years old (about 59 percent). [2]

A normal progress of lifetime shows that after the first noticed technical defect the error rate increases exponentially until it needs to be shut down in consequence of a breakdown [3].

V. A SHORT HISTORY OF HYDRO POWER PLANTS IN POLAND

During the interwar period, Poland had twelve hydro power plants, however the power output of none of them exceeded 10 Mega Watt and their total power output amounts only to 18 Mega Watt. Before the Second World War, the biggest power plant in Poland operated at Gródek in Pomerania with 3.9 Mega Watt and it supplied electricity to Gdynia. [4]

To get an idea, 5 Mega Watt should be useful for about 4.500 households [5].

In 1930s, the first preparations for construction of some larger power plants on the Dunajec, the Soła and the San rivers were started. The Second World War stopped not only the normal development of an country, but also the development of Polish hydro power engineering. Due to the post-war territorial changes, Poland gained several power plants in the western part of the country, among others the larger plants are in Pilchowice and Dychów on the Bóbr River. The total power output of Polish plants in 1946 increased to 160 Mega Watt. The post-war period saw a gradual growth in the number of hydro power plants, although the speed of their development was significantly slower than that of the whole Polish power industry. These are backgrounds for the low usage of hydro power in Poland. During the 1960s, only a few hydro power plants were opened, such as those in Koronowo, Myczkowce, Dębe, Solina, Tresna, Żydowo and Włocławek. [4]

At present there are about 590 hydro power plants in Poland, most of which are small units with power output of less than 5 Mega Watt, with only 18 units having the output of more than 5 Mega Watt. [4] The Elektrownie Szczytowo-Pompowe (ESP) company operates 23 hydroelectric power plants in Poland, which account for 75 percent of the total capacity installed in the country's hydroelectric power plant system [6].

The existing electric power companies are mostly owned by the state and as a result, they have a seat on the table of cabinet. We find the same situation in the mining sector. The leading company "Compania Wgłowa" is the biggest coal concern of Europe and belongs to the state equally. Together with the traditional union "Solidarno" they represent a huge lobby and power against renewable energy sources [7].

The largest hydro power plants are Żarnowiec (716 MegaWatt), Porąbka-Żar (500 Mega Watt),

Solina (200 Mega Watt), Włocławek (162 Mega Watt) and Żydowo (150 Mega Watt) [4]. The future of domestic hydro power engineering, as seen by specialists, lies in the development of small hydro power industry, this development can be found everywhere in Europe, where the most important rivers are used anyway. Although the construction of hydro power plant in Nieszawa is being looked onto. [4]

The hydro power plant should have a rated power of up to 46.5 Mega Watt, with an annual average power generation of up to 280.0 Giga Watt hours/year [8].

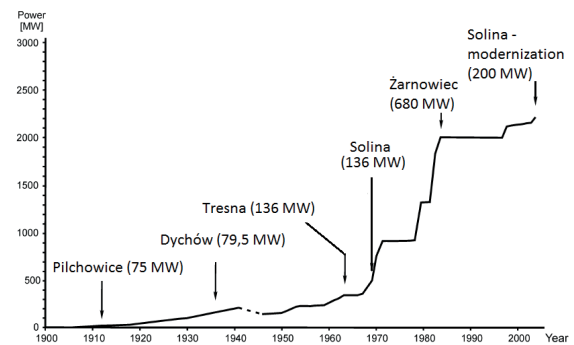


Figure 1. Development of hydro power plants in Poland [9]

Looking at the potential of renewable energy sources in Poland, hydroelectric power plants play the most significant role in the production of renewable energy. The total power-generating capacity of Poland's rivers is estimated at 12 Terra Watt hours a year, but only 15 percent of this capacity is used today. Roughly 70 percent of the total capacity is available in the Vistula River Basin, and the Oder river and coastal rivers account for the remaining 30 percent. In comparison, France uses almost 100 percent, Norway 84 percent and Germany 80 percent of their water reserves [4].

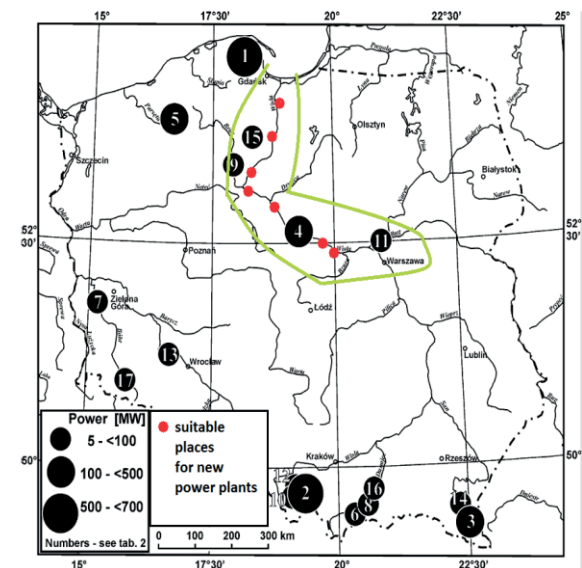


Figure 2. Location of existing in Poland and possible stations in the Vistula River Basin [4, 21]

VI. GEOGRAPHICAL VIEW

Most of the country's hydroelectric power plants are located in northern Poland in the Western Pomerania and Warmia-Mazuria provinces. Quite a few power plants can also be found in Kujawy-Pomerania province in north-central Poland. There are around 130 large hydroelectric power plants in the country, along with 350 or so smaller power plants and other renewable-energy generation facilities.

Most hydroelectric power plants in Poland are operated by state-controlled power generation and distribution companies, and some are privately owned. Hydroelectric power plants account for just 7 percent of the country's total installed power capacity of 34,000 Mega Watt. [10] Poland still has thousands of sites where small hydroelectric power plants could be built and dozens of locations that could host medium-sized plants [10].

A.

Necessary factors which have influence of development and utilization[2]:

- Statistics, industrial and technological potential
- Institutional arrangements and economic issues
- Environmental factors
- Supporting policy instruments
- Specification of main risks
- Market and other barriers

VII. OVERVIEW ABOUT COSTS AND ECONOMIC IN EUROPE

The revenues from generated electricity vary between the markets in the European Union and are not consistent. On a deregulated market the price differs a great deal between years. As revenues are very dependent on the agreements with the purchaser, they do not only vary between countries, but also from one power plant to another. As the support systems in the European Union vary greatly from one country to another, the conditions also differ to a large degree between countries. Grid compensation exists in some countries such as Sweden, where especially the small hydro power plant owners participate by generating power in such a way that it stabilizes the grid and minimizes transport losses. If you look at countries such as Sweden, suppliers can use an "extra" value from the small hydro power plants from which they buy their electricity. [2]

The capital required for small hydro power plants, which has the most important role for planning the construction of a new hydro power plant, depends on the size, head, flow rate,

geographical location, equipment (turbines, generators etc.), civil engineering work and flow variations throughout the year. Making use of existing weirs, dams, storage reservoirs and ponds can significantly reduce both the environmental impact and costs. This kind of way to invest in hydro power should be really useful. Sites with low heads and high flows require more capital investment because greater civil engineer works and bigger turbine machinery will be needed to handle the larger flow of water. [2]

A small hydro power plant represents a major investment over an extremely long production period of normally 30-40 years. In Contrast, other industrial investments have a payback time of around five years. Consequently, the small hydro power plant sector has a need for a long-term stable income. A small hydro power plant also has a higher cost per produced kilo Watt hours produced as compared to large ones, but offers social advantages such as higher rates of employment, reduced energy losses and stimulation of small and medium-sized enterprises to support the sector. Building a small hydro power plant is attended with high investment costs, until the loans have been completely amortized within 15-20 years. [2]

VIII. OPERATION AND MAINTENANCE COSTS

The operation costs can vary a great deal between countries and parts of them due to the fact that there are different types and sizes of fees. Special attention must be paid to the cost of using water (water charges and/or concession fees). Operation and maintenance costs vary in line with the quality and design of a power plant and the availability of specialist maintenance resources in the different member states. [2]

When we look at the following diagram, we can deduce why the polish development still retards to invest in new hydro power plants.

Country		Range of investment costs	Average SHP production costs
		Euro/kW	Eurocent/kWh
Austria	AT	3000 - 5500	8 - 30.9
Belgium	BE	1000 - 8000	6-8
Denmark	DK	n/a	n/a
Finland	FI	1750 - 10000	3 - 3.5
France	FR	1850 - 4000	0.5 - 1.8
Germany	DE	5000 - 12000	0.7 - 1.1
Greece	EL	1500	70
Ireland	IE	1600 - 5000	0.87 - 6.34
Italy	IT	2150 - 4500	10.5 - 17.4
Luxemburg	LU	6000 - 3000	10 - 15
Netherlands	NL	3000 - 6000	10 - 15
Portugal	PT	1800 - 2500	0.56 - 0.6
Spain	ES	1000 - 1500	3.5 - 7
Sweden	SE	2150 - 3500	2.0 - 2.5
United Kingdom	UK	2200 - 6000	5.0 - 15.0

Bulgaria	BG	1000 - 1500	0.4 - 0.8
Cyprus	CY	n/ap	n/ap
Czech Republic	CZ	1000 - 6000	1
Estonia	EE	1000 - 4000	2 - 5
Hungary	HU	n/a	3.8 - 4.6
Latvia	LV	1800 - 2000	1
Lithuania	LT	2200 - 2500	2.5 - 3
Malta	MT	n/ap	n/ap
Poland	PL	2200 - 2500	3 - 4
Romania	RO	1250	4
Slovakia	SK	2000	0.6 - 0.8
Slovenia	SI	1500 - 3000	n/a
Croatia	HR	1300 - 2500	1.5
Macedonia	MK	1200 - 3000	n/a
Turkey	TR	500 - 1100	0.2
Norway	NO	1000 - 1500	1.5 - 2
Switzerland	CH	4000 - 10000	3 - 15
Bosnia & Herzegovina	BA	1300 - 1600	1.5
Montenegro	ME	n/a	n/a

Table 1. Investment and production costs, some countries have very high SHP, explained by included capital costs [2]

IX. PROS AND CONS

Generally speaking, hydro power plants offer a lot of substantial advantages on the one hand; on the other hand this technology poses some disadvantages, depending on the area being considered.

First, hydro power belongs to the category of renewable energy sources. Neither does it release any toxic chemicals, nor does it create any harmful substances [11]. Beyond that, the level of efficiency is about 90 percent [12]. This is a very efficient way of gaining electricity compared to its other renewable energy counterparts [13]. Figure shows the net energy gain of hydro power. It is calculated by the energy yield divided by the input energy. This quotient is an extraordinarily high one in the energy sector.

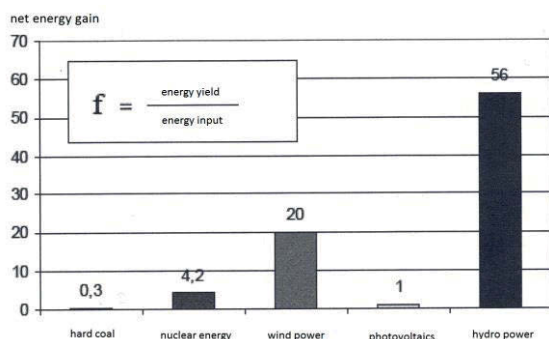


Figure 3. Net energy gain of most important energy sources [22]

The production costs of hydro generated electricity are low and stable as this type of energy is not dependent upon the price of uranium, oil, or other kinds of fuel and as it does not require many

employees to run a hydroelectric station [14]. Hydro power plants have a high operational life span and very few breakdowns [15]. They can be set up in almost any size, depending on the river used to operate them [14]. Unlike the sun, it is very reliable and consistent, not least because the power of water is available around the clock [11]. Operated by the backwater, dams effect a constant water table and furthermore the revolving hydro turbine enriches the water with oxygen [16].

To achieve the difference of heights between the water levels, a dam is required. There is always the theoretical risk of dams breaking in a massive flash flood. Besides, reservoirs that flood many acres of land are needed to store big masses of water in artificial lakes, which has negative effects on the ecological balance [13]. The flooding of large areas of land means that the natural environment is destroyed. It has to be assured that fish can pass the dam, for example via fish ladders. [13, 15] Finding a suitable place in the landscape for these widespread reservoirs and dams is often a problem. Families who are living in the area that has been selected for the construction of the reservoir have to be relocated [11]. In case of droughts, the power plant will become useless or will produce much less electricity than originally planned [17].

X. KINDS OF WIDELY USED HYDRO POWER PLANTS

The three most widely used hydro electric power plants are conventional hydroelectric-, run-of-the-river and pumped storage power plants. There are many further ways of arranging the components, that is the reason why we only write about the main types in this paper.

A. Impoundment

The most common type of hydroelectric power plant is an impoundment facility. An impoundment facility, typically a large hydropower system, uses a dam to store river water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity. The water may be released either to meet changing electricity needs or to maintain a constant reservoir level. This type has the most extensive ecological influences and consequences. In Germany it is nearly impossible to build new ones, because of politically regulations and problems to find right place at all. [18]

B. Pumped storage

The only background to build pumped storages is the difference of energy costs between day and night. At night, when electricity is still cheaper than at daytime, the pumps move water to the upper level (the lake). At daytime the potential energy can be used to produce electricity with high pressure turbines, which can be sold for higher price than costs to pump the water to the upper level. In future this concept is questionable because of the price regulation, which will be changed in the next years

(constant level for production of electricity to make power plants more efficient [17]). [18]

C. Run-of-the-river hydroelectricity

Run-of-the-river power plants use the natural flow and height difference of the consistent flowing river. Currently, it has the highest potential of future expansion in Europe. Especially small hydro power plants play a big role, still are quite view rivers or creeks are used. For example Poland still has 80 percent of unused potential. There are multiple varieties to arrange the turbines. [18]

XI. FUTURE PROSPECTS

Currently, the extension of hydro power in Germany is regulated by European laws and the BMU-defaults (Bundesministerium für Umwelt).

Because of new general conditions it is profitable again to invest in hydro power plants. In general, the German potential of usage of big hydro power plants and dams is nearly exploited. Consequently, approvable locations only exist at established old power plants with low heights of fall. The profitability of conventional hydro power plants and general conditions are not guaranteed. Therefore new technologies for an efficient usage have to be developed. Besides, high ecological standards have to be taken into account.

These are the reasons why small hydro power plants are more interesting for Europe than the bigger ones. By means of increased levels of efficiency and new types of turbines, which protect the fish population, the whole hydro power system has become more attractive.

Regarding these circumstances, lots of companies and research projects deal with that topic. The Technical University of Munich developed a smart concept of a new generation of small hydro power plants, which meet especially the requirements of Germany and Poland, as the landscape offers thousands of places where small hydro power plants could be built [14].

A rudimentary characteristic of this “shaft-hpp” (shaft hydro power plant) is the horizontal intake. The system is located completely under water. It has a vertically moveable gate, which enables the system to reach the following three different states.

The normal service with gate overflow enables a large horizontal screen surface, floating debris transport across the gate, vortex prevention by surface flow and a fish downstream migration with overflow.

In flood situations the gate moves down flush with trash rack to transport the sediments and trapped rubbish across the weir.



Figure 4. Gate modes [23]

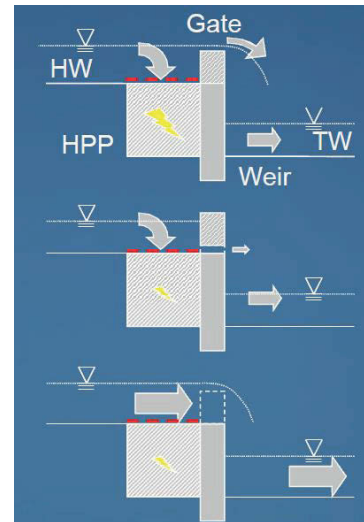


Figure 5. Gate modes side view [23]

The most important innovation of the “shaft-hpp” is the trash rack cleaner development.

If the debris jams the trash rack, the wiper is moving the debris to the gate. After, the gate opens a little slot to flush the debris out of the system. In this situation downstream migration of fish (species which rest close to the river bed) can pass the weir.

When the rack is cleaned, the gate closes again and the system switches back to normal mode. [23]

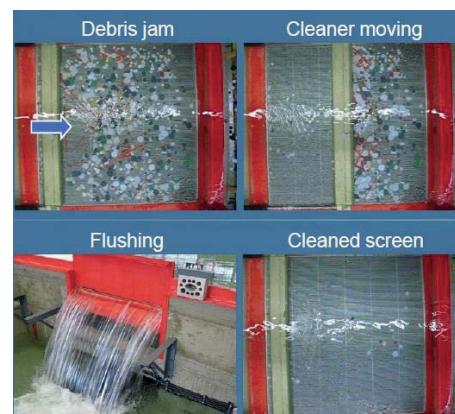


Figure 6. Self-cleaning system [23]

A remarkable principle of this concept is the underwater arrangement of all components. There are no visible facilities or buildings, no noise emissions and an integrated flood safety as well.

There is no sediment deposition as the sediments are transferable and a large screen surface remains. The constructional extension of the cavern is small. It is ecologically compatible as fish streams are not interrupted.

The building costs are 30 - 50 percent lower as comparable hydro power sites. [20]

To reach a higher capacity, several units of shafts can be arranged adjacent to one another.

The generator is powered by a dive turbine, which has a long operational life span and an efficient run.

The “shaft hpp” system is not only set up theoretically, it is tested in real and the first active feeding plant will start to work in spring 2011. This prototype has an average power of 40kilo Watt a flow rate of two cubic meters per second and a height difference of 2.5meters. [23]

XII. RESULTS

Summarizing our paper, we recognize that Germany and Poland use their potentials differently.

By reason of European guidelines, furtherances and requirements, it is economically worthwhile again, to use hydro electricity. In Poland and Germany essential hindering effects to build a hydro electric power plant are environmental guidelines, law concerning waterpower, duties, production costs and amortization time.

The current technology enables an efficient operation. New developments, like the “shaft hpp”, will obviously make it possible to use Germanys creeks to create the bridge to the 100 percent usage of the potential like France.

In our opinion, uniform guidelines, uniform laws and a well structured procedure to plan and build a small hydro power plant would push the spreading of the most efficient renewable energy source. Additionally, financial benefits for initial investment would stimulate private owners of ground with creeks or rivers to think about using this potential.

While occupying with the topic, we met different persons, who wanted to build a new small hydro power plant and on the one hand partly dashed against the water laws concerning the environment and on the other hand had to conform the following requirements: put up a fish ladder and care for the riverside on a length of 200 meters (in Germany).

As a whole consideration, political flexibility and an involvement of smaller companies help to reduce the imbalance of the distribution of power plants in Poland.

Furthermore it helps to re-equip the old hydro electric power plants to increase the level of efficiency in both countries.

REFERENCES

- [1] <http://www.erec.org/renewable-energy/hydropower.html>
- [2] http://www.erec.org/fileadmin/erec_docs/Documents/Publications/ESHA%20Strategic%20Study%20for%20Development%20of%20SHP%20in%20EU_2008.pdf
- [3] Bernard Comte, Betrieb und Wartung von Wasserkraftwerken, Verbandsschrift Schweizerischer Wasserwirtschaftsverband, 1998, p.18 figure 2
- [4] http://www.schooljournals.net/GymnasiumBeekvliet/media/Resultspercent20Poland/2007/Hydro-energy_in_Poland.doc
- [5] http://www.energieportal24.de/artikel_1349.htm
- [6] <http://www.warsawvoice.pl/WVpage/pages/article.php/18182/article>
- [7] <http://www.faz.net/s/RubC5406E1142284FB6BB79CE581A20766E/Doc~E8619435BC257401CAD08E542EDF5701C~ATpl~Ecommon~Scontent.html>
- [8] <http://www.hydroprojekt.com.pl/index.php?wersja=ang&ID=670>
- [9] <http://www.wgsr.uw.edu.pl/pub/uploads/mcg04/21mikulski.pdf>
- [10] <http://www.warsawvoice.pl/WVpage/pages/article.php/18182/article>
- [11] <http://www.buzzle.com/articles/hydroelectricity-pros-and-cons.html>
- [12] <http://www.steckdose.de/wasserkraftwerk.html>
- [13] <http://www.bionomicfuel.com/pros-and-cons-of-hydro-energy-generation/>
- [14] <http://hubpages.com/hub/advantages-hydroelectric-power>
- [15] Dipl.-Ing. Dr. Franz Ramsauer: „Die Herausforderungen der Wasserkraft“, Elektrotechnik & Informationstechnik, Heft 1-2.2010, S.1
- [16] <http://www.wasserkraft-deutschland.de/>
- [17] <http://drake.marin.k12.ca.us/stuwork/rockwater/Upload%20this%20doc--dams%20and%20hydropower%20report/pros%20and%20cons.html>
- [18] http://www1.eere.energy.gov/windandhydro/hydro_plant_types.html
- [19] statement from staff of Vattenfall in discussion
- [20] <http://www.energie-bau.at/index.php/profi/tu-muenchen-kleinwasserkraft-soll-guenstiger-werden.html>
- [21] Wojciech Majewski, Hydropower, Energy and the Environment, Conference Proceedings, Technical University of Gdansk, Poland, International Energy Agency, 1993, p.271
- [22] Wasserbauliche Mitteilungen Heft 39, Wasserkraftnutzung im Zeichen des Klimawandels – Waterpower and climate change, Technische Universität Dresden, 2009, p. 26
- [23] TU munich, in cooperation with Peter Rutschmann and A. Sepp, Versuchsanstalt für Wasserbau Oberrach/TU München

(Annotation: The pageview of our world wide web sources took place in the timeframe of 10.11.2010 to 05.01.2011.)

The sun as a source of energy

Jens Dutschmann
BTU, Cottbus
10th EEEIC Conference
dutscjen@tu-cottbus.de

Denny Weiser
BTU, Cottbus
10th EEEIC Conference
weiseden@tu-cottbus.de

Abstract- In the following paper we will discuss about the use of solar energy and their future.

Keywords: solar energy, solar power plants, photovoltaic, Storage possibilities,

1. Introduction

For many years we have been using machines that simplify our lives. Some of these machines consume a great deal of energy. Before the invention of the steam engine, this energy was provided by making use of wind power and the combustion of wood. Afterwards these two energy sources were replaced by coal. Later, oil, natural gas and nuclear power were used as sources of energy. Up to the present day, fossil fuels have played an important role in meeting the world's growing demand for energy. However, the supply of fossil fuels as well as the supply of uranium will start to run out over the next few decades. In addition, the use of fossil fuels is a major source of carbon dioxide emissions and other pollutants that harm the air quality and the ozone layer in particular. Fossil fuels therefore have adverse effects on the global climate. This is aggravated by the fact that coal mining profoundly alters the landscape and interferes with human and animal habitats. Accidents on drilling rigs like the *Deepwater Horizon* as well as the environmental pollution caused by leaky oil pipelines have shown that it is important to look for new, eco-friendly sources of energy. The use of nuclear energy poses enormous risks in the event of accidents (e.g. Chernobyl) and storing spent fuel rods. Therefore, it is necessary to look for alternative energy sources. At the moment, renewable energies seem to be the best option to secure the energy supply and with it the quality of life.

1.1 How solar energy is generated^{[1],[2],[4]}

The sun is the center of our solar system and takes up 98% of its total mass. That means that the sun's interior could hold 1.3 million earths. The sun was formed about 4.6 billion years ago and its fuels will last for approximately five billion more years. Then it will expand until it eventually engulfs the earth and will become a red giant. After about one billion more years it will shrink to a white dwarf and it will take another billion years for it to cool down.

The sun consists of five layers: the core, the radiation zone, the convection zone, the photosphere and the corona. The core takes up about 1.5% of the sun's volume and amounts to half

of the solar mass. The temperature of the core reaches ~15 million K and the solar core pressure is ~100 million bars. These conditions enable the conversion of energy by nuclear fusion. The most important fusion reaction is the proton-proton chain reaction which turns four hydrogen nuclei to one helium nucleus with the helium nucleus only being 0.7% of the mass of the four hydrogen nuclei. The remaining mass is converted into energy. The production of 1 kg of helium nuclei therefore releases about 630 terajoules of energy. The solar core produces 6,000 megatons of helium per second, which equals 3,780 yottajoules per second. A 1-GW nuclear power plant would need 1.25×10^{11} years to produce that much energy.

1.2 The importance of solar energy^[3]

The sun's energy reaches the earth as radiated power with about 1.37 kilowatt per square meter. This equals 170,000 terawatt on the earth's total surface. That means that in one year approximately 2.5×10^{17} kilowatt hours reach the earth, which is about 2,500 times as much as the annual global energy consumption. For many millions of years, this energy has been made use of on earth. The solar energy is being converted into various forms of energy like the kinetic energy of air flows and the potential energy stored in natural reservoirs. Therefore wind power is actually solar power. Furthermore, solar energy is being used by biological processes, like the photosynthesis, and in coal, gas and oil deposits a small part of the solar energy that reached the earth million years ago is stored. All these fossil fuels are used to cover the major part of our energy needs. There are various options to make use of the solar radiation which will be described in the following.

2.1 Solar thermal electric power plants

2.1.1 Types and functional principle

Solar thermal electric power plants use the heat produced by the solar radiation to drive turbines. Solar thermal electric power plants are divided into two main categories:

- solar power plants with mirrors
- solar power plants without mirrors

2.1.1.1 Solar power plants with mirrors^{[10][12][13][17]}

This type of solar power plants uses mirrors to bundle the sun's rays and reflect them onto a tube or tower containing a heat transfer fluid that transports the thermal energy. This heat transfer fluid can be a special type of oil as well as water or gas. The heat transported by this fluid produces steam which, in turn, drives turbines generating electric power.

The two main types of solar power plants with mirrors are parabolic trough power plants and solar tower power plants.

Parabolic trough power plants use parabolic mirrors to collect the sunbeams and to reflect them onto a tube, which is positioned along the reflector's focal line and contains heat transfer fluid. Following, in the generating unit a heat exchanger produces steam. This steam turns turbines which, in turn, drive the generator which then produces electricity. During periods of intense sunshine there is an oversupply of energy, but the surplus of thermal energy can be stored in tanks containing molten salt (for further information, refer to section 4). The stored energy can later be used for the generation of power. This allows for a 24/7 power generation using eco-friendly solar energy.

Solar tower power plants consist of a huge solar tower and a vast number of mirrors that concentrate the light on a central receiver atop of the tower. In the process, temperatures of far more than 1,000°C are being generated. Here too, the heat is being transported by a heat transfer fluid to the generating unit to produce steam. The fluid, however, is different to that of parabolic trough power plants because the temperatures in the tower are considerably higher than those in the tubes of parabolic trough power plants. In some cases nitrate salt is used as transfer fluid because it also serves as heat storage. This, however, requires heated pipelines since its melting point is 140°C. Furthermore, the tubes need to be protected from corrosion. The advantage of solar tower power plants is that they need less space and offer a higher efficiency than parabolic trough power plants.

2.1.1.2. Solar power plants without mirror^{[10][13][17][18]}

These solar power plants do not use mirrors to concentrate the incident sunlight and, due to their low level of efficiency, are far less used than those with mirrors. These power plants can be divided into three different subtypes: updraft power plants, downdraft energy towers and solar pond power plants.

Updraft power plants use the greenhouse as well as the chimney effect to generate power. They basically consist of a very large, glass-covered circular area, which can be taller

than 100km², and a more than 1km high chimney at the collector center. The air underneath the glass roof is heated by the incident sunrays to a temperature of more than 70°C. The heated air then streams towards the chimney at the collector center where the resulting convection causes the air to rise up the chimney at 15m/s. This airflow drives turbines positioned in the chimney and thereby generates electricity. Even though this concept is very trivial, these kinds of power plants are currently not cost-effective because they have an efficiency level of only 1% and they need a lot of space.

Downdraft energy towers are similar to updraft power plants. Here too, the air streams through a more than 1km high tower. The only difference is that the air streams top-down instead of bottom-up. For this purpose, water is sprayed on hot air at the top of the tower in order to withdraw its thermal energy. The cold air falls downwards, spinning a turbine at the bottom of the tower. The turbine then drives a generator which produces the electricity.

Even though solar ponds only have a low level of efficiency of maximally 15%, they are of great interest for developing countries. Due to the fact that there are a lot of unused areas in the African desert regions, this kind of power plants could be constructed with little effort.

2.1.2 Prospect^{[15][16][19][21]}

Parabolic trough power plants and solar tower power plants will be the most important solar power plants of the future, not least because the major goal of the DESERTEC Foundation is to provide "clean power from deserts" for Europe and the world. The DESERTEC Foundation includes members like Siemens, ABB, RWE, MAN Solar Millennium and 16 more.

The concept of the DESERTEC Foundation is to build solar power plants in the desert regions of North Africa and to transfer the generated power to Europe with low loss, using high-voltage, direct current (HVDC) electric power transmission. Furthermore, these power plants will be used for the desalination of sea water because they are the only ones that have a sufficiently high level of sufficiency.

In the future, especially the heat storage reservoirs will be improved in order to store the surplus of energy more efficiently and for a longer period of time (see section 4, *Storage possibilities*).

2.2 Photovoltaics

2.2.1 Functional principle^{[10][13][20]}

Photovoltaic cells convert solar radiation into electric energy. Silicon based photovoltaic cells work as follows:

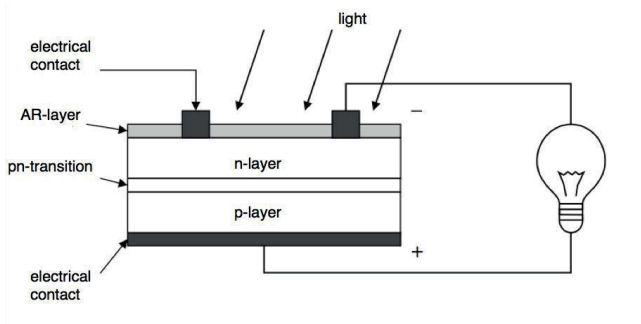


Fig. 1: Functional principle of a silicon based cell

When light hits the anti-reflection coating, it is absorbed and produces positively charged particles in the n-layer. The n-layer is a semiconductor with a surplus of negatively charged particles. Moreover, negatively charged particles are produced in the p-layer. The p-layer is also a semiconductor with the difference that it has a surplus of positively charged particles. The positively as well as the negatively charged particles move towards the p-n junction where they form electron-hole pairs. The charge carriers are then attracted by the layer with the same charge surplus, i.e. the positive charge carriers are attracted to the p-layer whereas the negative charge carriers are attracted by the n-layer which, in result, causes voltage. Photovoltaic cells always produce direct current electricity. Since DC is not usable in our conventional electricity grids, an inverter has to convert DC to AC.

Photovoltaics can either be used directly or indirectly. The former, the so-called stand-alone systems, make households self-sufficient. Energy that is not needed immediately, that is to say surplus energy, is stored in batteries for later use. In the indirect use of photovoltaics the generated solar energy is fed into the public grid and then sold to electricity suppliers. The household then gets his electricity from the public grid.

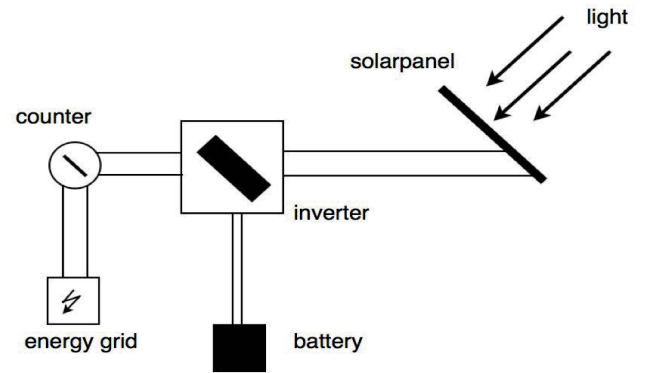


Fig. 2: Concept of a self-sufficient household

The level of efficiency plays an important role when it comes to photovoltaic cells. Common silicon based cells, as described above, have an average efficiency level of 14 to 18 per cent. The level of efficiency depends on various factors. On the one hand, the orientation of the solar panels towards the sun and the intensity of the sun play a decisive role in the cost effectiveness of a solar cell. To achieve an angle of incidence as ideal as possible, the solar panels need to face south and be adjusted to the temporary position of the sun by servomotors, if necessary. Furthermore, only photons with a high energy state can be absorbed by the cell. When a photon is absorbed, it produces an electron-hole pair. The surplus energy is then released in the form of heat. Conductors and metal contacts on the surface may be other reasons for energy loss.

2.2.2 Types of photovoltaic cells^{[10][16]}

Photovoltaic cells are usually categorized depending on the used material or the processing of the material. The following table gives an overview of the most important types of photovoltaic cells:

Type of cell	Efficiency
Concentrator cells	up to 41.1%
Gallium arsenide cells	19-41.1%
Monocrystalline cells	11-20%
Polycrystalline cells	10-14%
Thin film cells	8-10%

According to the *Deutsche Gesellschaft für Sonnenenergie e.V.* (German Solar Industry Association), about 85% of all solar modules used worldwide are monocrystalline and polycrystalline solar panels. These two types only differ in the texture of the lattice structure inside the cells due to their different manufacturing methods. The manufacture of polycrystalline modules is more cost-effective, but usually they have a lower level of efficiency. The theoretical optimum of silicon based cells is an efficiency of 26%.

Owing to the production process, the semiconductor layer of thin film cells is only a hundredth or a thousandth of the thickness of mono- or polycrystalline cells. They are considerably less expensive than silicon based solar cells. The level of efficiency, however, is usually only half as good.

Amorphous thin film cells are often used in calculators and watches because they can absorb a wide range of the solar spectrum. Therefore, this type of solar cell is also suitable for inside use.

Gallium arsenide solar cells do have much better properties than silicon based solar cells. On the one hand, these cells convert a wide range of light to energy. On the other hand, they are characterized by a very high level of efficiency of up to 41.1 per cent. Furthermore, gallium arsenide cells are very resistant to changing temperatures and UV radiation. These cells are about 50 times more expensive as common solar cells, though. For that reason, they are mainly used in the aerospace industry.

Concentrator cells do have a lens above the cell to concentrate the incident sunlight on the surface of the semiconductor. Thereby, expensive semiconductor material can be saved, which leads to cost savings, and, in addition, the level of efficiency is increased by the factor 500 because of the increased intensity of the radiation. This type of cells, however, must be adjusted to the position of the sun in order to concentrate the light properly. The *Fraunhofer Institut für Solare Energiesysteme* (Fraunhofer Institute for Solar Energy Systems, ISE) has developed a concentrator cell with an efficiency of 41.1%.

2.2.3 Prospects^{[10][16]}

In the future, the main goal will be to reduce the production costs of solar modules by processing “dirty” silicon. At the moment, a refined, highly purified form of silicon is used for the production of photovoltaic cells, which is, however, 50 to 60% more expensive than “dirty” silicon. Usually, the less contaminated, the higher the level of efficiency of the silicon.

The ISE is trying to develop concentrator cells with an efficiency of 39 to 40 per cent that is suitable for the industrial production. Furthermore, they are doing research on multilayer cells consisting of two different silicon layers put on top of one another. The upper layer only absorbs light from the upper end of the light spectrum whereas the lower layer only absorbs red light from the lower end of the light spectrum. In that way, a theoretical efficiency of more than 30% can be achieved.

3. Storage possibilities^{[5],[6],[7],[9]}

A major disadvantage of solar energy is the dependence on solar time. Therefore, it is necessary to find ways to use solar energy also during the night time. One possibility is the storage of the energy in the form of electric energy in batteries. This possibility is mainly used in common households.

However, this kind of storage is not suitable for big solar power plants because it is not cost-effective to store electric energy to such an extent. Thus, they are trying to store thermal energy.

At the largest European test center for solar energy, the *Plataforma Solar de Almería*, an effectively working storage was put into operation. Owing to latent storage material, this storage is able to store the solar generated steam for many hours and then emit it to the power plants when needed. This storage has a power output of 100 kilowatts at temperatures of more than 200°C. The same concept has already been used for many years, e.g. in hand warmers. When storing heat, the storage material undergoes a phase transition, i.e. it changes its aggregate state from solid to liquid. While the material changes the phase, the temperature does not increase. Only after the material has changed its aggregate state, the temperature starts to change. This method allows for storing relatively much thermal energy in a rather small temperature range. This newly developed storage is built like a “sandwich”, i.e. various layers of graphite foil and storage material are alternately layered upon another. This results in a high power density, which makes it attractive for industrial use.

Another possibility to store thermal energy is salt. This kind of storage consists of one hot tank (380°C) and a cold one (280°C). In order to charge the storage, cold salt is fed into the hot tank by a heat exchanger. The *Andasol* power plant, situated in Granada in the south of Spain, possesses two underground heat storage tanks filled with 28,500 tons of a mixture of potassium nitrate and sodium nitrate. These tanks allow for the plant to keep working at night or in overcast

conditions for up to 7.5 hours. The tank has an efficiency of 95%.

Furthermore, you can store energy by using molten salt. The Andasol plant in Granada uses 30,000 tons of a special mixture of salt as storage material. Using this method, the salt is being pumped through a tube positioned in-between two well insulated tanks. A section of this tube is covered by heat transfer oil. On sunny days, this oil reaches a temperature of about 400°C which the oil transfers to the molten salt. If there is no sun, the salt is pumped back and thereby heats the oil.

Another method is the heat storage by the use of ceramics. Here, a part of the hot air is blown into porous bricks that give off the heat at night.

In a pilot plant in Jülich they are doing research on sand as a heat transfer medium. This method could help to make solar towers more attractive. According to Jülich's scientists, the sand could make the storage cheaper by one third because in the deserts sand is available at no cost. In the future pilot plant, sand shall be conveyed by an air-sand heat exchanger to a hot bunker. During this process, hot air will be blown across the sand that is trickling from above. Then, a sand-water heat exchanger will be used to recover the heat. Water-filled tubes are running in the sand, which gives off the heat to the water. In the process, the sand is constantly kept in motion.

4. Advantages and disadvantages of solar energy^{[10][12][13][23][24][25][26]}

The generation of power by means of solar power plants has many advantages, but also some disadvantages.

According to efficiency and quality, the production of photovoltaic cells is quite costly. Furthermore, ecologically harmful chemicals like arsenic and cadmium are used in the fabrication of solar cells and have to be disposed separately.

One of the arguments against solar energy, especially when it comes to the use of photovoltaic cells on rooftops, is the fact that the sun is not steady. This is aggravated by the fact that, after 25 years, solar cells only have 80% of their efficiency left and have to be changed after 30 to 35 years. In the past, people against solar energy often criticized the low level of efficiency of solar cells. Furthermore, solar power plants can only be used efficiently in the earth's sunbelt. Their water consumption is approximately the same as that of a conventional power plant. Therefore, and due to the fact that solar power plants work most efficiently in dry regions,

pipelines have to be laid and deep wells have to be drilled with the only purpose to supply the plants.

These disadvantages, which could be solved by the economically feasible costs, are opposed by a variety of advantages. With the climate change in mind and the costs and challenges that come with it, the most important argument surely is the emission-free generation of electricity and heat. In the Sahara, the sunrays of a period of 6 hours are enough to supply the global population with energy for a whole year. Owing to this, in the future, solar energy will play an important role in Africa and the Middle East when it comes to power generation and water supply. Furthermore, humanity will be less dependent on fossil fuels like oil and coal, which will run short in the future. Quite contrary to the sun, which will exist another 5 billion years and reliably is providing energy. Moreover, the search for coal and oil deposits is quite costly and profoundly alters the landscape. Thanks to the enormous progress in the field of solar research during the last years, solar power plants can economically keep up with conventional power plants such as coal power stations.

5. Prospects for Europe^[8]

The future-oriented energy policy has to achieve the following three goals:

- security of supply
- cost-effectiveness
- environmental sustainability

The resolution for a healthy energy policy must be a "balanced energy mix". There are a lot of possibilities to generate energy by using renewable resources. Each source of energy has both advantages and disadvantages. For this reason, the energy policy should not be a matter of either/or, but a reasonable mixture of all possibilities. It is necessary to shift from oil, gas and uranium to renewable energies step by step in order to not further damage our planet.

Solar energy is the one renewable energy with the greatest technical potential. Scientists assume that by 2050 24% and by 2100 even 63% of the worldwide demand for energy will be met by solar power. Moreover, solar energy provides new jobs and economic growth. Thus, the turnover in the field of solar technology in 2005 amounted to 3.75 billion euro. Forecasts indicate that the turnover will increase up to 24 billion euro by

2020. Furthermore, the solar industry assumes that there will be more than 350,000 employees in this field by 2020.

Indeed, nowadays solar electricity is still more expensive than conventional electricity, but it will be cheaper in the course of 2020 to 2030 due to the increasing prices of fuels and environmental costs. An important project to help to achieve this goal is DESERTEC in North Africa, where huge solar power plants are constructed in order to supply Europe, North Africa and the Middle East with solar electricity. It is planned to establish high-voltage direct current transmission lines to transport the electric power. These lines, however, have an energy loss of 4-5% per 1000km of length. Owing to that loss, the price for solar electricity increases by 1-2ct/kWh. That means that the price can differ according to the length of the transmission line. Capital and operating costs are already included in the price.

Solar energy as well as other renewable energies will play an important role in the future when it comes to meeting the demand for energy. However, we cannot yet refrain from using energy generated by fossil fuels and uranium. For this reason, we cannot totally rely on renewable energies immediately, but have to keep developing these technologies until they are as cost-effective to entirely and comprehensively replace the conventional forms of generating energy.

References

- [1] <http://www.solarviews.com/germ/sun.htm> [11.12.2010]
- [2] <http://lexikon.astronomie.info/sonne/index.html> [11.12.2010]
- [3] <http://www.waermepumpe-installation.de/infos/sonne.html> [11.12.2010]
- [4] <http://www.mps.mpg.de/projects/soho/sumer-lab/isermann/sonne.html> [12.12.2010]
- [5] http://www.welt.de/wams_print/article3250416/Salze-speichern-Sonnenenergie.html [14.12.2010]
- [6] http://www.energieportal24.de/artikel_2614.htm [14.12.2010]
- [7] http://www.focus.de/wissen/wissenschaft/klima/tid-14870/energie-mythen-3-mythos-solarenergie-laesst-sich-nicht-speichern_aid_416595.html [15.12.2010]
- [8] http://www.schott.com/solar/german/download/schott_solarfibel.pdf [15.12.2010]
- [9] <http://www.spiegel.de/wissenschaft/technik/0,1518,684965,00.html> [15.12.2010]
- [10] http://othes.univie.ac.at/363/1/01-31-2008_0005396.pdf [13.12.2010]
- [11] <http://de.wikipedia.org/wiki/Solarzellen> [13.12.2010]
- [12] <http://www.solarmillennium.de/technologie/parabolrinnen-kraftwerke/funktionsweise/index.html> [15.12.2010]
- [13] <http://www.zdf.de/ZDFmediathek/beitrag/video/1072594/Kraftwerk-Sonne> [14.12.2010]
- [14] <http://www.desertec.org/> [14.12.2010]
- [15] <http://www.desertec.org/de/presse/pressemitteilungen/091030-1-gruendung-der-dii-gmbH/> [15.12.2010]
- [16] <http://www.zdf.de/ZDFmediathek/beitrag/video/1082266/Neue-Solarzelle-billiger-und-effektiver> [15.12.2010]
- [17] <http://www.solarserver.de/wissen/lexikon/s/solarturmkraftwerk.html> [16.12.2010]
- [18] <http://www.enviromission.com.au/EVM/content/home.html> [16.12.2010]
- [19] <http://www.handelsblatt.com/unternehmen/industrie/solarprojekt-desertec-findet-partner;2462843> [12.12.2010]
- [20] <http://www.zdf.de/ZDFmediathek/beitrag/interaktiv/216680/Energie-bewegt-die-Welt> [11.12.2010]
- [21] http://www.enviromission.com.au/EVM/content/media_animations.html [16.12.2010]
- [22] <http://www.abb.de/cawp/seitp202/1d2af6c371b6f728c12575e10024eccc.aspx> [13.12.2010]
- [23] <http://www.solarenergie-sonnenenergie.com/Vorteile-Nachteile.html> [14.12.2010]
- [24] <http://www.abc-solar-energy.de/vorteile-nachteile-sonnenenergie.html> [15.12.2010]
- [25] <http://www.strom-infos.net/vor-und-nachteile-der-sonnenenergie.html> [10.12.2010]
- [26] <http://www.solarheizen.at/26/vor-und-nachteile-der-Sonnenenergienutzung> [12.12.2010]

Methods of obtaining energy in Poland and Germany

Andrzej Wilczyński

Branderburgische Technische Universität
Cottbus, Germany
wilczan1@tu-cottbus.de

Wioletta Simlat

Branderburgische Technische Universität
Cottbus, Germany
viola.simlat@wp.pl

Power is the science and technology involved in the acquisition, processing, stockpiling and use of various forms of energy, useful forms of energy obtained from the processing of primary energy, primary fuel mainly chemical, nuclear, water, Earth, air, solar radiation.

I. ABOUT ENERGY ON EARTH IN GENERAL

The inhabitants of Western Europe, Canada, the United States and Japan, who constitute only 12.5% of the population of the globe, consuming as much as 60% of the total world energy output. The remaining 87.5% of the population of the Earth in less developed countries who can not afford the higher consumption, is therefore given the remaining 40%.

Most of the energy is obtained from fossil organic materials, namely coal, oil and natural gas. These energy resources were created from the fossilized remains of prehistoric animals and plants and their crops, and thus are of limited supply that declines at an alarming rate. According to the optimistic data, resources of coal and lignite are sufficient at its present extraction rate for about 150 years, natural gas will be available for about 80 years and the oil should drain in the next 40 years. In addition, extracting energy from these raw materials presents a disadvantage to the natural environment, as during their combustion produces a lot of environmentally harmful substances is released.

Another source of power currently enjoyed by the large number of countries is the nuclear energy created during the splitting of atoms. However, despite the fact that nuclear plants are more efficient than traditional thermal power plants, they pose a risk of failure that could affect the entire planet. Equally or perhaps even more dangerous is radioactive waste generated during operation of nuclear power plants; long-term storage and neutralization entails huge costs and poses health dangers to the people involved in its processing.

Only 19% of the world energy output is generated by alternative methods. Of those 19 percent, 17% are hydro plants, with the remaining 2% solar, wind, tidal, geothermal. They have a huge advantage over thermal power plants and nuclear reactors, because they are largely safe for the environment and their resource base is renewable.

II. WHY PRODUCING OF ENERGY IS SO IMPORTANT?

A. For electricity supply

Electrical energy is a form of energy that can be transmitted over distance. Transmission of electricity is possible because of the phenomenon of current: the movement of negatively charged electrons. Majority of electricity comes from power stations. The electricity is then transported through electricity network to all end-users.

B. Specifications of the electricity

Electricity has multiple uses and finds its use even for electric vehicles. The advantage of this energy is that it is possible to transform the energy into another sort of energy, without significant losses in energy. Additionally, electricity is easy to transport. Nowadays economies of developed countries are dependent on imported electricity; any supply disruption results in economic losses for entire countries. Without electricity humanity sinks into chaos of communication with an unsafe future. Today life without electricity is unimaginable for all people.

III. THE FUTURE OF GERMANY DEPENDS ON ECONOMICAL AND ENVIRONMENTALLY-FRIENDLY ENERGY SOURCES

The energy policy requirements are raised by Germany's dependence on energy imports, increasing energy prices as well as climate change. Close by low prices and sure energy obtaining, the process must be environmentally friendly. Germany will try to get the energy in connection with these requirements.

IV. DEPENDENCE GERMANY OF IMPORT

Germany lacks natural energy resources. About 97 % of oil, 83% of gas and 61% of coal come from imports. Uranium is 100 percent imported. More or less than one fifth are imported from Russia and about 8 percent from France.

IV. PRIMARY ENERGY SUPPLY

It has become a political, ecological and economical issue to reduce the carbon dioxide emission and to conserve coal, oil and other natural resources. The energy sources used by Germany are diverse; oil energy constitutes the largest share in its energy output, close to the EU-27 average of 38%. The share of nuclear energy in primary energy supply has increased

slightly in recent years. The use of renewable sources shows an extraordinary increase of 141% since the 1990s.

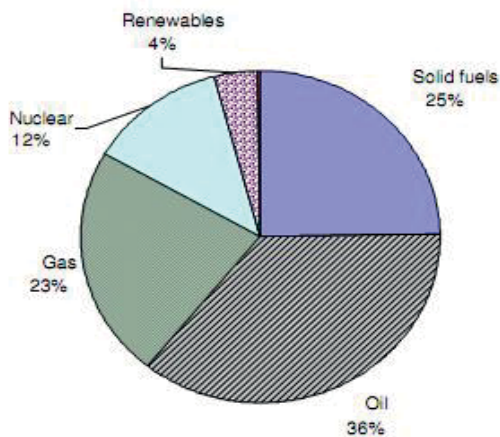


Figure 1: Primary energy sources in Germany

Domestic Production

Germany is the second largest producer of coal in European Union, with about 6739 million tonnes coal reserves discovered at the end of 2005. Germany is the second largest producer of nuclear energy in EU. Moreover, after UK and Netherlands, Germany is the third largest producer of natural gas. The share of renewable sources in domestic energy production totals about 10 percent.

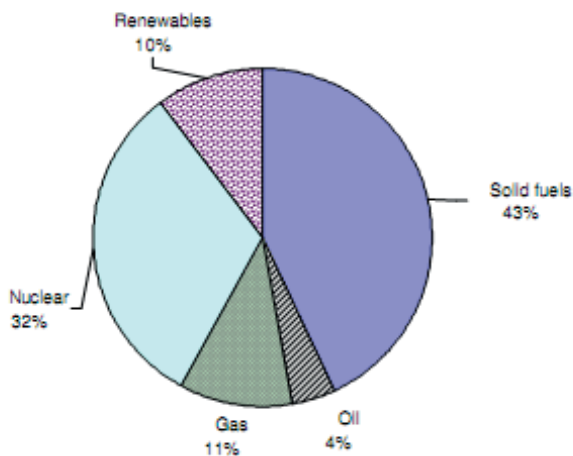


Figure 3: Domestic production in Germany

Germany's resistance against nuclear power

The Germans protest against nuclear energy. Nevertheless, the German government plans to generate 80% of the country's energy from renewable sources by 2050. Currently Germany produces 16% of its energy from renewable sources. Under the new energy scheme, the nuclear reactors will continue to run for an average of 12 years beyond 2021.

V. WHAT ABOUT POLAND?

In Poland, coal, brown coal, petroleum, natural gas, water are the main energy sources.

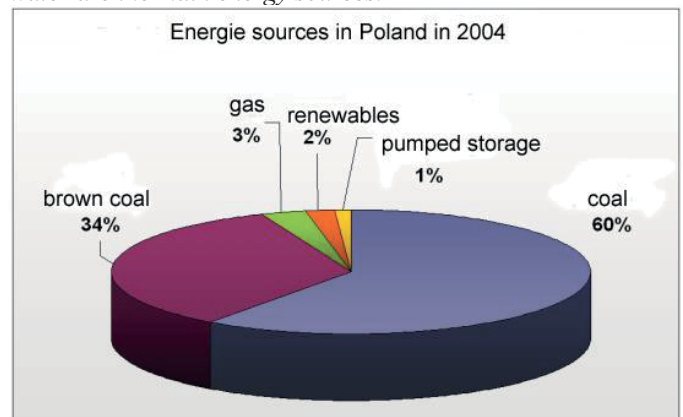


Figure 2: Primary energy sources in Poland

Poland is an important producer of coal in the world (ninth in 2007) and the largest producer of coal in the European Union. Attributable to coal production in Poland is about 56% of EU production. In 2006 Poland has supplied the European market of approximately 16 million tons of coal, while in 2007 some 12 million tons. This was mostly steam coal.

The role of the EU as a Polish producer of coal in the future will depend on the capacity of the Polish mines to compete effectively with coal imported from outside the Member States of the EU and the competitiveness of coal compared to other energy sources.

- For example, coal can be extracted - Upper Silesian Basin, Alberta Basin, Basin Lublin, Rybnik Coal District, reserves are estimated at around 100 million tonnes
- Brown coal (the Tertiary) - around Bełchatów area: Konin - Wheels - Turk, Bogatynia around, around Legnica, Zielona basin; reserves are estimated at about 60mln tonnes;
- Oil - at the Carpathian Basin oil - Sanok, Krosno, Jasło, Gorlice, Krosno Odrzańskie region, around Kamień Pomorski, under the Baltic Sea;
- Natural gas is extracted in Podkarpacie - Przemyśl, Lubaczów, in the region of Western Pomerania, Wielkopolska - Garki, Zalecze, Ostrów Wielkopolski, Poland also imports natural gas from Ukraine and Russia via pipeline Jamaican;

VI. THERMAL POWER STATIONS IN POLAND

In Poland, up 97.3% of energy is produced in thermal power stations:

- Coal-fired power: Dolna Odra, Połaniec, Kozienice, Ostrołęka, Opole,
- Brown coal-fired power plants: Belchatow, Konin, Legnica, Adams, Turow.
- Hydropower: pumped storage: Porąbka near Żywiec, Żydowo near Koszalin, near Wejherowo Żarnowiec, and power stations in Solina, Rożnów, Włocławek, Koronowo, Dychów and Dębno.

- Geothermal plants: invested in Podhale, in the Sudetenland, Pырzyce Uniejów;

VII. RENEWABLE ENERGY SOURCES IN POLAND

Currently the world there are many sources from which to derive energy. These include raw materials such as oil or coal. However, their resources are dwindling, making it increasingly goes to other, renewable sources.

Poland is rich in renewable energy. It is believed that the potential of these sources is 3.850 PJ per annum, which amounts to approximately 90% of the energy needs of Poland. Despite the substantial resources of energy from renewable sources in Poland is very low. It amounts to only about 1.5% of primary energy demand.

The richest renewable energy sources in Poland are:

- geothermal energy (1.512 PJ / year)
- solar energy (1.340 PJ / year)
- biomass energy (619 PJ / year).

In addition, Poland also has some wind resources (43 PJ / year) and water (36 PJ / year).

Production of renewable energy in 1999 [PJ]		%
Biomass	101.8	98.05
Hydropower	1.9	1.83
Geothermal	0.1	0.1
Wind energy	0.01	0.01
Solar Energy	0.01	0.01
Total	103.82	100

VIII. WHAT WITH THE FUTURE?

In the near future, Poland must adapt its economy (including the production of electricity) to European Union standards. The development is progressing very slowly, because the politicians are investing in the import of non-renewable resources (gas agreement with Russia - import huge quantities of gas over the next 26 years).

Poland has more and more alternative energy sources, primarily by private investors. It has become fashionable to wear solar panels on the roofs of buildings, or putting windmills. Despite high construction costs, these investments will pay off quickly.

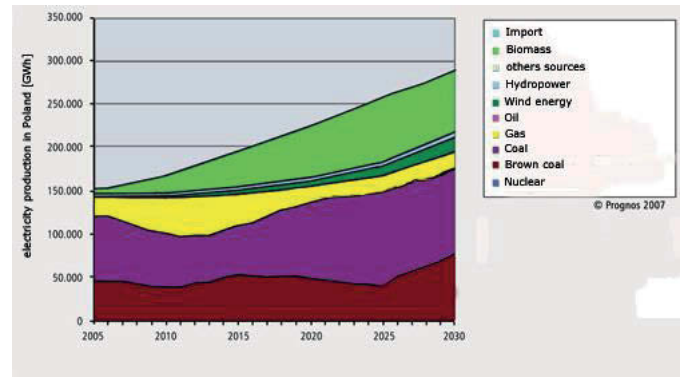


Figure 4: Electricity Production in Poland

[1] <http://www.energyboom.com/policy/germanys-new-energy-plan-wins-renewables-and-loses-nuclear>

[2] http://en.wikipedia.org/wiki/Nuclear_power_in_Germany

[3] <http://www.bundesregierung.de/Content/DE/Magazine/MagazinWirtschaftFinanzen/064/sa-energie-fuer-deutschland.html>

[4] http://sciaga.nauka.pl/index.php?id=index/dept=54/cath=221/sc_id=8936/title=Sposoby_pozyskiwana_energii_w_Polsce_w_porowaniu_do_innych_krajow_swiate

[5] http://www.bryk.pl/teksty/liceum/geografia/geografia_spoleczno-ekonomiczna/8690-odnawialne_zrodla_energii_w_polsce_stan_aktualny_i_mozliwosci_zwiekszenia_nego_ich_wykorzystania.html

[6] <http://www.biomasa.org/index.php?d=artykul&kat=67&art=66>

[7] <http://gospodarka.dziennik.pl/news/artykuly/104805,mamy-gaz-z-rosji-jest-umowa.html>

[8] <http://geografia.na6.pl/surowce-naturalne-jako-alternatywne-zrodla-energii>

Upcoming challenges to German energy politics caused by the change from conventional to renewable energy sources

Wieland Baum, Johannes Gräbel
Lehrstuhl Energieverteilung und Hochspannungstechnik
Brandenburgische Technische Universität Cottbus
Cottbus, Germany

Abstract—In times of climate change and the shortage of resources, Germany, as one of the most important industrialized countries in the world, sees itself confronted with various political challenges. This paper will focus on challenges caused by regenerative energy sources.

I. INTRODUCTION:

Mankind has always been dependent on energy sources in order to survive and evolve. While especially wood was the most important energy source for thousands of years, it was replaced by oil, natural gas, coal and nuclear energy in the last two centuries. These so called conventional energy sources have been the foundation for the rapid technological progress of mankind in these years. But since the middle of the 20th century, people became aware of the narrowness these resources are subject to. Additionally, the global warming and the climate change are nowadays considered to be caused by fossil fuels in most instances. In consequence of their narrowness and their impact on the world's climate, reasonable handling and consumption of these fossil fuels have become very important. Furthermore, researching for alternative energy sources and extending their utilization is of inevitable necessity. Especially the industrialized countries are in charge to lead the way when it comes to promoting regenerative energy sources. As one of the most important national economies worldwide, Germany is particularly responsible to support the progress in alternative energy technology. Hence, German energy politics sees itself confronted with numerous upcoming challenges which are caused by the change from conventional to renewable energy sources.

II. USAGE OF FOSSIL FUELS AND RENEWABLE ENERGY SOURCES IN GERMANY NOWADAYS

First of all, the current situation concerning energy sources and their usage in Germany is of importance. Although Germany is very dedicated to the development of renewable energy sources, the countries primary energy consumption is still mainly based on fossil fuels. As can be seen in image 1, the majority of primary energy consumption is still related to oil, coal, gas and nuclear power, although the shares of brown

coal have decreased from 1990 to 1999, which can be traced back to the fact, that in this period, many east German power plants operated by brown coal have been put out of service. At the same time, black coal, gas and nuclear power have been used with just slight variations. Mineral oil has first been stable in its consumption but decreased as well from 1998. Nevertheless, regenerative energy sources such as hydropower, wind power, photovoltaic and other energy sources have constantly increased their shares of the primary energy consumption.

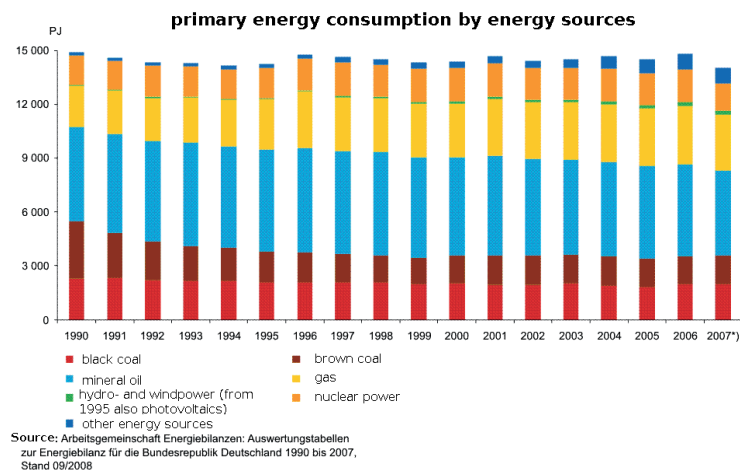


Figure 1. primary energy consumption in Germany

The details of their increase can be seen in figure 2. The total percentage of renewable energy sources in power generation has constantly grown since the year 2000 with only one small gap in 2003. Especially wind power and biomass have extended their shares within the last years, making them the most important of the renewable energy sources. Although hydropower has been the most important regenerative energy source in 2000 it was ousted by the other sources. Photovoltaic has also increased its share over the shown period but is still not as important as hydropower or the other regenerative energy sources. This is due to the fact, that photovoltaic is more expensive than the others and not as effective as them at the same time.

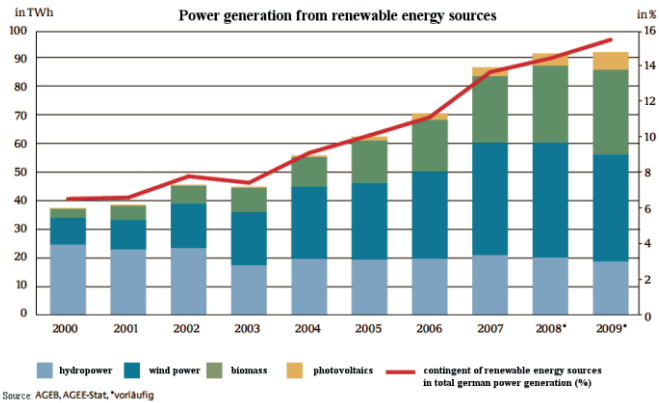
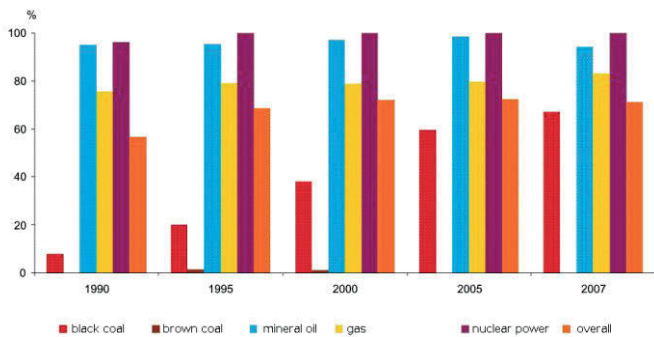


Figure 2. power generation from renewable energy sources in Germany

III. SOURCES AND SUPPLIES OF FOSSIL FUELS AND URANIUM

Although being one of the major national economies in the world, Germany is very poor in resources. Except large deposits of brown coal, some deposits of black coal and a small amount of oil fields, Germany has no resources in its disposal. Therefore, German economy and power supply industry are dependent on foreign imports. The exact shares of primary energy needed to be imported can be seen in figure 3. Nuclear power respectively uranium has to be imported by nearly 100 percent as no uranium is mined in Germany, except some small amounts which result from the restoration of old uranium mines. Mineral oil has also been imported by nearly 100 percent between 1990 and 2005. The imported percentages of mineral oil have just lowered by a few percent in 2007. Gas has been imported in mostly constant percentages as well, with just slight fluctuations. In contrast to the constantly imported sources like oil, uranium and gas, black coal has been imported in amounts constantly increasing since 2007, which is a result of closing most of the German black coal mines during the last two centuries. The overall percentage of imported primary energy sources has increased between 1990 and 2000 but has stagnated ever since.



Source: Arbeitsgemeinschaft Energiebilanzen, Statistik der Kohlenwirtschaft, Bundesverband Braunkohle, Bundesamt für Wirtschaft und Ausfuhrkontrolle, Mineralölwirtschaftsverband. Entnommen: Energiedaten (BMW) 2008, Stand: 10.10.2008

Figure 3. Imports of primary energy sources to Germany

IV. EXPECTED CHANGES IN SUPPLIES

In recent decades, the world's oil production has increased exponentially. Because of fewer and fewer new discoveries of oil facilities, the so-called peak oil will be reached within the next 20 years, as scientists expect. Peak oil considered to be the day the maximum rate of global petroleum extraction is reached. After reaching this point, the global rate of oil extraction will terminally decline. As seen in figure 4, the rate of oil production in 1950 was only around 15 million barrels, today it is already at about 80 million barrels a day. This curve is often illustrated with a bell curve. Figure 3 also shows, that there are two different estimated points of peak oil. This occurs due to once including unconventional oil.

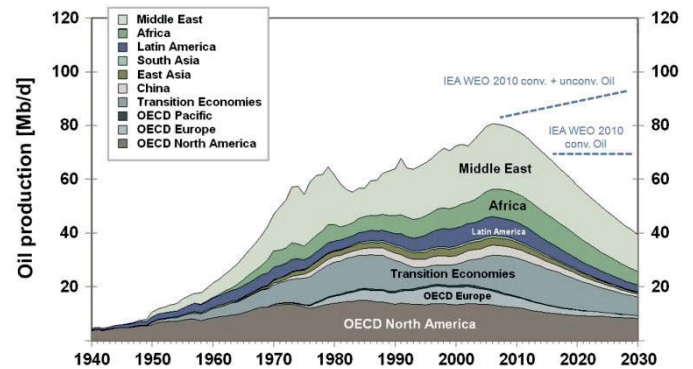


Image : Energy Watch Group www.energywatchgroup.org / Ludwig-Bolkow-Systemtechnik www.lbst.de

Figure 4. predicted changes in worldwide oil production

The so-called unconventional oil comprises oil sources which are nowadays considered too expensive to be delivered such as oil sands, oil shale, heavy oil, deep-water oil, polar oil and liquefied petroleum gas. The reduction of these raw materials is associated with higher financial, energy and environmental costs as the promotion of conventional crude oil [1]. Nevertheless, the unconventional oil is a significant portion of reserves. Accordingly, the various figures for peak oil are far apart. According to the IEA the conventional oil production peak was reached in 2006, with 70 mega barrels a day. Including unconventional resources, the maximum production is predicted to be reached in the 2020s or 2030s at 96 mega barrels per day by the IEA.

An increase in oil prices is considered a possible consequence of the global production peak, this will lead to the inevitable condition that Germany must find other energy sources to cover its energy needs. Because of environmental and economic conditions, renewable energies are in the foreground. Germany – a cosignatory to the Kyoto Protocol – has set a target to produce at least 20 % of its energy needs from renewable energy sources by 2020. This proportion was already at 15% in 2010, so it is proven that the target can be achieved and maybe even exceeded.

As seen in figure 5, the share of renewable energies of 2005 was still about 10%, which is already a significant increase when considering, that this percentage still was about half as large at five percent in 1998 [2]. Optimistic estimates suggest that accounts of more than 40% can be achieved in 2020.

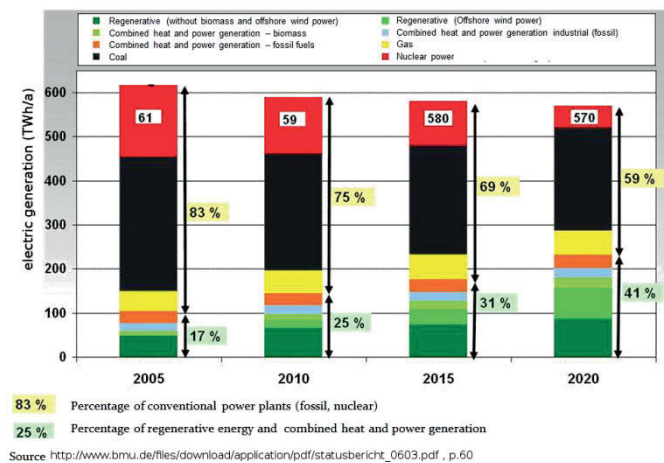


Figure 5. predicted power generation in in germany until 2020

V. PROBLEMS CAUSED BY THE EXTENDED USE OF RENEWABLE ENERGIES

Of course problems also occur in the use of renewable energies sources, for example some energies are highly dependent on geographical conditions. Solar power plants are a good example of geographical dependence, as these are, of course, best placed in very sunny regions. Another example are wind turbines, which are best placed in marine and coastal regions. Since Germany has no surplus of both, it may happen that a dependence on other countries with better conditions will be unavoidable again, just as it already is nowadays, considering mineral oil, uranium and gas.

There are controversial debates about some of the new methods of generating energy, often discussing whether they have negative environmental consequences. Especially wind power is considered to have lots of negative aspects on local wildlife such as birds and bats [3][4]. In some regions, hundreds of bats were already killed in correlation to wind turbines. Research about the exact reasons is still going on so it is not sure yet, if more problems caused by wind turbines will occur someday.

One of the infrastructural problems is the fact, that renewable energies are not always reliably available, such as fossil fuels. Other obstacles lie in producing and providing enough energy to satisfy the demand. Additionally, opportunities to store unused energy are still missing. Furthermore, the variability of produced amounts of current strains the power network, as it will sometimes be nearly overloaded and sometimes supplied with too little energy.

VI. POSSIBLE PERSPECTIVES FOR GERMAN ENERGY POLITICS

The change from fossil fuels to renewable energy sources provides both, duties and chances, for German energy politics. The most important duty is the promotion of a balanced mixture of different renewable energy sources. On the one hand, this mixture is able to guarantee an optimal utilization of natural phenomena such as wind, tide, sun and others. On the other hand, relying on just one renewable energy source would be insufficient as most of them are not able to assure the base load which is nowadays provided by nuclear power plants and brown coal power plants. This is due to the fact that renewable energy sources, especially photovoltaic and wind power, are dependent on the availability of natural resources which cannot be influenced by humans at all.

Furthermore it is necessary to upgrade the German power grid. As the usage of renewable energy sources is bound to geographical preconditions, it will often be inevitable to transport the energy from the place it is generated at, to the place it will be consumed at. For example, large amounts of wind power produced in Germany, origin in the northern, coastal part of Germany while most of the factories consuming the energy are situated in southern and western Germany. Therefore, upgrading the German power grid is of essential importance to the further development of regenerative energy sources in Germany.

Connected to upgrading the German power grid, it is also supposable to enhance the cross-border co-operation in Europe. By doing this, local problems in energy supply can be accommodated by surplus production of energy in other countries. This would result in a more stable and reliable power supply for German consumers.

At the same time, German politics should invest in the research of storage technologies. As most of the regenerative energy sources cannot guarantee a constant and undisturbed supply with energy but on the other hand sometimes produce more energy than is actually needed, new improved storage technologies can solve both problems at the same time. Pumped storage hydro power stations are just one possibilities of storing spare energy. But these power stations will not be able to store enough energy without being supported by other storage technologies as there is only a limited amount of possible locations for them.

Nevertheless, there are also chances for German energy politics conditioned by turning away from fossil fuels.

By using more and more energy gained by renewable energy sources, Germany is given the opportunity to reduce its dependence of imports. Especially the dependence on oil, which is getting more and more expensive and is at the same time partially located in politically unstable regions, can be notably lowered when relying on regenerative energy sources. But imports of uranium and coal will also be reduced when large amounts of energy will be generated by renewable sources.

Another benefit from the predicted changes in German energy supplies could be lower costs for energy production. Although renewable energy sources are often referred to as expensive, rising prices for fossil fuels could soon make regenerative energy sources cheaper than conventional ones.

By investing in research of storage technologies and supporting local manufacturers of solar panels, wind turbines and hydro-electric power stations, Germany will also be able to sustain its local economy and resident high-tech companies.

- [1] Wolfgang Gründinger. Die Energiefalle, München 2006
- [2] <http://www.umweltbundesamt-daten-zur-umwelt.de/umweltdaten/public/theme.do?nodeIdent=2850>
(called: 10.01.2011)
- [3] B. K. Sovacool, "Contextualizing avian mortality: A preliminary appraisal of bird and bat fatalities from wind, fossil-fuel, and nuclear electricity". *Energy Policy* 37: pp. 2241–2248, 2009.
- [4] Erin F Baerwald; Genevieve H. D'Amours; Brandon J Klug; Robert MR Barclay, "Barotrauma is a significant cause of bat fatalities at wind turbines," *Current Biology* 18 (16): pp. R695–R696, August 2008