How could Germany reorganize their electricity production if nuclear power plants were shut down?

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ABSTRACT

Our purpose for this seminar paper is to summarize and evaluate the plan of shutting down all the nuclear power plants in Germany. The paper should give an overview about the current electricity power plant structure in Germany and also give an outlook over the future electricity production after the nuclear power plant shutdown. For that we want to create a scenario in order to analyze how Germany could handle the nuclear power plant shutdown within 2020. One of our main questions is how the future electricity structure has to be planned or restructured in order to reduce the Emissions of kgCO_2/MWh in the state. After having analyzed the power plant structure in the country, we will try to find out what the best solution would be: to restructure old coal fired power plants, using and building more gas fired- and combined cycled gas power plants or force the development of RES even faster than intended?

We divided the whole considered period into two parts: at first we focus on short term changes till 2020, then changes over long term from 2020 onwards. In both sub-chapters we will analyze what the best technical solution would be to get back to the current electricity production and if it`s needed even higher.

Finally, we will discuss how and what future prices for one ton of emitted CO2 will affect the power plant structure in the country. We will try to analyze how different prices for CO2 per ton will affect the future electricity price and also the future power plant structure because of restrictions due to too high emissions in the country. At last we want to show what the best way for Germany after the shutdown would be from our point of view and give an outlook for future research in this field.

It must be pointed out the every assumption is purely theoretical since going any further would go beyond the scope of this paper and a lot more factors would have to be considered when approaching the topic more thoroughly

KEY WORDS

CO2 emissions, power plant structure, Germany, renewable energy sources, nuclear power plants shut down

Content

1 Introduction

1.1 Reorganization of electricity production

First of all we have to take a look at the currently installed capacity of nuclear power plants to get an idea as to why we have to talk about a reorganization of the German power plant structure. After taking effect of the act called "Atomgesetznovelle" from 31.07.2011 nine nuclear power plants are still operating now with a net capacity of 12068 MWe installed. As we can see in *Table 1*, Germany now has a total installed capacity of 177574 MWe, so by a phase-out of nuclear power, they will shed 6,796% of their total installed capacity. This shut-down of all nuclear power plants in Germany has now been subject of discussion since the elections in 1998[1]. The new founded federal government was billed by different parties, who all wanted the nuclear phase-out. Since then every new federal government tried to get to an end in this discussion but so far no one has spoken out a concrete date for the phase-out for various reasons.

To get to the first part of our research question, namely how prices for CO2/ton affect the power plant structure over long term, we first have to take a look on the currently existing and used installed capacity by different sources.

The following table shows all the existing power plants in Germany as listed by the "Bundesnetzagentur" on 27th March 2013[2].

[1]GRIN: Der Atomausstieg in Deutschland. [online]. [cit.2013-03-28]. Available from: http://www.grin.com/de/e-book/176330/der-atomausstieg-in-deutschland

[2]Bundesnetzagentur. [online]. [cit.2013-03-28]. Available from: http://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetGas/Sonderthemen/Kraftwerksliste/VeroeffKraftwerksliste_node.html

Summ of Net- Capacity (elec.) in MW	Status of the Power Station					
Energy source	Operating state	Cold re-serve	Special case	Definitly inoperative 2012	Definitly inoperative 31.12.2011	Reserve-power station	**Total**
Geothermal	12						12
Sewer Gas	90						90
Mine Gas	254						254
Landfil Gas	262						262
Offshore Wind power	268						268
Waste	1.100	52	12	6			1.169
Other energy sources	1.147						1.147
Dammed Water (w/o pump storage)	1.309						1.309
Mineral oil products	3.713	29		30			3.772
Running Water	3.798						3.798
Biomass	5.569						5.569
Pump storage	8.939		290				9.229
Nuclear power	12.068						12.068
Several energy sources	14.517	335	28	133		415	15.428
Natural Gas	16.823	1.250	199	64		1.117	19.454
Brown coal	17.793	260		1.321	383		19.757
Stone coal	19.159	566	249	386		203	20.562
Onshore Windpower	30.016						30.016
Solar radiant energy	33.409						33.409
Total	**170.246**	**2.492**	**778**	**1.940**	**383**	**1.735**	**177.574**

Table 1: Installed capacity in power plants by energy source in Germany

The *Table 1* shows a diversion of the electricity production by energy resources. As we can see Germany has an installed capacity of 177, 6 GW. In *Table 1* are only listed power plants with a net capacity over 10M and power plants which are used as Net importers of electricity from Luxembourg, Austria, France and Switzerland are also included. Moreover, power plants with a net capacity under 10MW are listed if they have an improved capability. The above mentioned 6, 796 % of total installed capacity may not appear very important, but if we consider that nuclear power plants are usually in operating state for 7640 hours per year as base load power plants, we got a total produced electricity demand of 108 TWh in 2011[3].

The total electricity production in Germany was 615 TWh in 2011[4], so we see that by using nuclear power about 17, 7 % in 2011 and 16% in 2012[5] of total electricity consumption were

[3] Federal Statistical Office (Destatis): Economic Sector. [online]. [cit.2013-04-14]. available from: https://www.destatis.de/EN/FactsFigures/EconomicSectors/Energy/Production/Tables/GrossElectricityProduction.html

[4] BMWi: Stromversorgung. [online]. [cit.2013-03-28]. available from: http://www.bmwi.de/DE/Themen/Energie/stromversorgung.html

produced. In *Image 1* the average full load hours for the year 2010 of the different power plants in Germany are shown.

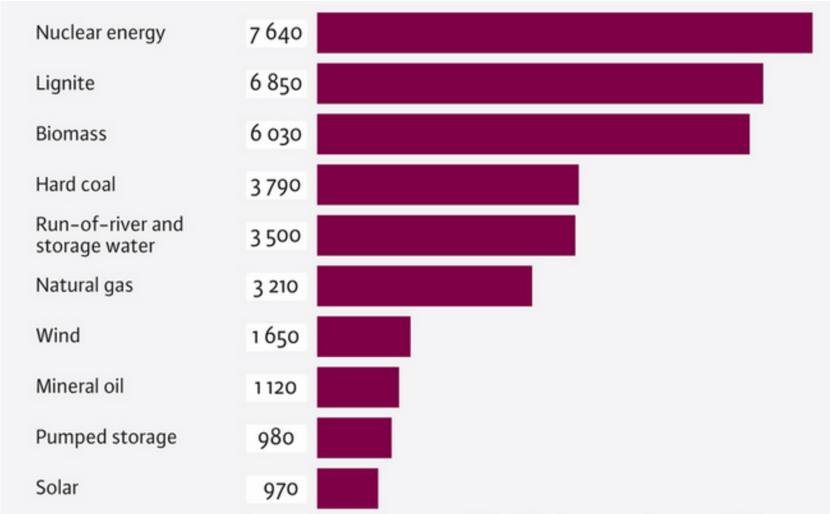

Image 1: Annual full-load hours of German power plants in 2011 *(Source: bdew.de)*

For the second part of our research question we want to take a look at how the increasing use of coal or gas to produce electricity affects the CO_2- price. For that reason we want focus on the CO_2- emissions of the energy sources in *Chapter 1.2*.

1.2 CO_2 prices after shutting down of nuclear power plants in Germany

If we take a close look at the table, we can see that for every kWh of electricity produced by nuclear power, 27 g of CO_2 are produced as well. What is missing in this table is the value of other production technologies, like oil fired Power Plants, which produce 650 g/kWh of CO_2-Emissions[6].

As already explained in the Abstract, we want to find out what the best decision for Germany would be to produce the missing electricity caused by a nuclear phase-out. Even though Germany has produced 20% of its total electricity out of renewable energy sources[7] in 2011, the missing 15% after the nuclear phase-out cannot be produced by renewable energy sources right now. For this reason we want to analyze the output of Germany's CO_2- emis-

[5] See #2

[6] E-CONTROL: STROMKENNZEICHNUNGSBERICHT 2012. [online]. [cit.2013-04-21]. available from: ttp://www.e-control.at/portal/page/portal/medienbibliothek/oeko-energie/dokumente/pdfs/Stromkennzeichnungsbericht%202012.pdf

[7] BMU: Erneuerbare Energien 2011. [online]. [cit.2013-03-28]. available from: http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/ee_in_zahlen_2011_bf.pdf

sions by 2020 As can be seen in *Image 2*, there is a difference of more than 50% between CO_2- emissions of a natural gas powered generating plant and a stone coal fired power plant. And when comparing gas and lignite, there is a difference of more than 75% as regards CO_2-emissions. Hence what we wanted to do in *Chapter 4* is to calculate the amount of CO_2-emissions that every individual power plant produces and then combine the power plant list from today with the list of our scenario after the nuclear power plant shutdown.

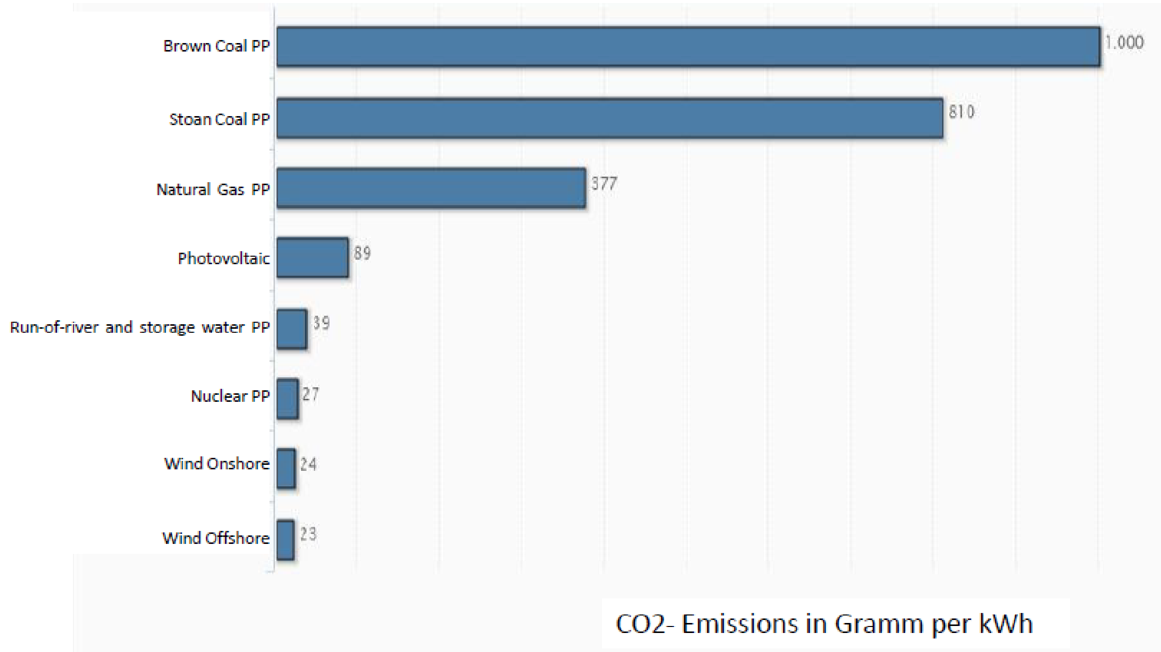

Image 2: CO2 Emission of Electricity production in Germany by different technologies in 2010 ***(Source: de.statista.com)***

In *Table 1* not only the power plants in operating state are shown, but also the power plants which are either used as cold reserve, or for special cases, or as reserve power stations and these ones that definitely do not operate. That way, we will have the whole installed capacity listed, even if they are already out of order, and can use all the installed capacity for our calculations. In this regard, Germany has to find out whether it will be better to put them totally out of order or reactivate and restructure them. Also we have to make the same considerations to create a scenario, with or without the cold reserve and the ones already out of order, for the future power plant structure.

What we wanted to obtain is a scenario where we can see the different CO_2- emissions producing the needed electricity by using the current power plant structure and the one from the scenario in 2020. So we want to find out what the best combination would be to produce the missing 92, 2 TWh with as little CO_2- emissions as possible to be able to hold the

26% of emission reduction compared to the emissions in 1990[8] or, even better, increase the reduction of the emissions in order to reach the self-set ambition of reducing the emissions by 40% by 2020 compared to 1990[9].

In the last part of our paper we want to see at which certain level the CO_2- Price per ton will take effect at the cost effectiveness of different PP`s, if we use the merit order system to generate our electricity price. By that, we can then see how prices per ton of CO_2 affect the power plant structure after the nuclear power plant phase-out.

2 CURRENT SITUATION

2.1 Current energy demand in Germany

In 2011 electricity consumption grew by 3, 1 %[10] in global. Total global consumption was 19 016 TWh[11]. And Germany´s consumption was 541 TWh[12]. What is approximately 2, 85 % of total global consumption.

Power plant structure in Germany has increasing share of renewable energy sources. In 2010 was share of renewable energy sources 16, 4%[13] (almost half of production is from wind power) of total Germany´s production 628, 6 TWh[14]. In comparison, nuclear power generation is going in the opposite way. Nuclear power produced 22, 4 %[15] in 2010 and in 2012 was "only" 16 % of total production.

[8] BMU: Kyoto protocol. [online]. [cit.2013-04-12]. available from: http://www.bmu.de/themen/klima-energie/klimaschutz/internationale-klimapolitik/kyoto-protokoll/

[9] BMU: IEKP. [online]. [cit.2013-04-12]. available from: http://www.bmu.de/detailansicht/artikel/das-integrierte-energie-und-klimaschutzprogramm-iekp/

[10] BP: Electricity - Review by energy type. [online]. [cit.2013-04-10]. available from: http://www.bp.com/sectiongenericarticle800.do?categoryId=9037156&contentId=7068663

[11] Enerdata: Global Energy Statistical Yearbook 2012. [online]. [cit. 2013-04-12]. available from: http://yearbook.enerdata.net/electricity-domestic-consumption-data-by-region.html

[12] BDEW: Energy consumption. [online]. [cit.2013-04-09]. available from: http://www.bdew.de/internet.nsf/id/DA2ADF9EE4270788C1257A76004055A6

[13] DESTATIS: Economic sector - Production. [online]. [cit.2013-04-10]. available from: https://www.destatis.de/EN/FactsFigures/EconomicSectors/Energy/Production/Tables/GrossElectricityProduction.html

[14] See above

[15] See above

Changing production structure is reaction on events in Fukushima in March 2011. Several days later Norbert Rottgen – Environment Minister, said: "*It's definite. The latest end for the last three nuclear power plants is 2022. There will be no clause for revision.*"[16]

This plan for nuclear PP caused increasing influence of coal PP. Only lignite PP increased by 2, 5 % in 2012 beside 2010[17]. Renewable power sources are not able to cover electricity consumption by itself. It will take some time than new PP structure will be built. During this time is probably the most reasonable solution to reactivation coal PP.

2.2 In comparison: power plant structure in Austria and Czech Republic

The power plant structure in Austria and the Czech Republic is completely different. As we can see in *Image 3* the main source of electricity in the Czech Republic is combustible PPs. On the other hand, in Austria the main source is hydroelectric PPs, as can be seen in *Image 3*. The major reason for this difference is the geographic profile of the respective countries. Considerable parts of Austria are covered by the Alps. The total production of electricity in the Czech Republic was 87 561 GWh[18] in 2011. In Austria this number is 63 412 GWh[19].

In the Czech Republic the second largest source of electricity is nuclear PPs. Nuclear PPs produced 25 512, 6 GWh[20] in 2011. Even though both countries are situated in Central Europe, their respective energy policies differ considerably. From this point of view, we can assume that impacts caused by shutting down nuclear PPs in Germany will be more significant for the Czech Republic.

16 BBC: BBC News - Europe. [online]. [cit. 2013-04-10]. available from: http://www.bbc.co.uk/news/world-europe-13592208

17 See above

18 Energostat: Elektrina. [online]. [cit.2013-03-31]. available from: http://energostat.cz/elektrina.html

19 International Energy Agency: Monthly Electricity Statistics. [online]. [cit.2013-03-31]. available from: http://www.iea.org/stats/surveys/mes.pdf

20 See 19.

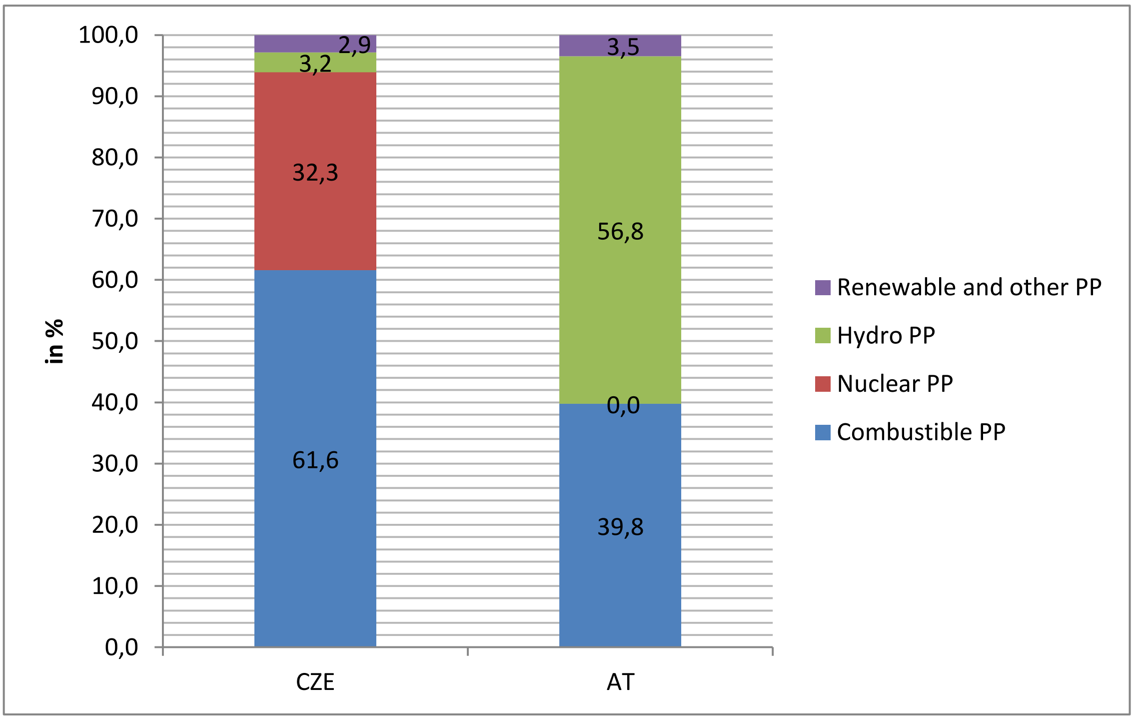

Image 3: Electricity structure in Czech Republic and Austria by source in 2011 (Source: own calculation; energostat.cz, iea.org)

3 METHOD: REPLACEMENT OF THE AMOUNT OF ELECTRICITY PRODUCING BY NUCLEAR POWER PLANTS

3.1 Short term: From now on till 2020

In short term (ST) we will take a closer look at the time period from now until 2020. We can say that we consider the electricity structure for our calculation as a fixed structure. Thus we are operating with the whole existing capacity of individual sources until 2020. In other words, we did not think about building new or shutdown conventional PPs in this time period to focus just on nuclear PP shutdown. We can say that we ignore the normally used capacity retirement graphs for the old operating power plants, because we wanted to see if it`s possible to produce enough electricity without nuclear PP by 2020.

As we know, the retirement of a PP is affected by its CO2- emission- factor per MWh, its efficiency and its normally given operating time. Since we just tried to use the existing conventional PP- structure, we looked for possibilities of elapsed time extensions for existing fossil fired PPs at first. In this context we found a paper of the German federal environmental agency on lifetime extension by retrofitting old PPs[21]. From our point of view, all technologies which help to produce fewer CO_2- emissions help to lower the electricity demand, store energy from RES or to retrofit old conventional PPs to become fast adjustable PPs, have to be analyzed to see if they can contribute in this situation.

3.2 Calculation of secured electricity production nowadays and in 2020

The PP structure in Germany by March 2013 has already been shown in *Table 1*. Out of that we tried to calculate the secured generation capacity in order to see if we can reach the value for the prognosis of maximum production needed in 2020.

In *Image 4* the values which we used as comparison to our calculation are shown.

Year	Scenario decreasing electricity Need [MW]	Secured generation capacity [MW]	Scenario constant electricity Need [MW]	Secured generation capacity [MW]
2013	75012,6	80880,6	76700	82700
2014	74705,8	80549,8	76700	82700
2015	74399	80219	76700	82700
2016	74092,2	79888,2	76700	82700
2017	73785,4	79557,4	76700	82700
2018	73478,6	79226,6	76700	82700
2019	73171,8	78895,8	76700	82700
2020	72865	78565	76700	82700

Table 2: Scenarios for the electricity need till 2020 ***(Source: dena.de)***

In *Table 4* our calculation is shown. The row “Installed capacity 2013 [MW]” shows the given values out of the “Veröffentlichte Kraftwerksliste” (published list of all operating PP`s in Germany by March 2013) from the “German Federal Network Agency by source. The percentage values to calculate the secured generation capacity by every source are out of the short analysis for the power plant development in Germany until 2020 (“Kurzanalyse der Kraftwerksplanung in Deutschland bis 2020”) from the German Energy Agency[22]. We chose 88% of secured generation capacity for the energy source Waste (non RES and RES), which is

[21]Versorgungssicherheit in der Elektrizitätsversorgung. [online]. [cit.2013-05-11]. available from: http://www.umweltdaten.de/publikationen/fpdf-l/3853.pdf

[22]DENA: Kurzanalyse der Kraftwerksplanung in Deutschland bis 2020. [online]. [cit.2013-05-11]. available from: http://www.dena.de/fileadmin/user_upload/Projekte/Energiesysteme/Dokumente/KurzanalyseKraftwerksplanungDE_2020.pdf

just given for Biomass. To calculate the secured generation capacity for Mine-, Sewer-, Landfil- Gas and several energy sources we used the same value as for normal gas turbines.

For the installed capacity of RES in 2020 the values out of the final report of dynamic simulation of the electrical power supply in Germany based on the development scenario of the RES- industry were used[23]. The percentage values of the secured generation capacity are the same as for the calculation for the year 2013. As result for the secured generation capacity in 2020 we calculated a value of 93 876, 04 MW. That means that the secured generation capacity in 2020 is 2549, 75 MW lower than 2013. But if we take a look at the Scenario for the expected demand of electricity we get a high enough value for every scenario with our calculation. In total we then get a secured generation capacity of 96 425, 79 MW for Germany until March 2013.

[23] DENA: Aktualisierung der Kurzanalyse der Kraftwerksplanung in Deutschland bis 2020: Schlussfolgerungen und Fazit. [online]. [cit.2013-05-12]. available from: http://www.dena.de/fileadmin/user_upload/Projekte/Energiesysteme/Dokumente/KurzanalyseKraftwerksplanungDE_2020.pdf

Source	Installed capacity 2013 [MW]	Secured generation capacity in %[1]	Secured generation capacity in MW 2013	Prognosis Extension 2020 [MW][2]	Secured generation capacity in %	Secured generation capacity 2020 [MW]
Stone coal	20 176,20	86	17 351,53	20 176,20	86	17 351,53
Lignite	18 052,90	92	16 608,67	18 052,90	92	16 608,67
Natural Gas	19 253,37	86	16 557,90	19 253,37	86	16 557,90
Nuclear Energy	12 068,00	93	11 223,24	0,00	0	,00
Other Energy sources non RES	1 146,78	42	481,65	1 146,78	42	481,65
Several energy sources non RES	15 102,02	86	12 987,74	15 102,02	86	12 987,74
Pump storage	9 229,04	90	8 306,14	9 229,04	90	8 306,14
Mineral oil products	3 741,98	86	3 218,10	3 741,98	86	3 218,10
Waste non RES	551,00	88	484,88	551,00	88	484,88
Running Water	3 797,87	40	1 519,15	6 500,00	40	2 600,00
Dammed water w.o. pump stroage	1 308,50	40	523,40	0,00	0	0,00
Onshore Wind	30 016,50	10	3 001,65	45 000,00	10	4 500,00
Offshore Wind	280,30	40	112,12	10 000,00	40	4 000,00
Solar radiant energy	32 508,37	1	325,08	39 500,00	1	395,00
Geothermal	12,34	90	11,11	655,00	90	589,50
Biomass	5 568,79	88	4 900,54	3 100,00	88	2 728,00
Waste RES	613,00	88	539,44	1 063,00	88	935,44
Sewer Gas	90,00	42	37,80	275,00	42	115,50
Landfill Gas	262,15	42	110,10			
Several energy sources RES	145,91	42	61,28	4 800,00	42	2 016,00
Mine Gas	254,35	42	106,82			
Sum non RES	99 575,64		87 219,84	87 253,29		75 996,60
Sum RES	74 603,73		9 205,95	110 893,00		17 879,44
TOTAL	174 179,37		96 425,79	198 146,29		93 876,04
w.o. Nuclear Generation	-		85 202,55	-		-

Table 3: Secured generation capacity till 2020 (Own calculation; dena.de, bee-ev.de)

3.3 CO2- emissions today and in 2020

What we want to calculate now is what CO_2- emissions we get for 2013 and in comparison to that for 2020, if we shut down all the nuclear power plants with relatively low CO2- emissions and instead use the installed RES by 2020. As it would be too complicated and time-consuming for this seminar paper, we decided to take only the calculated values for the secured generation capacity for one hour and multiply those values by source with the CO_2-emissions in kg/MWh.

4 RESULT: PRODUCING MISSING ELECTRICITY FROM NUCLEAR POWER PLANTS

4.1 Existing methods for lowering CO_2 emissions in short term

As shown in *Image 2* the PPs with the highest emissions are brown and stone coal fired PPs. There, the whole process has to start to make them more efficient and to reduce their amount of CO2. Moreover, the need of fast adjustable PPs will be increasing in the upcoming years in order to be able to stabilize the volatile electricity production of RES.

Therefore, one option could be to consider if it`s useful to retrofit old coal fired power plants into fast operating gas fired combined cycled PPs.
An option, with which the efficiency of a PP can definitely be increased is the combined heat and power technology. In *Table 3* the potential of CO2- emission economization by combined heat and power PPs is shown. However it is important to note here that any market-based factors couldn`t be considered in this regard.

	Emission factors for CHP- Systems	
	CO2- equivalences in kg/MWh_output (incl. Upstream chains)	
	CHP- Heating	CHP- Electricity
CHP –SYSTEM	"eta"	"eta"
GAS CHPP	195,6	420,3
Coal CHP- SC (steam condensation)	239,0	513,6
Oil CHP- SC	174,2	374,3
Gas CHP- SC	133,0	285,8
Waste CHP- SC	188,6	405,3
Gas GT CHP	197,6	424,7
GAS CCPP	150,8	324,1
Biogas and Manure supply CHPP	75,0	161,3
Biogas- RRM- CHPP	73,2	157,3
Wood- chip- forest- CHPP	56,1	120,5
Wood- SR- forestry- CHPP	68,2	146,5
Compaired to reference systems (Gas CHPP for heating, Mix for electricity in Germany)	**284,7**	**644,9**

Image 4: Emission factor of different combined heat and power systems24

In comparison to the values of *Image 2*, we can see that the saving potential is not to be underestimated.

Furthermore, the possibility of Carbon Capture and storage could be a way to at least save the CO_2 until better options to handle it will come up. But the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety says in its paper "structural, economic, ecological comparison of regenerative energy technologies with Carbon Capture and Storage (CCS)" (translation of German title by the author) that the time period until 2020 should be used to do research on the development- and lowering costs –potential and to try to show that the technology is feasible[25].

Another way to cut down the CO2- emissions by 2020 is to install compressed air depositories or hydrogen depositories but batteries might be a solution in the upcoming years, where the produced electricity of wind and solar PPs, which cannot be used at the moment of pro-

24 Adapted from the German original: Bestimmung spezifischer Treibhausgasemissionen für Fernwärme [online] [cit. 21.05.2013] available from: http://www.umweltdaten.de/publikationen/fpdf-l/3476.pdf

[25] BMU: Internetseite des Bundesumweltministeriums. [online]. [cit.2013-05-11]. available from: http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/reccs_endbericht_lang.pdf

duction, can be saved for a while, even if the efficiency is not very high at the moment[26]. A point which is presupposed for the whole ST- time period is that the development of RES is forced as fast as possible to get the highest possible installed capacity by 2020. Moreover, the reduction of electricity consumption has to be progressed in the fastest possible way.

4.2 Import from surrounding countries

In 2O11 Germany's electricity import was 49, 7 TWh.[27] Almost half of import came from France – 20, 3 TWh.[28] France produces most electricity from nuclear PP's. This number is 78 %[29], so we can consider supplies from France as stable one. The Czech Republic supplied to Germany 9, 41 TWh.[30] Another neighboring state – Austria, delivered to Germany 5, 36 TWh.[31] If we consider absence of nuclear PP's in Austria, it is quite good number.

From the perspective of the future France seems to be most reliable supplier. With high share of nuclear PP's is small possibility to interrupting supplies. Due to lignite PP's are supplies from the Czech Republic also stable. Austria has high share of hydro PP's and this source is also stable.

4.3 Covering electricity consumption by 2020 without nuclear power plants

As calculated in *Chapter 3.2* we see that the secured generation capacity in 2020 is 11176, 04 MW higher than the highest scenario value in *Table 6*. Giving the values in *Table 4* a closer look, we have to take into account that this is merely a prognosis and not statistically correct values. As already explained, we want to do our calculations with all existing conventional PPs in 2013 and let them all run until 2020 except for the shutdown of nuclear PPs because we think that restructuration, rebuild and retrofit are the best alternatives for this period of time, beside the fastest possible development of RES.

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[26]Agentur für Erneuerbare Energien: Renews Spezial. [online]. [cit.2013-05-11]. available from: http://www.unendlich-viel-energie.de/uploads/media/57_Renews_Spezial_Strom_speichern_mar12_online_01.pdf

[27]Entsoe: Country data packages. [online]. [cit.2013-05-10]. available from: https://www.entsoe.eu/db-query/country-packages/production-consumption-exchange-package/.

[28] See above.

[29]World Nuclear Association: Nuclear Power in France. [online]. [cit.2013-05-10]. available from: http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/France/#.UYzFw8ovs2g

[30] See no 1.

[31] See no 1.

In *Table 3* we calculated a secured generation capacity with our PP- structure of the scenario in 2020 a value of 93 876, 04 MW. That means that the secured generation capacity in 2020 by 2 549, 75 MW lower than in 2013. But if we take a look at the three scenarios for the expected demand of electricity we get a high enough value for every scenario with our calculation.

Scenario 2020 DENA Increasing demand for electricity	**72865 MW**
Secured generation Capacity needed 2020	78565 MW
Scenario 2020 DENA Constant demand for electricity	76700 MW
Secured generation Capacity needed 2020	82700 MW
Scenario Frauenhofer out of BEE- Scenario	58000 MW

Table 4: Different scenarios for the demand of electricity in 2020 ***(Source: dena.de)***

4.4 CO_2 emissions in 2013 and 2020

Since it would be too complicated for the extent of our seminar paper to calculate the exact CO_2- emissions for the total electricity production in TWh by every source, we just wanted to get a comparison between the year 2013 and 2020. So we multiplied the calculated secured generation capacities of both years with the CO_2- emissions in kg/MWh to get the output of CO_2 for the maximum possible production for only one single hour.

Table 5 shows the used CO_2- emissions by source and the calculated CO_2- emissions for the two years.

Since we haven`t found values for the CO_2- emission for Waste RES we took the same value as for Biomass. For several energy sources RES we took the same value as for Mine gas.

As can be seen, the difference between the CO2- emissions by using the max. Capacity today and in 2020 6433,28 kg is not that high, especially if we think consider that the conventional PP- structure will not stand still until 2020. The possibilities explained in *Chapters 3.1 and 4.1* will be implemented and help Germany to reduce their CO_2- emissions in comparison to today. We also have to consider that we did our calculation with the highest possible value of production. If we take a look at *Image 4* we see that the forecasted values for the maximum electricity demand are lower than the maximum possible production. So if Germany finds a way to restructuring their old PPs in order to make them more volatile and efficient they can save a lot of CO_2 emissions and then use as much electricity of RES as possible and, to guarantee a secure electricity supply, produce the rest with their retrofitted conventional PPs.

	Secured generation capacity in MWh 2013	Secured generation capacity in MWh 2020	CO2- Emission [kg/MWh][32]	CO2- Emissions 2013 of max. secured Production [kg]	CO2- Emissions 2020 of max. secured Production [kg]
Stone coal	17 351,53	17 351,53	810	14 054 740,92	14 054 741,00
Lignite	16 608,67	16 608,67	1000	16 608 668	16 608 668,00
Natural Gas	16 557,90	16 557,90	377	6 242 326,97	6 242 327,00
Nuclear Energy	11 223,24	0,00	27	303 027,48	0,00
Other Energy sources non RES	481,65	481,65		313 070,94	313 071,00
Several energy sources non RES	12 987,74	12 987,74		16 561 029	16 561 029,00
Pump storage	8 306,14	8 306,14	650		
Mineral oil products	3 218,10	3 218,10			
Waste non RES	484,88	484,88			
	25 478,51	25 478,51			
Running Water	1 519,15				
Dammed water (without pump storage)	523,40	2 600,00	39	79 659,34	101 400,00
	2 042,55				
Onshore Wind	3 001,65	4 500,00	24	72 039,59	108 000,00
Offshore Wind	112,12	4 000,00	23	2 578,76	92 000,00
Solar radiant energy	325,08	395,00	89	28 932,45	35 155,00
Geothermal	11,11	589,50	294	3 265,16	173 313,00
Biomass	4 900,54	2 728,00	6	29 403,23	16 368,00
Waste RES	539,44	935,44	6	3 236,64	5 612,64
Sewer Gas	37,80	115,50	101	14 938,20	11 665,50
Landfill Gas	110,10				
Several energy sources RES	61,28	2 016,00	0	0,00	0,00
Mine Gas	106,82		0	0,00	
Sum non RES	87 219,84	75 996,60		54 082 863,33	53 779 835,85
Sum RES	9 205,95	17 879,44		234 053,38	543 514,14
TOTAL	96 425,79	93 876,04		54 316 916,71	54 323 349,99

Table 5: CO2- Emissions calculated for the total secured generation capacity in 2013 and 2020 ***(Source: own calculation)***

5 Discussion

5.1 Effect of nuclear phase to CO_2 price

In 2010 Germany was missing 53 462 742 CO2 allowances[33] (tons). If we consider the gradual shutting down of nuclear PP's in 2020 it could be a provisional problem with CO2 allowances amount. But as we mentioned earlier, the difference between CO2 emission in 2013 and

[32] Mostly used values from Image 3 but also Klima und Umweltschutz durch erneuerbare Energien [Online] [21.05.2013] available from http://www.unendlich-viel-energie.de/uploads/media/49_Renews_Spezial_Klima_und_Umweltschutz_online_01.pdf

[33] Energostat: Emisni povolenky. [Online]. [cit.2013-05-12]. available from: http://energostat.cz/emisni-povolenky.html

2020 according our scenario is 6 433, 3 kg. From this point of view is more important development in other industry.

But now we are in last period of EU ETS 2013 - 2020, where are all allowances trades only by using auction. In combination with lower amount tradable allowances it may cause increase of CO2 allowances subsequently electricity price in Germany.

In short term there is possibility of increasing CO2 emissions. Impact of shutting down nuclear PP's and thus CO2 emissions could be eased by import electricity. In *Chapter 4.2 import* we said, that most imported electricity is delivered from France. France produced 410, 1 TWh by nuclear PP's in 2010 and had surplus 16 050 484 CO2 allowances in the same year.[34] Grid and installed capacity in France is not considered.

At this point of our seminar paper we are not able to conclusively determine CO2 emission price caused by shutting down nuclear PP's in Germany.

From political point of view the important role has European Union. Because we also have to consider Germany as an economic leader in Europe and also in the European Union. In case high CO2 emission increase could raise prices of industrial products and slow down economic growth.

5.2 Possibilities of further research in the field of CO2 prices

In chapter *discussion* we only suggested possible consequences caused by shutting down nuclear PP's in Germany. Further research can take several ways.

In field of economy is possible to focus on reduction GDP growth, electricity price and price in general according CO2 price. Although this question had been already examined[35], the influence of shutting down of nuclear PP's in Germany was not known in that time.

In energetic is possibility to develop question in which level of CO2 price would be energy mix significantly changed. In European allowances market we can examine CO2 price according increase CO2 emissions by creating different scenarios.

[34] (Slingeberg, DG Environment EK, 2008)

[35] (Slingeberg, DG Environment EK, 2008)

6 SUMMARIZATION OF OUR RESEARCH

From our seminar paper is evidently, that Germany can replace nuclear power plants by RES until 2020. CO2 price will not be affect by shutting down nuclear power plants. This paper is not considering all important factors what have to be taken into account if we want to be closer to realty

7 Sources

- GRIN: Der Atomausstieg in Deutschland. [online]. [cit.2013-03-28]. Available from: http://www.grin.com/de/e-book/176330/der-atomausstieg-in-deutschland

- Federal Statistical Office (Destatis): Economic Sector. [online]. [cit.2013-04-14]. available from: https://www.destatis.de/EN/FactsFigures/EconomicSectors/Energy/Production/Tables/GrossElectricityProduction.html

- BMWi: Stromversorgung. [online]. [cit.2013-03-28]. available from: http://www.bmwi.de/DE/Themen/Energie/stromversorgung.html

- Bundesnetzagentur. [online]. [cit.2013-03-28]. available from: http://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetGas/Sonderthemen/Kraftwerksliste/VeroeffKraftwerksliste_node.html

- BDEW: Energy mix. [online]. [cit.2013-03-28]. available from: http://www.bdew.de/internet.nsf/id/0AB381E4EC443E9BC1257A7600404535

- E-CONTROL: Stromkennzeichnungsbericht 2012. [online]. [cit.2013-04-21]. available from: http://www.e-control.at/portal/page/portal/medienbibliothek/oeko-energie/dokumente/pdfs/Stromkennzeichnungsbericht%202012.pdf

- Statista: CO2 Emissionen. [online]. [cit.2013-03-29]. available from: http://de.statista.com/statistik/daten/studie/233868/umfrage/co2-emissionen-bei-der-stromerzeugung-nach-erzeugungsart/

- BMU: Erneuerbare Energien 2011. [online]. [cit.2013-03-28]. available from: http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/ee_in_zahlen_2011_bf.pdf

- BMU: Kyoto protokoll. [online]. [cit.2013-04-12]. available from: http://www.bmu.de/themen/klima-energie/klimaschutz/internationale-klimapolitik/kyoto-protokoll/

- BMU: Das Integrierte Energie- und Klimaschutzprogramm (IEKP). [online]. [cit.2013-04-12]. available from: http://www.bmu.de/detailansicht/artikel/das-integrierte-energie-und-klimaschutzprogramm-iekp/

- BP: Electricity - Review by energy type. [online]. [cit.2013-04-10]. available from: http://www.bp.com/sectiongenericarticle800.do?categoryId=9037156&contentId=7068663

- Enerdata: Global Energy Statistical Yearbook 2012. [online]. [cit. 2013-04-12]. available from: http://yearbook.enerdata.net/electricity-domestic-consumption-data-by-region.html

- BDEW: Energy consumption. [online]. [cit.2013-04-09]. available from: http://www.bdew.de/internet.nsf/id/DA2ADF9EE4270788C1257A76004055A6

- DESTATIS: Economic sector - Production. [online]. [cit.2013-04-10]. available from: https://www.destatis.de/EN/FactsFigures/EconomicSectors/Energy/Production/Tables/GrossElectricityProduction.html

- World Nuclear Association: Nuclear Power in France. [online]. [cit.2013-05-10]. available from: http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/France/#.UYzFw8ovs2g

- Entsoe: Country data packages. [online]. [cit.2013-05-10]. available from: https://www.entsoe.eu/db-query/country-packages/production-consumption-exchange-package/.

- Dynamische Simulation der Stromversorgung in Deutschland nach dem Ausbauszenario der Erneuerbaren-Energien-Branche. p. 14. available from: http://www.bee-ev.de/_downloads/publikationen/studien/2010/100119_BEE_IWES-Simulation_Stromversorgung2020_Endbericht.pdf

- Statista: CO2-Emissionen bei der Stromerzeugung in Deutschland nach Art der Erzeugung im Jahr 2010. [online]. [cit.2013-03-29]. available from: http://de.statista.com/statistik/daten/studie/233868/umfrage/co2-emissionen-bei-der-stromerzeugung-nach-erzeugungsart/

- DENA: Kurzanalyse der Kraftwerksplanung in Deutschland bis 2020. [online]. [cit.2013-05-11]. available from: http://www.dena.de/fileadmin/user_upload/Projekte/Energiesysteme/Dokumente/KurzanalyseKraftwerksplanungDE_2020.pdf

- BMU: Internetseite des Bundesumweltministeriums. [online]. [cit.2013-05-11]. available from: http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/reccs_endbericht_lang.pdf

- Agentur für Erneuerbare Energien: Renews Spezial. [online]. [cit.2013-05-11]. available from: http://www.unendlich-viel-energie.de/uploads/media/49_Renews_Spezial_Klima_und_Umweltschutz_online_01.pdf

- Energostat: Emisni povolenky. [online]. [cit.2013-05-12]. available from: http://energostat.cz/emisni-povolenky.html

- Bestimmung spezifischer Treibhausgasemissionen für Fernwärme [online] [cit.2013-05-12] available from: http://www.umweltdaten.de/publikationen/fpdf-l/3476.pdf

- Klima und Umweltschutz durch erneuerbare Energien [Online] [cit.2013-05-11] available from http://www.unendlich-viel energie.de/uploads/media/49_Renews_Spezial_Klima_und_Umweltschutz_online_01.pdf

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