INITIAL ANALYSIS OF BACKGROUND AND ECONOMIC MODELS OF NUCLEAR PLANT

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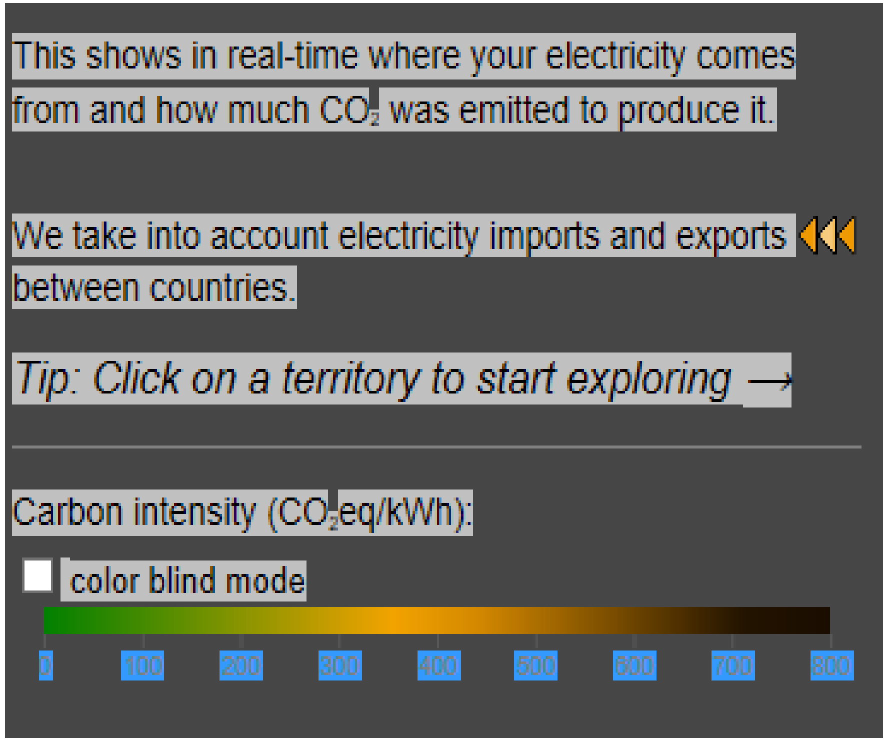
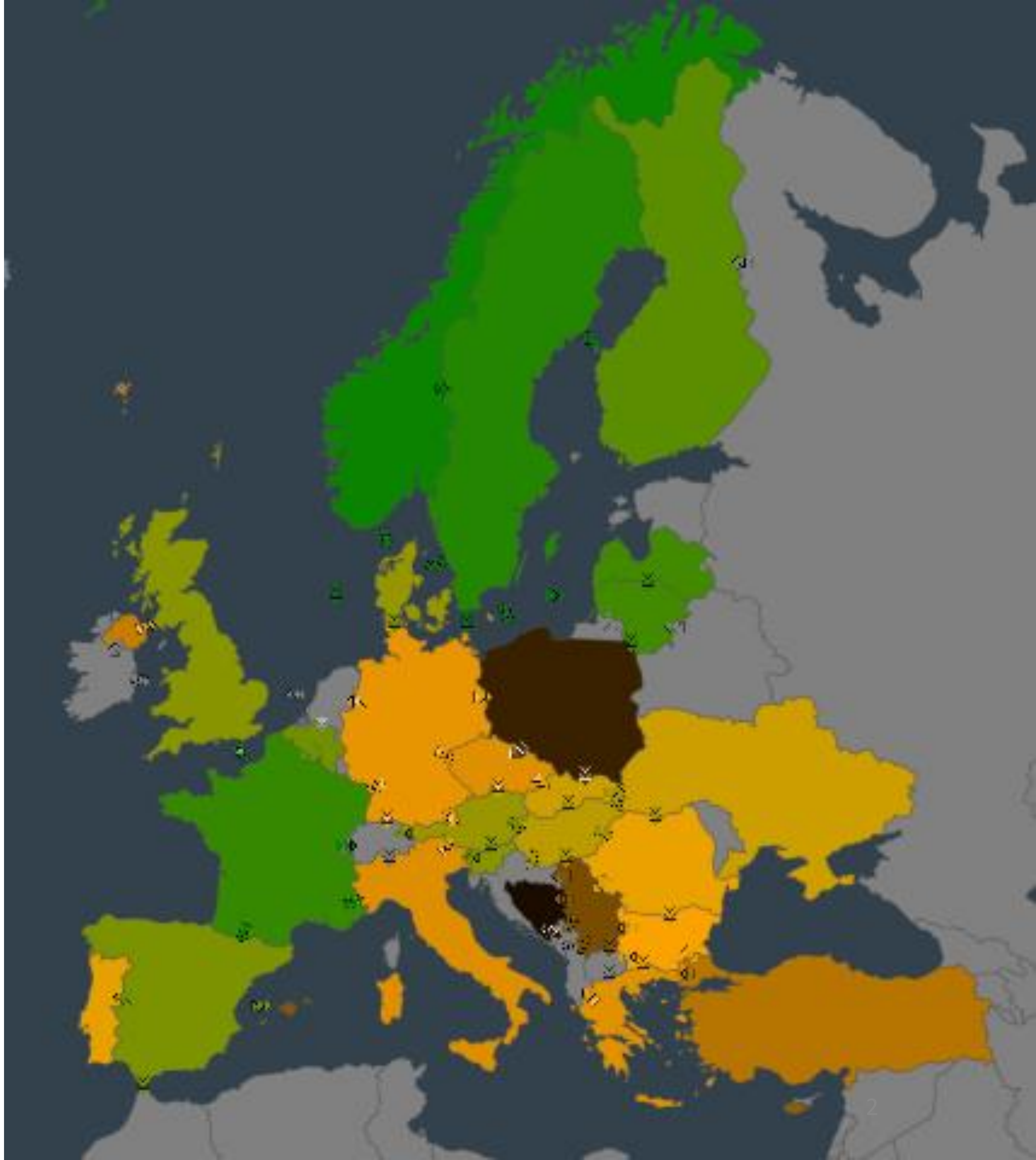
NERS 2017 – Praha

Impact of Energy policy of EU and neighbors from the point of Carbon Intensity CO_2eq/kWh
data 5.11.2017 at 14.00 CET

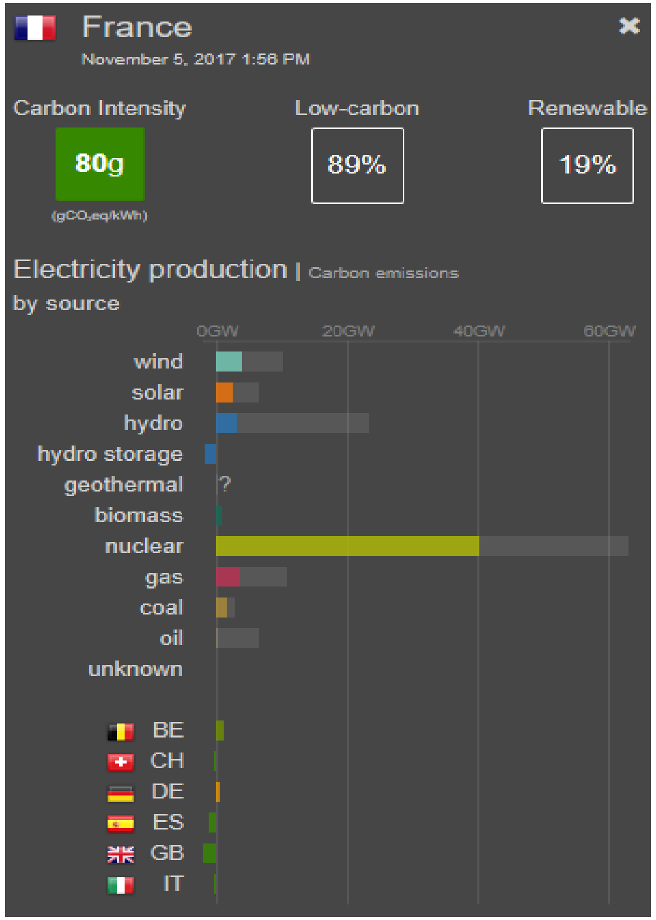


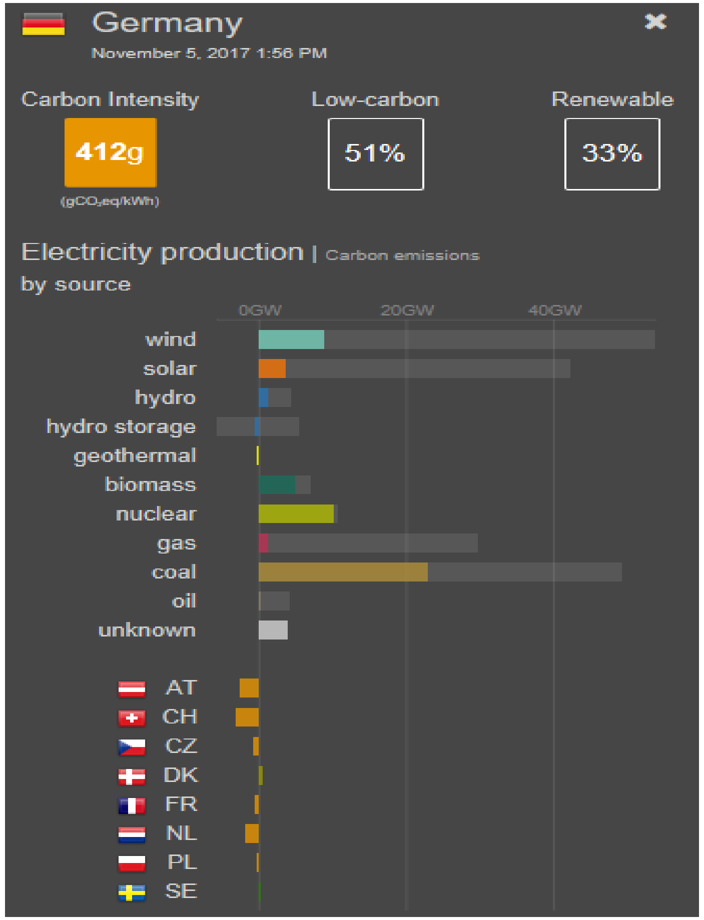
Source:
https://www.electricitymap.org/?wind=false&solar=false&page=country&countryCode=CZ

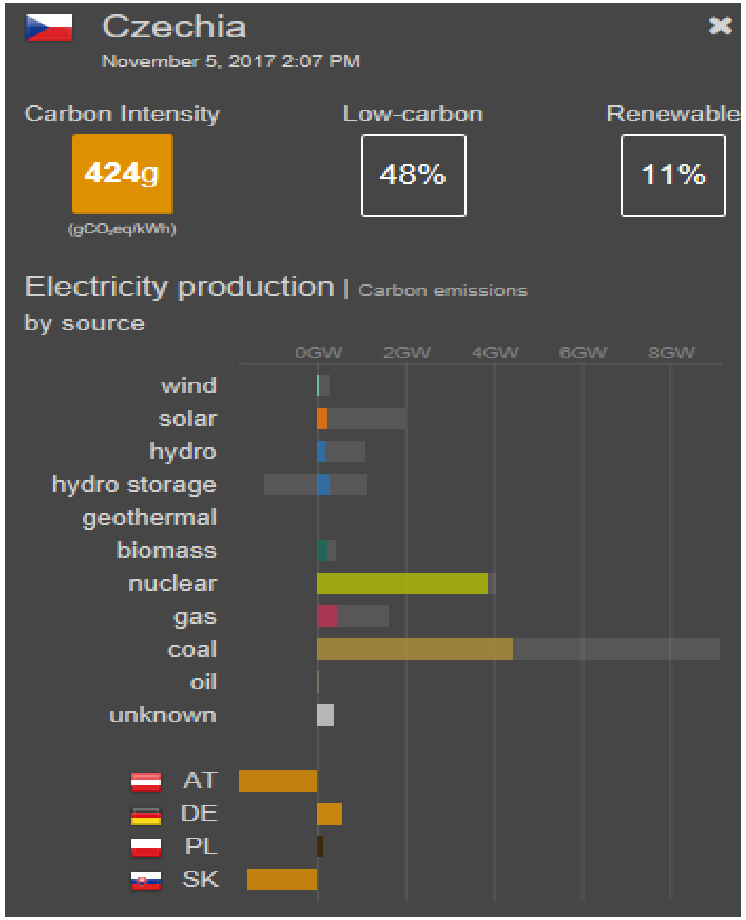


Impact of Energy policy of EU and neighbors from the point of Carbon Intensity data 5.11.2017 at 14.00 CET

– the advantage of energy mix with nuclear power

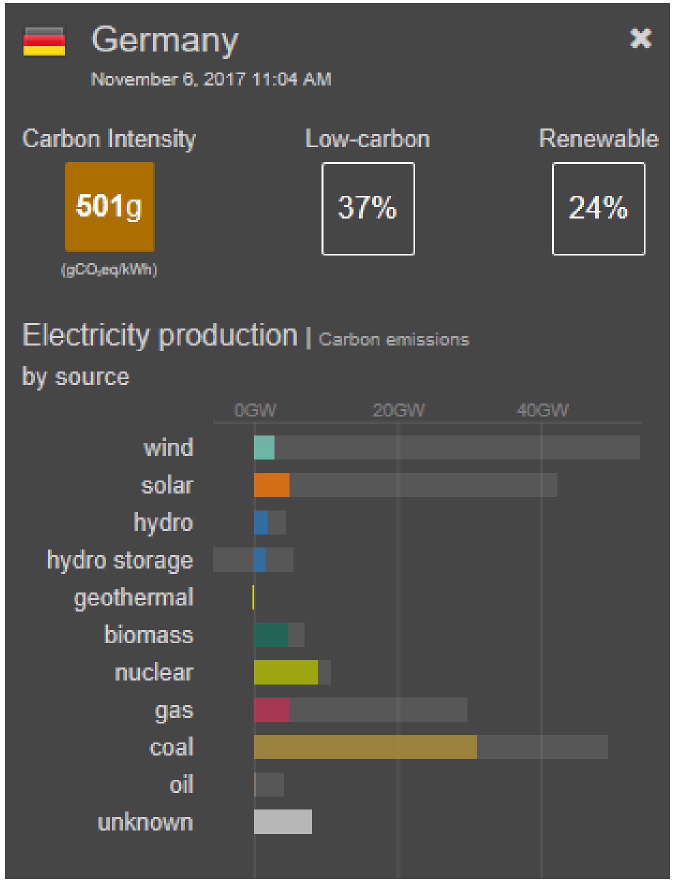


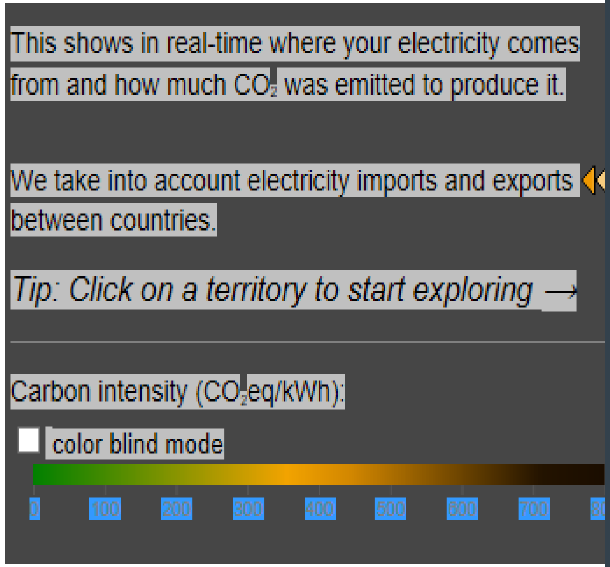


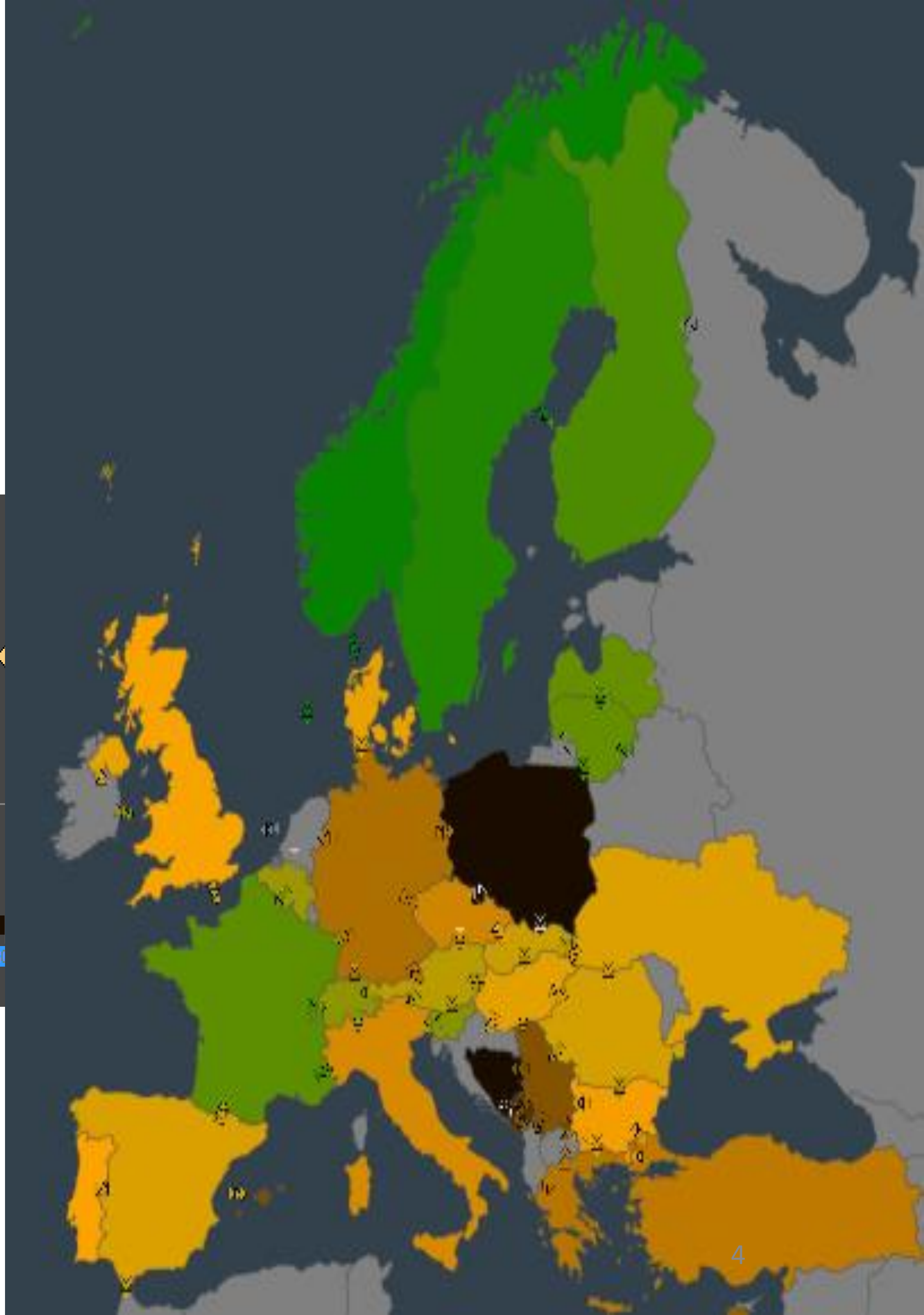


Source: https://www.electricitymap.org/?wind=false&solar=false&page=country&countryCode=CZ

Impact of Energy policy of EU and neighbors from the point of Carbon Intensity CO2eq/kWh data 6.11.2017 at 11.00 CET
German carbon intensity higher then Czech







[Source: https://www.electricitymap.org/?wind=false&solar=false&page=country&countryCode=CZ](https://www.electricitymap.org/?wind=false&solar=false&page=country&countryCode=CZ)

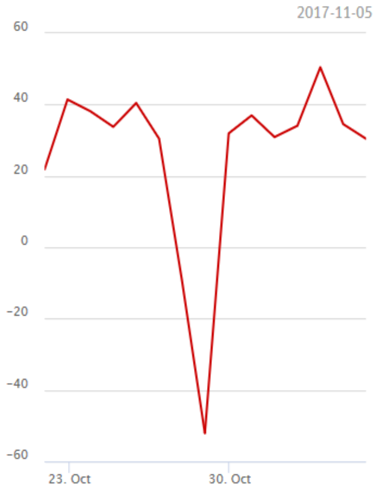
Impact of Energy policy of EU and neighbors from the point of volatility of price of power, gas and coal

data 5.11.2017 at 14.00 CET

Power | Natural Gas | Emissions | Coal

EPEX SPOT Auction	Del. Day	Price Base
Phelix DE/AT	11/05	30.41€
France	11/05	39.12€

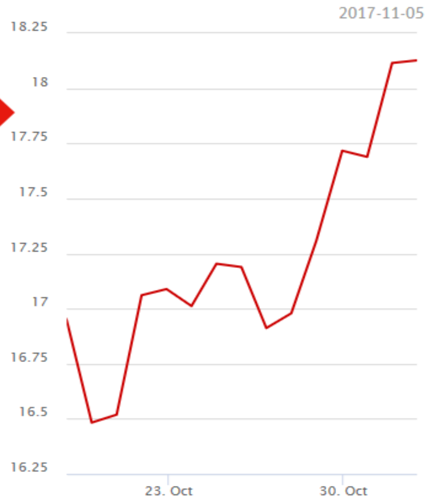
EEX Deriv.	Contract	Price Base
Phelix DE/AT Fut.	Cal-18	36.70€*
	Dec-17	38.26€*



Power | **Natural Gas** | Emissions | Coal

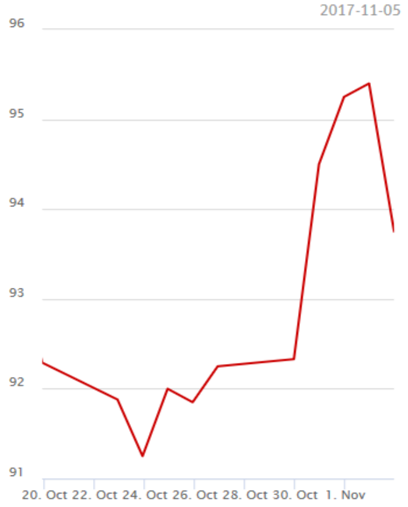
PEGAS Spot	Trading Day	Ref. Price
GPL	2017/11/02	18.127€
NCG	2017/11/02	18.237€
TTF	2017/11/02	18.229€

Deriv.	Index	Price
EGIX DE Day	2017/11/03	18.317€
EGIX DE Month	2017/11/03	18.426€



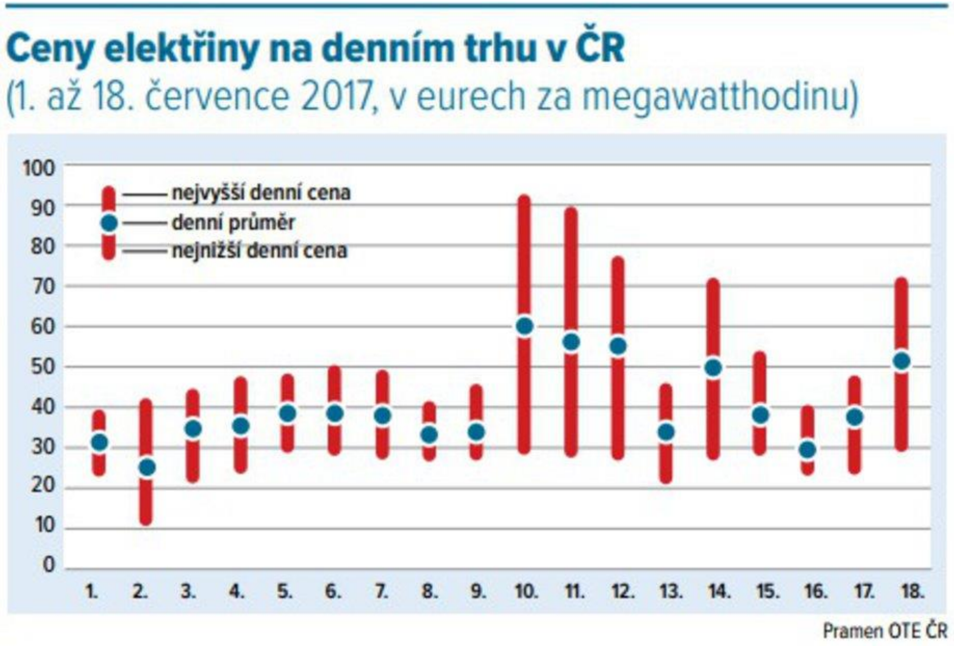
Power | Natural Gas | Emissions | **Coal**

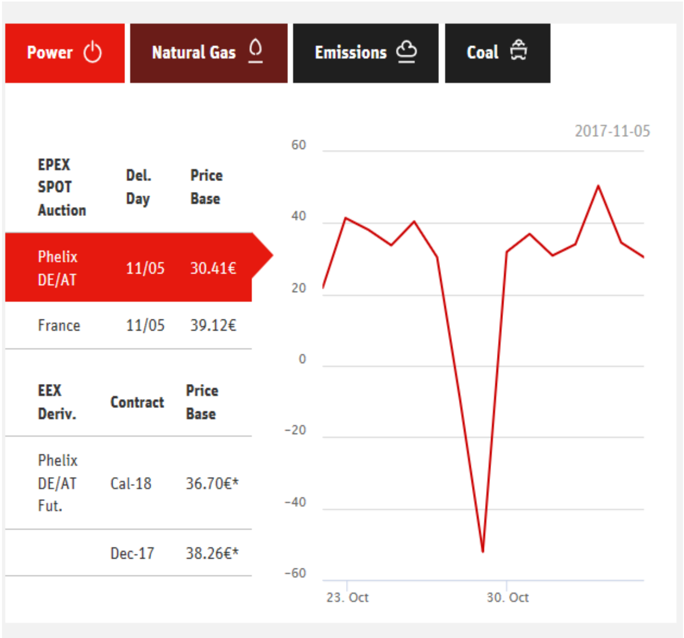
EEX Deriv.	Contract	Price
ARA Futures	Nov-17	93.75 $*
	Dec-17	93.09 $*
	Jan-18	91.93 $*
RB Futures	Nov-17	93.60 $*
	Dec-17	93.29 $*
	Jan-18	92.66 $*



Source: https://www.eex.com/en/?lipi=urn%3Ali%3Apage%3Ad_flagship3_feed%3B6jooidxbSZqThwIoIqpOTA%3D%3D#?lipi=urn:li:page:d_flagship3_feed%3B6jooidxbSZqThwIoIqpOTA%3D%3D

Volatility of power price per MWh within 7/2017 due to the Impact of Energy factors originated within CR and neighbors. pro info EE 10/2017 and separated market clusters of Germany & Austria vs. France





Czech price of power reached over EUR 60/MWh on 10.7.2017 that was by EUR 20-30 higher than in Germany. In the period of temporary repairs of domestic nuclear power blocks (3.and 4th block of Dukovany, one block of Dukovany out of operation **halving the total nuclear performance**) and lack of water in balkan water power plants, the further sympathy for nuclear source was supported by price volatilities caused by the reconstruction of the grid connecting CR with Germany and used also for imports. Source: OTE ČR, http://zpravy.e15.cz/byznys/prumysl-a-energetika/odstavene-draty-a-horko-na-balkane-zdrazily-v-cesku-elektrinu-stoji-vic-nez-v-nemecku-1335033 a https://www.eex.com/en/?lipi=urn%3Ali%3Apage%3Ad_flagship3_feed%3B6jooidxbSZqThwIoIqpOTA%3D%3D#?lipi=urn:li:page:d_flagship3_feed%3B6jooidxbSZqThwIoIqpOTA%3D%3D

The closing of nuclear reactors in Germany in 2022

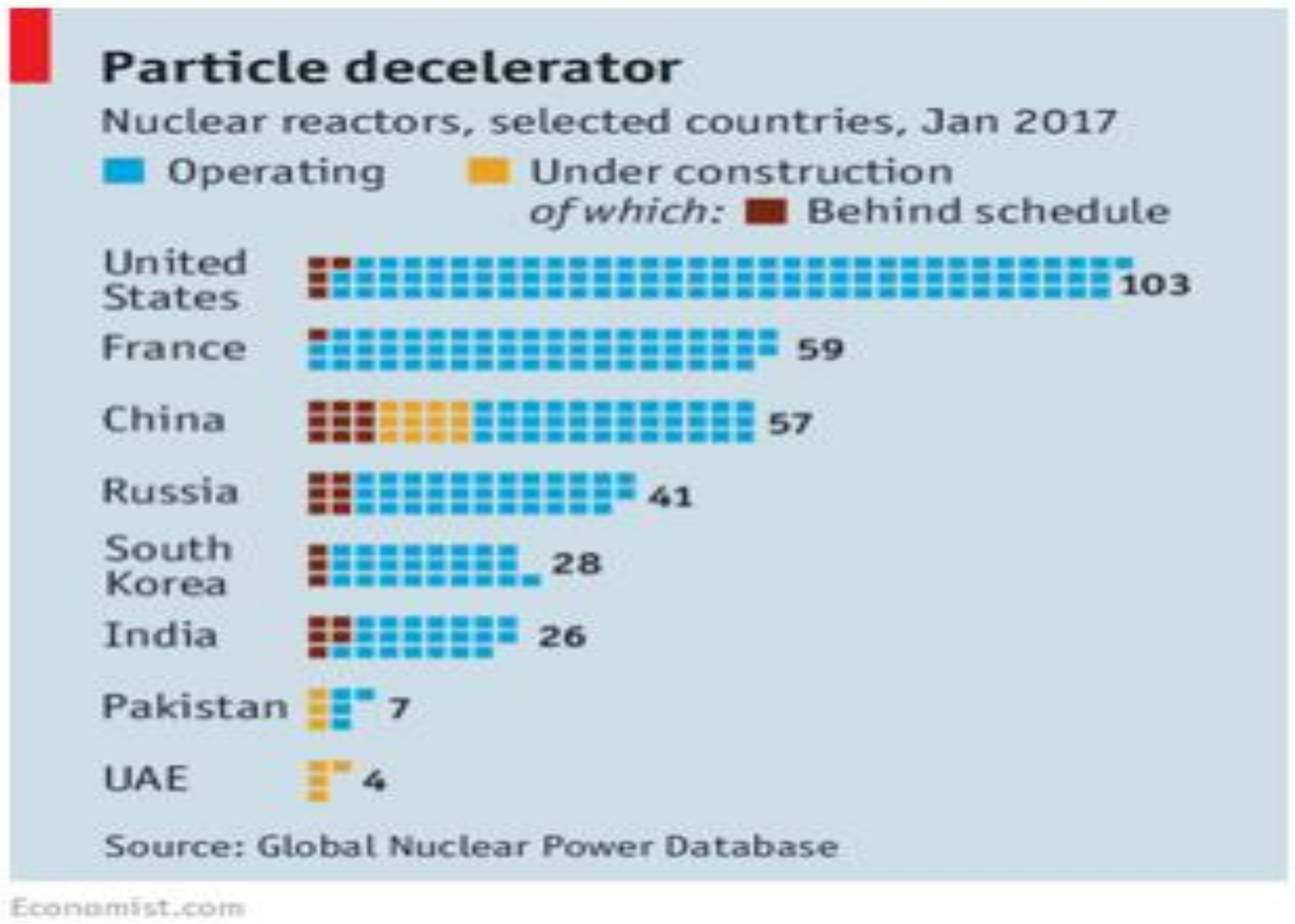
- **Current renewables subsidization system of guaranted priority energy take-off for 20 years with feed-in tarif over 65 EUR/MWh is very costly (so far aggregated costs over EUR 650 billion for their 38% contribution in 2017) gradually disappears. Maximization of capacity and performance of renewables supported from 2022 by the system of price and performance auctions. Who requires the minimum state subsidy for renewables production, would get the permission to operate the source.**
- **Big German discussion on power energy mix including the fate of coal-fired power plants. While Germans assured the public about the opposite**, the nuclear power plants production is replaced by coal plants (that complement also volatile renewables), many of which are old fashioned brown coal/lignite power plants with dirty operation, but cost efficient due to cheap coal, influenced by shale gas industry competition in the USA. Paradoxically in spite of enormous subsidization, the German energy emissions have been again growing.
- **The complicated situation on power market (renewables production mostly on North, energy consumption in Mid and South Germany) might arise due to weak NorthSouth high-voltage grid, that is slowly and costly built** (often in the underground cables)
- Weak spots in the power network in South Germany and more flexible balancing of volatile alternative sources (*sunny vs. cloudy, windy vs. calm*) should be gradually **complemented by new gas sources with total performance 2000 megawatts (MW). CCGT : Combined Cycle Gas Turbine plants** are highly efficient and relatively flexible sources that can be connected into the net within 25-30 minutes and cover the peaks in power consumption E.g. Dusseldorf CCGT provides 603,8 MW and 100% performance can be reached within 25 minutes. Combination of power and heating assures the 85 % efficiency, while carbon emissions CO_2 decrease to 230 grams/kWh.
- Efficiency of **OCGT open-cycle gas turbines** is much lower – German standard is below 40% efficiency (around 20 starts per day within two minutes do not allow more economic operation) Due to current and expected gas price (prices on EE energy exchange) OCGT economically suitable only as a peak source.

Any reliable producers of Nuclear Power plants ?

Recent analysis from k 1.1. 2017 based upon Global Nuclear Database published in Economist on 28.1 provides the global survey of nuclear reactors under operation (in blue) and under construction distinguishing construction along schedule (in yellow) and construction behind schedule (in brown). Delays can be short term but also long-term. Construction of some delayed plants had been cancelled since.

The comparison shows that two new reliable international suppliers are showing up – companies from South Korea (construction in UAE Abú Dhabi) and China (construction in Pakistan).

South Korean KHNP/Korea Electric Power (KEPCO) supplies 4 reactors in UAE. The first reactor in Barakah in Abu Dhabi is nearly finished according to the schedule (now it is under scrutiny of domestic and foreign regulators) and within an budget of around USD 5 bil. In contrast delayed construction by competitors increased the price by multiple 2-3.



Sources : https://www.economist.com/news/business/21715685-new-crop-developers-challenging-industry-leaders-how-build-nuclear-power-plant

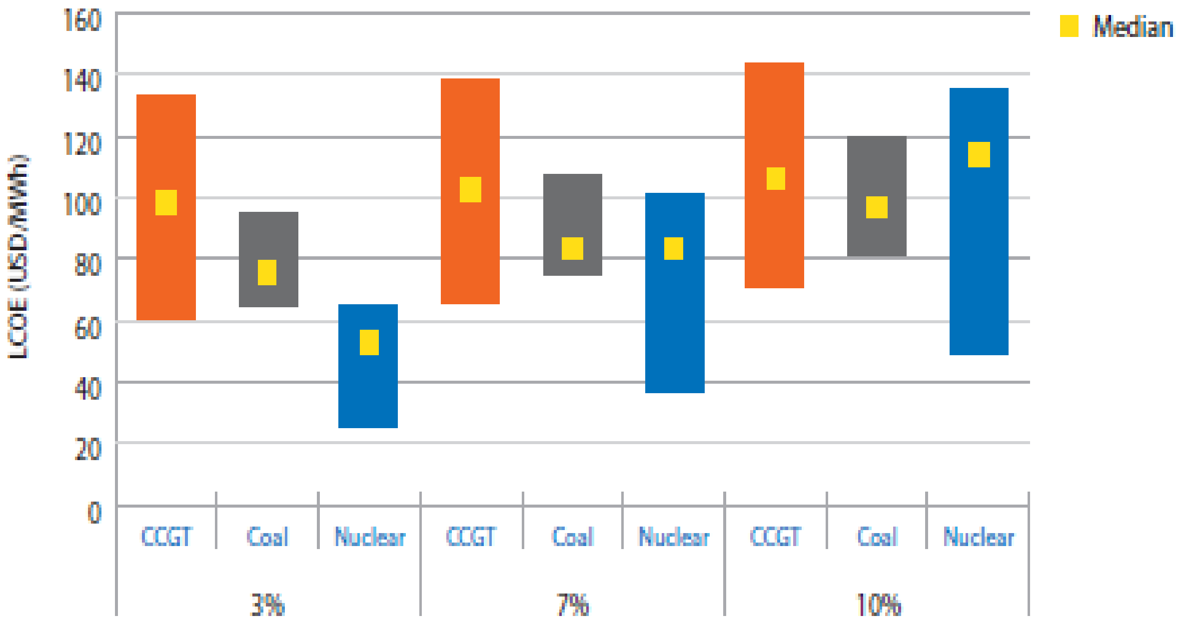
http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea.aspx

OECD/NEA and International Energy Agency publikuje LCOE (levelized cost of electricity generation) for 181 different sources of electricity including nuclear and renewables. LCOE discounts both investment and operation costs.

“Projected Costs of Generating Electricity” (2015 Edition) in 22 countries

Figure ES.1 shows the range of LCOE results for the three baseload technologies analysed in this report (natural gas-fired CCGTs, coal and nuclear). **At a 3% discount rate, nuclear is the lowest cost option for all countries.** However, **consistent with the fact that nuclear technologies are capital intensive relative to natural gas or coal, the cost of nuclear rises relatively quickly as the discount rate is raised. As a result, at a 7% discount rate the median value of nuclear is close to the median value for coal, and at a 10% discount rate the median value for nuclear is higher than that of either CCGTs or coal.** (These results include a carbon cost of USD 30/tonne, as well as regional variations in assumed fuel costs). But one should recognize the minimal levels represented by two new suppliers of nuclear plants (companies from South Korea and China) while slower construction by competitors increase their price 2-3 times, what increases LCOE over $ 120/MWh .

Figure ES.1: LCOE ranges for baseload technologies (at each discount rate)



The ranges presented include results from all countries analysed in this study, and therefore obscure regional variations. For a more granular analysis, see Chapter 3 on "Technology overview".

Source: https://www.oecd-nea.org/ndd/egc/2015/

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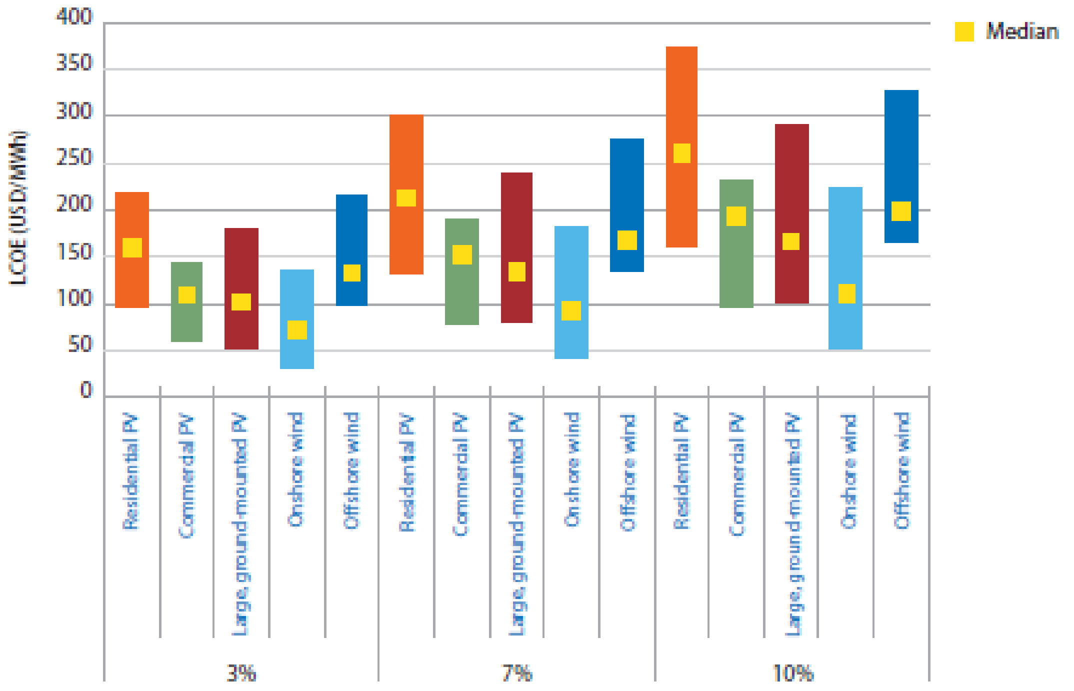
Figure ES.2 shows the LCOE ranges for various renewable technologies – namely, the three categories of solar PV in the study (residential, commercial and large, ground-mounted) and the two categories of wind (onshore and offshore). It is immediately apparent that the ranges in costs are significantly larger than for baseload technologies. It is also notable that the costs across technologies are relatively in line with one another. While at the high end, the LCOE for renewable technologies remains well above those of baseload technologies, at the low-end costs are in line with – or even below – baseload technologies. Solar PV in particular has seen significant declines in cost since the previous study, though onshore wind remains the lowest cost renewable technology (discounted both by **3%, 7% i 10%**), while offshore parks in sea are more expensive. Solar PV is the cheapest in large parks, then on commercial and residential buildings. In Germany auctions with delivery after 2022 push the costs down due to technology development.
The median values for these technologies are, for the most part, closer to the low end of the range, a reflection of the fact that this chart obscures significant regional variations in costs (in particular for solar PV). This is not surprising, because the cost of renewable technologies is determined in large part by local resource availability, which can vary significantly among countries or even within countries.

Zdroj: https://www.oecd-nea.org/ndd/egc/2015/

Figure ES.2: LCOE ranges for solar PV and wind technologies (at each discount rate)



The ranges presented include results from all countries analysed in this study, and therefore obscure regional variations. For a more granular analysis, see Chapter 3 on “Technology overview”. Based on IEA analysis and commentary from the EGC Expert Group, an alternative measure to median value was also included in this study, namely the generation weighted average cost. For more on that topic, see Chapter 6 on “Statistical analysis of key technologies”.

Conclusions : LCOE a overnight costs range

Overnight costs

- The range of **overnight costs** for **nuclear technologies** in OECD countries is large, **from a low of USD 2 021/kWe in Korea to a high of USD 6 215/kWe in Hungary**.

LCOE

- **at a 3% discount rate range from USD 29/MWh in Korea** to USD 64/MWh in the United Kingdom
- at a 7% discount rate from **USD 40/MWh (Korea) to USD 101/MWh (United Kingdom)** a
- **at 10% discount rate** from **USD 51/MWh (Korea) to USD 136/MWh (United Kingdom).**

It is evident that power plant financing on the lower range of LCOEs is easier for investors and banks more feasible than on high end of range.

Two notes: The potential of new smaller nuclear reactors has not been covered yet.

The final note should update the fact that South Korean suppliers had been already awarded by European certificate confirming the compliance of their reactors with EU standards.

Source: page 48 https://www.oecd-nea.org/ndd/egc/2015/, simplified definitions attached

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Attachment: Simplified definitions according to “Projected Costs of Generating Electricity” (2015 Edition) 2.chapter

The levelised cost of electricity The LCOE is a useful tool for comparing the unit costs of different technologies over their operating life. These costs are discounted to the commercial operation of an electricity generator. The LCOE methodology reflects generic technology risks, not specific project risks in specific markets. Given that such risks exist, there is a gap between the LCOE and the financial costs for owner-operators in real electricity markets facing specific uncertainties. For the same reason, LCOE is closer to the real cost of investment in electricity production in regulated monopoly electricity markets with regulated prices rather than to the real costs of generators in competitive markets with variable prices. $LCOE = PMWh = \Sigma[(Capitalt + O\&Mt + Fuelt + Carbont + Dt) * (1+r)^{-t}] / \Sigma\ MWh\ (1+r)^{-t}$ where this constant, *PMWh*, is defined as the levelised cost of electricity (LCOE) = The constant lifetime remuneration to the supplier for electricity; and where the different variables indicate: MWh = The amount of electricity produced in MWh, assumed constant; $(1+r)^{-t}$ = The discount factor for year t (reflecting payments to capital); Capitalt = Total capital construction costs in year t; O&Mt = Operation and maintenance costs in year t; Fuelt = Fuel costs in year t; Carbont = Carbon costs in year t; Dt = Decommissioning and waste management costs in year t.

Overnight costs Overnight construction costs include: i) direct construction costs plus pre-construction costs, such as site licensing, including the environmental testing; ii) the indirect costs such as engineering and administrative costs that cannot be associated with a specific direct construction cost category, as well as capitalised indirect costs; iii) owners’ costs include expenses incurred by the owner(s) associated with the plant and plant site, but excluding off-site, “beyond the busbar”, transmission costs; and iv) contingency to account for changes in overnight cost during construction, for example 15%.

Construction cost profiles Allocation of costs during construction followed country indications. It is linear in cases where no precise indications were provided. In the absence of national indications for the length of construction periods, the following default consensus assumptions are used: Non-hydro renewables: 1 year Natural gas-fired power plants: 2 years Coal-fired power plants: 4 years Nuclear power plants: 7 years *Investment costs* Investment costs include overnight cost with contingency and financing costs (e.g. interest during construction), referred to in Equation LCOE as total capital construction costs, or “capitalt”. On the other hand, “capital costs” in Chapter 4 include refurbishment and decommissioning costs.

Treatment of fixed operations and maintenance costs Fixed O&M costs were added to each year in the cash flow model.

Source: https://www.oecd-nea.org/ndd/egc/2015/