Security of electricity supply as the prerequisite for Energy Transition

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Development of electricity supply industry

- There were two decisive elements impacting the power supply industry:
  - Application of the Rankine cycle in electrical energy production,
  - The use of alternating current for transmission of electricity.
- During last 150 years electrical energy has become a crucial factor in the existence of the societies and operation of economies.
- **Electrical energy must be continuously supplied: 24 hours per day and 7 days a week, in 8760 hours during a year.**
- To the 90-ties of XX century the power supply systems, their operation and development depended only on technical and economic factors.
- The decisive role was played by engineers and economists, but not politicians.
- Energy Transition imposed on the Member States of the European Union is the implementation of economic interests by the legal regulations resulting from the political decisions.

Energy transition – old and new technologies

- Conventional energy production technologies embrace: lignite and hard coal power stations, natural gas plants and nuclear installations.
- Convectional power plants are always dispatchable, what means, that they are able to operate independently on external conditions including, in particular, weather.
- Dispatchability requires storage of input fuels or energy.
- **Energy Transition aims at the replacement of always dispatchable plants by renewable energy sources.**
- Operation of renewables is limited in time and dependent on weather. They are not able to replace the fully dispatchable power plants.
- There are some hopes directed to hydrogen technologies as they can store hydrogen as a fuel for electricity generation. However, the physical features of hydrogen known for 150 years indicate on wishful thinking.

Power sector

- **Crude oil.** Polish oil fields are limited. Over 90% of oil must be imported, however the import directions are quite diversified,
- **Natural gas.** Poland extracts around 5 bcm of natural gas which represent about 30% of the total energy consumption reaching 18 bcm per year.
  - Around 40% (10 bcm) is imported from Russia through Yamal pipeline.
  - The LNG can be imported through the LNG Terminal in Świnoujście (5 bcm)
  - Around 6 bcm can be supplied by Germany (virtual and physical reverse via Yamal pipeline).
  - When Baltic Pipe starts operation, the import capacity will be increased by additional 10 bcm.

Conventional generation

- **Hard coal and lignite.** The substantial hard coal fields are located in Poland in Lubusz basin and Upper Silesia basin. Lignite is located in Greater Poland, Lower Silesia and near Konin. Many of the identified coal basins are not being exploited and there are no such plans.
  - Coal fields are the basis for electrical energy production in Poland.
  - Hard coal fields are estimated to be sufficient for Polish energy sector for the next 50-100 years.
  - Hard coal can be imported.
- **Nuclear energy.** There are currently no nuclear power plants in Poland.
  - The polish nuclear power plan is being implemented since 2009 which indicates the difficulty related to this investment.
  - Barriers: high investment costs and lack of social acceptance.

Nuclear energy

- Majority of the currently existing plants were constructed parallelly to the nuclear weapon programs.
- Energy production in nuclear plants is 2-3 times more expensive in comparison to conventional power stations.
- Even minor failure can lead to the disastrous events: Chernobyl and Fukushima.
- Currently there is no long-term storage for radioactive waste (the EPR reactor of 1600MW produces 40 tonnes of radioactive waste a year).
- Radioactive waste is currently stored in the oceans, uranium mines or in the spent fuel pools at the reactor sites.
- Other promising technology: nuclear fusion (ITER).

Small modular reactors (SMR)

- Small reactors do not benefit from small scale effect:
  - they are very expensive, comparing the cost per unit of installed power ($/MW), so the demand is low ;
  - low demand does not allow for industrial prefabrication which could reduce costs.
- Two largest problems of SMRs are: high costs and security issues.
- Frequent leakages appear during tests.
- SMR are no alternative to large-scale nuclear plants.
- Currently there is no SMR technology that could be easily employed – the existing designs need further improvement.
- The technology development is being strongly subsidised by the US, UK, Chinese and Canadian governments.

Bierman P.,
„The US Army tried portable nuclear power at remote bases 60 years ago – it didn’t go wel”
www.theconversation.com

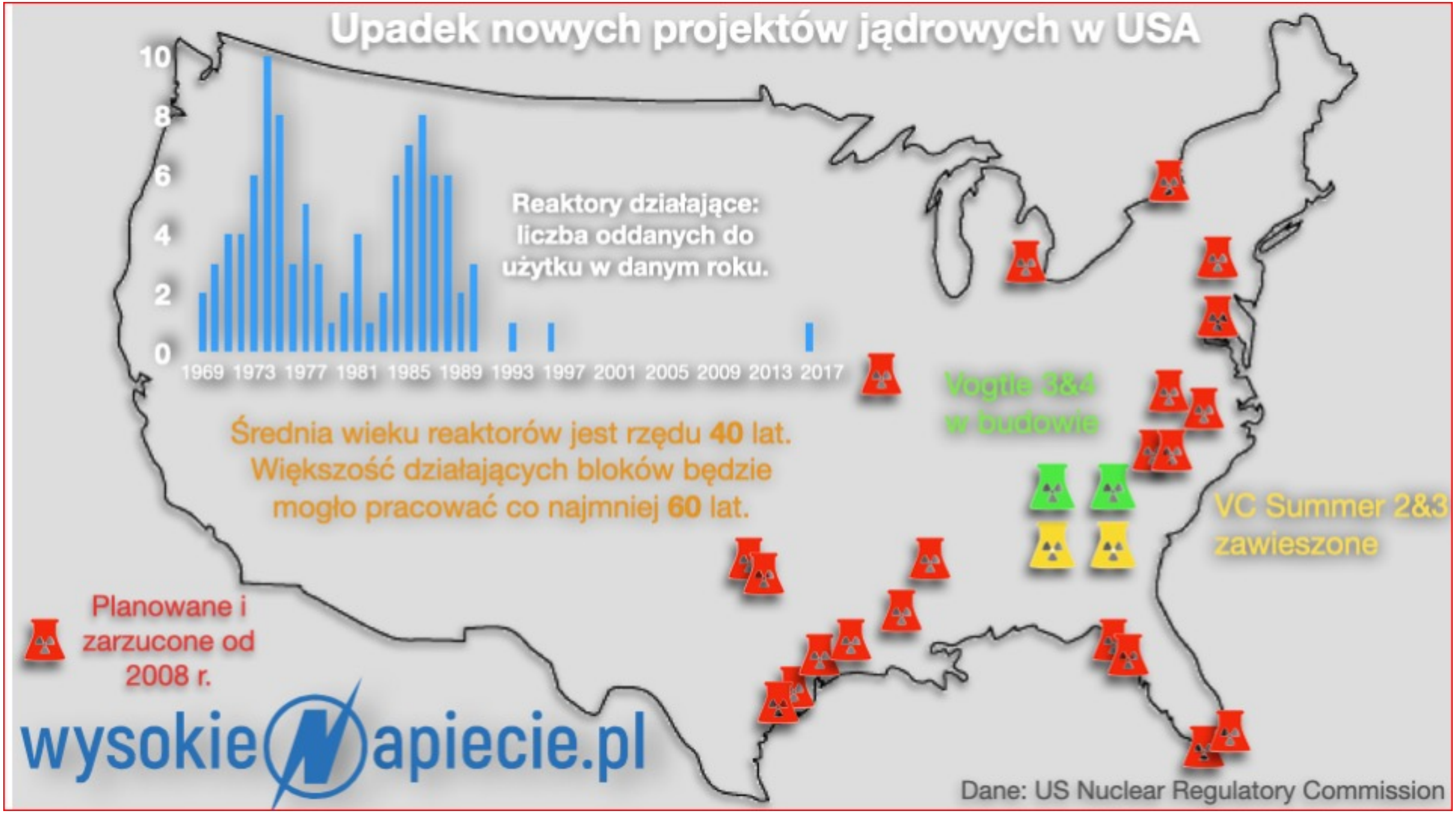
Nuclear power plants in Europe

- Among 27 EU countries, 13 do not have any nuclear power plants.
- The Austrian constitution bans this technology.
- **Germany closes remaining three nuclear reactors in December 2022.**
- Majority of the European countries **are not planning to refurbish their nuclear power plants** when the existing plants decommission.
- The decommissioning of the power plant can take 50 years and it is very expensive.
- Currently, in Europe there are 3 plants under construction:

Country		type	Power (MW)	construction began	expected comissioning	predicted cost (mld Euro)
Finland	Oikiluoto 3	EPR	1600	2005	2021	12
France	Flamanville	EPR	1650	2007	2022 (??)	15
England	Hinckey Point C	2*EPR	1600	2018	(???)	25-35

Slovakia, Hugary and Bulgaria plan to refurbish existing plants

New 2*WWER 1200 MW plant has been constructed in Ostrowiec (Belarous)



Upadek nowych projektów jądrowych w USA
10
8
6
4
2
0
1969 1973 1977 1981 1985 1989 1993 1997 2001 2005 2009 2013 2017
Reaktory działające: liczba oddanych do użytku w danym roku.
Średnia wieku reaktorów jest rzędu 40 lat. Większość działających bloków będzie mogło pracować co najmniej 60 lat.
Vogtle 3&4 w budowie
VC Summer 2&3 zawieszone
Planowane i zarzucone od 2008 r.
wysokieNapiecie.pl
Dane: US Nuclear Regulatory Commission

Renewable Energy Sources (RES) technologies

In Poland, RES have been subsidised:

- Green Certificates – until 2017
- Feed-in Tariffs – since 2017

Types of RES:

- on-shore & off-shore
- photovoltaic panels and solar thermal collectors
- biomass & biogas
- tides & waves
- geothermal energy
- landfill and sewage treatment gas

Hours of effective operation

REMARK - for RES, two parameters are important:

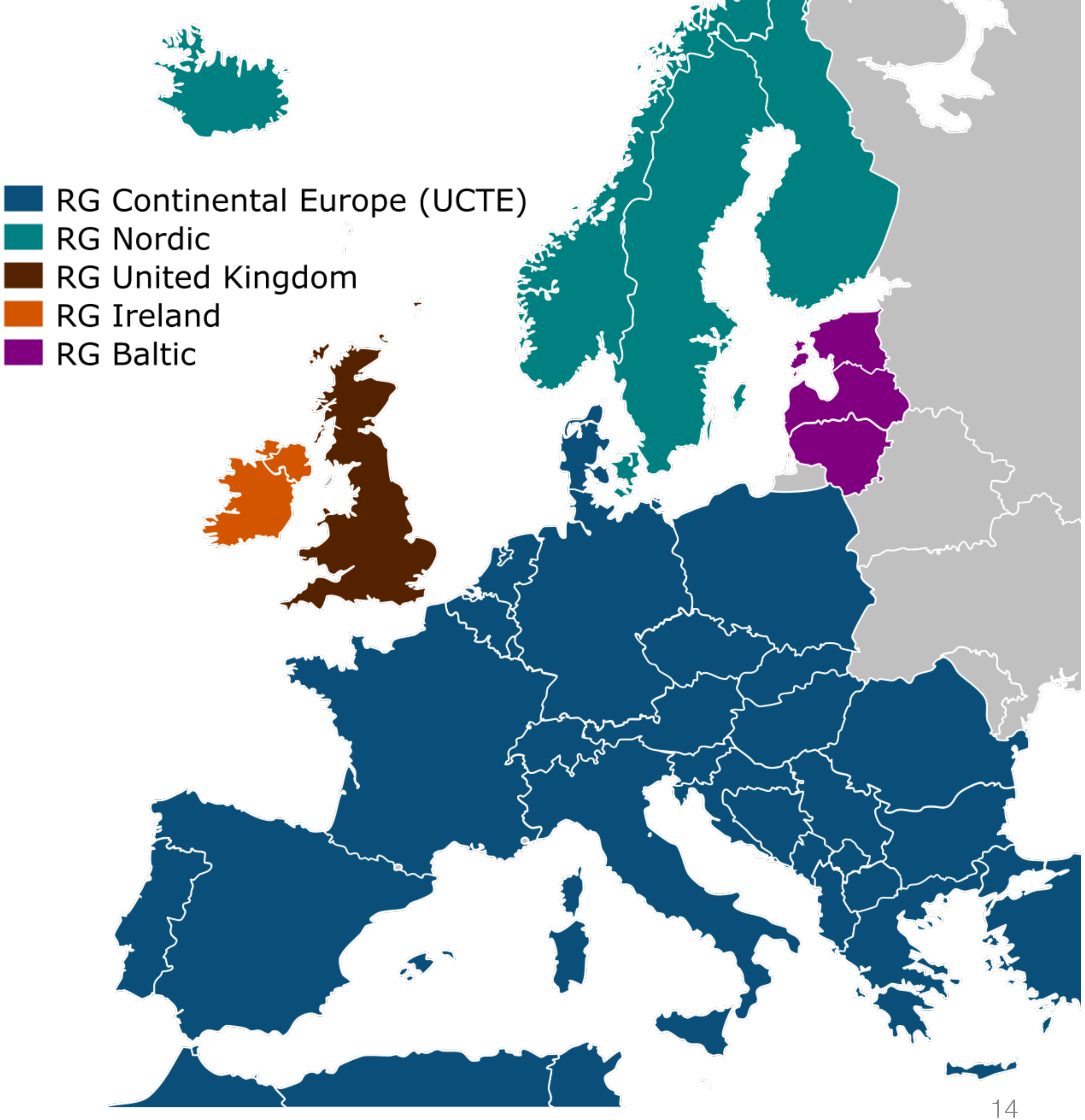
1. Number of hours when the RES operate at their rated capacity (table)
2. RES energy efficiency:
   1. WIND – the use of wind's kinetic energy arriving at the disk area: 40% (theoretical max= 59%)
   2. PV – Multicrystalline (blue): 19%; single crystal (black) at theoretical maximum: 31%

Technology Operating Hours Year = 8760 hours	Annual Operation Hours (theoretical)	Annual Operation Hours (practical)
on-shore wind	2500	2000
off-shore wind	4500	5000
solar (North and Central Europe)	1000	850
solar (South Europe)	2500	2000
nuclear	8000	7000
lignite	7000	6000
hard coal	7000	5000
gas	7000	4500

Renewable Energy Sources (RES)

- RES provide around 15% of electrical energy in Poland.
- The RES share will be growing and should reach 32% in 2030 on average due to the EU energy policy.
- Renewable energy can be only a supplement for continuous energy delivery as it is not dispatchable and depends on weather conditions.
- Renewable energy is too intermittent to contribute to the power balance -> the RES barely contribute to the energy security.
- The RES have negative impact on electrical networks:
  - transmission of large amount of energy is required from areas of energy production to those of consumption;
  - PV in distribution grid increase voltage and cause uncontrolled energy flows;
  - transmission and distribution grid requires strong development.

European power systems



https://en.wikipedia.org/wiki/Synchronous_grid_of_Continental_Europe#/media/File:ElectricityUCTE.svg

Polish power sector

- Low interconnection capacity: only 10% of Polish energy demand can be imported.
- Grid is not sufficiently developed, and energy sources are not effectively scattered.
- The energy flow from the north (energy supply area) to the south (high energy demand) is often problematic.
- The problems will deepen after 5900 MW of off-shore wind will commission in 2030 (and next 5000 MW until 2035).
- Another plant: nuclear power plant cannot be constructed on the north.
- In April, on-shore wind farms were centrally switched off because of their overproduction (to maintain security of supply).

Polish power system

MAPA KSE

Mapa prezentuje planowe i chwilowe przepływy mocy na przekrojach handlowych

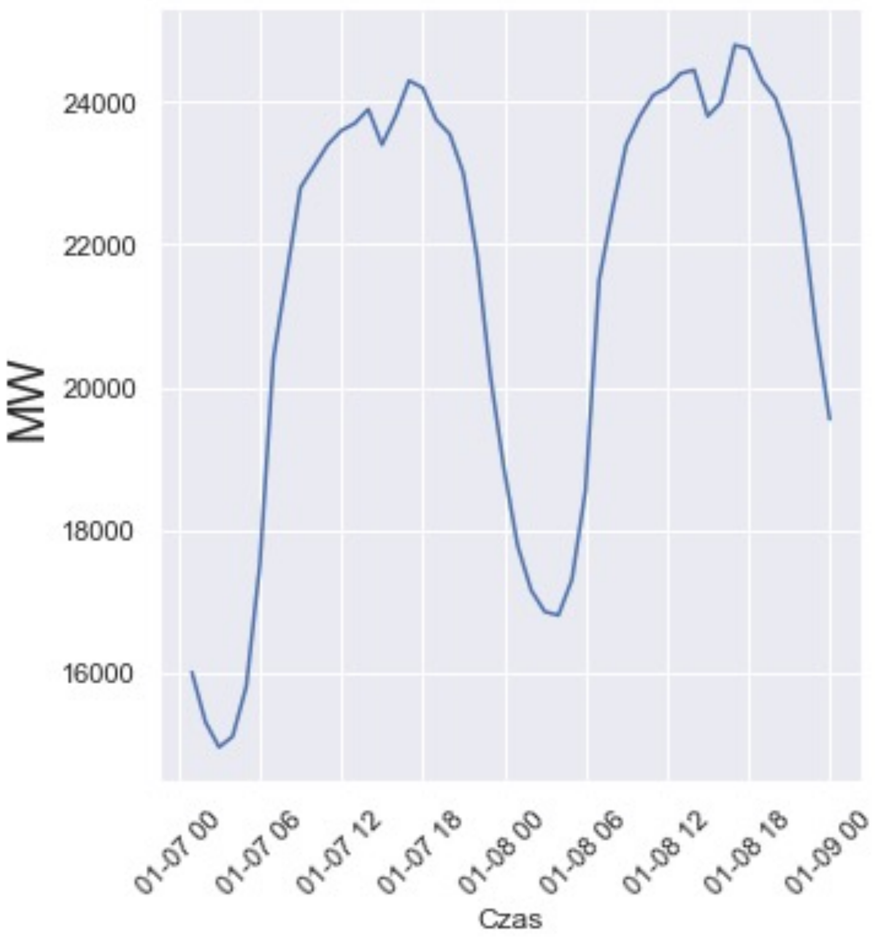
ZAPOTRZEBOWANIE [MW]	23 844
GENERACJA [MW]	24 291
el. cieplne	21 376
el. wodne	83
el. wiatrowe	1 857
el. fotowoltaiczne	974
el. inne odnawialne	0
SALDO WYMIANY CAŁKOWITEJ [MW]	323 EKSPORT
CZĘSTOTLIWOŚĆ [Hz]	49,998

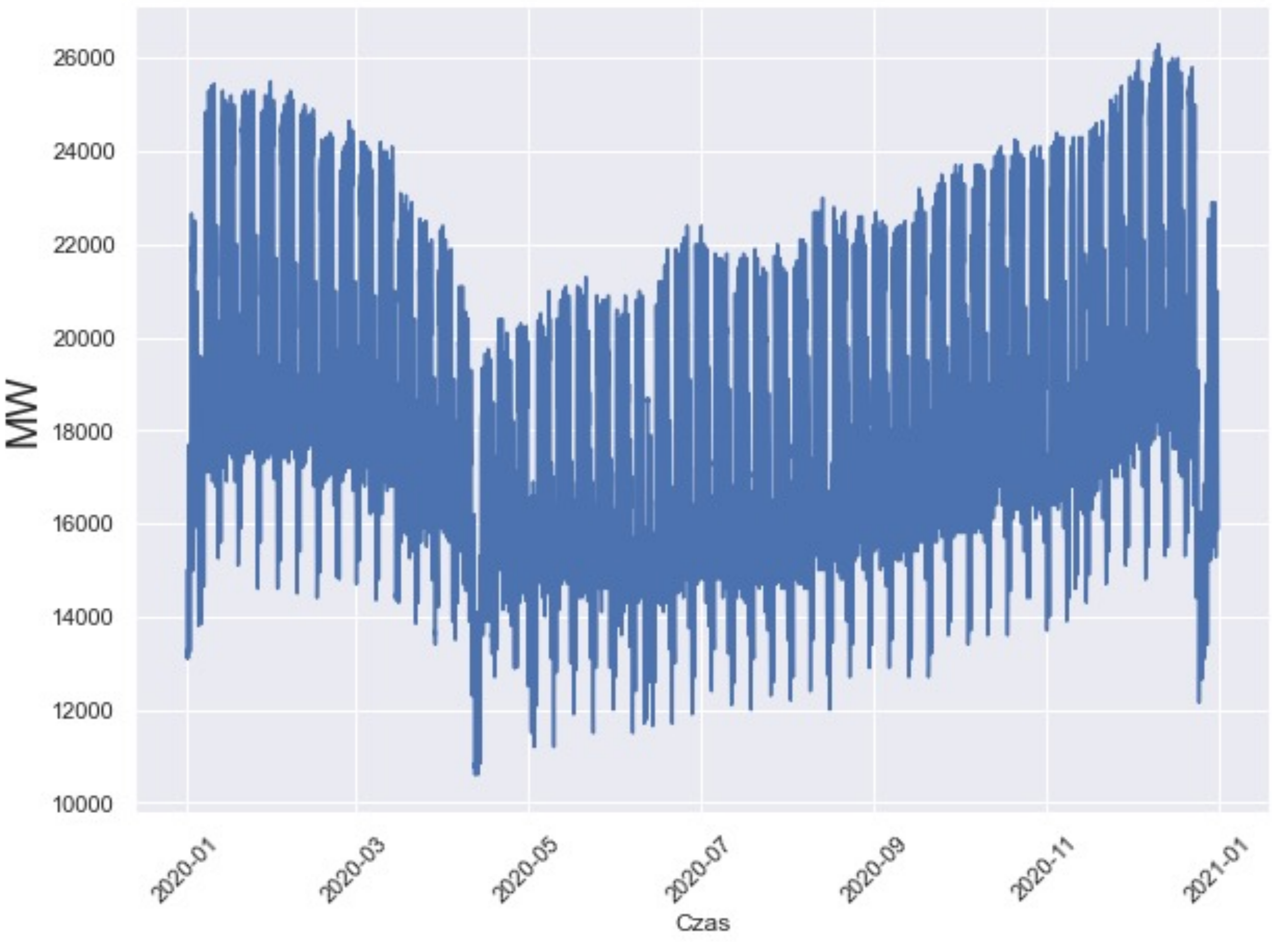
25-11-2021 11:43:16

Energy security

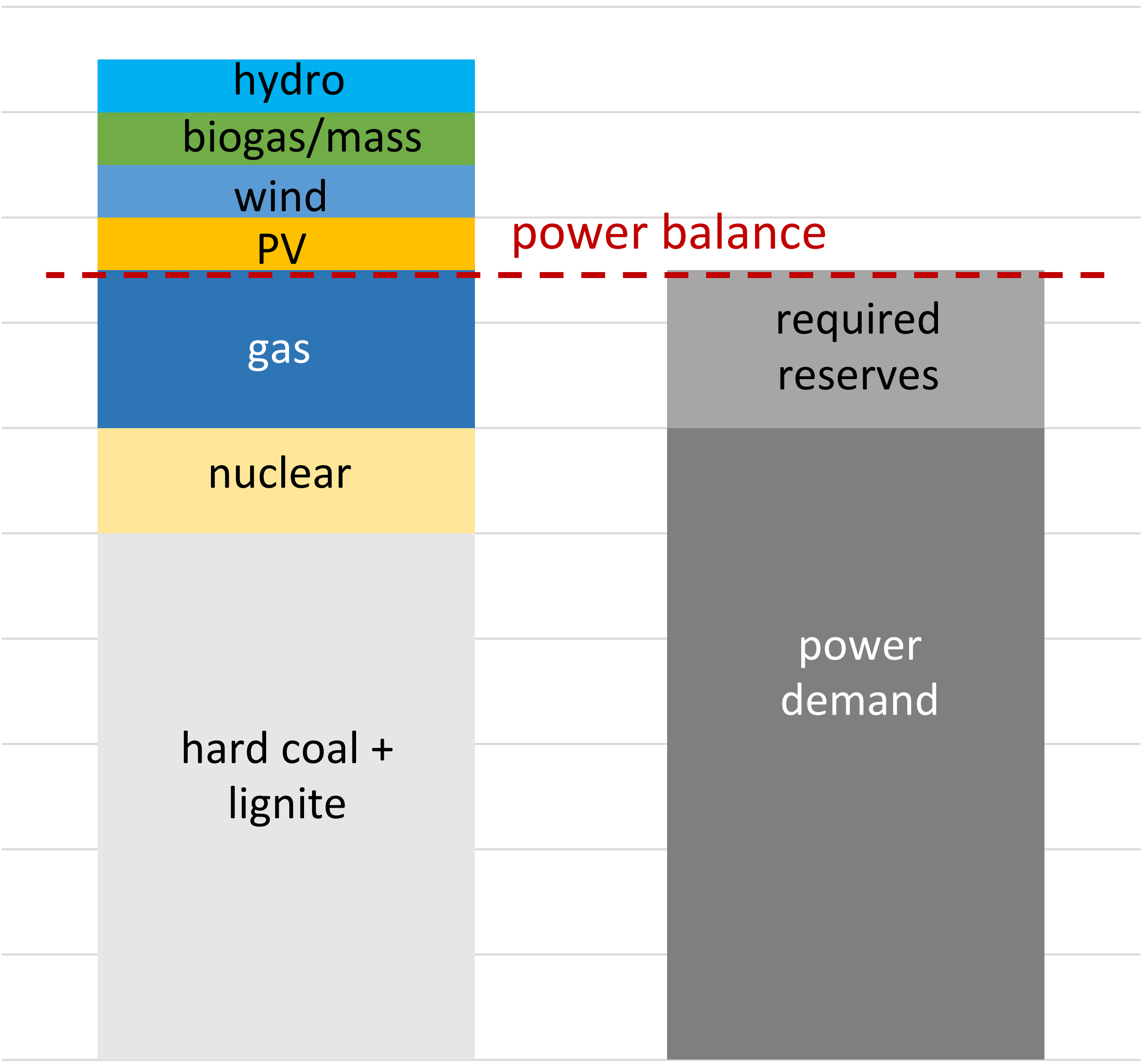
- Energy security: the continuous supply of energy and fuels at an affordable price.
- The continuity of supply must be maintained 24 h/day 7 days a week regardless weather conditions.
- Affordable price: the economy remains competitive, and the society does need to limit its consumption of other goods.
- **Energy security is verified by power and energy balances.**
- Power balance is maintained when the highest demand (usually during a cold February evening) is satisfied by the dispatchable power plants.
- Energy balance is maintained when the demand and production are balanced thorough the year.

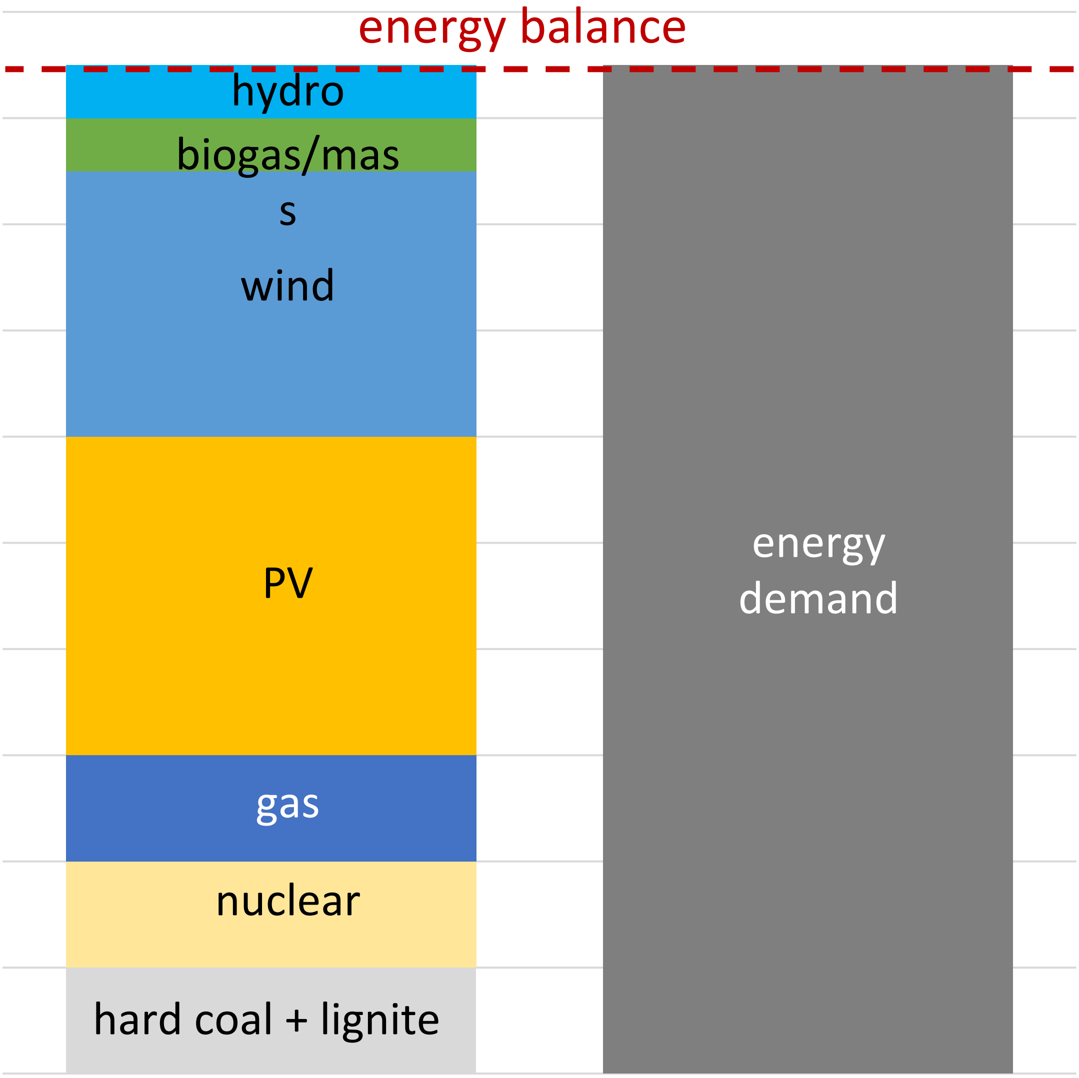
Demand profiles





Power balance and energy balance

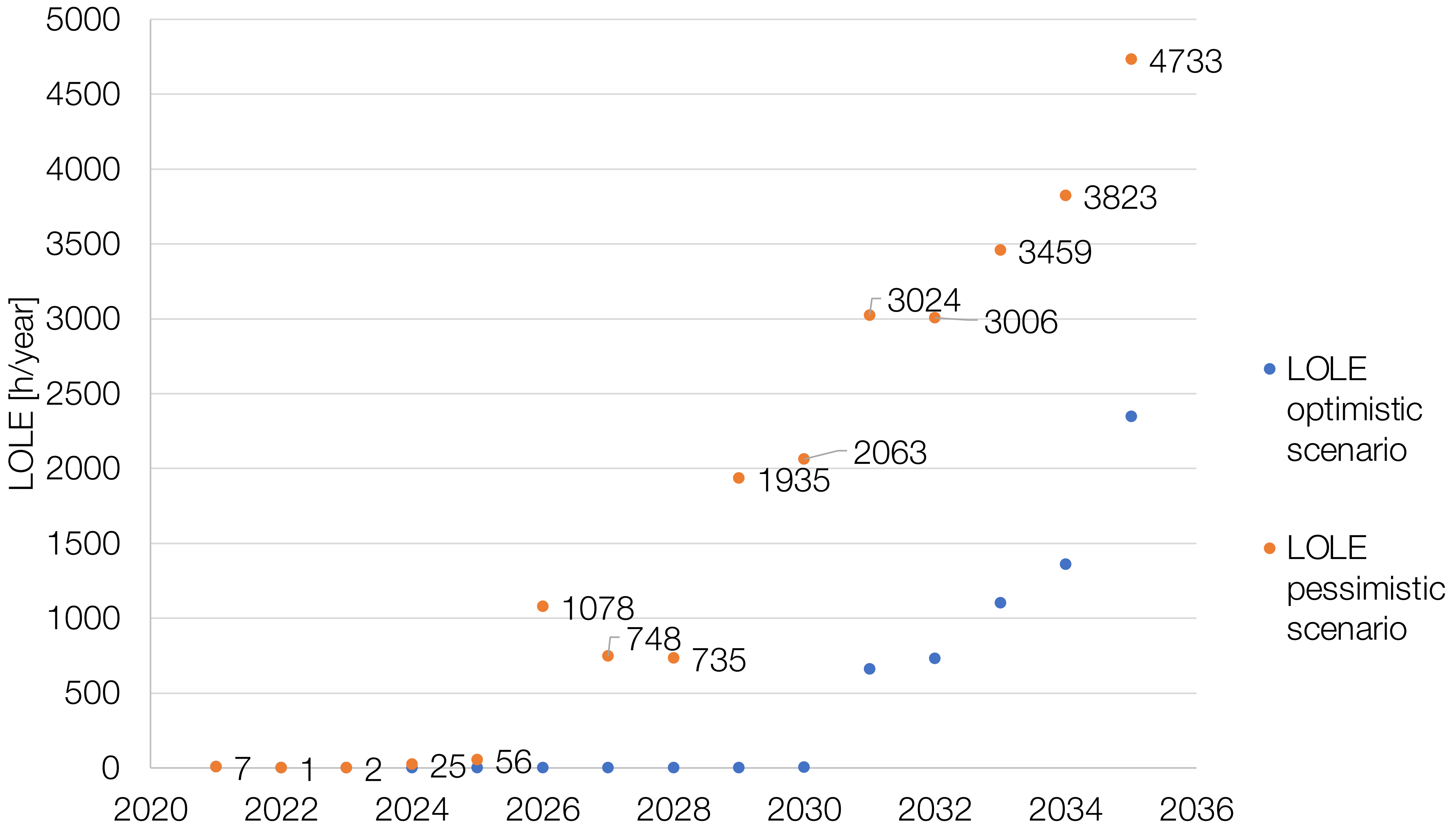




Report on energy security monitoring (2021)

- Majority of power generating assets have been commissioned in the XX century.
- Over 73% of boilers and almost 68% of turbo generators are over 30 years old.
- Ageing infrastructure is a challenge for energy security.
- The Report of Ministry for Climate indicates a need for the construction of 8000-10 000 MW of dispatchable power units to 2030
- Only two gas power units of 1400 MW in the Dolna Odra power station are under construction.
- Construction time: gas – 5-6 years, coal – 8-10 years, nuclear installations – 10-20 years.

Loss of load expectation (according to the Report)



The European standard – 3 hours per year without electricity

High electricity prices in 2021 and 2022

High electricity prices which occurred in 2021 and the beginning of 2022 result from:

- **Speculation** in the trade of CO2 allowance in the European Emission Trade System causing the increase of the allowances' prices from about € 10/MWh in 2018 to over € 80/MWh in 2021. It means that the prices of electrical energy produced by convectional power stations have raised from PLN 280/MWh (€ 62/MWh) to PLN 550/MWh (€ 122/MWh).
- **Reduction of hard coal mining** in Poland due to the decarbonization program.
- A lack of **realistic plans for the construction of new dispatchable power plants.**
- The increase of **demand for electricity** after the first waves of the Covid pandemic. It is a short term impulse leading to the rise of electricity prices.
- The prices in forward contracts for 2022 and 2023 indicate **permanent increase of electricity prices.**

High electricity price reasons (1)

The analysis of electricity prices as presented above indicates:

- Electricity prices in December 2021 were five times higher and the production costs counting for near PLN 600/MWh (€ 130/MWh) even taking into account costs of CO2 allowances.
- Lower electricity prices are observed in forward contracts for January and February 2022 but they are still higher twice than the cost of electricity generation.
- For March and April 2022 prices in forward contracts approach the costs of electrical energy generation.
- **It indicates the high electricity prices are stimulated by fears of shortages in electricity delivery.**

High electricity price reasons (2)

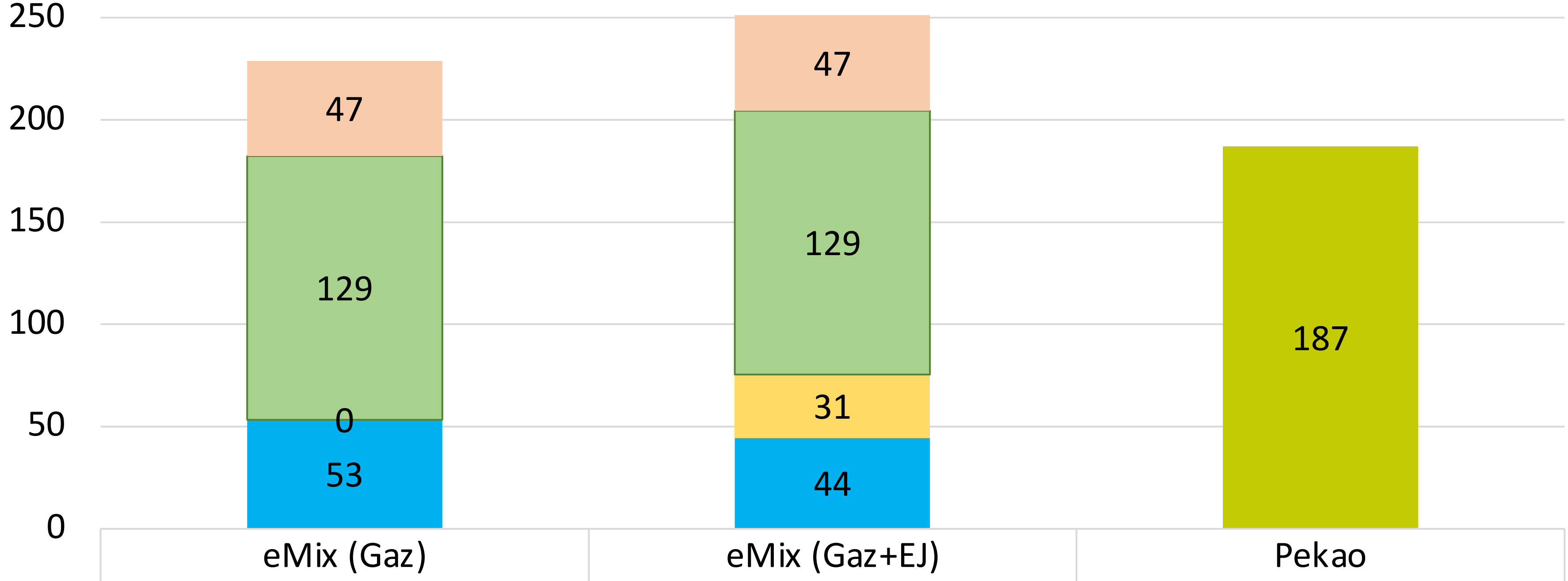
The fears of shortages in electricity supply are justified as:

- **There is no program for construction of new dispatchable power plants**. Due to the Report of Ministry of Climate and Environment there is a need for construction of 8000-10000 MW in new fully dispatchable power plants to 2030. Only, two power plans are under construction with the total rated power of 1500 MW in Dolna Odra power stations.
- **Nuclear power plants, if they are constructed, can be commissioned no earlier than after 2038-2040** what does not affect the negative balance of demand and supply of electrical energy
- **Poland has limited resources of natural gas** counting for about 25% of the total demand. The increase of natural gas supply is limited by capacities of international gas connection and poor development of domestic gas pipe system.
- **Only coal power stations, if we like them or not, can ensure energy security and continuous electricity supply. The alternative is black-out.**
- However, the decarbonisation program leads to the elimination of lignite and hard coal as fuels in electricity production.

Perspective for Energy Transition

- **The entire elimination of fossil fuels from electricity production is unlikely** as only such fuels are able to guarantee energy security of continuous supply of electricity to the public and the economy.
- **There is no alternative to fossil fuels from security of supply point of view.**
- The possible applications of hydrogen in large scale electricity production will be limited.
- **RES can supply more electricity but they are not able to guarantee continuous electricity supply**
- Energy Transition will increase the costs of living and industry production in particular in the countries as Poland without high technologies allowing for the production of renewables installations.
- Program for offshore wind farms will cost PLN140 billions to 2035. Over 95% of this investment will be transferred to more developed member states of the EU.

Costs (overnight) of Energy Transformation in Poland
(€ billion)



	eMix (Gaz)	eMix (Gaz+EJ)	Pekao
Pekao			187
Networks	47	47	
RES	129	129	
Nuclear	0	31	
CCGT	53	44	

CCGT Nuclear RES Networks Pekao

Business: Energy Transition

- Energy Transition is a new business for the technically developed countries by the imposing the legal regulations that create forced demand for new technologies.
- In the 90-ties of XX century, developed countries of the Western Europe undertook and attempt to impose limitations of CO2 emission by a system of international agreements – Kyoto protocol, Climate Summits (Conference of the parties).
- Despite 23 Climate Summits, the countries outside the European Union agreed for only vague declarations without binding obligations.
- Such binding obligations have been imposed on the EU member states.
- Such obligations cause the transfer of economic assets from less technically developed Member states to more developed countries.
- Additionally, because of the offshore wind farms program costing PLN 140 billion to 2030, Poland each year transfers PLN 8 billion to owners of onshore wind farms who invested before 2015 and currently their operation costs ranges about 20% of the revenue.

What next?

- Despite the Energy Revolution (Energiewende) coal consumption and CO_2 emissions are increasing in Europe and worldwide
- In Germany, the leader of Energy Transition, the CO_2 emission increased in 2021 by 33 million tons (5%). The forecasts indicate further increase of CO_2 emission 5-10% in 2022, as the increasing use of lignite power stations replacing the decommissioned nuclear plants.
- The increase of CO_2 emission does not affect business of Energy Transformation.
- The competitiveness of the EU economy will be reduced as results of Energy Transition.
- **Whether climate neutrality can be achieved or not the Energy Transition will be continued as it is a business for the developed the EU countries.**

Power supply industry – critical infrastructure

- **Power supply industry was and still is the critical infrastructure similarly as railways or roads.**
- This infrastructure ensures the functioning of the societies and economies in each external and provides the continues supply of electricity: **24 hours per day and 7 days a week.**
- The main elements of the critical infrastructure embrace **transmission and distribution power lines** and **always dispatchable power plants.**
- Whatever are other targets for the power supply industry, its reliable operation is imperative for the societies and economies.

dr inż. Izabela Filipiak

Doktor nauk technicznych i ekonomistka. Ukończyła studia inżynierskie i magisterskie z zakresu energetyki na Wydziale Mechanicznym i Wydziale Elektrotechniki, Elektroniki, Informatyki i Automatyki Politechniki Łódzkiej. Dodatkowo, ukończyła z wyróżnieniem studia magisterskie na kierunku Ekonomia w Akademii Leona Koźmińskiego. W 2019 r. obroniła pracę doktorską pt. *„Long-term, dynamic modelling of the power system development”* w dziedzinie automatyka, elektronika i elektrotechnika. Współautorka 8 artykułów naukowych publikowanych w międzynarodowych czasopismach.

Główne zainteresowania zawodowe to: rozwój sektora elektroenergetycznego, transformacja klimatyczno-energetyczna, ochrona środowiska, zmiany klimatu i adaptacja do nich. Pracę zawodową rozpoczynała w firmach realizujących inwestycje z zakresu energetyki. W Kancelarii Prezesa Rady Ministrów jako główny specjalista w Centrum Analiz Strategicznych przygotowywała analizy merytoryczne dotyczące energetyki, klimatu i środowiska w Polsce, a także opiniowała przygotowywane akty prawne.

W 2018 r. uczestniczyła jako członek delegacji Polski w zakończonym sukcesem COP24 w Katowicach (ogólnoświatowa Konferencja Stron Ramowej konwencji Narodów Zjednoczonych w sprawie zmian klimatu) jako łącznik z KPRM oraz wsparcie dla Głównego Negocjatora Polski.

Od 2020 r. pracuje w Krajowym Ośrodku Zmian Klimatu (Instytut Ochrony Środowiska – Państwowy Instytut Badawczy) jako ekspert ds. energetyki i finansowania ekologicznych inwestycji. Jest autorką Wyszukiwarki EkoDotacji. Od lutego 2021 r. pracuje również jako manager w Enea Trading zajmując się analizami rynku energii i rynków powiązanych.

Profesor dr hab. inż. Władysław Mielczarski

Profesor dr hab. inż. Władysław Mielczarski pracuje na stanowisku profesora w Instytucie Elektroenergetyki Politechniki Łódzkiej, będąc jednocześnie członkiem Europejskiego Instytutu Energii (*European Energy Institute*), wybranej grupy szesnastu ekspertów z krajów Unii Europejskiej, pełniących funkcję doradczą (*think tank*) w sprawach energetycznych dla instytucji i firm europejskich. Profesor W. Mielczarski jest jedynym przedstawicielem Polski w European Energy Institute i jednym z dwóch przedstawicieli z krajów, nowych członków Unii Europejskiej.

Pełnił w latach 2008-2016 funkcję Przewodniczącego Rady Nadzorczej LitPol Link, firmy powołanej przez Polskie Sieci Elektroenergetyczne SA oraz LitGrid w celu budowy połączenia elektroenergetycznego pomiędzy Litwą i Polską. Był także członkiem europejskiego Think Tank „International Business Council: Grid & Infrastructure", Essen, Niemcy w latach 2017-2020.

Profesor W. Mielczarski posiada ponad 40 letnią praktykę w elektroenergetyce, włączając w to 10 lat pracy zagranicą w krajach takich jak Australia, Kanada i Singapurze. Brał udział w projektowaniu i wdrażaniu rynków energii elektrycznej w Australii, kanadyjskiej prowincji Ontario oraz Polsce.

Ukończył studia na Wydziale Elektrycznym Politechniki Łódzkiej w roku 1973. Kolejno w latach 1978 oraz 1987 uzyskał stopień dr nauk technicznych i doktora habilitowanego nauk technicznych, w roku 2002 tytuł profesora, a w roku 2005 stanowisko profesora zwyczajnego.

W latach 1973 – 1975 pracował w Elektromontażu nr 3 w Katowicach w Grupie Regulacyjno-Rozruchowej oddając do eksploatacji nowe obiekty energetyczne zasilające: Kombinat Hutniczy w Bolesławcu, kopalnię w Olkusze, hutę Katowice i inne. W latach 1975-1978 odbywał studia doktoranckie na Politechnice Łódzkiej, gdzie po trzech latach uzyskał stopień dr inż. nauk technicznych. Następnie w roku 1987 uzyskał stopień dr hab. inż. nauk technicznych.

Na zaproszenie Curtin University of Technology z Perth, Zachodnia Australia, pracował na tym uniwersytecie w latach 1991-1992 jako wykładowca. W roku 1992 wygrał międzynarodowy konkurs na stanowisko Associate Professor na Monash University w Melbourne, największym uniwersytecie w Australii gdzie pracował do 2000 roku. W latach 1996/1997, w czasie urlopu sabbatical, pracował na Nanyang Technological University w Singapurze jako Research Associate.

W latach 1992-1997 uczestniczył w projektowaniu i wdrażaniu rynku energii elektrycznej w stanie Victoria. W latach 1997-2001 uczestniczy w projektach wprowadzających rynek energii elektrycznej w prowincji Ontario w Kanadzie.

Dwukrotnie był doradcą rządu RP. W latach 1999-2001 przygotowywał projekt polskiego rynku energii elektrycznej, który został przyjęty przez rząd RP w grudniu 1999 roku i wdrożony w latach 2000-2001. W tym okresie projektował dla Polskich Sieci Elektroenergetycznych SA zasady działania rynku bilansującego oraz programy komputerowe – LPD – Linear Programming Dispatch do planowania pracy systemu elektroenergetycznego w systemie Day Ahead.

Jako doradca Ministra Gospodarki w latach 2005-2007 przygotowywał program konsolidacji polskiej elektroenergetyki przyjęty w marcu 2006 przez rząd i wdrożony w latach 2006-2007 oraz uczestniczył w opracowaniu ustawy rozwiązujące kontrakty długoterminowe i wprowadzającej system opłat kompensacyjnych.

We wrześniu 2007 był delegowany przez polski rząd do Komisji Europejskiej, gdzie pełnił w latach 2007-2011 funkcję European Energy Coordinator w DG Energy będąc odpowiedzialnym za rozwój międzynarodowych połączeń transgranicznych systemów elektroenergetycznych w Północnej i Centralnej Europie. Z jego inicjatywy powstał LitPol Link połączenie elektroenergetyczne Polski i Litwy, które było oddawane do eksploatacji w grudniu 2015 r.

Jest założycielem corocznej konferencji “*European Energy Markets*”, największej międzynarodowej konferencji w tej dziedzinie. Dotychczas odbyło się 18 konferencji, która gromadzi corocznie ponad 300 uczestników, a referaty konferencyjne są publikowane w bazie IEEE XPLORER.

Jego dorobek publikacyjny obejmuje 11 książek i wydań specjalnych, 21 rozdziałów w książkach, 45 artykułów w pismach naukowych oraz ponad 200 referatów wygłoszonych na konferencjach naukowych. Profesor W. Mielczarski kierował ponad 65 projektami badawczymi i wdrożeniowymi. Otrzymał nagrodę Prezesa Rady Ministrów za programy komputerowe optymalizujące pracę systemu elektroenergetycznego w obszarze rynku bilansującego: Day Ahead Market dla Polskich Sieci Elektroenergetycznych SA.

Jest członkiem IEEE (Life Member), a w roku 2020 został odznaczony Krzyżem Kawalerskim Orderu Odrodzenia Polski przez Prezydenta RP.

Lista książek opublikowana przez Prof. W Mielczarskiego

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