Energy Situation in Poland and Efficient Use of Lignite

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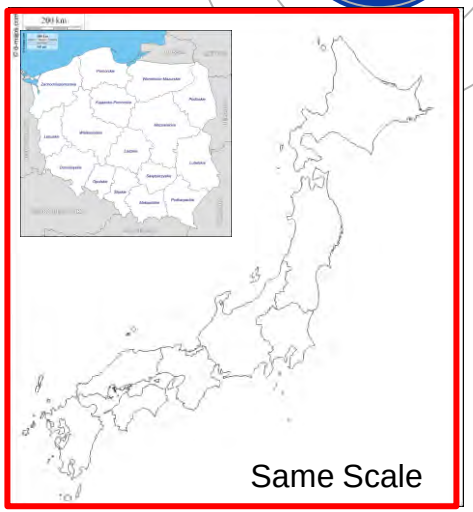
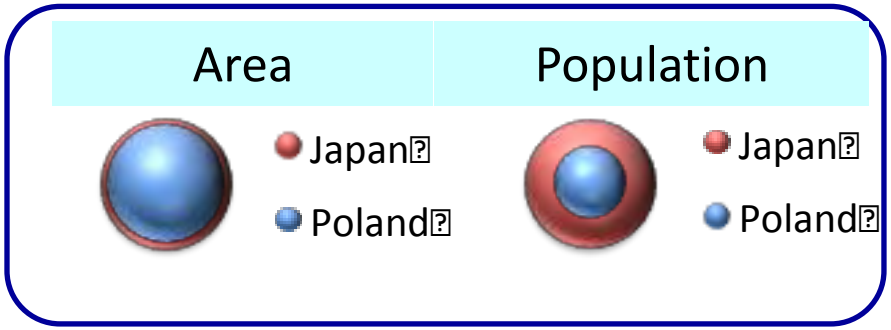
Where is Poland? Who are we?

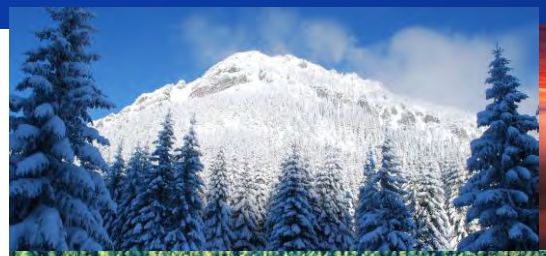


- **Population: 38,5 mln**
- **Area: 312 679 km²**
- **Language: Polish**
- **Religion: Catholic (97%)**
- **Capital: Warsaw**
- **Currency: Zloty (PLN)**
- **Political system: Constitutional democracy**



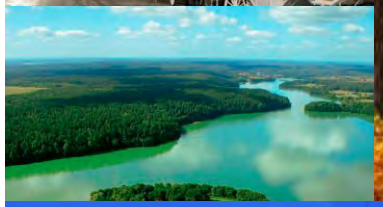
- The country's name, Poland or ***Polska***, is derived from the word ***Polanie*** (people of the fields)

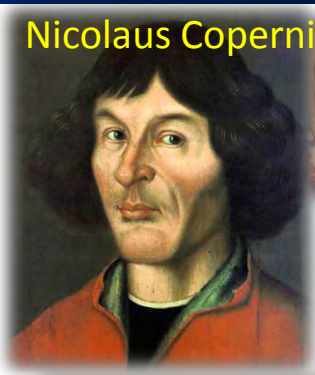
Where is Poland? Who are we?











Nicolaus Copernicus

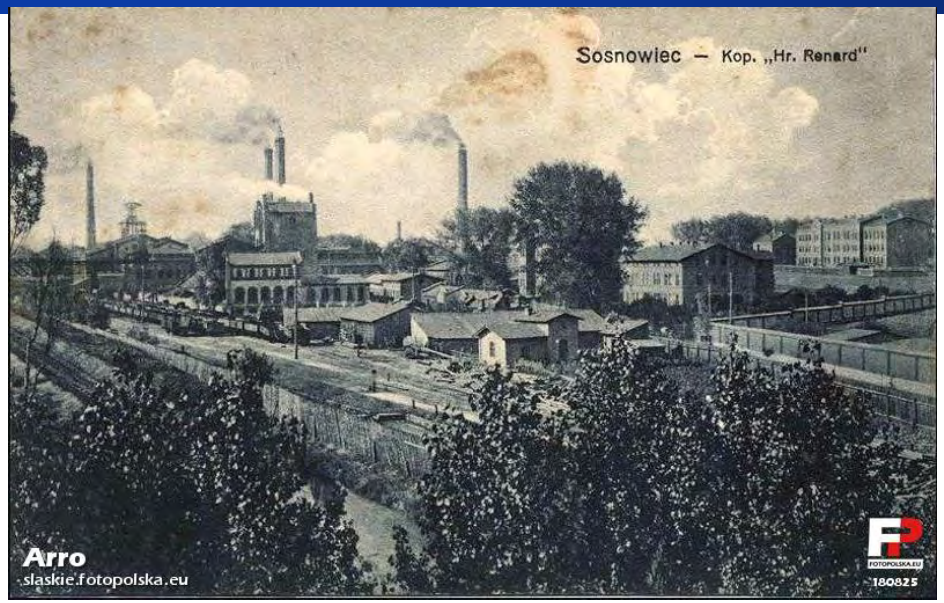

Frédéric Chopin


Marie Curie


Pope John Paul II

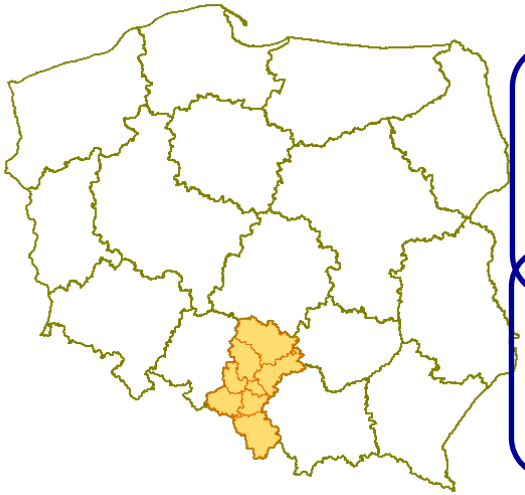

Lech Wałesa

SILESIA PROVINCE



1890, Sosnowiec, Silesia, coal mine

Celebration of St. Barbara day at AGH University (traditional miners outfit)

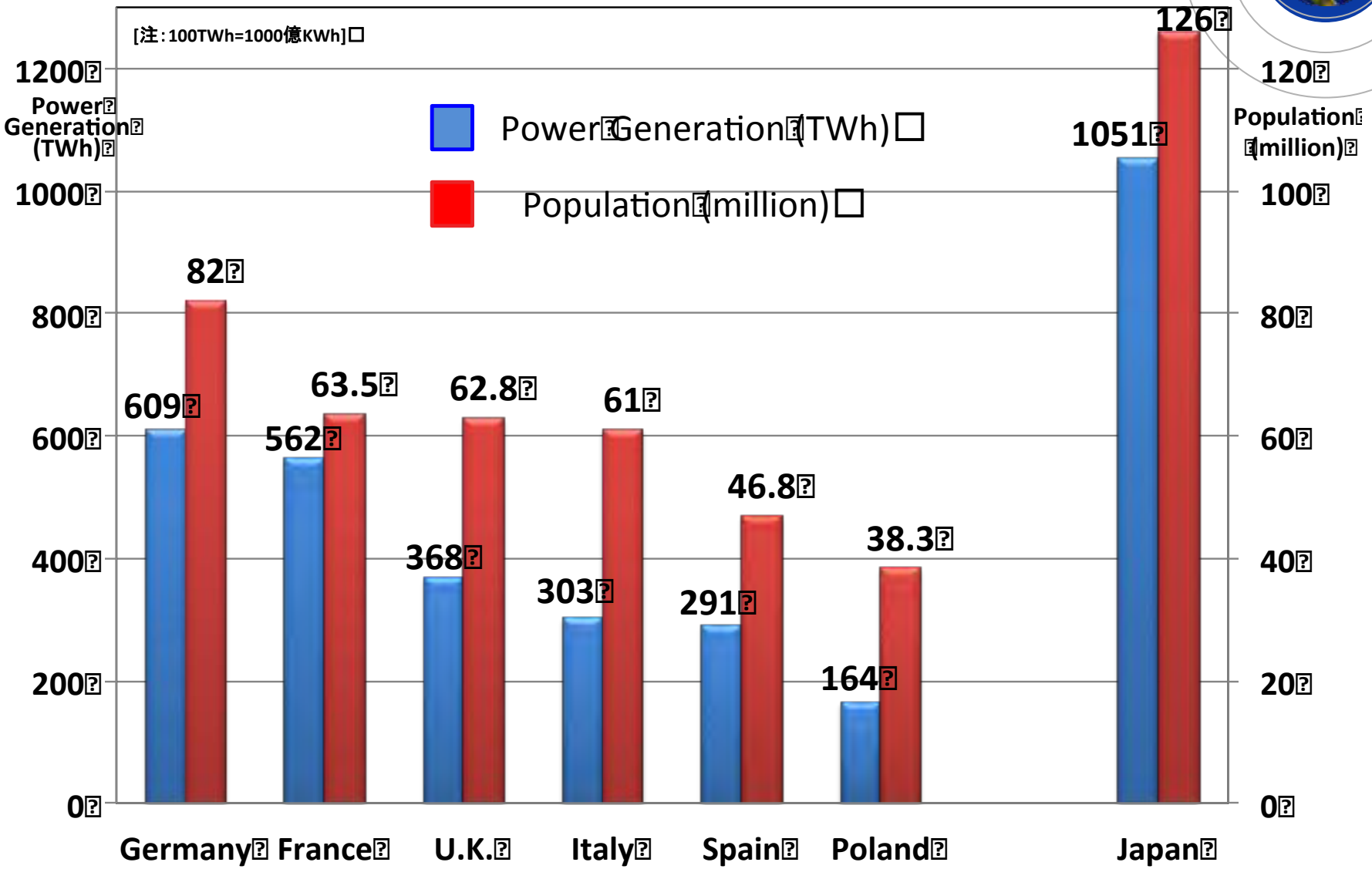


- First coal mine in Poland was established in Silesia Region in 17th century.
- Silesian history, industry and culture are strictly connected with mining traditions .

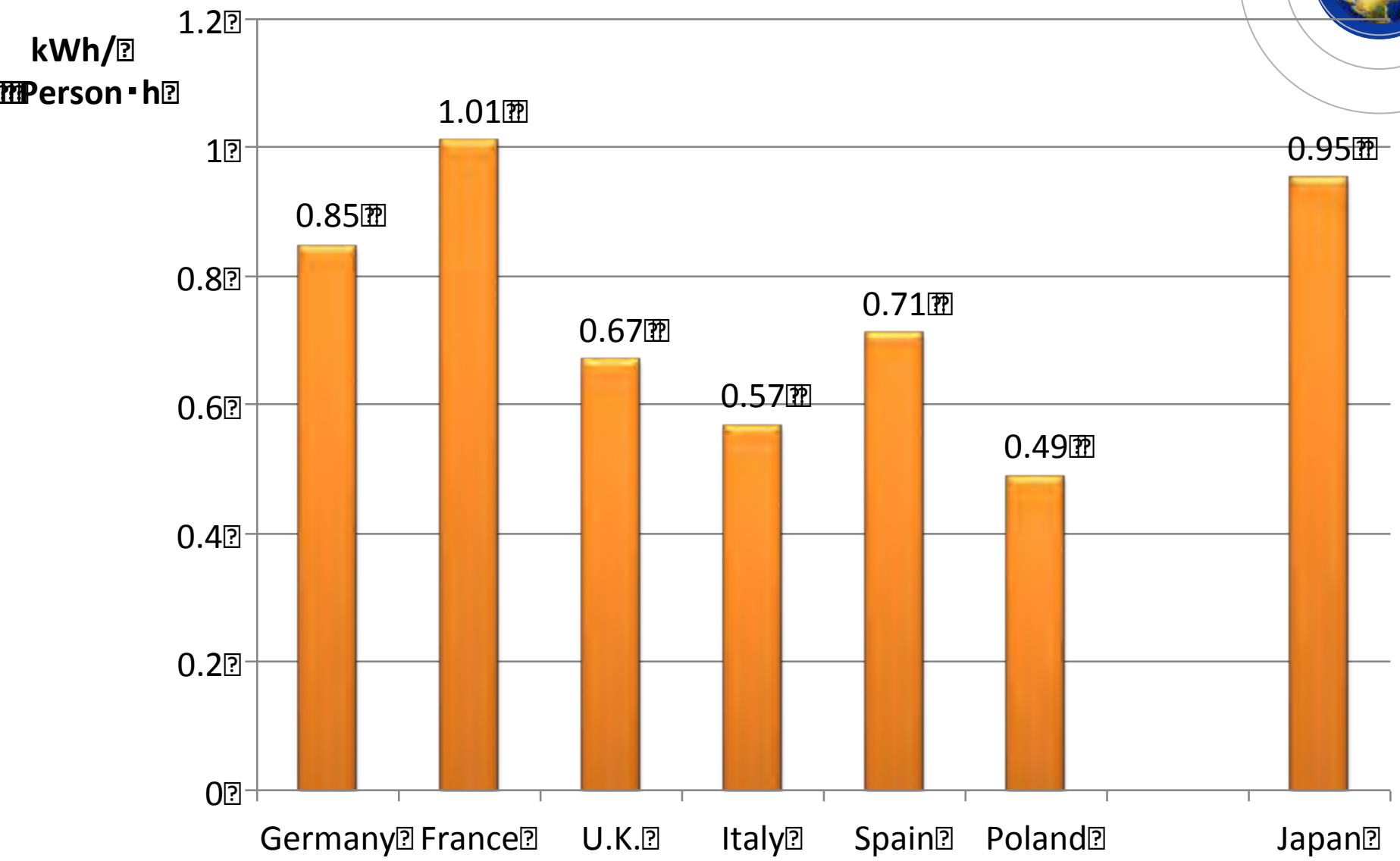
Santa Barbara, patron of miners

1. Power Generation in Europe

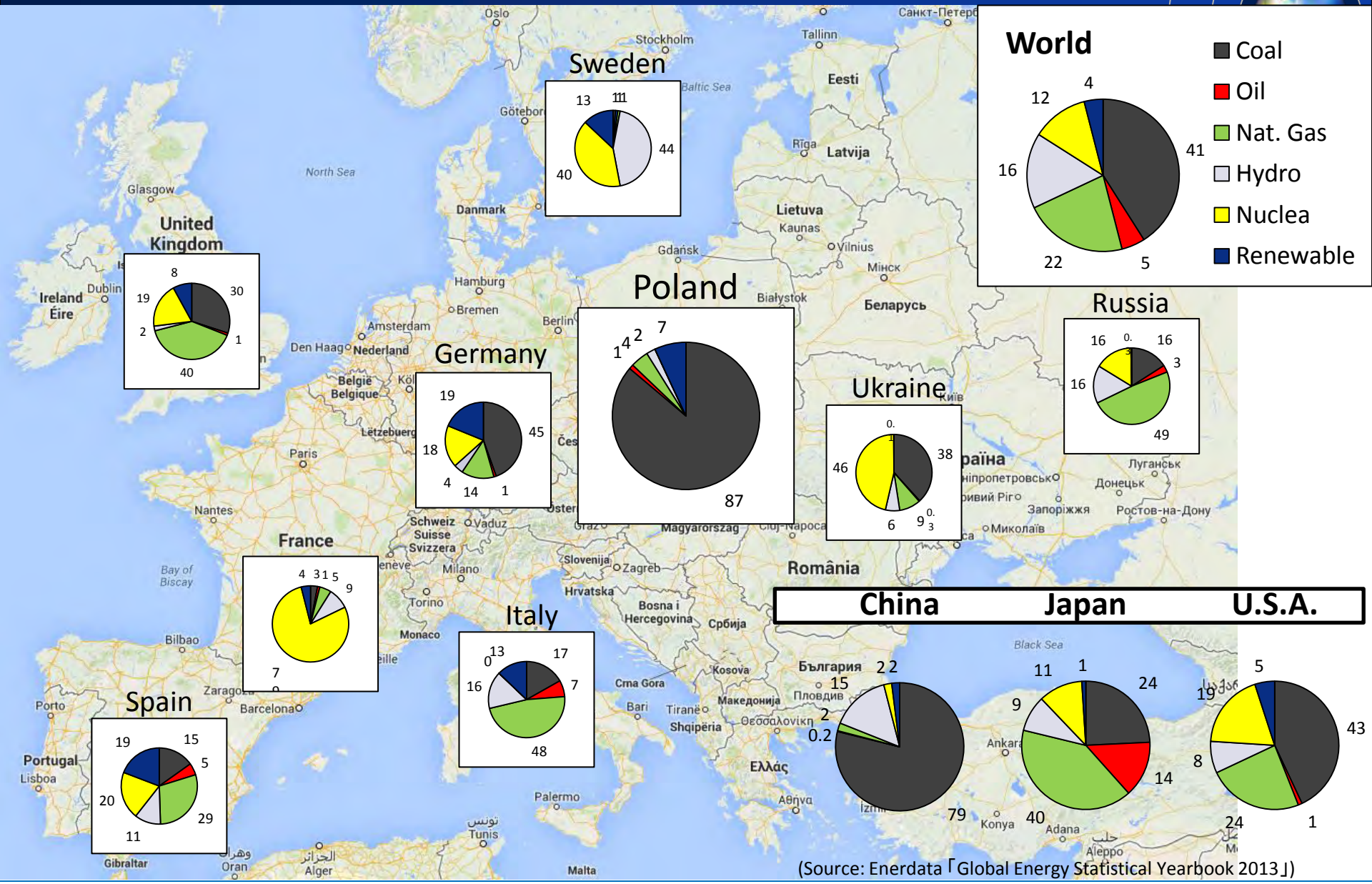
Power Generation in Europe



Power Generation per capita

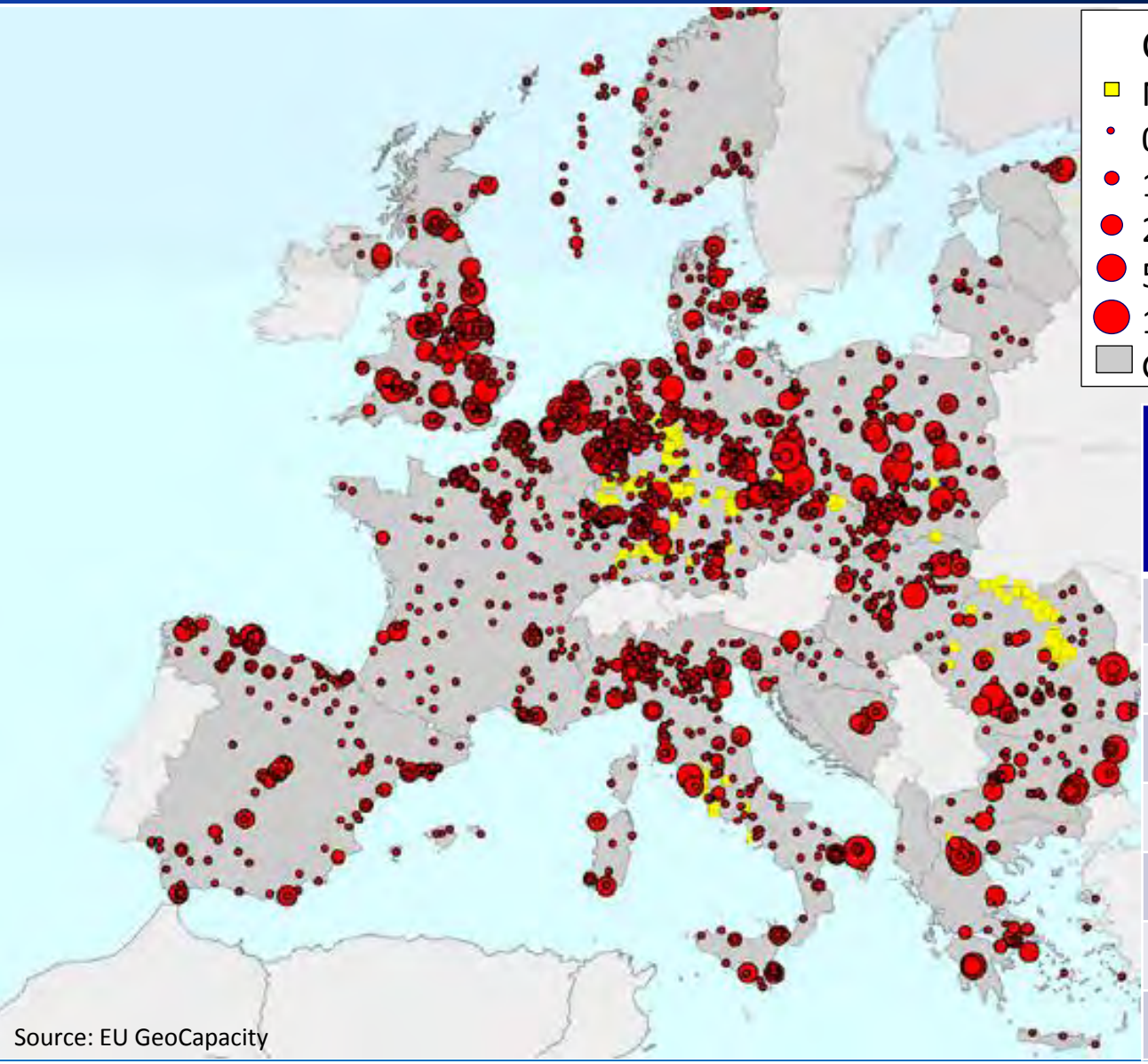


Power Source Distribution in Europe



(Source: Enerdata「Global Energy Statistical Yearbook 2013」)

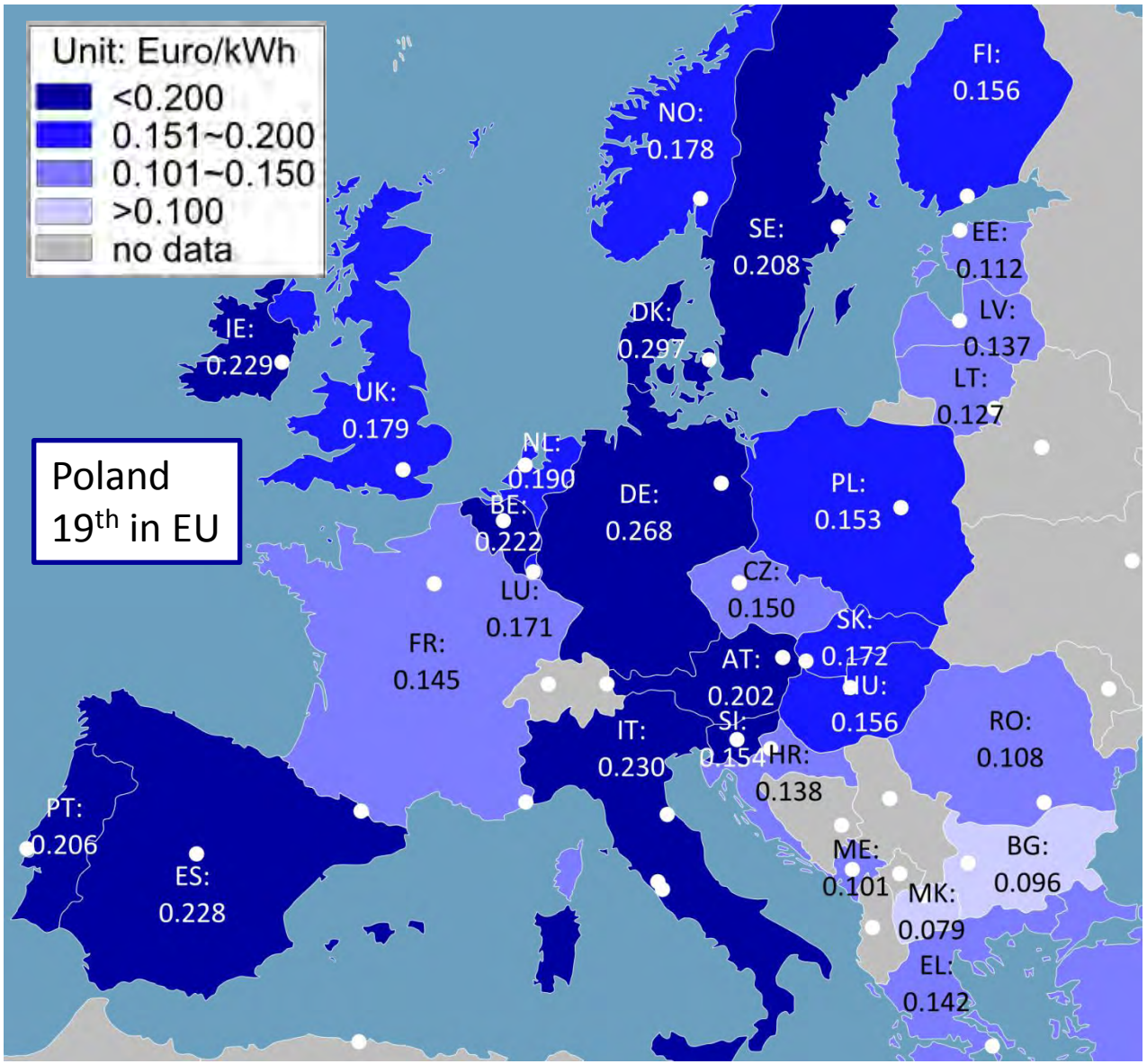
Stationary CO_2 Emissions in European Countries



Source: EU GeoCapacity

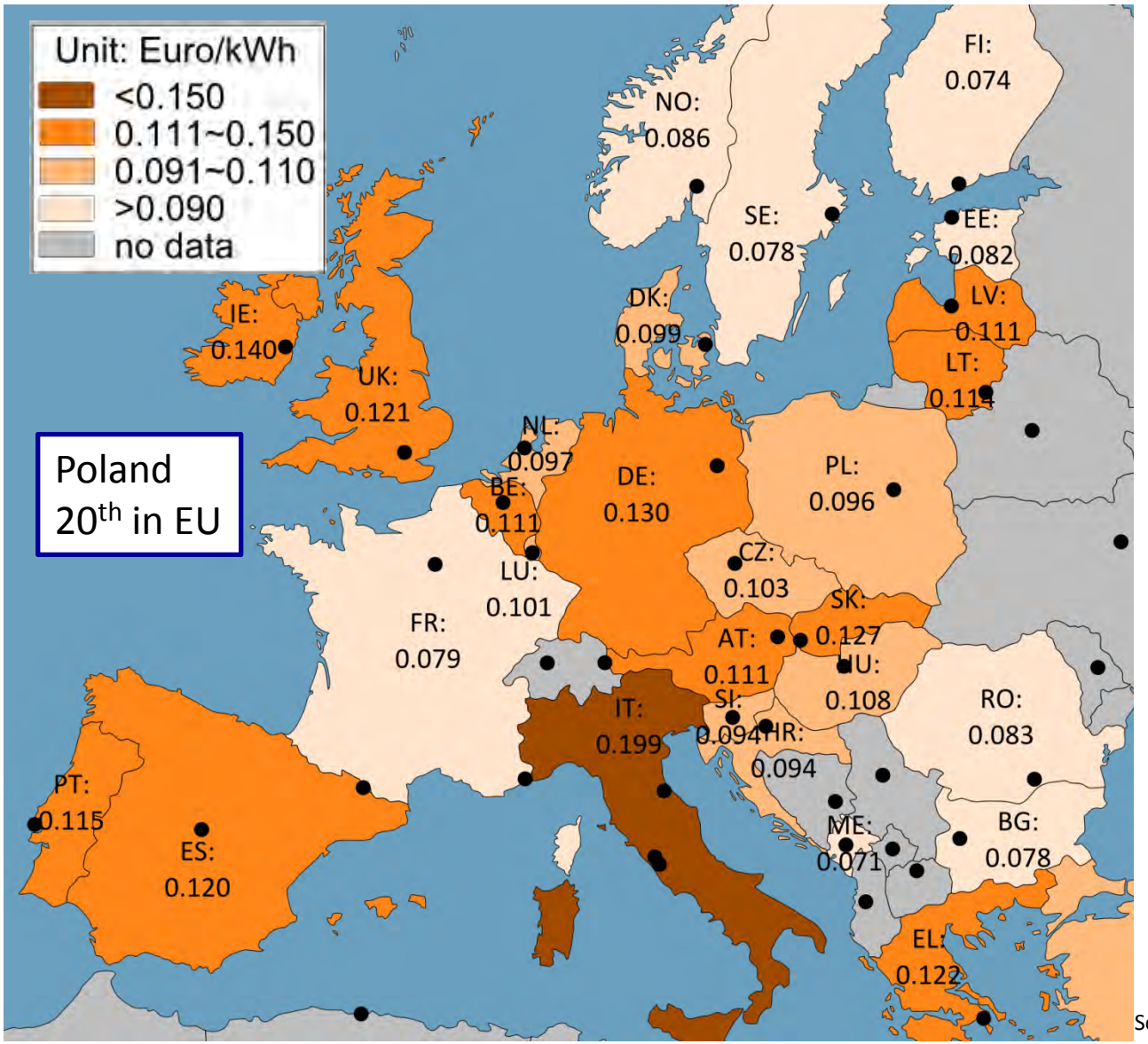
Country	Annual total emissions of CO2 (Mt)
Germany	864
UK	555
Spain	423
Poland	325
Italy	212
Netherlands	180
Czech	128

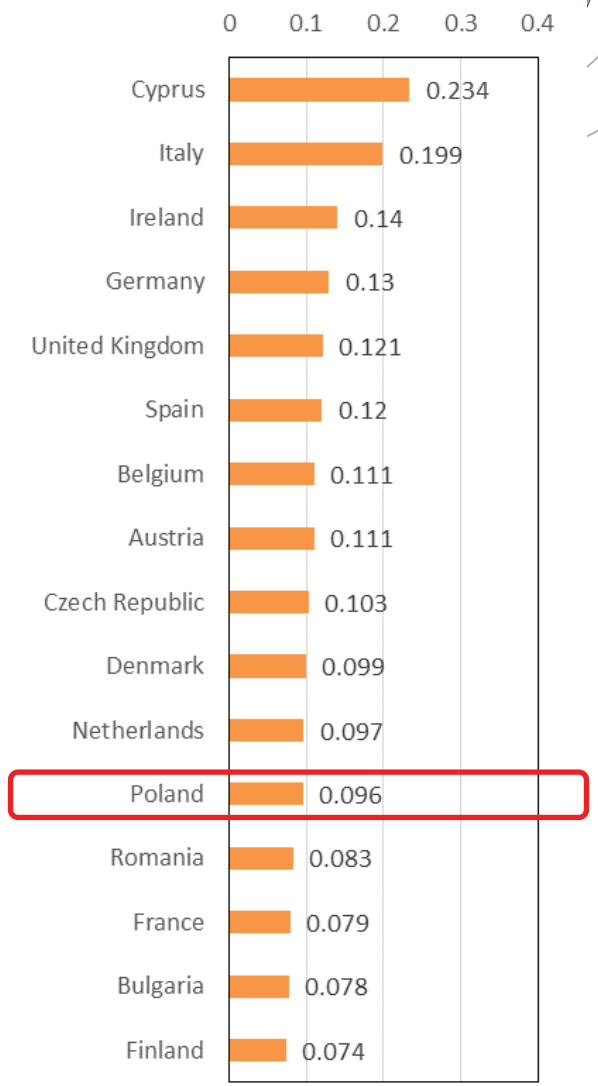
Electricity Prices in Europe for Residential Euro/kWh



Source: Eurostat, European Comission, 2010

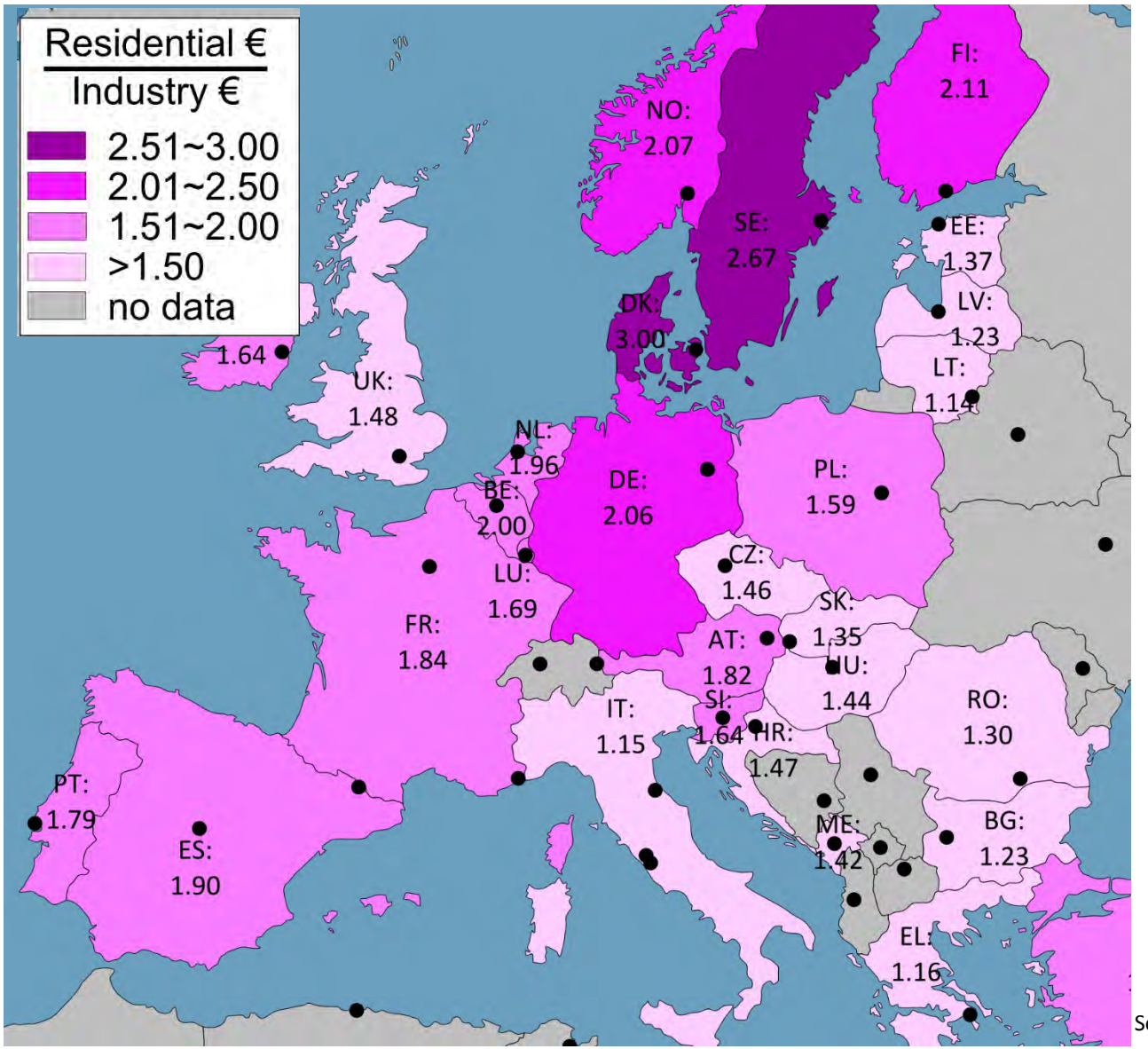
Electricity Prices in Europe for Industry Euro/kWh





Source: Eurostat, European Comission, 2010

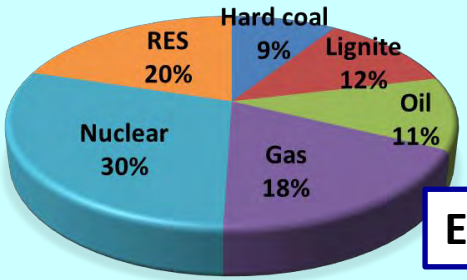
Ratio of the Residential Price to Industry Price



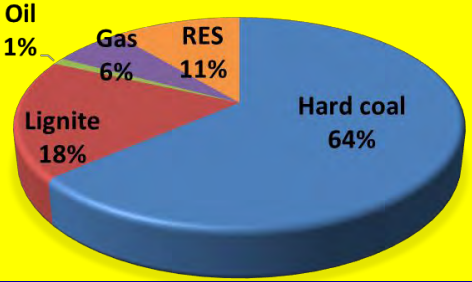
Source: Eurostat, European Comission, 2010

Domestic Primary Energy Production

EU



Poland

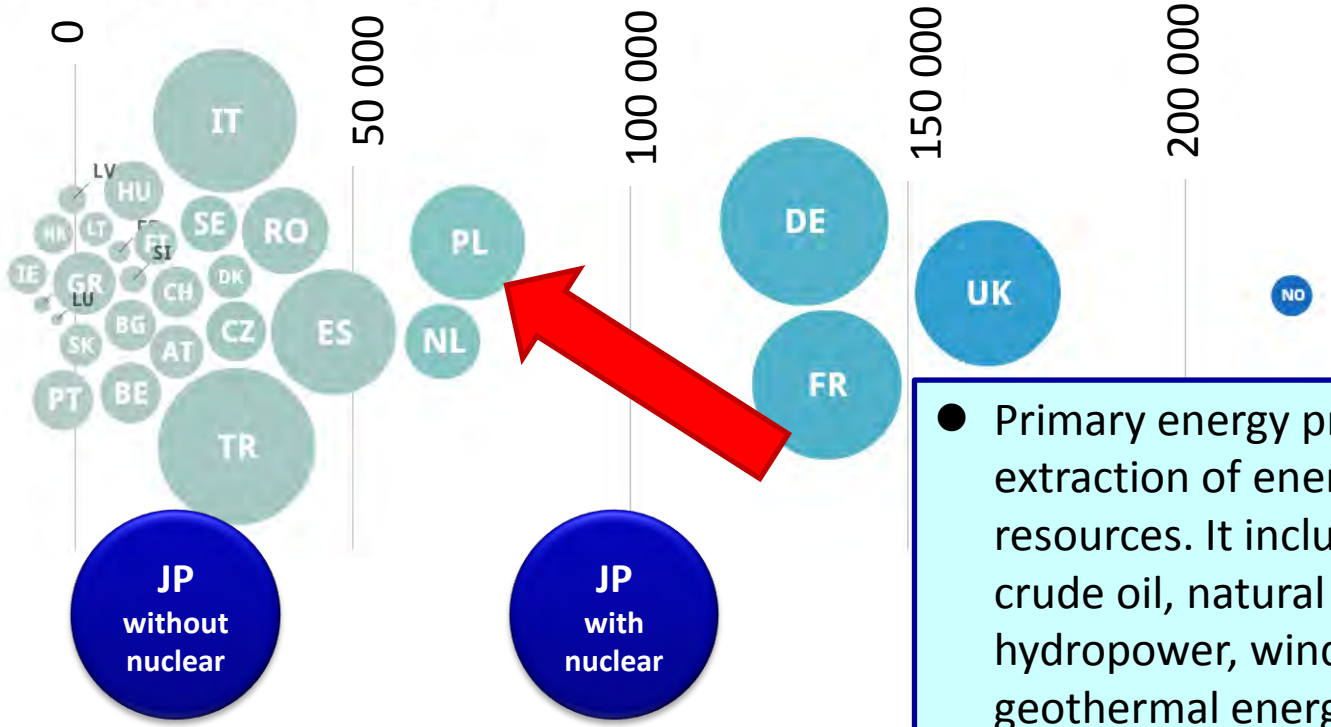


Energy Production Mix

Domestic Primary Energy Production

In thousands of tonnes of oil equivalent

2008



Area of the circle is proportional to the population

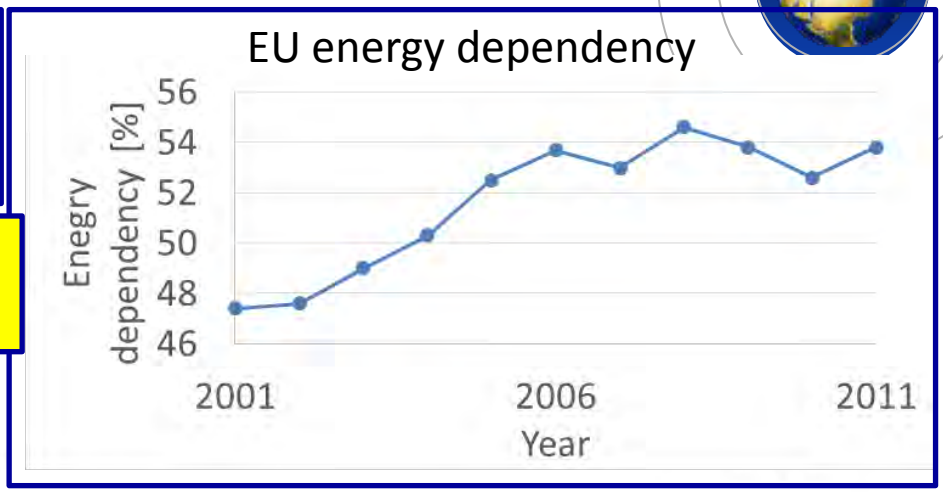
- Primary energy production is the extraction of energy from natural resources. It includes hard coal, lignite, crude oil, natural gas, nuclear heat, hydropower, wind, solar photovoltaic , geothermal energy and biomass.

http://energy.publicdata.eu/

Energy Dependency

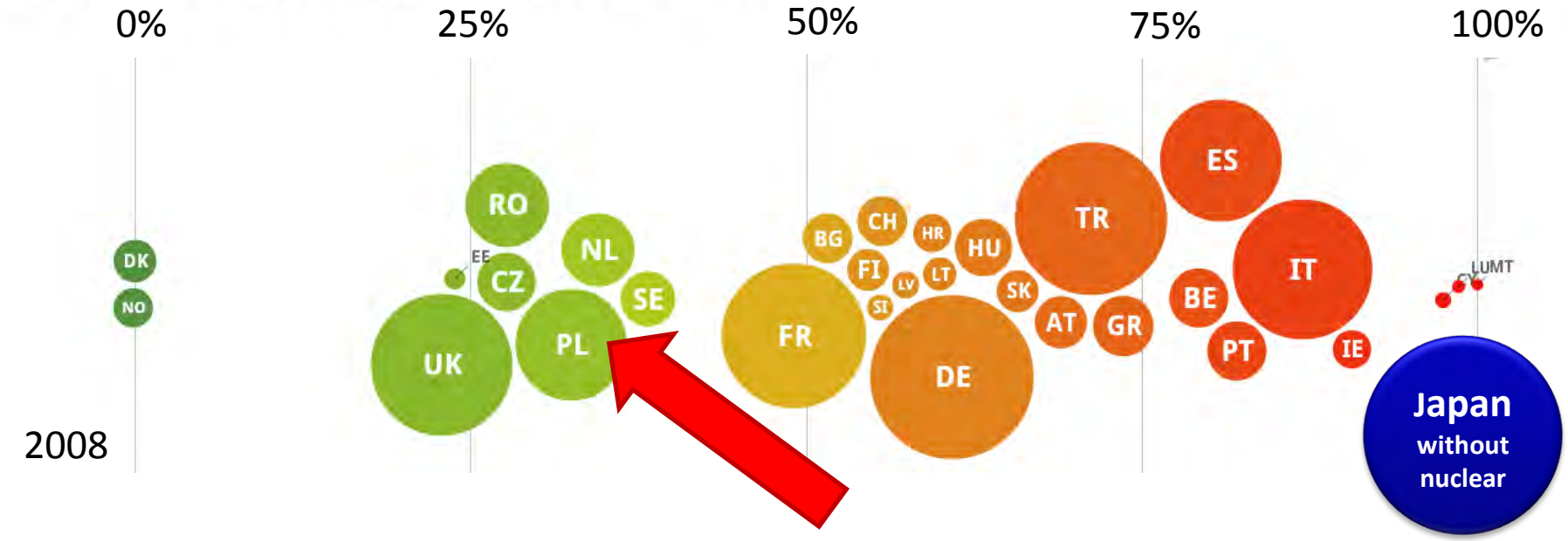
- Energy dependency shows the extent to which a country relies upon imports in order to meet its energy needs.

EU – 54.6%
Poland – 30.6%



Energy Dependency on Import

What proportion of gross energy consumption is from imports?



Area of the circle is proportional to the population

http://energy.publicdata.eu/

2. Power Generation and Consumption in Poland

Where Poland stands now and where we will go?

Polish Governmental Policy

- "Poland will continue to back coal and invest in the coal-mining industry,"
- "Poland's economy will continue to be based on coal, but in a more modern way,"
- "**The future of Polish energy is in brown and black coal**, as well as shale gas,"
- "Some wanted coal to be dispensed with, but energy independence requires not only the diversification of energy resources, but also the maximum use of one's own resources,"

D. Tusk, Polish Prime Minister,

---The International Fair of Mining, Power Industry and Metallurgy, Katowice, 10th Sep., 2013

Source: PAP

"Changing Polish Energy Mix?"
"Technological innovation"

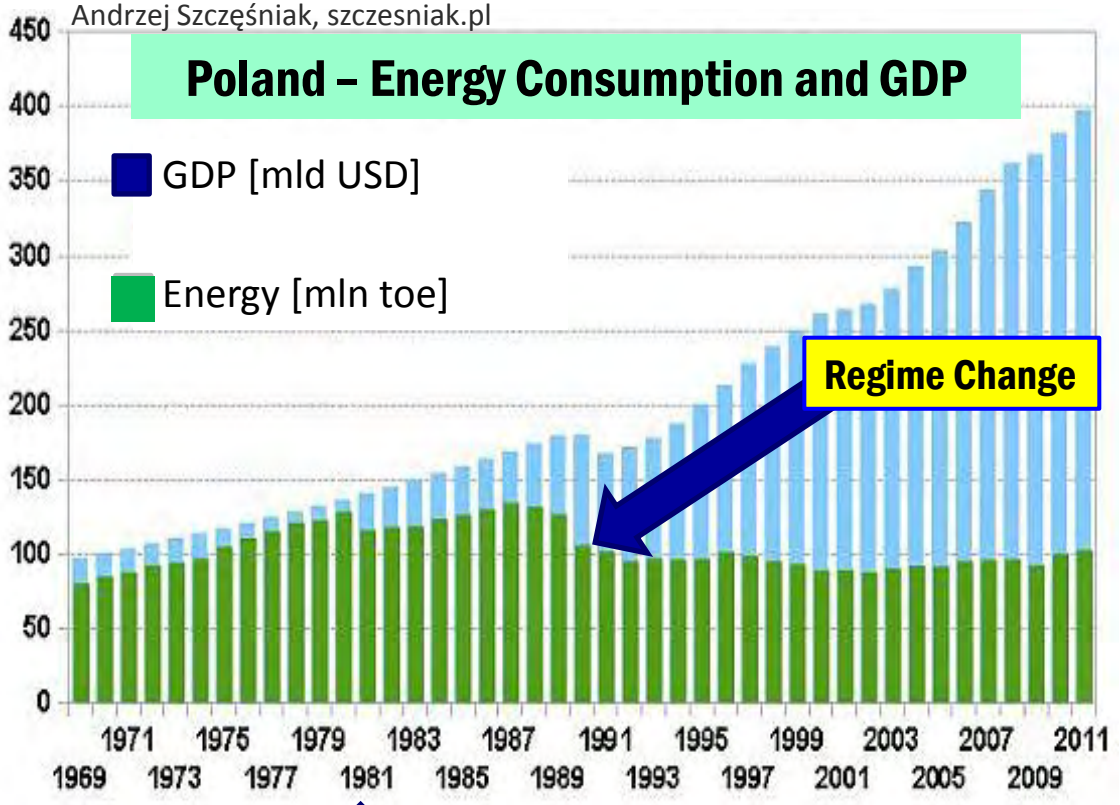
Governmental Regulations

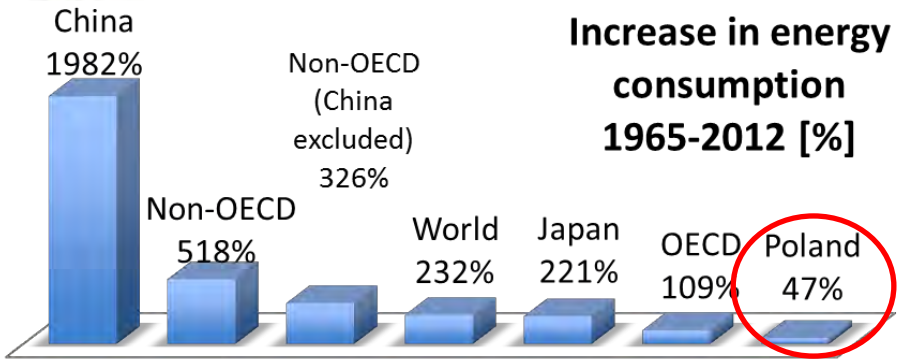
European Union Standard/Regulations

- Market Economy
- National Security
- Environmental Issues

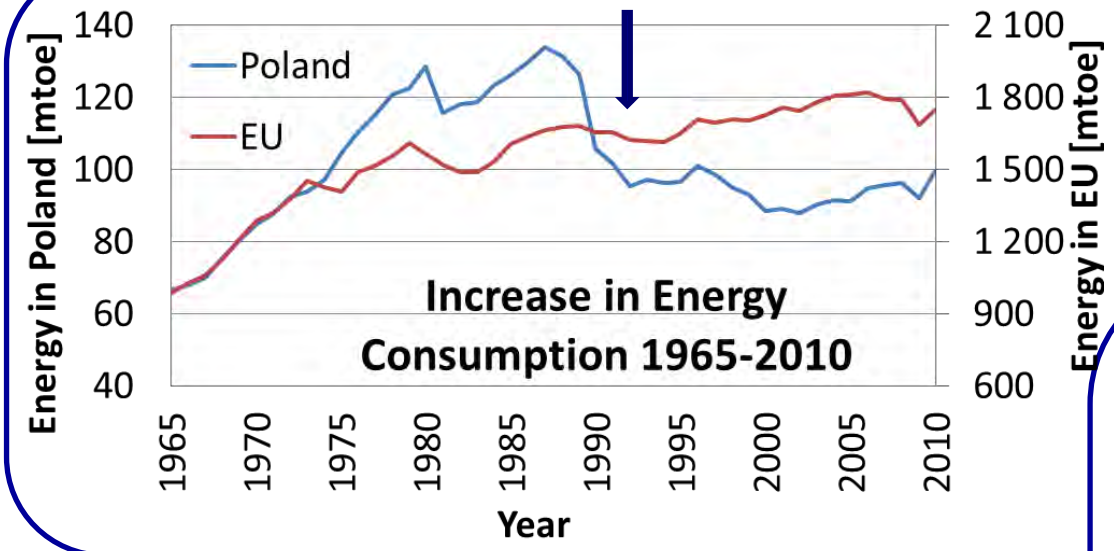
Polish Energy Consumption and GDP

Andrzej Szczęśniak, szczesniak.pl



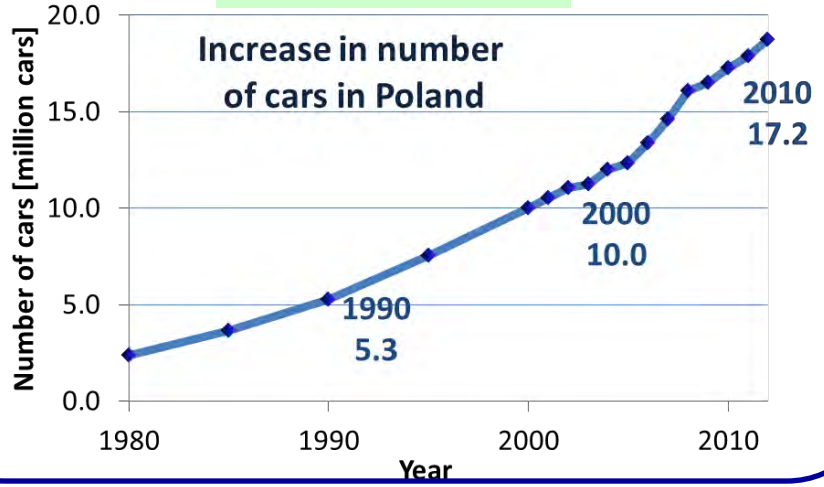


Polish Energy Consumption Trend

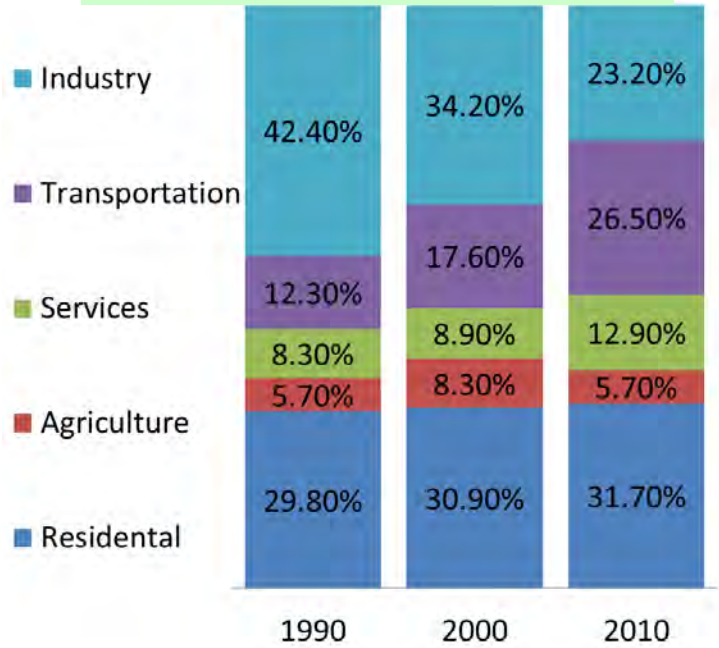


Energy Consumption in Poland and Europe

Number of Cars

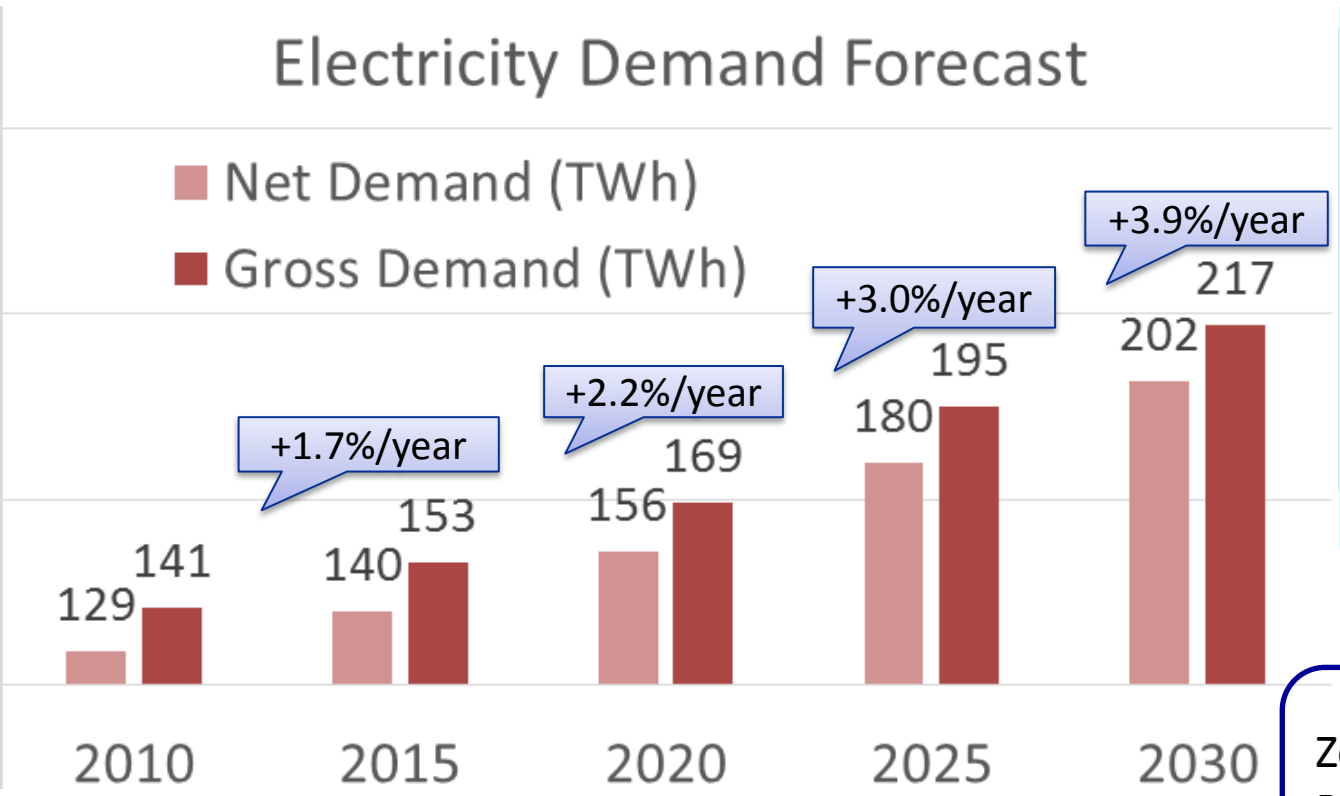


Polish Energy Consumption by Sectors



BP, GUS

Polish Electricity Demand Forecast



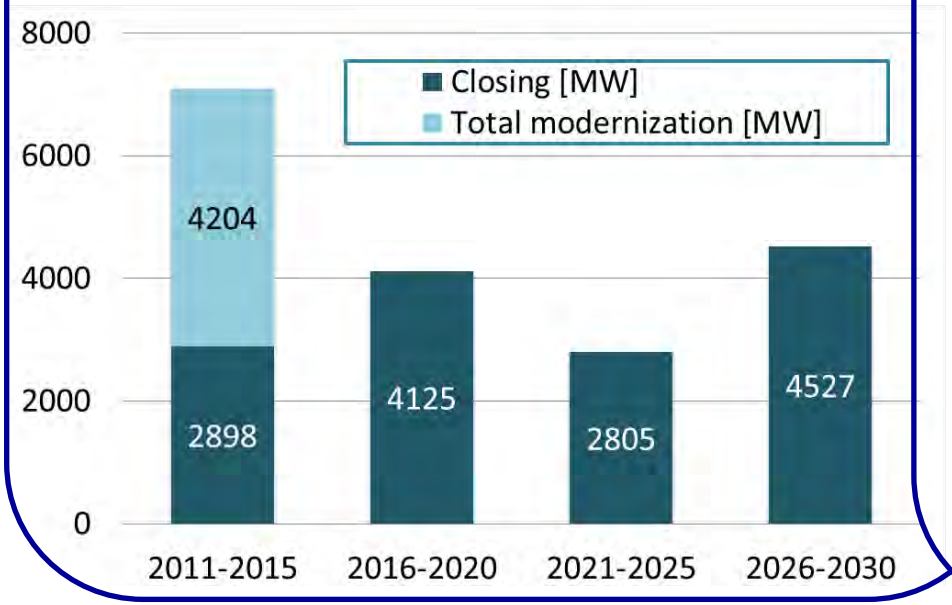
Assumptions:
- Increasing energy efficiency
- Security of energy system
- Introduction of Nuclear
- Development of RES
- Environment preservation

Zero energy economic growth
Reducing the energy intensity

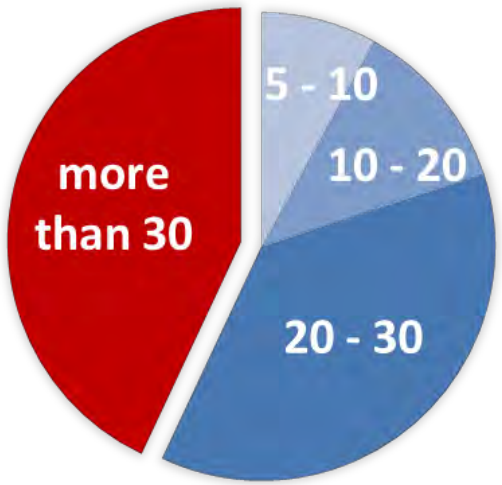
Ministry of Economy

Aged Plants and Units planned to be closed

Units Planned to be closed (MW)



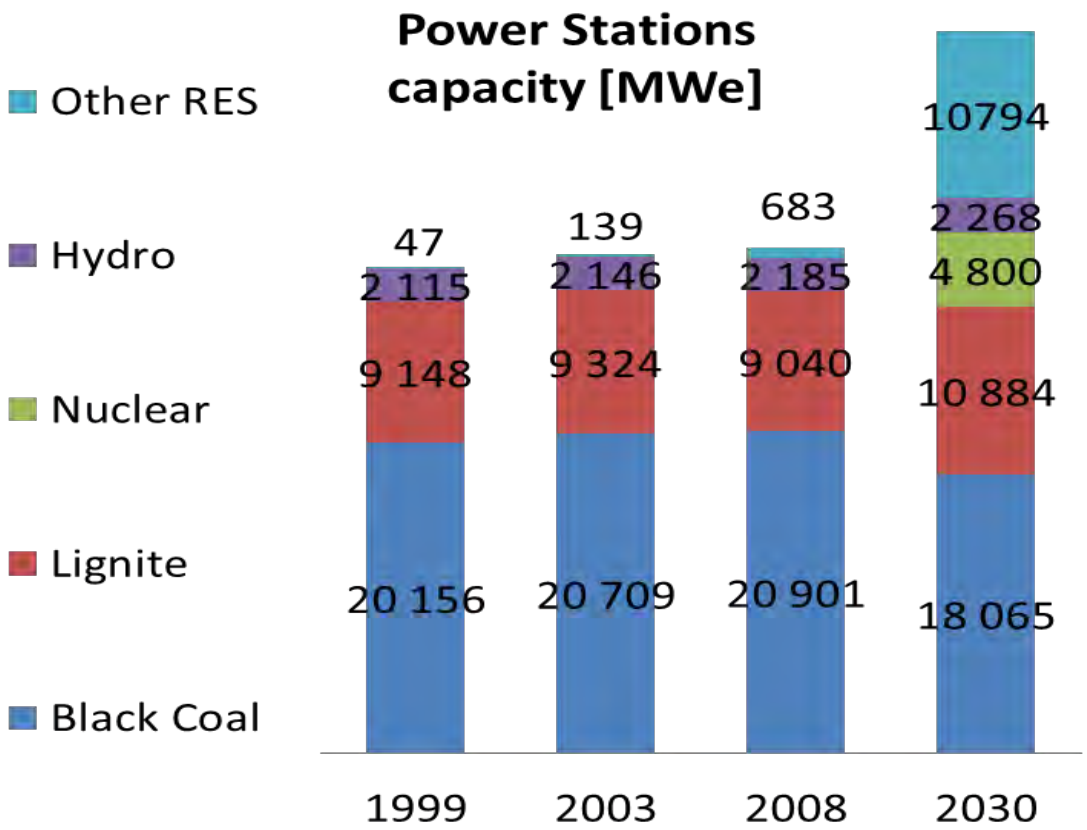
Age of Polish Power Generation Units (years)



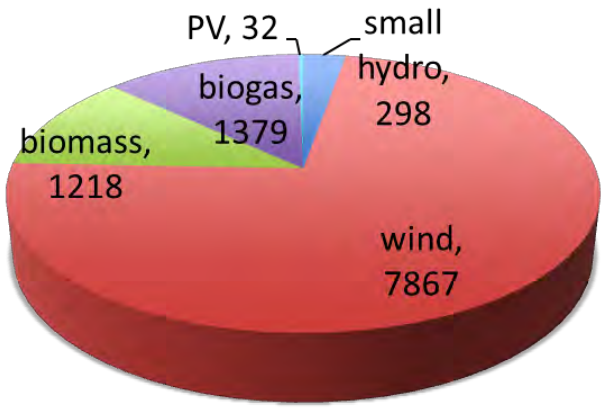
Ministry of Economy

Power Generation in Poland

	1999	2003	2008	2030
Total Installed Capacity [MWe]	34 260	35 419	35 599	51 412
Max Power Demand [MWe]	22 821	23 454	25 121	

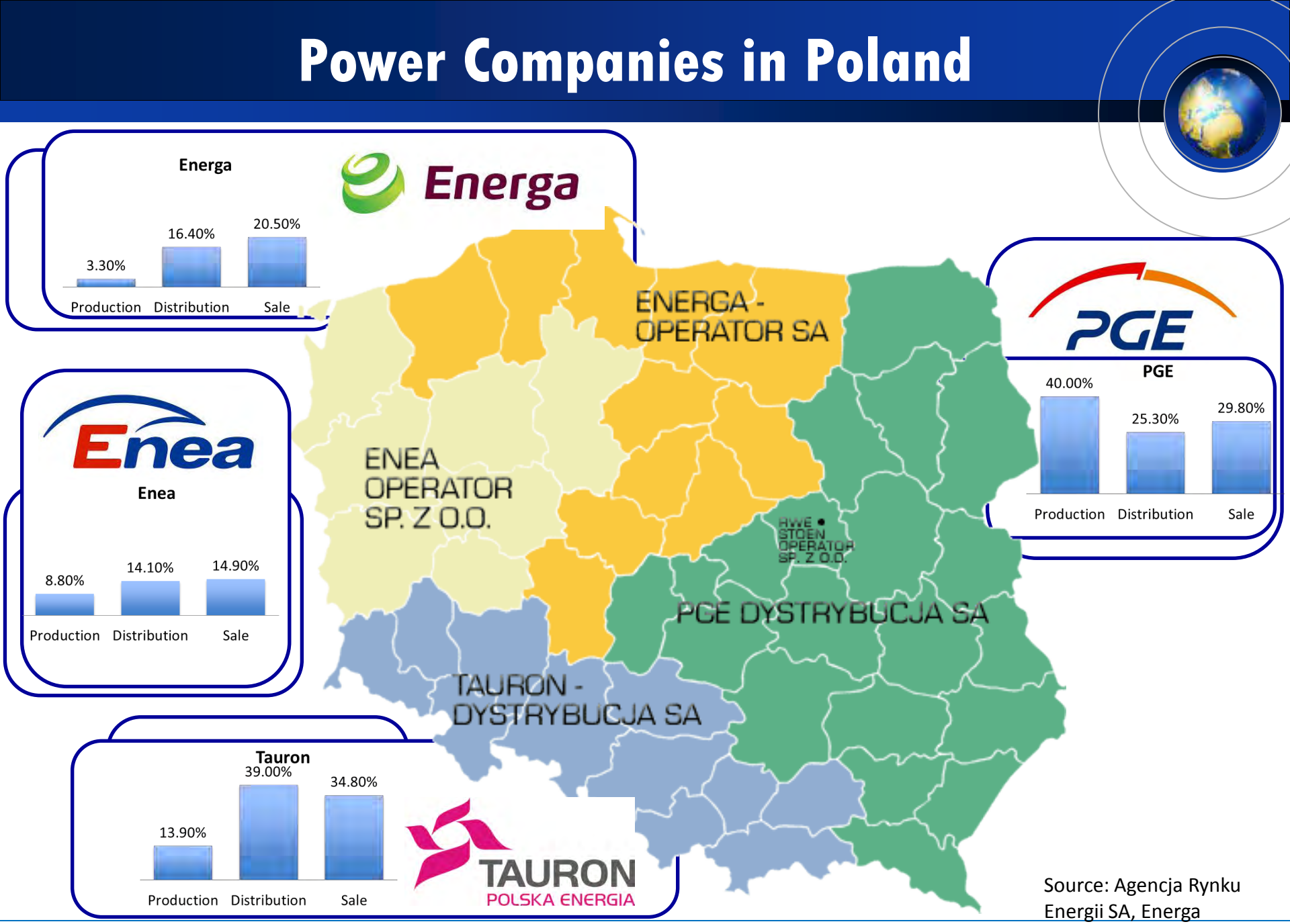


Renewables in 2030



Instytut na rzecz Ekorozwoju, URE, ARE, Ministry of Economy

Power Companies in Poland

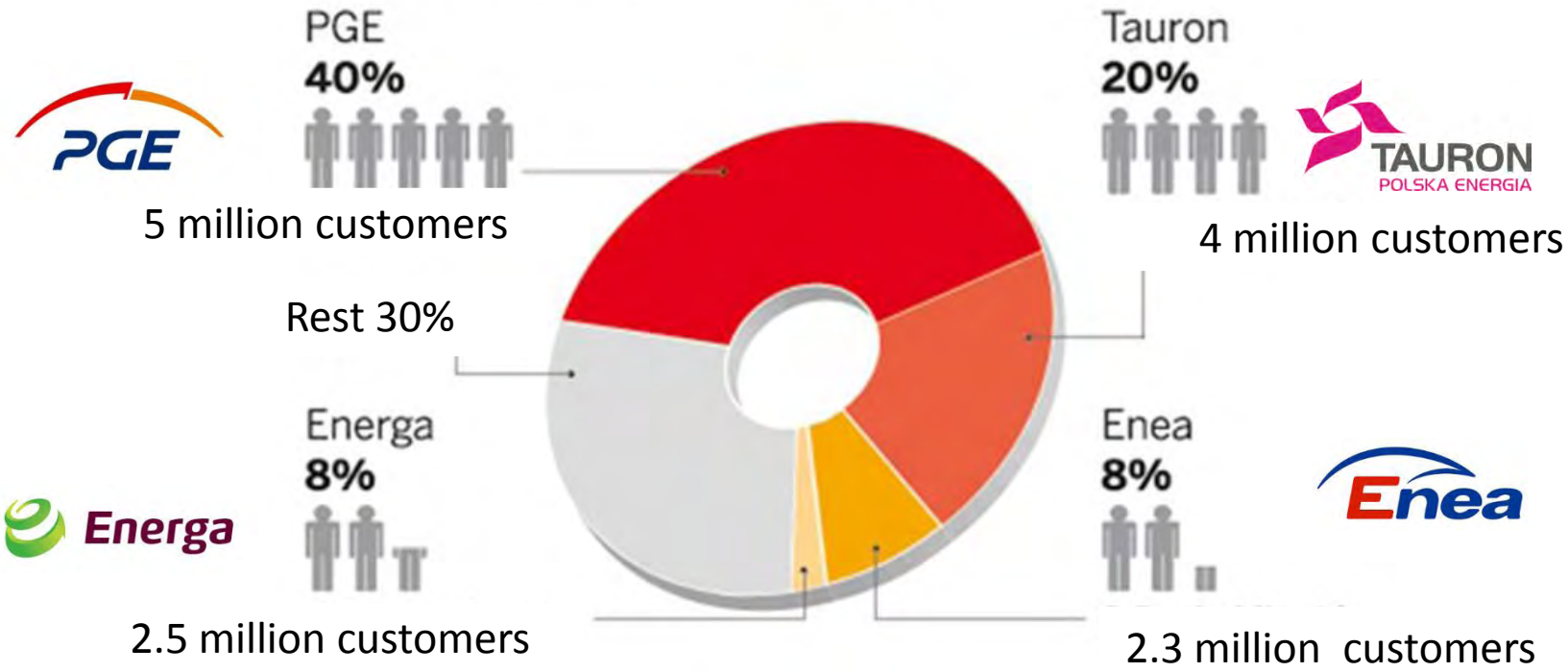


Source: Agencja Rynku Energii SA, Energa

Share of Energy Market in Poland

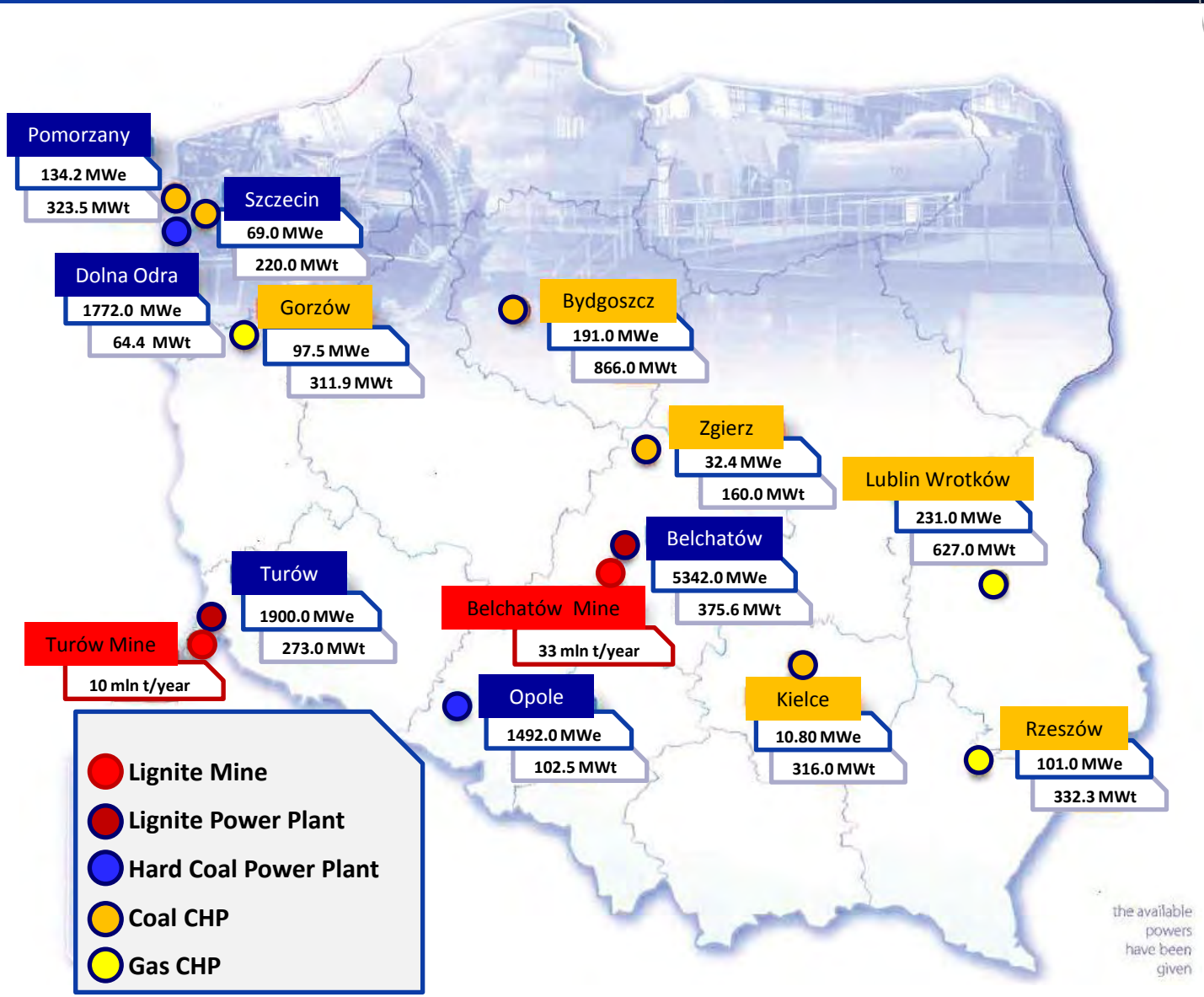
- PGE is the largest power generating company in Poland and the power production, which is about 40% of the country.

Share in Power Generation by Polish Companies



Source: Polityka

PGE Group



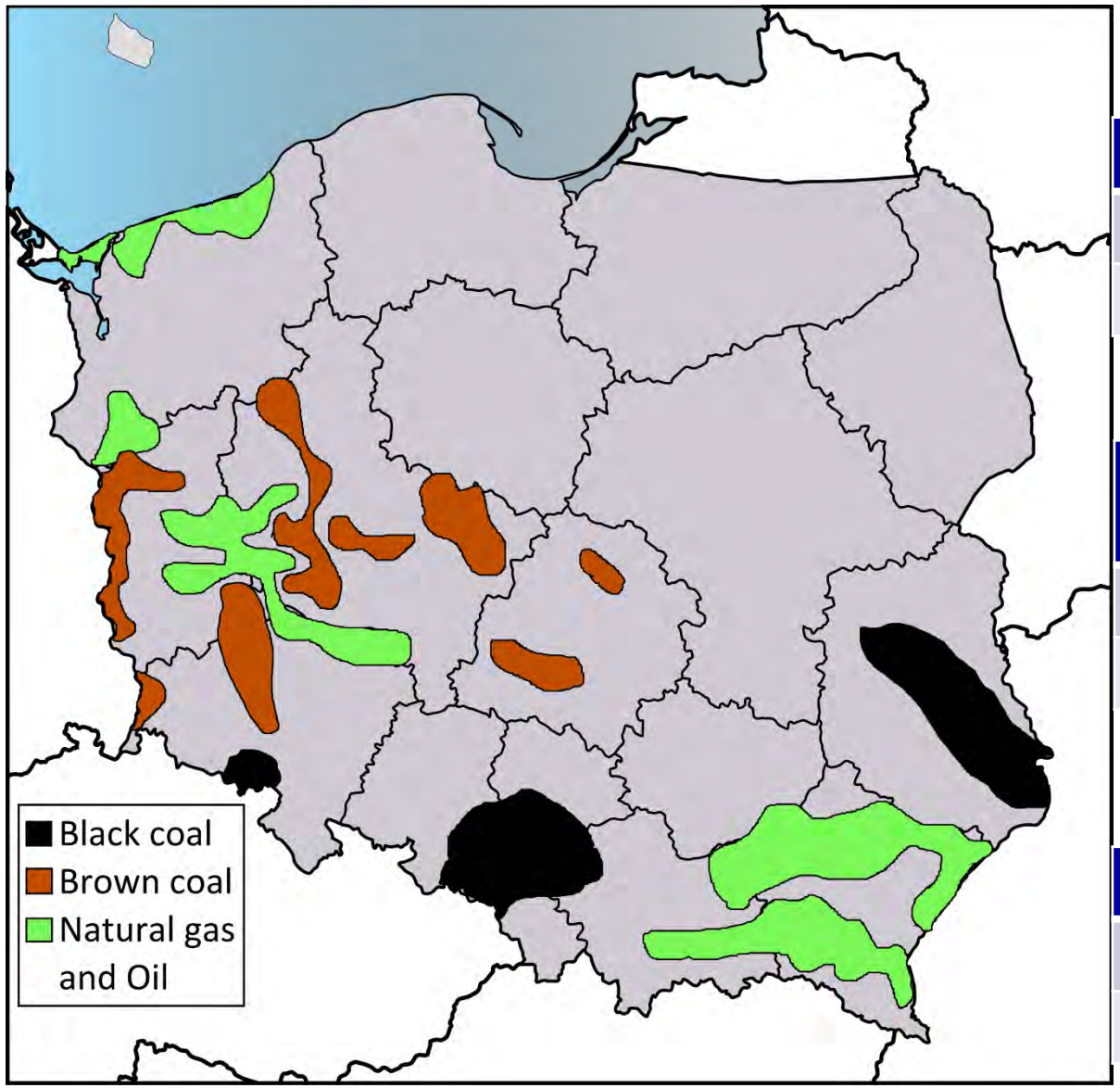
PGE Gornictwo i Energetyka Konwencjonalna SA

1. Largest power company in Poland, and supplies about 40% of whole Polish demand. 62% of the stock is held by the Government.
2. Total power generating capacity is 12.2GW and power generation is 52.7 TWh and heat supply is 6.1 GWth. Employees: 19,000.
3. Lignite mining is 43.2 million tonnes and share in Poland is 79%.
4. Lignite fired Belchatow Power Station is the largest power station in Poland and supplies about 20% of Polish power. Generating cost is Euro 38/MWh.
5. Total generating capacity of Belchatow Power Station is 5,342MW. Old units are of same design and started operation constructed between 1981 and 1988.
6. New unit, Unit No.14, is a 858MW supercritical pressure unit and started operation on October 1st , 2011.
7. Distribution of Fuels in PGE in 2012:

Lignite: 62.29%
Hard Coal: 24.11%
Natural gas: 3.25%
Biomass: 3.12%

3. Coal Resources in Poland

Resources of Poland: Black Coal, Brown Coal, Natural Gas and Oil



Coal Resources and Reserves

	Resources	Reserves
Black Coal	44.2 Gt	16.9 Gt
Lignite	60.0 Gt	14.9 Gt

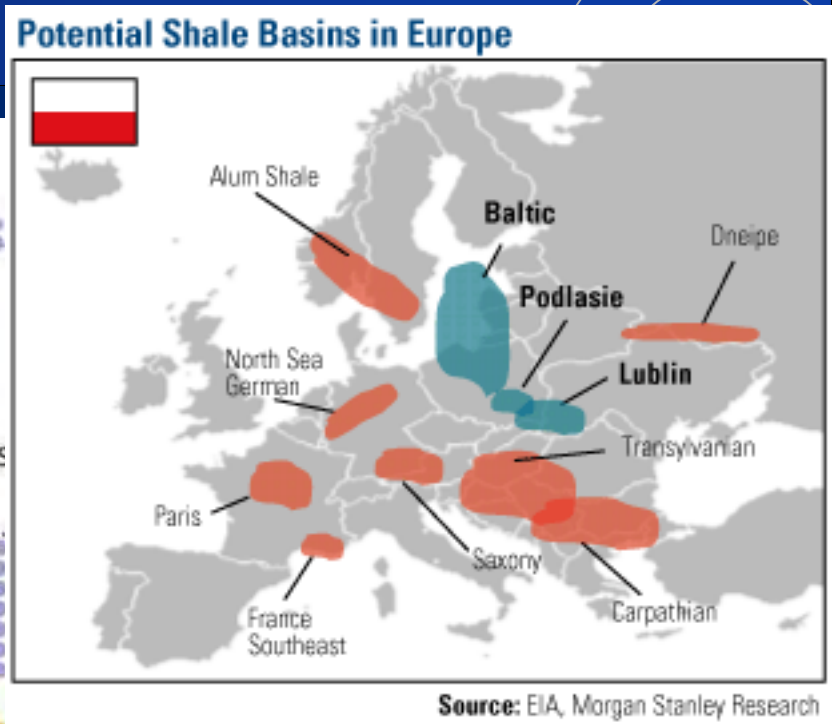
Annual Coal Production

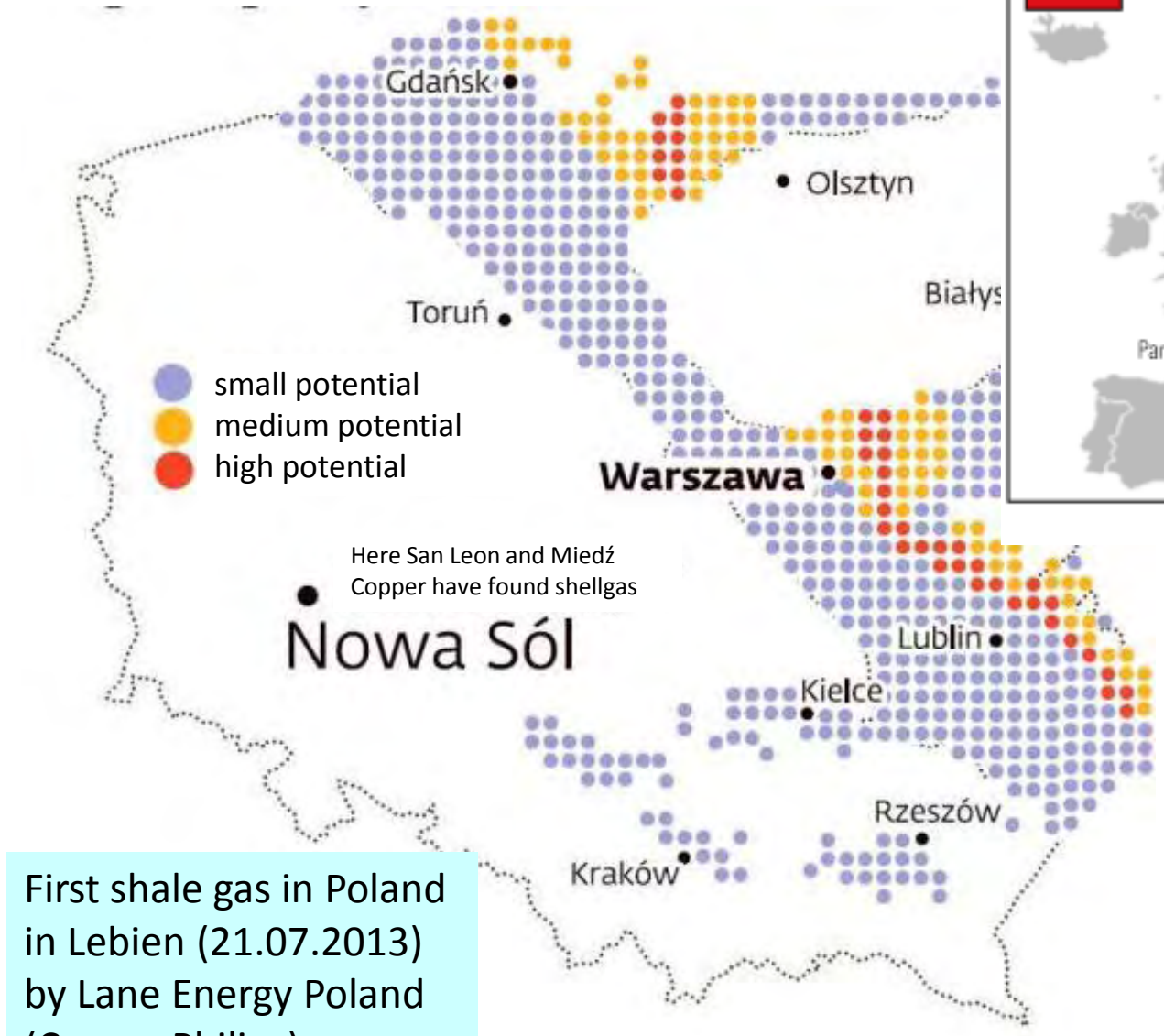
	Production/year (saleable output)
Black Coal	76.6 Mt
Lignite	56.3 Mt

Employment in Coal Industry

	Person
Black Coal	114 100
Lignite	16 300

Shale-gas in Poland





In 2012 Polish resources were estimated for 346-768 mld m^3 (minimal estimation – 38mld m^3 and maximal 1.92bln m^3)

First shale gas in Poland in Lebien (21.07.2013) by Lane Energy Poland (ConocoPhilips)

DGP, EIA,PwC

4. Lignite and Its Efficient Use

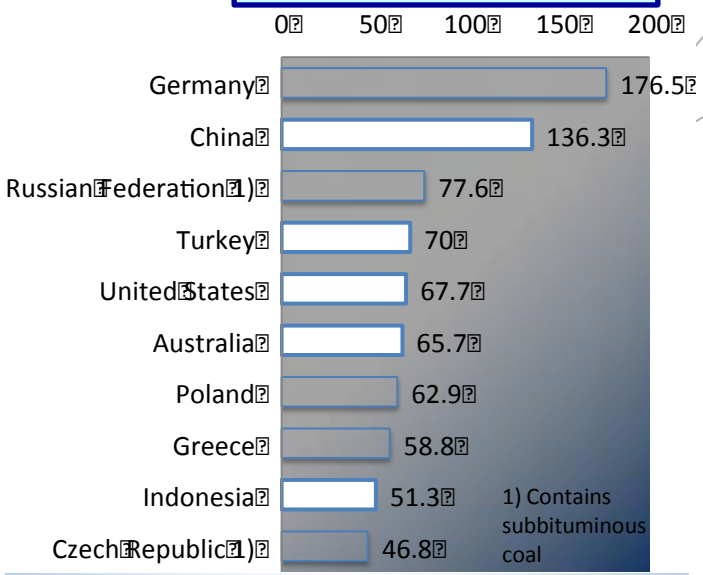
Dependence on Coal and Lignite in Europe

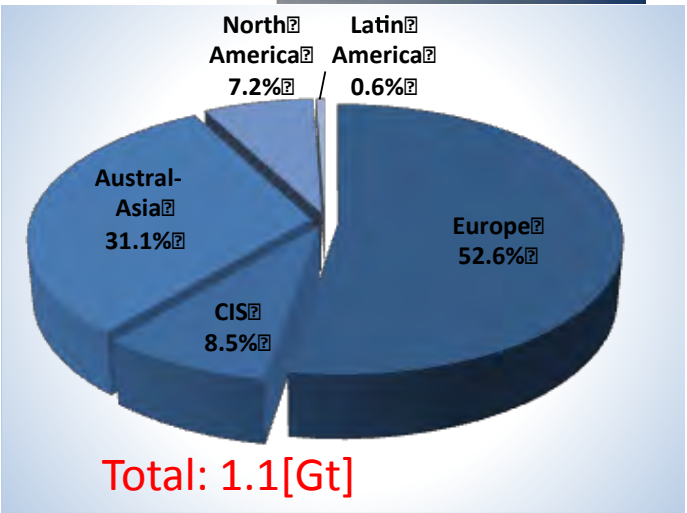
Coal and Lignite Power Generation (MWh-%)

Country	Lignite	Black coal	Total
Germany	25	20	45
Poland	31	56	87
Greece	57	0	57
Romania	39	8	47
Czech	51	8	59
Serbia	69	0	69
Turkey	17	9	26

* Data for 2010, Source: European Association for Coal and Lignite "EURACOAL"

Lignite Production



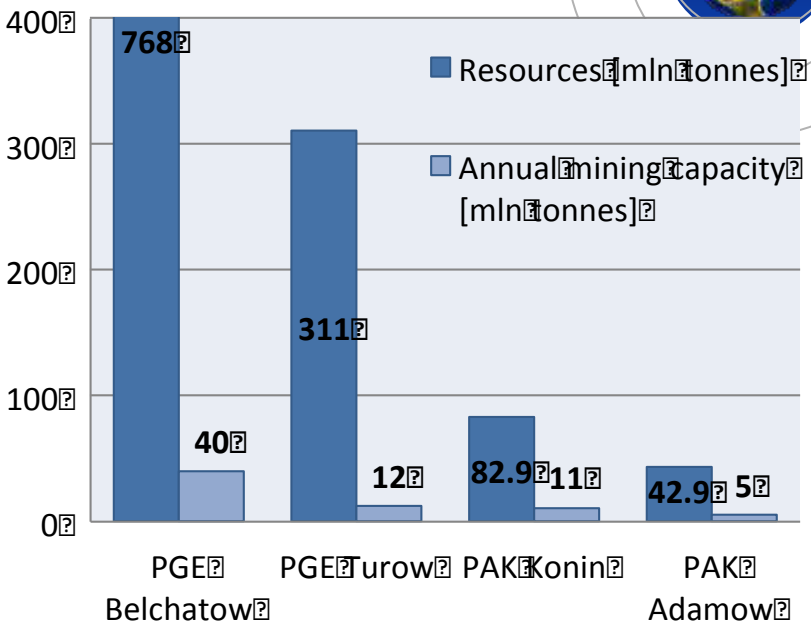


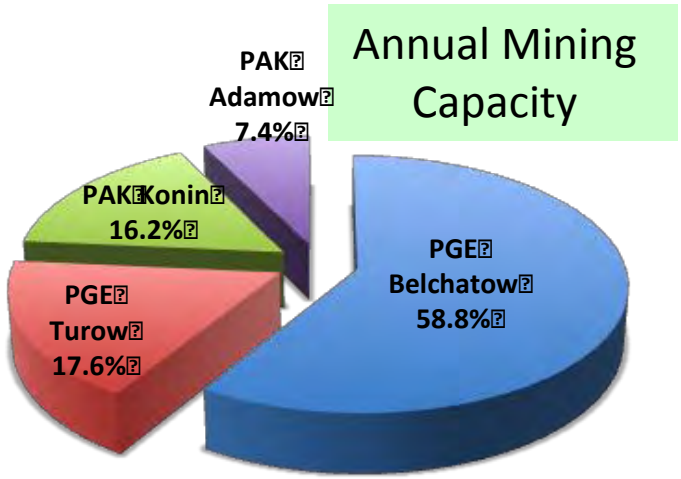
Data Source: Federal Institute for Geosciences and Natural Resources (Hanover)

Lignite Mines in Poland

Lignite resources

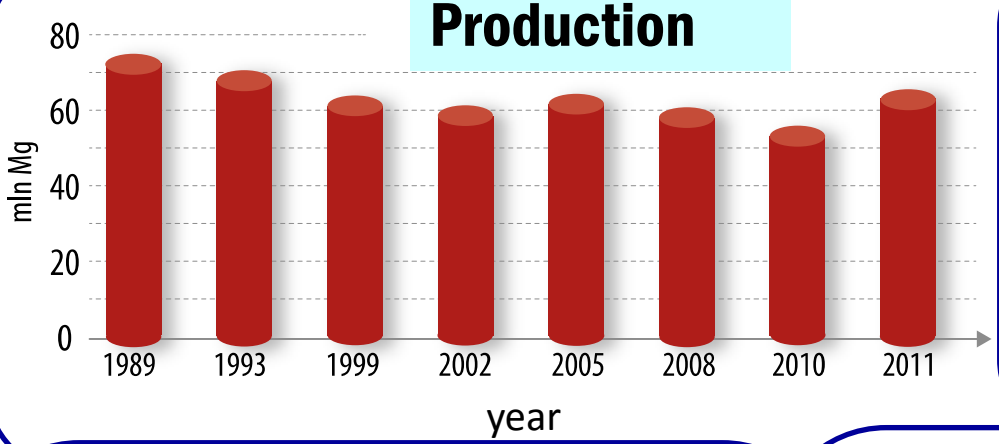
Deposits under exploitation



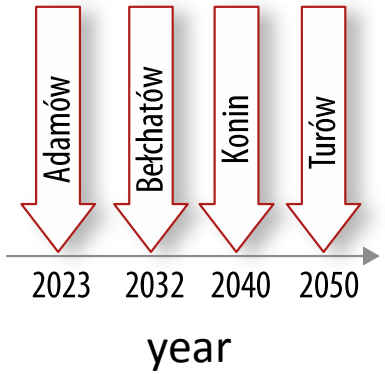


Lignite Production in Poland

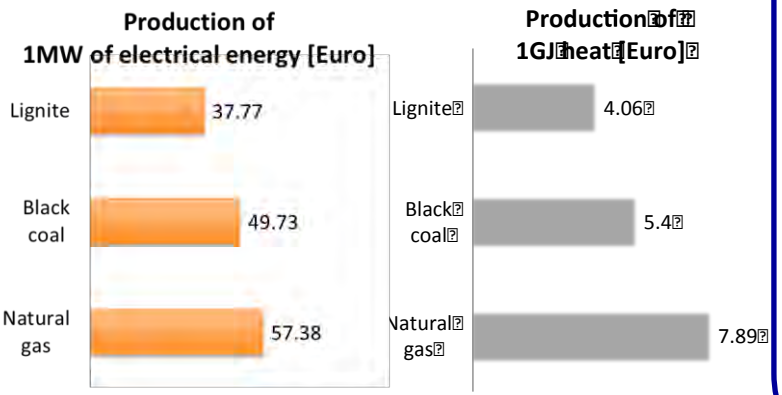
Production



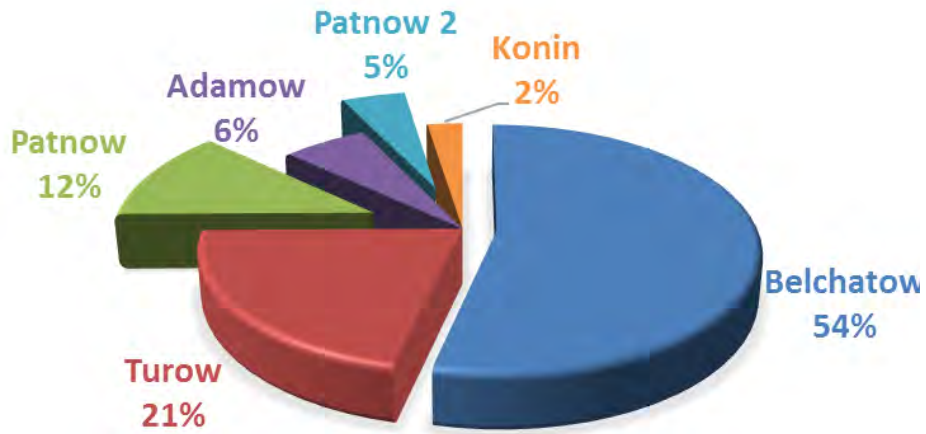
Completion Year



Price of electricity

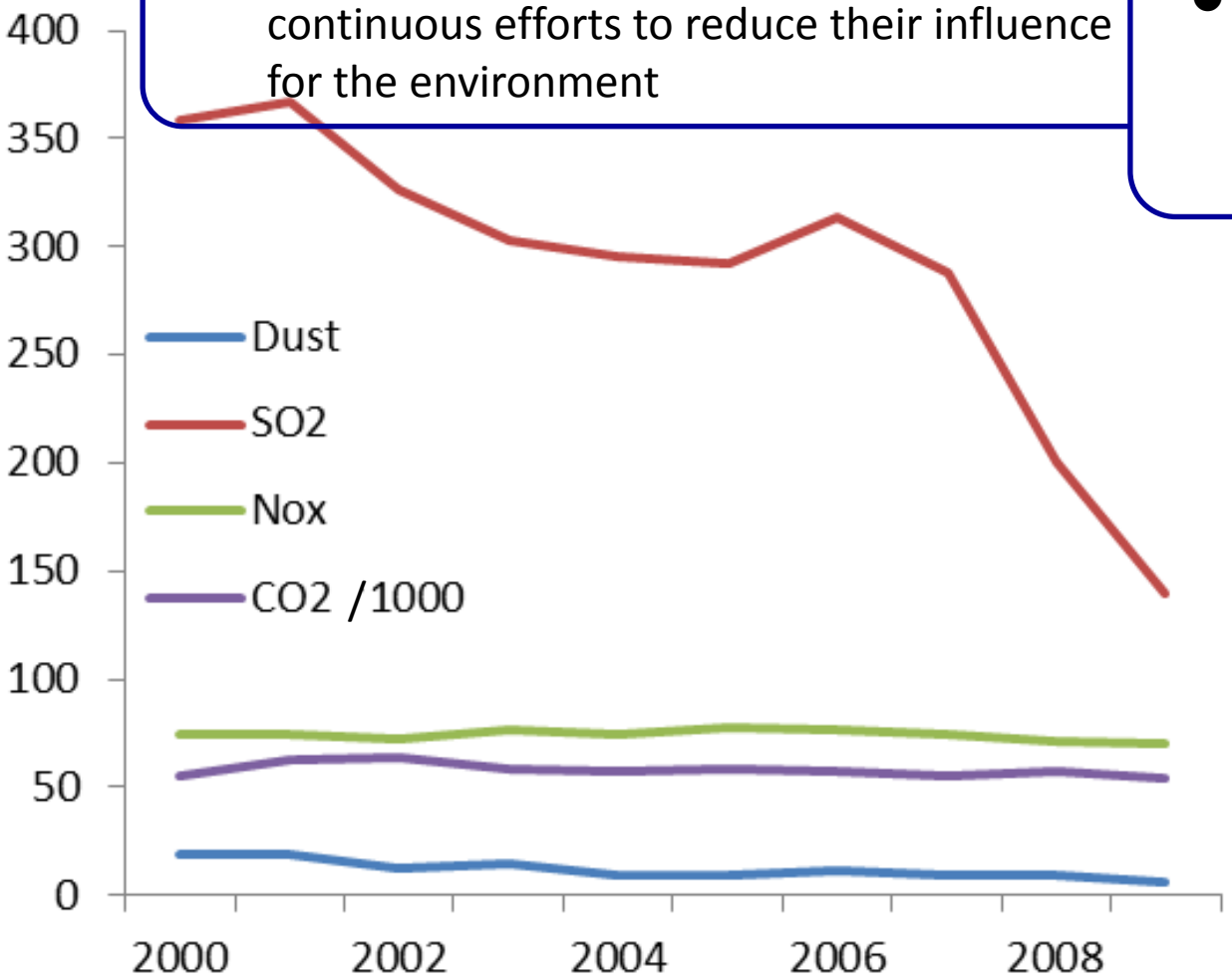


Share of Different Lignite Power Plants in Power Production



Total emissions generated by the production of electricity from lignite [Gg]

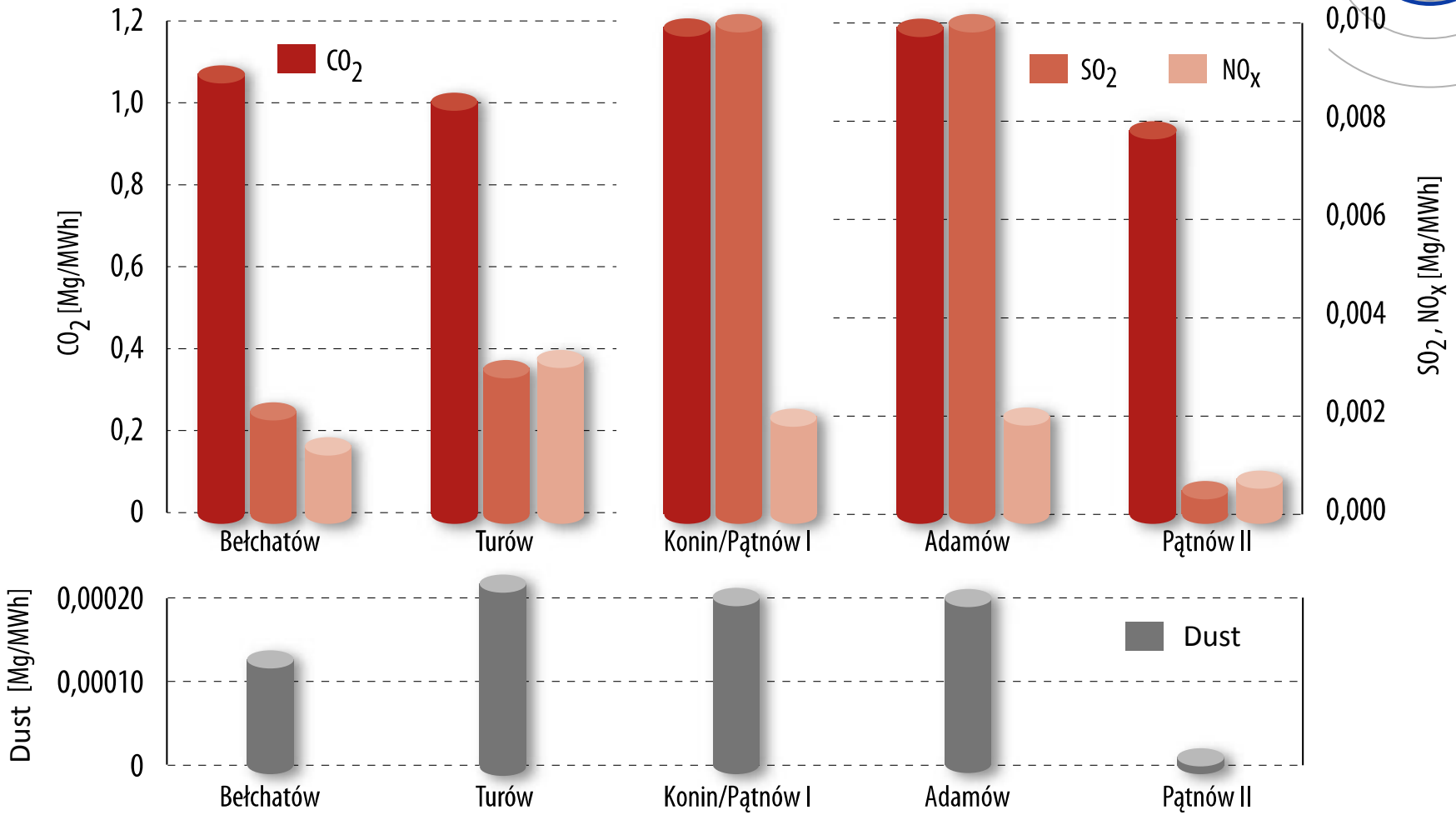
- Belchatow used to be the biggest SO_2 producer in Poland, but from 1990 they put continuous efforts to reduce their influence for the environment



- Modernization of Belchatow Units – reduction SO_2 emissions from 402 000t to 60 000t (1990-2007)
- From 2016 the new EU regulations: 200 mg SO_2/Nm3
- Until 2015 all units in Belchaow will have low – emission burners
- **Continues efforts to minimize influence for natural environment**

Agencja Rynku Energii 2010, PGE SA, ZE PAK SA

The Emissions from Each Local Lignite Source



PGE, ZE PAK, Instytut na Rzecz Ekorozwoju, 2009

Belchatow Lignite Mine

KWB Belchatow
http://www.kwb.pl

Belchatow Lignite Mine and Power Station

Belchatow Power Station

New Unit

- 858MW
- Steam Press.: 26.6/5.5MPa
- Steam Temp.: 550/580°C
- Annual Lignite Consumption: 7.0 million tonnes

Old Units

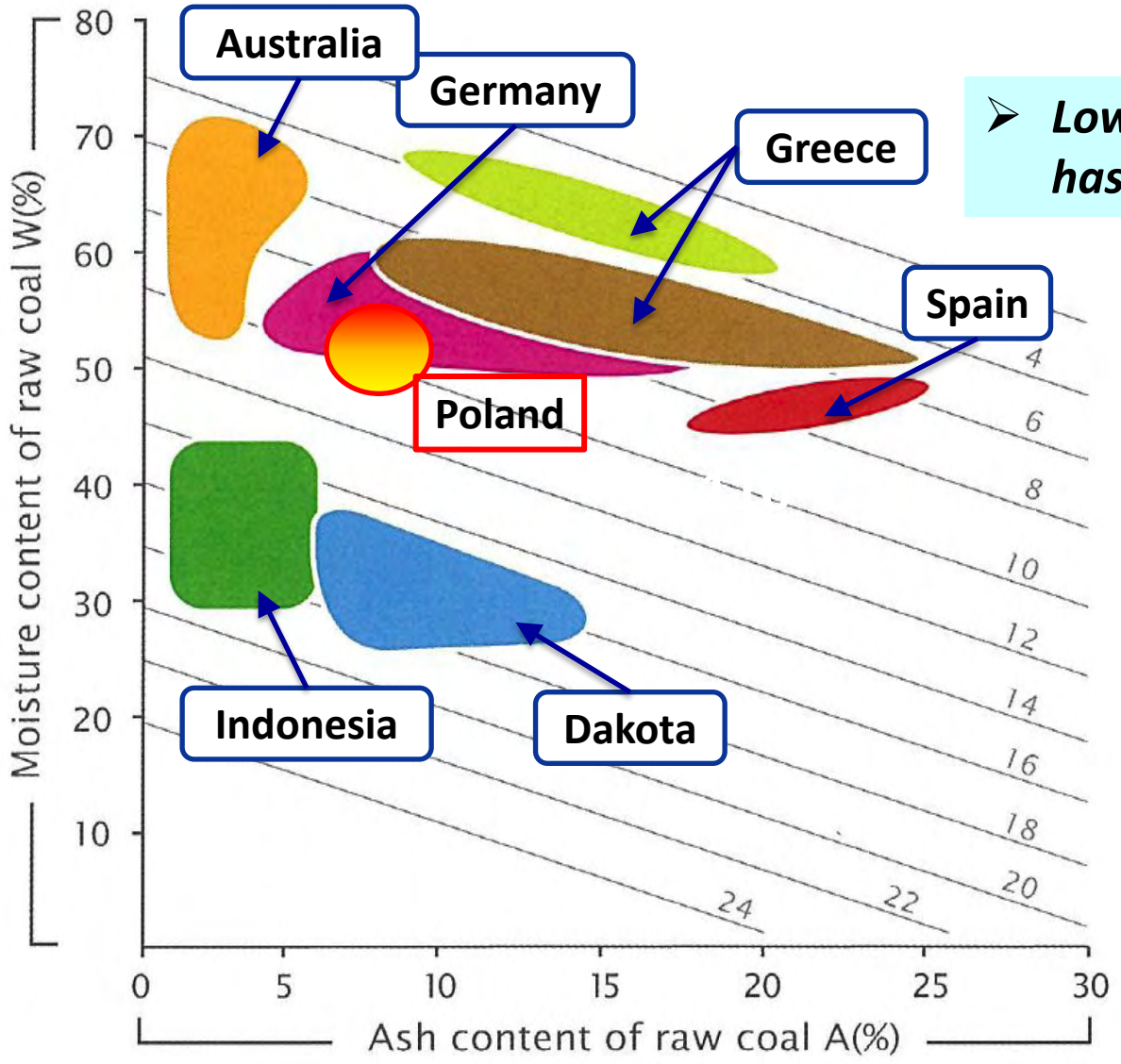
- 12 Units of 380MW – total 4.6 GW
- Steam temp.: 540/540°C
- Each unit is under modernization one by one.

Details of Belchatow Lignite Mine

1. On December 9th , 1960 lignite seam with 127m thickness was discovered.
2. On January 1st , 1975 power plant was started construction.
3. Largest lignite mine in Poland and one of the largest in Europe; shares about **50% of whole Polish lignite production.**
4. Three fields: **"Belchatow", "Szczercow"** and **"Kamiensk"**.
5. Belchatow lignite is **about 20 million** years old

6. Thickness of the Overburden: **200m**
7. Thickness of lignite seam: **120 – 150m**
8. Mining capacity is **38.5 million tons of coal a year** (with an average overburden removal of 100-120 million m^3) .
9. Recoverable reserve: 830 million tonnes and the total coal resources are approximately **1,930 million tonnes**
10. Average heating value (LHV): **7.6-8.1 MJ/kg**
11. Mining completion schedule: **2038**

Low Rank Coals



- ***Low rank coal is the coal which has low calorific value***

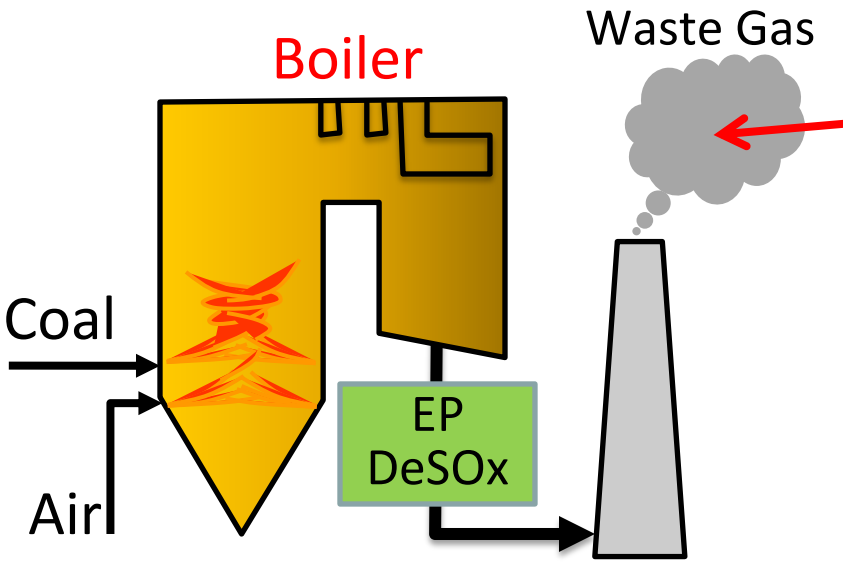
Increasing moisture content
↓
Decreasing Calorific Value

Increasing ash content
↓
Decreasing Calorific Value

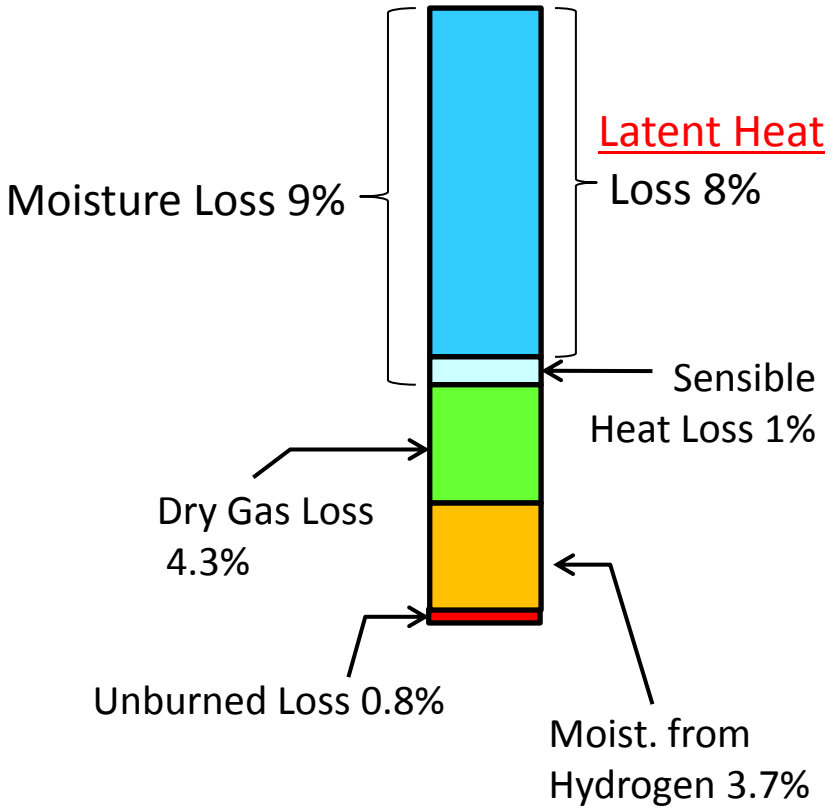
Latrobe Valley
Megalopolis Greece
Ptolemais Greece
Neurath D, Germany
Puentes Spain
Dakota Texas U.S.A
Indonesian Low Bank
Net Specific Energy=2MJ/Kg

Source: Allardice Consulting Ltd

High heat loss due to high moisture content



Latent heat of water is never recovered!

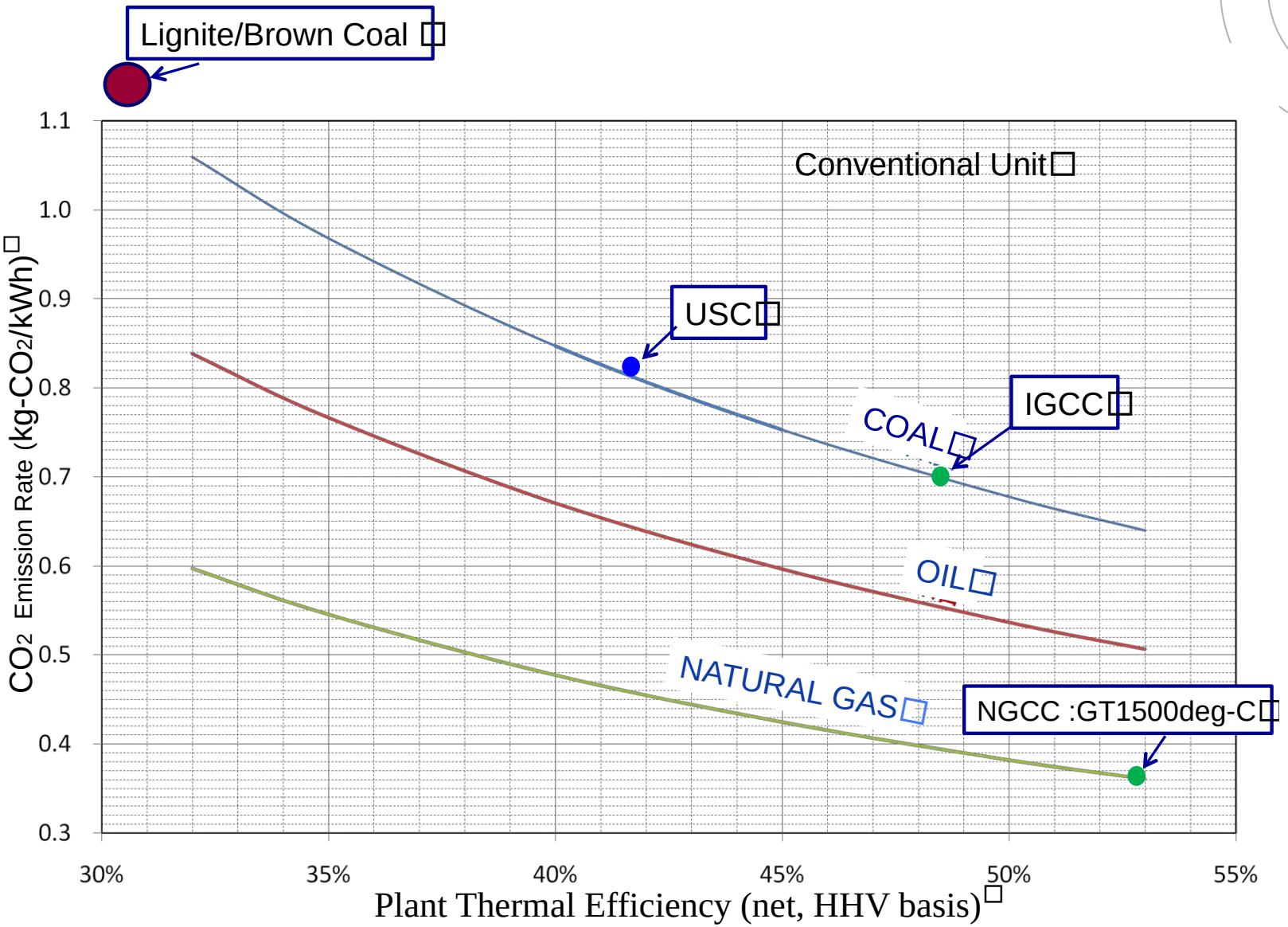


How to recover "Latent heat" and prevent losses

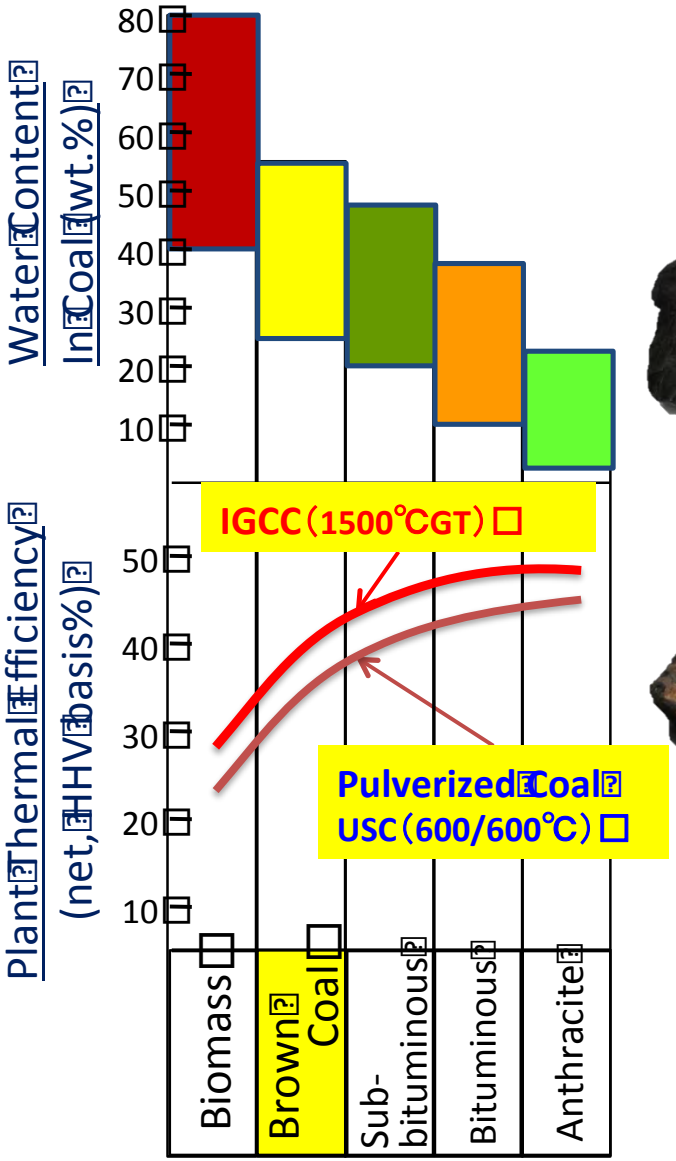
① To lower flue gas temperature below dew point

② Remove moisture by drying with minimum heat loss

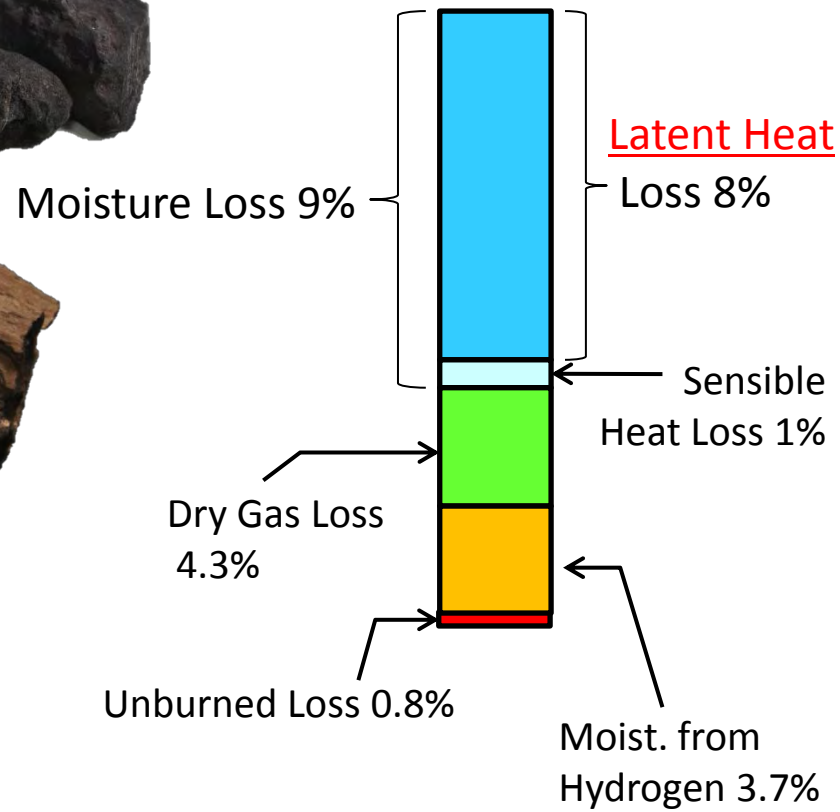
Emission of CO_2 for various fuels



Water content in Lignite and Plant Efficiency

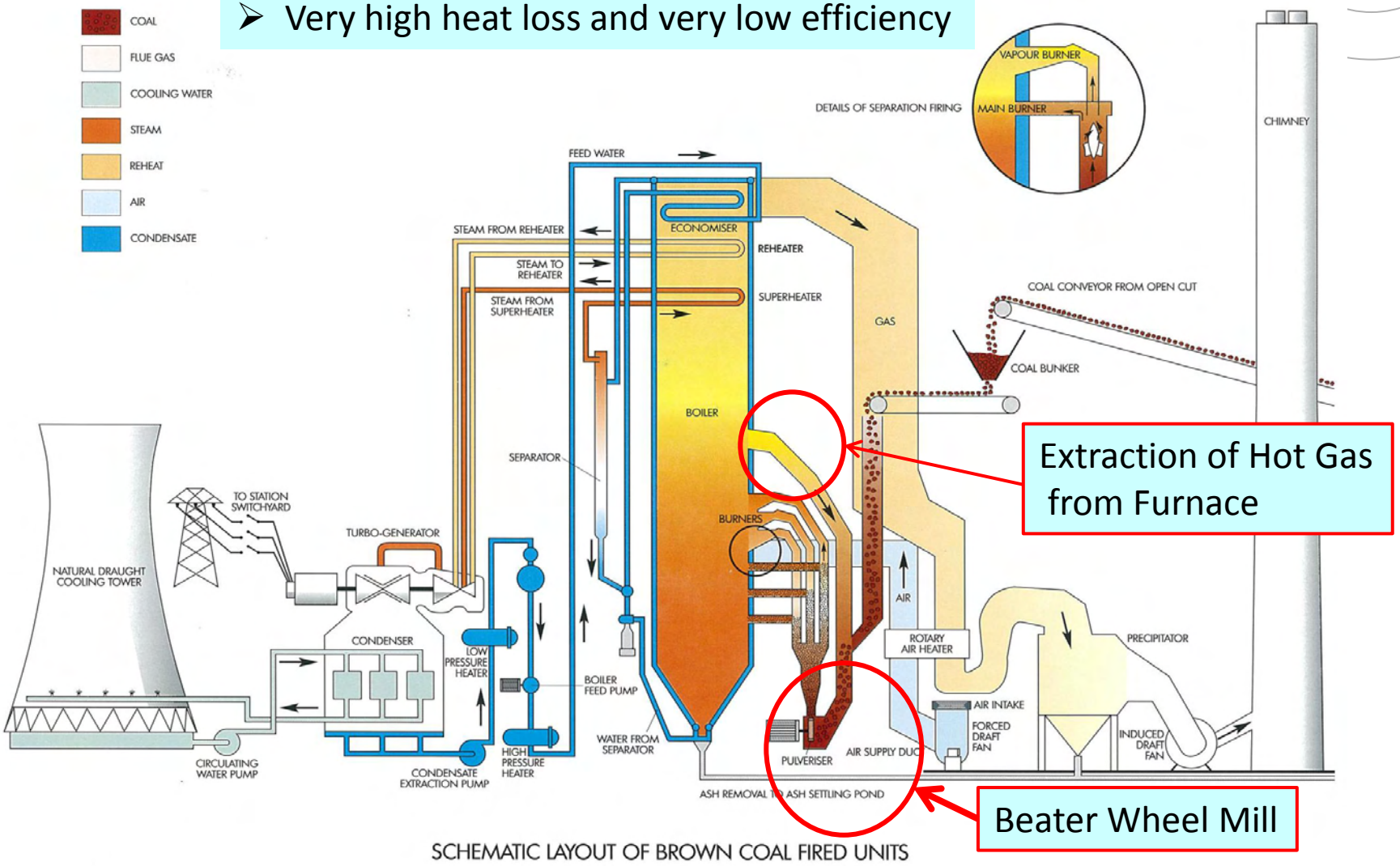


➢ Why the efficiency of brown coal is so low?



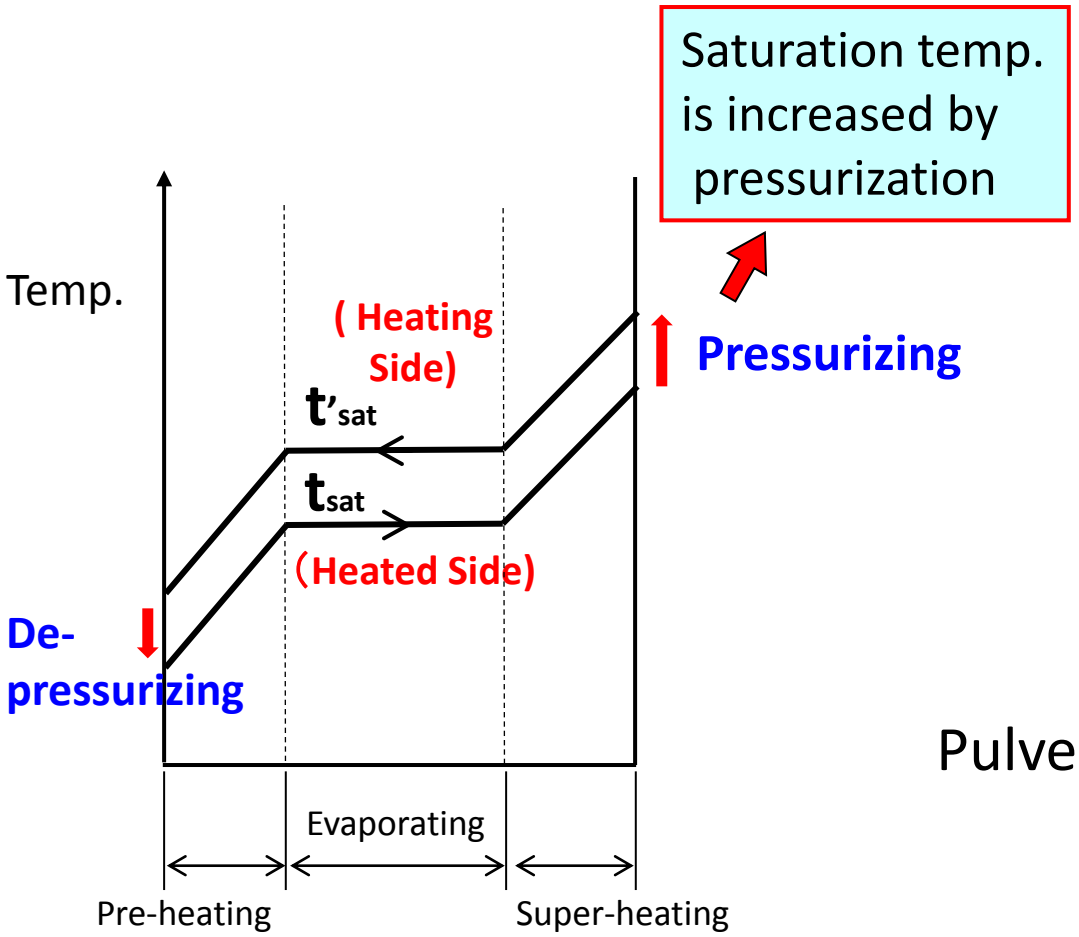
Conventional Lignite Fired Plant

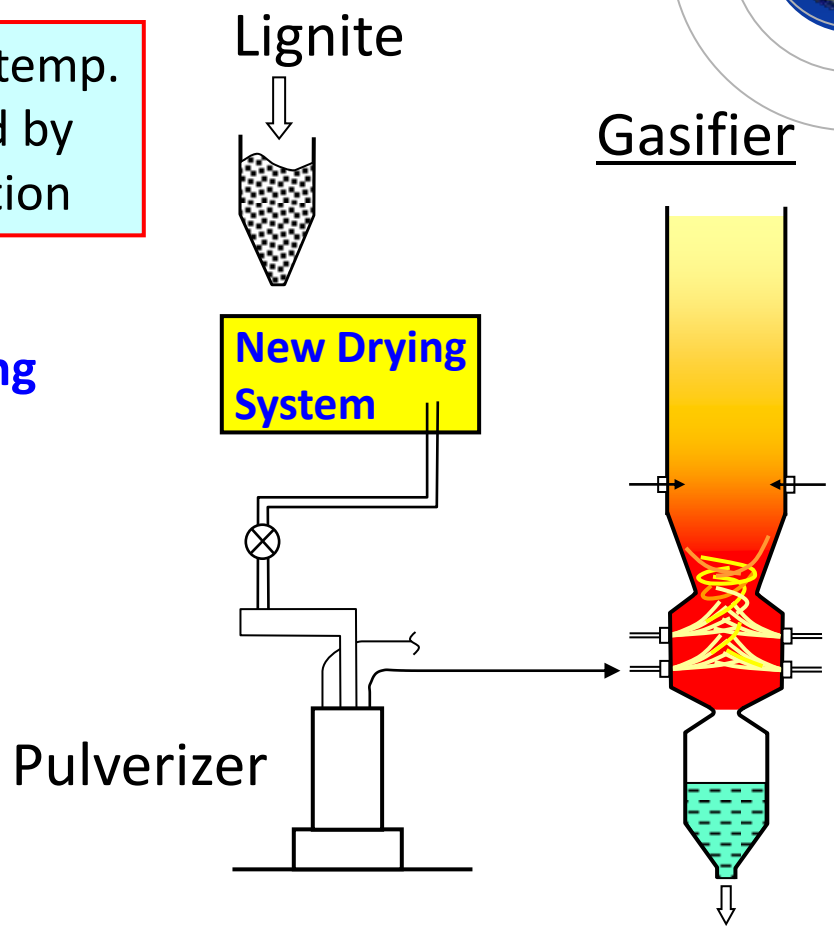
- Tall, large furnace and Beater Wheel Mills
- Very high heat loss and very low efficiency



SCHEMATIC LAYOUT OF BROWN COAL FIRED UNITS

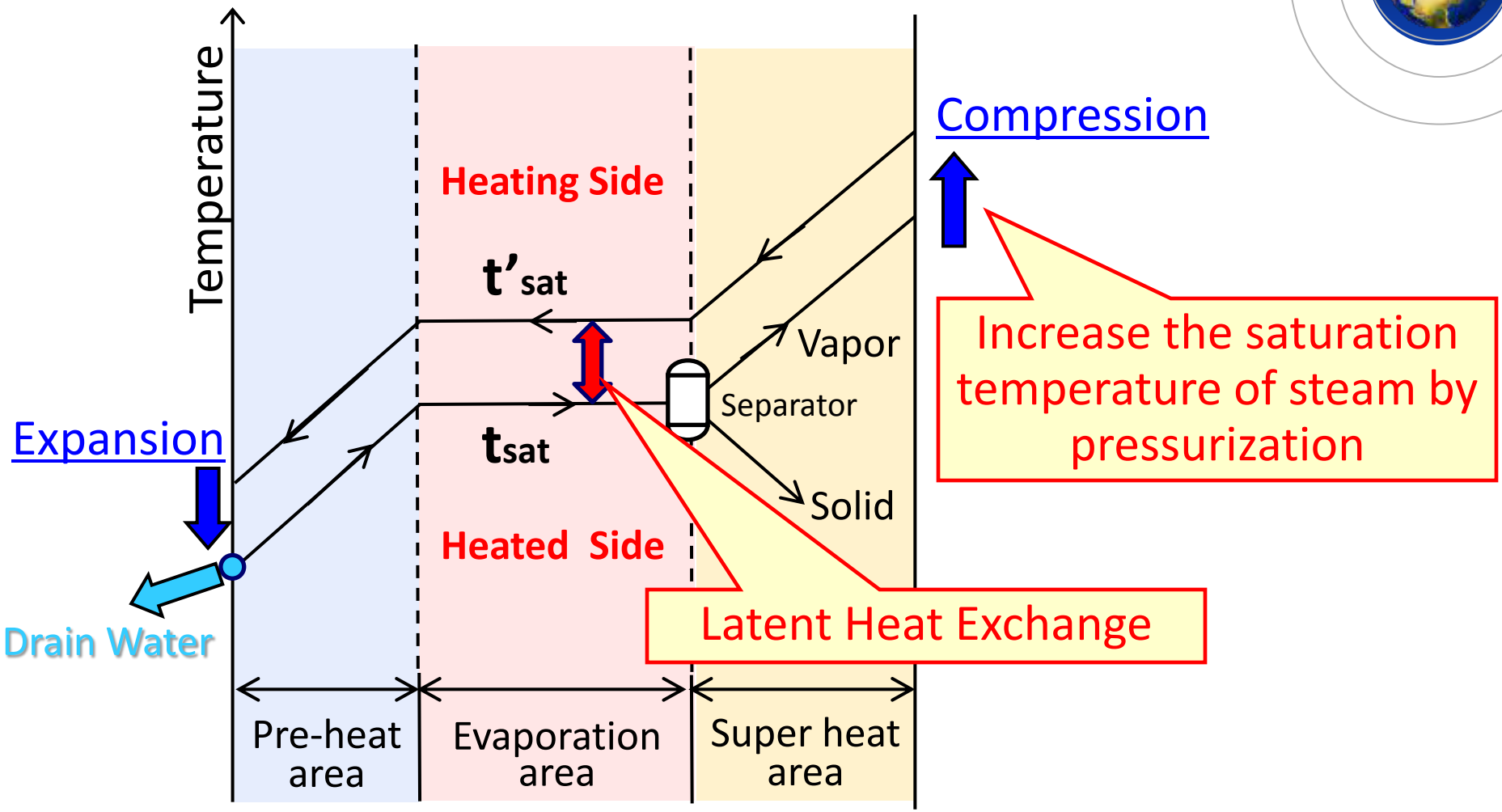
Innovative Drying System for Lignite





Moisture : 50%→20%　Heating energy is decreased by 80%!

Drying by Self-heat Recuperation

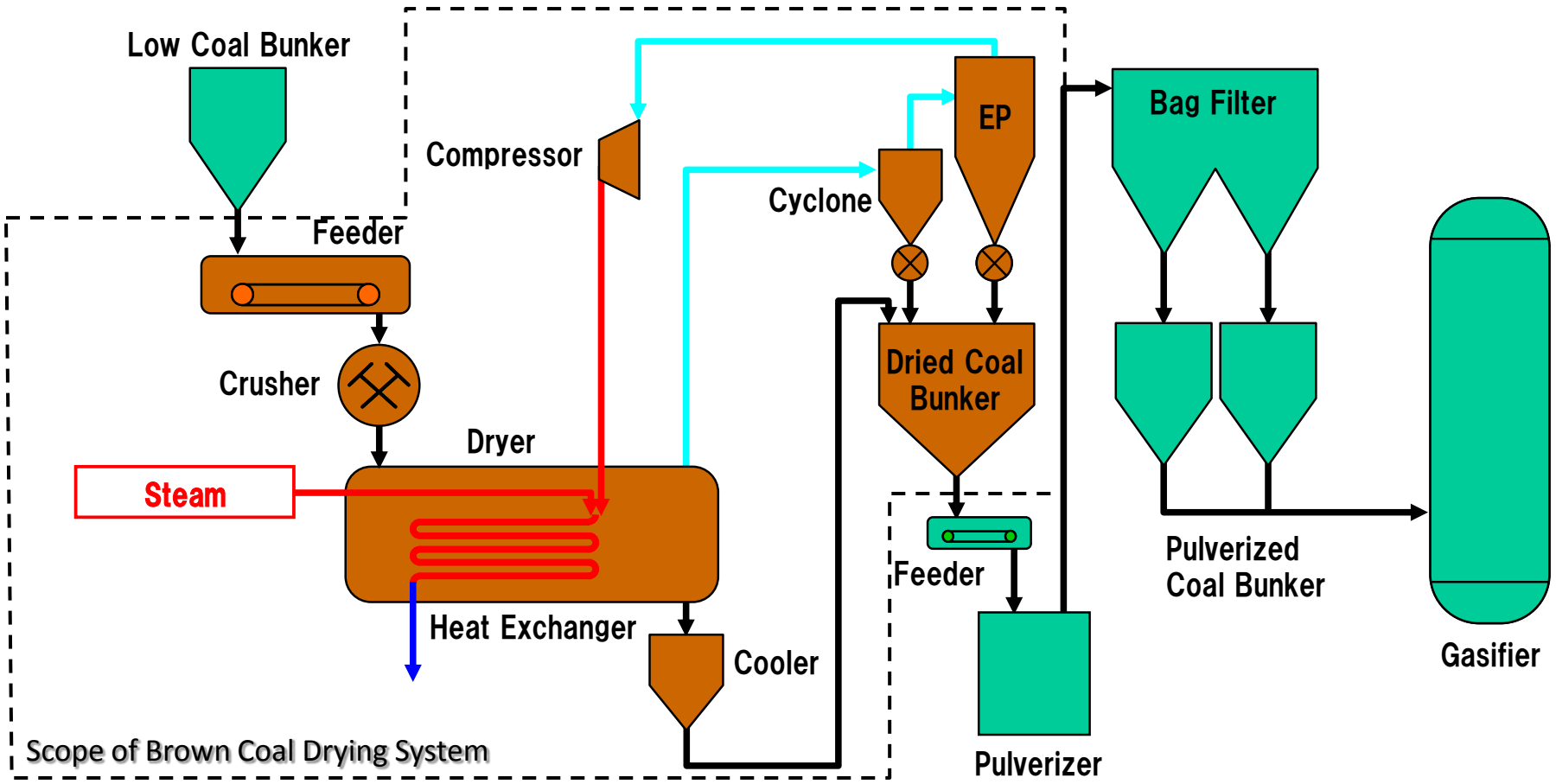


Moisture : 50%→20%　Heating energy is decreased by 80%!

Superheated Steam Fluidized Bed Lignite Drying System

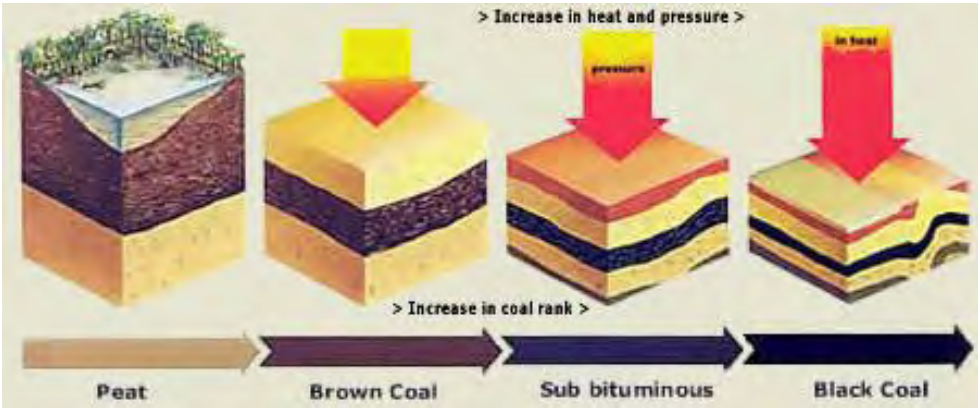
- High Efficient Brown Coal Drying System by recovering latent heat from evaporated steam.
- If combined with IGCC, generation efficiency will be improved up to 50%

  ⇒ Reducing CO_2 Emission by 40%.



Importance of Drying Lignite

- Lignite is one of the most important natural resources domestically obtained in Poland.
- More than 30% of power generation depends on lignite.
- Polish lignite has moisture content about 50%, so heat loss due to moisture is so great
- And the heat loss can be as much as 10%. This lowers thermal efficiency of power plants .
- Accordingly CO_2 emission per KWh is so high as 1.0 kg/KWh one of the highest in European coal fired power stations.
- By drying lignite before combustion we can reduce the heat loss nearly half.
- Superheated steam drying in fluidized bed is considered to be most efficient drying system, theoretically.



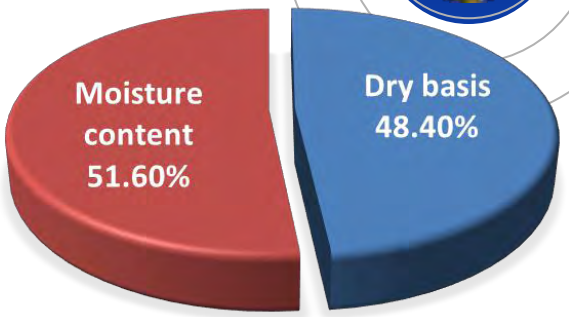
Source: Rio Tinto Coal Australia

5. Features of Polish Lignite

Analysis of Belchatow Lignite

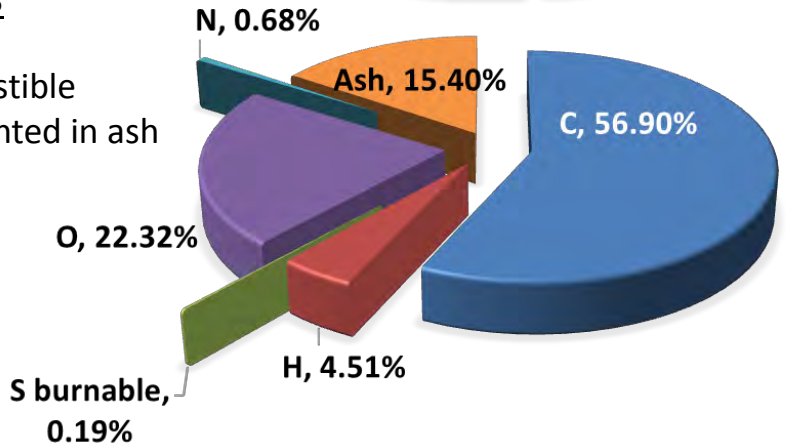
Item			Unit	Value
Total Moisture			wt%	51.6
Surface Moisture			wt%	43.0
Proximate Analysis (Air-dried base)	Moisture		wt%	14.6
	Fixed Carbon			29.6
	Volatile Matter			42.6
	Ash			13.2
	HHV		MJ/kg	19.08
			Kcal/kg	4.560
Elemental Analysis (Moisture-free)	C			56.9
	H			4.51
	S	Total	wt%	1.30
		Combustible		0.19
		Incombustible		1.11
	O			22.32
	N			0.68
	Ash			15.4

As received basis

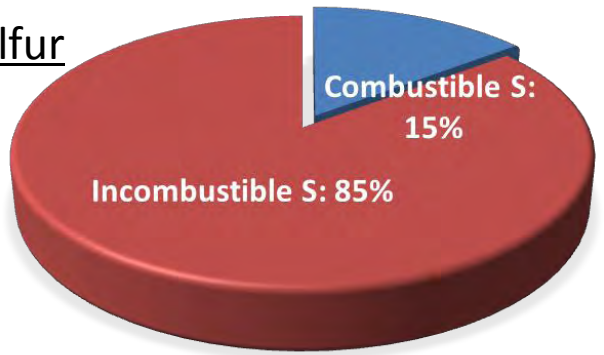


Dry basis

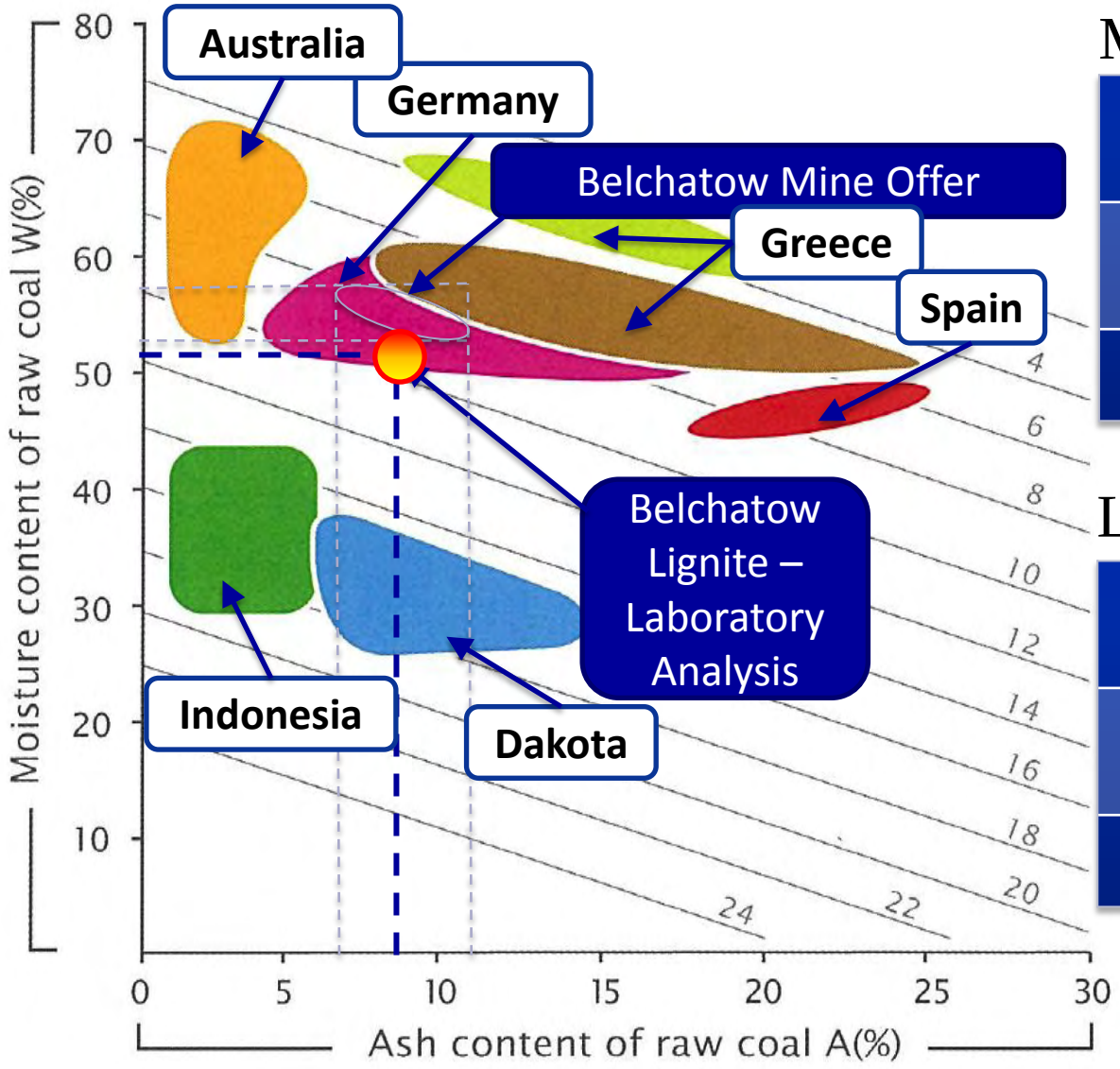
*Incombustible sulfur counted in ash content



Composition of sulfur



Where the Belchatow Lignite is located….



Mine Offer

Calorific value (LHV)	7.6 – 8.1 MJ/kg
Natural moisture	53 - 58%
Ash content	6,5 – 11%

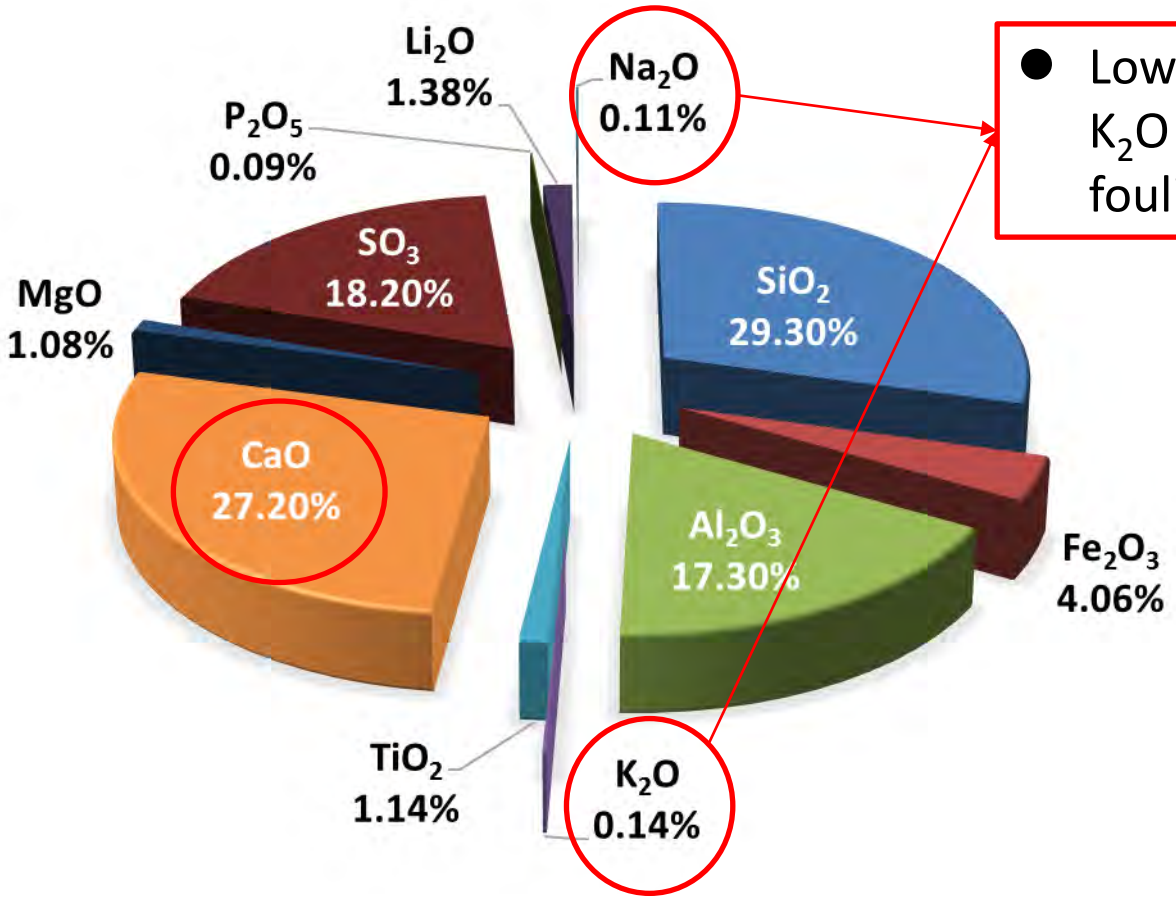
Laboratory Analysis

Calorific value (LHV)	9.82 MJ/kg
Natural moisture	51.60%
Ash content	8.78%

Latrobe Valley
Megalopolis Greece
Ptolemais Greece
Neurath D, Germany
Puentes Spain
Dakota Texas U.S.A
Indonesian Low Bank
Net Specific Energy=2MJ/Kg

Source: Allardice Consulting Ltd

Ash Composition



- Low composition of Na_2O and K_2O decreases the occurrence of fouling in the heating surfaces

- ***The composition and properties of the ash are the significant factors deciding of the usability of the lignite for different purposes.***

Ash Fusibility

Ash Melting Temperatures of Belchatow Lignite

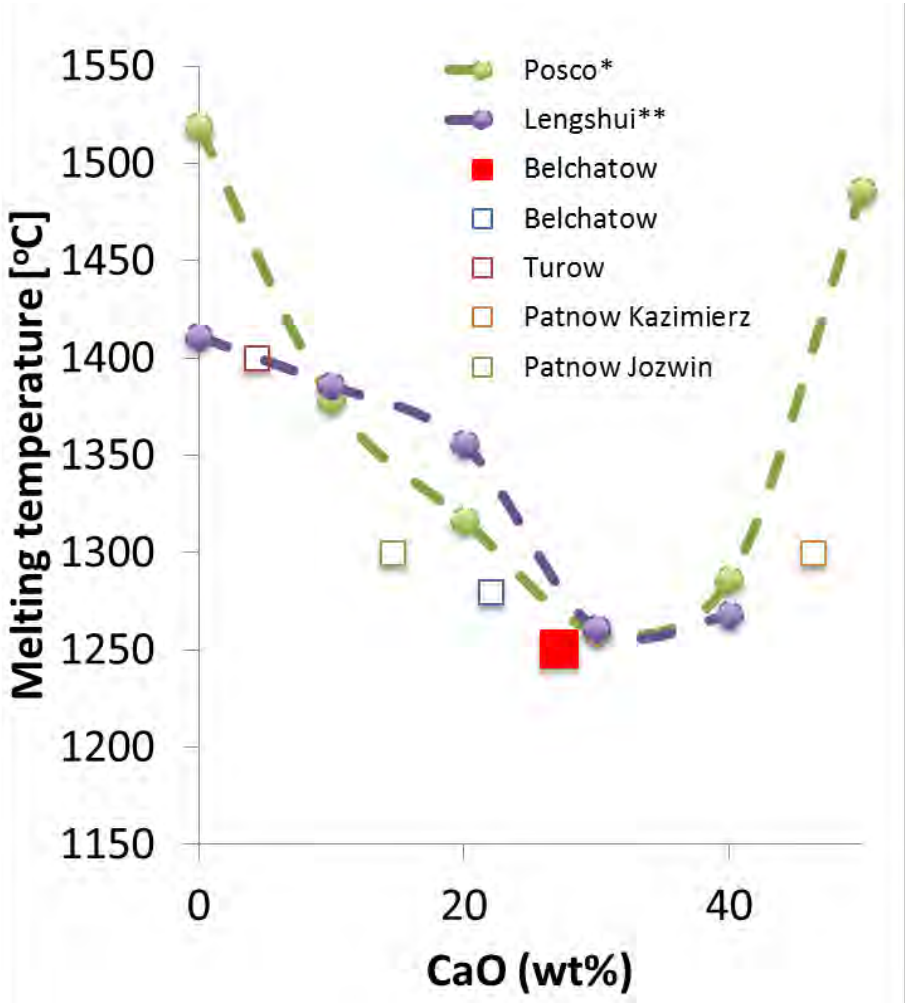
	ASTM	DIN
Initial deformation temperature (EP/IDT) [°C]	1205	1230
Softening temperature (/ST) [°C]	1235	-
Hemispherical temperature (SP/HT) [°C]	1240	1245
Fluid temperature (FP/FT) [°C]	1250	1250

ASTM D1857 (Oxidizing Atmosphere)

DIN 51730 (Reducing Atmosphere)

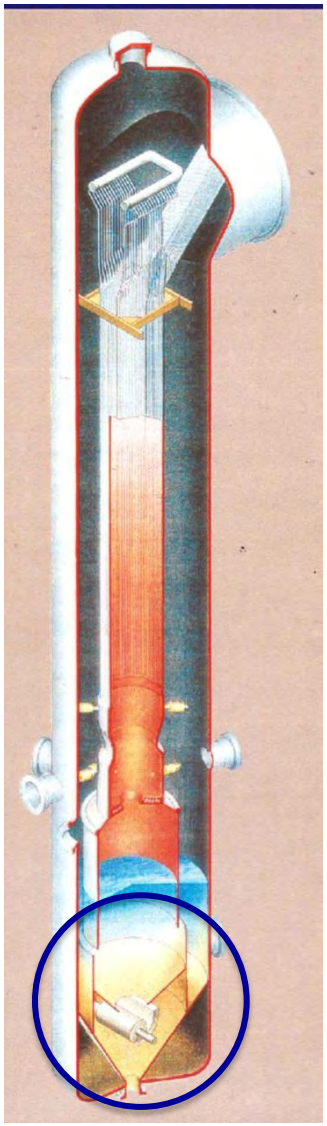
- *Low ash melting temperature*
- *Very short range between Softnening and Fluid temperatures*
- *Very stable temperatures from the analyses in both of oxidizing and reducing atmospheric conditions*

Ash Fusion Temperature



* Hyun-Taek K., Han-jin B.; *A prediction of coal ash slagging under the gasification condition*, American Chemical Society of Fuel Chemistry

** Y. Jun, C. Donglin, T. Hualong, P. Xiaochong; *Experimental Investigation On the Effects of CaO on Coal-Ash Slagging on Refractory Boards, 2009 International Conference on Energy and Environment Technology*



CaO content is the most significant factor to the ash fusion temperature

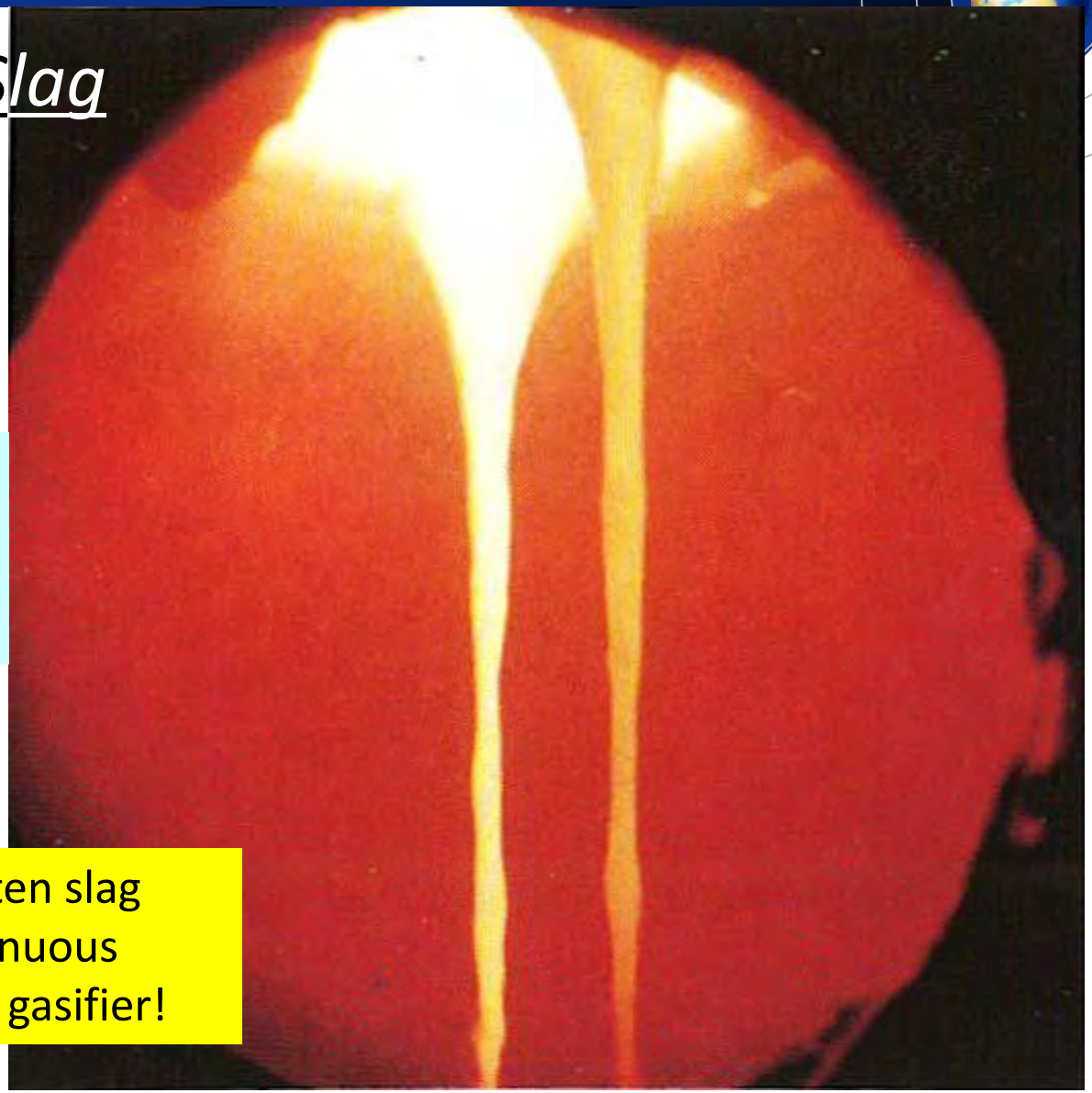
Belchatow lignite:

- Ash melting temperature: **1250°C**
- CaO content: **27.2%**

For the furnace or combustor design, the ash fusion temperature is especially important.

Smooth Slag Removal is the key…..

Flow of Molten Slag



- Low Ash Fusion Temp. provides smooth molten ash flow

- Continuous disposal of molten slag is necessary for stable continuous operation of entrained flow gasifier!

Lignite IGCC Premium

- *Why IGCC is advantageous to use brown coal?*

1. Scale-up merit

➡ Capacity increase formula :

- IGCC : Capacity $\propto D^3$
- Conventional boiler &turbine : Capacity $\propto D^2$

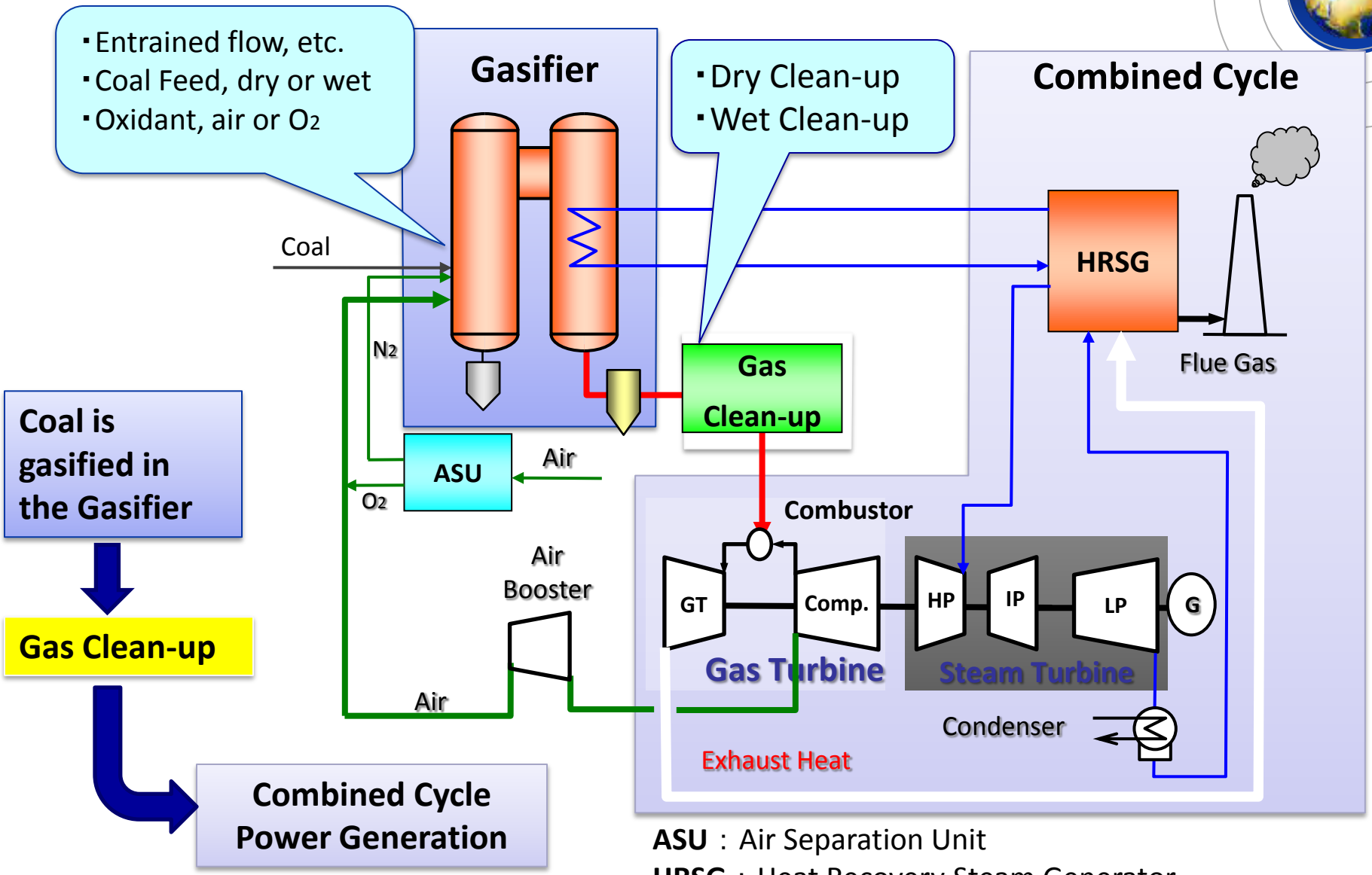
2. Low ash melting point

➡ Easy slag removal in high temperature gasification

3. CCS advantage

➡ Easy and efficient removal of CO_2 in compressed fuel gas

IGCC System

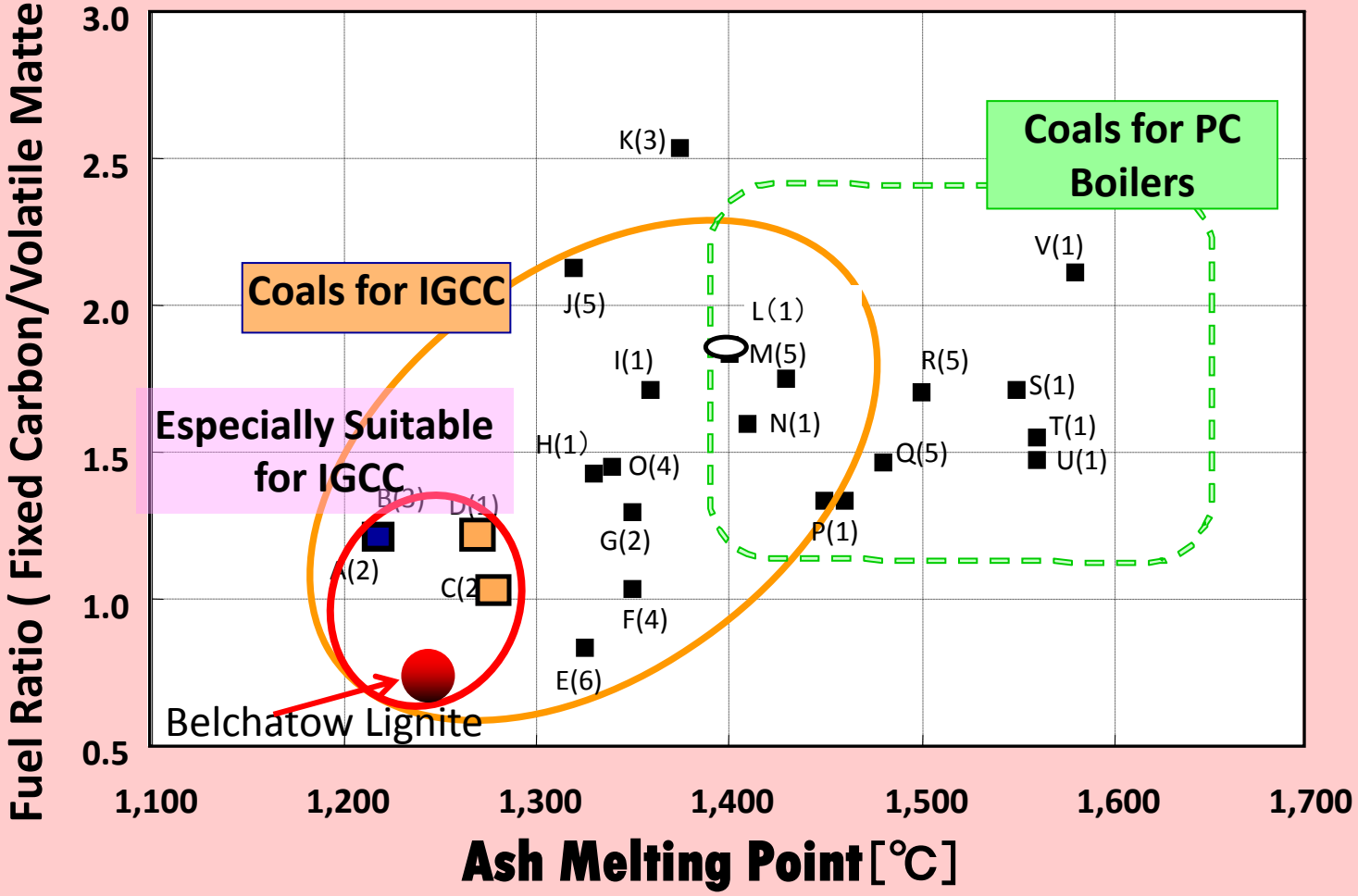


ASU : Air Separation Unit

HRSG : Heat Recovery Steam Generator

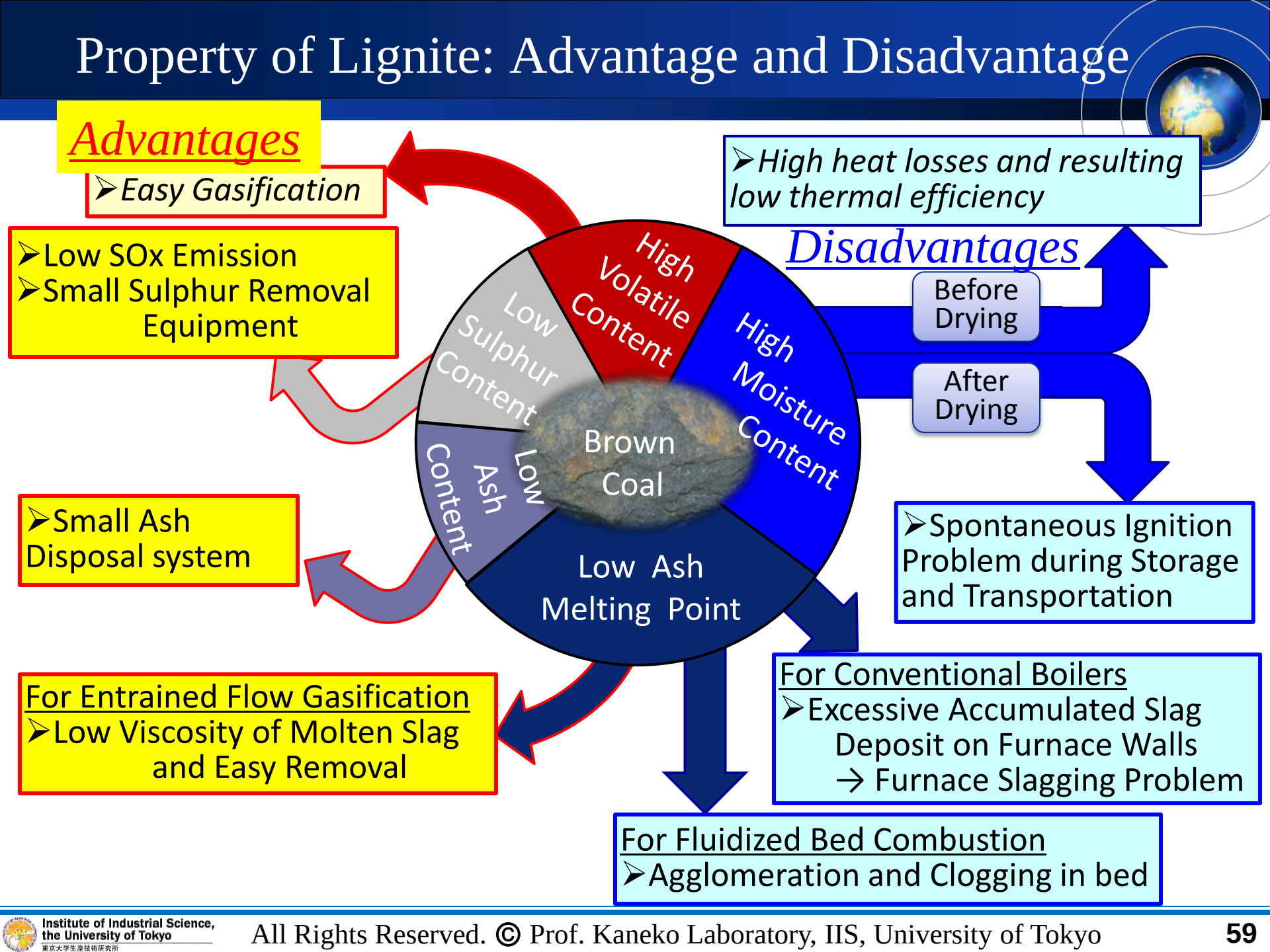
Coals for Pulverized Coal and IGCC

Low ash melting point coals are suitable for IGCC!



Note : 1: Australia 2: USA 3: China 4: Indonesia 5: South Africa 6: Japan

Property of Lignite: Advantage and Disadvantage



6. Cooperation between Poland and Japan

AGH and UT cooperation

Cooperation between AGH University of Science and Technology and Institute of Industrial Science, UT was started on **8th May 2013**.

AGH

AGH University of Science and Technology

- Department of Fundamental Research in Energy Engineering
- ◆ Faculty of Energy and Fuels

東京大学
THE UNIVERSITY OF TOKYO

The University of Tokyo

- Collaborative Research Center for Energy Engineering (CEE)
- ◆ Institute of Industrial Science

Komaba Research Campus

Agreement Signing Ceremony

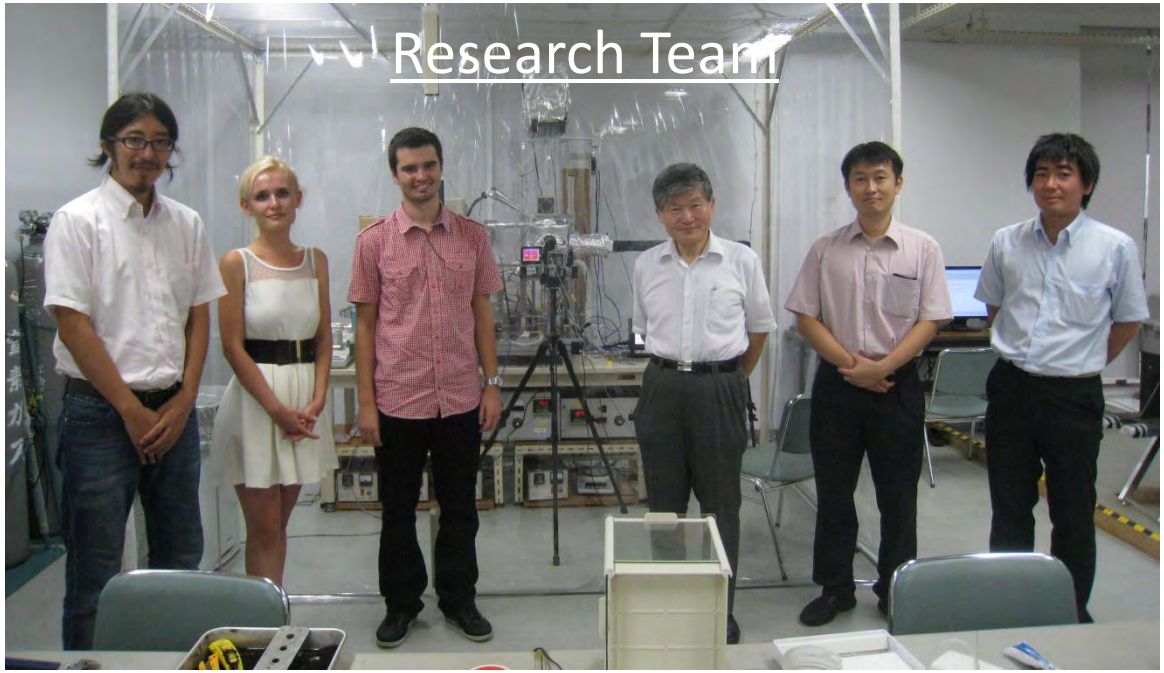
Agreement between AGH and UT signing ceremony on 8th May 2013.
In presence of Mr. Cyryl Kozaczewski, Polish Ambassador to Japan

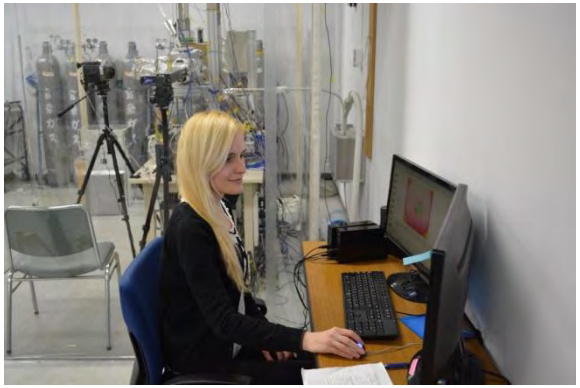
AGH and UT Cooperation

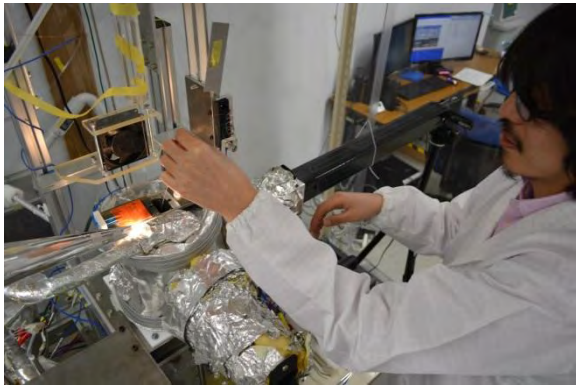
Prof. Y. Nakano, Director general of IIS, UT and Prof. T. Szmuc, Vice Rector of AGH

Prof. S. Kaneko and Prof. T. Szmuc, Vice Rector of AGH

Fundamental Drying Test of Lignite





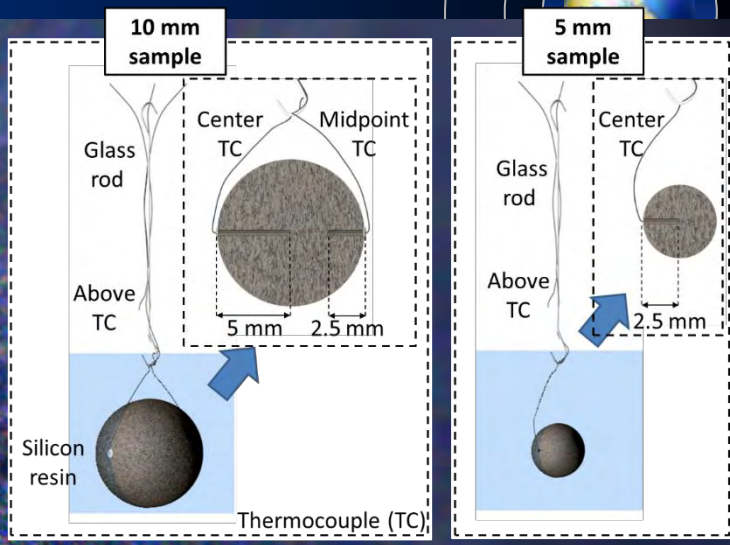


Prof. S. Kaneko

Prof. J. S. Szmyd

Experimental Facility:
Advanced Energy Conversion Engineering, Institute of Industrial Science, the University of Tokyo, Tokyo, Japan

Test Sample

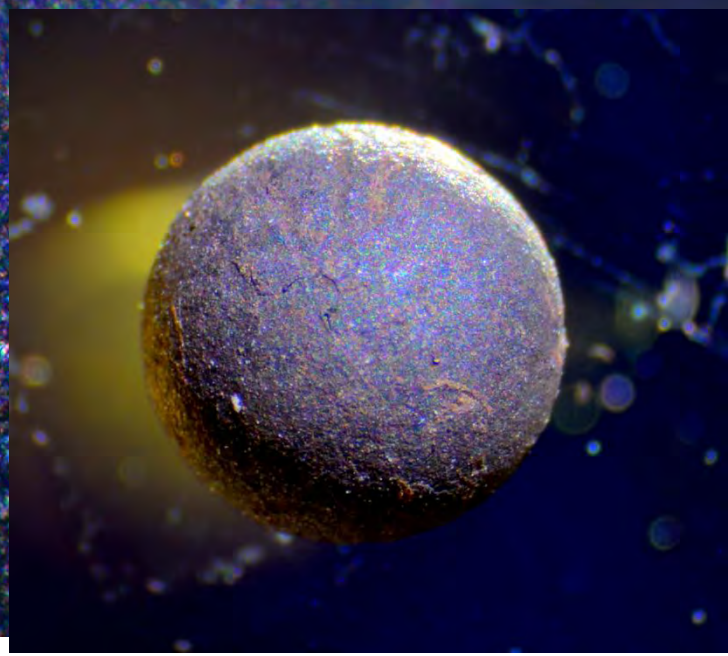


Two types of samples were investigated:

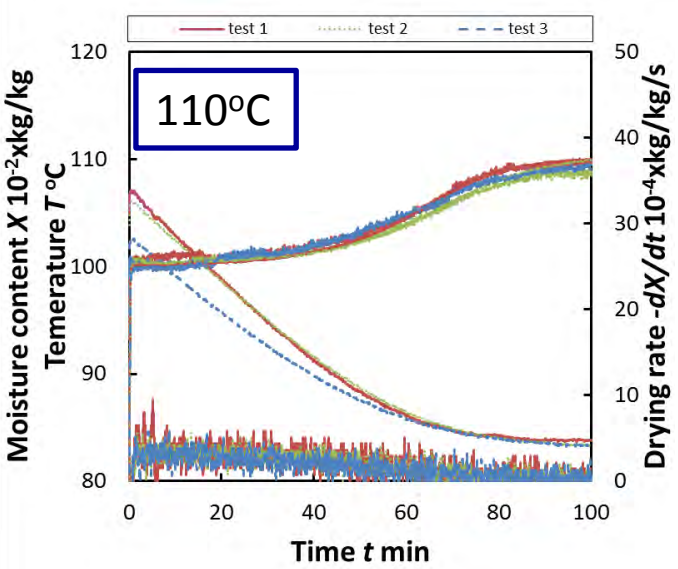
- 10 mm ϕ sample
- 5 mm ϕ sample

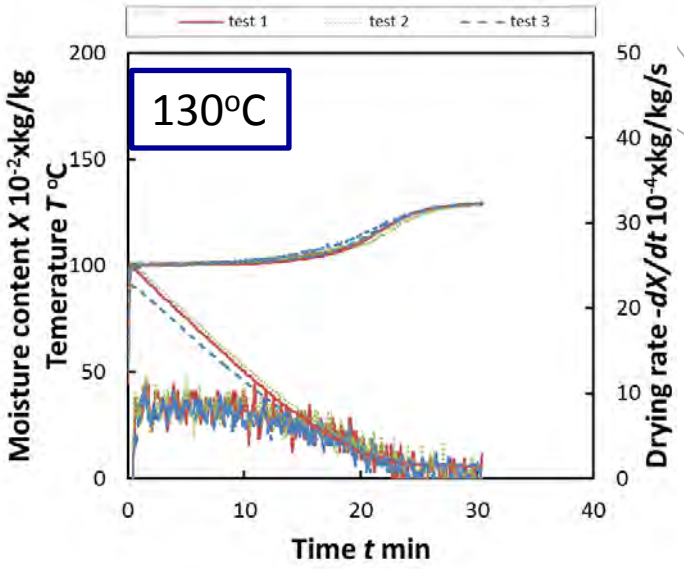
In four different drying temperatures:

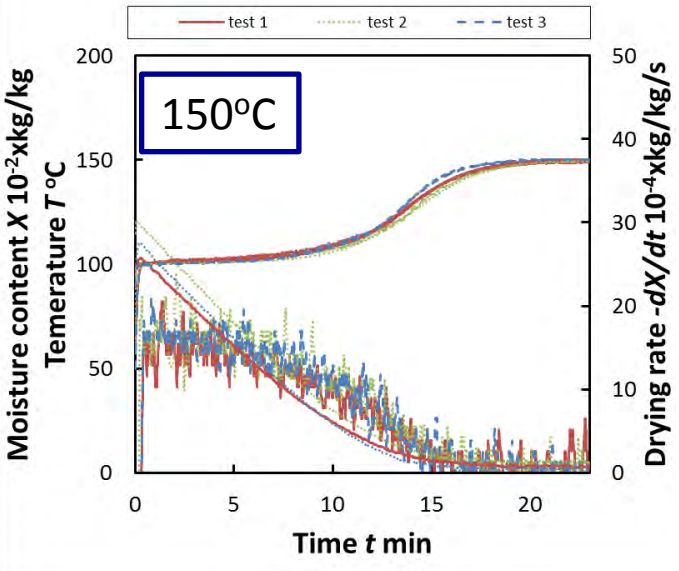
- 110°C
- 130°C
- 150°C
- 160°C

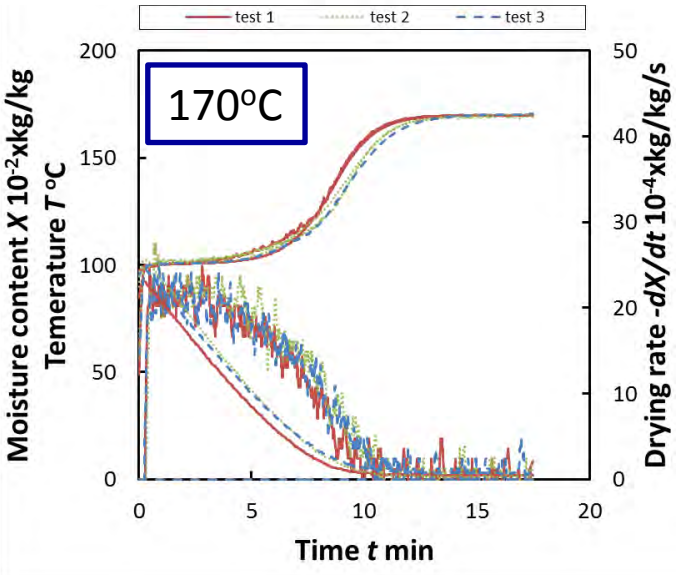


Drying characteristics of 5mm sample

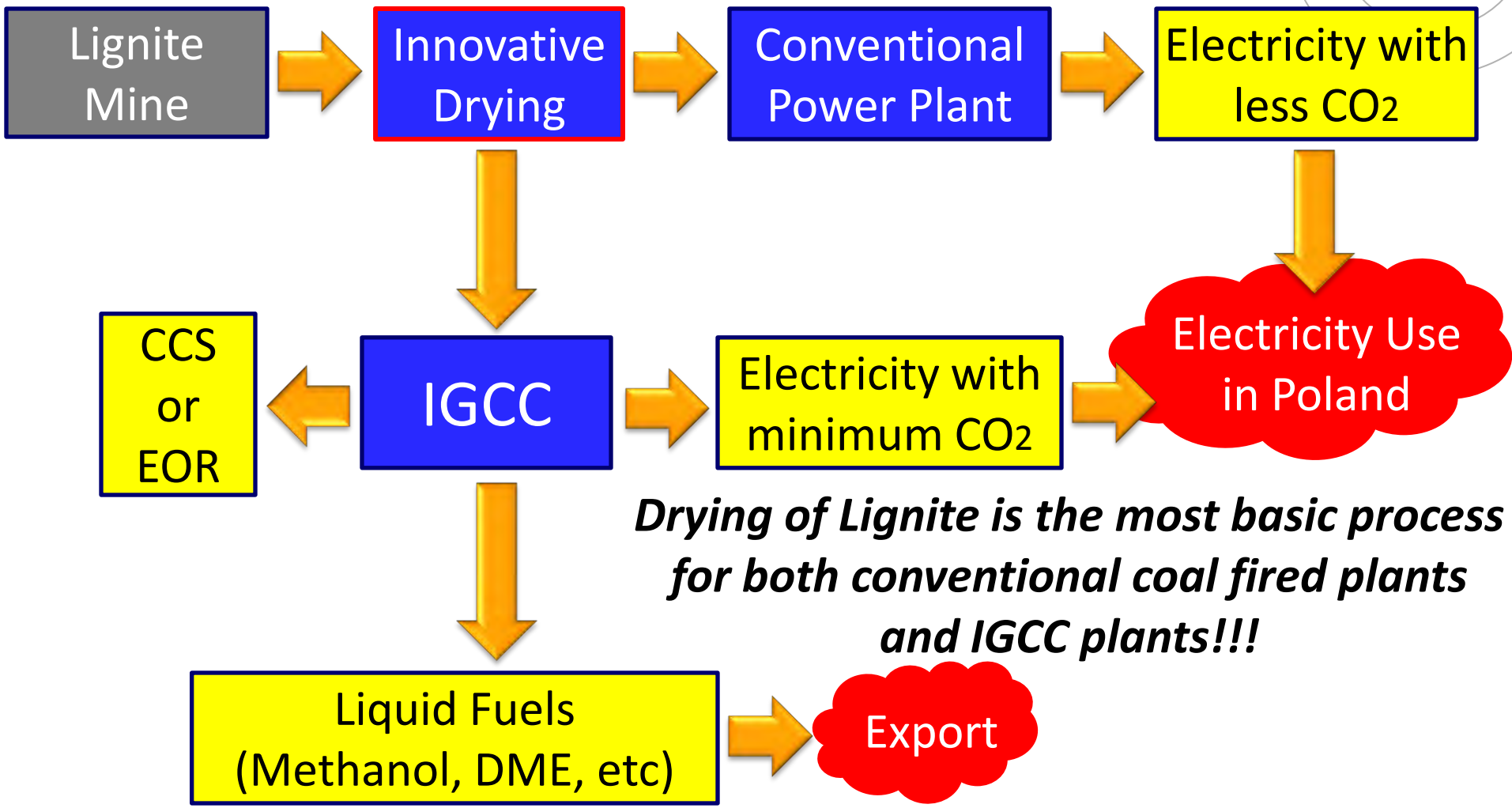








Industrial Application of Lignite



Drying of Lignite is the most basic process for both conventional coal fired plants and IGCC plants!!!


Thank you very much for your kind attention!
Wishing for further cooperation
between Poland and Japan