MUNI
FSS

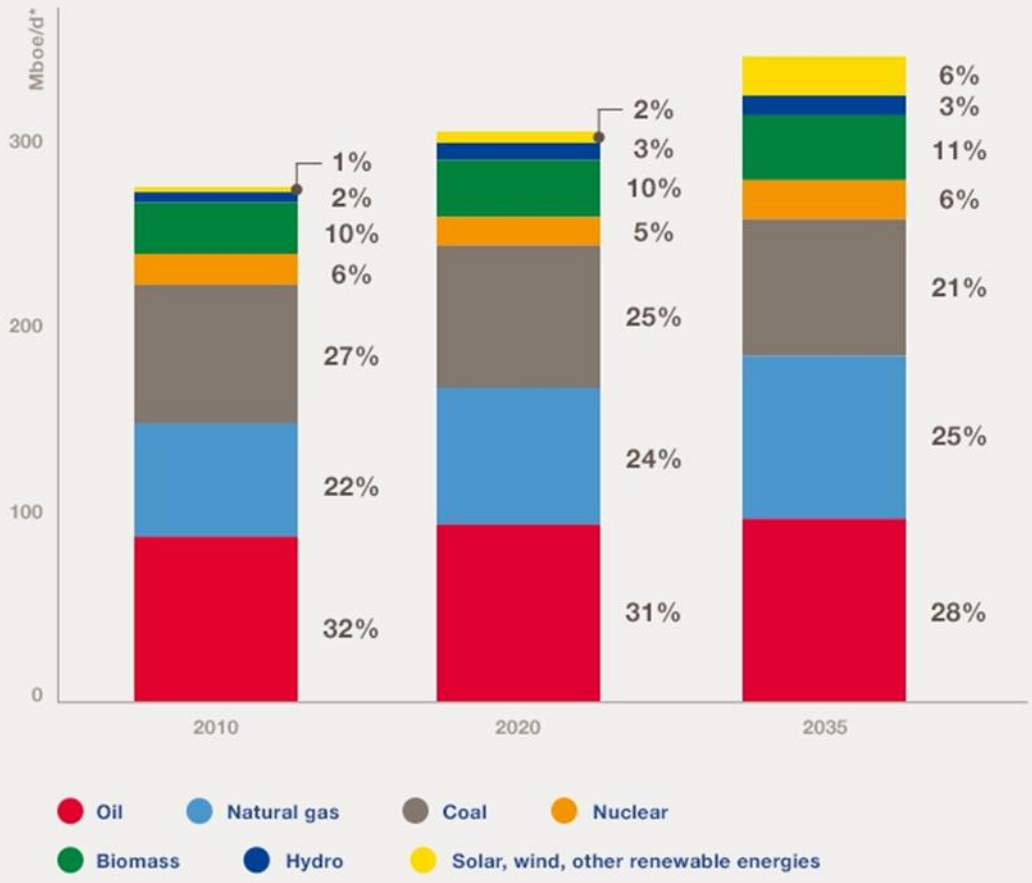
Coal and Nuclear Energy

Martin Jirušek, PhD.

Context – use of coal on the global scale

- 27% in global energy mix
- 40% of elctricity
- 68% of steel produced
- Major source that has been offsetting the rising energy demand
- Coal is available in 80 countries worldwide
- 860 billion tonnes of worldwide proven reserves
- > 17 000 Gt of resources

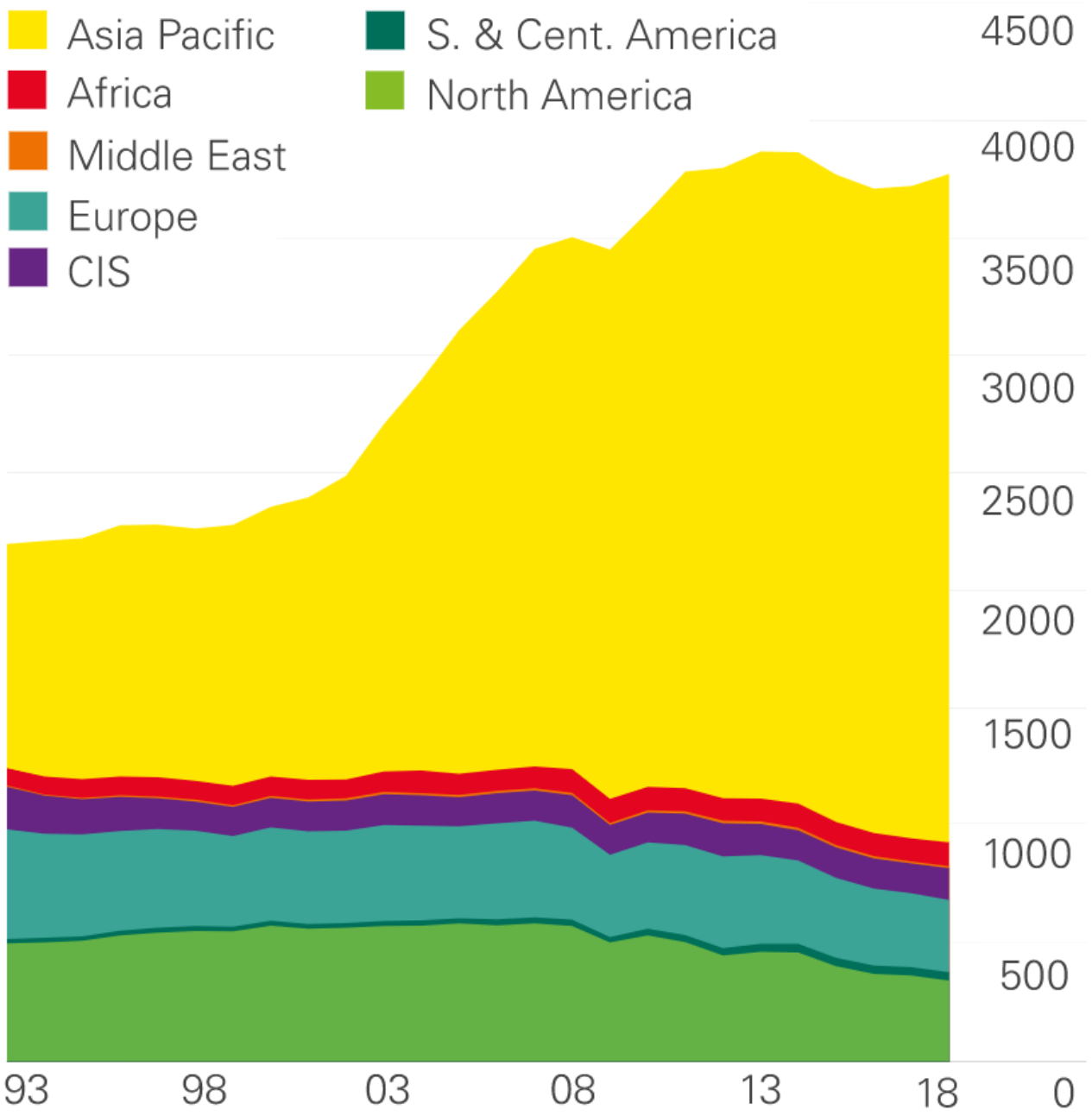
WORLD PRIMARY ENERGY MIX
(2035 FORECAST)



*Million barrels of oil equivalent per day

Source: Total estimates

MUNI FSS


Asia Pacific
Africa
Middle East
Europe
CIS
S. & Cent. America
North America
4500
4000
3500
3000
2500
2000
1500
1000
500
0
93
98
03
08
13
18

MUNI FSS

Coal – a global picture

- Drop of coal use in 2015 – 2016, slight increase in 2017 & 2018
- Tale of two worlds
- Countries poised to tackle pollution, squeezing coal out of the mix
  - China (bid to improve air quality)
  - Europe (e.g. UK - carbon price)
  - North America (e.g. Canada, US - natural gas)
- Countries where demand remains strong – source of cheap electricity addressing demand growth
  - India
  - Pakistan
  - SE Asia
- Consumption expected to remain stable or increase slightly as a result of development in the 2nd group
- Coal prices to remain volatile

Coal – reserves, producers, consumers & importers

Biggest coal reserves

-USA 237 Bt

-Russia 157 Bt

-China 114 Bt

-Australia 76 Bt

Top coal producers

-China

-USA - 13% of world total

-India

-Australia

-Indonesia

Biggest coal consumers

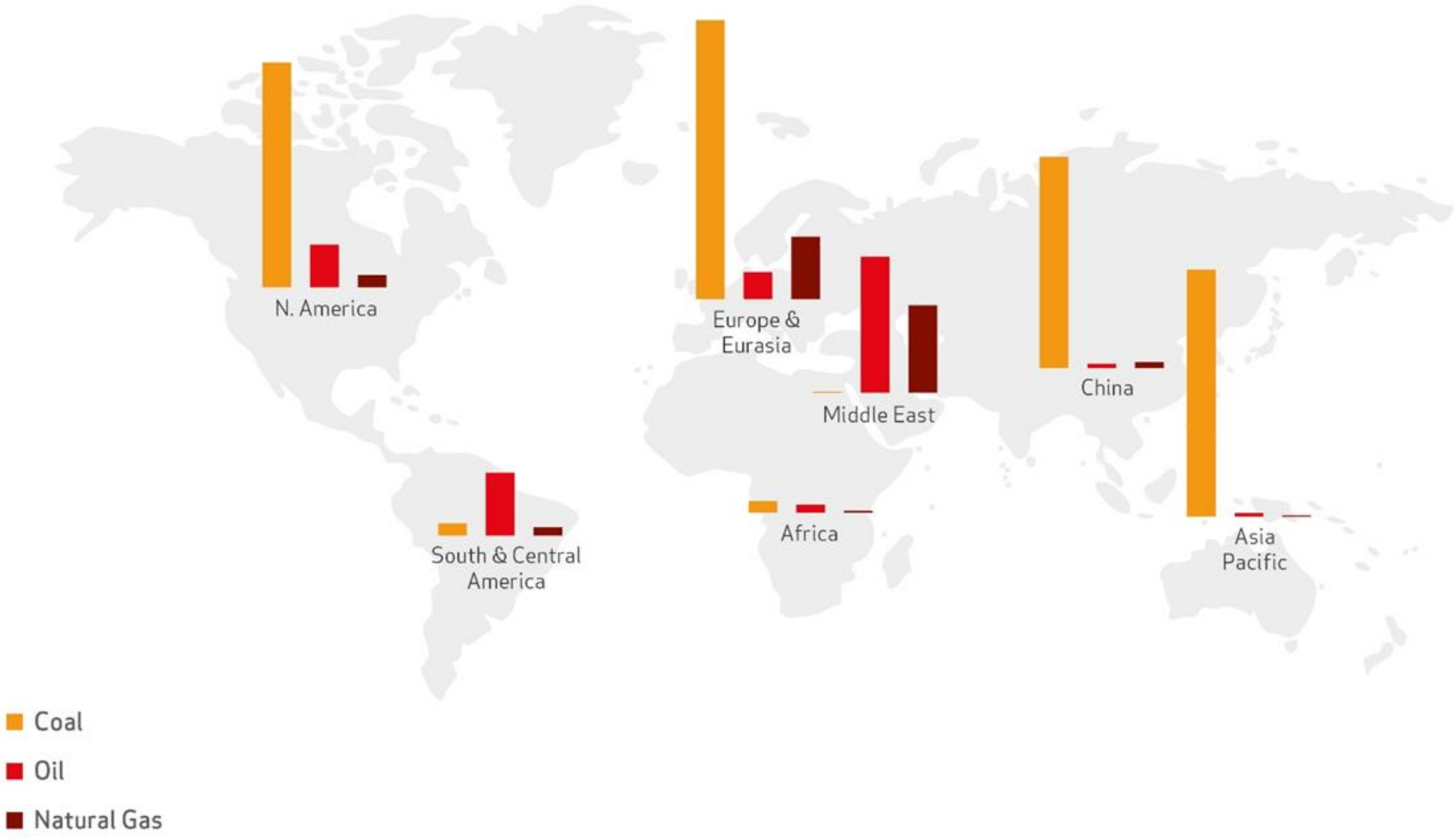
- China
- USA (11%)
- India
- Japan

Biggest coal importers

- China
- India
- Japan
- S. Korea

MUNI FSS

Location of the world's main fossil fuel reserves (Mtoe)



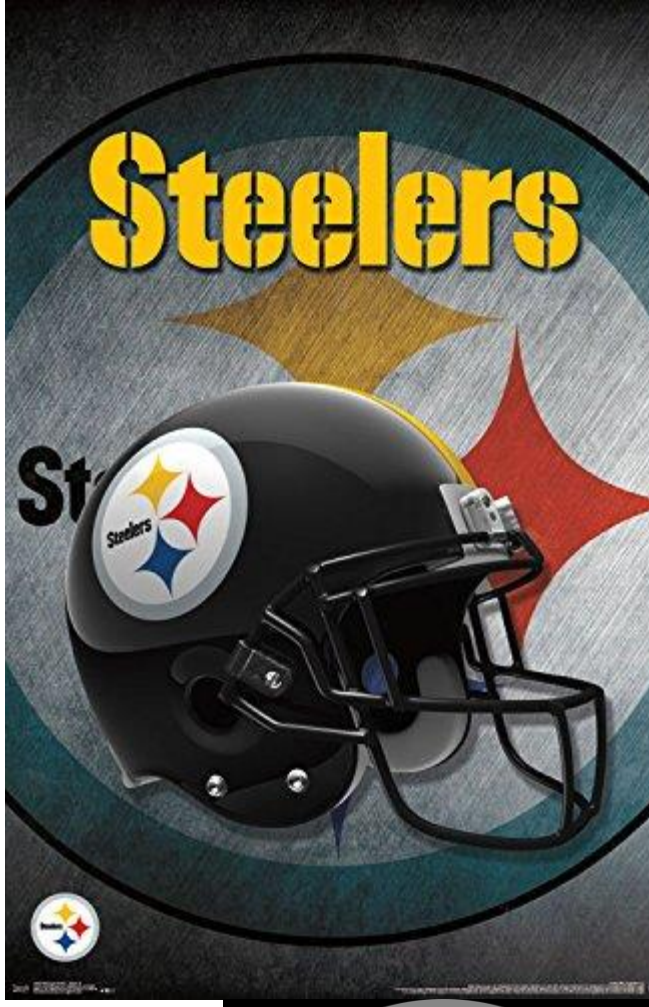
Source: BP Statistical Review of World Energy 2017 and WCA analysis 2017

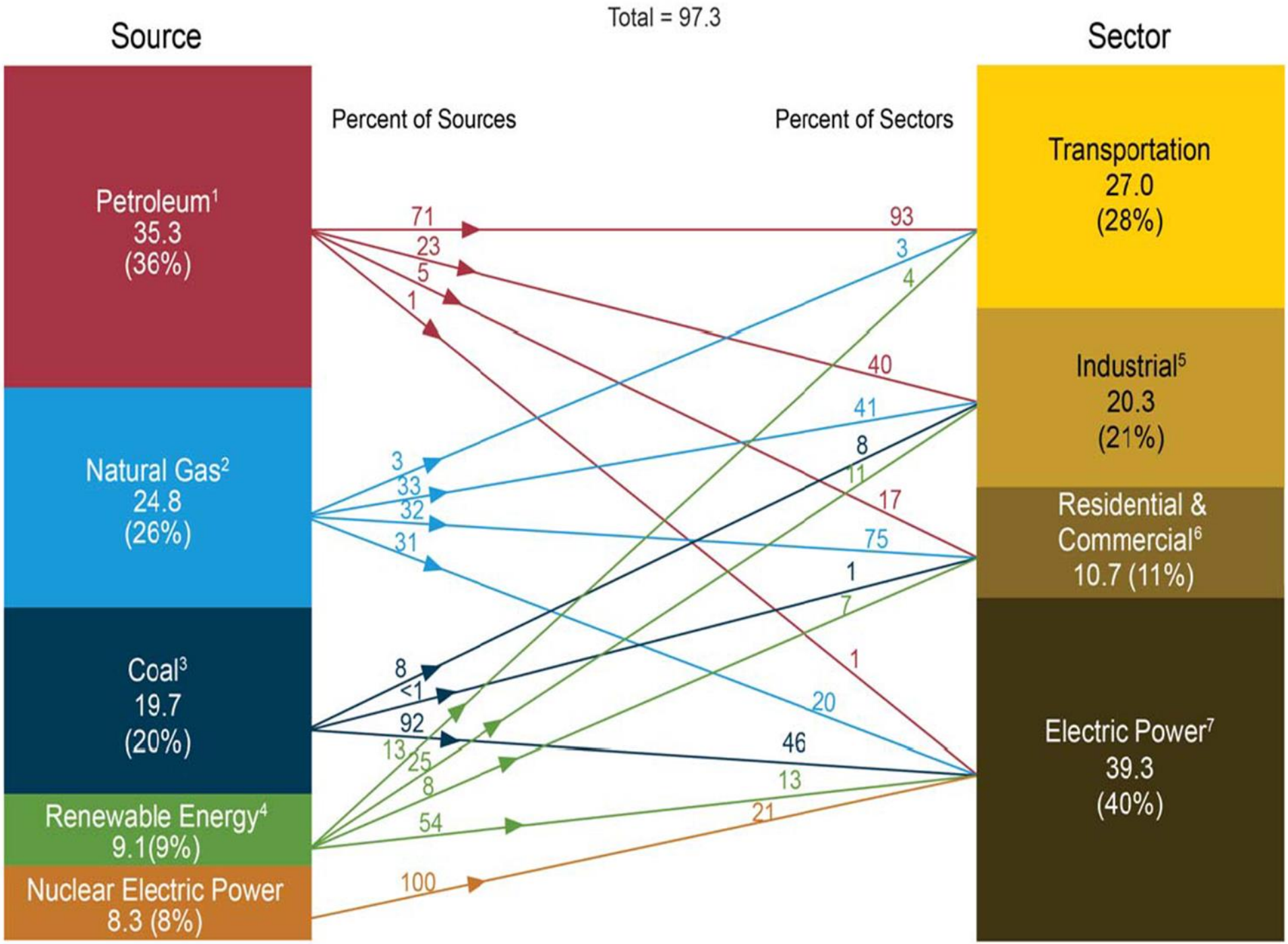
Coal and the US – a history

- Coal use surged during the industrial revolution, replaced wood
- Coal was originally imported from UK
- Birth of the coal industry on the Eastern coast
  - quality black coal from Pennsylvania
- Railroads played key role (again)
- The civil war accelerated use of coal, coal (coke) replaced charcoal in steel furnaces (Pennsylavnia)
- Key role in colonization of Western territories – transport and use of railroads
- Key role for industry and transportation until WWII
- Electricity generation as the main consumer came later

Coal and the US – a history

- Decline in coal use started after the WWI
  - European coal mines re-opened
  - economic crisis hit US industry hard
- WWII partially revived the coal use
- Industry switched to gas and (partially) oil, so did transportation
- Another increase came with the oil shocks
- Today, coal still among the mainsources for power generation
  - decline in recent years (increase of gas)




Total = 97.3
Source
Sector
Percent of Sources
Percent of Sectors
Petroleum[1]
35.3
(36%)
Natural Gas[2]
24.8
(26%)
Coal[3]
19.7
(20%)
Renewable Energy[4]
9.1(9%)
Nuclear Electric Power
8.3 (8%)
Transportation
27.0
(28%)
Industrial[5]
20.3
(21%)
Residential &
Commercial[6]
10.7 (11%)
Electric Power[7]
39.3
(40%)
71
23
5
1
3
33
32
31
8
<1
92
13
25
8
54
100
93
3
4
40
41
8
11
17
75
1
7
1
20
46
13
21

MUNI FSS

US electricity generation by source

2013 - 2015

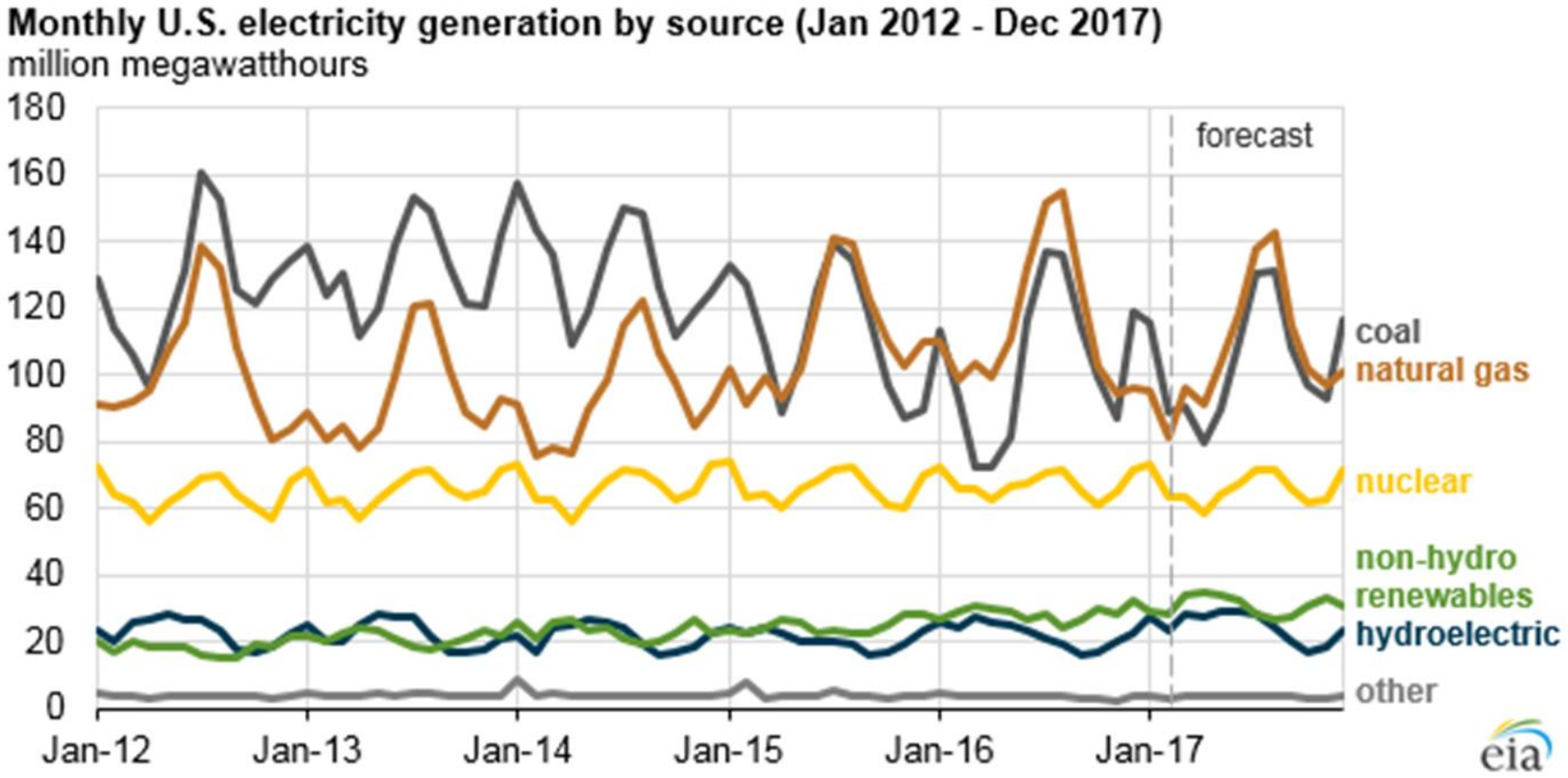
- Coal 39%
- Natural gas 27%
- Nuclear 19%
- Hydropower 6%
- Biomass 1.7%
- Geothermal 0.4%
- Solar 0.4%
- Wind 4.4%
- Oil 1%
- Other gases <1%

2018

- Natural gas 35,2%
- Coal 30.4%
- Nuclear 19,4%
- Hydropower 7%
- Wind 6.5%
- Biomass 1.4%
- Solar 1.5%
- Geothermal 0.4%
- Petroleum 0.6%
- Other gases 0.3%

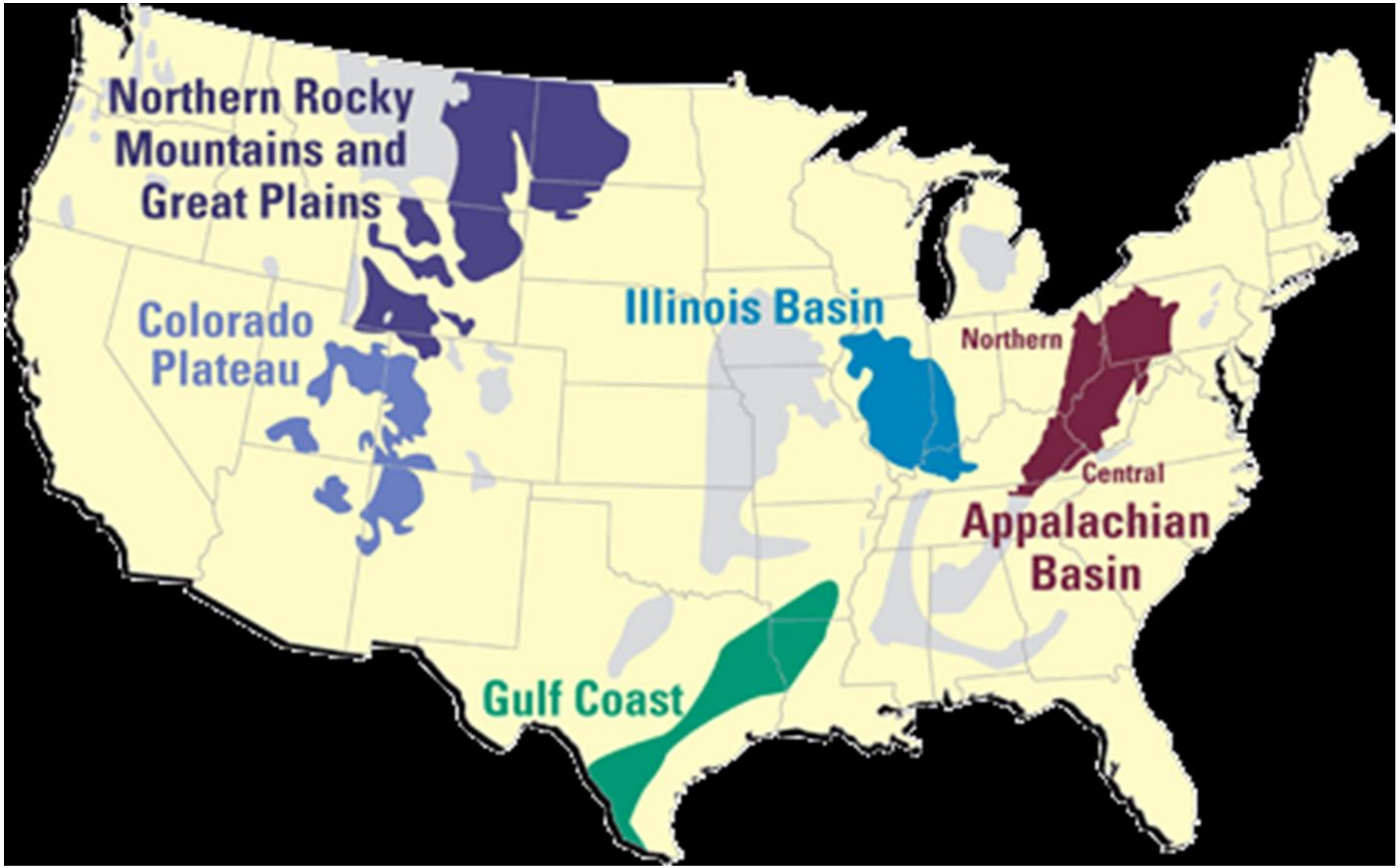
MUNI FSS

Power generation by source



MUNI FSS

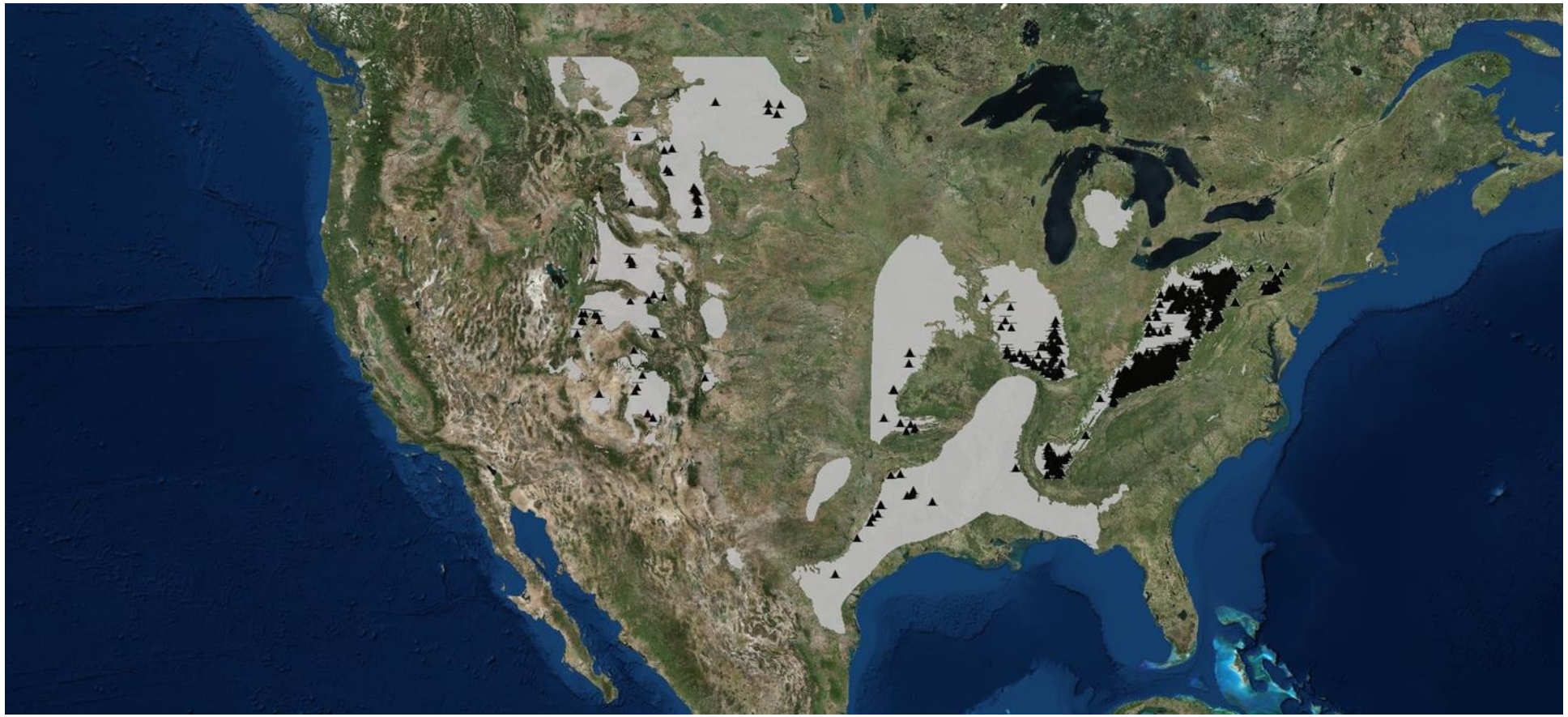
Main coal plays



MUNI FSS

Coal mines in the US

- Coal mines located in 25 states, mostly in Wyoming, Virginia, Kentucky, Pennsylvania, Texas
- Biggest reserves in Wyoming (with the biggest potential to increase production)



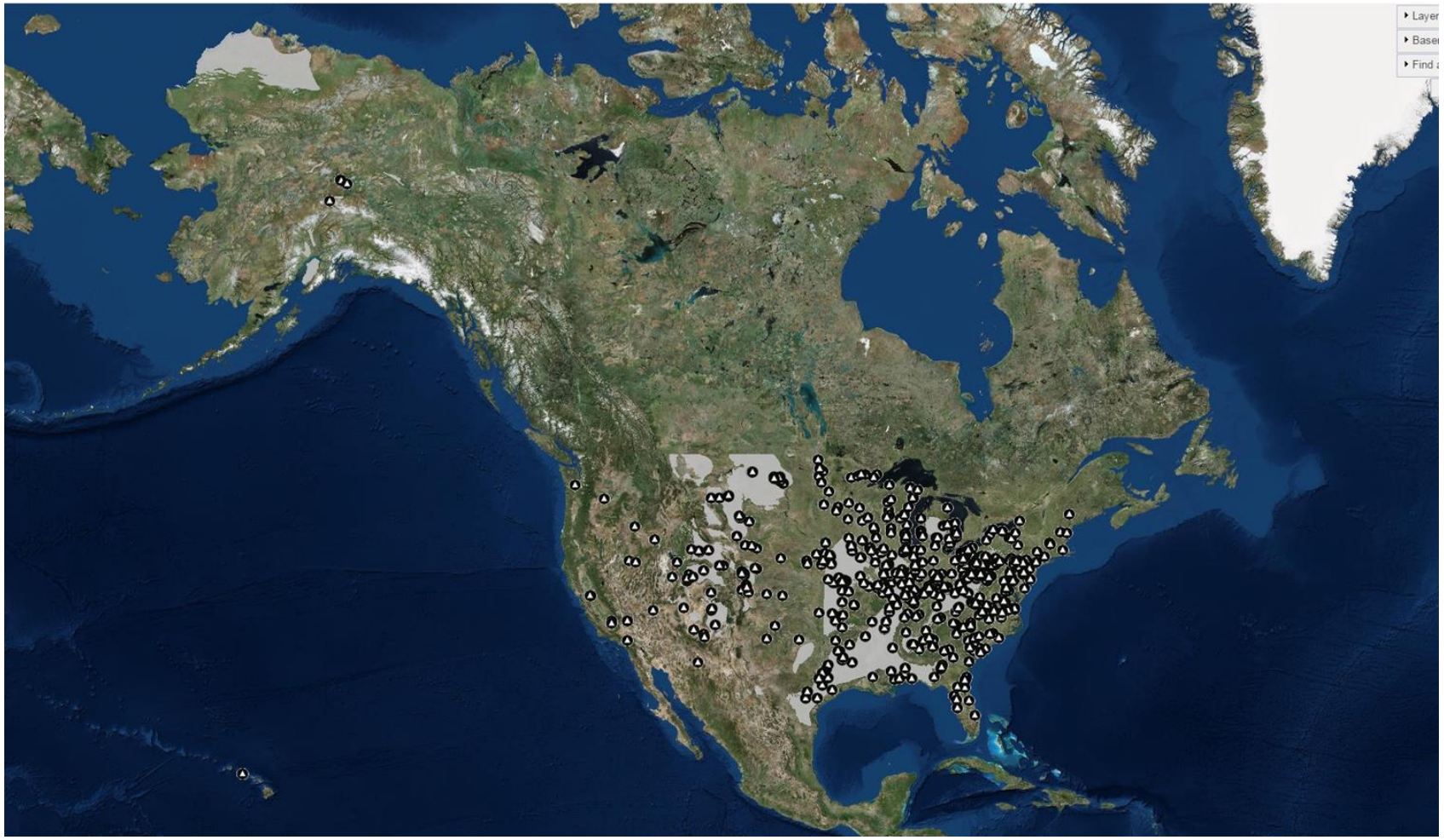
MUNI FSS

North Antelope, Wyoming

- The biggest open cast mine in the world
- 1,8 bn. tonnes since its opening
- 2,4 bn tonnes to go

Coal power plants in the US

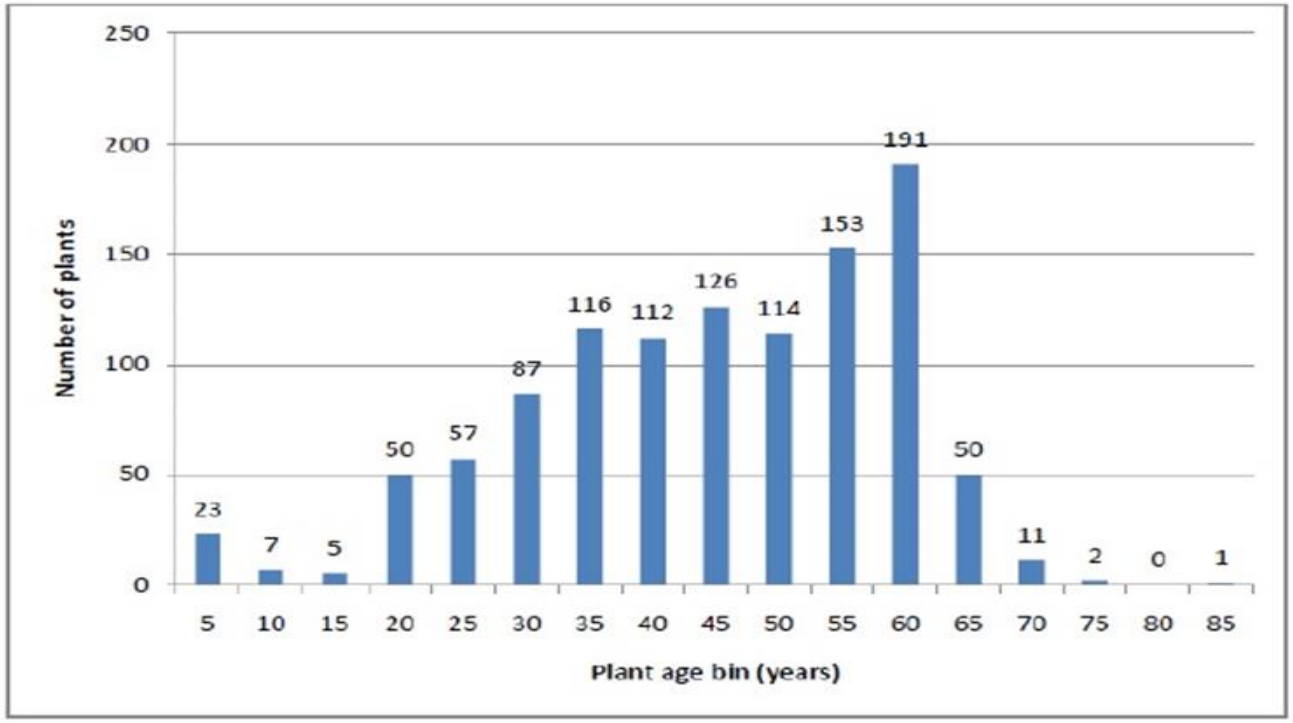
- Close to the main centres of consumption - the economy of coal use becomes unfavourable with longer distances



MUNI FSS

Production - trends

- Production stagnates or decreases
- Electricity generation increases its share, ageing PPs
  - rather short- to mid-term lived trend (power plants are getting old)

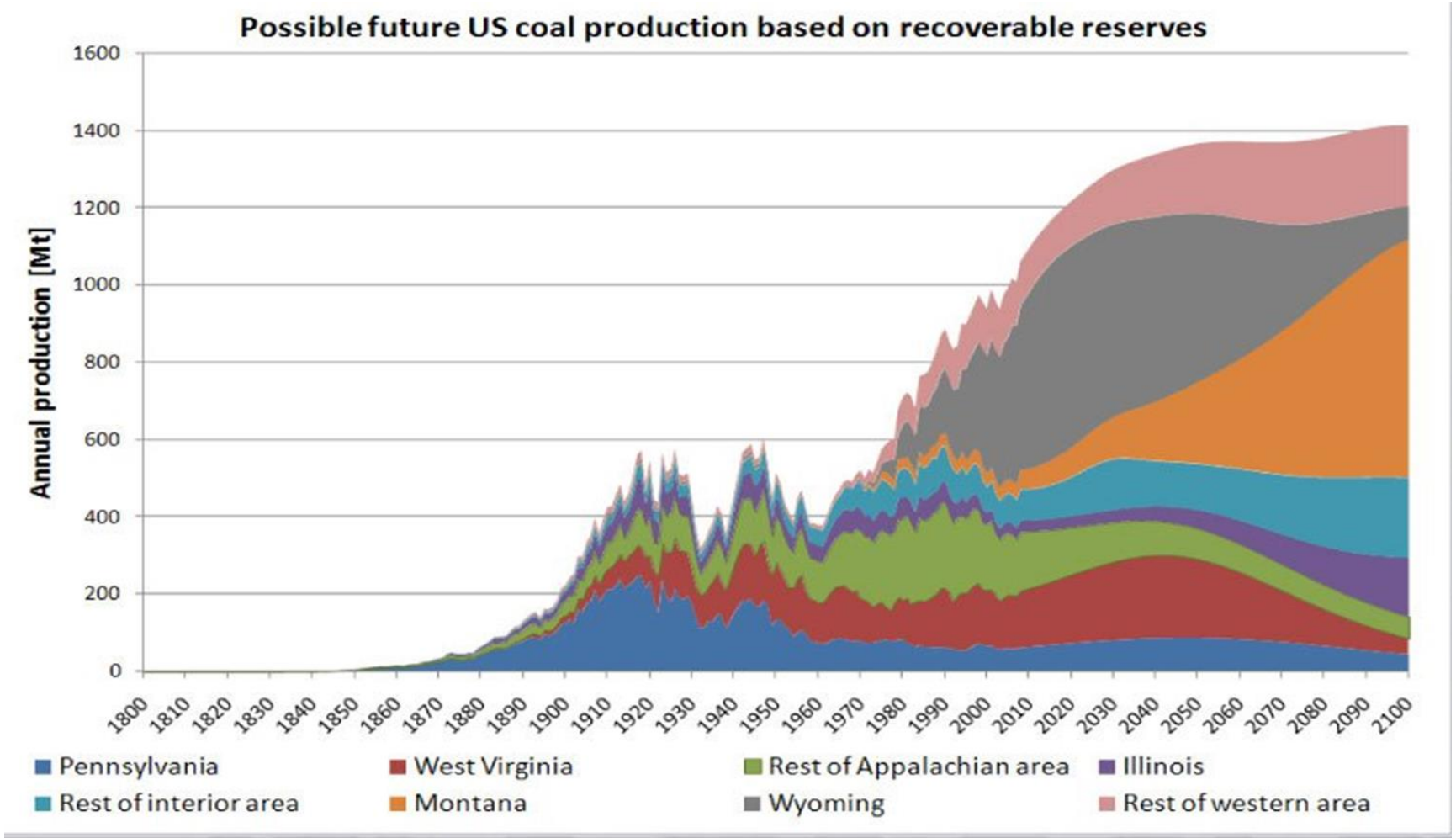


Source: "Clean Energy Standards: State and Federal Policy Options and Implications ," Policy Discussion Paper, Regulatory Assistance Project and The Center for Climate and Energy Solutions, November 2011

MUNI FSS

Predictions...

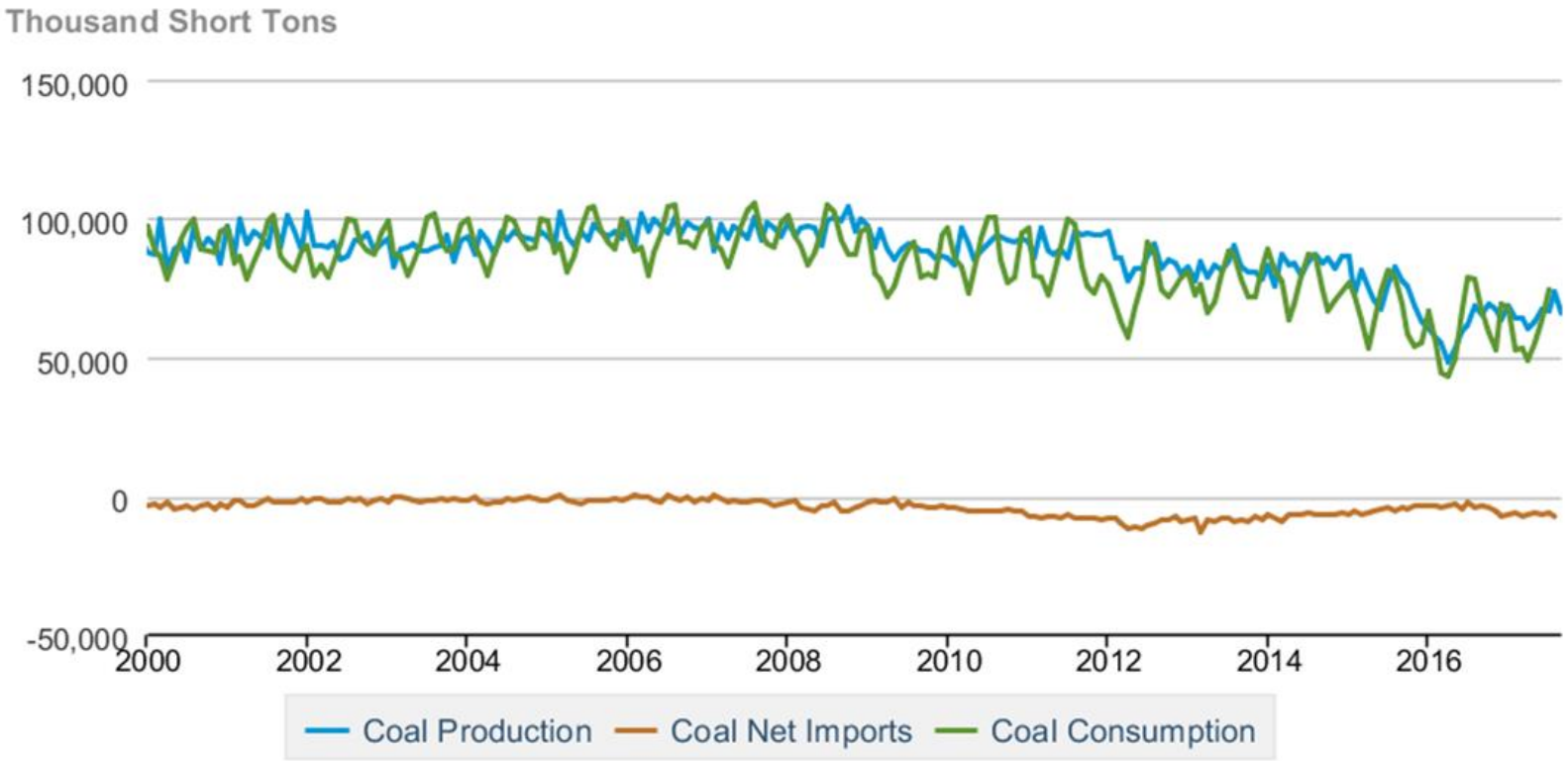
– Wyoming as potentially the biggest producer in future if the coal use continues...



MUNI FSS

Reality...

Table 6.1 Coal Overview

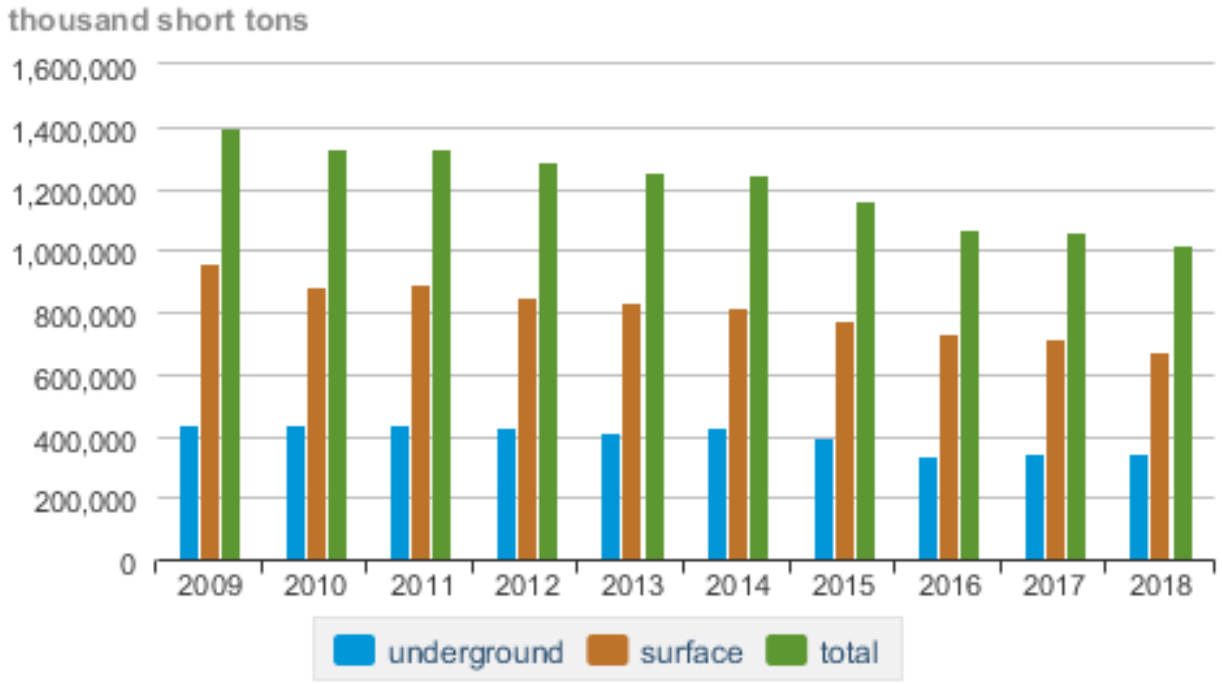


Source: U.S. Energy Information Administration

Contemporary trends

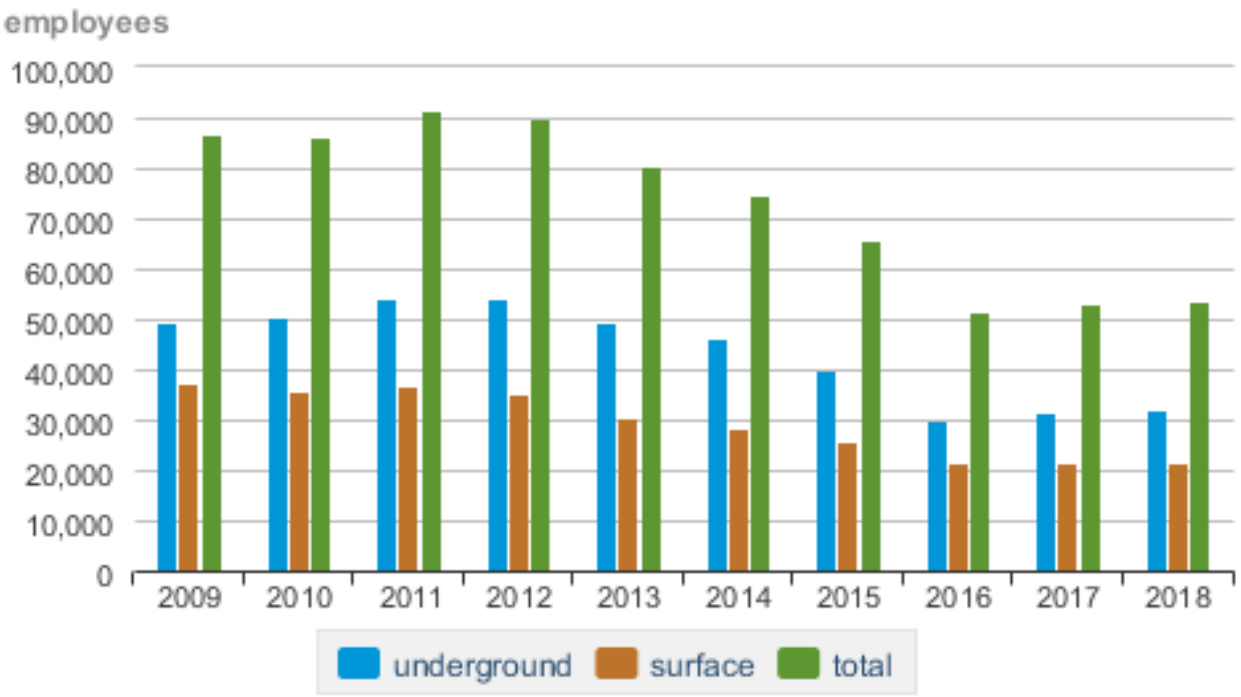
- Abundance of cheap gas, economic crisis, environmental issues
  - abundance of coal
  - US coal forced to seek new markets
- Worldwide abundance, slowing economy (mostly in SE Asia) - US coal exports decreased (20% annually) as well production (20% since 2008)
- Cheap coal is putting a pressure on US producers (Columbia, Indonesia)
- US still a net exporter though
- Peak of imports in 2007, before the crisis
- 2019 - the lowest coal production since late 1970s (ca. 10% yearly decline and counting)

Productive capacity of coal mines by mine type, 2009–18



Source: Annual Coal Report Table 11.

Average number of employees by mine type, 2009–18



Source: Annual Coal Report Table 18.

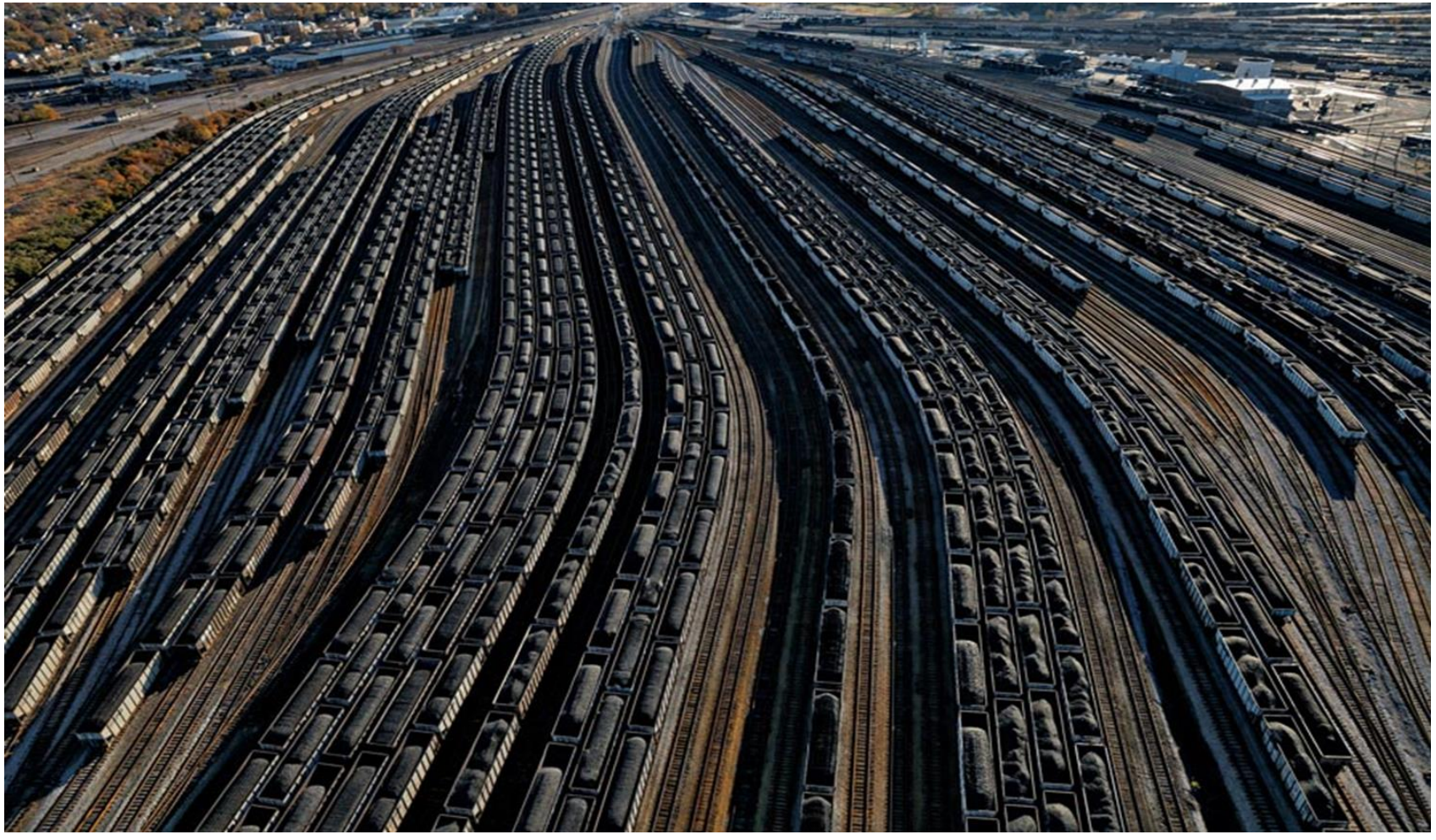
Contemporary trends

- Trump´s vows to revive the coal industry
  - limited impact
  - industry´s prospects remain weak
  - the market beats the administration´s plans
  - Support for sources (guaranteed prices, grid operators obliged to buy elektricity from designated sources) that can be stockpiled (i.e. coal and nuclear)

- Power generation is shifting to natural gas and renewables
  - no significant shift despite alleviated environmental policies
  - e.g. on waste water from mines
  - “Trump Can’t Save Coal Country” (see IS)

Coal in the US energy sector and on the global scale

– Lambert Point docks, Norfolk, Virginia – coal terminal



MUNI FSS

World´s biggest…

- Increase in steam coal production
- Coking coal stagnates
- SE Asia to fuel the demand
- US & Canada dropped out of the top exporters

TOP COAL IMPORTERS (2016)	Total of which	Steam	Coking
PR China	256 Mt	197 Mt	59 Mt
India	200 Mt	152 Mt	48 Mt
Japan	189 Mt	138 Mt	51 Mt
South Korea	134 Mt	99 Mt	35 Mt
Taiwan	66 Mt	59Mt	7 Mt

TOP COAL EXPORTERS	Total coal exported	Steam	Coking
Australia	389	201	188
Indonesia	370	369	1
Russia	171	149	22
Colombia	83	82	1
South Africa	76	75	1

Unwanted coal?

- Abundance of cheap natural gas (quiet revolution), massive increase of RES
  - RES development spurred by preferential treatment (grid operators), incentives and low production costs
- Tightening environmental measures (Obama´s war on coal)
  - Clean Power Plan aimed on cutting CO2 pollution generated by PPs – aimed at coal PPs
  - criticized by Trump´s administration - repealed and replaced by (much milder) Affordable Clean Energy rule (6/2019)
  - softened vehicle efficiency standards (light, medium and also heavy-duty)
  - Relaxed restrictions on methane (O&G producers to regulate themselves) 3 ways of cutting CO2 according to CCP – efficiency, substituting gas for coal, substituting RES for hydrocarbons
- Coordinating bodies: DoE, FERC

Unwanted coal?

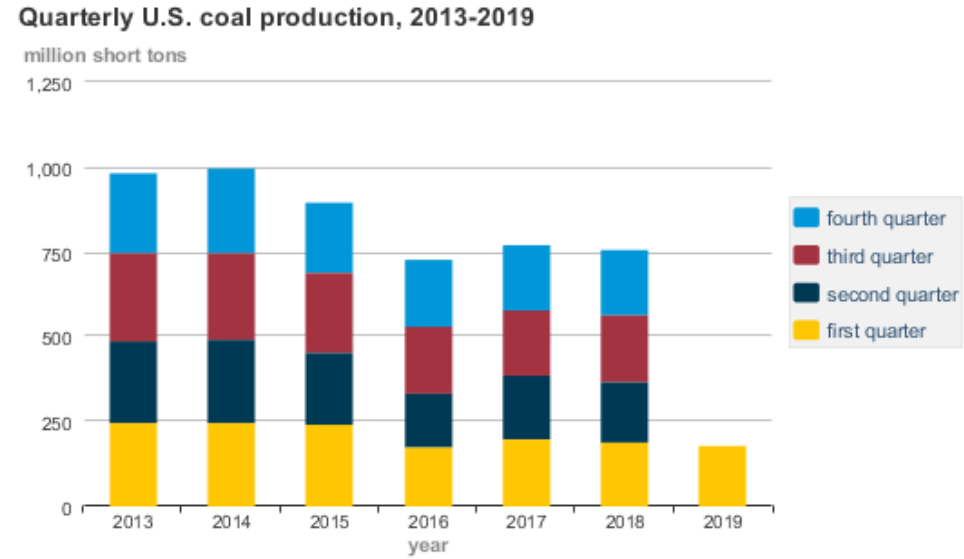
- Tightening measures and less favourable economy of coal-based sources is squeezing coal out of the market and also has wider consequences for other technologies (e.g. CCS)
- Combined-cycle power plants (coal + gas) – shift to gas-based production compared to a situation a decade ago

- **Coal-fired PPs**
  - Construction costs, environmental restrictions (increasing costs)
  - Unstable electricity prices – lower predictability of investment
  - More competitive sources

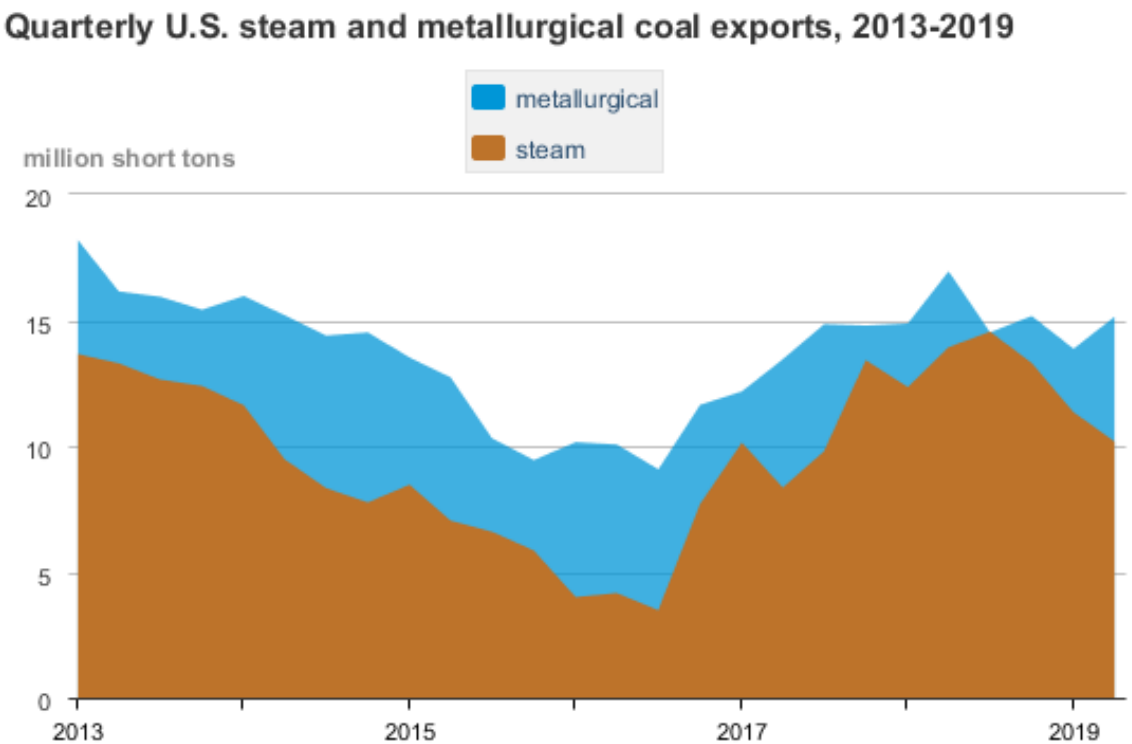
Can export be the cure?

- Europe in the lead in imports until 2016
  - simplified: metallurgical- Europe, steam – Asia
- Consumption is predicted to rise out of the OECD countries (SE Asia)
- US coal exports – short- to mid-term lived trend
  - GER (20% US) & UK, NED, ITA importing US hard coal
- European environmental goals about to aggravate the position of US coal
- Coking coal demand predicted to be stable
- Exporting emissions/carbon leakage?

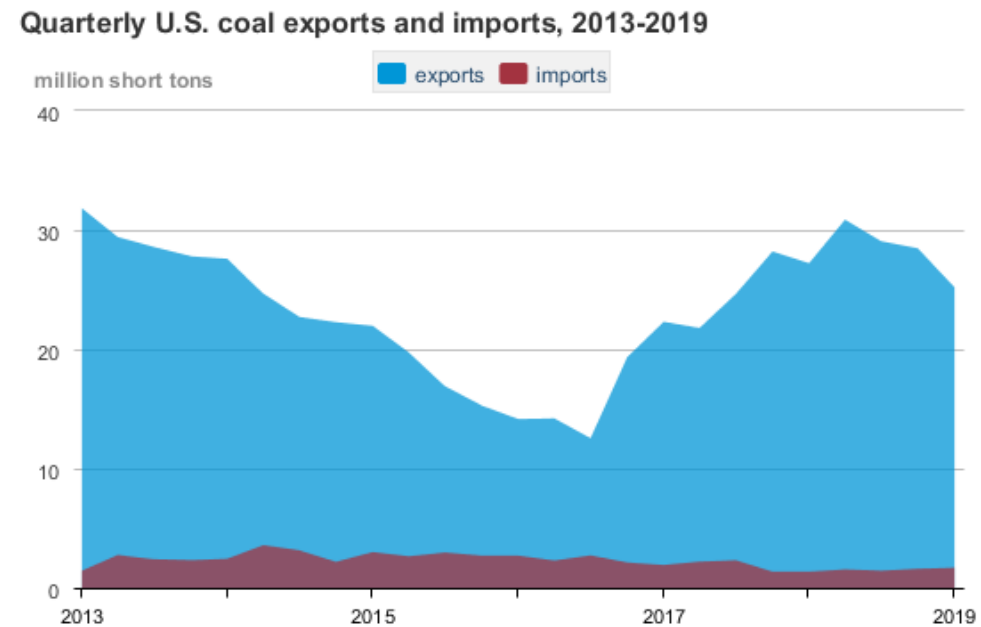
Can export be the cure?



eia Includes refuse recovery. Source: U.S. Energy Information Administration: *Quarterly Coal Report*

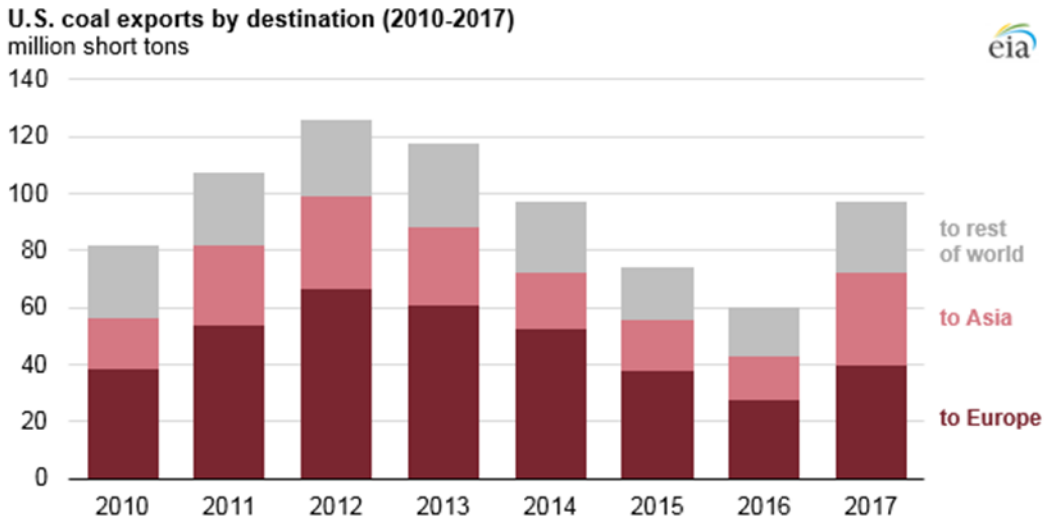


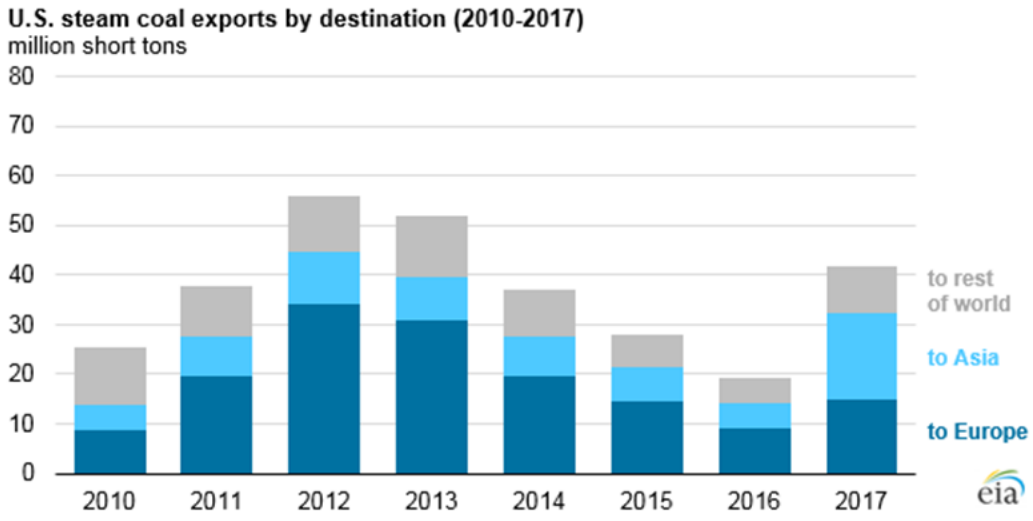
eia Source: U.S. Energy Information Administration: *Quarterly Coal Report*

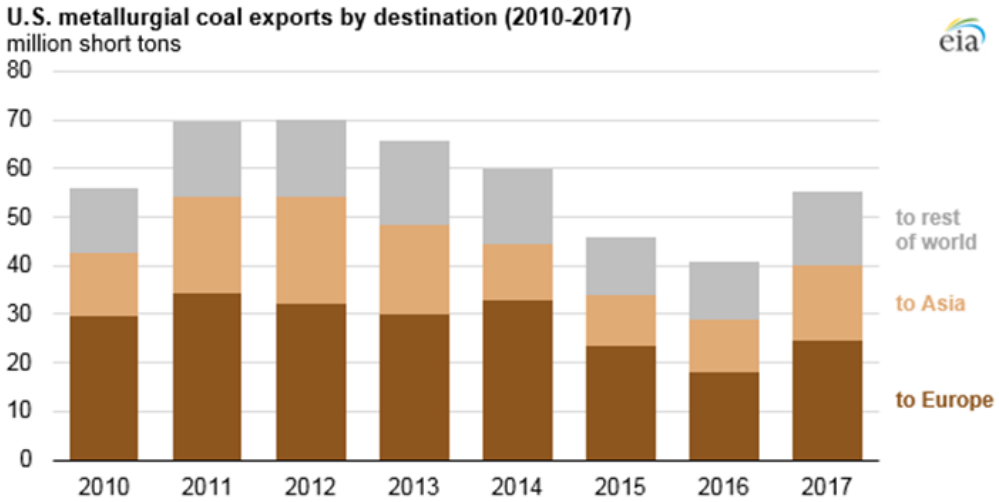


eia Source: U.S. Energy Information Administration: *Quarterly Coal Report*

Can export be the cure?







MUNI FSS

Can export be the cure?

Top destinations for US coal (metallurgical)

- Japan
- Brazil
- Ukraine
- Canada
- India
- South Korea

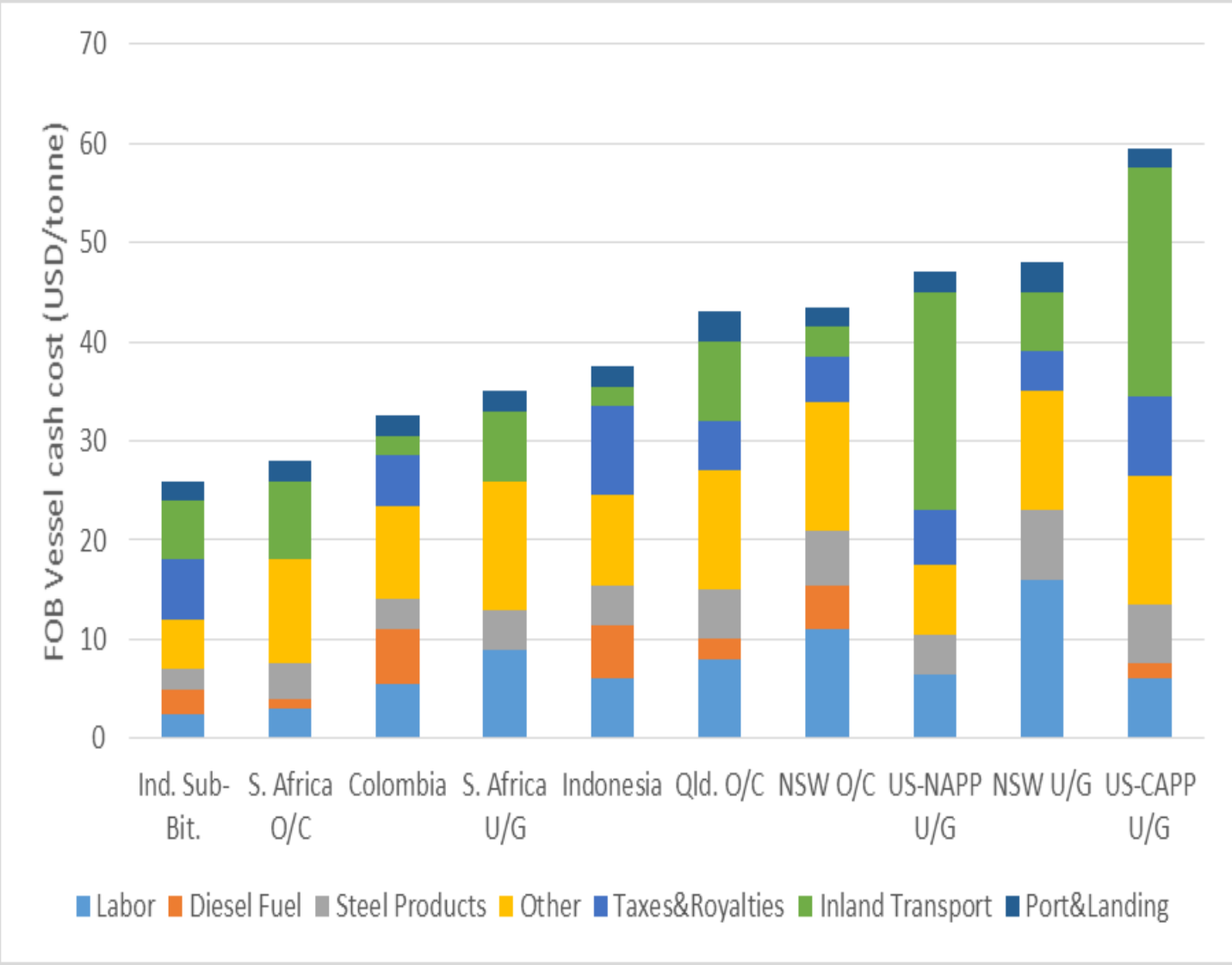
Top destinations for US coal (steam)

- S. Korea
- India
- Japan

Can export be the cure?

- Asian consumers as the future of coal consumption
- Importance of costs that increase the selling price
  - production, inland transport, taxes,... (Free-on-Board - FOB)
  - increasing production costs (no more ‘easy coal’)
  - high costs of inland transport
  - production is set to decline
- Long distance to major consumers compared to Indonesia and Australia
- S American coal has more favourable economy and is pushing to US markets

FOB costs: Comparison



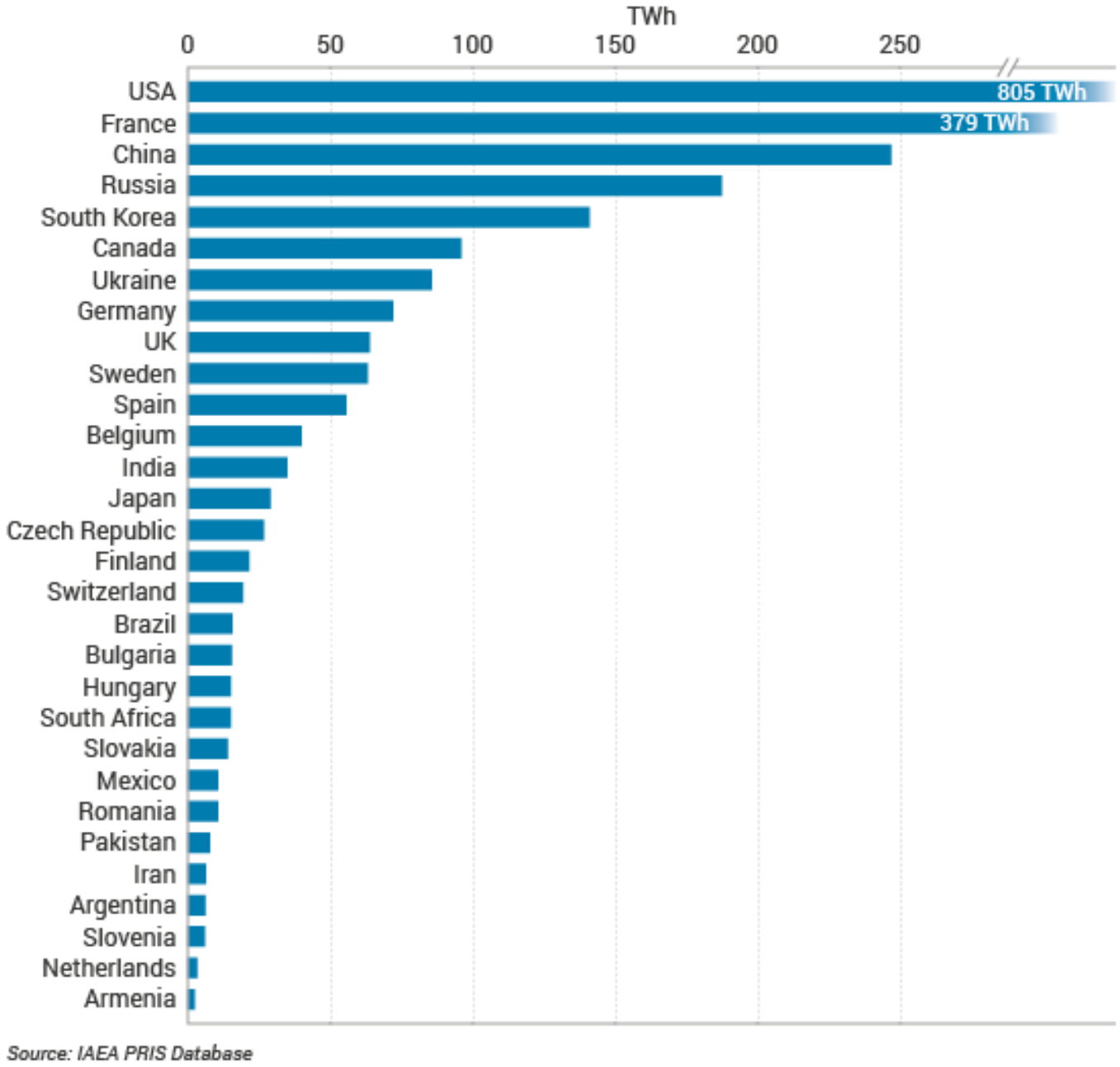
MUNI FSS

Nuclear energy

- US is the world´s biggest nuclear-based electricity producer (30% of world´s production)
- 20% of produced electricity
- 98 reactors in 30 states, 2 under construction
- Operated by 30 different companies
- Majority bulit between 1967 – 1990
  - 1953 „Atoms for Peace“
  - influence of the project Independence
  - BWR & PWR reactors
- Key role of private investments
- Chicago Pile 1 – 1st reactor (1942, Uni. of Chicago)
- Part of the Manhattan Project
- Atoms for Peace – D. Eisenhower
  - redirected the effort towards pecful utilization of atomic energy


WA
Columbia
OR
CA
Diablo Canyon 1,2
San Onofre 2,3
ID
NV
MT
WY
UT
AZ
Palo Verde 1,2,3
CO
NM
ND
SD
NE
Fort Calhoun
Cooper
KS
Wolf Creek
OK
TX
Comanche Peak 1,2
South Texas Project 1,2
MN
Monticello
Prairie Island 1,2
IA
Duanne Arnold
Quad Cities 1,2
MO
Callaway
AR
Arkansas Nuclear One 1,2
LA
River Bend
Grand Gulf 1
MS
WI
Kewaunee
Point Beach 1,2
IL
LaSalle 1,2
Clinton 1
Byron 1,2
Dresden 2,3
Braidwood 1,2
MI
Palisades
Fermi 2
Cook 1, 2
IN
OH
KY
TN
Watts Bar 1
Sequoyah 1,2
Browns Ferry 2,3
AL
Farley 1,2
GA
Vogtle 1,2
FL
Crystal River 3
St. Lucie 1,2
Turkey Point 3,4
SC
Oconee 1,2,3
Robinson 2
Summer 1
NC
McGuire 1,2
Catawba 1,2
Brunswick 1,2
Harris 1
VA
North Anna 1,2
Surry 1,2
WV
Beaver Valley 1,2
PA
Perry 1
Three Mile Island 1
Peach Bottom 2,3
Susquehanna 1,2
Limerick 1,2
Oyster Creek
Hope Creek 1
Salem 1,2
NJ
MD
Calvert Cliffs 1,2
DE
NY
FitzPatrick
Nine Mile Point 1,2
Ginna
Indian Point 2,3
CT
Millstone 2,3
MA
Pilgrim 1
VT
Vermont Yankee
NH
Seabrook
ME

MUNI FSS



Source: IAEA PRIS Database

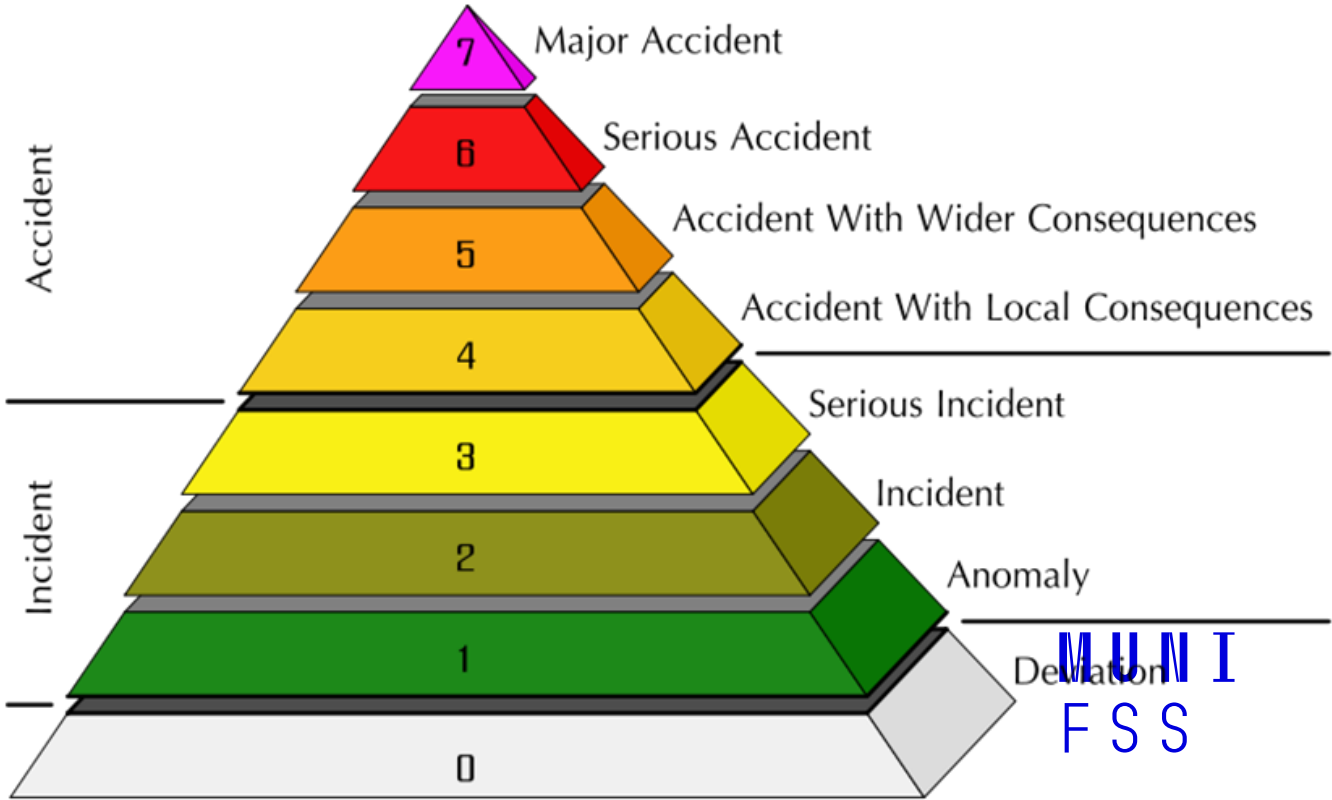
MUNI FSS

Nuclear sector – history

- US as a pioneer of research and use of nuclear fission
- Used in military – submarines and ships (development of PWR)
- Construction boom in 1960s & 1970s
- Advantage of regulated electricity market + state-owned utilities – financing was secured
  - Consumers payed the costs
- Deregulation accelerated in 1990s (EP Act of 1992)
- 1st commercially operated NPP – Shippingport, PA – 1957

Three Mile Island

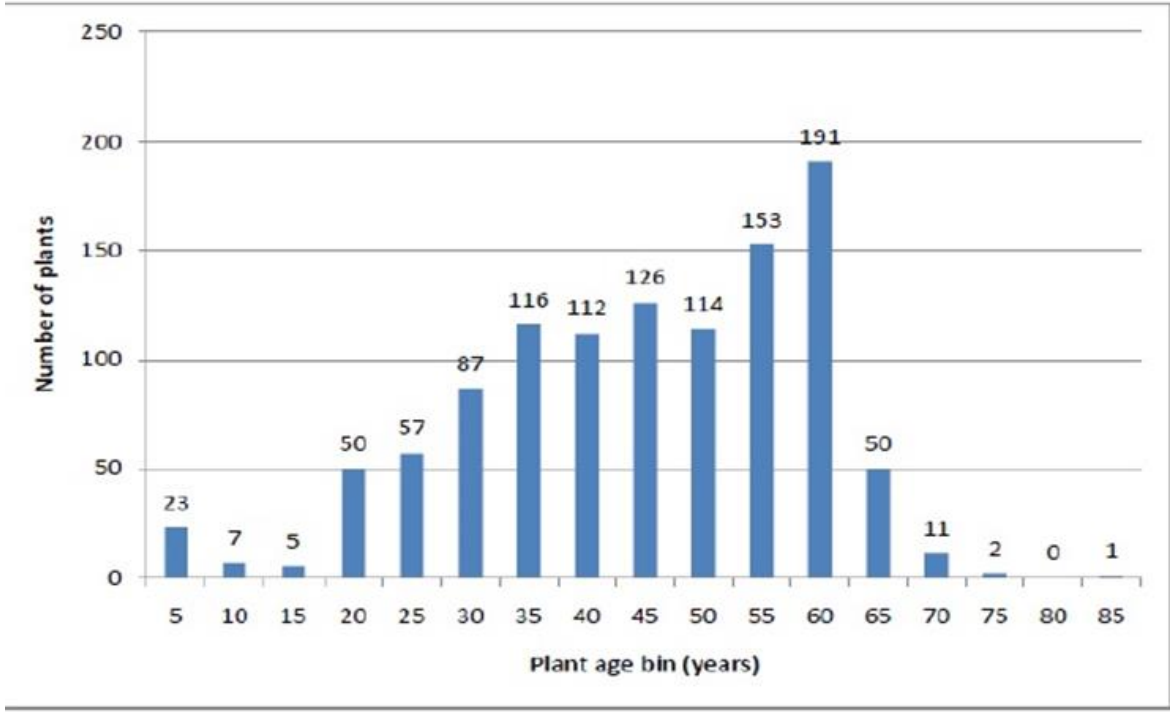
- A major setback for the industry
- 28.3.1979 – cooling section malfunction – partial meltdown of the core
- Level 5 accident of the INES scale



MUNI
FSS

Trends in the Sector

- No new projects between 1977-2013
  - economy of nuclear sources (compared to e.g. gas PPs)
  - increasing fixed costs (construction, insurance,...)
  - tightening safety measures (after TMI)
- Ageing PPs (nuclear and coal) – need investments
- NPPs life can be extended up to 60 years
- Sector is heterogenous and commercially driven
  – undermines planning
- **Energy Policy Act of 2005**
  - tax reliefs for newly installed units, state guarantees for loans and decommissioning



Trends in the Sector

- Fixed vs. Variable costs – problems of financing of the construction vs. cheap fuel and operation
- Cheap gas and RES making the NPPs´ economy unfavourable
- Ageing NPPs can theoretically be operated up to 80 years – 40 years life cycle was calculated as a life-span needed to repay the initial costs and with regard to the lifetime of the reactor vessel
- Gas-fired PPs – relatively lower investment risk given the lower initial costs
- EP Act of 2005 – substantial investment incentives for the nuclear sector – applications for new projects pilled up

Trends in the sector

- Government´s long-term (since the late 1990s) efforts to spur new projects
  - Conducted by DoE (Nuclear Power 2010, NE Research Initiative, Plant ageing, Generation IV,....)
- Problematic economy of the sector
  - low prices and uncertain return of initial costs (up to 13 reactors are considered as uneconomical and poised to close even before the end of their life expectancy)
  - deregulated market is not able to guarantee return of costs within the life-cycle of a power plant
  - rise of RES and gas – lower initial costs and more favourable economy
  - Gas-based elektricity price so low that it posesses even bigger threat to nuclear (and coal) than RES
- 3/2017 - Westinghouse filed for bankruptcy reorganization
- Higher taxation of CO2 emitting sources would help
- Given the current situation, operators are inclined to rather close the PP than to upgrade it

Trends in the sector

- Uneven deregulation
- NPP closures mostly in de-regulated states
  - yellow – deregulated power sector
  - grey – temporarily halted
  - white - regulated