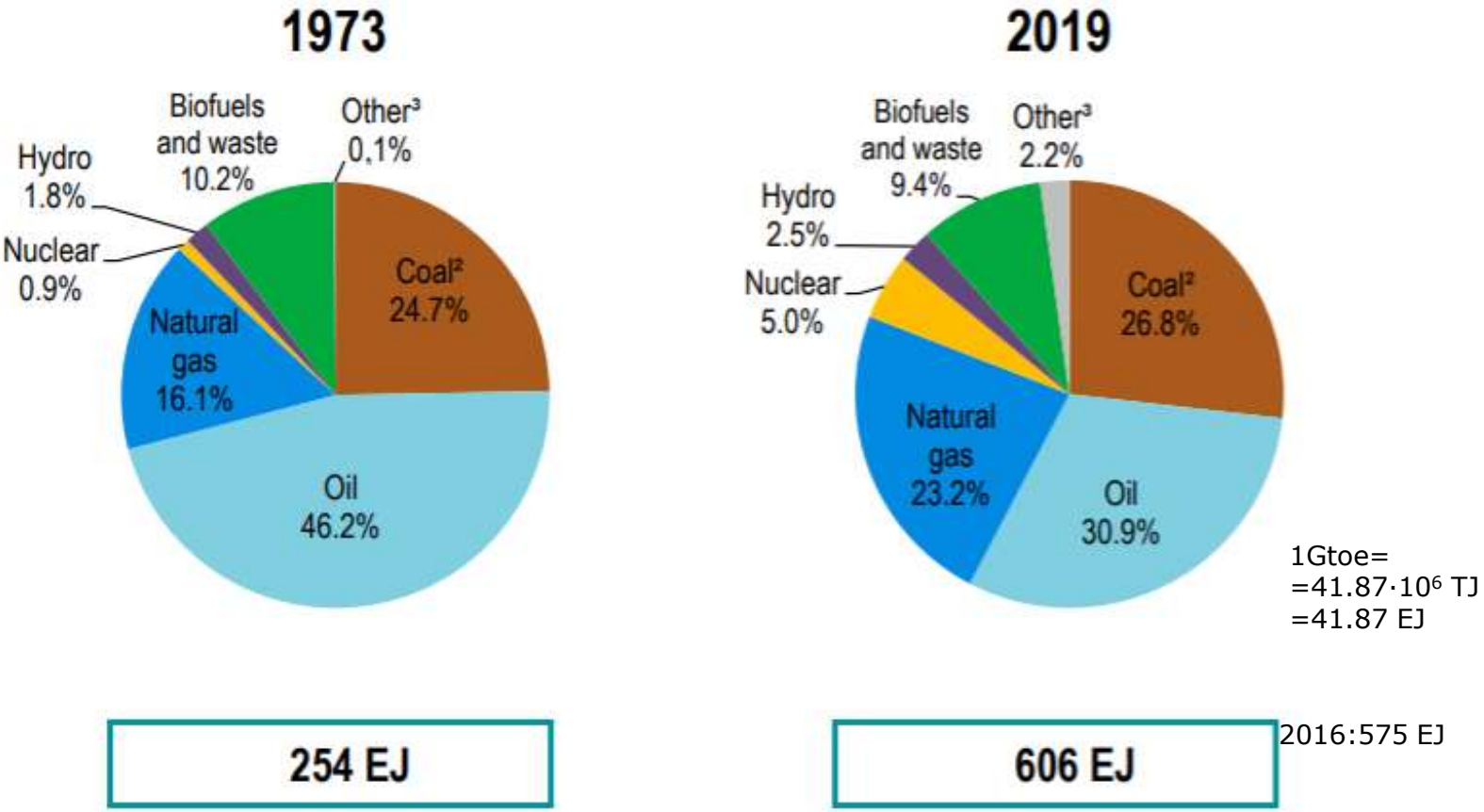

ENERGY DEMAND & SUPPLY
OUTLOOK WORLD

Agenda

- Fuels and tools in human history
- World-wide total energy supply
- World-wide energy use and projections
- Accuracy of predictions
- Resources in primary energy carriers
- Domestic fuel supply and development

World Primary Energy Supply: Fuel Shares

https://iea.blob.core.windows.net/assets/52f66a88-0b63-4ad2-94a529d36e864b82/KeyWorldEnergyStatistics2021.pdf
https://www.iea.org/data-and-statistics/data-product/world-energy-balances



1Gtoe=
$=41.87 \cdot 10^6$ TJ
=41.87 EJ

2016:575 EJ

Trends: Less use of oil more use of cleaner fossil fuel (natural gas=CH_4). Slight overall increase in burning coal (China). Large buildup in nuclear energy. Hydro has small increase. Biofuels = traditional wood, dung, waste, …. , corn ethanol, biodiesel

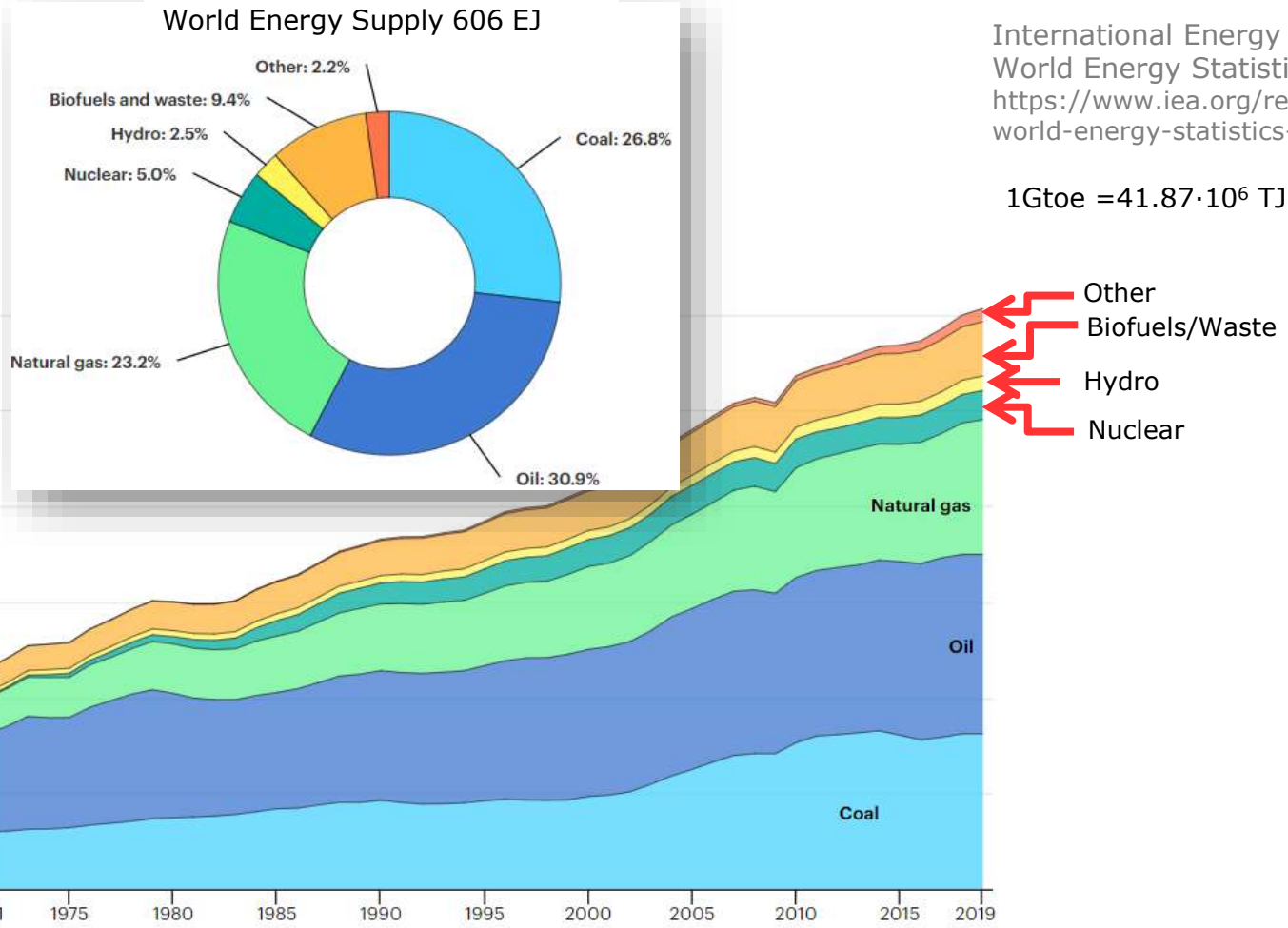
Conversion Factors For Energy Units

To:	TJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
TJ	1	2.388×10^{2}	2.388×10^{-5}	9.478×10^{2}	2.778×10^{-1}
Gcal	4.187×10^{-3}	1	1.000×10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.187×10^{4}	1.000×10^{7}	1	3.968×10^{7}	1.163×10^{4}
MBtu	1.055×10^{-3}	2.520×10^{-1}	2.520×10^{-8}	1	2.931×10^{-4}
GWh	3.600	8.598×10^{2}	8.598×10^{-5}	3.412×10^{3}	1

1 quad $= 10^{15}$ BTU (a short-scale quadrillion)

$= 1.055 \times 10^{18}$ J = 1.055 EJ (in SI units).

World Total Primary Energy Supply (TPES)



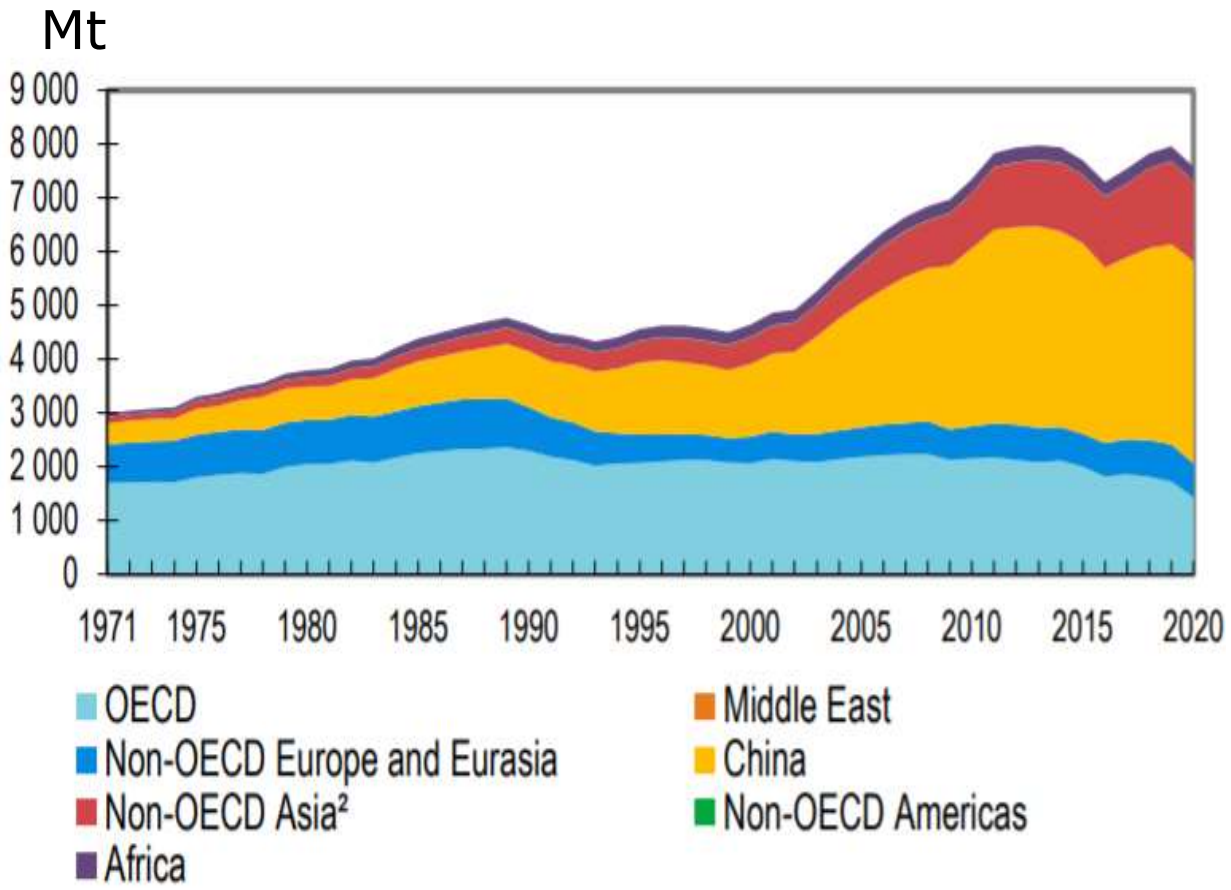
International Energy Agency: Key World Energy Statistics 2019
https://www.iea.org/reports/key-world-energy-statistics-2021/supply

1Gtoe =41.87·10⁶ TJ=41.87 EJ

BAU policies: Trend towards proportional use of traditional fossil fuels (Coal, oil, nat gas). Small fractions in nuclear, hydro, renewables.

→ Changes to new policies (Paris agreement, COP 24 → COP26)

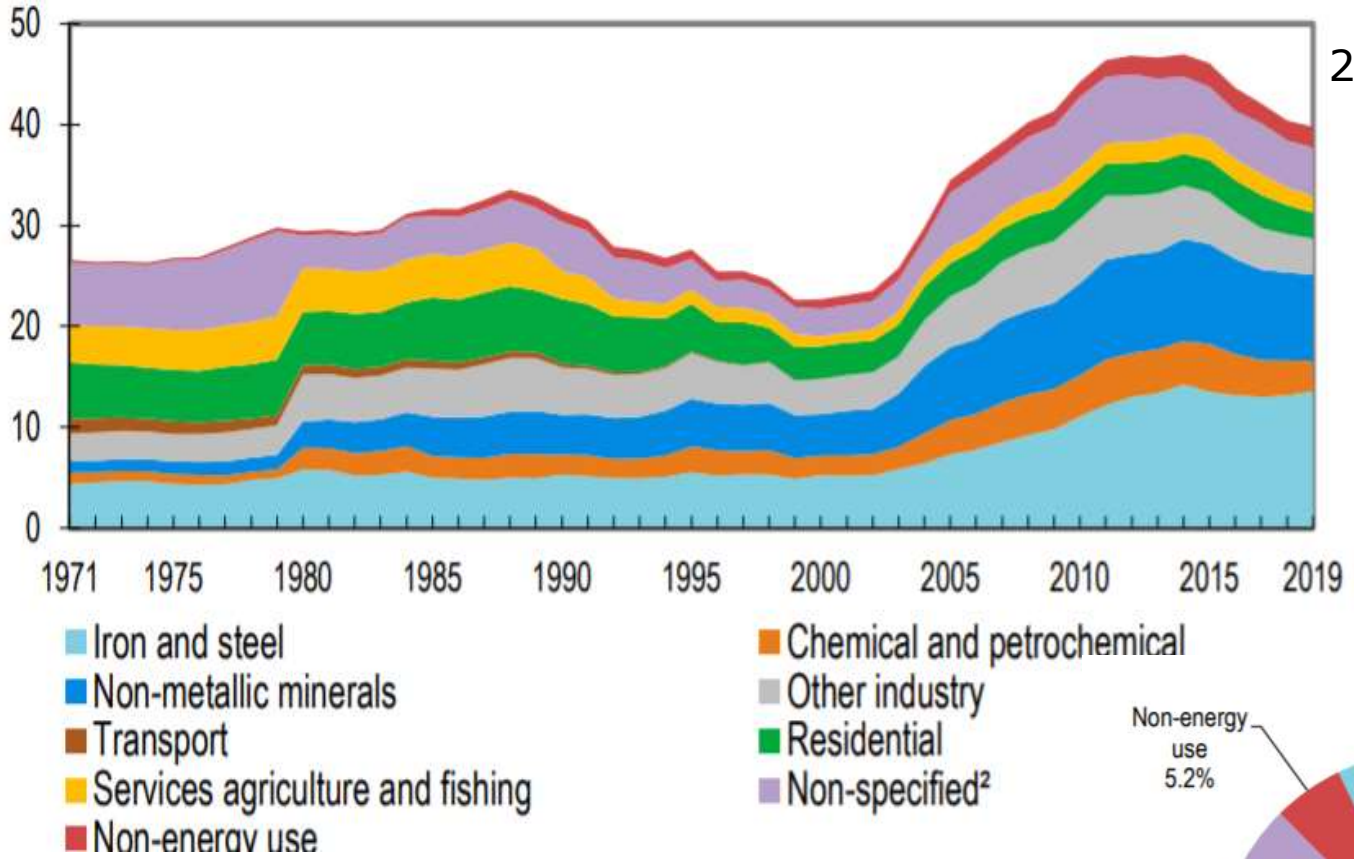
World Coal Production



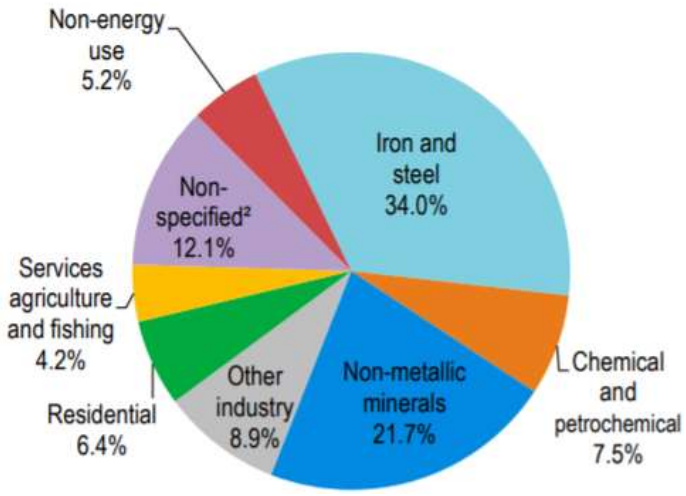
Producers	Mt	% of world total
People's Rep. of China	3 764	49.7
India	760	10.0
Indonesia	564	7.4
Australia	493	6.5
United States	485	6.4
Russian Federation	398	5.3
South Africa	247	3.3
Germany	107	1.4
Poland	101	1.3
Kazakhstan	100	1.3
Rest of the world	556	7.4
World	**7 575**	**100.0**

2020 provisional data

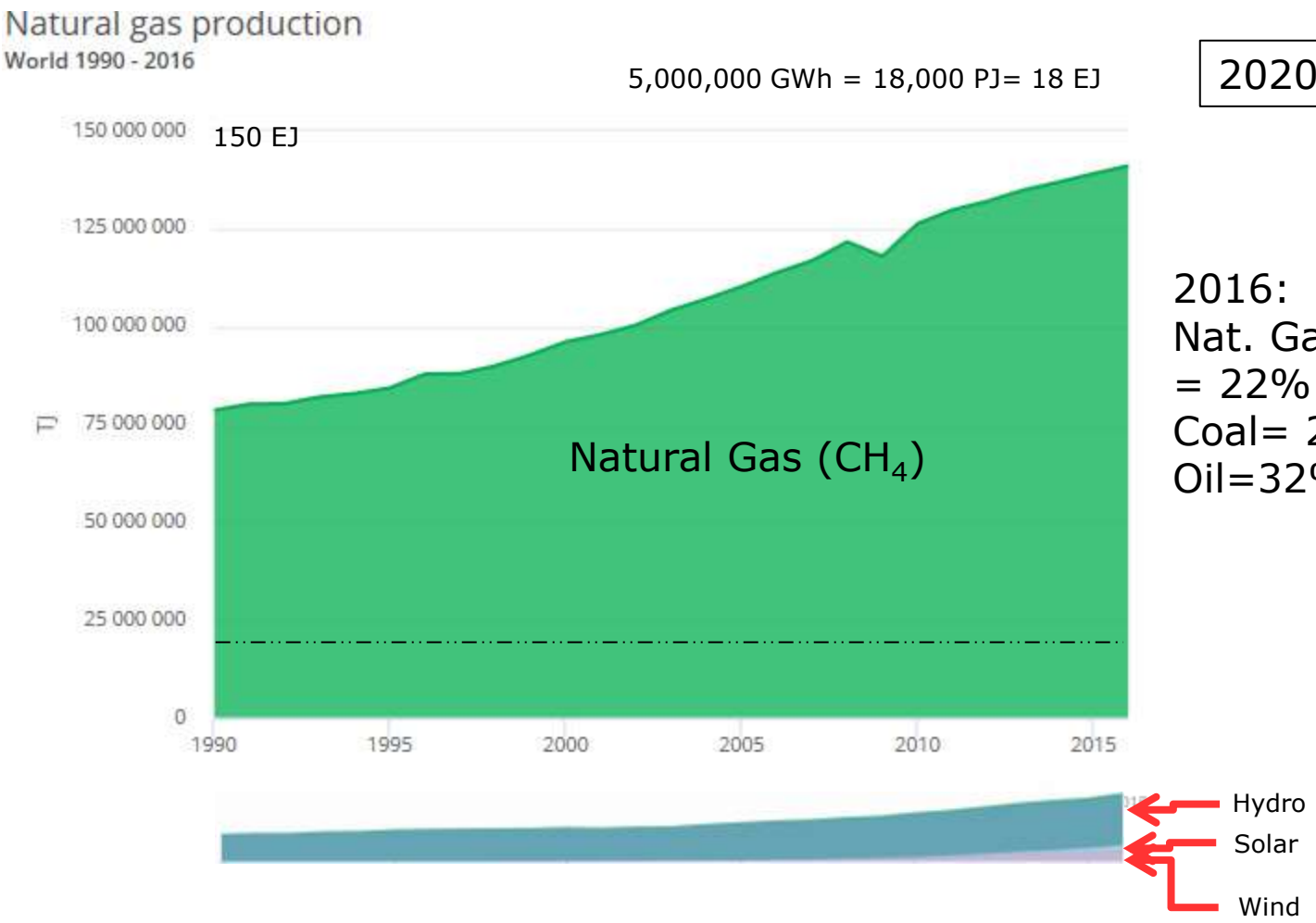
World Coal Use by Sector



2019: 40EJ



World Specific Primary Energy Supply



New policies: Trend towards greater use of cleaner fossil fuels (CH_4)
Increased use of low-carbon fuels such as renewables, hydro and nuclear, most notable in OECD countries (minus US for now)

Nat Gas: Producers-Export-Import

Producers	bcm	% of world total
United States	949	23.6
Russian Federation	722	18.0
Islamic Rep. of Iran	235	5.9
People's Rep. of China	191	4.8
Canada	184	4.6
Qatar	167	4.2
Australia	148	3.7
Norway	116	2.9
Saudi Arabia	99	2.5
Algeria	92	2.3
Rest of the world	1 111	27.5
World	**4 014**	**100.0**

2020 provisional data

Net exporters	bcm
Russian Federation	230
Qatar	127
Norway	111
Australia	103
United States	77
Turkmenistan	56
Canada	47
Algeria	41
Nigeria	27
Malaysia	22
Others	176
Total	**1 017**

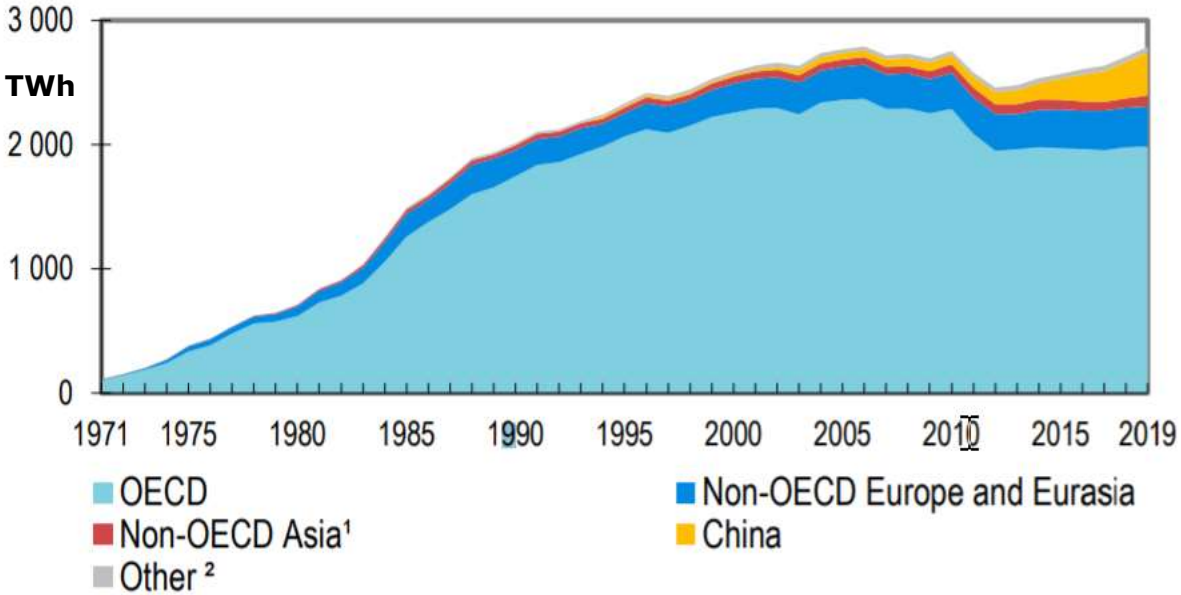
2020 provisional data

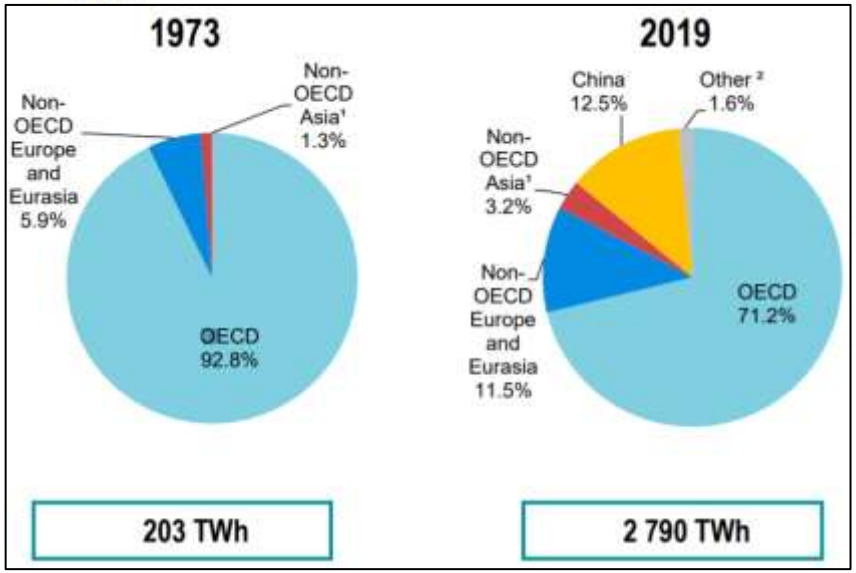
Net importers	bcm
People's Rep. of China	125
Japan	105
Germany	83
Italy	66
Mexico	64
Korea	54
Turkey	47
France	37
United Kingdom	34
India	34
Others	324
Total	**973**

2020 provisional data

https://iea.blob.core.windows.net/assets/52f66a88-0b63-4ad2-94a5-29d36e864b82/KeyWorldEnergyStatistics2021.pdf

World Nuclear Electricity Production

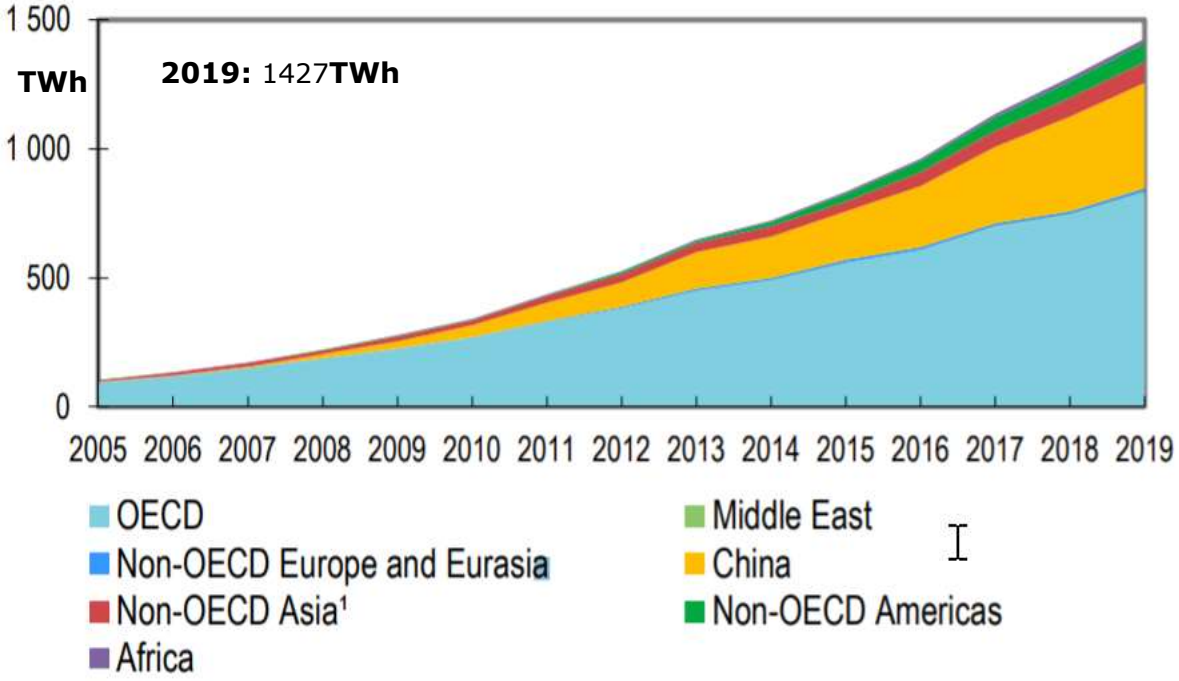




Producers	TWh	% of world total
United States	843	30.2
France	399	14.3
People's Rep. of China	348	12.5
Russian Federation	209	7.5
Korea	146	5.2
Canada	101	3.6
Ukraine	83	3.0
Germany	75	2.7
Sweden	66	2.4
Japan	64	2.3
Rest of the world	456	16.3
World	**2 790**	**100.0**

2019 data

World Wind Energy Production



World Wind Energy Share

Producers	TWh	% of world total
People's Rep. of China	406	28.4
United States	298	20.9
Germany	126	8.8
India	70	4.9
United Kingdom	64	4.5
Brazil	56	3.9
Spain	56	3.9
France	35	2.4
Canada	33	2.3
Turkey	22	1.5
Rest of the world	262	18.5
World	**1 427**	**100.0**

2019 data

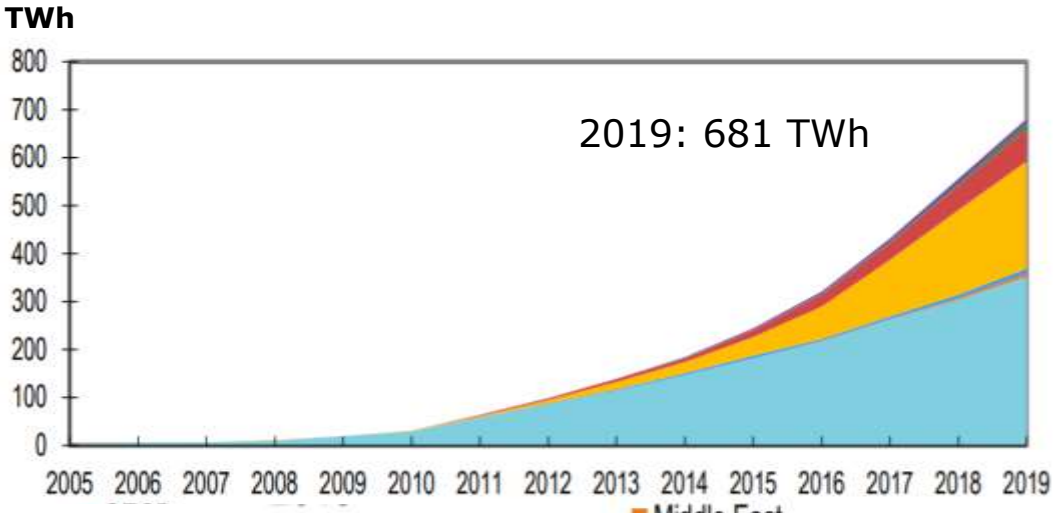
Net installed capacity	GW
People's Rep. of China	210.3
United States	103.7
Germany	60.9
India	37.7
Spain	25.5
United Kingdom	24.0
France	16.3
Brazil	15.4
Canada	13.4
Italy	10.7
Rest of the world	105.1
World	**622.9**

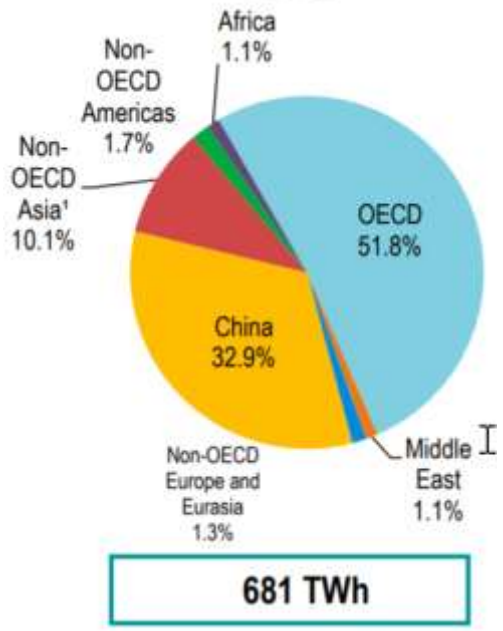
2019 data

Country (top-ten producers)	% of wind in total domestic electricity generation
Germany	20.7
Spain	20.4
United Kingdom	19.9
Brazil	8.9
Turkey	7.2
United States	6.8
France	6.1
People's Rep. of China	5.4
Canada	5.1
India	4.3
Rest of the world[1]	3.0
World	**5.3**

2019 data

World Solar-PV Electricity Production





Country (top-ten producers)	% of solar PV in total domestic electricity generation
Italy	8.1
Germany	7.6
Japan	6.6
Australia	5.6
United Kingdom	4.0
India	3.1
People's Rep. of China	3.0
Korea	2.2
United States	2.1
France	2.1
Rest of the world[1]	1.3
World	**2.5**

2019 data

U.S. Energy Consumption (2011)

Energy and economic factors	2010	2011
Primary energy production (quadrillion Btu)	(**Quads**)	
Petroleum	14.37	15.05
Dry natural gas	21.82	23.51
Coal	22.04	22.21
Nuclear/Uranium	8.43	8.26
Hydropower	2.54	3.17
Biomass	4.05	4.05
Other renewable energy	1.31	1.58
Other	0.76	1.20
Total	**75.31**	**79.02**
Net imports (quadrillion Btu)		
Liquid fuels and other petroleum[a]	20.53	18.62
Natural gas (- indicates exports)	2.69	2.02
Coal/other (- indicates exports)	-1.58	-2.32
Total	**21.64**	**18.31**
Consumption (quadrillion Btu)		
Liquid fuels and other petroleum[a]	37.76	37.02
Natural gas	24.32	24.91
Coal	20.81	19.66
Nuclear/Uranium	8.43	8.26
Hydropower	2.54	3.17
Biomass	2.87	2.74
Other renewable energy	1.31	1.58
Other	0.31	0.35
Total	**98.35**	**97.70**

Customary Energy Units

1 Quad= 1 quadrillion Btu =

$1.05505585 \times 10^{18}$ J ≈ 1.06 EJ

Mbpd: million barrels per day (liquid)

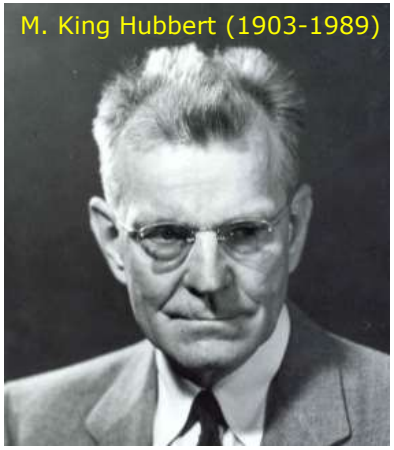
Tcf: terra cubic feet (gas)

Mst: million short tonnes (solid)

Not including unconventional sources

	2010	2011
Liquid fuels (million barrels per day)		
Domestic crude oil production	5.47	5.67
Other domestic production	4.25	4.74
Net imports	9.43	8.51
Consumption	19.17	18.95
Natural gas (trillion cubic feet)		
Dry gas production + supplemental gas	21.40	23.06
Net imports (- indicates exports)	2.60	1.95
Consumption	23.78	24.37
Coal (million short tons)		
Production and waste coal	1,098	1,108
Net exports	64	96
Consumption	1,049	999

Challenges in Predicting an Accurate Future

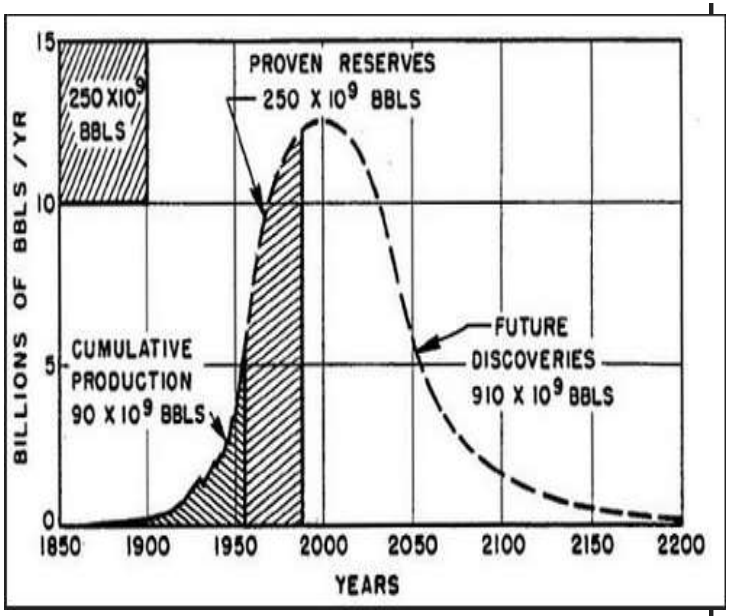


Geophysicist M. King Hubbert predicted in 1956 that U.S. oil production would reach its highest level in the early 1970s.

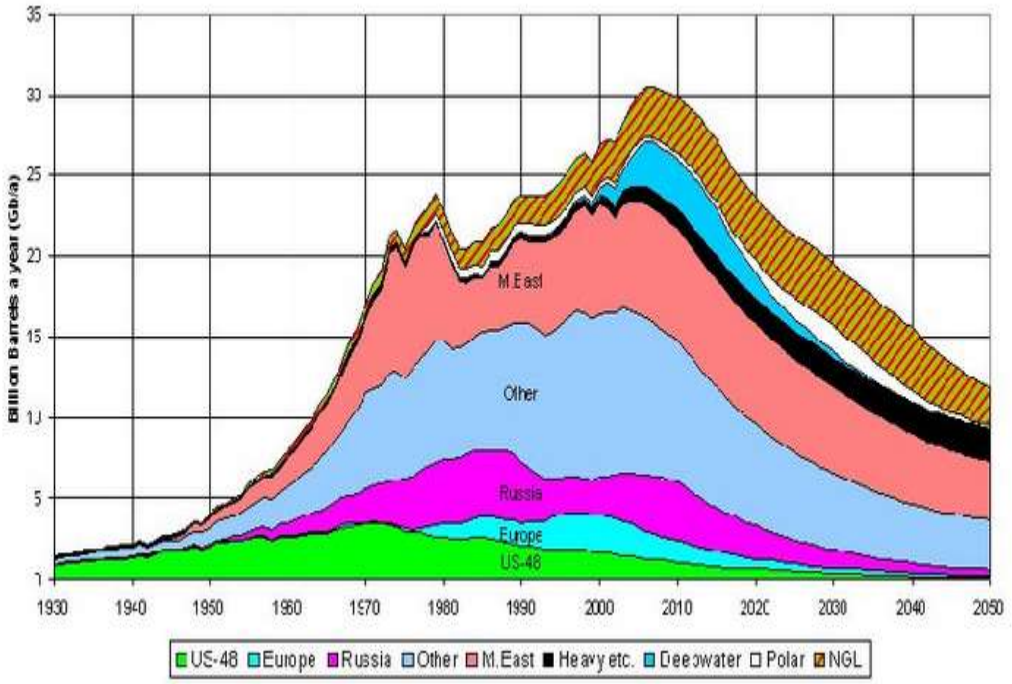
Hubbert's simplified scenario:

1. Production starts at zero;
2. Production then rises to a peak which can never be surpassed;
3. Once the peak has been passed, production declines until the resource is depleted.

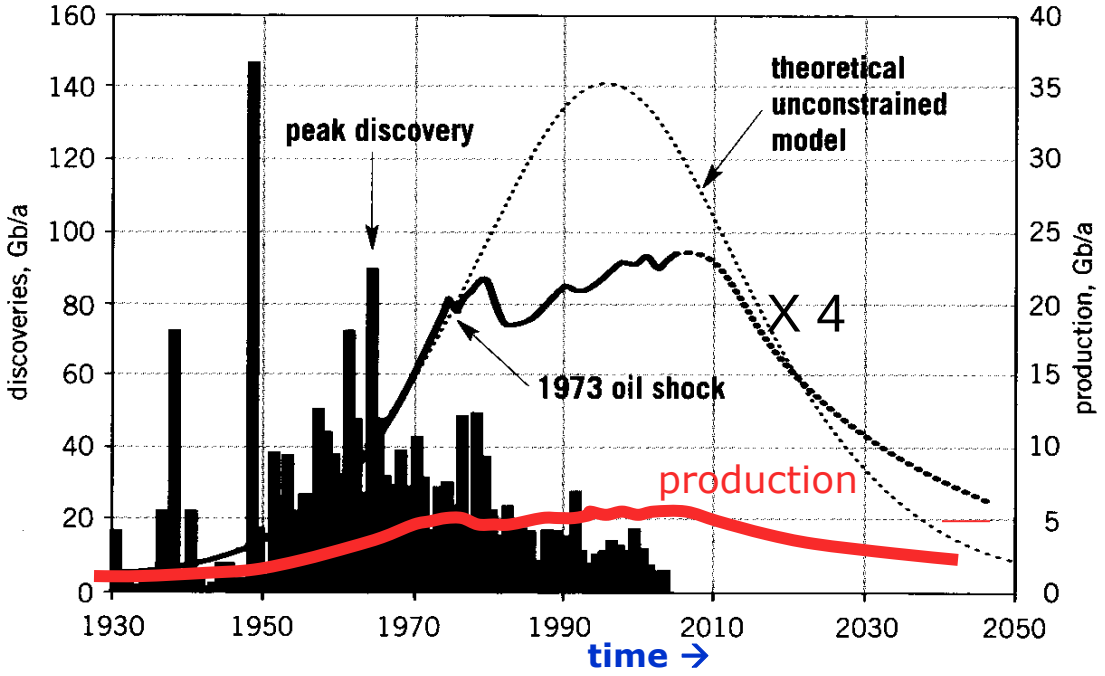
Assumed Gaussian Production Profile

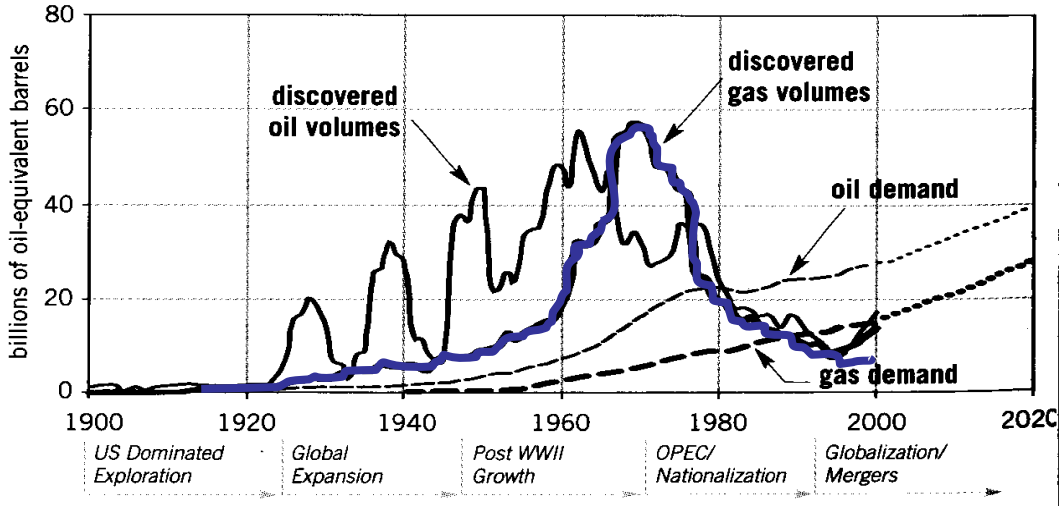


World Oil & Gas Scenario 2004 & Outlook



Hubbert's Peak: Finite Fossil Energy Resources





Yesterday's wisdom:

Most existing oil and gas fields have already been discovered.

Major new discoveries not expected (world-wide)

Oil companies have not built any new refineries in > 30 years. No confidence in future!

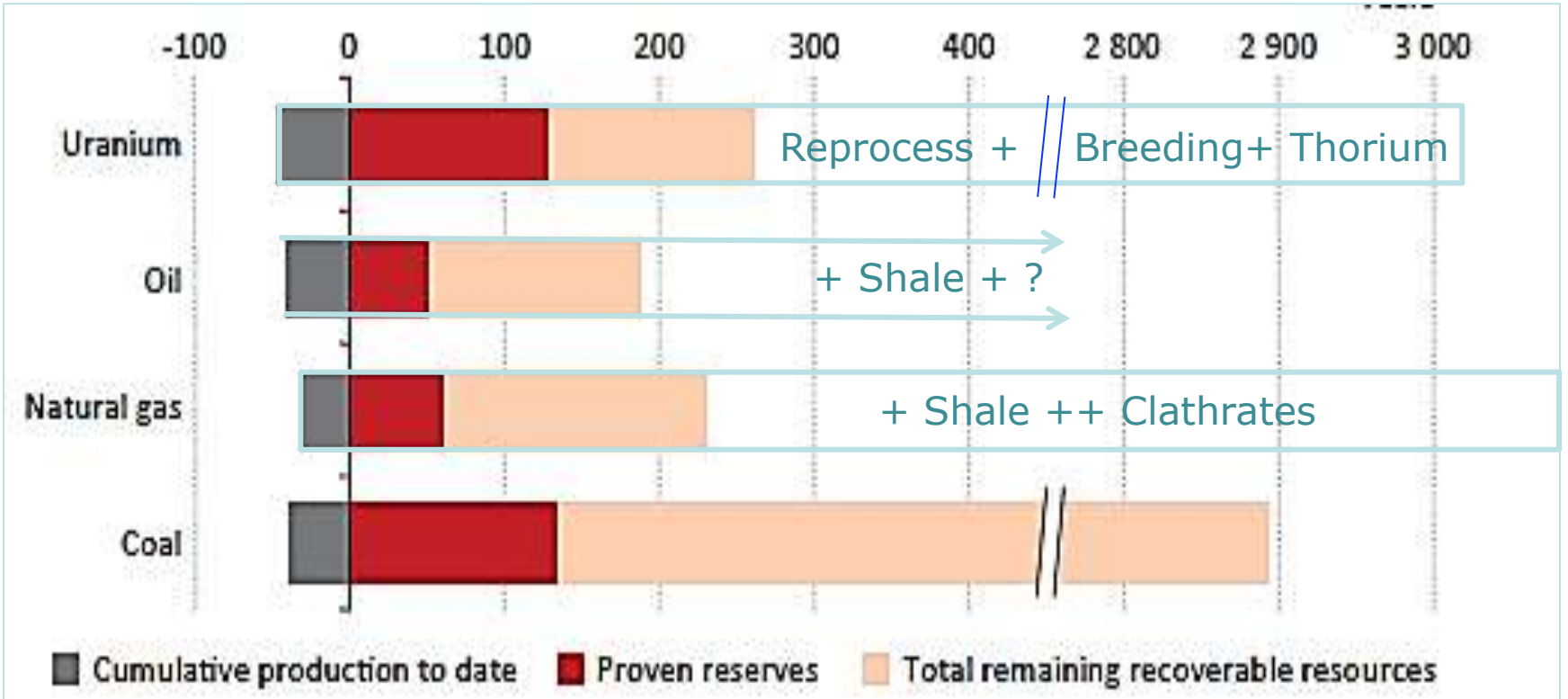
"World will run out of conventional oil, gas & coal within 1-2 human generations."

Maybe not (?!)

Depletion rates have been overestimated, political reporting by governments,

Neglected: Asynchronous investment/demand cycles, new technologies, unconventional resources profitable at >$ thresholds

World Primary Energy Resources

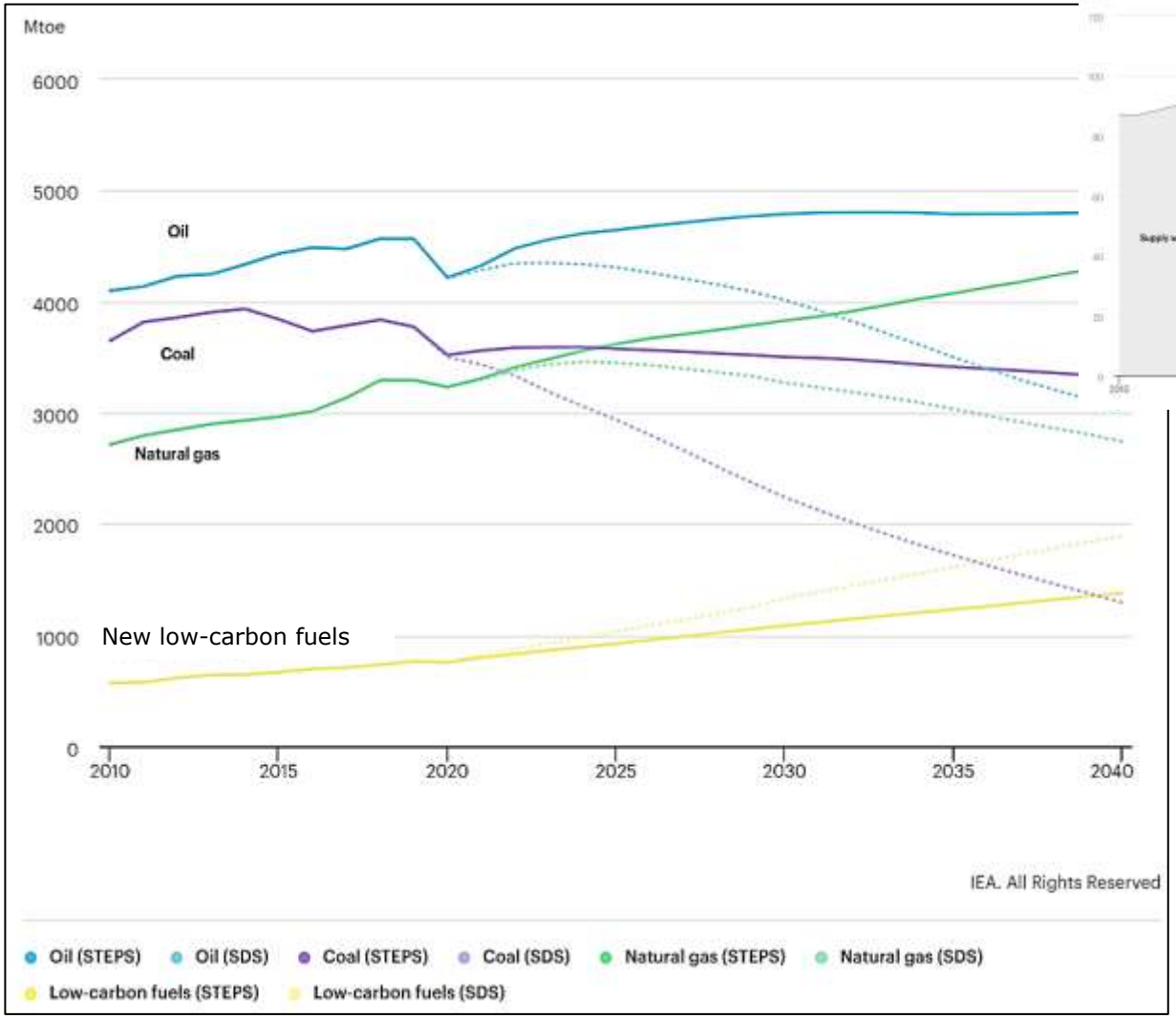


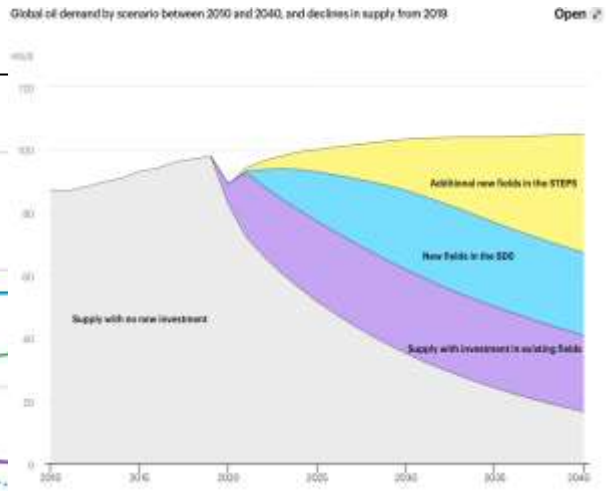
Modified after IEA World Outlook 2014, in light lettering: use reprocessing + U-238 breeding, Th 232 fertile fuel,

unconventional gas (fracking) + clathrates in frozen environments.

Neglect losses in reprocessing and breeding. Assumed present rate of consumption in future.

Global Fuel Supply-Outlook





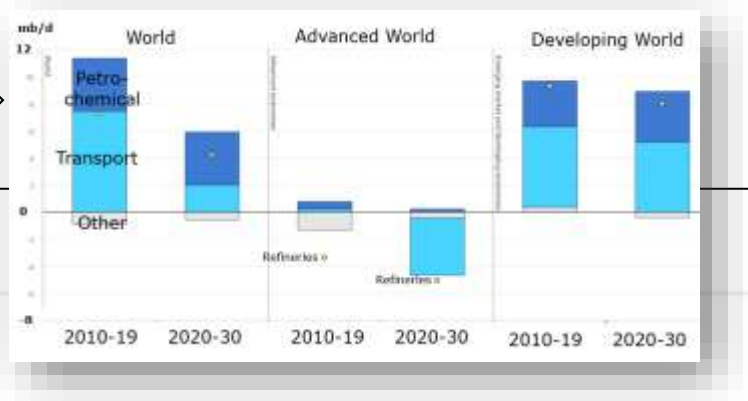
2020 situation due to Covid-19 induced GDP decline.

Future developments extrapolated from historical trends (~decades) but offset, depending on speed of economic recovery.

Dotted: required for sustainability.

Outlook Global Oil Demand-Scenarios

Changes acc. policies



2020 situation due to Covid-19 induced GDP decline.

Future developments extrapolated from historical trends (~decades) but offset, depending on speed of economic recovery.

Summary: World Primary Energy Reserves & Uses

Reserves

- Proven and estimated fossil, nuclear, renewable energy resources are plentiful, centuries at current consumption rates.
- New hydro-electrical resources are limited
- Sustained or increased production requires new investments
-

Future developments extrapolated from historical trends (~decades)

- Use of coal for energy will slightly decrease
- Development of oil and gas resources continues to increase, specifically for natural gas and LNG.
  Oil has large uncertainties, will depend on price and geo-political environment
- Development of nuclear power is region-specific, overall slow
- Development of renewable wind and solar technologies is region-specific, overall slow, small (<1%) share in overall electricity production.
- New transportation fuels are under R&D development