Lomonosov Moscow State University
Business School

Global Limits of Economic Growth

Lomonosov Moscow State University,
Inter-Departmental Course, 2024-2025, Spring Fall

Course Reader:

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Requirements to Pass the Course

1) At least 50% of sessions are attended (6 sessions)

2) At least 60% points for the final course test

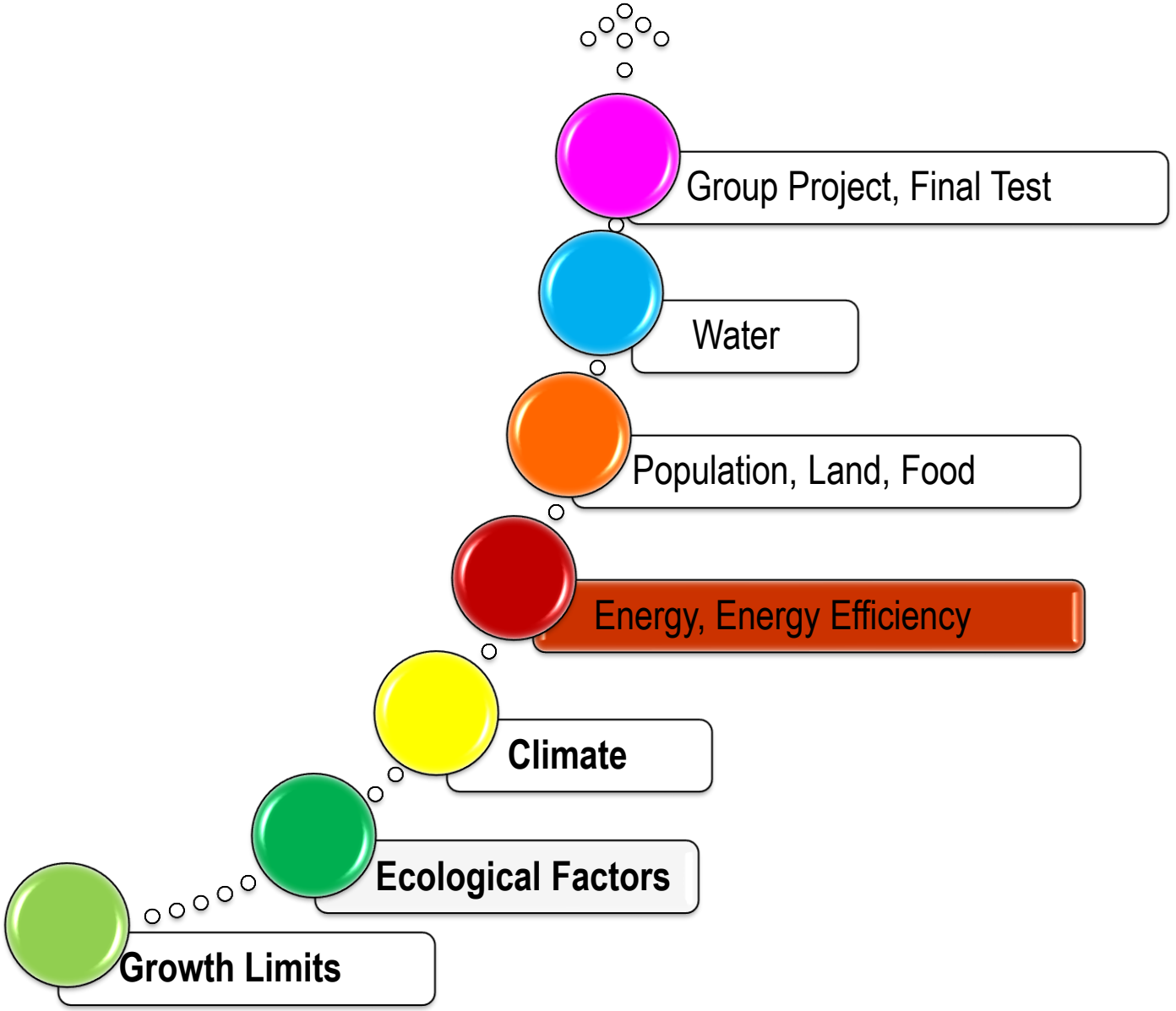
3) Individual Project (Presentation) is done properly and delivered in time

General Scheme for Resource Limitations Analysis

Scheme for the Individual Project (1-2 students per 1 project)

Resources	Steps of Analysis					
	Step 1	Step 2			Step 3	Step 4
	Role/ Importance	Limitations produced for			Ways used to overcome existing limitations	Suggestions how to improve these ways of coping with limitations
		World economy	National economy	Industries/ Business		
Unique Resource or Problem selected by you *Scale: world or a country or an industry*	...	...	...	...	...	...

Course Route



Pre-Reading and Food-for-Thought Assignment before and after Session 6 (March, 26)

RENEWABLES

1) What kind of data is presented in BP Statistical Reviews of World Energy (bp.com or https://www.bp.com/en/global/corporate/energy-economics/energy-outlook.html) regarding renewables?
2) What are the actual trends in this area?

Read the Situation Analysis "Brazil and Biofuels"

1) What were advantages and disadvantages of producing biofuels in Brazil?
2) What kind of measures to improve existing benefits and to reduce possible risks do you see?

Read the abstract of from Perkins J. "Confessions of an Economic Hit Man" (Chapter 33, pp.196-202):

1) What were positive and negative social and economic effects of oil dependence for Venezuela at different times?
2) How was the energy security understood by Chavez government and by multinational companies?

CHAPTER 33

Venezuela: Saved by Saddam

I had watched Venezuela for many years. It was a classic example of a country that rose from rags to riches as a result of oil. It was also a model of the turmoil oil wealth foments, of the disequilibrium between rich and poor, and of a country shamelessly exploited by the corporatocracy. It had become the epitome of a place where old-style EHMs like me converged with the new-style, corporate version.

The events I read about in the newspaper that day at Grour Zero were a direct result of the 1998 elections, when the poor disenfranchised of Venezuela elected Hugo Chávez by a landsl their president.[1] He immediately instituted drastic measures control of the courts and other institutions and dissolving zuelan Congress. He denounced the United States for its imperialism," spoke out forcefully against globalization, a a hydrocarbons law that was reminiscent, even in n Jaime Roldós had brought to Ecuador shortly be went down. The law doubled the royalties charge panies. Then Chávez defied the traditional state-owned oil company, Petróleos de Vene top executives with people loyal to him.[2]

ILO climate change and employment

Case study no. 1

Brazil and biofuels

February 2008

Introduction

Increasing developments in how best to address climate change – through mitigation and adaptation have in some cases led to aggressive market responses, none more so than in the rapid growth of the global biofuels industry. Analysts forecast that the global annual biofuel capacity will double to 25 billion gallons over the next five years and could reach 80 billion gallons by 2020 (Riese, 2007).

This recent boom in biofuel production is generating vigorous debate on social, economic and environmental grounds. This case study will examine the impact of climate change on livelihoods and employment, by looking at Brazil's rapidly growing biofuel industry and its impact on agriculture and poverty reduction.

Biofuels

Global production of biofuels reached 20 million tons of oil equivalents (Mtoe) in 2005, representing about 1% of total road transport fuel energy consumption (International Energy Agency, 2007). Brazil and the United States together account for 90% (GTZ *et al.*, 2006) of global supply. Ethanol production is increasing rapidly in many parts of the world due to higher oil prices, climate change, government incentives, increasing availability of flex fuel cars, and mandates on fuel blending.

Biofuels are liquid, solid or gas fuels derived from biomass, either from recently living organisms or from their metabolic waste. Biomass refers to organic matter made from plants and animals. (For an explanation of first- and second generation biofuels see Box 1.)

Brazil's ethanol experience

Session 6

Energy Resources and Energy Demand-Supply

2025

The Aims of the Session 6

1. To know basic information on the World Market of Energy Resources (types, dominating resources, trends)
2. To know peculiarities of different energy indicators and be able to interpret them correctly
3. To assess the effect of alternative energy sources comprehensively

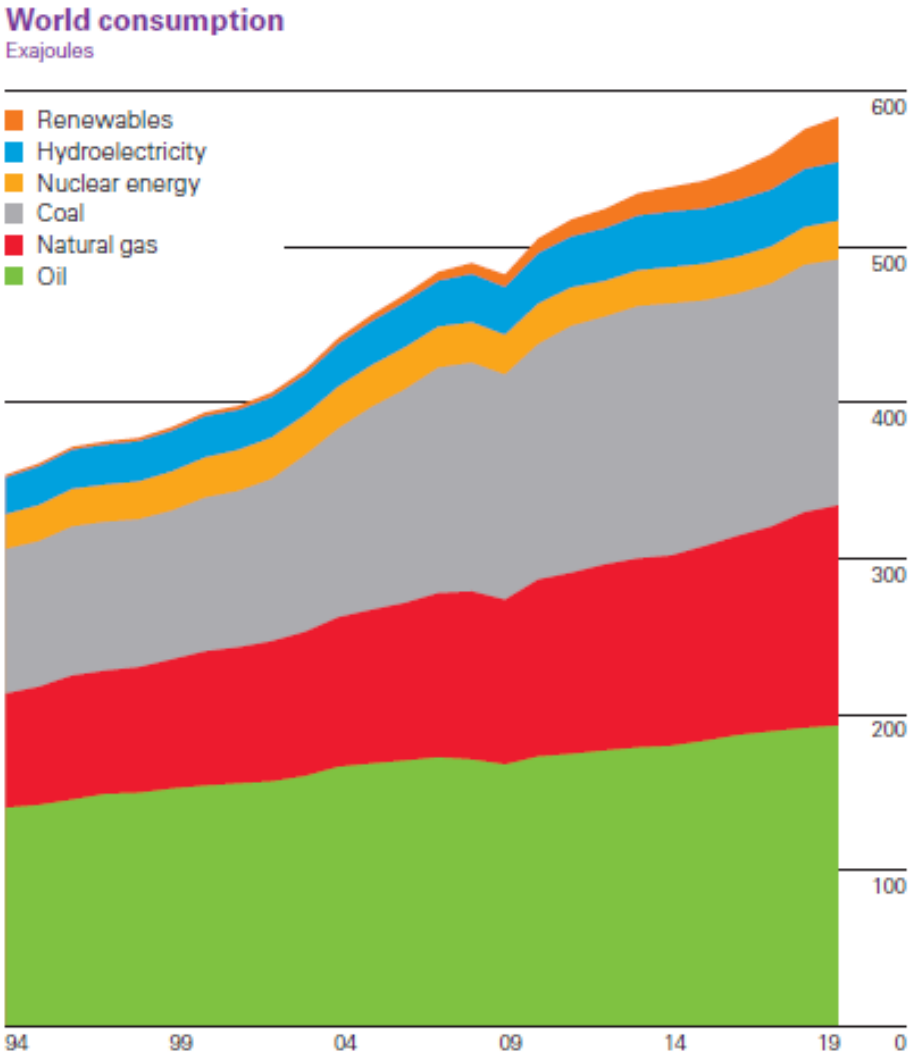
PLAN of the Session 6

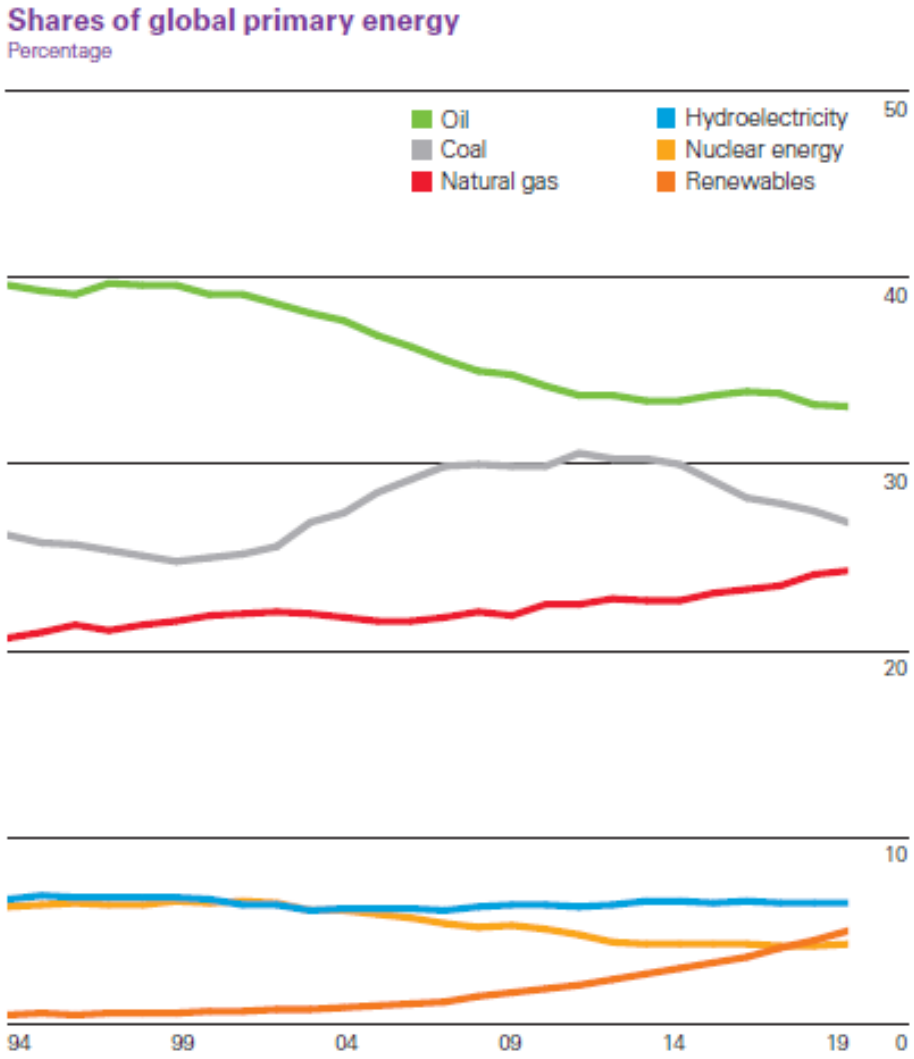
1. World Market of Energy Resources

2. Energy Intensity of Different Economies and Industries

3. Alternative Energy Sources vs. Nonrenewables

World Primary Energy Sources

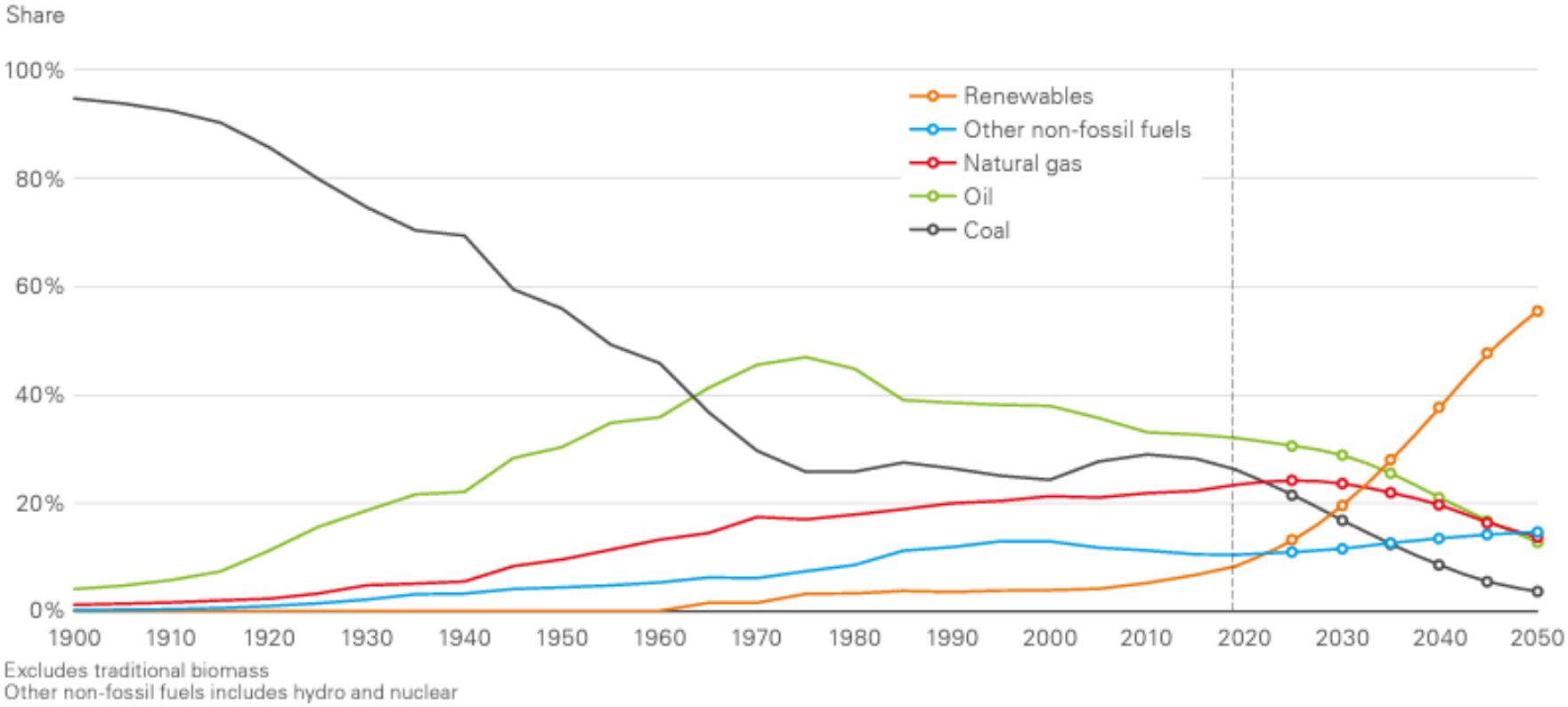




Source: BP Statistical Review of World Energy, 2020

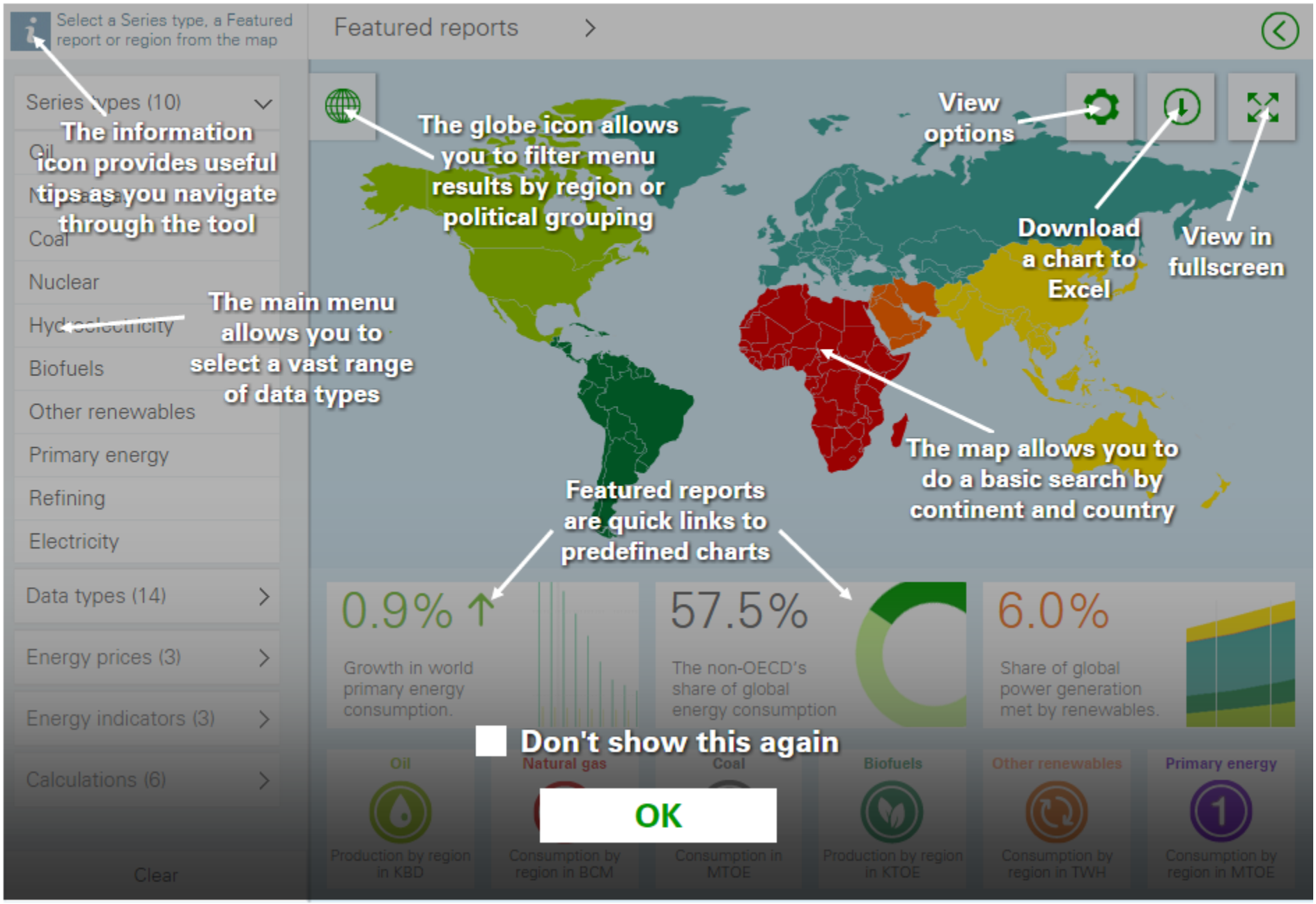
Changing nature of global energy markets: more diverse energy mix, increased competition and greater customer choice

Share of primary energy in *Accelerated*



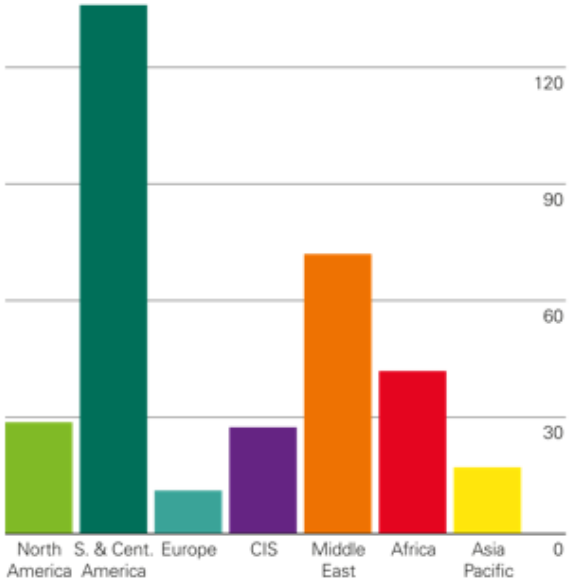
Source: BP Statistical Review of World Energy, 2023.

Energy charting tool



R/P ration of … Coal, Oil, Gas

?



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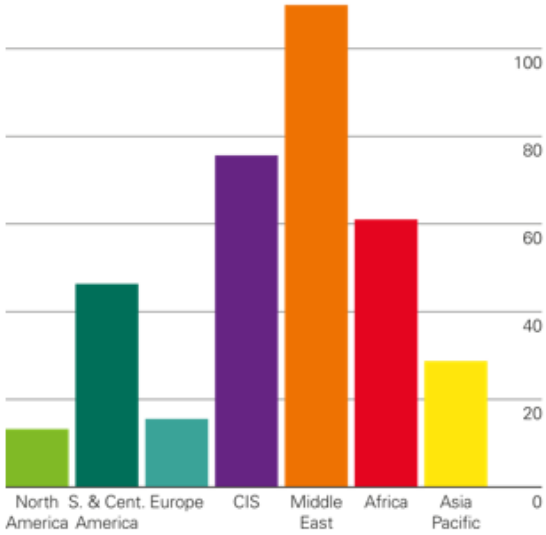

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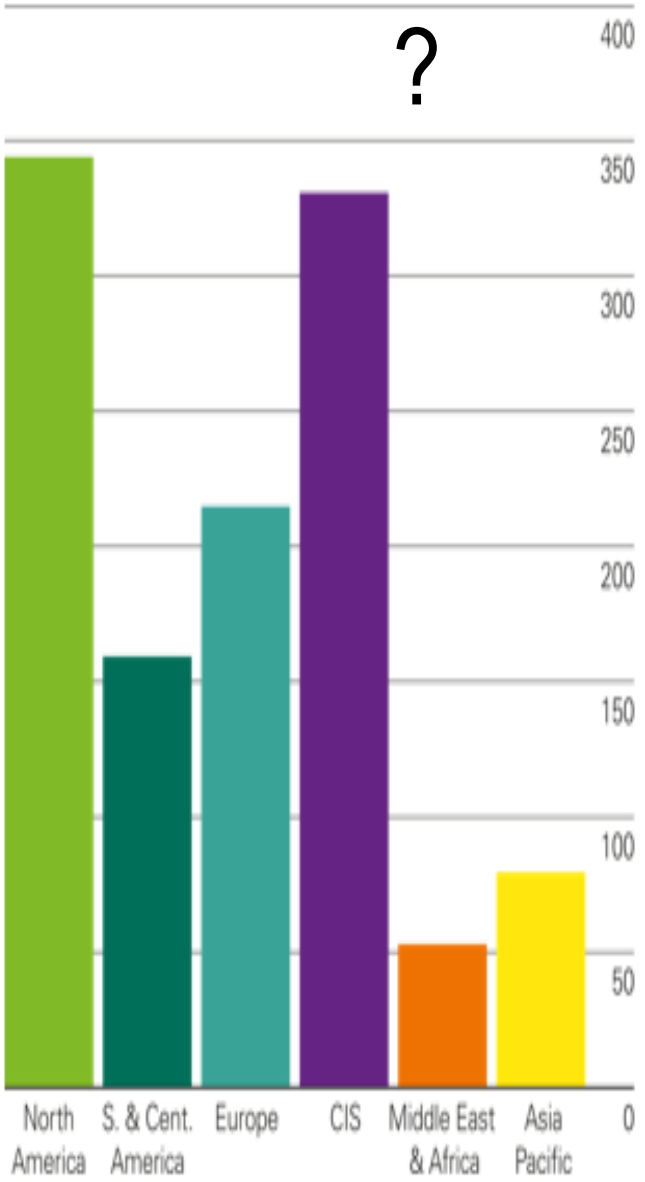
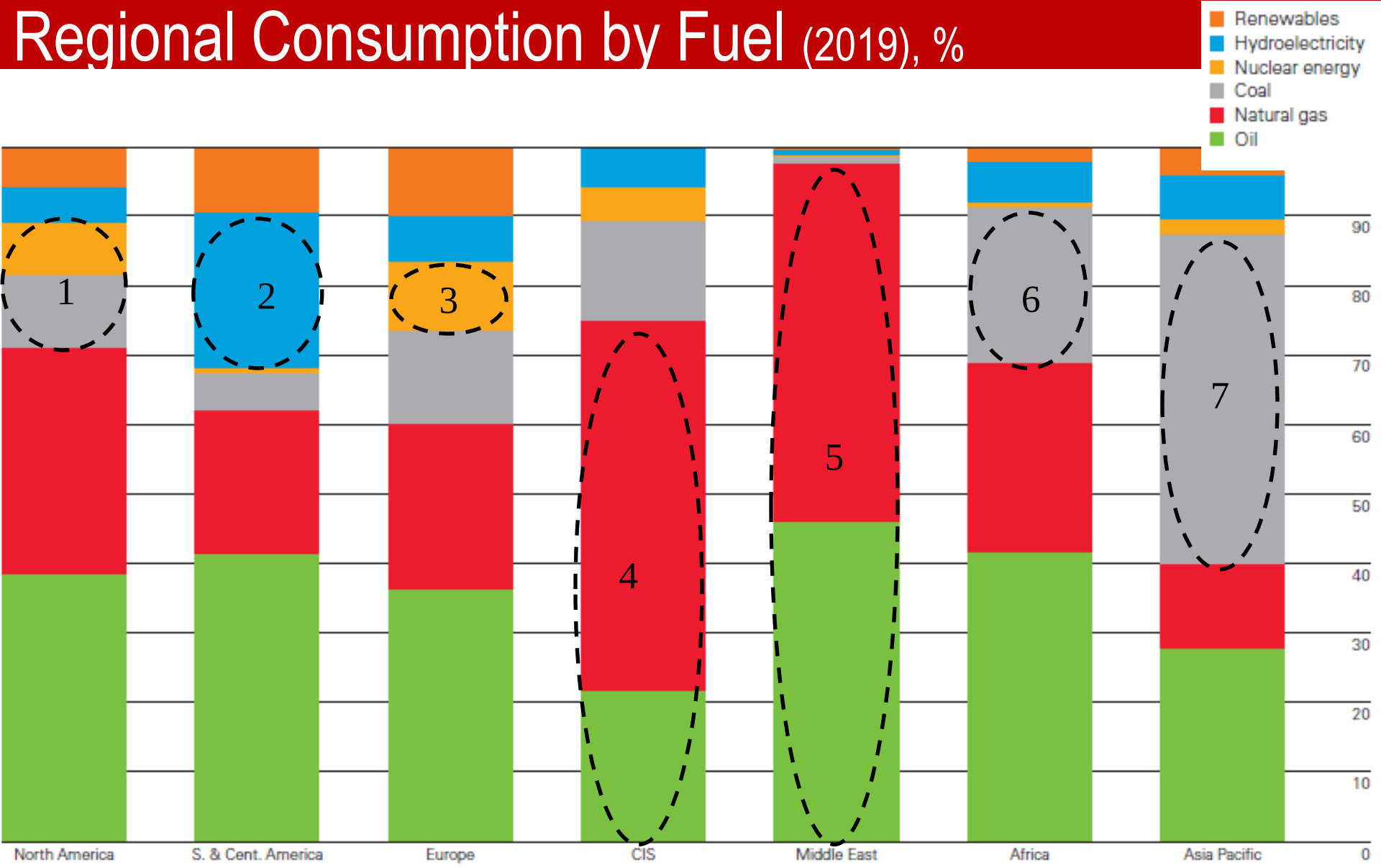
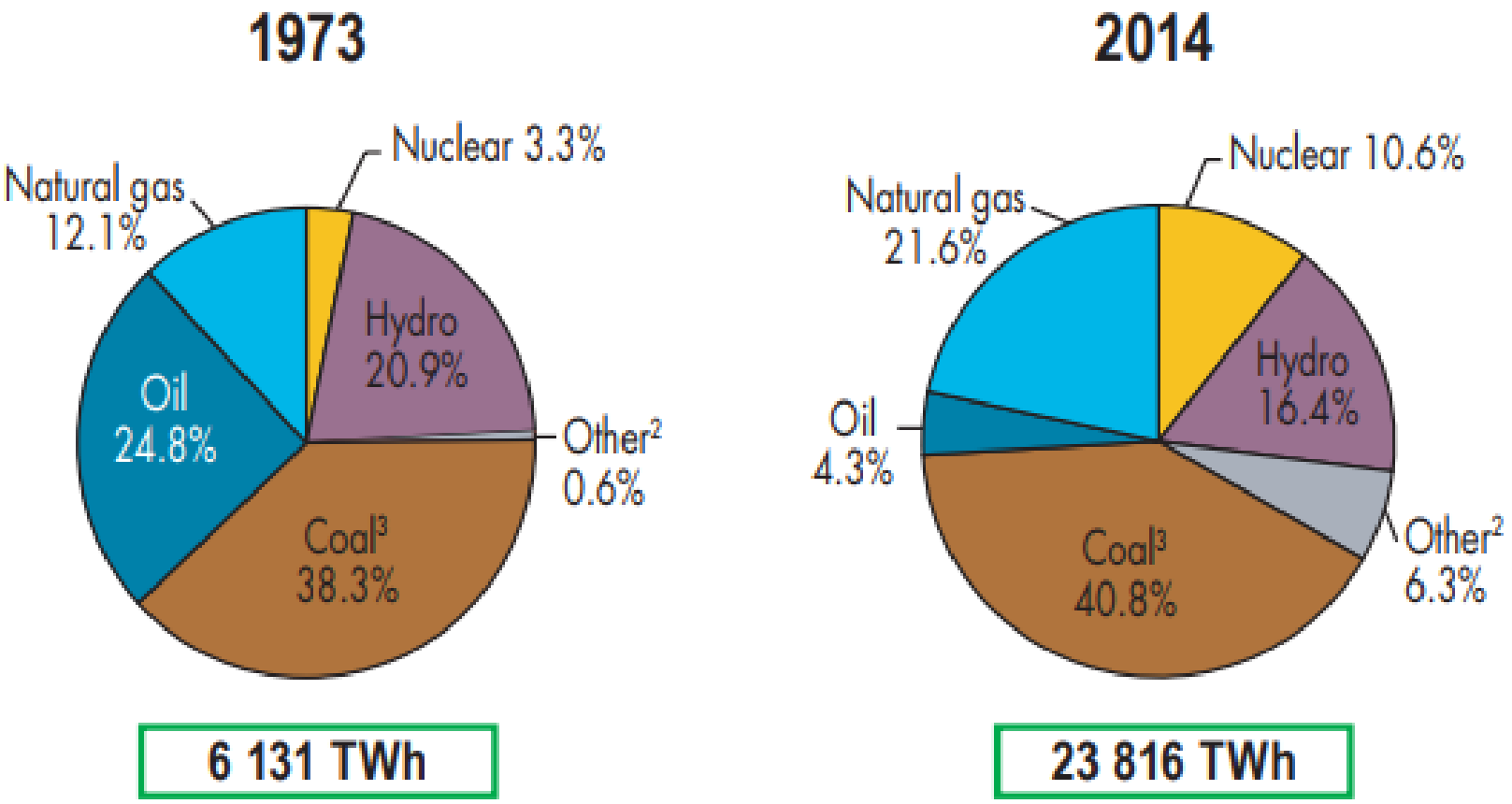


Regional Consumption by Fuel (2019), %



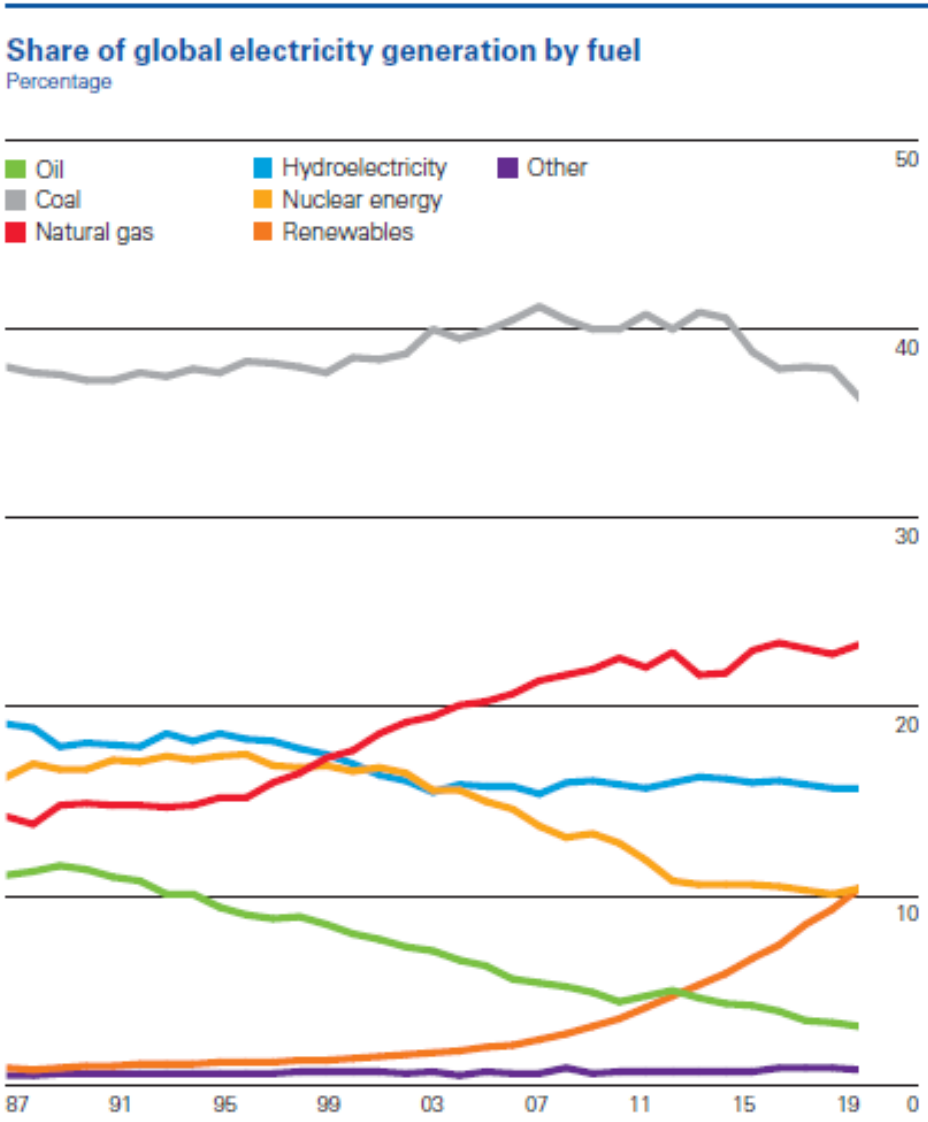
Source: BP Statistical Review of World Energy, 2020

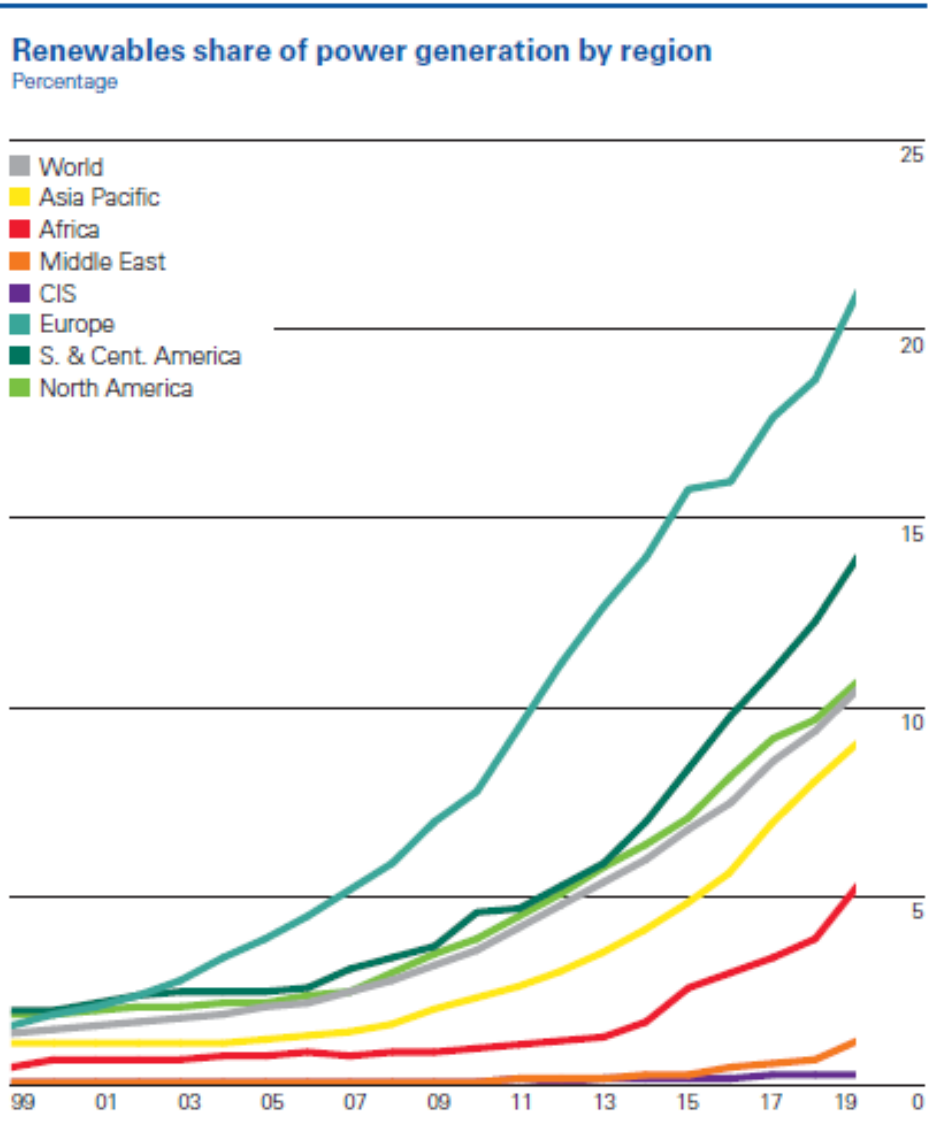
Fuel Shares of Electricity Generation



1. Excludes electricity generation from pumped storage.
2. Includes geothermal, solar, wind, heat, etc.
3. In these graphs, peat and oil shale are aggregated with coal.

Fuel Shares of Electricity Generation

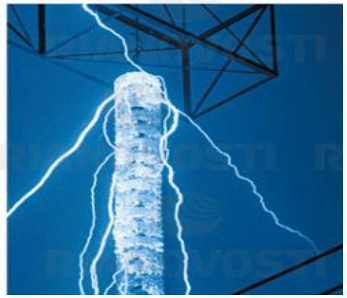




World's Largest Electricity Producers

Producers[1]	TWh	% of world total
People's Rep. of China	5 666	23.8
United States	4 319	18.1
India	1 287	5.4
Russian Federation	1 062	4.5
Japan	1 036	4.4
Canada	656	2.8
Germany	622	2.6
Brazil	591	2.5
France	557	2.3
Korea	546	2.3
Rest of the world	7 474	31.3
World	**23 816**	**100.0**

- **56.2% of the world's electricity (IEA, 2016)**



Net exporters	TWh
France	67
Canada	46
Paraguay	41
Germany	34
Czech Republic	16
Sweden	16
Norway	16
People's Rep. of China	11
Bulgaria	9
Ukraine	8
Others	64
Total	**328**

2014 data

Net importers	TWh
United States	53
Italy	44
Brazil	34
United Kingdom	21
Finland	18
Belgium	18
Netherlands	15
Hungary	13
Iraq	12
Thailand	11
Others	117
Total	**356**

2014 data

 2014 data

Electricity Production from Fossil Fuels

Coal[1]	TWh
People's Rep. of China	4 115
United States	1 713
India	967
Japan	349
Germany	285
South Africa	232
Korea	232
Russian Federation	158
Australia	152
Poland	132
Rest of the world	1 372
World	**9 707**

2014 data

Natural gas	TWh
United States	1 161
Russian Federation	533
Japan	421
Islamic Rep. of Iran	196
Mexico	172
Saudi Arabia	160
Egypt	135
Korea	130
Turkey	121
Thailand	119
Rest of the world	2 007
World	**5 155**

2014 data

Oil	TWh
Saudi Arabia	152
Japan	116
Islamic Rep. of Iran	59
Iraq	50
Kuwait	43
Pakistan	42
United States	40
Brazil	35
Mexico	33
Indonesia	26
Rest of the world	427
World	**1 023**

2014 data

Producers of Nuclear Electricity

Producers	TWh	% of world total
United States	831	32.8
France	436	17.2
Russian Federation	181	7.1
Korea	156	6.2
People's Rep. of China	133	5.2
Canada	108	4.3
Germany	97	3.8
Ukraine	88	3.5
Sweden	65	2.6
United Kingdom	64	2.5
Rest of the world	376	14.8
World	**2 535**	**100.0**

2014 data

Net installed capacity	GW
United States	99
France	63
Japan	42
Russian Federation	25
People's Rep. of China	24
Korea	21
Germany	14
Canada	14
Ukraine	13
Sweden	9
Rest of the world	60
World	**384**

2014 data

Country (top-ten producers)	% of nuclear in total domestic electricity generation
France	78.4
Ukraine	48.6
Sweden	42.3
Korea	28.7
United States	19.2
United Kingdom	19.0
Russian Federation	17.0
Canada	16.4
Germany	15.6
People's Rep. of China	2.3
Rest of the world[1]	9.4
World	**10.7**

2014 data

Producers of Hydro Electricity

Producers	TWh	% of world total
People's Rep. of China	1 064	26.7
Canada	383	9.6
Brazil	373	9.4
United States	282	7.1
Russian Federation	177	4.4
Norway	137	3.4
India	132	3.3
Venezuela	87	2.2
Japan	87	2.2
France	69	1.7
Rest of the world	1 192	30.0
World	**3 983**	**100.0**

2014 data

Net installed capacity	GW
People's Rep. of China	311
United States	102
Brazil	89
Canada	76
Russian Federation	51
Japan	50
India	40
Norway	31
France	25
Turkey	24
Rest of the world	372
World	**1 171**

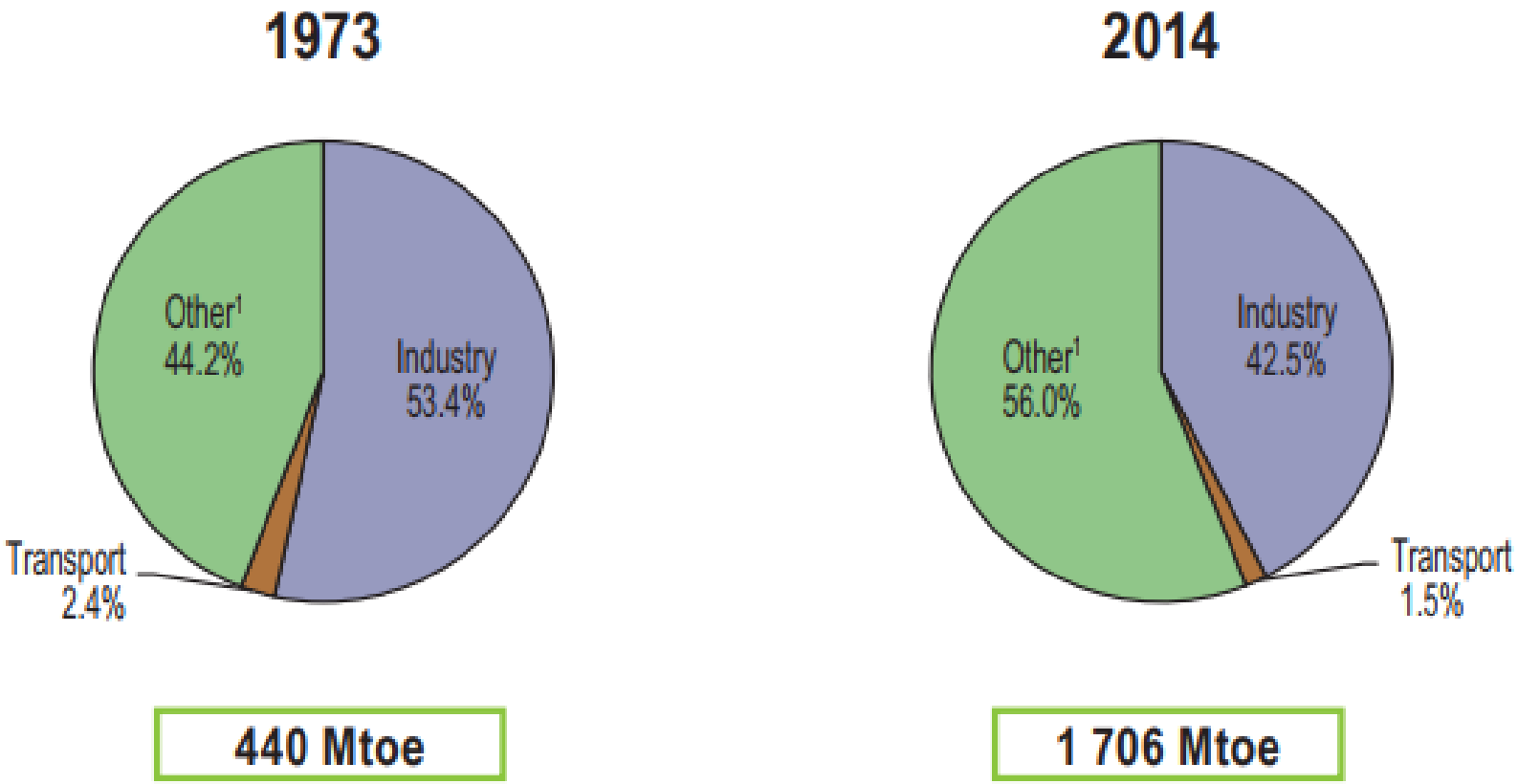
2014 data

Country (top-ten producers)	% of hydro in total domestic electricity generation
Norway	96.0
Venezuela	68.3
Brazil	63.2
Canada	58.3
People's Rep. of China	18.7
Russian Federation	16.7
France	12.2
India	10.2
Japan	8.4
United States	6.5
Rest of the world[2]	15.6
World	**16.7**

2014 data

Sources: IEA, United Nations.

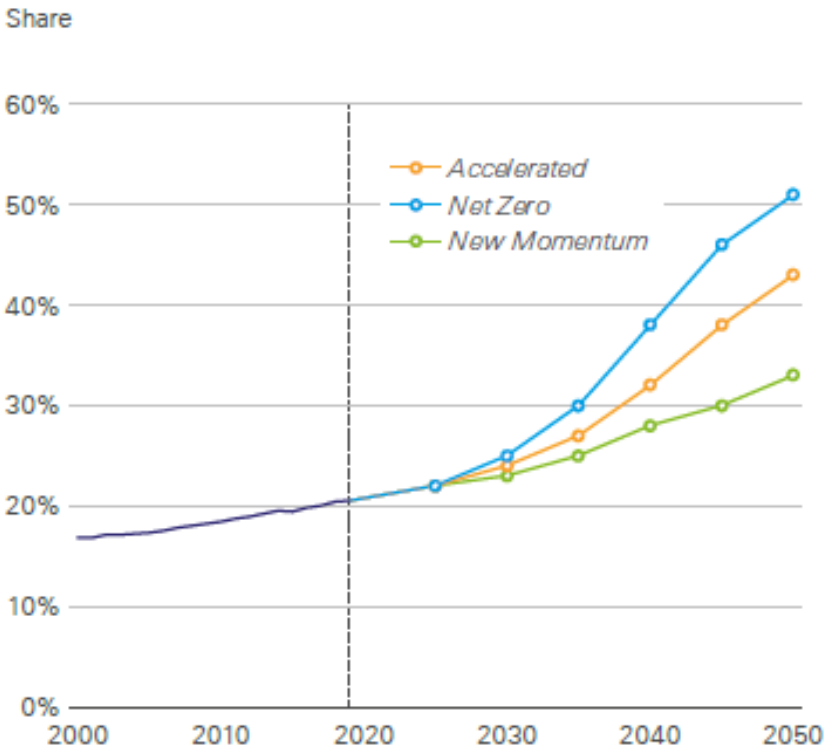
Shares of World Electricity Consumption



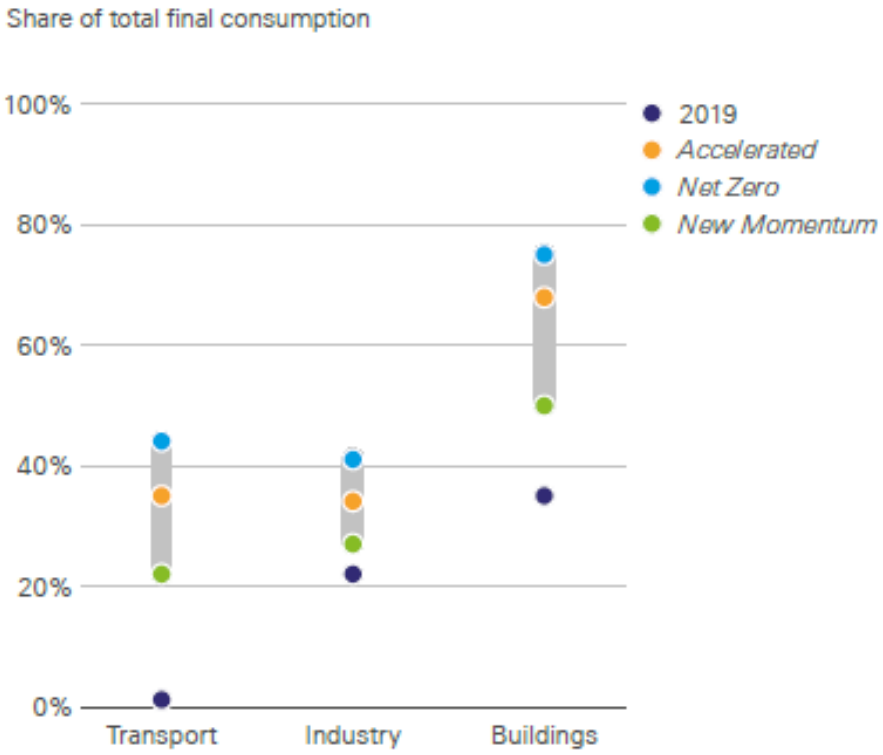
1. Includes agriculture, commercial and public services, residential, and non-specified other.

Electricity demand expands significantly as prosperity in emerging economies grows and the world increasingly electrifies

Electricity as a share of total final consumption



Range of electrification across end-use sectors in 2050



COVID-19 influence on Energy Sector

Main impacts:

1) Direct impact(s)
2) Indirect impact(s)

1. Primary energy consumption fell by 4.5% in 2020 with oil demand accounting for 72% of the decrease
2. Renewables power grew by a record 358 TWh and increased its share of total generation to 12%
3. Carbon emissions fell by 6.2% and the carbon intensity of the energy mix (the average carbon emitted per unit of energy used) declined by 1.8%

Units in EJ unless otherwise stated	Level			Growth rate per annum (%)		(EJ)		Share (%)		
	2009	2019	2020	2009-19	2020	2009-19	2020	2009	2019	2020
Consumption										
Primary energy	482	582	557	1.9	-4.5	10	-24	100	100	100
Oil	167	192	174	1.4	-9.5	2.5	-18	35	33	31
Natural gas	106	141	138	2.9	-2.3	3.5	-2.9	22	24	25
Coal	145	158	151	0.9	-4.2	1.3	-6.2	30	27	27
Nuclear	25	25	24	-0.2	-4.1	-0.1	-0.9	5.3	4.3	4.3
Hydro	31	38	38	2.1	1.0	0.7	0.5	6.4	6.5	6.9
Renewables	8.2	29	32	13	9.7	2.1	2.9	1.7	5.0	5.7
Wind	2.6	13	14	17	11	1.0	1.5	0.5	2.2	2.5
Solar	0.2	6.3	7.6	41	20	0.6	1.3	0.0	1.1	1.4
Other renewables*	5.4	9.9	10	6.3	0.8	0.5	0.1	1.1	1.7	1.8

COVID-19 influence on Energy Sector

Main impacts:

1) the direct impact of coronavirus on employees of energy companies and on the stability of enterprises

2) the consequences of various kinds of restrictive measures for the fight against coronavirus, leading on the one hand to *disruptions in the supply chain*, and on the other - to *a sharp decline economic activity and reduced demand for energy*

3) a tough price triggered by a drop in demand competition and, as a result, a sharp drop in prices

What's next? Decarbonization.

Source: https://energy.skolkovo.ru/downloads/documents/SEneC/Research/SKOLKOVO_EneC_COVID19_and_Energy_sector_RU.pdf

Definitions of some energy terms & indicators

Energy	Electricity, fuels, steam, heat, compressed air, and other similar media.
Energy use	The manner or type of application of energy.
Energy consumption	The quantity of energy used.
Energy efficiency	Formally the ratio between energy input and energy output but usually used to mean energy performance.
Energy performance	The ratio between delivery of an output e.g. production output and energy input.
Energy conservation	Reducing energy use by reducing or stopping an energy using activity e.g. switching off a light or a machine.
Energy management	The set of processes and tools to manage energy demand within enterprises i.e. managing the process of improving energy efficiency, managing energy costs and managing energy risks.
Energy intensity	Energy use per unit of Gross Domestic Product e.g. toe/USD 1000 of GDP.
Energy productivity	Gross Domestic Product per unit of energy input – the inverse of energy intensity.

Fawkes S., Oung K., Thorpe D., (2016) Best Practices and Case Studies for Industrial Energy Efficiency Improvement – An Introduction for Policy Makers. Copenhagen Centre on Energy Efficiency.

Energy Intensity

- Energy intensity is the ratio of energy use to output.

$$\text{Energy intensity} = \frac{\text{Energy use}}{\text{Output}}$$

[MJ, Kcal, t, etc.]

[$ of GDP, $ of Gross Output, $ of Industry Production; tonnes, cubic metres, etc.]

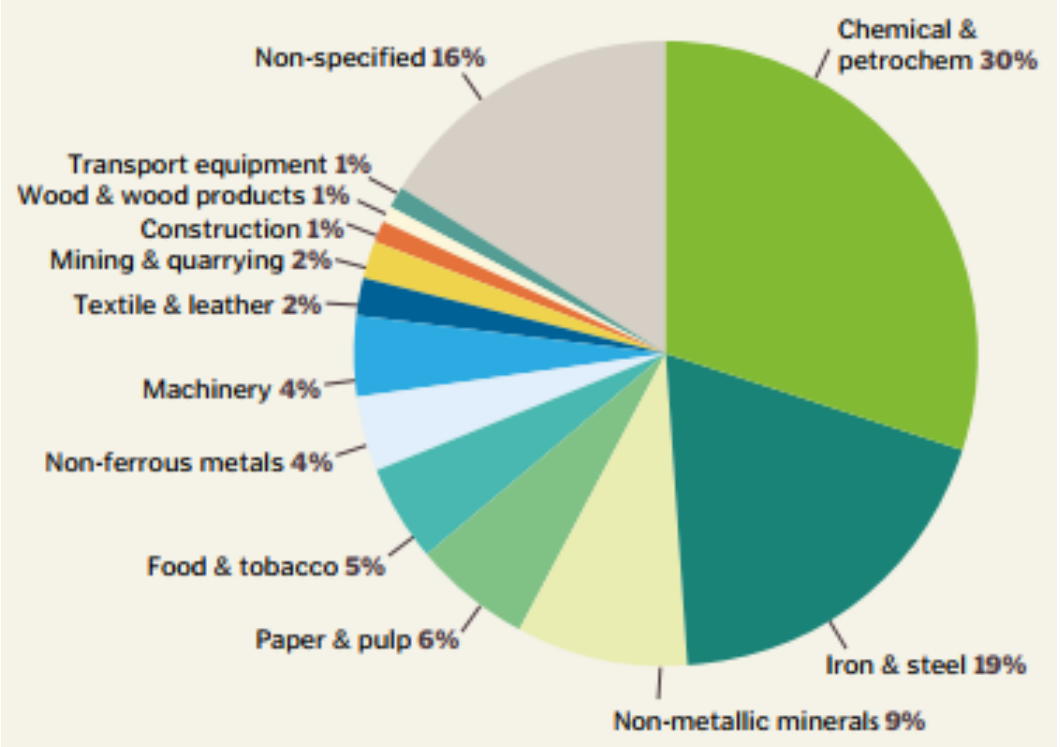
What factors influence the energy intensity of a country?

Energy Intensity of Industries

Nearly two-thirds of industrial energy use is accounted for by 4 industries:

1. *Chemical and petrochemical*
2. *Iron and steel*
3. *Non-metallic minerals*
4. *Paper and pulp*

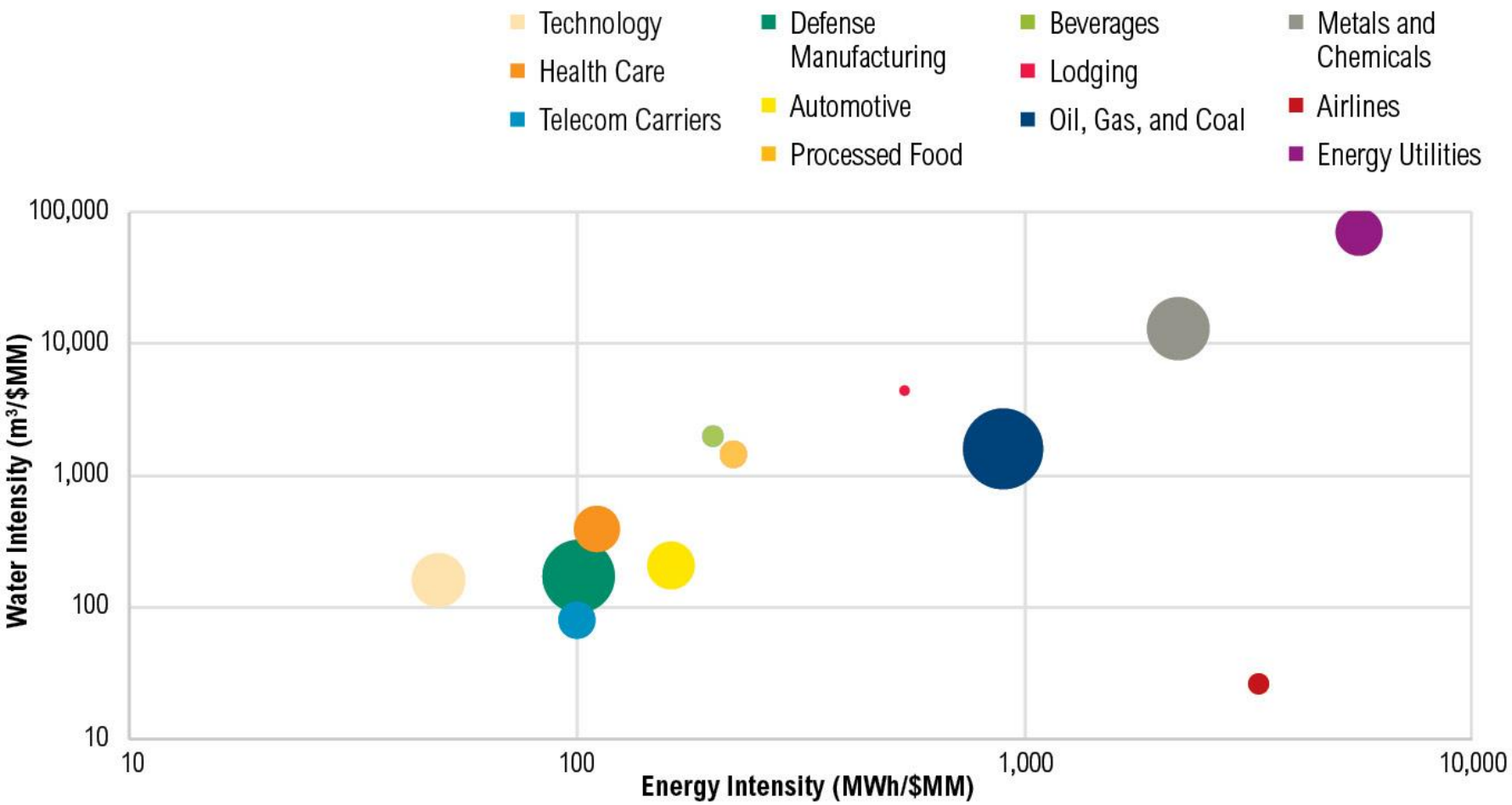
Breakdown of industrial energy use by sector 2004.



Sources:

- IEA, 2007
- Fawkes S., Oung K., Thorpe D., (2016) Best Practices and Case Studies for Industrial Energy Efficiency Improvement – An Introduction for Policy Makers. Copenhagen Centre on Energy Efficiency.

Water and Energy Intensity of Major Industries



Note: Bubble area proportional to total industry revenue.

Source: Industry data for 2013 accessed via Bloomberg Terminal (Bloomberg 2015).

www.wri.org/publication/water-energy-nexus

WORLD RESOURCES INSTITUTE

Energy Intensity of Countries

What factors influence the indicator of energy intensity?

Factors influencing an economy's overall energy intensity

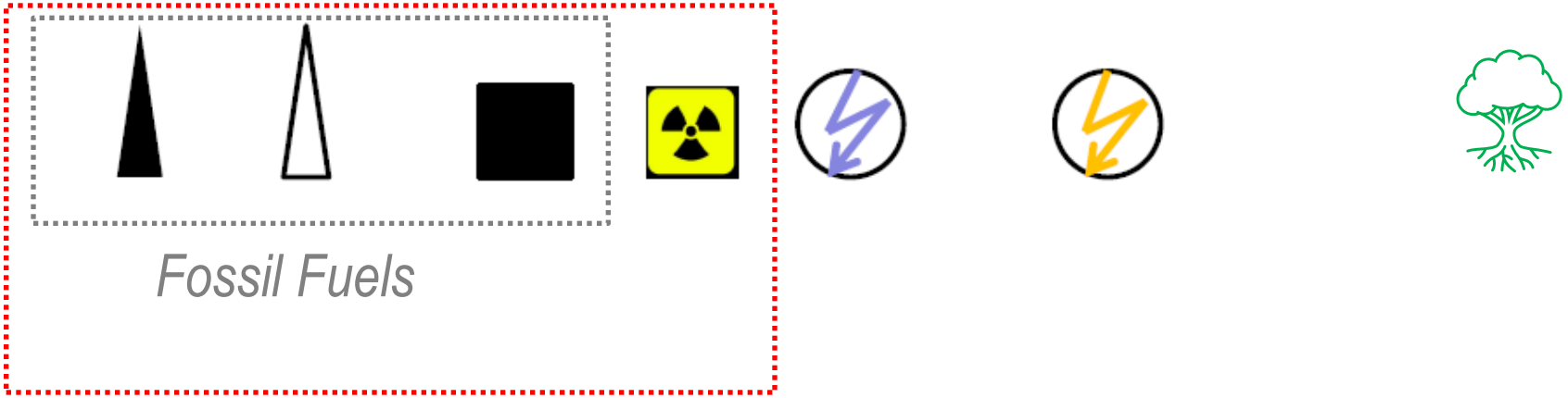
1. requirements for general standards of living
2. weather conditions in an economy
3. energy efficiency of appliances and buildings
4. fuel economy of vehicles
5. vehicular distances travelled (frequency of travel or larger geographical distances)
6. better methods and patterns of transportation
7. capacities and utility of mass transit
8. energy rationing or conservation efforts
9. economic shocks such as disruptions of energy due to natural disasters, wars, massive power outages,
10. unexpected new energy sources
11. efficient uses of energy
12. energy subsidies

The list is not complete still!

Renewable Energy

World Market of Energy Resources

- Primary energy sources
  - Oil, natural gas, coal, nuclear, hydro and geothermal power, biomass



World Market of Energy Resources

- Primary energy sources
  - Oil, natural gas, coal, nuclear, hydro and geothermal power, biomass

- Secondary energy sources
  - Electricity, such renewables as wind and solar power, different derivatives from oil like fuel oil, kerosene etc.

Alternative Energy ≈ Renewables

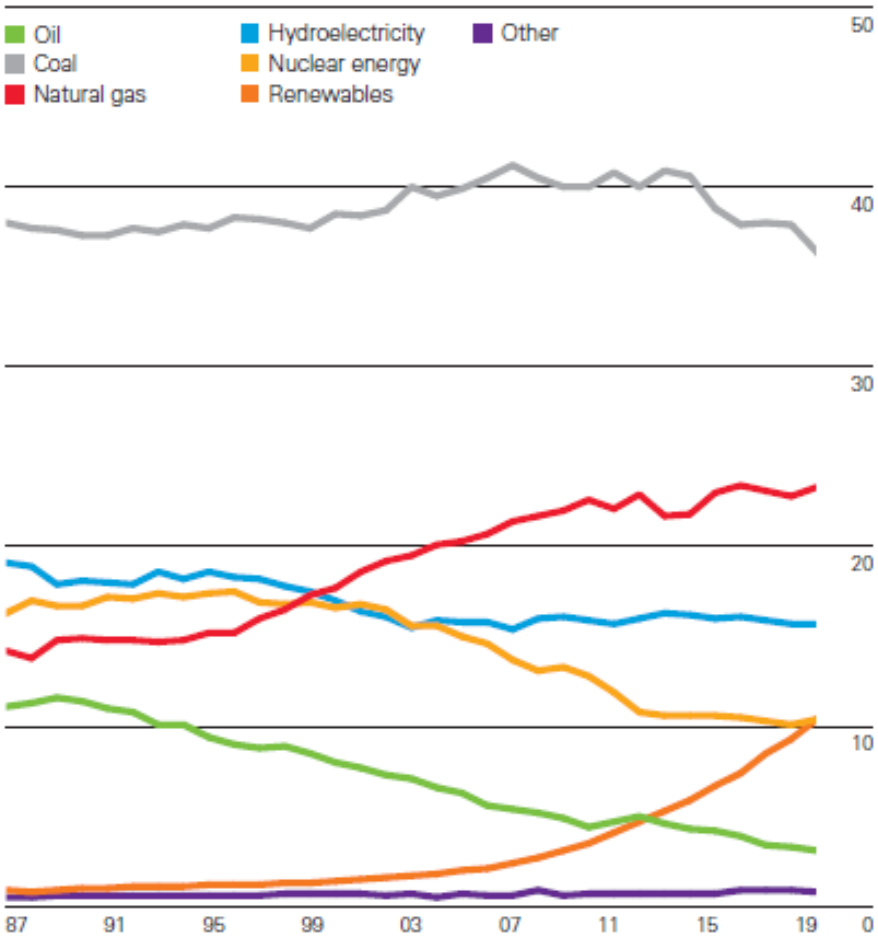
- 6 main renewable energy technologies:
  1) wind power
  2) solar energy
  3) biomass energy
  4) biofuels
  5) geothermal energy (?)
  6) hydroelectric power
- Nuclear energy

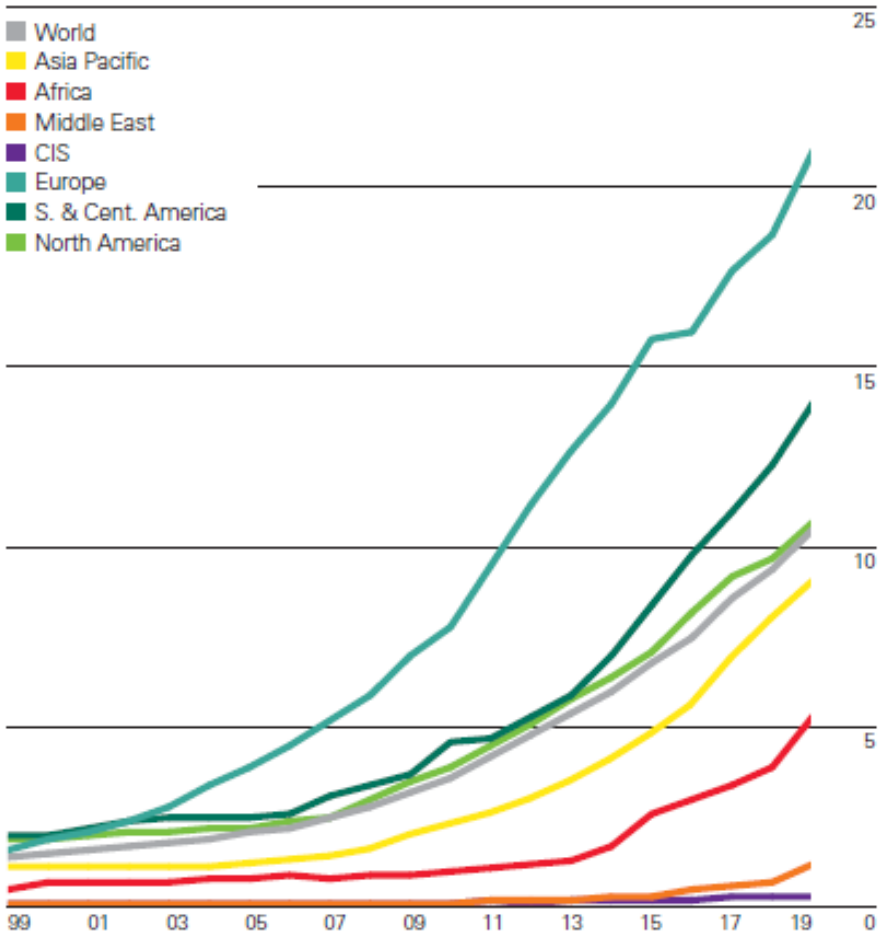
All of them faced unique economic challenges that made it difficult for them to compete with energy generated by traditional fossil fuels.

Nowadays the situation is changing.

Global Trends in Energy Use

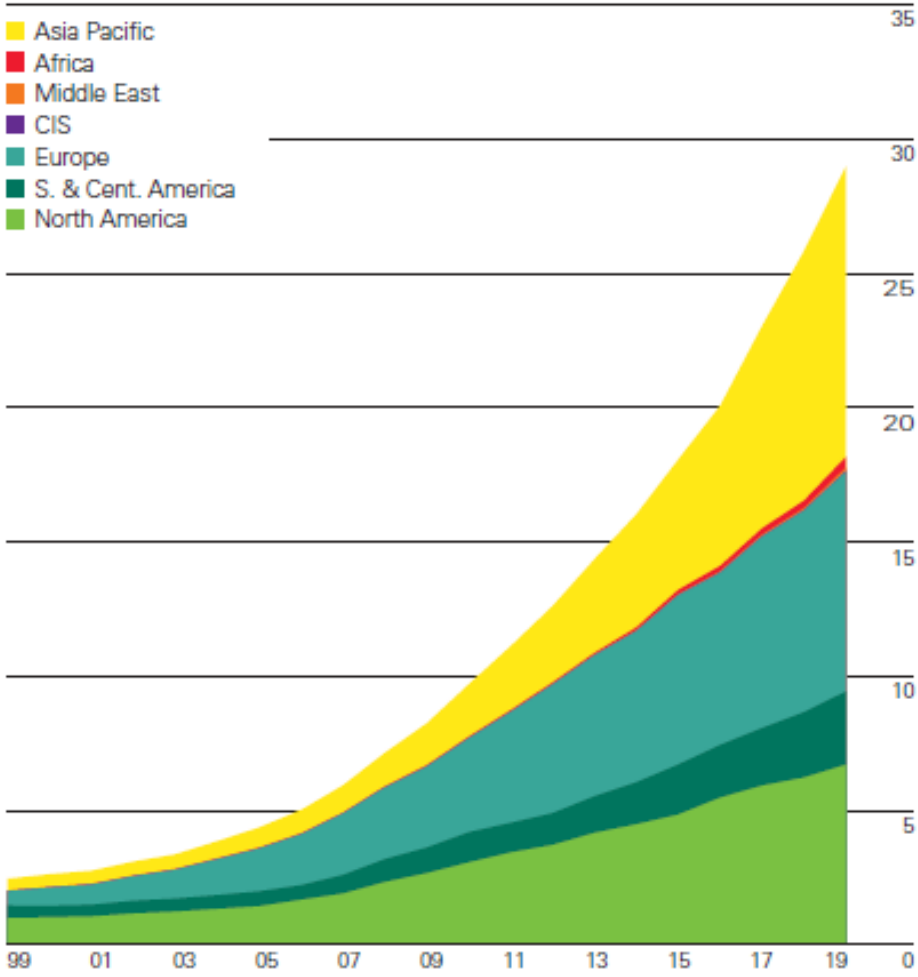
- Renewables are the fastest growing energy source (but from a relatively small base)





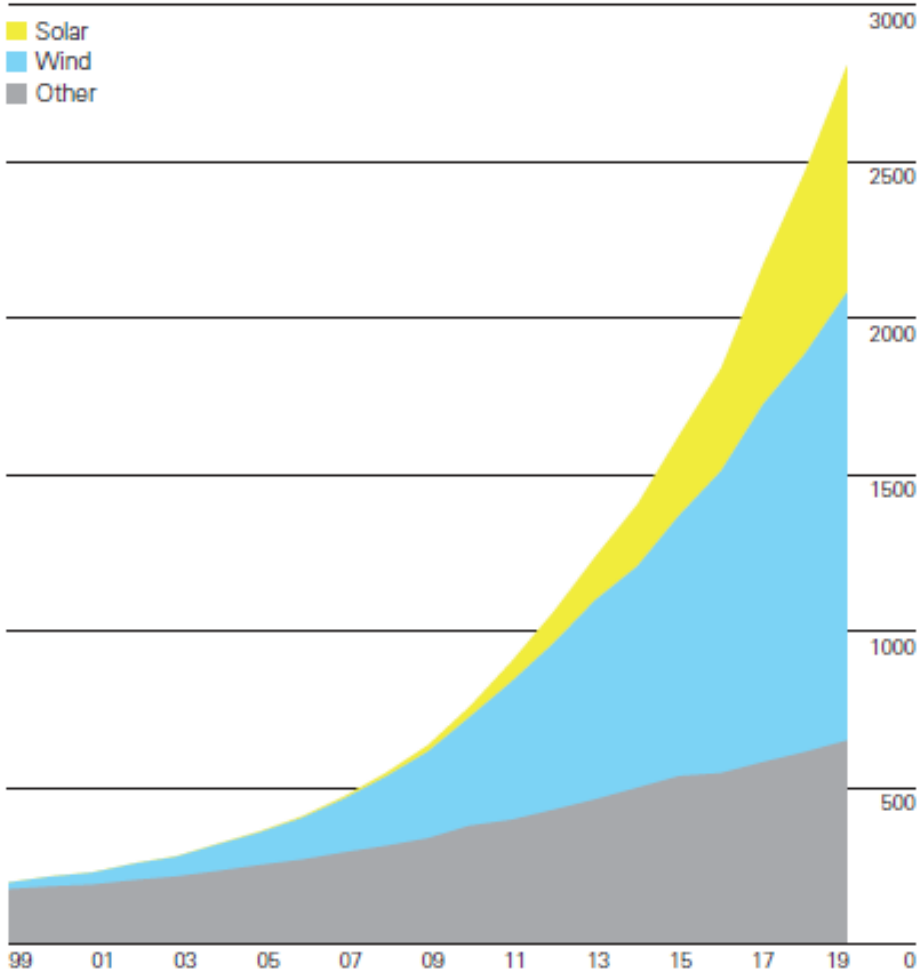
Renewables consumption by region

Exajoules



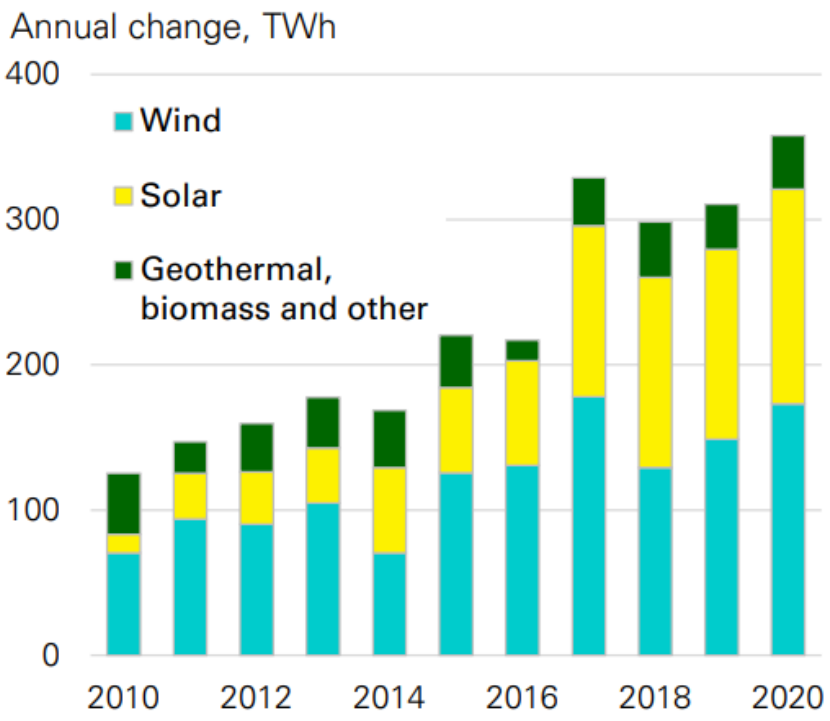
Renewables generation by source

Terawatt-hours

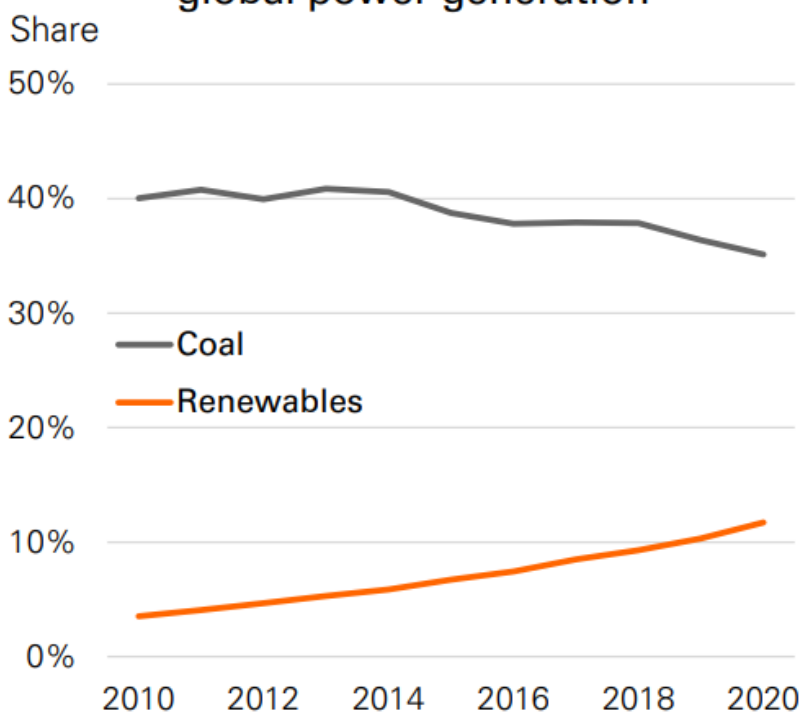


Power generation

Renewable power generation



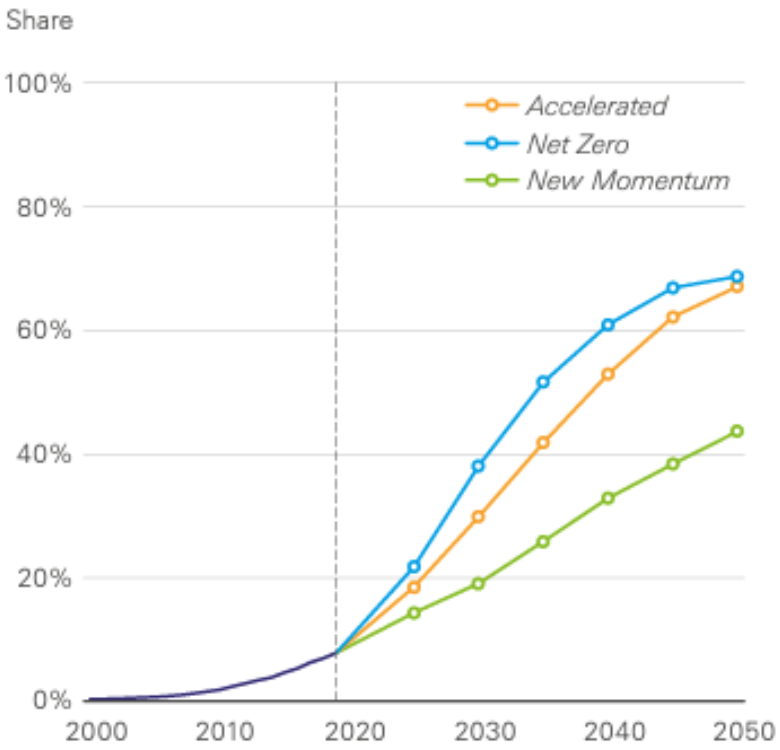
Share of renewables and coal in global power generation



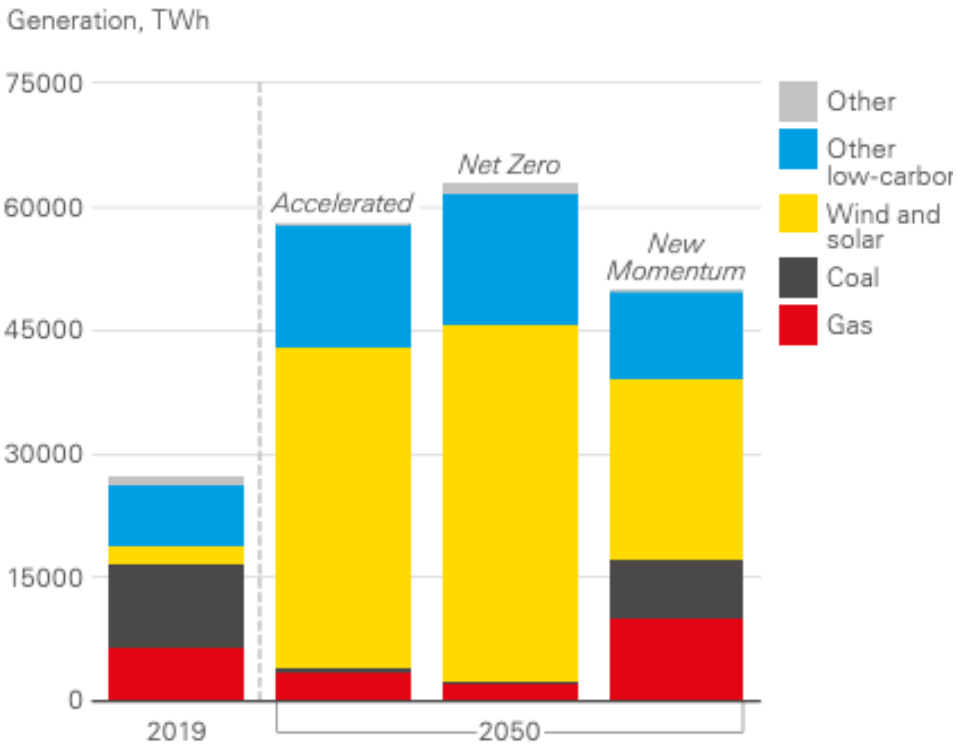
bp Statistical Review of World Energy

Growth in power generation is dominated by wind and solar as the global power system decarbonizes

Wind and solar as a share of total power generation



Electricity generation by fuel



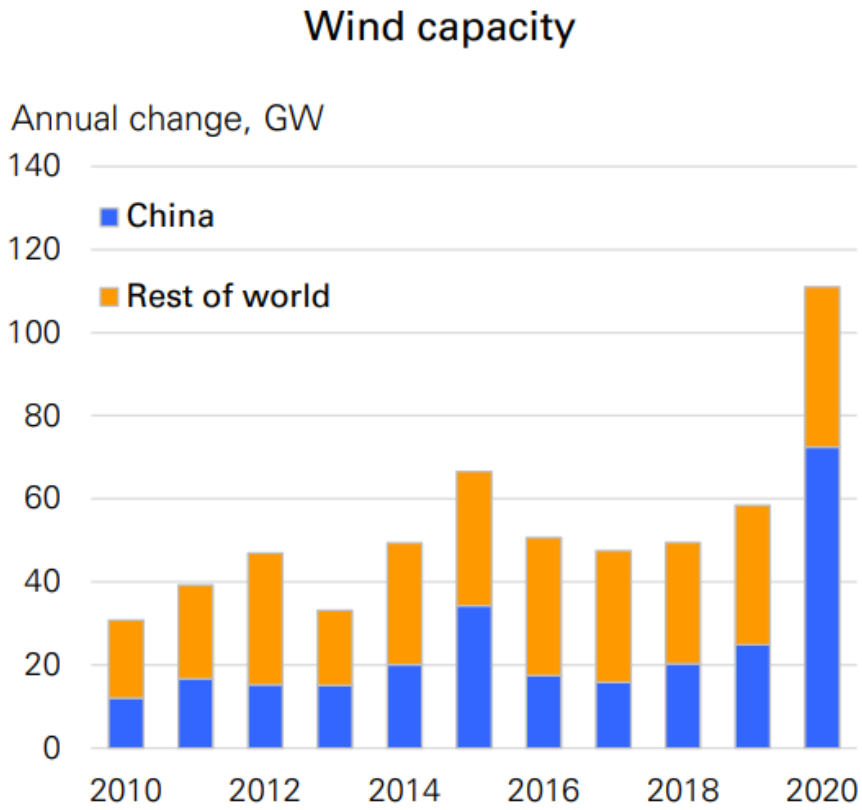
Gas includes natural gas and biomethane
Other low-carbon includes biomass, nuclear, hydro and geothermal

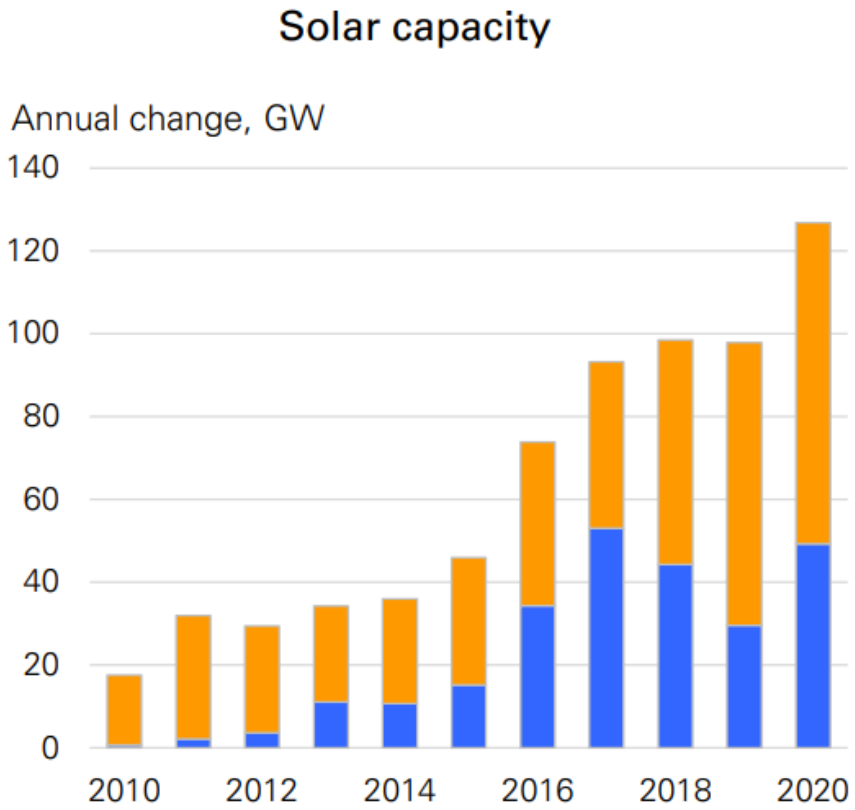
Structural changes in global macro conditions in Favor of Renewables

What factors do contribute to the Growth of Renewables?

1. …
2. …
3. …
4. …
5. …

Wind and solar power capacity





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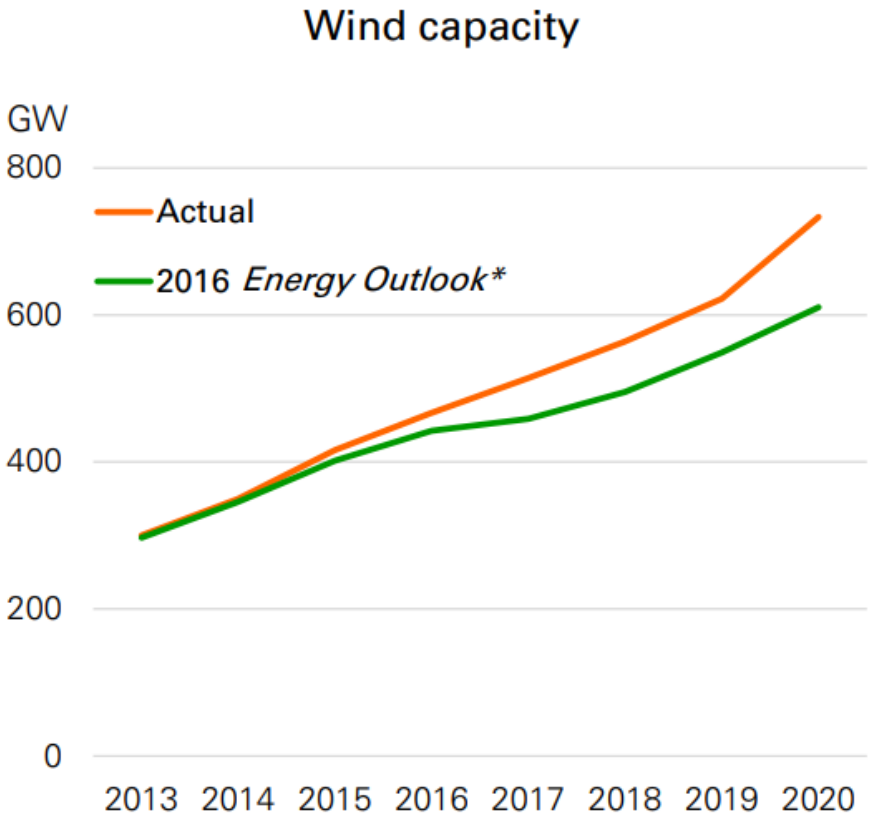
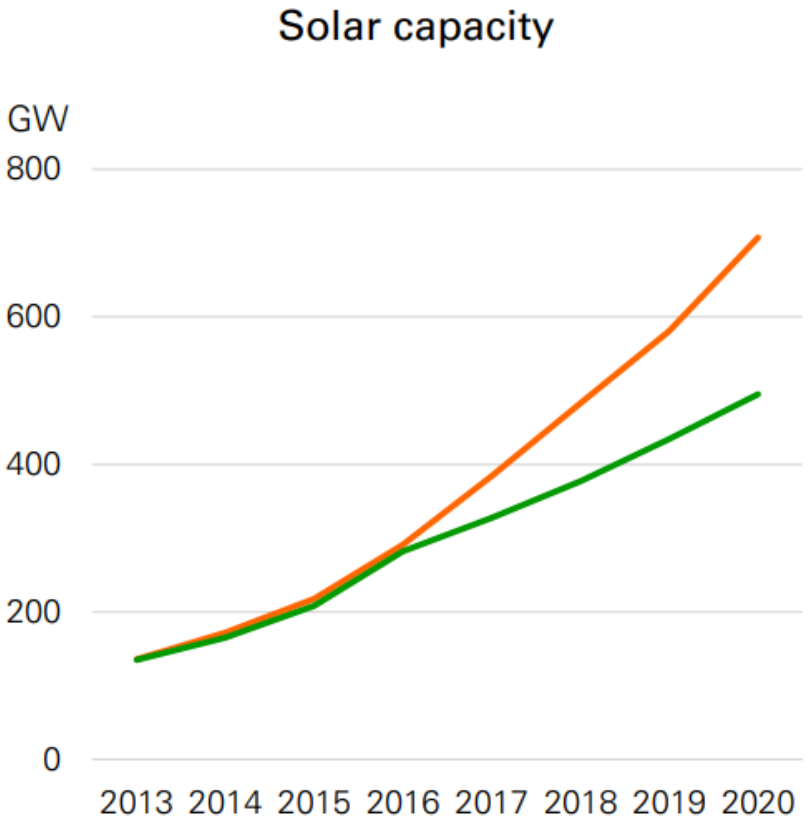
Wind and solar capacity





*2016 Energy Outlook (EO 2016) capacity profiles based on EO 2016 generation and EO 2020 historic capacity factors.

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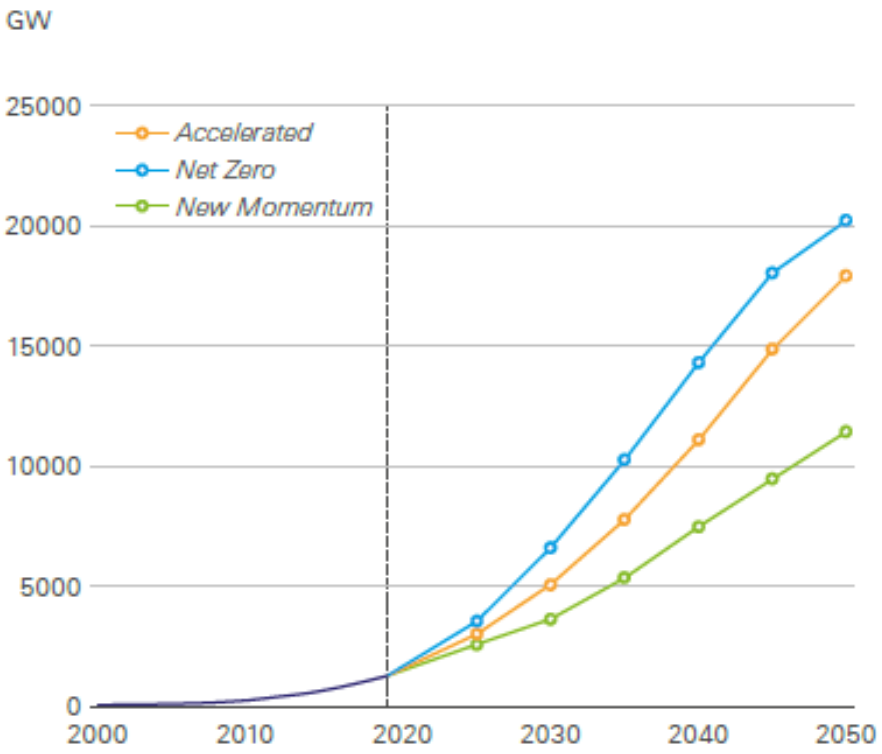
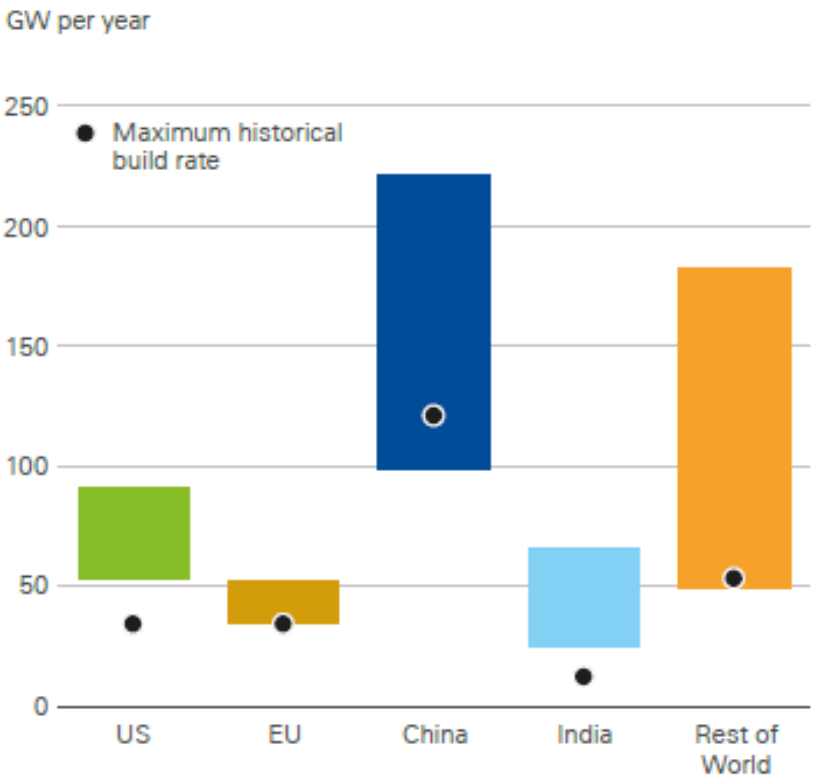
Wind and solar power expands rapidly, requiring significant acceleration in financing and building new capacity

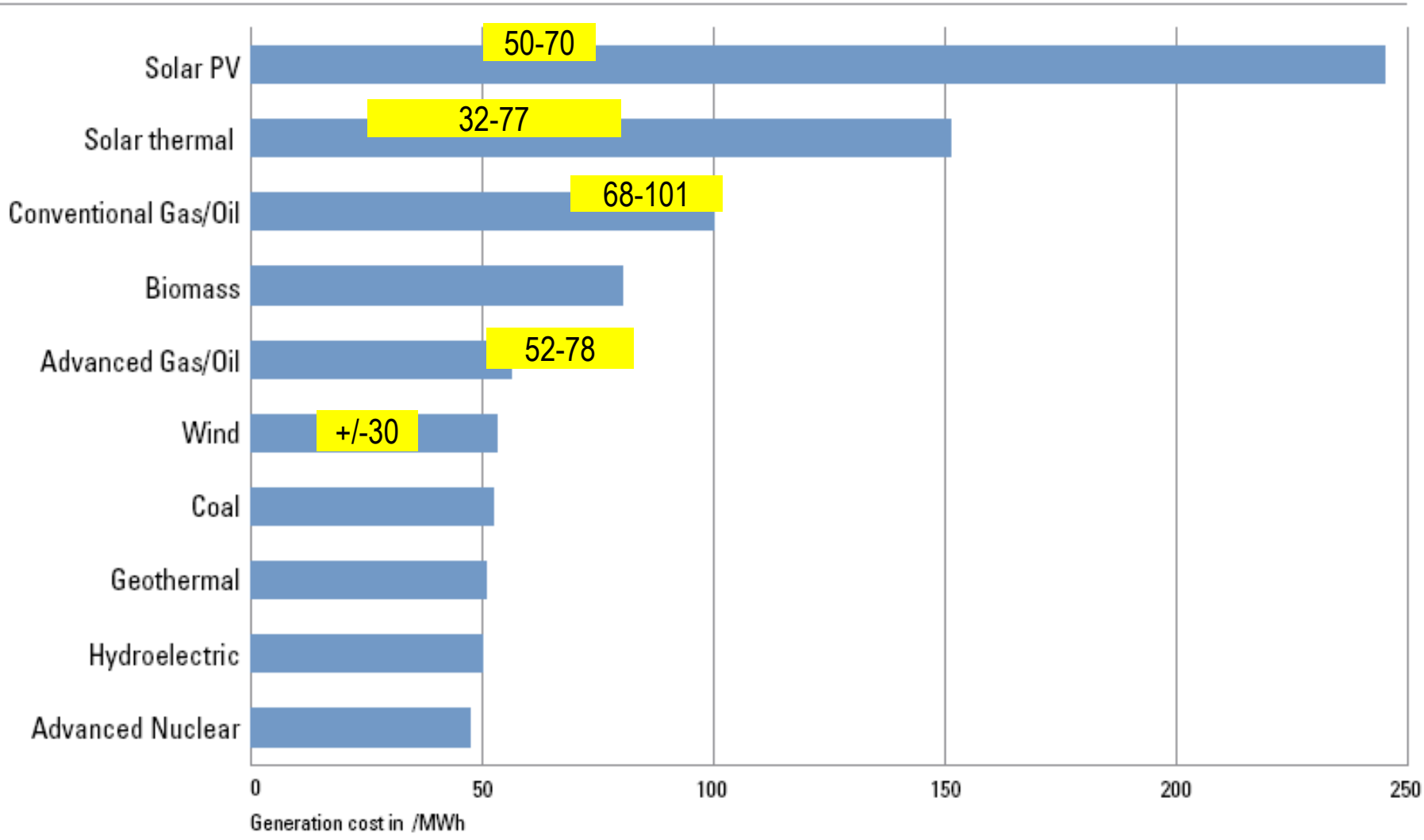
Installed wind and solar capacity



Range of wind and solar capacity build rates in the three scenarios 2022-2035



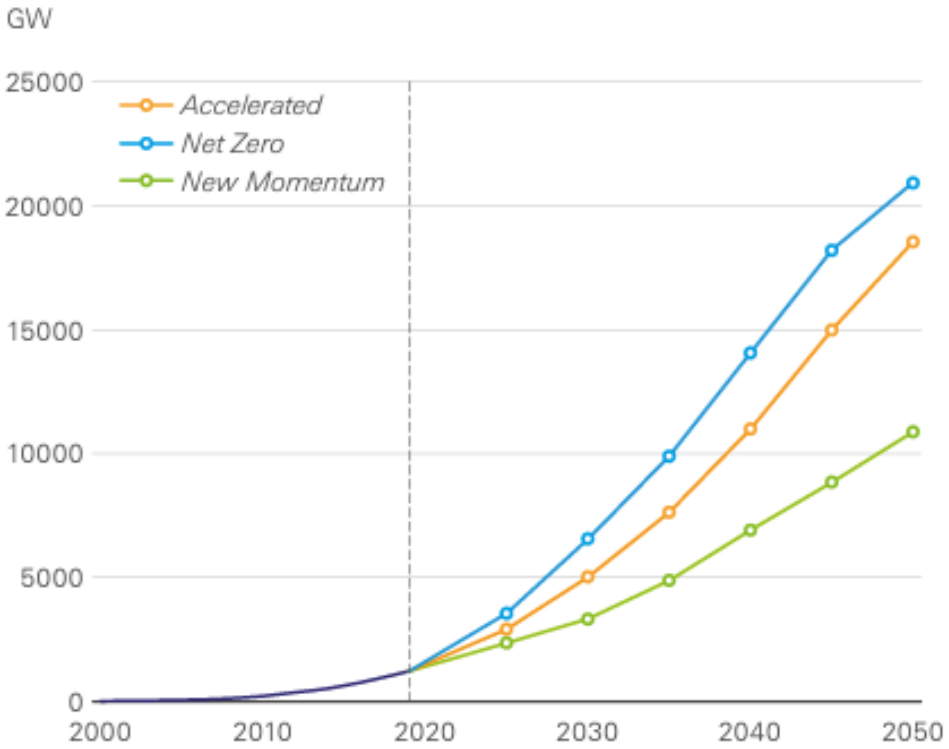
Cost Competitiveness of Electricity Sources



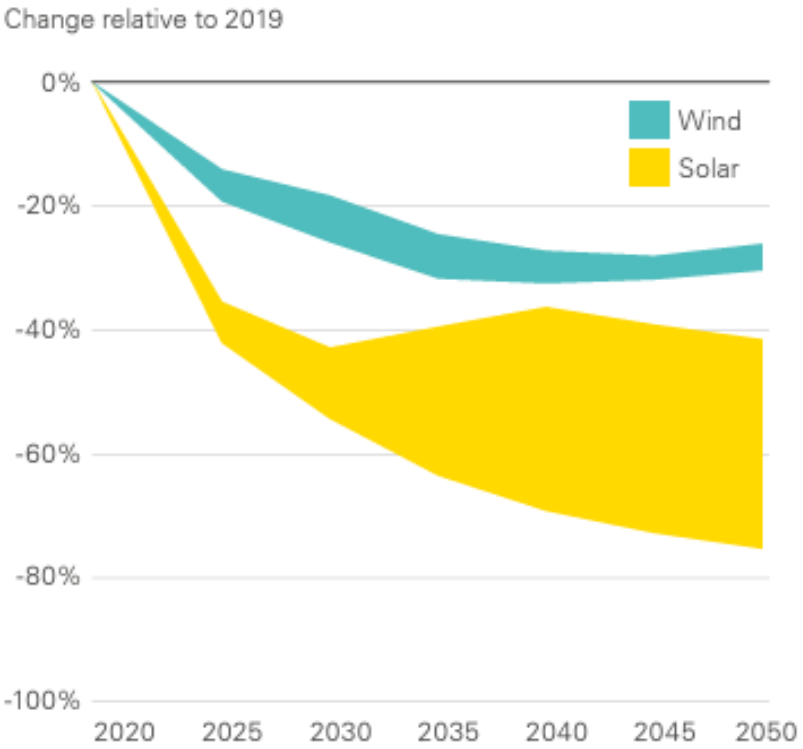
Source: IEA, European Solar Thermal Industry Association, 2006.

Wind and solar power grow rapidly

Installed wind and solar capacity

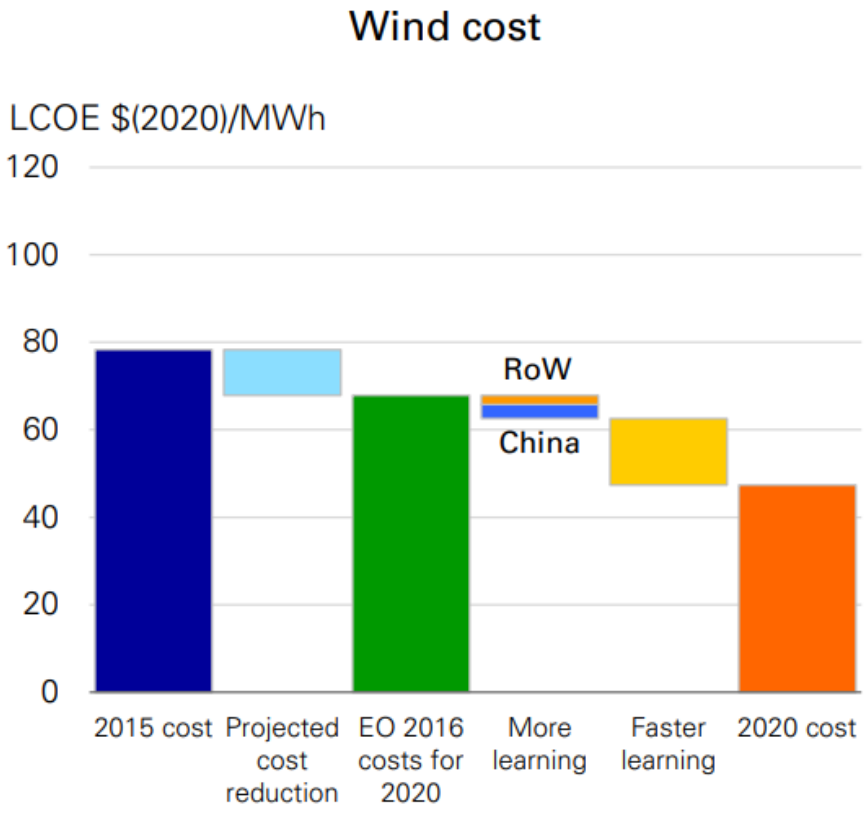


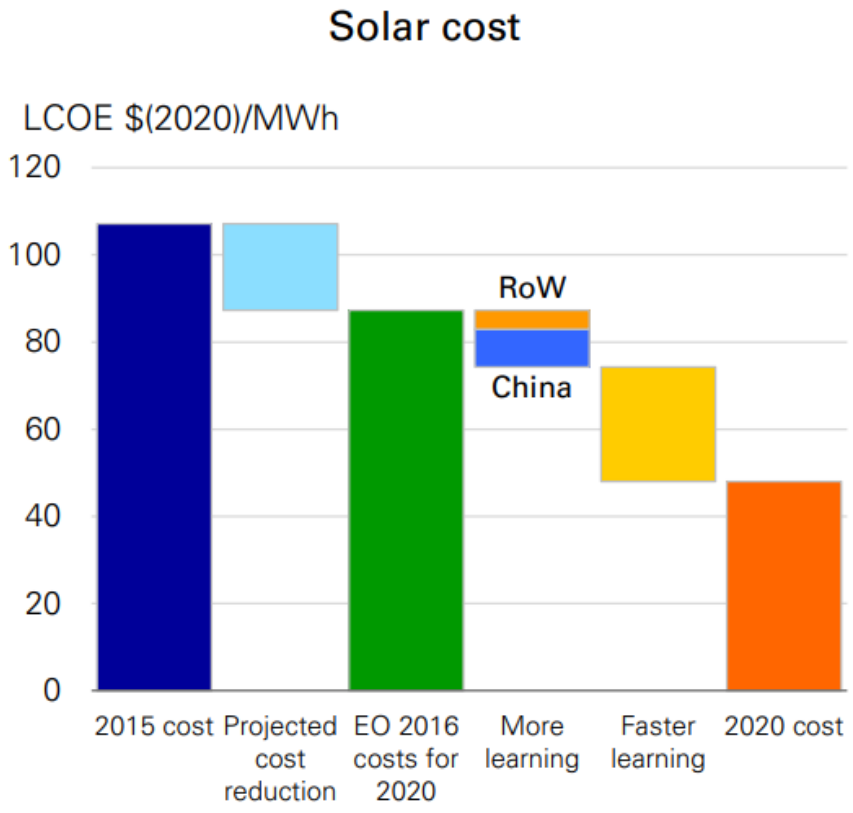
Cost of wind and solar



Cost of wind and solar refers to their global average levelized cost of electricity, including their integration costs

Cost of wind and solar





LCOE: Levelized cost of energy, global benchmark.

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Table 1b. Estimated unweighted levelized cost of electricity (LCOE) and levelized cost of storage (LCOS) for new resources entering service in 2027 (2021 dollars per megawatthour)

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[a]	Levelized variable cost	Levelized transmis-sion cost	Total system LCOE or LCOS	Levelized tax credit[b]	Total LCOE or LCOS including tax credit
Dispatchable technologies								
Ultra-supercritical coal	85%	$52.11	$5.71	$23.67	$1.12	$82.61	*NA*	$82.61
Combined cycle	87%	$9.36	$1.68	$27.77	$1.14	$39.94	*NA*	$39.94
Advanced nuclear	90%	$60.71	$16.15	$10.30	$1.08	$88.24	-$6.52	$81.71
Geothermal	90%	$22.04	$15.18	$1.21	$1.40	$39.82	-$2.20	$37.62
Biomass	83%	$40.80	$18.10	$30.07	$1.19	$90.17	*NA*	$90.17
Resource-constrained technologies								
Wind, onshore	41%	$29.90	$7.70	$0.00	$2.63	$40.23	*NA*	$40.23
Wind, offshore	44%	$103.77	$30.17	$0.00	$2.57	$136.51	-$31.13	$105.38
Solar, standalone[c]	29%	$26.60	$6.38	$0.00	$3.52	$36.49	-$2.66	$33.83
Solar, hybrid[c,d]	28%	$34.98	$13.92	$0.00	$3.63	$52.53	-$3.50	$49.03
Hydroelectric[d]	54%	$46.58	$11.48	$4.13	$2.08	$64.27	*NA*	$64.27
Capacity resource technologies								
Combustion turbine	10%	$53.78	$8.37	$45.83	$9.89	$117.86	*NA*	$117.86
Battery storage	10%	$64.03	$29.64	$24.83	$10.05	$128.55	*NA*	$128.55

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2022*

[a] O&M = operations and maintenance

Indicators of changes

Less Expensive?

- Solar energy became 80% cheaper (2017) than 7 years ago
- Costs of renewable energy are (2017) 7 times less in 9 years

- *In 2028 solar energy will become so cheap and widespread that it will satisfy the entire total energy demand of mankind*, according to the Technical director of Google and well-known technological futurist **Ray Kurzweil** (2017).

- **Heinberg R.** (2009), *Searching for a Miracle*: *There is no reliable scenario in which alternative energy sources can completely replace fossil fuels when it completely runs out*

Risks of Solar and Wind Energy

	SOLAR stations	WIND stations
Environmental Risks	Deforestation, utilization problems, cleaning chemicals, soil deterioration, local warming effect	Construction materials (steel, copper, aluminum, concrete), infrastructure around, special roads, deforestation (1 wind generator → 0.35 sq.km), industrial pollution, fire cause, utilization problem, local warming effect


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Risks of Solar and Wind Energy

	SOLAR stations	WIND stations
Risks for Health	Utilization → soil & water contamination, especially in Africa, due to the impossibility of rare earths safe storage or utilization	Reduction of bird's population, negative effect on health of animals and people on local farms nearby, animal's miscarriages on local farms
Risks of New Technologies	Public unpopularity of this topic (it is customary to respond only positively)	Underestimating noise pollution (only the audible range is considered, without infrasound and vibrations) Public unpopularity of this topic (it is customary to respond only positively)
Energy Security Risks	Dependence on sun Deterioration of the stability of the power grid and dependence on electricity imports	Dependence on wind Deterioration of the stability of the power grid and dependence on electricity imports