Energy and Climate Policy

Sumie Nakayama
J-POWER

December 8, 2020

Contents

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Energy 101 : Unit and Metrix

Unit for energy

- toe: ton oil equivalent, 1toe = 10 Gcal = 41.87 GJ
- BTU: British thermal unit, 1 MBTU = 1.06 GJ = 0.0252 toe
- 1 Quads = 10^{15}BTU = 26.7 Mtoe = 1.12 x 10^6 TJ

Metric Prefix

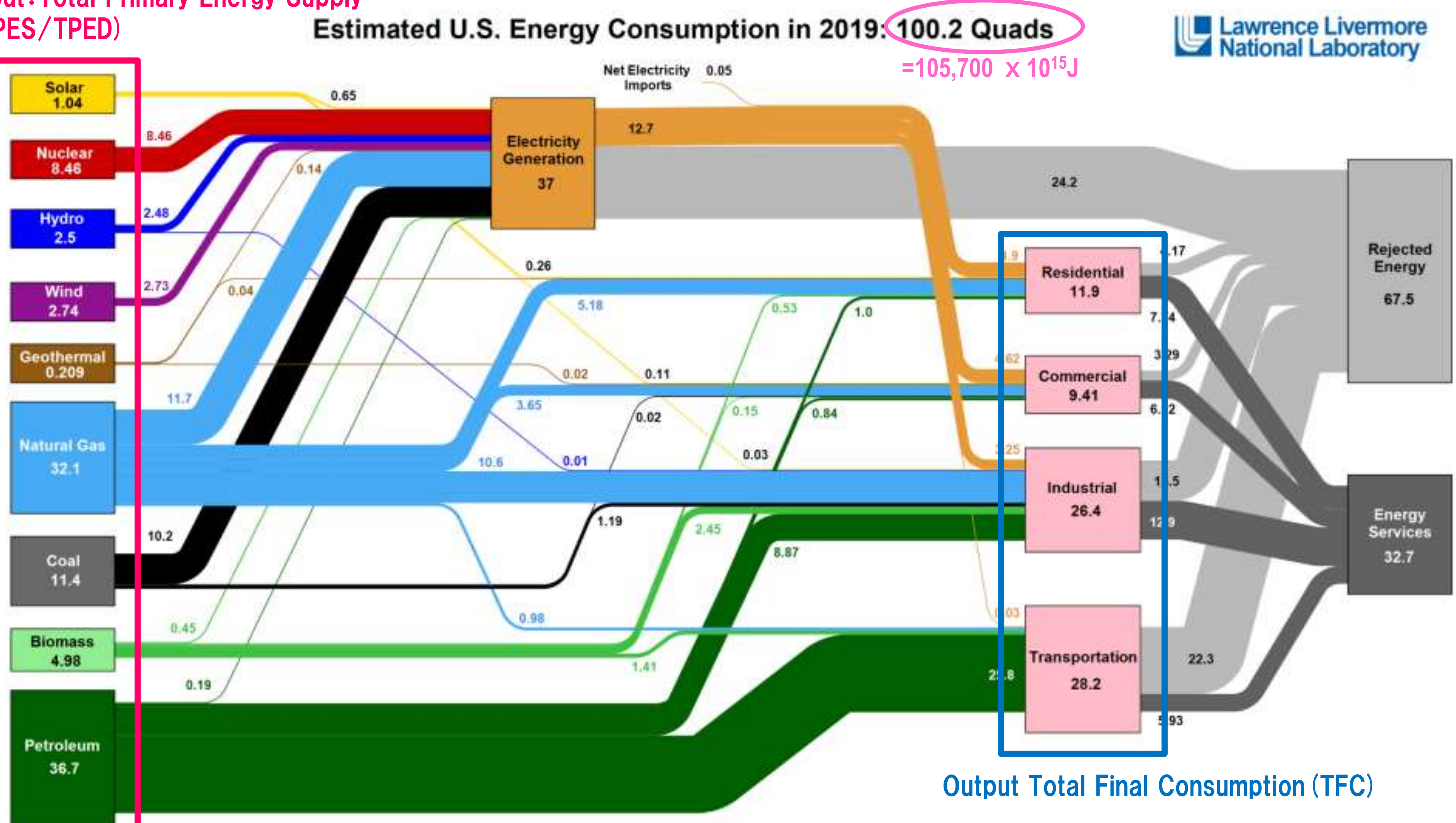
- k (kilo) = 10^3, M (mega) = 10^6, G (giga) = 10^9, T (tera) = 10^{12}

conversion table among major units

Convert to:	TJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
TJ	1	238.8	2.388 x 10^{-5}	947.8	0.2778
Gcal	4.1868 x 10^{-3}	1	10^{-7}	3.968	1.163 x 10^{-3}
Mtoe	4.1868 x 10^4	10^7	1	3.968 x 10^7	11 630
MBtu	1.0551 x 10^{-3}	0.252	2.52 x 10^{-8}	1	2.931 x 10^{-4}
GWh	3.6	860	8.6 x 10^{-5}	3 412	1

Energy 101: Energy Balance and Flow（USA）

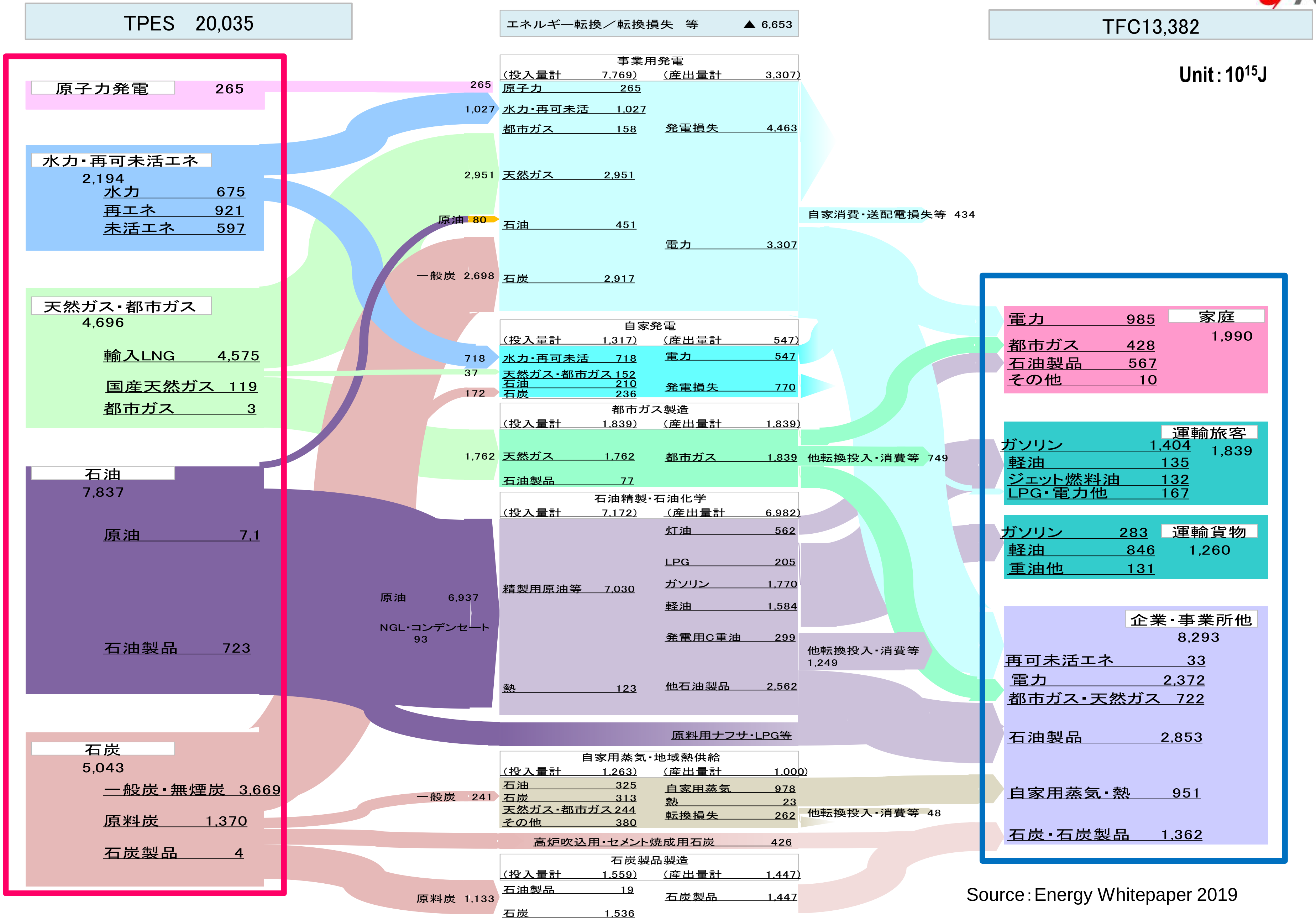
Imput：Total Primary Energy Supply （TPES/TPED）



Output Total Final Consumption（TFC）

Source: LLNL March, 2020. Data is based on DOE/EIA MER (2019). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Energy 101: Energy Balance and Flow (Japan）

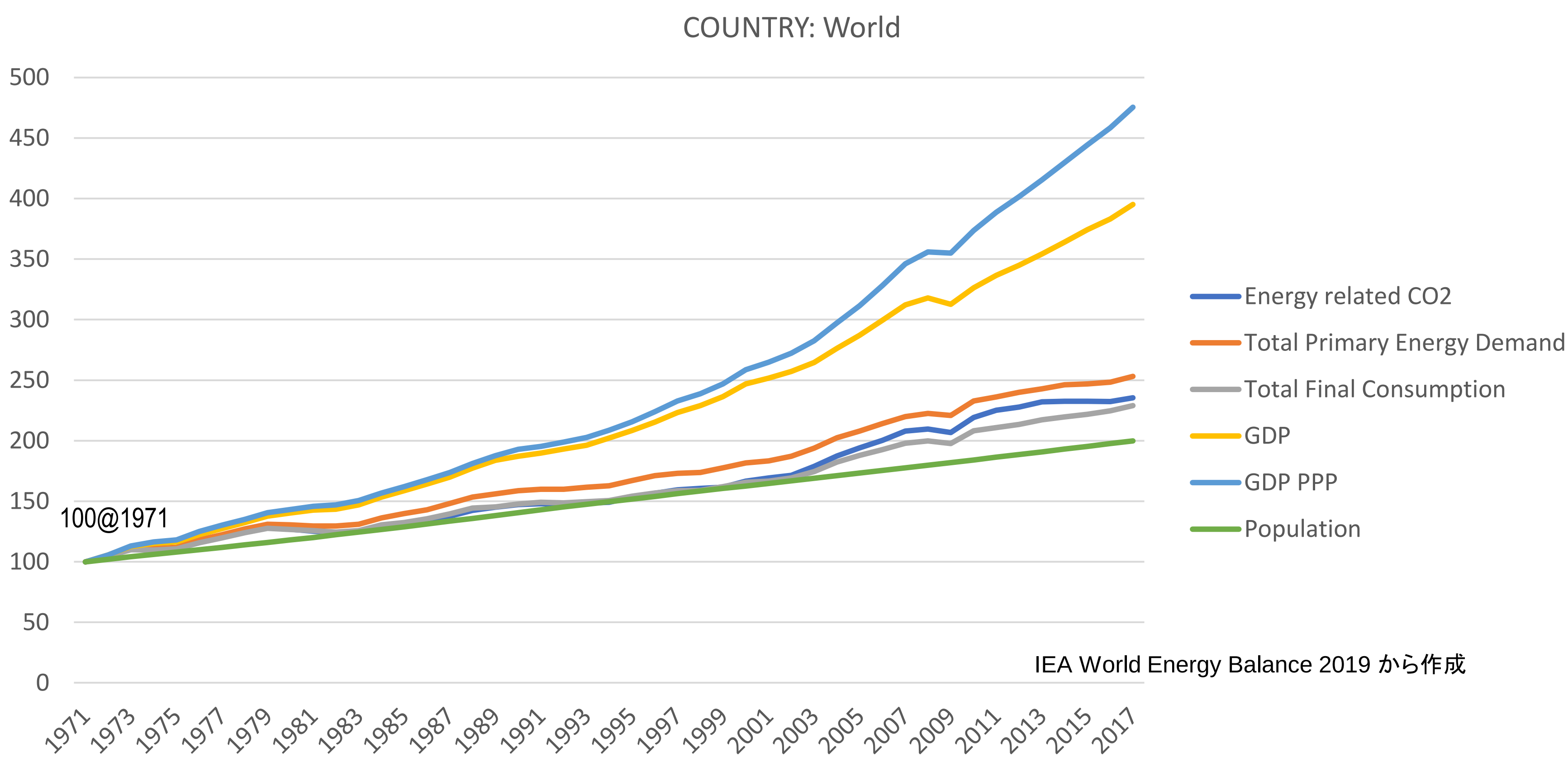


Source：Energy Whitepaper 2019

ENERGY TREND

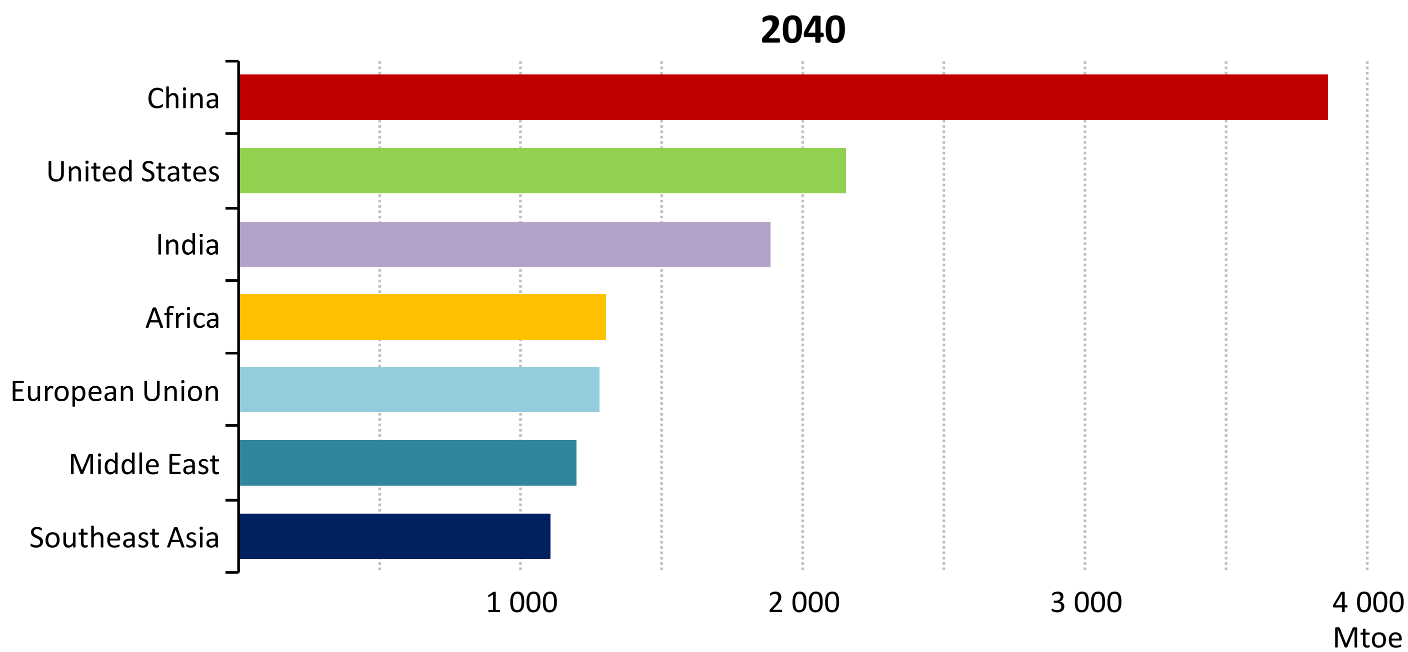
GDP, Population, Energy Demand and CO2 Emissions

- Global GDP, population, primary energy demand, final energy consumption and energy related CO2 emissions have kept increasing without exception over the last 50 years.
- The pace of increase population ＜ CO2 emissions ＜ energy demand ＜ GDP
- It means that CO2 emissions, energy demand and GDP per capita were all increased.



Energy Trend: Change in geography, record and outlook

Energy Demand

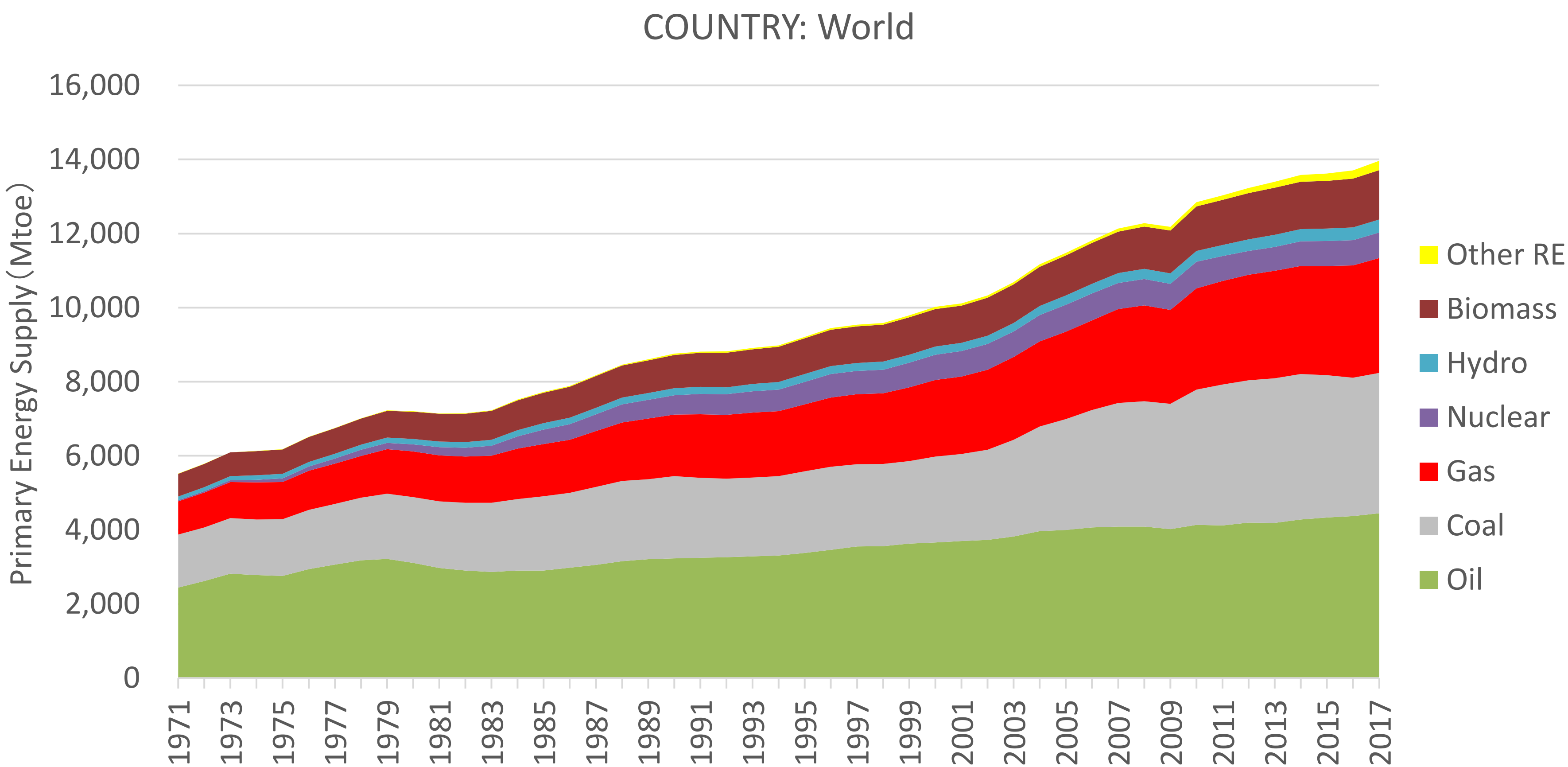


In 2000, more than 40% of global demand was in Europe & North America and some 20% in developing economies in Asia. By 2040, this situation is completely reversed.

Source: IEA “Word Energy Outlook 2018”

World Energy Trend in the last 50 years

- To meet the increasing world energy demand, supply of all the energy resources have grown over the last 50 years.
- The ratio of fossil fuel has remained over 80% to date.



Figures depicted based on data from IEA World Energy Balance 2019

Regional Energy Trend: Supply by Energy Resource

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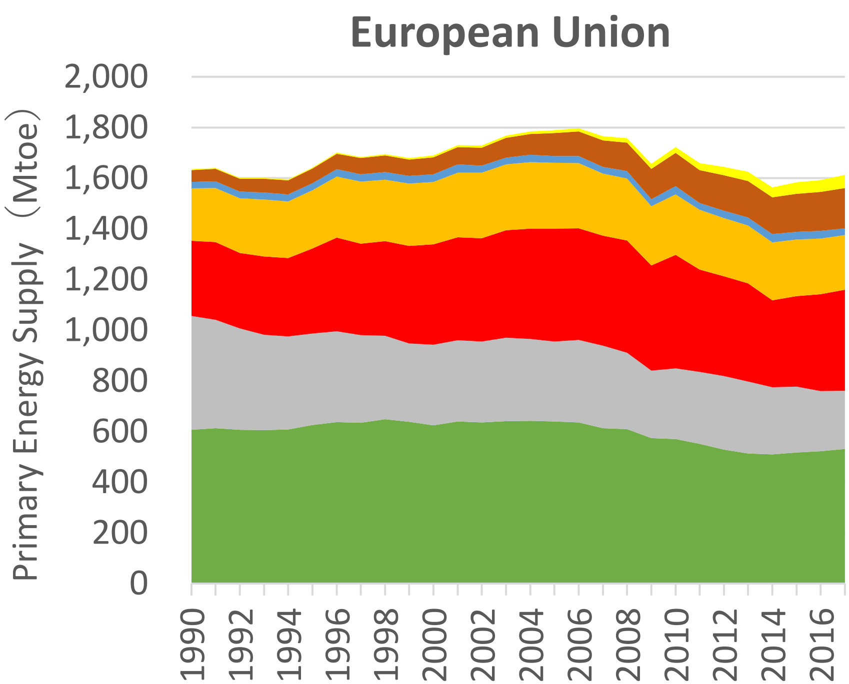
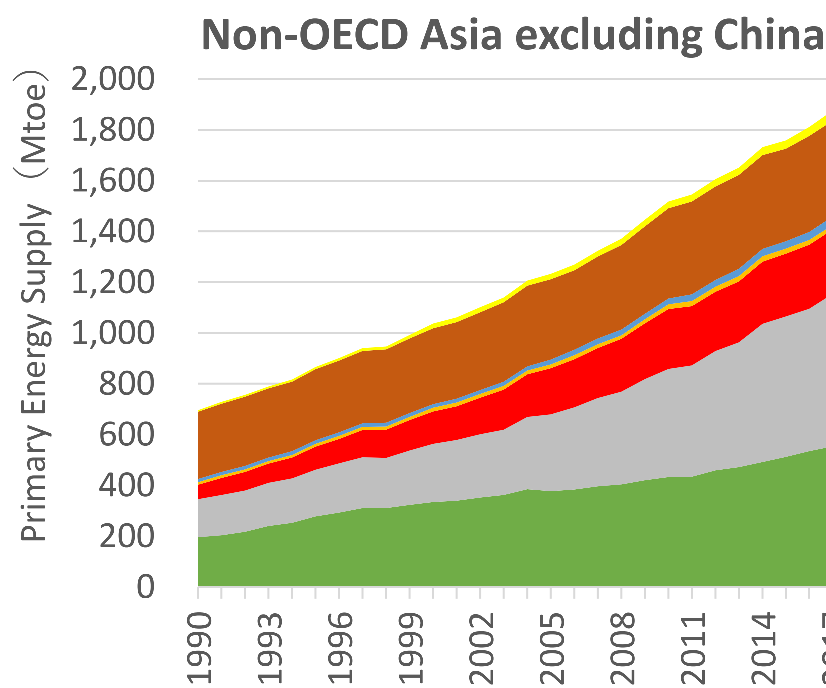
- In EU, energy demand growth has peaked in mid 2000s and started to decline, and reduction is the largest in coal.
- In Asia excluding China, energy demand has kept growing and coal has supported the largest part of the growth.



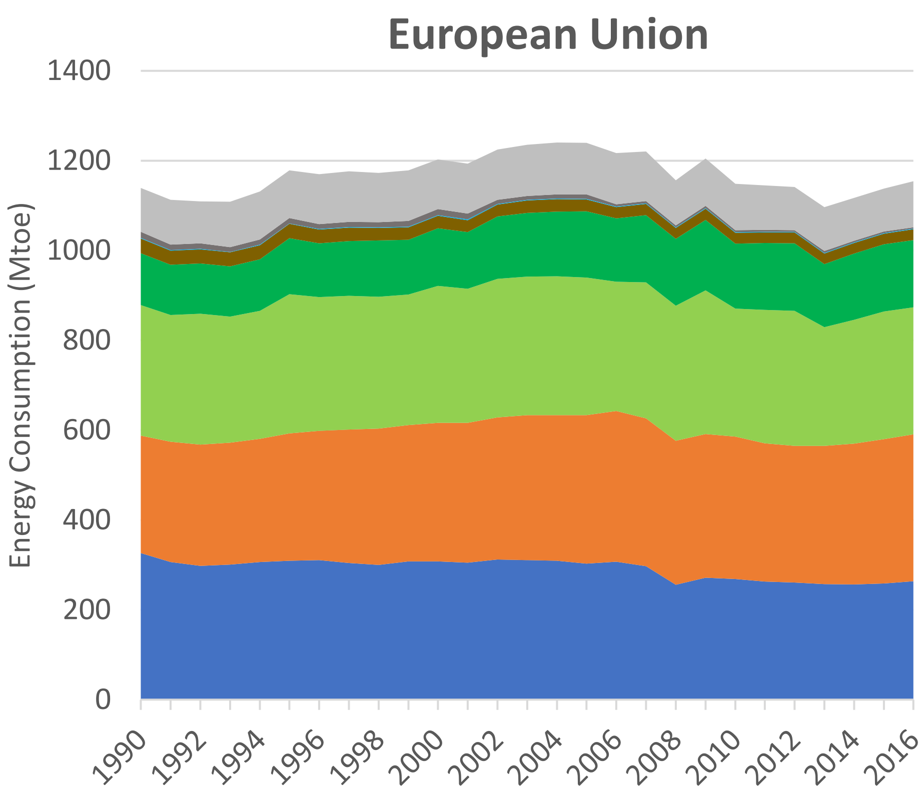


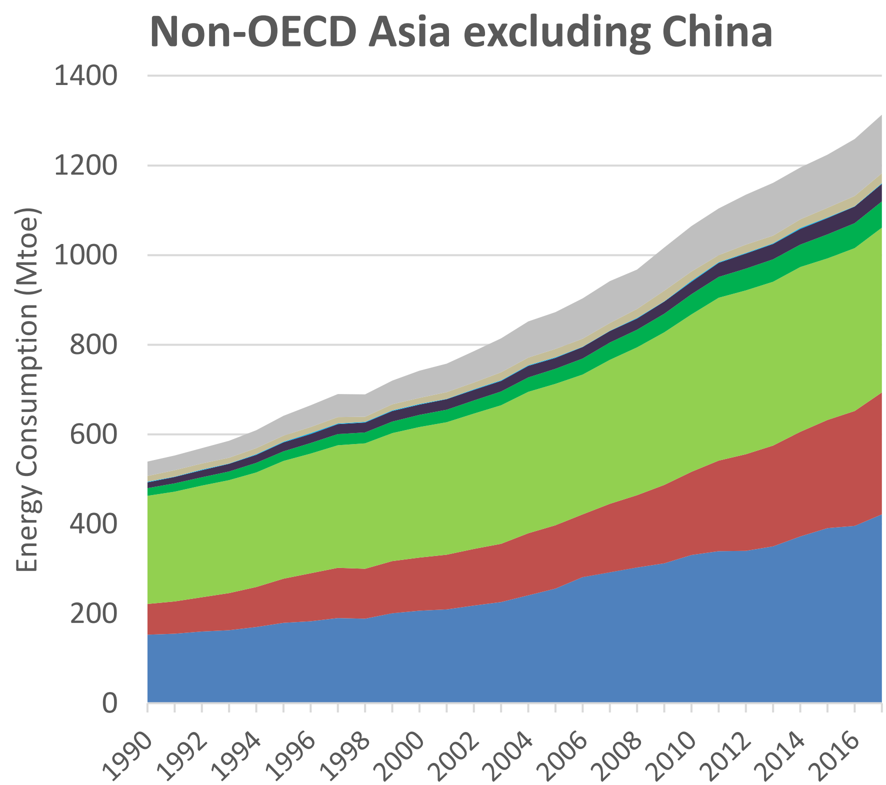
Oil Coal Gas Nuclear Hydro Biomass Other RE

Figures depicted based on data from IEA World Energy Balance 2019

Regional Energy Trend: Consumption by Sector

- In EU, total energy consumption has peaked in mid 2000s, but growth in commercial sector and decline in industry has been constant from 1990.
- In Asia, total energy consumption has kept growing and the largest growth is recorded in industry sector.



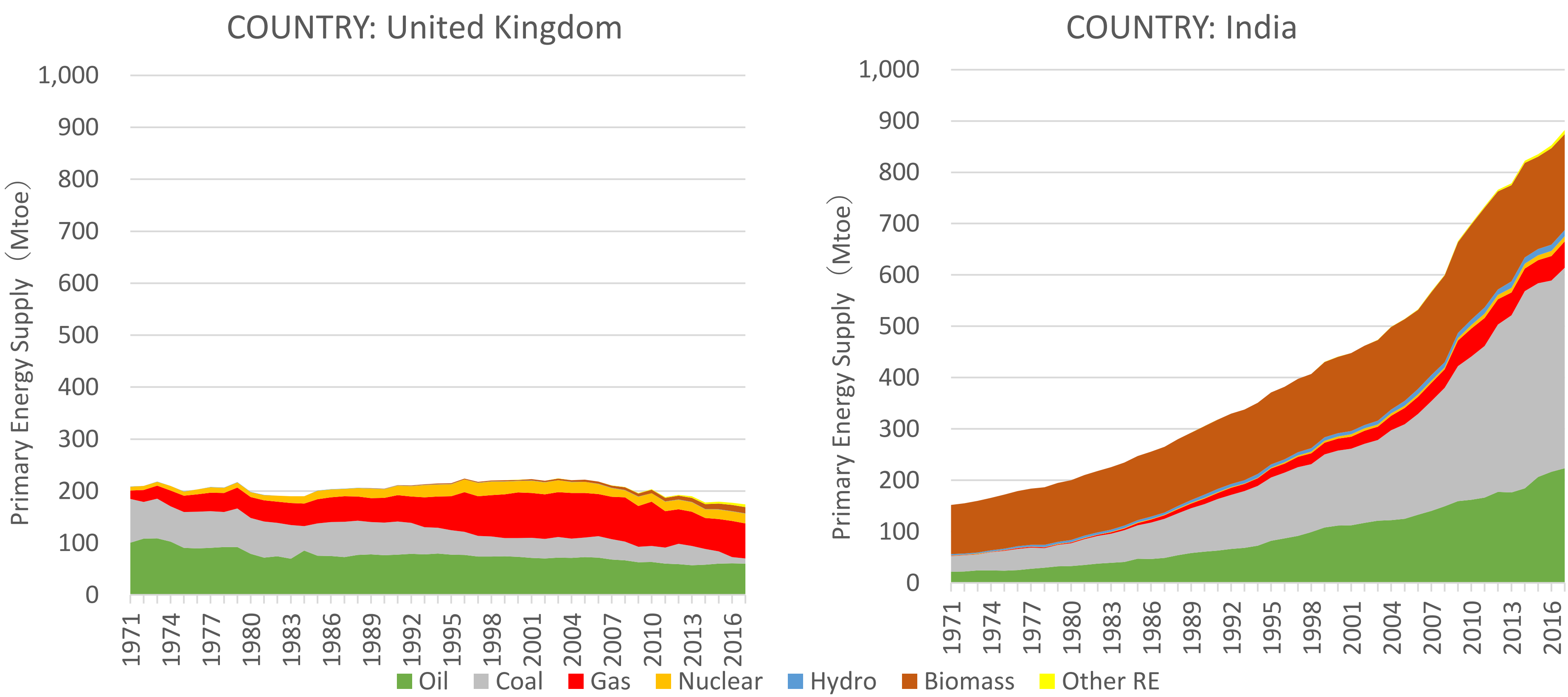


Industry
Transport
Residential
Commercial and public services
Agriculture/forestry
Fishing
Final consumption not elsewhere specified
Non-energy use

Figures depicted based on data from IEA World Energy Balance 2019

Country Energy Trend: Supply in UK and India

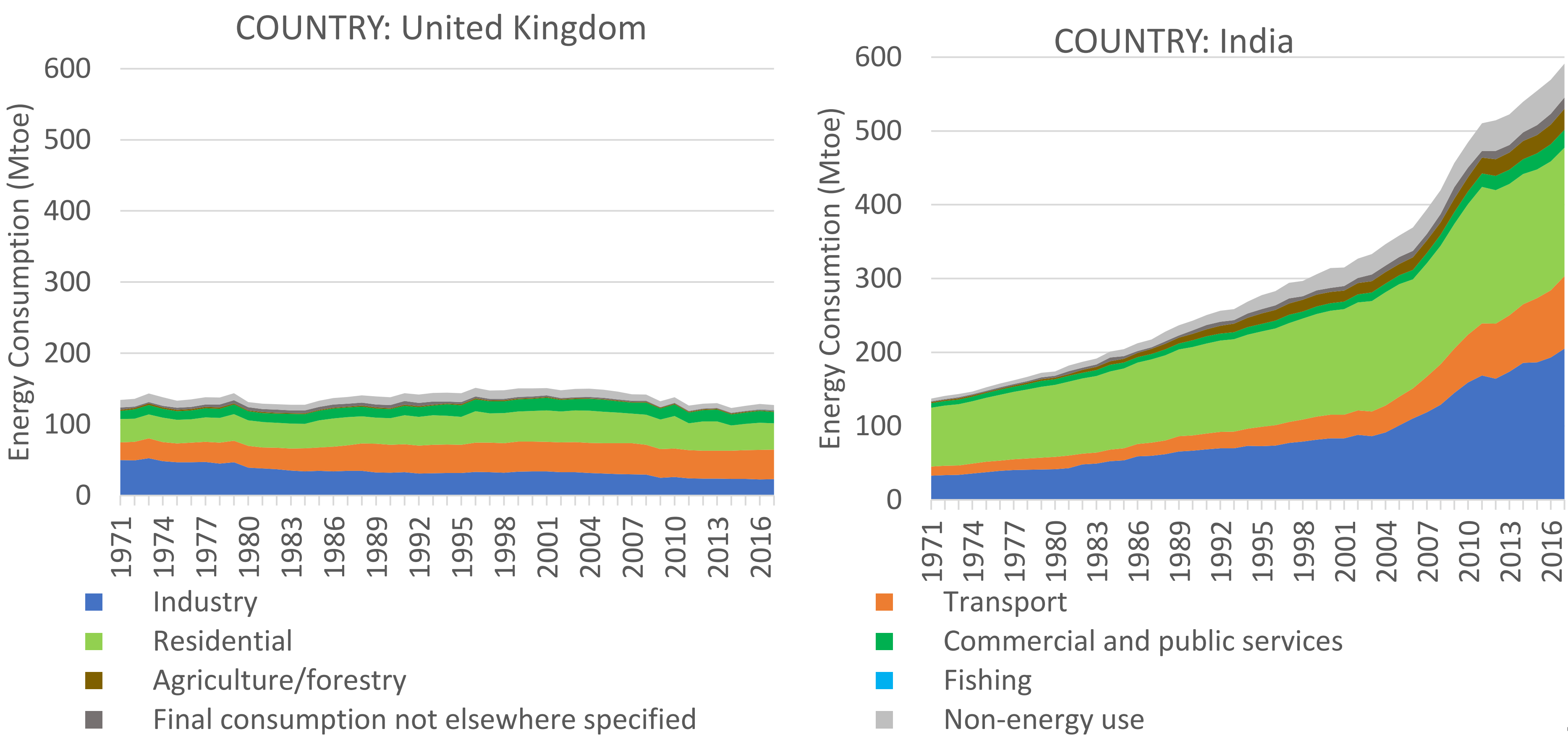
- In UK, energy demand has remained at similar level but there have been reduction in coal and increase in gas.
- In India, energy demand has kept growing and picked up pace in mid 2000s, and coal has supported the largest part of the growth.



Figures depicted based on data from IEA World Energy Balance 2019

Country Energy Trend: Consumption in UK and India

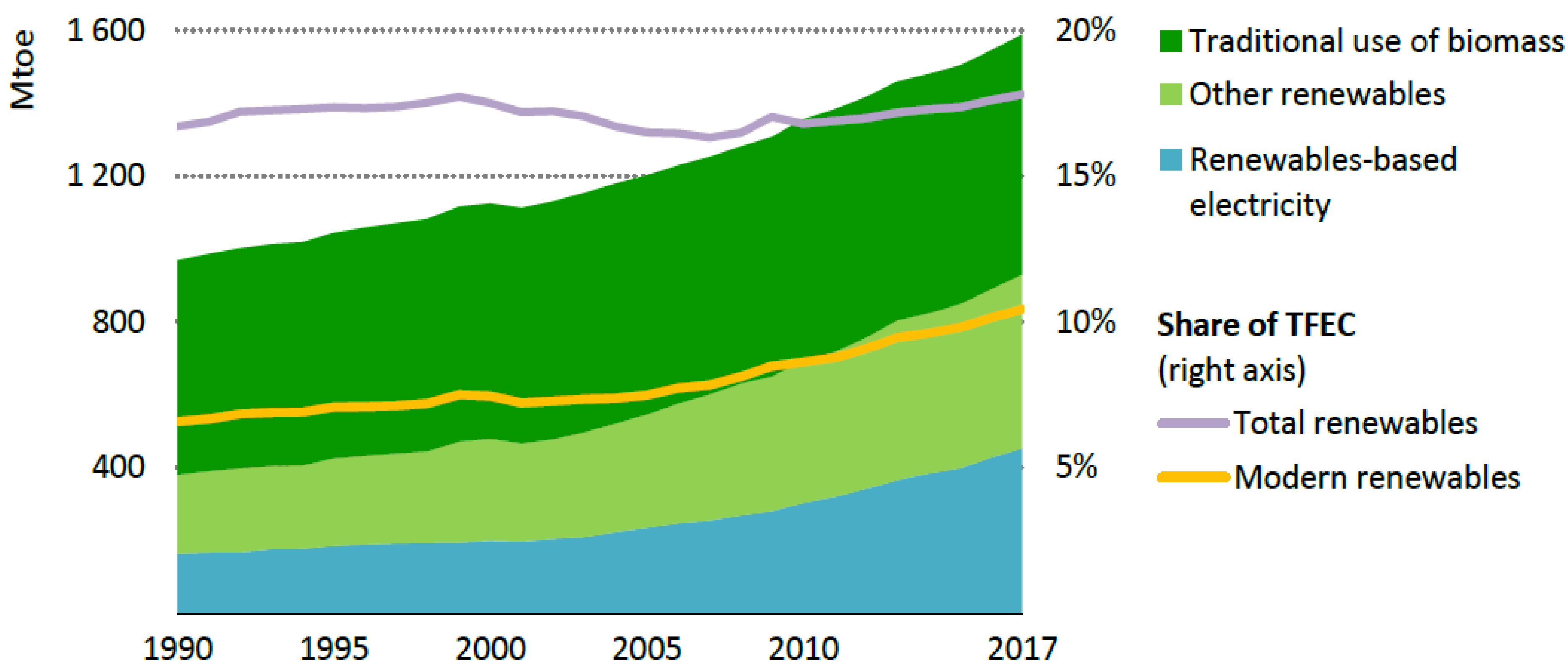
- In UK, total energy consumption has remained unchanged, but constant reduction is seen in industry sector.
- In India, total energy consumption has kept growing and picked up pace in mid 2000s. The largest growth is recorded in industry sector.



Figures depicted based on data from IEA World Energy Balance 2019

Renewable energy trend

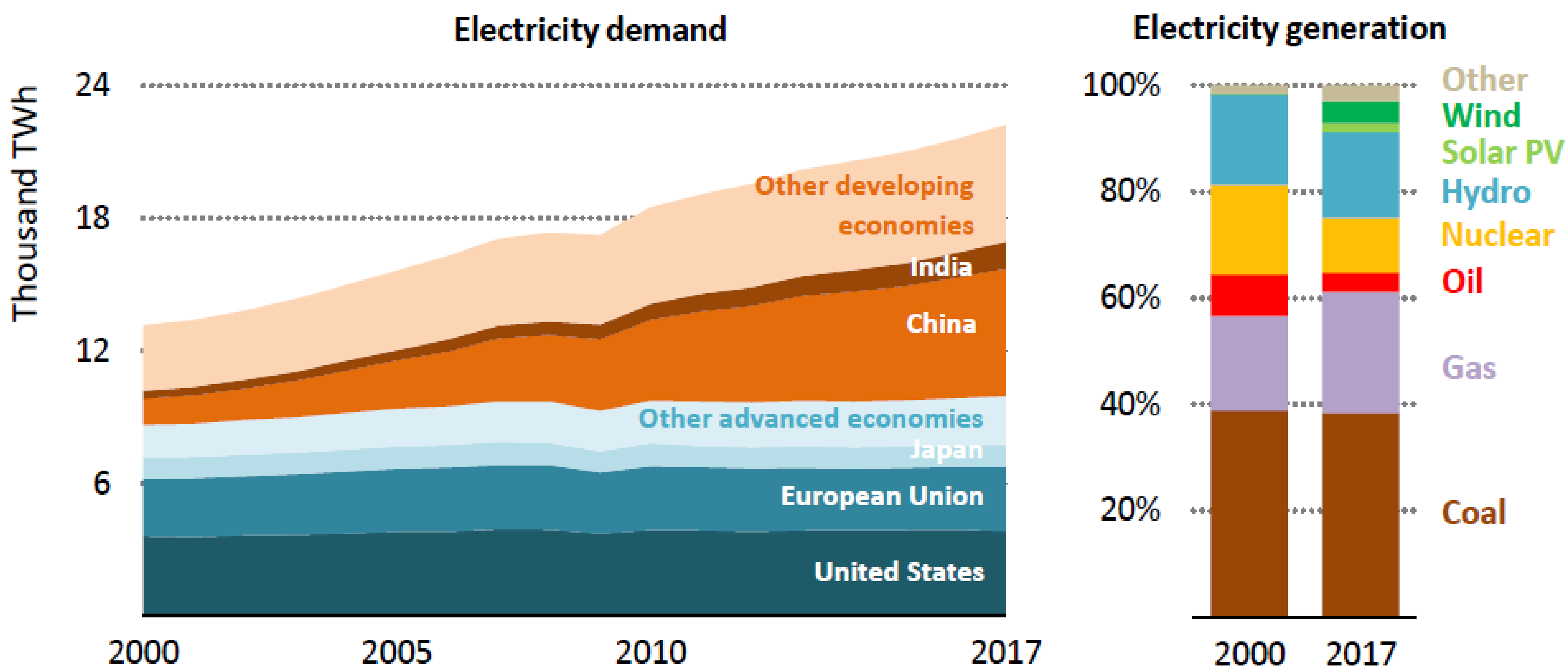
- The growth of renewable energy is faster than increase of energy consumption.
- Traditional biomass (firewood, animal waste) still remains the largest source of renewables.



Source: IEA "Word Energy Outlook 2018"

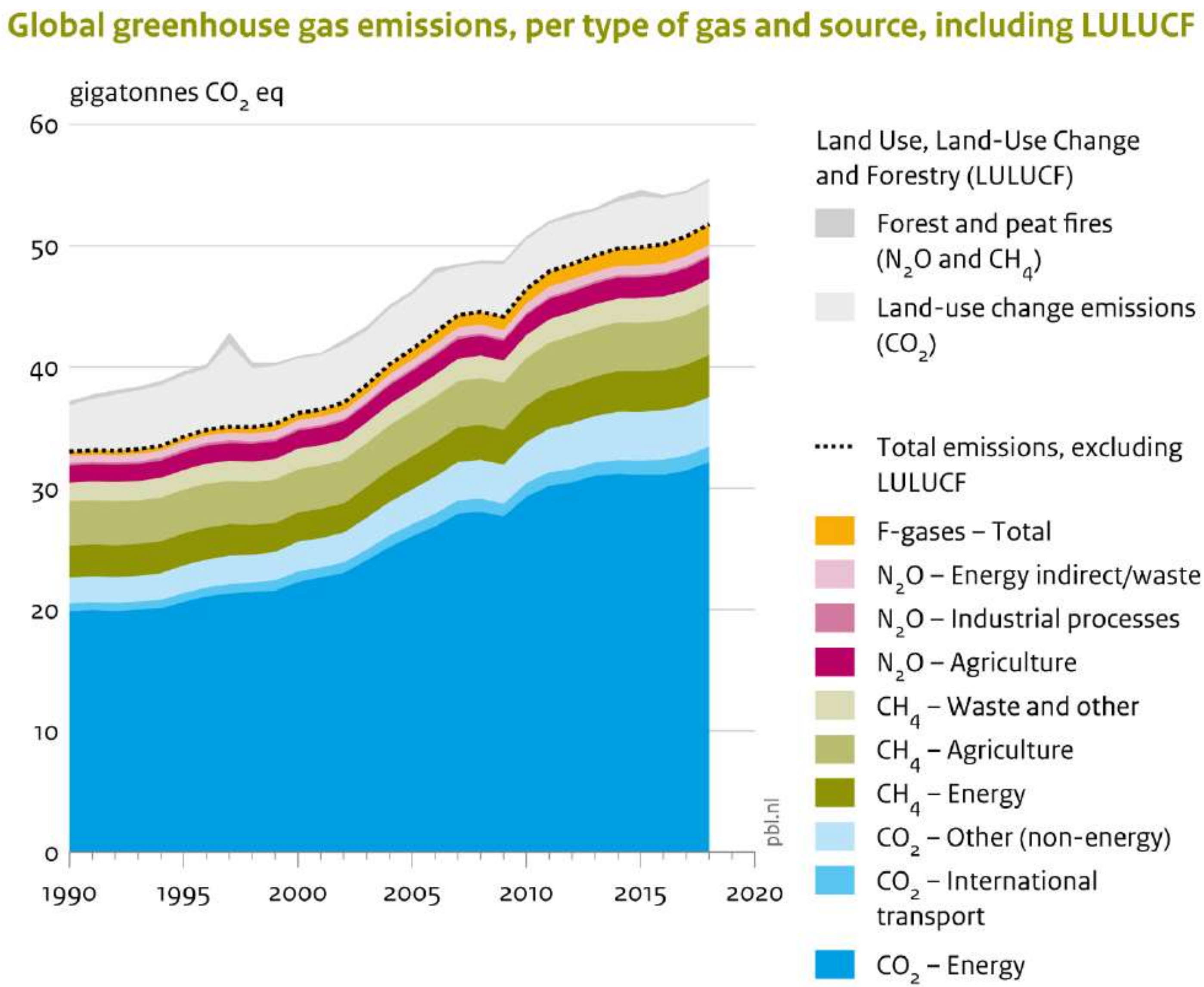
Power generation trend

- Global electricity demand ha increased around 70% from 2000 to 2017.
- Power mix remains dominated by fossil fuel, especially coal even with growth in renewables.



Source: IEA "Word Energy Outlook 2018"

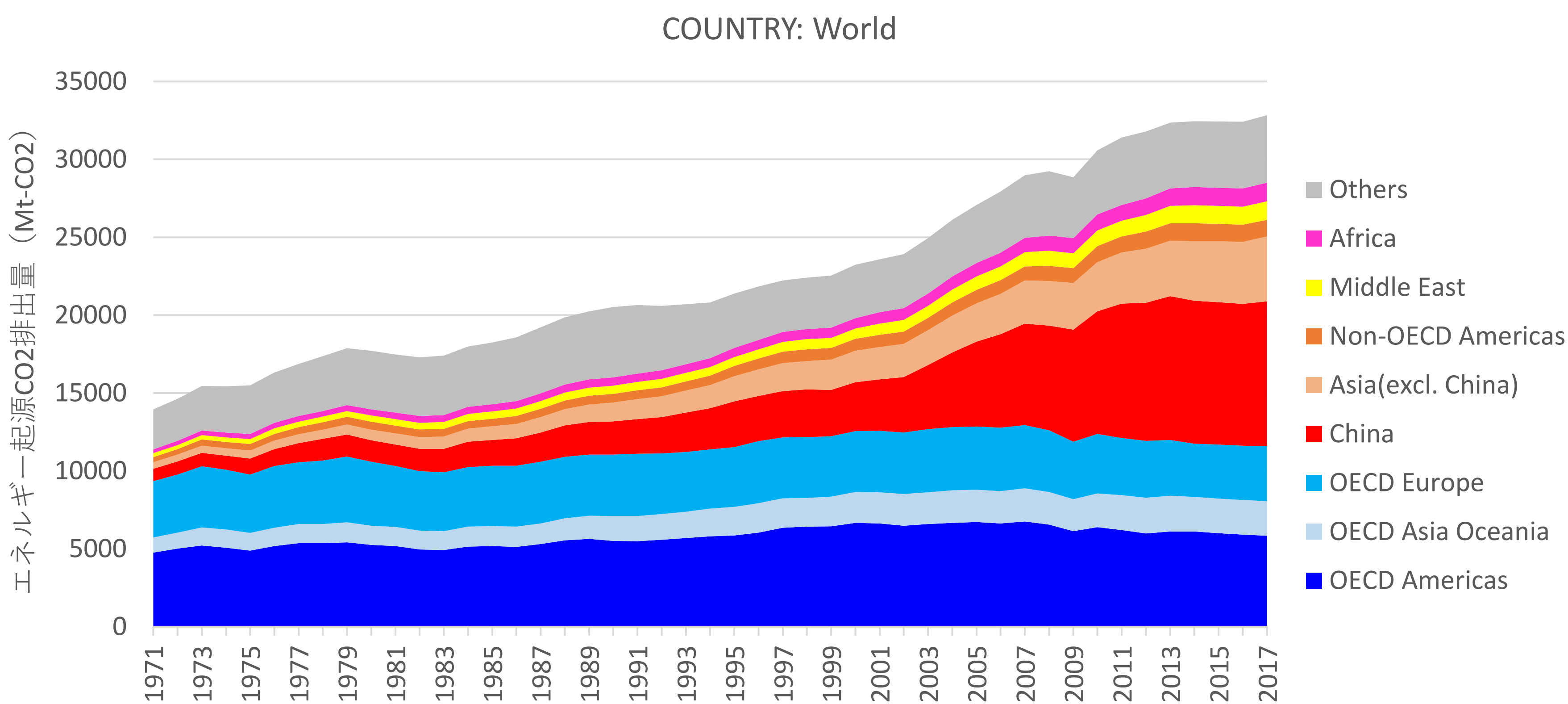
Emissions of Major Anthropogenic Greenhouse Gases



Source: PBL Netherlands Environmental Assessment Agency "TRENDS IN GLOBAL CO2 AND TOTAL GREENHOUSE GAS EMISSIONS 2019 Report"

Global Energy-related CO2 Emissions Trend by Region

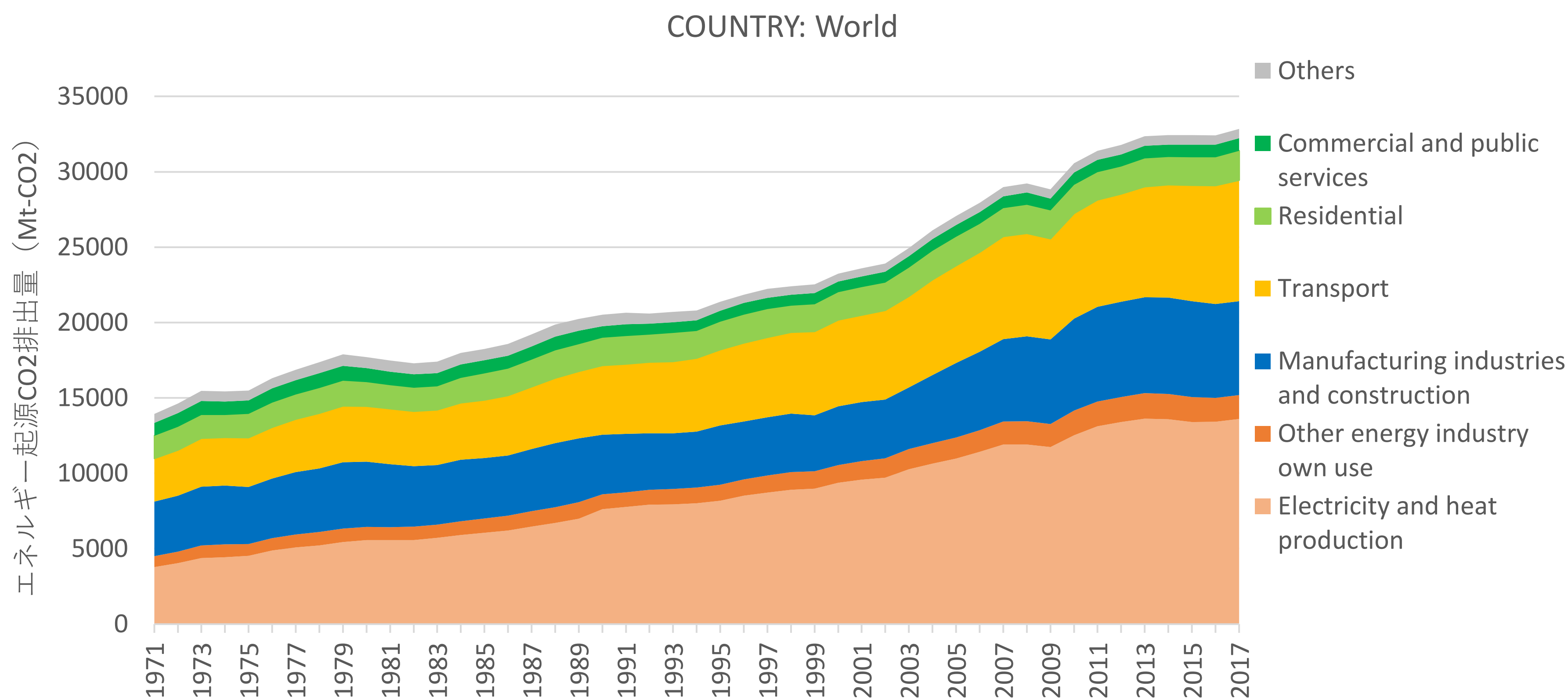
- CO2 emissions in OECD (colored in blue) has kept gradually declining since 2008
- CO2 emissions in non-OECD has kept increasing since 50 years ago especially led by strong rise in China, and it resulted net increase of global emission increase.



Data Source: IEA World Energy Balance 2019

Global Energy-related CO2 Emissions Trend by Sector

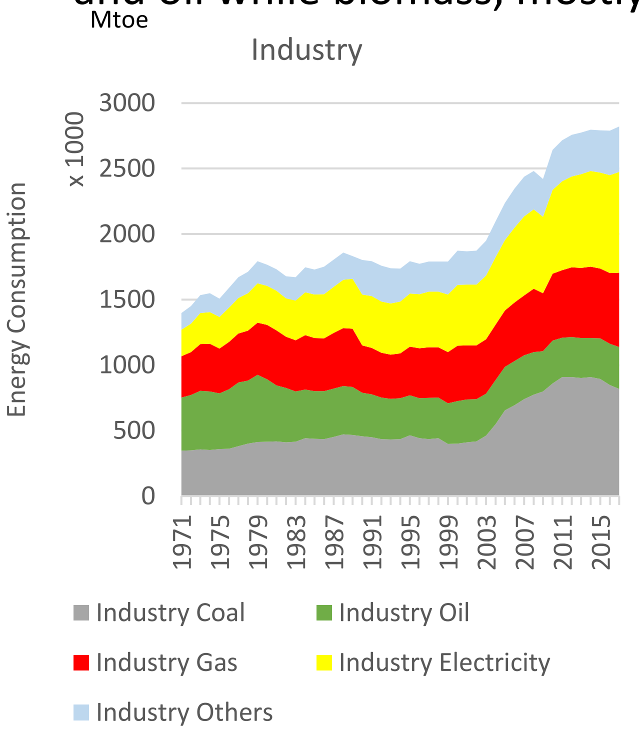
- Electricity and heat production has been the largest source of CO2 emissions while emissions in all sectors are growing.
- It means decarbonization should be addressed in all sectors.
- Decarbonization in electricity sector is deemed simple (if not easy); increase od zero-emission power (renewables and nuclear) and CCUS application for fossil-fired power.
- But it is not simple in industry and transport sector.

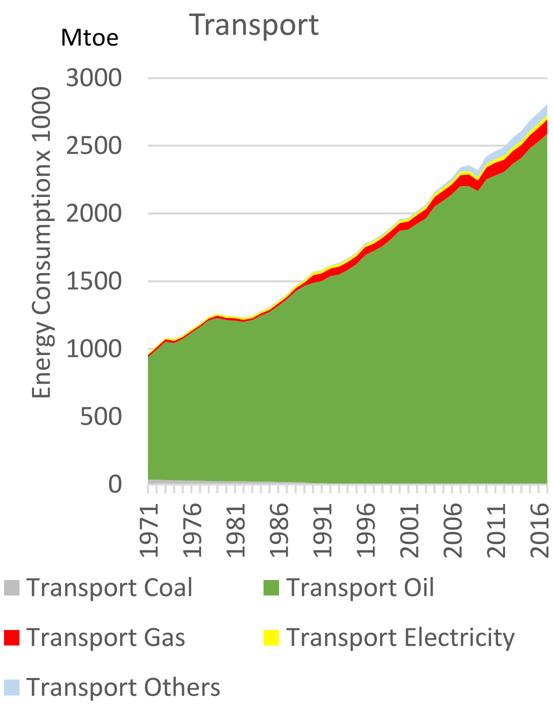


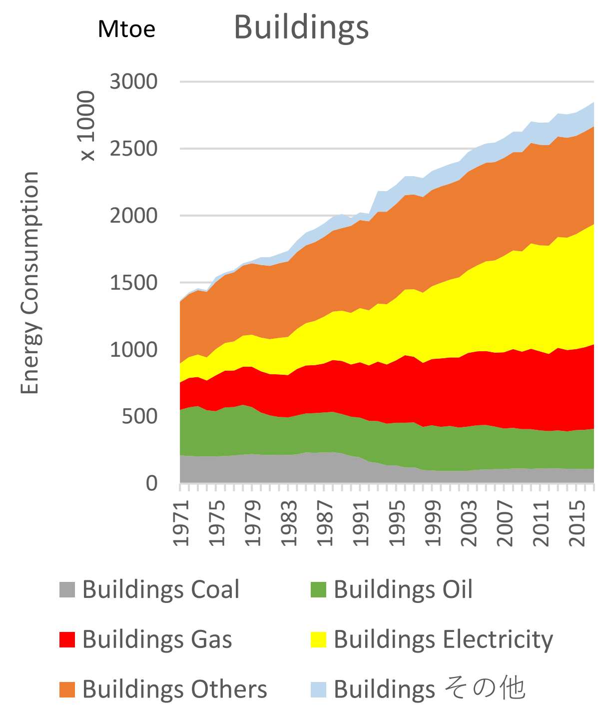
Data Source: IEA World Energy Balance 2019

Sectoral Final Energy Consumption Trend by Fuel

- Decarbonization should be addressed by sector in accordance with its characteristics.
- At this moment, energy consumption in three sectors are equal but the fuel mix are different.
- In industry sector, the rise of coal in 2000th is remarkable and it was mainly due to increase of material coal consumption for steel production in China.
- In transport sector, almost all of energy is oil and its growth is quicker than other sectors.
- In building sector, steady increase of gas and electricity is larger than decrease of coal and oil while biomass, mostly traditional biomass, remains.





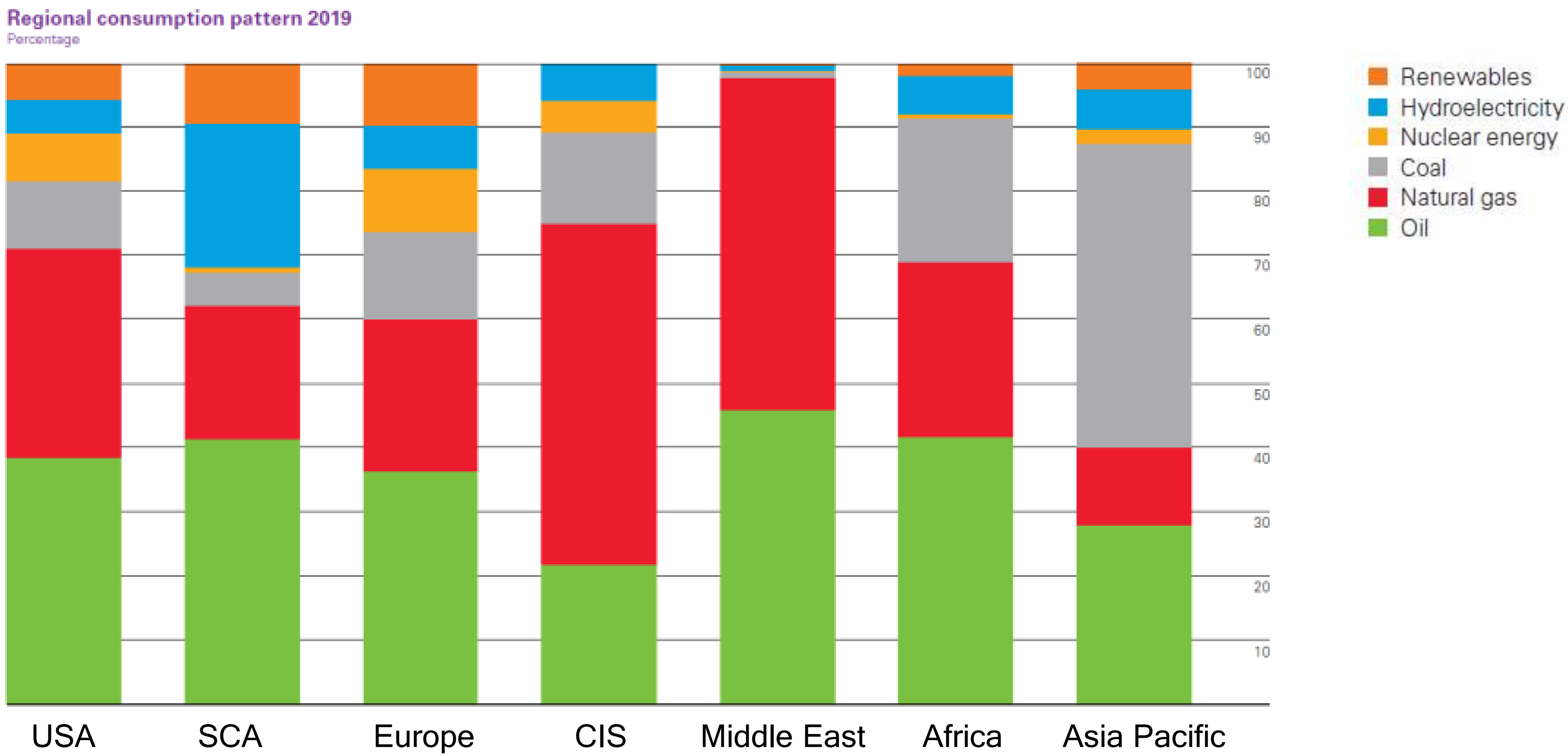


Data Source: IEA World Energy Balance 2019

CURRENT ENERGY SNAPSHOT

Fuel Mix of Primary Energy Demand by Region（2019）

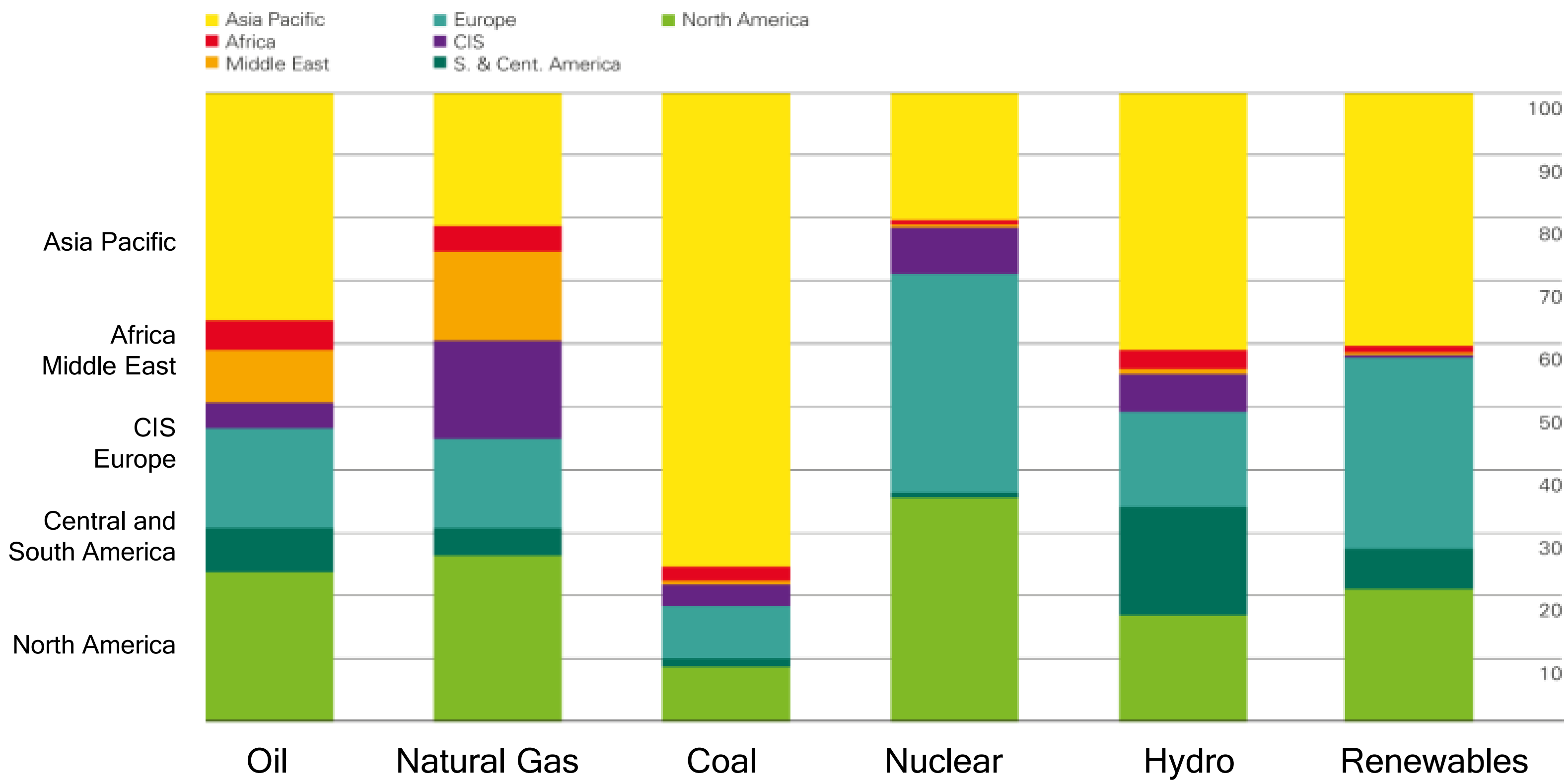
- Fuel mix of primary energy varies; high gas ratio in gas producing regions like Middle East and CIS, high coal ratio in coal producing Asia Pacific.
- Not only geological energy resource distribution, energy policy also affects fuel mix, as renewables in South and Central America and Europe.



Source: BP Statistical Review of World Energy 2020

Regional Mix of Primary Energy by Fuel (2018)

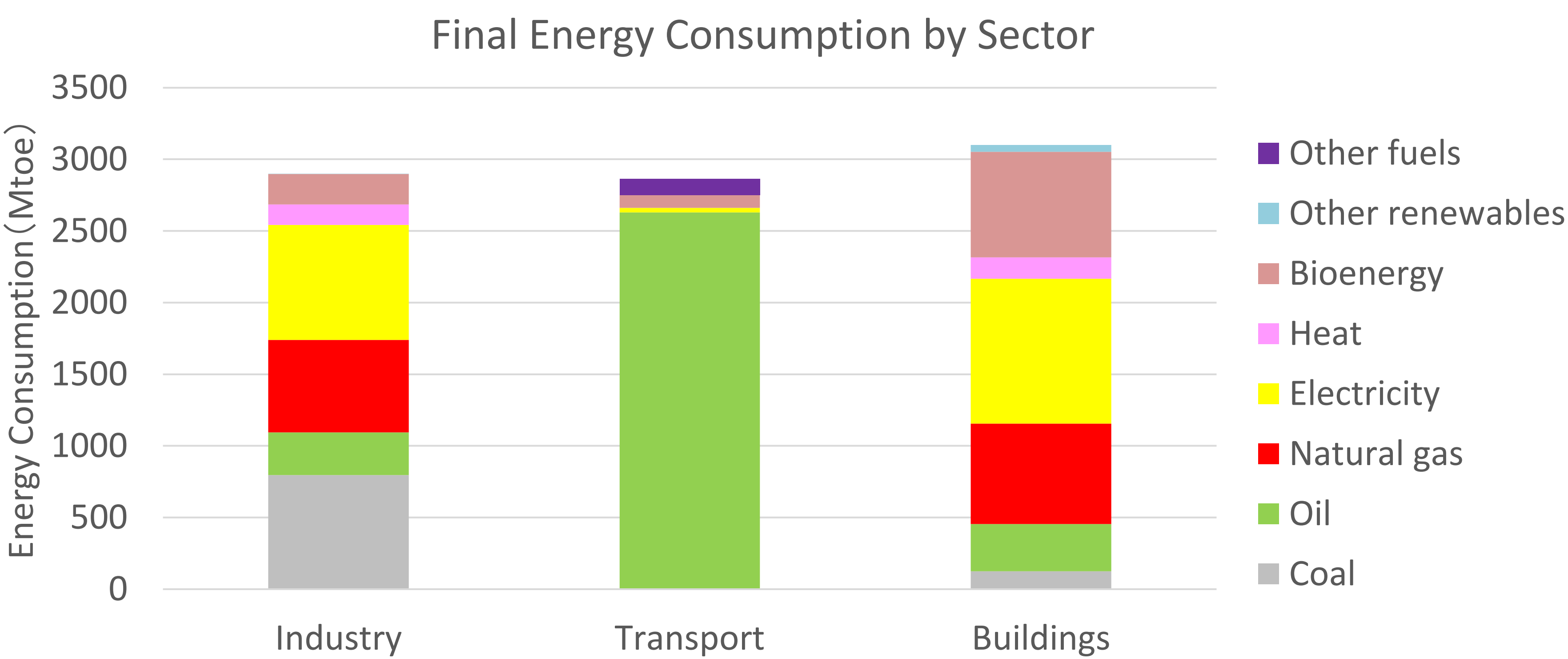
- High share of Asia and Pacific in coal due to strong demand in China and India
- Nuclear is limited mostly in North America and Europe
- Gas's good balance of region is lead by increased LNG trade.



Source: BP Statistical Review of World Energy 2019

Final Energy Consumption by Sector（2018）

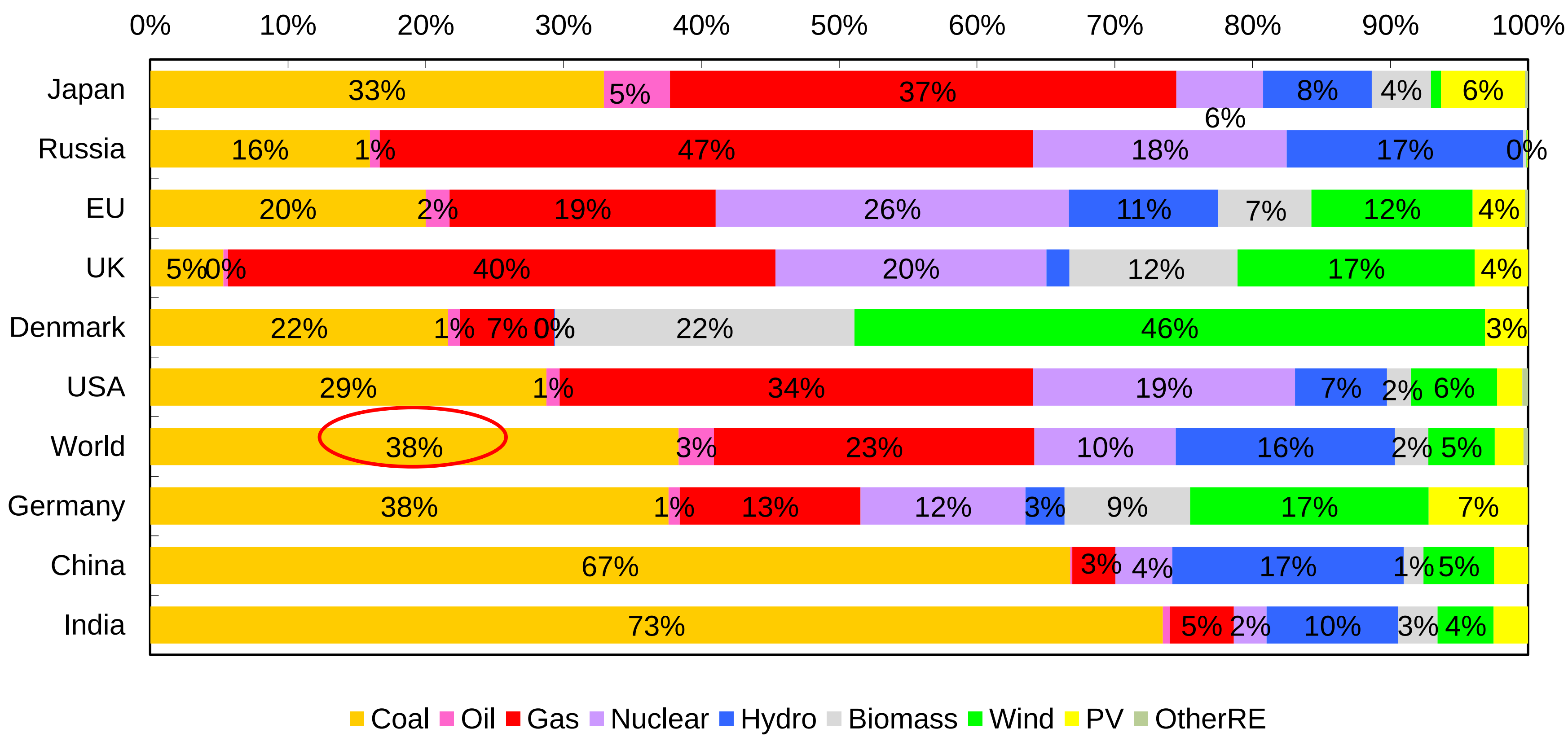
- Industry Sector: Fossil fuel has majority lead by big demand of coal, followed by good share of electricity.
- Transport Sector: Almost all is oil while electricity is almost invisible.
- Building Sector: Big share of electricity, followed by bioenergy that is mostly traditional biomass used in developing countries for cooking and heating.



IEA World Energy Outlook 2019 から作成

Power generation portfolio, the latest data（2018）

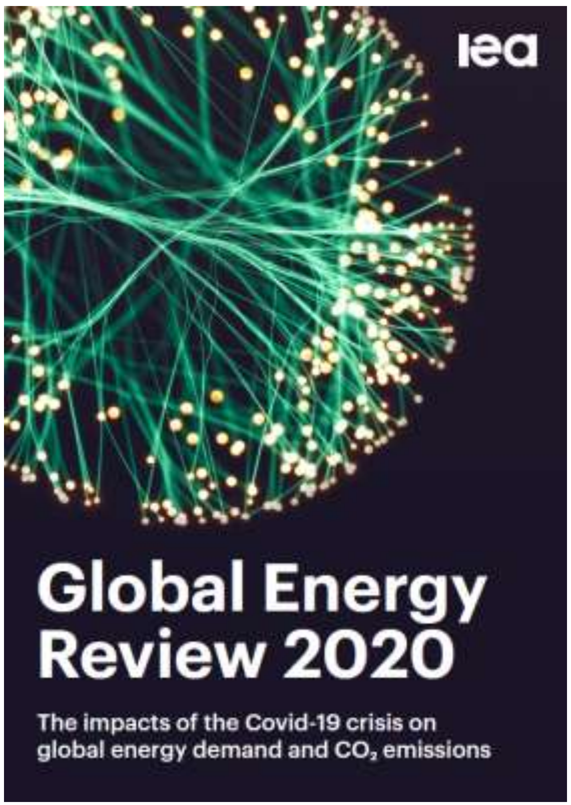
- Coal is supplying 38%, the largest share of global power generation.
- Especially in China and India, coal share is around 70%.
- In Germany, coal share is declining but still the largest.



Source: IEA "World Energy Outlook 2019", IEA "Electricity Information 2019"

COVID-19 Impact on Energy –IEA's Forecast–

- Global Energy Review, IEA's annual publication in April this year featured impact of COVID-19 with subtitle of "The impacts of the Covid-19 crisis on global energy demand and CO2 emissions".
  https://www.iea.org/reports/global-energy-review-2020
- World Energy Outlook 2020 published in October also analyzed the impact of COVID-19 in Chapter 2.



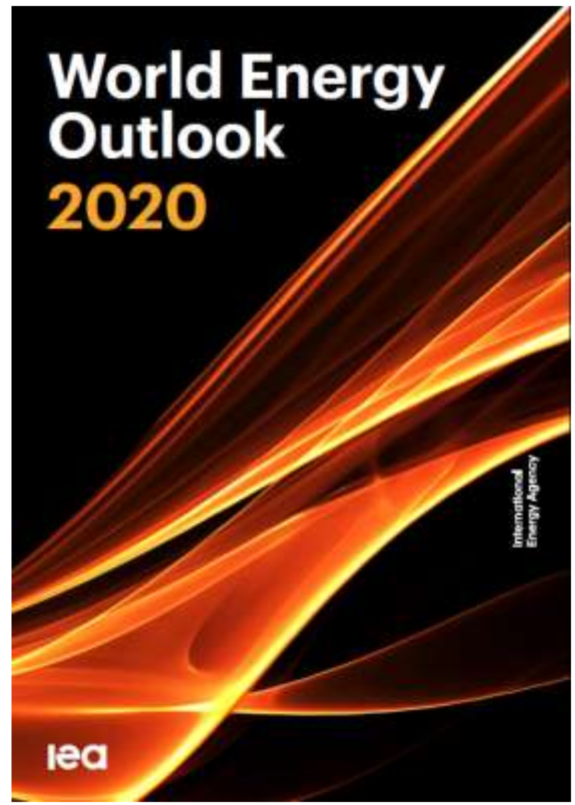
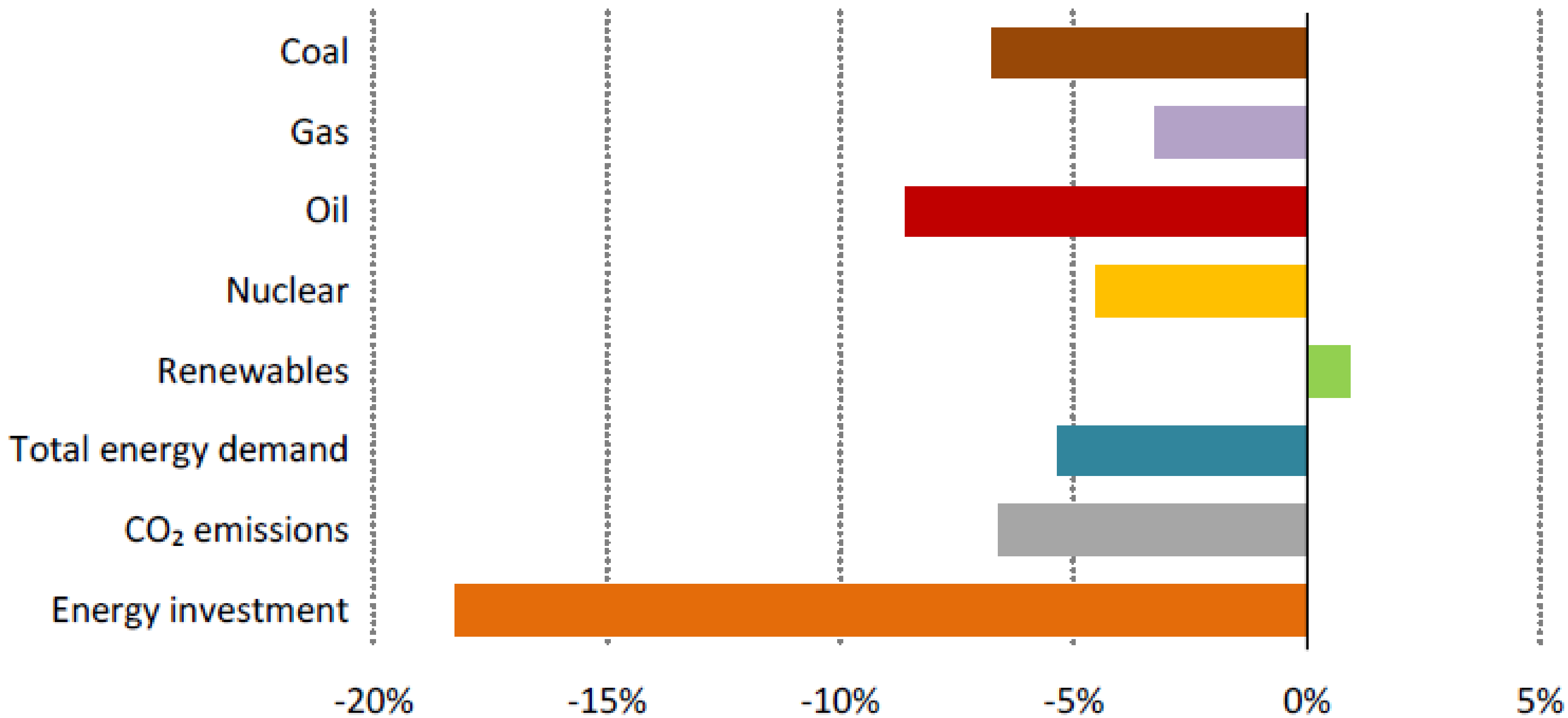


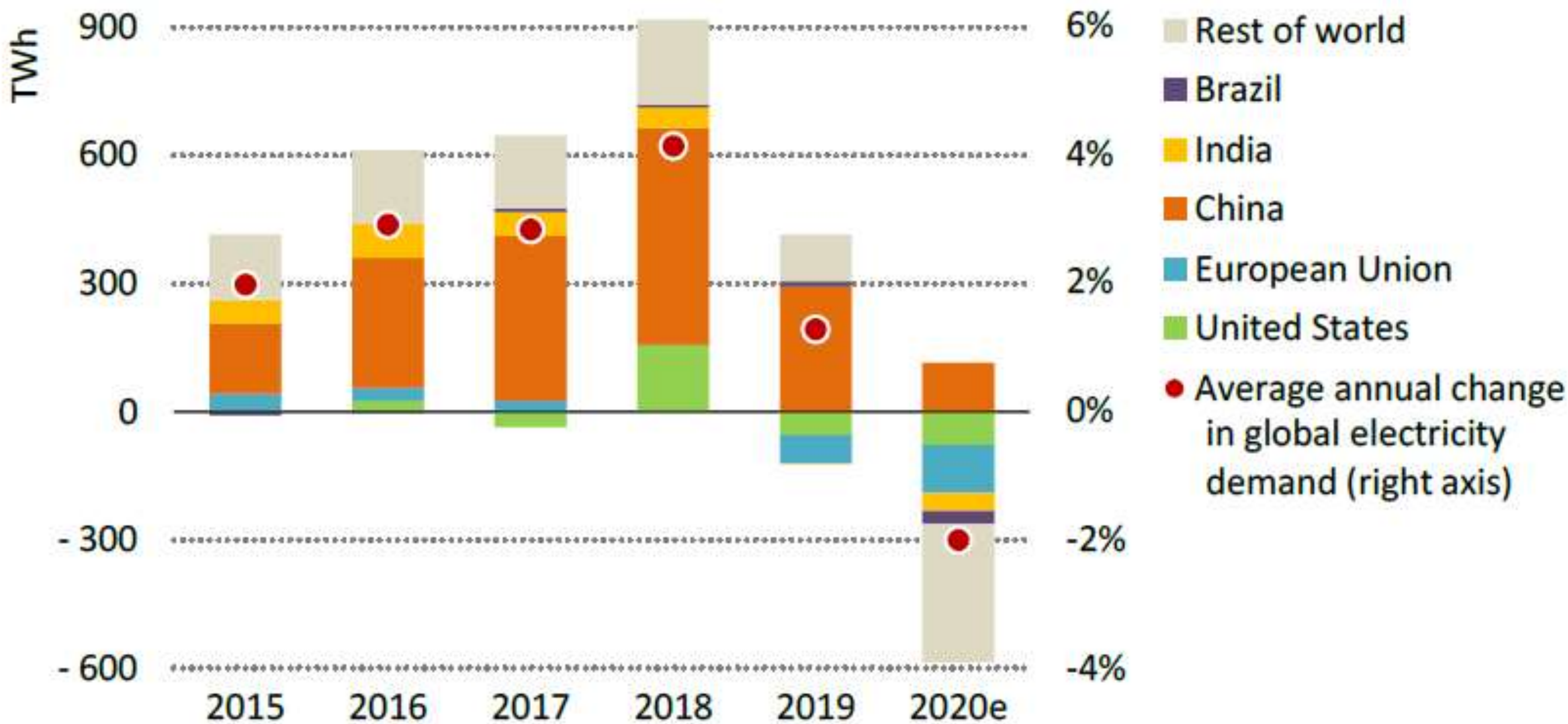
Figure 2.1 ▷ Key estimated energy demand, CO_2 emissions and investment indicators, 2020 relative to 2019



Resilient renewables output means the fall in emissions in 2020 is larger than the estimated 5% fall in energy demand, while investment plunges by 18%

Impact on Electricity Demand

Figure 2.8 ▷ Change in electricity demand by region



Electricity has been growing twice as fast as total energy demand in recent years, and its estimated 2% fall in in 2020 is less than half that of overall energy demand

Change in IEA's forecast of COVID-19 impact

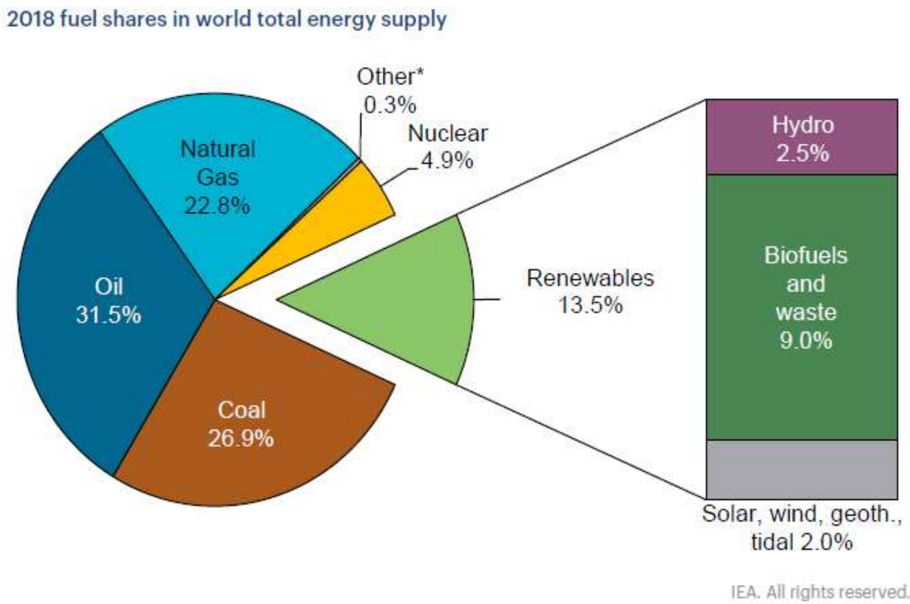
- Forecast in GRE2020 were revised and most of impacts were softened except nuclear.
- It is mainly because assumed GDP reduction was revised from -6% to -4.6%, supposedly mainly due to faster economic recovery in China than assumed in April.
- Forecast in October should be closer to the reality reflecting longer observation.

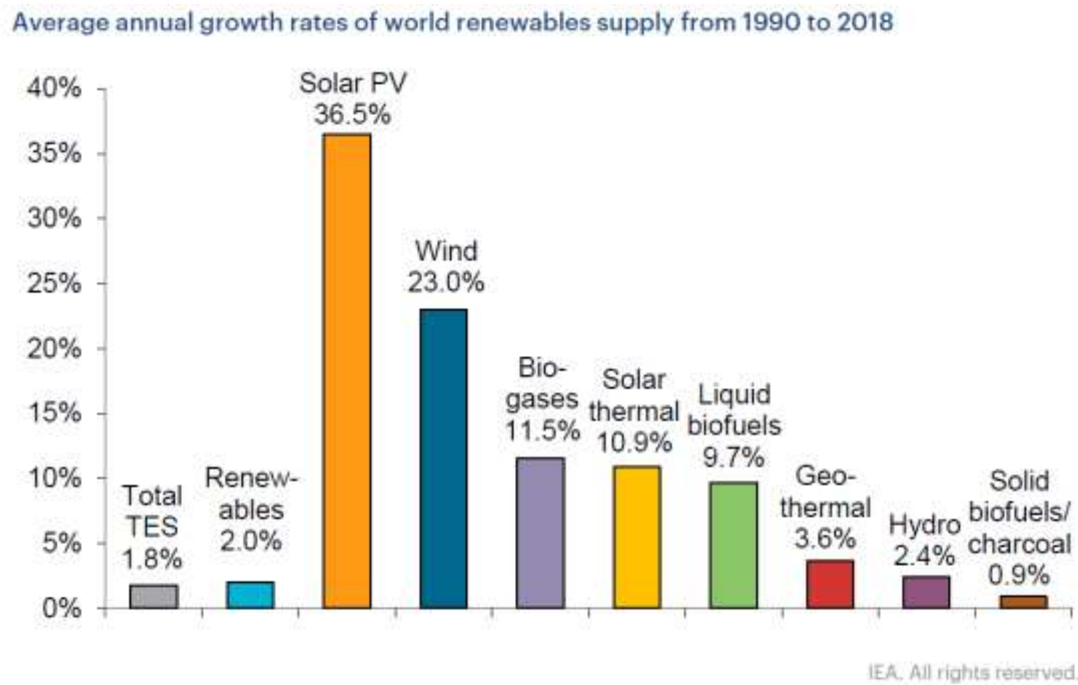
	Global Energy Review 2020 (April)	World Energy Outlook 2020 (October)
Assumed GDP growth	-6%	-4.6%
Primary Energy Demand	-6%	-5%
Oil	-9%	-9%
Coal	-8%	-7%
Natural Gas	-5%	-3%
Nuclear	-3%	-4%
Renewables	+1%	+1%
Electricity Demand	-5%	-2%
Energy Related CO2 Emissions	-8%	-7%

CHARACTERISTICS OF ENERGY BY TYPE

Renewables：Primary Energy

- Share of renewables in global primary energy demand is 13.5%, and around 70% of that is traditional biomass, e.g., firewood and animal waste for cooking and heating.
- Hydro has the second largest share of 19%, followed by wind (6%), geothermal (5%)

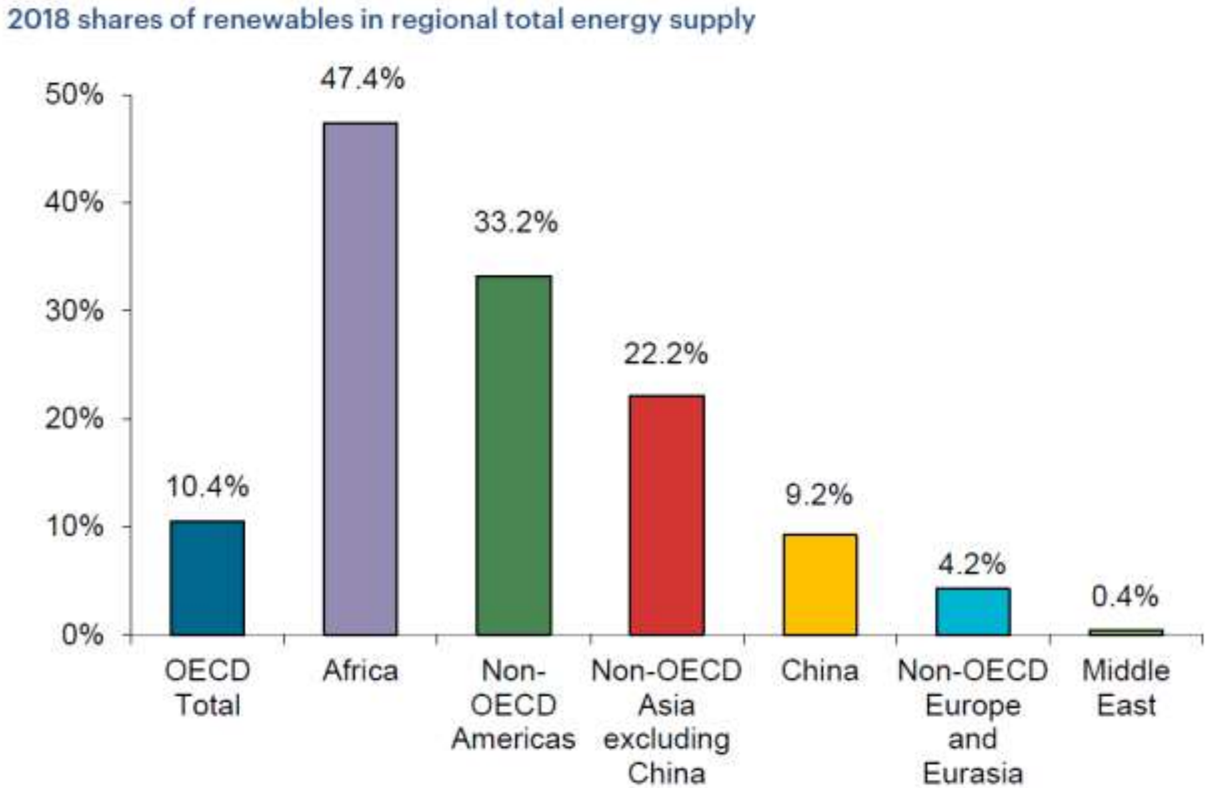


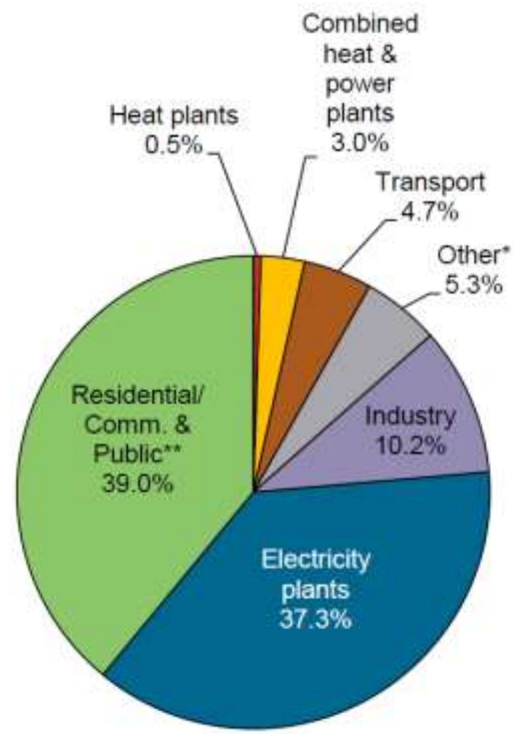


Source: IEA “Renewables Information Overview 2020”

Renewables：Use in Primary Energy by Region

- Renewables' share in reginal total energy supply is high in Africa followed by Latin America and Asia.
- In sectoral consumption of renewables, residential, commercial and public (e.g. buildings sector) has the largest share larger than electricity.



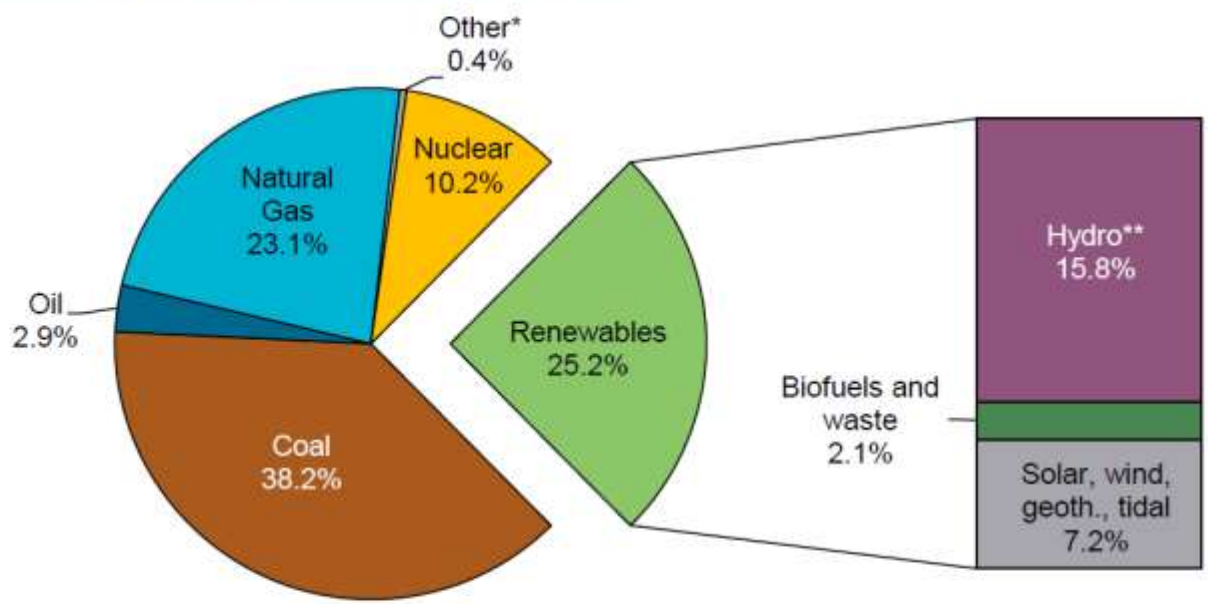


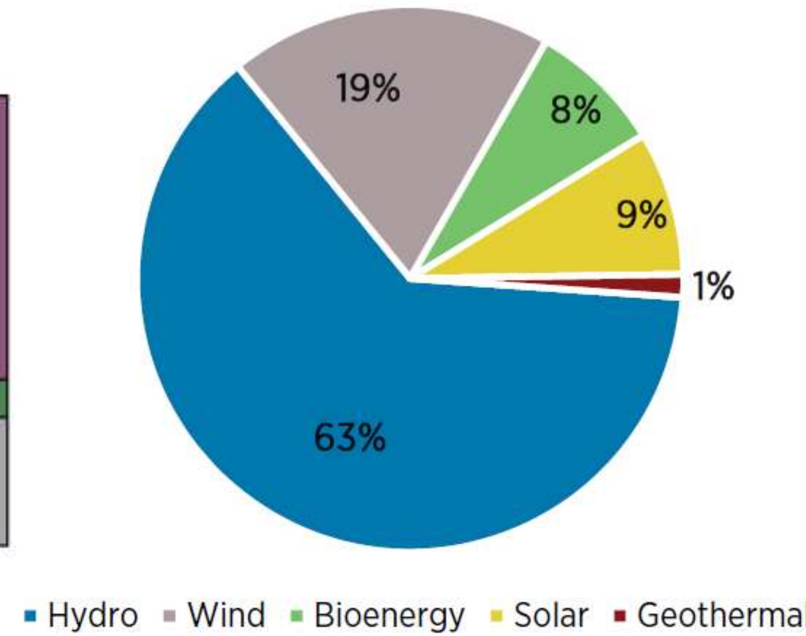
Source: IEA "Renewables Information Overview 2020"

Renewables：Power Generation

- Share of renewable electricity in global electricity generation accounts for 25%, i.e., quarter of power in the world is renewable originated.
- Among renewables, hydro has the far largest share of 16% in total and more than 60% in renewable power generation.

2018 fuel shares of world electricity production



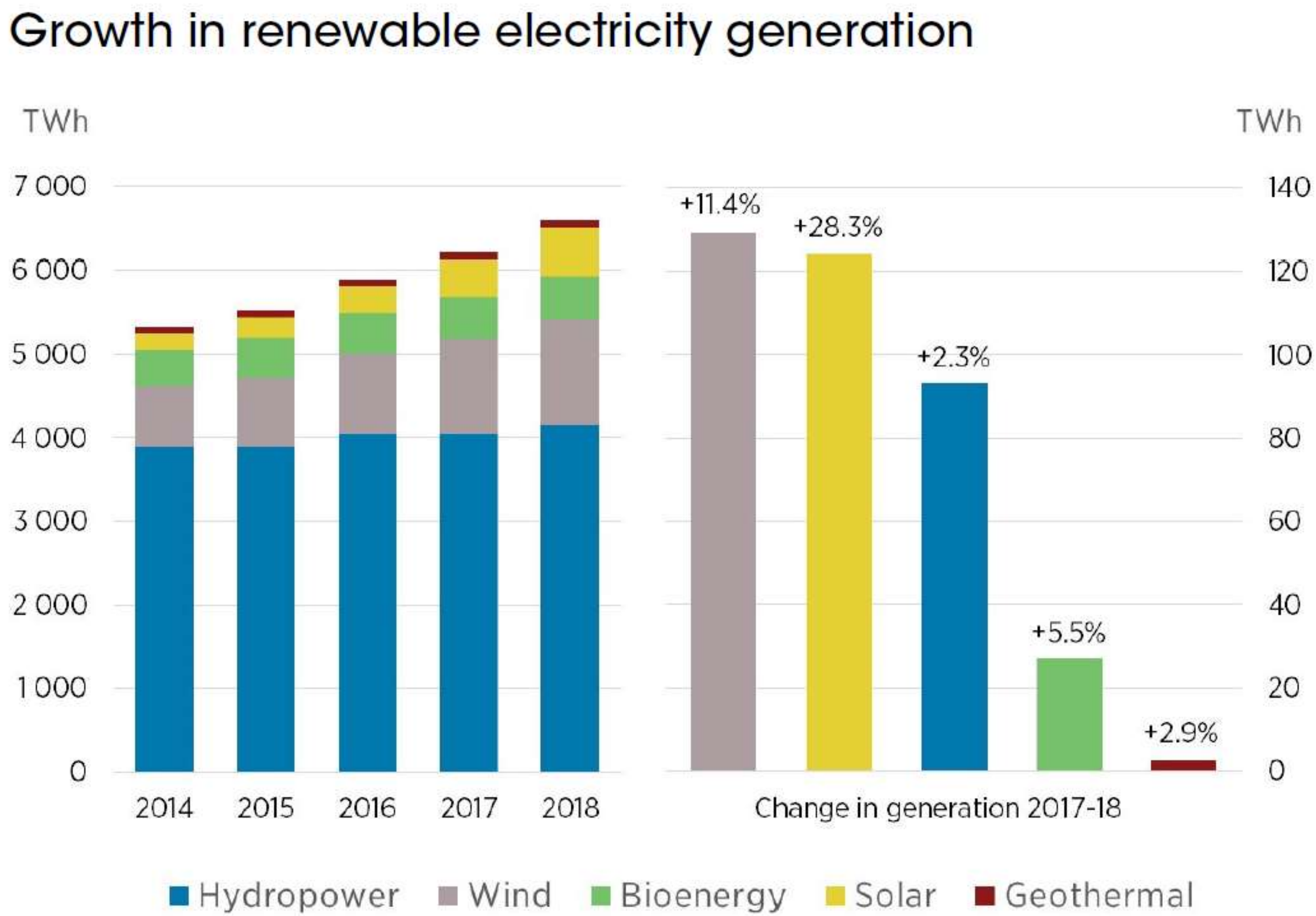


Source: IEA "Renewables Information Overview 2020"

Source: IRENA "Renewable energy highlights"

Renewables：Power Generation Growth by Type

- Renewable power generation has been growing recently.
- In the annual growth of power generation by type fron 2017 to 2018, Wind was largest in absolute amount followed by solar PV by a narrow margin. And in growth rate, solar PV was far largest than any others.



Source: IRENA "Renewable energy highlights"

Rnewables：Cost Trend by Type

- Global average cost of renewable power has kept falling. In 2019, solar PV recorded 13% year on year reduction, and wind 8%.
- Cost competitive renewables to fossil-fired power generation in 2010 were biomass, geothermal, hydro and onshore wind, and in 2019, solar PV and offshore wind joined the club.

Figure 1.1 Global LCOE from newly commissioned utility-scale renewable power

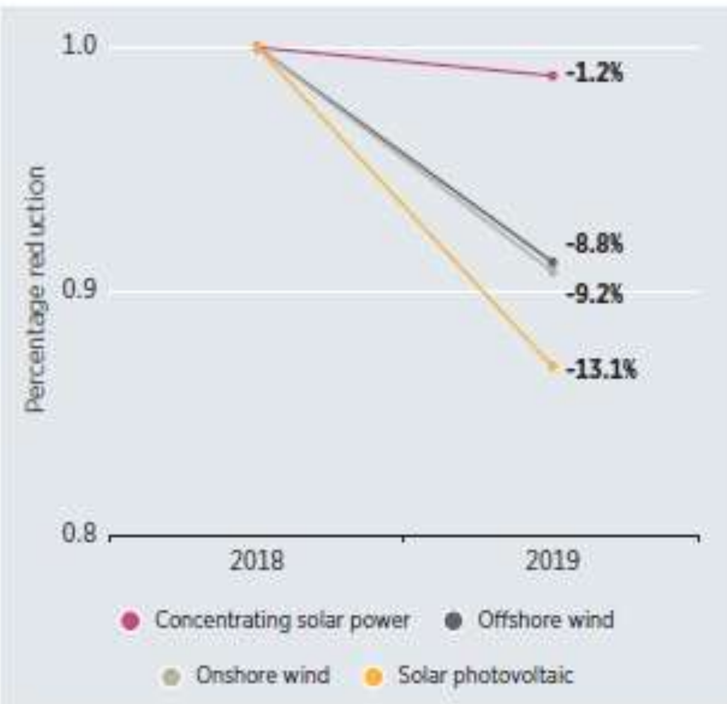
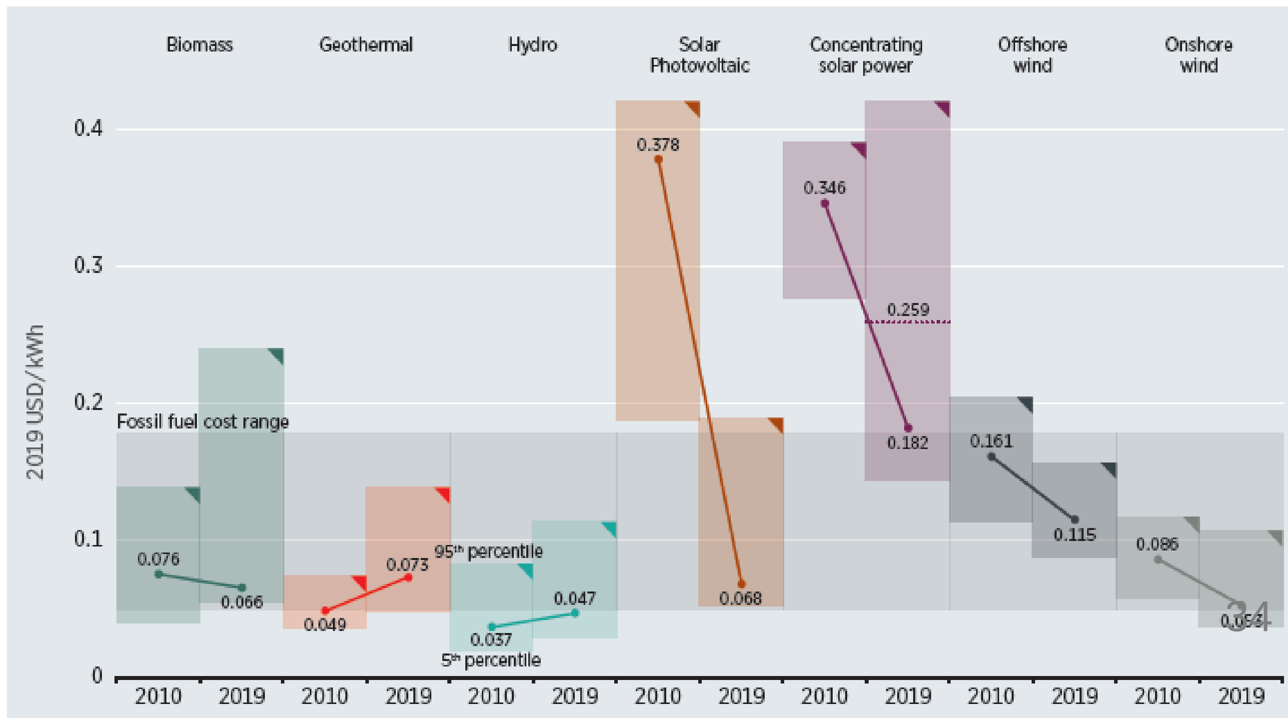


Figure ES.1 Global weighted average levelised cost of electricity from utility-scale renewable power generation technologies, 2010 and 2019



Source: IRENA "Renewable Power Generation Costs 2019"

Solar PV：Cost Trend and Cost Structure by Region

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- Cost reduction of solar PV varies by region. The cost reduction in Japan is smaller at higher cost level compared to other countries.（left）
- The cost structure indicates the reason why solar PV cost is high in Japan. substantial high level of installation cost could be the cause.（right）

Figure 3.2 Average monthly solar PV module prices by technology and manufacturing country sold in Europe, 2010 to 2020 (top) and average yearly module prices by market in 2013 and 2019 (bottom)

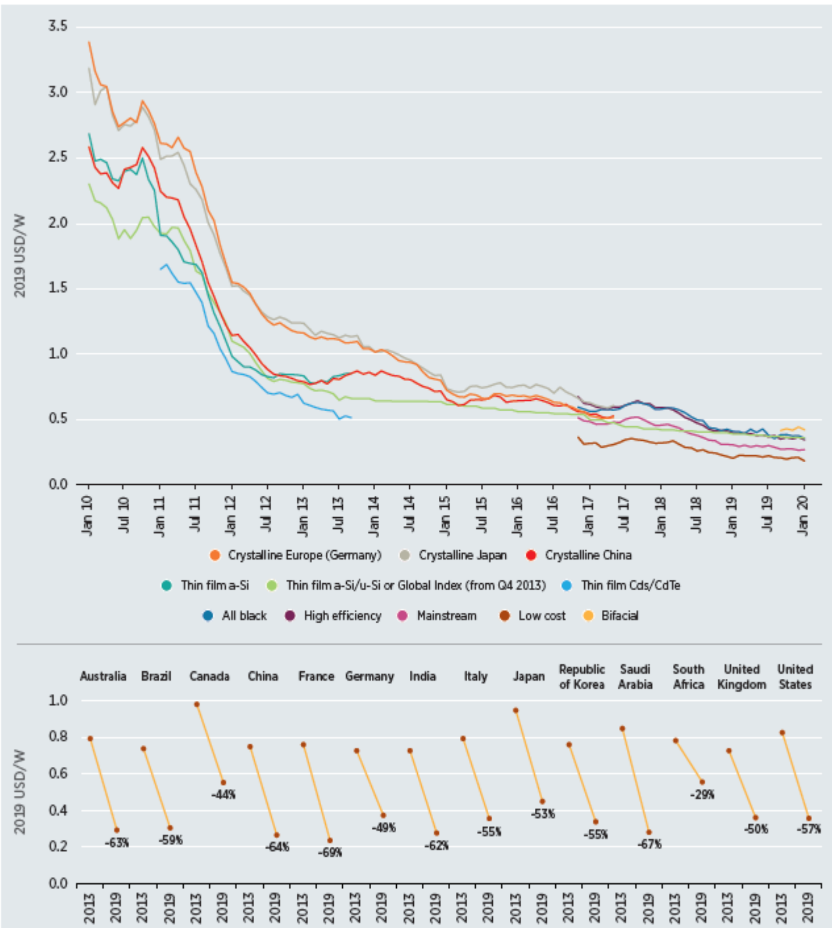
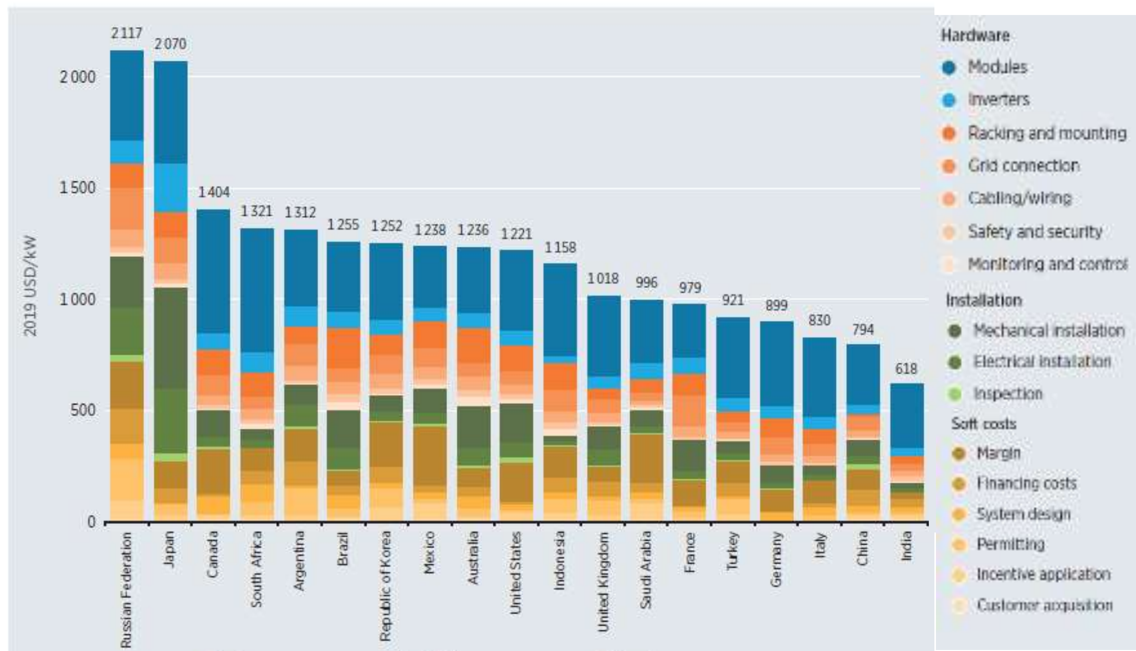


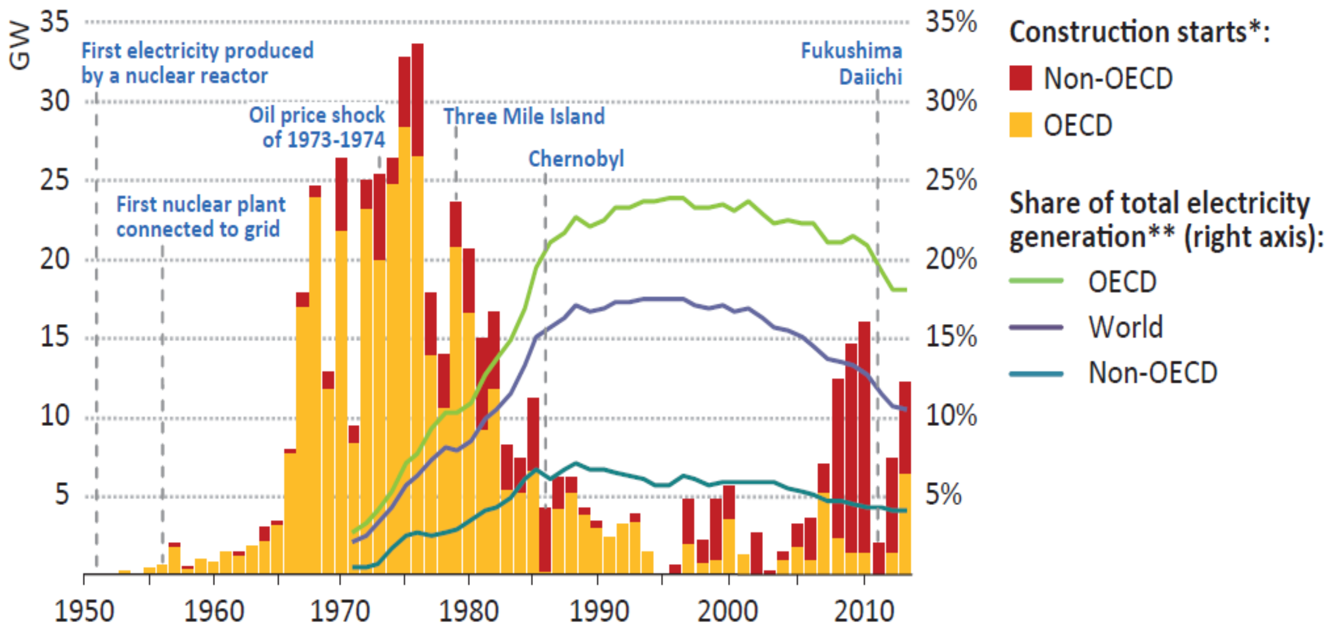
Figure 3.5 Detailed breakdown of utility-scale solar PV total installed costs by country, 2019



Source: IRENA "Renewable Power Generation Costs 2019"

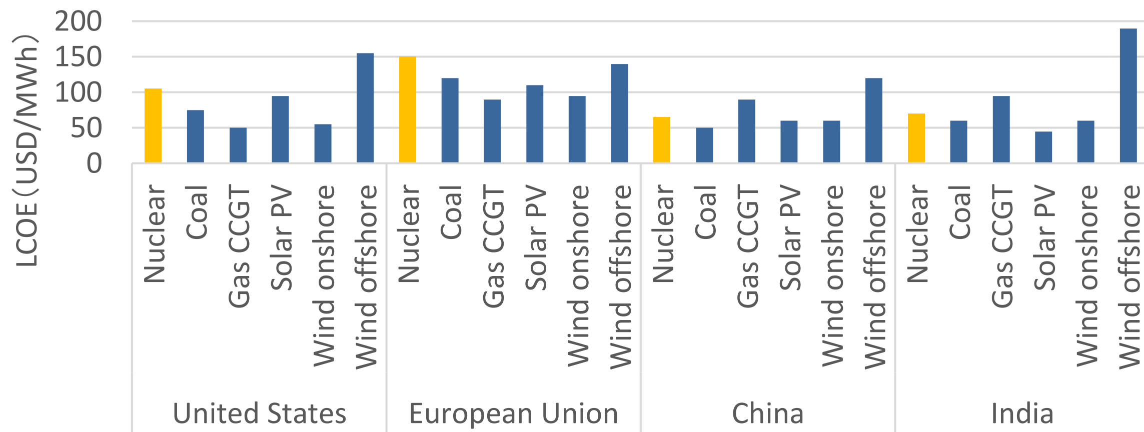
Nuclear：Historical Trend

Figure 10.1 ▷ Reactor construction starts and timeline of events



Source: IEA "World Energy Outlook 2014""

LCOE of power generation by type in 2017



Source: IEA "World Energy Outlook 2019""

Nuclear：Regional Trend

Figure 10.7 ▷ **Historical construction times and capacity factors for nuclear power plants by selected region**

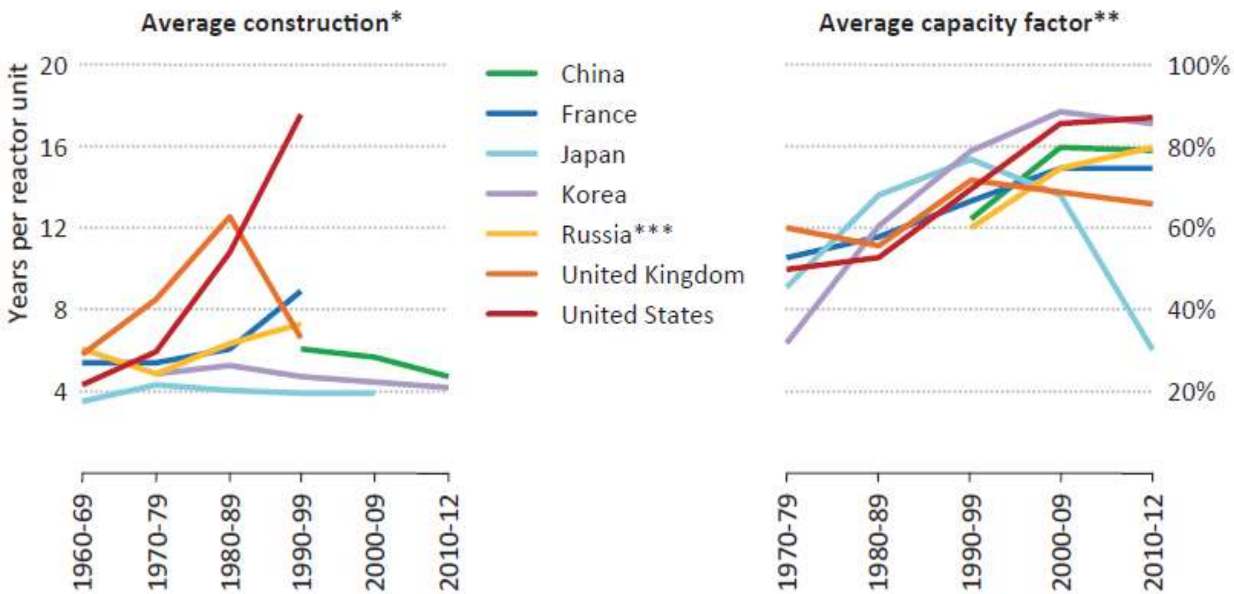
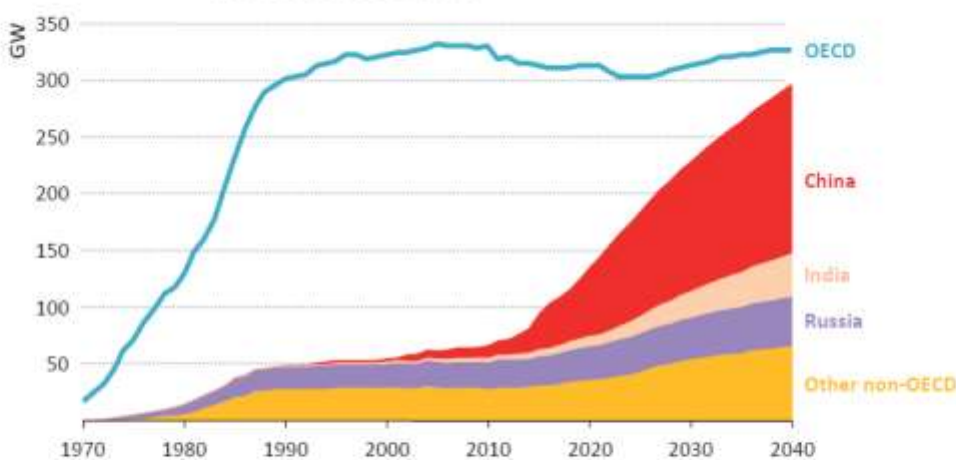


Figure 11.3 ▷ **Installed nuclear power capacity by key region in the New Policies Scenario**



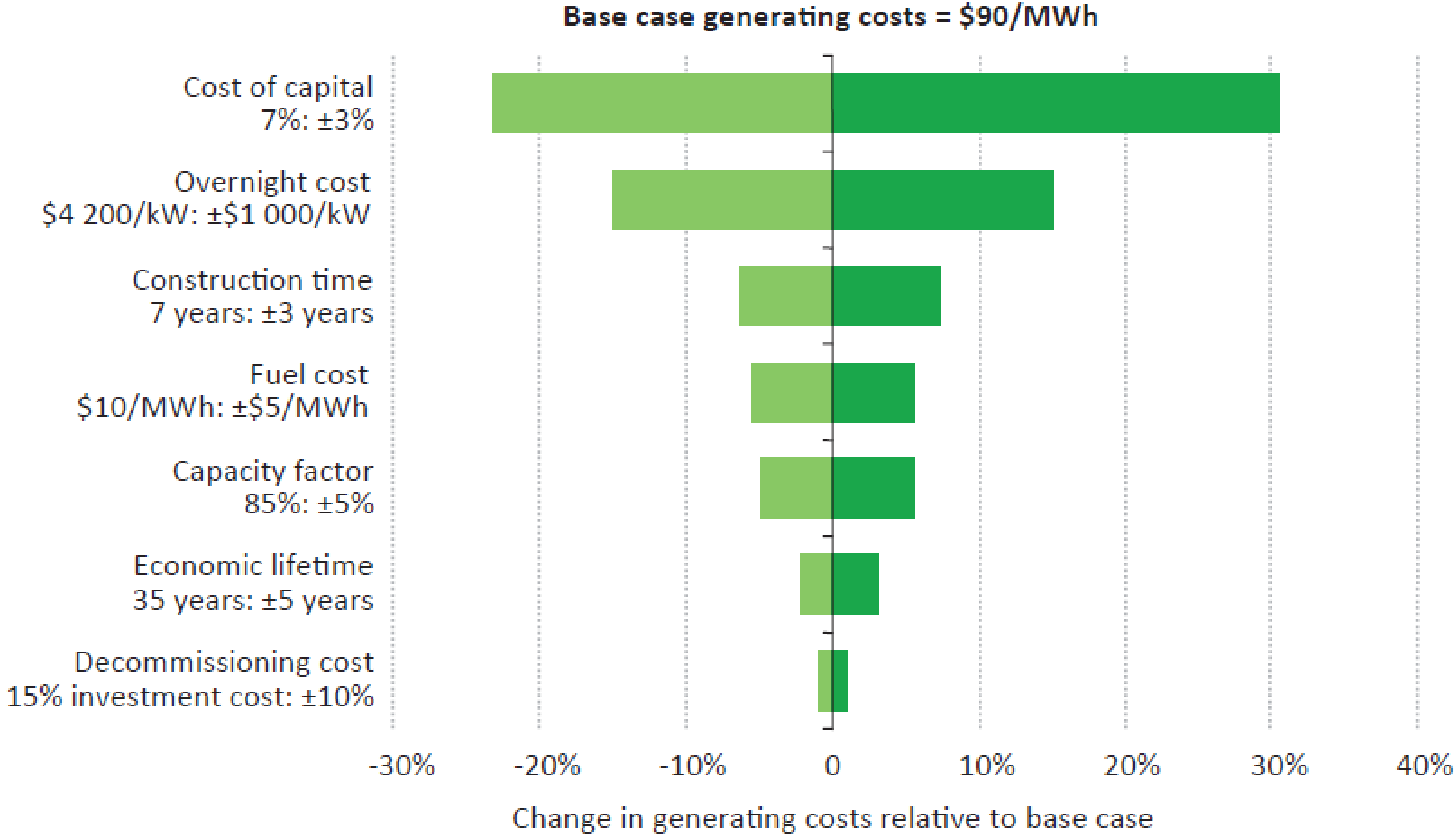
- Construction time had kept getting longer in the US and that increased construction cost. Similar trend can be seen in France and Russia. (upper left)
- Average capacity factor in the most of countries have increased while it has been falling in Japan. (upper right)

- Nuclear power capacity in OECD has been reduced recently and the expected future increase is small. (lower figure)
- Recent significant increase is seen in China, and India and other non-OECD are expected to follow it.
- In 2040, non-OECD will have near half of nuclear power capacity in the world.

Source: IEA "World Energy Outlook 2014""

Nuclear：Sensitivity Analysis for Generation Cost

Figure 10.8 ▷ Sensitivity of nuclear generating costs to changes in parameters

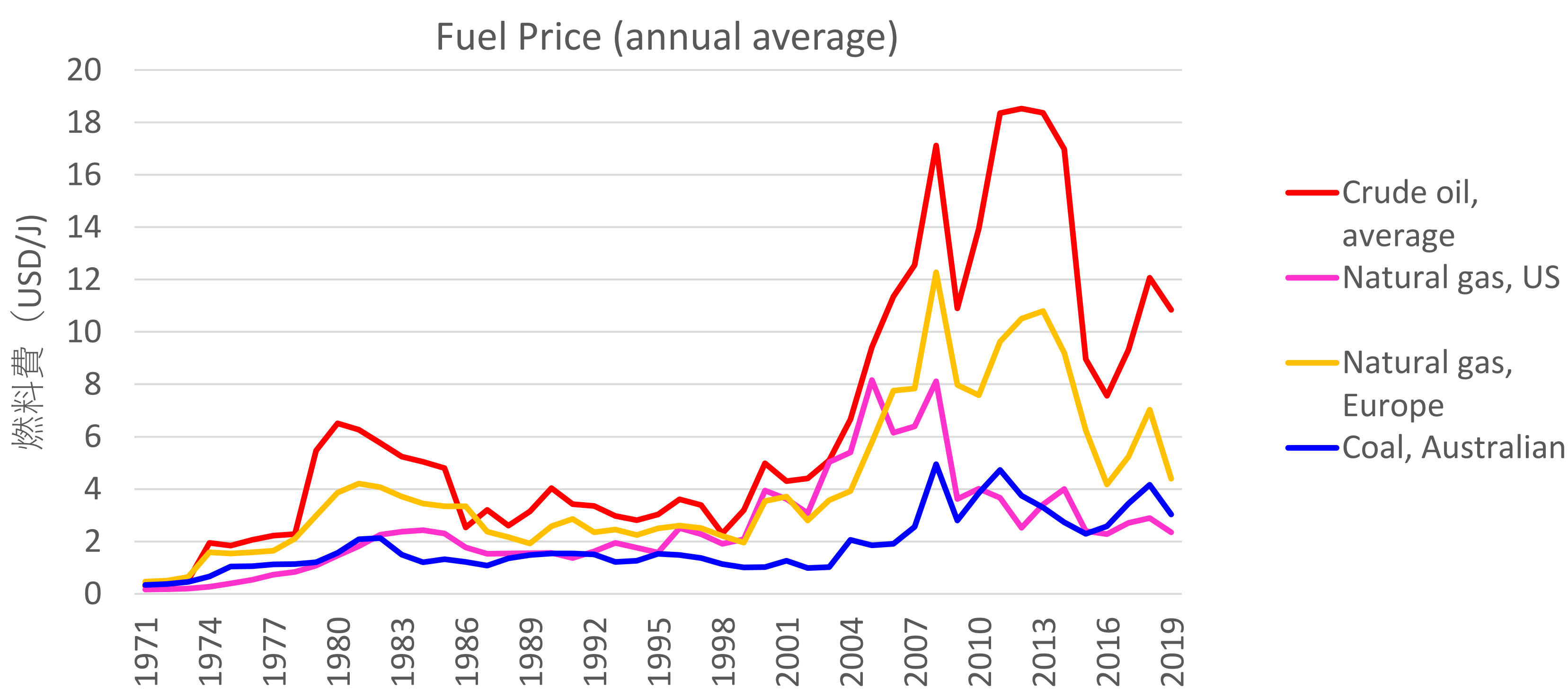


Note: The non-fuel O&M cost is assumed to be $170/kW.

Source: IEA "World Energy Outlook 2014""

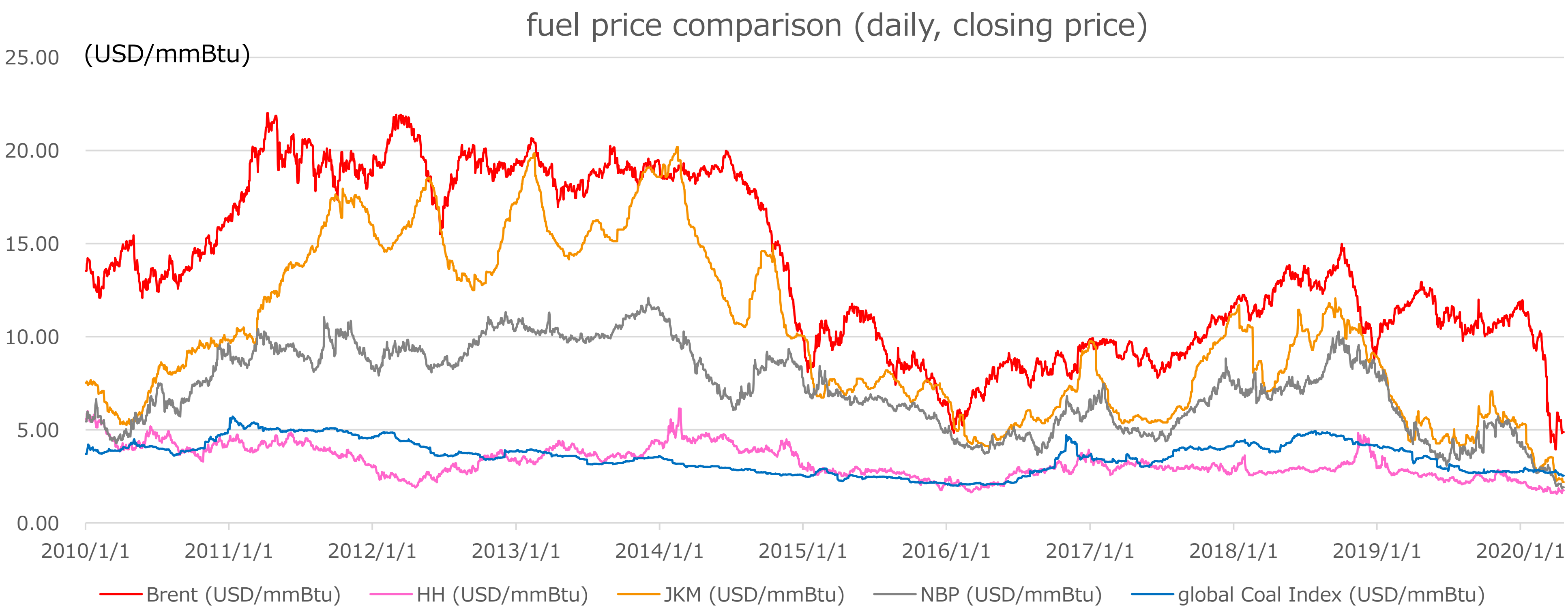
Fossil Fuel Price in Energy Equivalent（annual average）

- Oil is traded in USD/Barrel、natural gad in USD/MMBtu（pence/therm in UK）、coal in USD/t and difficult to compare.
- Fore comparison, they were converted to energy equivalent in USD/Joule
- US gas price declined sharply and the gap to European gas price remains since then.
- Recently, US gas price is even cheaper than Australian coal.



source: World Bank commodity data

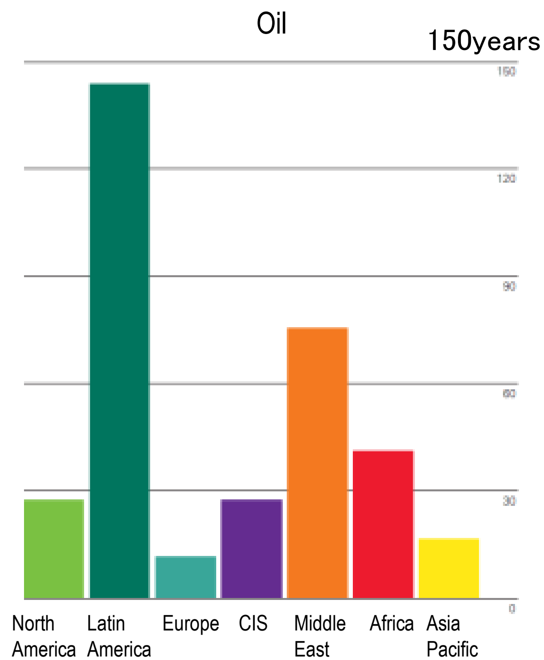
Fossil Fuel Price in Energy Equivalent (daily)

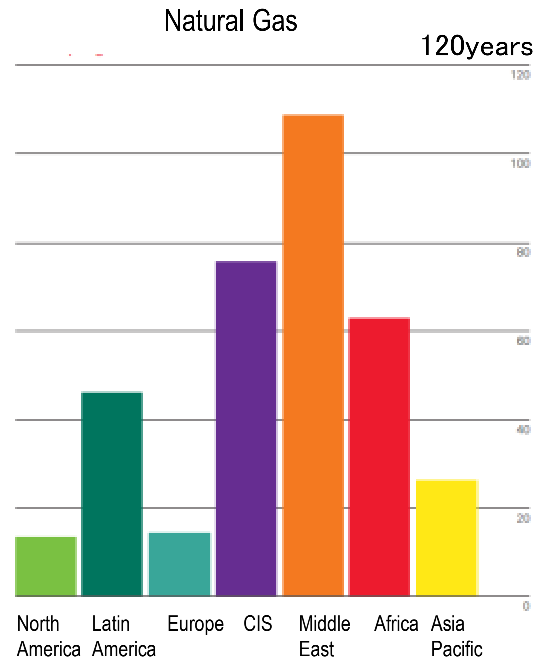


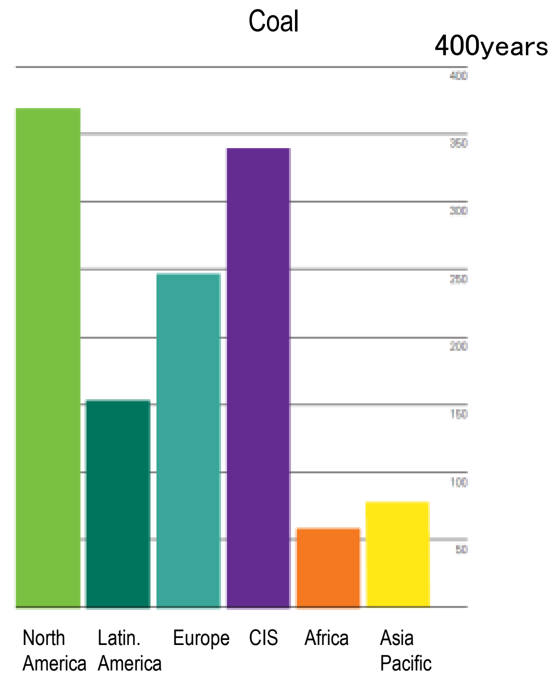
	Oil	Natural Gas			Coal
	Brent	USA（HH）	European（NBP）	LNG（JCM）	Australian
Coefficient Variation	33%	26%	44%	31%	24%

Fossil Fuel : Geographical Distribution

- RP ratio is reserve/production and it indicates remaining lifetime if current production lasts
- Oil RP ratio is far largest in Latin America followed by Middle East, while small in Europe and Asia
- Gas RP ratio is big in CIS, Middle East and Africa, while small in North America and Europe
- Coal RP ratio is big in North America, Europe and CIS, and its lifetime scale is several times longer than other fossil fuels



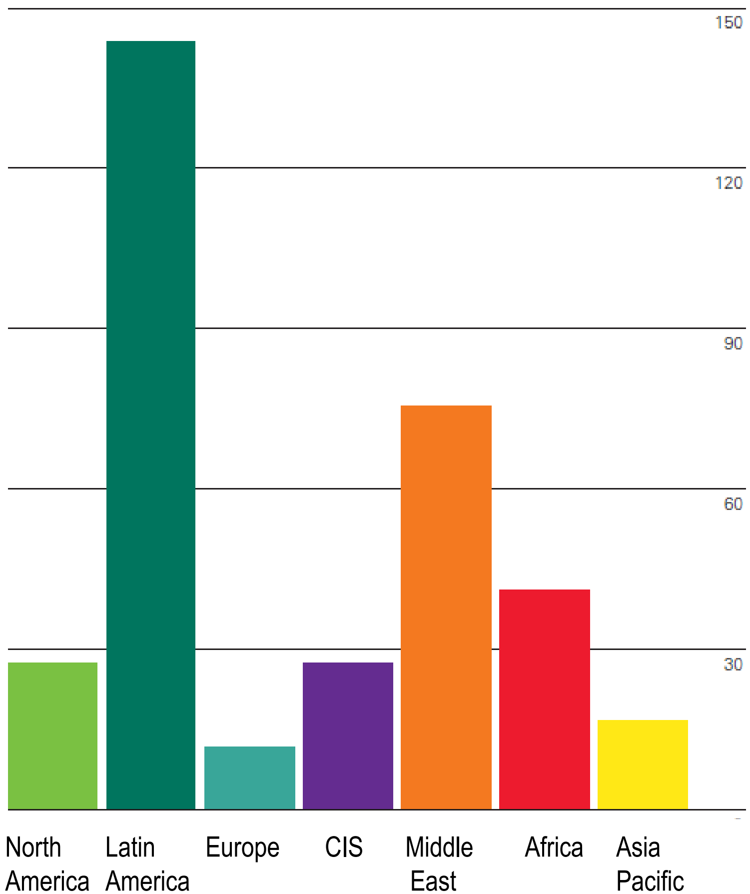


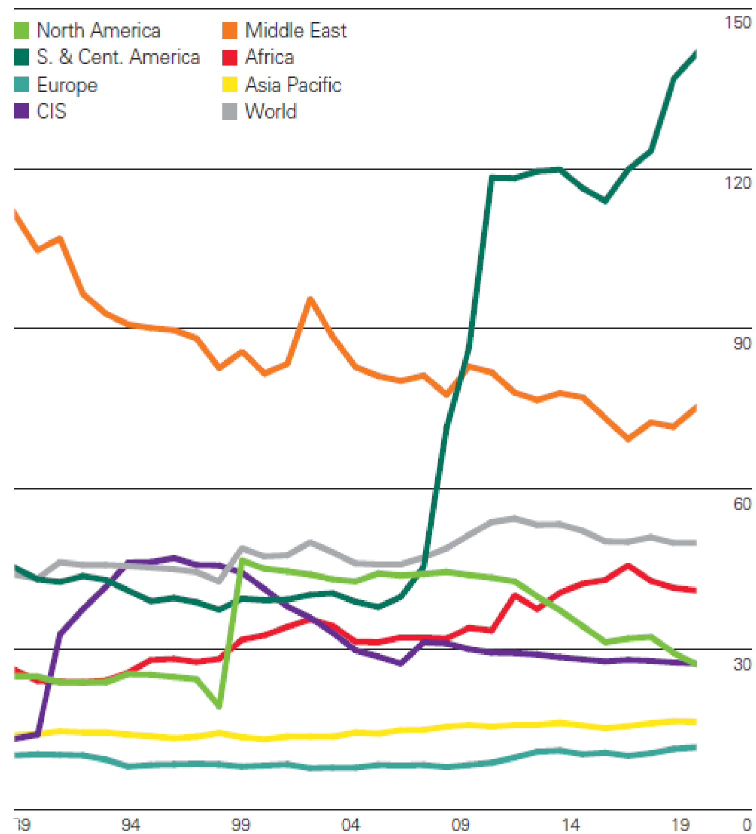


Source: BP Statistical Review of World Energy 2020

Change in R/P

- If R is constant, R/P decline over time to be zero. “Oil peak” theory had been popular until recently.
- Actually, R is not constant. Oil price hike incentivized technology development in exploration and boring/drilling that enabled to develop deep water oil well.
- Latin America’s R/P is currently largest but it was not before. When large scale deep water oil reserve was found in 2007 in offshore of Brazilian coast, Latin American R/P jumped up as depicted in the right figure below.





Source: BP Statistical Review of World Energy 2020

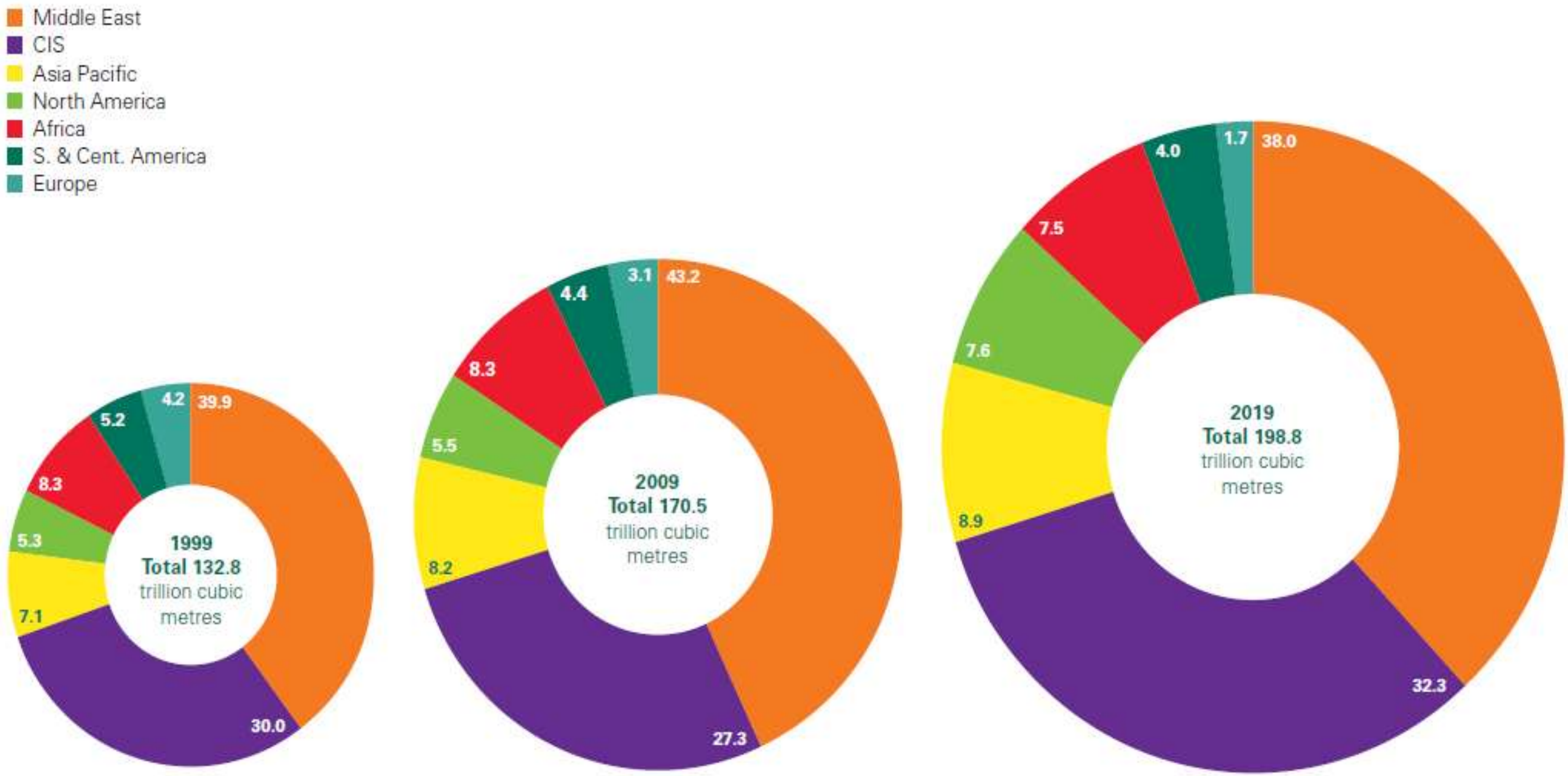
Oil Proven Reserve

- Proven reserve of oil increased by 60% since 1998.
- Middle East occupied more than 60% of global proven reserve 20 yeas ago, but it was reduced to less than 50% by uncreased share of South and Central America.

Source: BP Statistical Review of World Energy 2020

Gas Proven Reserve

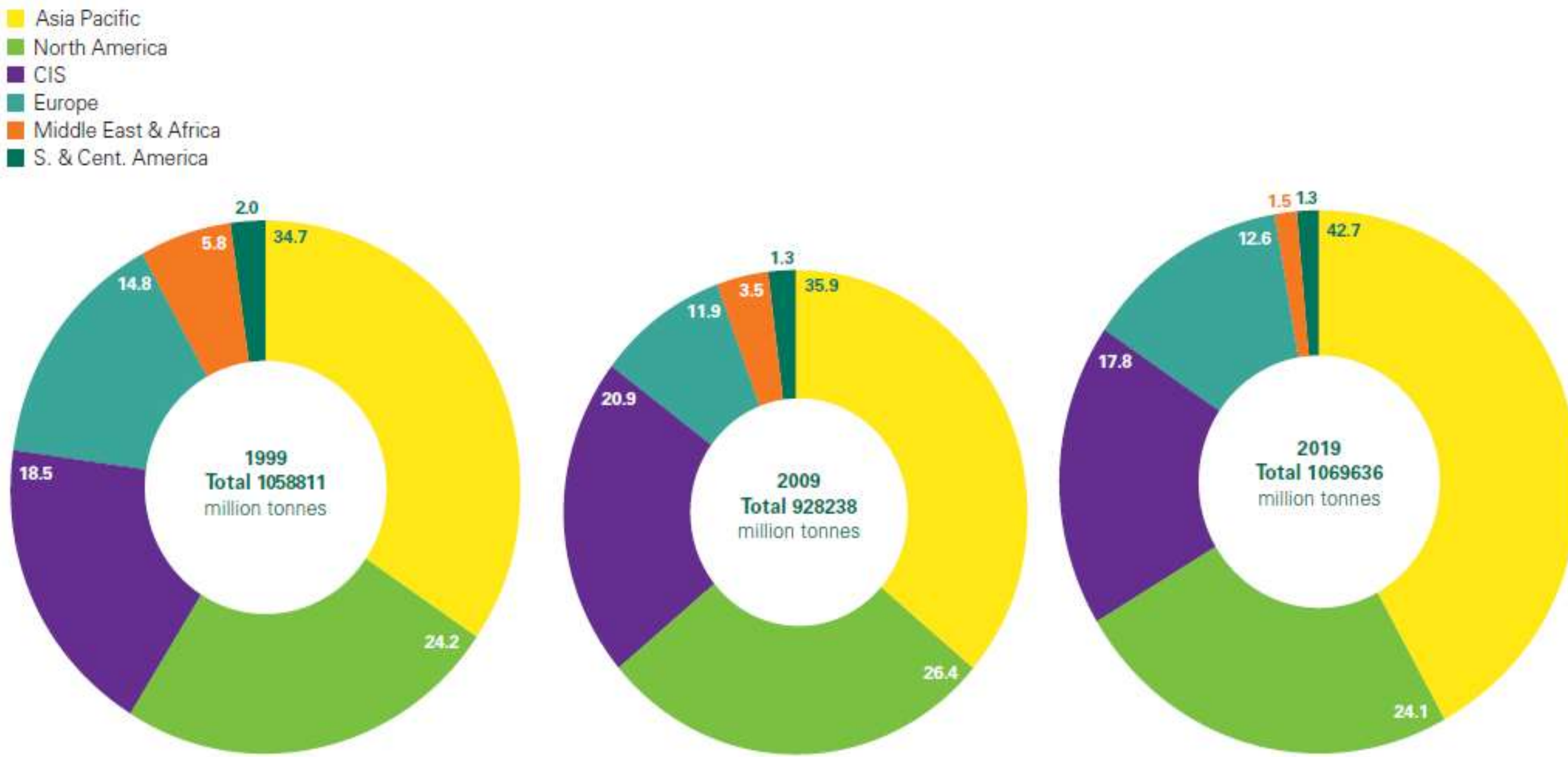
- Proven reserve of oil increased by 50% since 1998.
- Share of North America remarkably increased in last 20 years by shale gas production
- Yet Middle East and CIS still account more than 70 % collectively



Source: BP Statistical Review of World Energy 2020

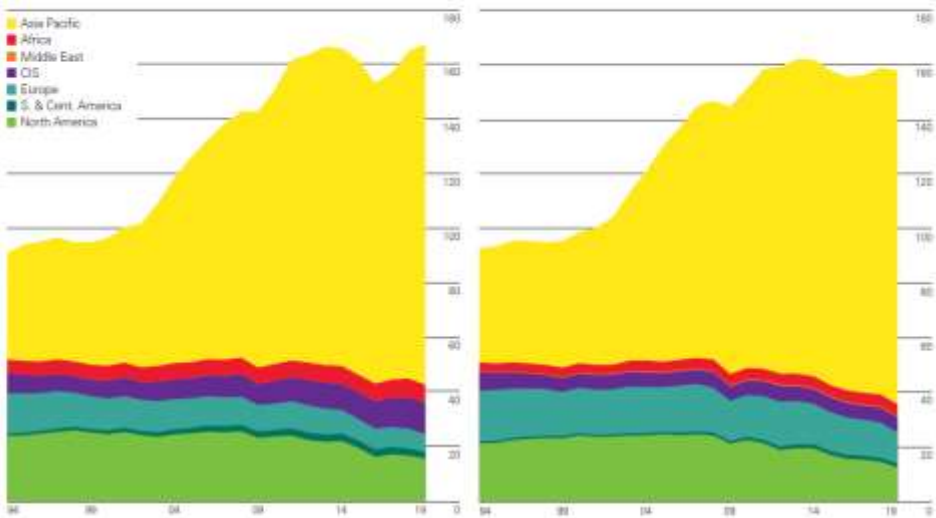
Coal Proven Reserve

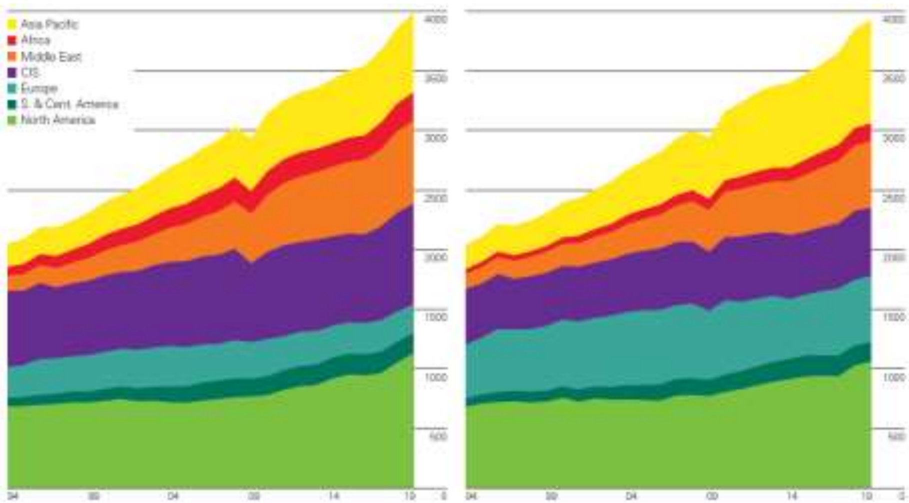
- Proven reserve of coal has remained unchanged for 20 years
- The collective share of Asia Pacific, Noth America and CIS has increased from three quarter to 80%
- Asia Pacific have such a big amount of coal reserve but its RP ratio is small. why?



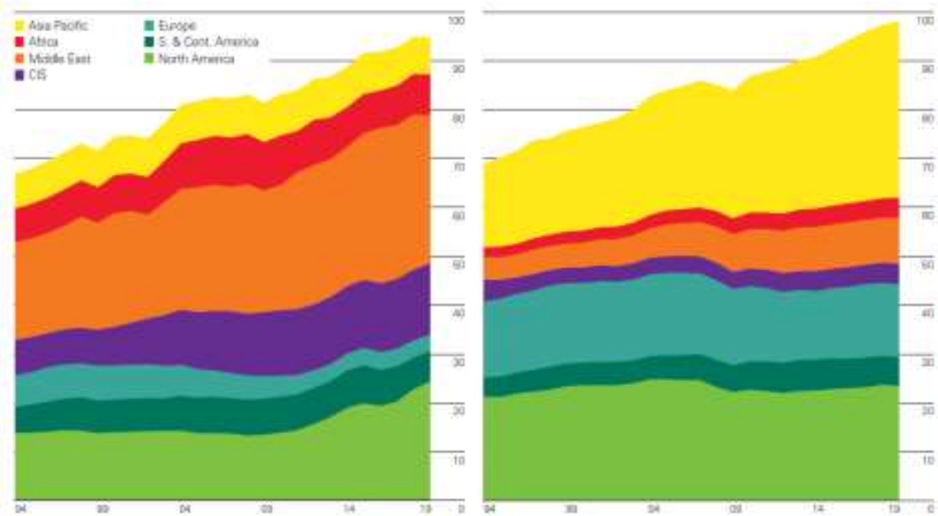
Source: BP Statistical Review of World Energy 2020

QUIZ：Production（left）and Consumption（right）, Who’s who?





Asia Pacific
Africa
Middle East
CIS
Europe
S. & Cent. America
North America

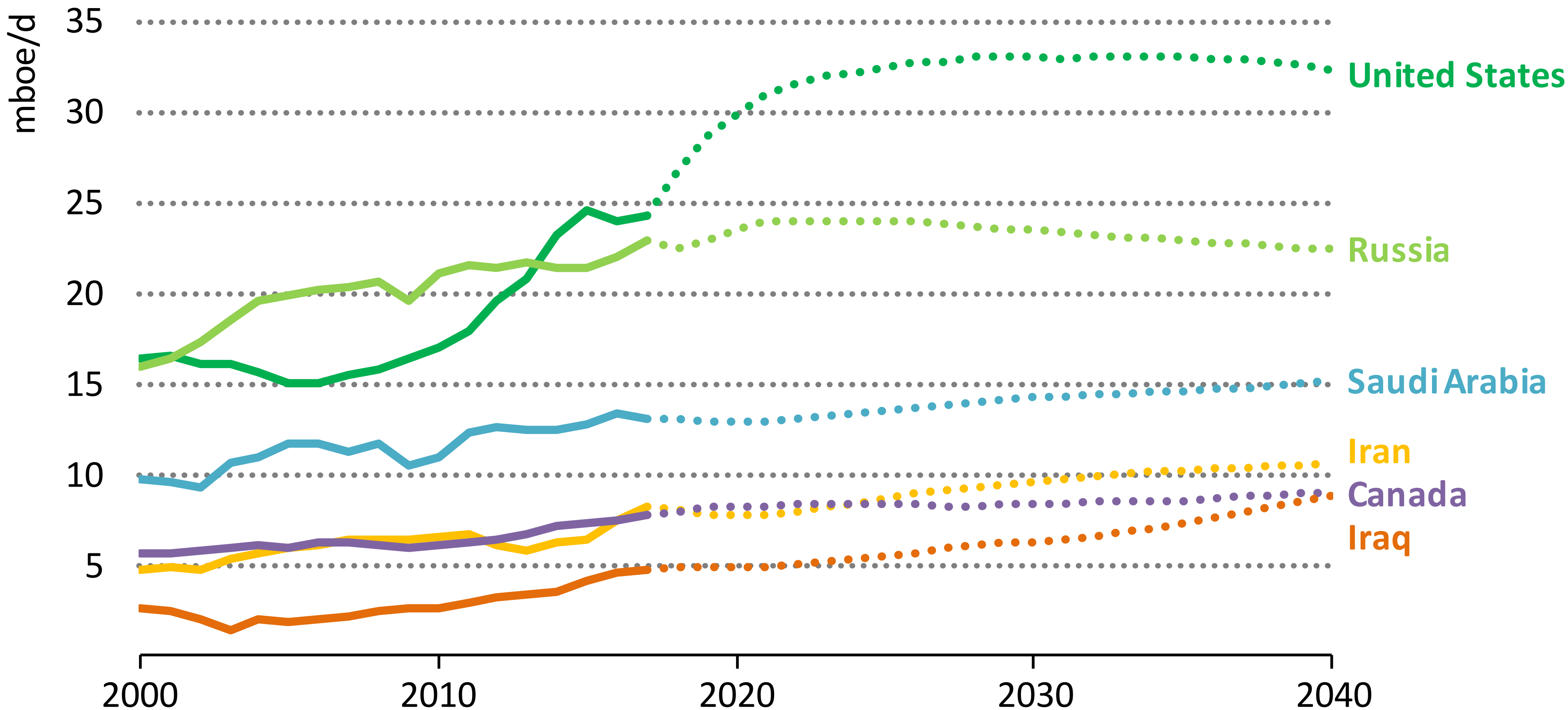


Source: BP Statistical Review of World Energy 2020

ENERGY OUTLOOK

Oil and gas production outlook for selected countries

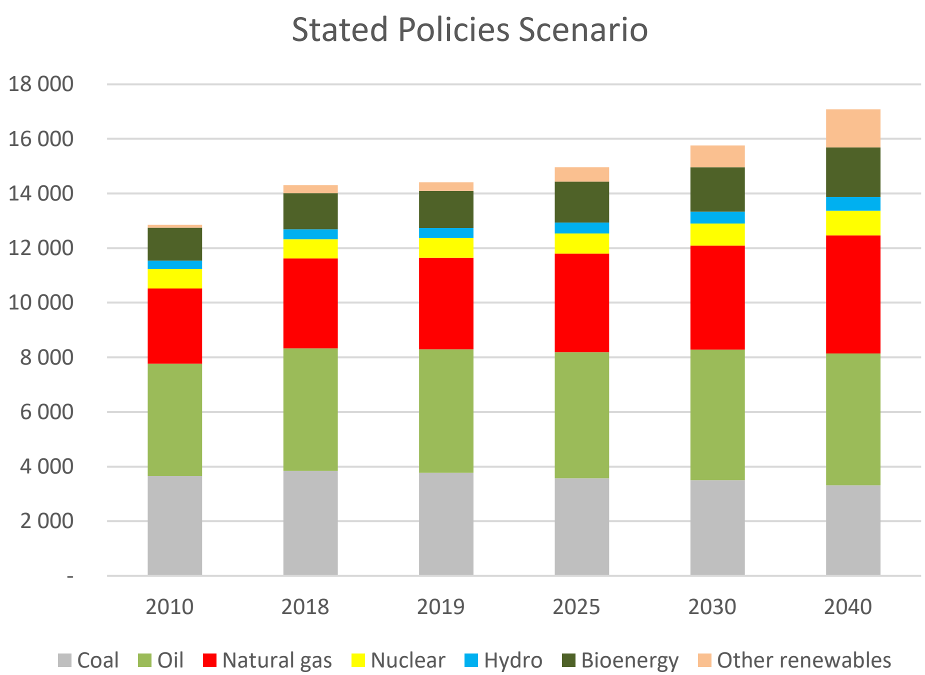
- The rise in US production of tight oil and shale gas since 2010 is the largest parallel increase in oil and gas output in history

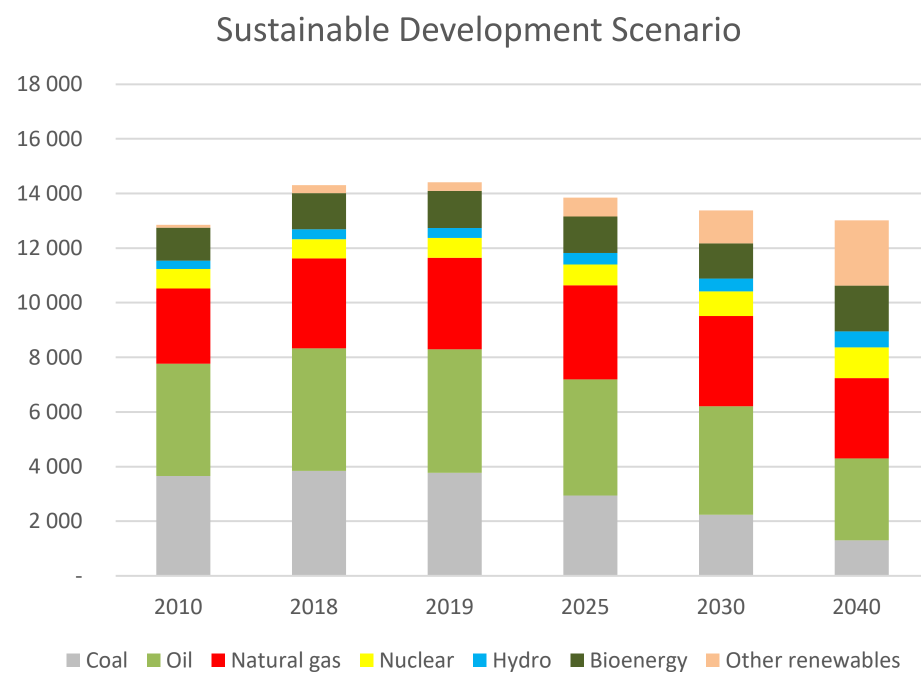


Source: IEA “Word Energy Outlook 2018”

Energy demand outlook

- Energy demand continues to grow through 2040.
- By energy resource, growth is seen in renewable energy.
- By region, growth is seen in developing countries, especially in Asia.

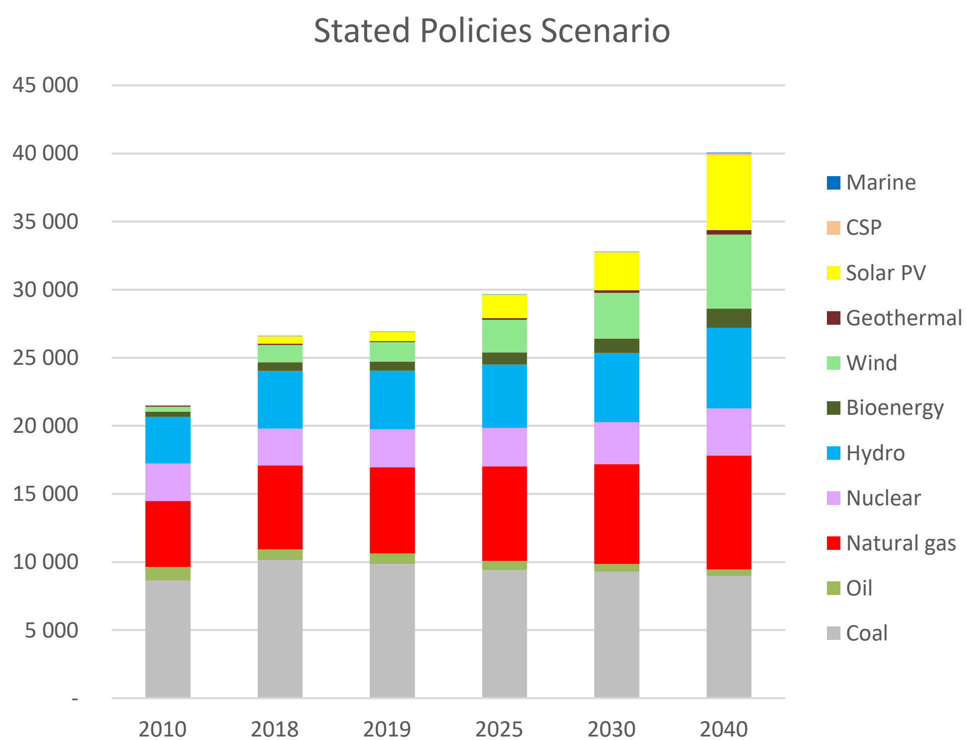


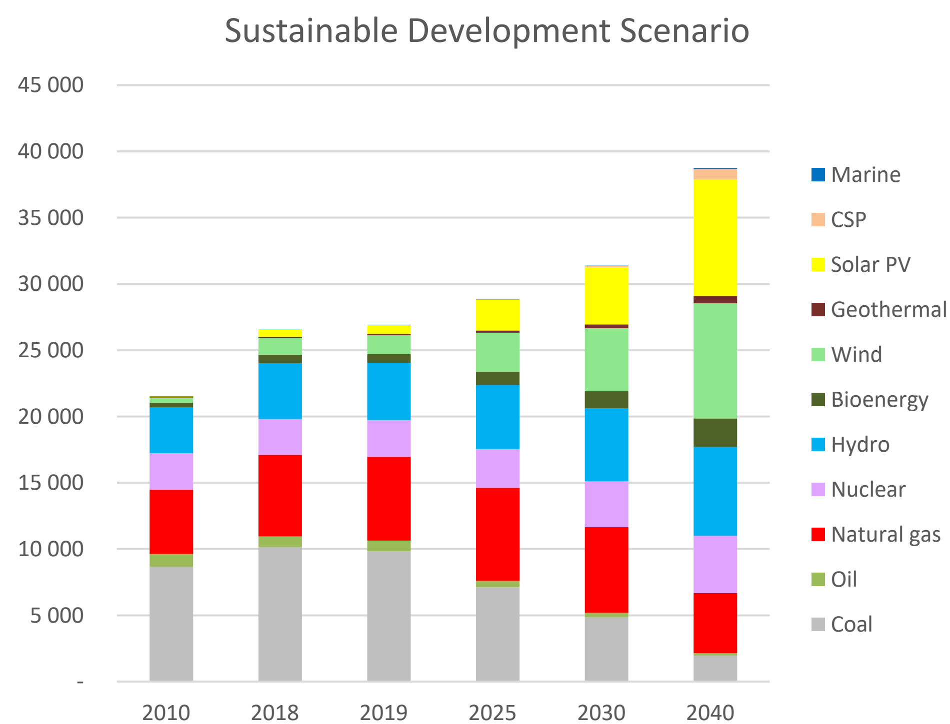


Source: IEA World Energy Outlook 2020

Electricity Outlook

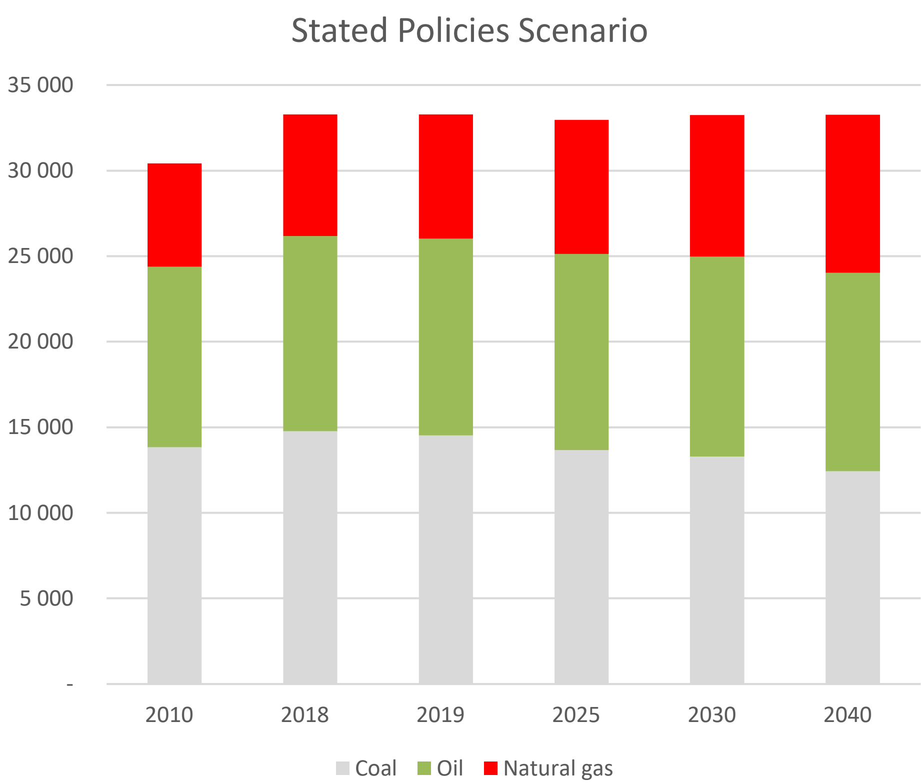
- In both scenarios, electricity demand continues to grow through 2040.
- In both scenarios, growth is seen in other renewables.
- Difference is in power mix; coal and gas remain same level in STEPS, while coal (and some gas) decline displaced by wind and solar in SDS.

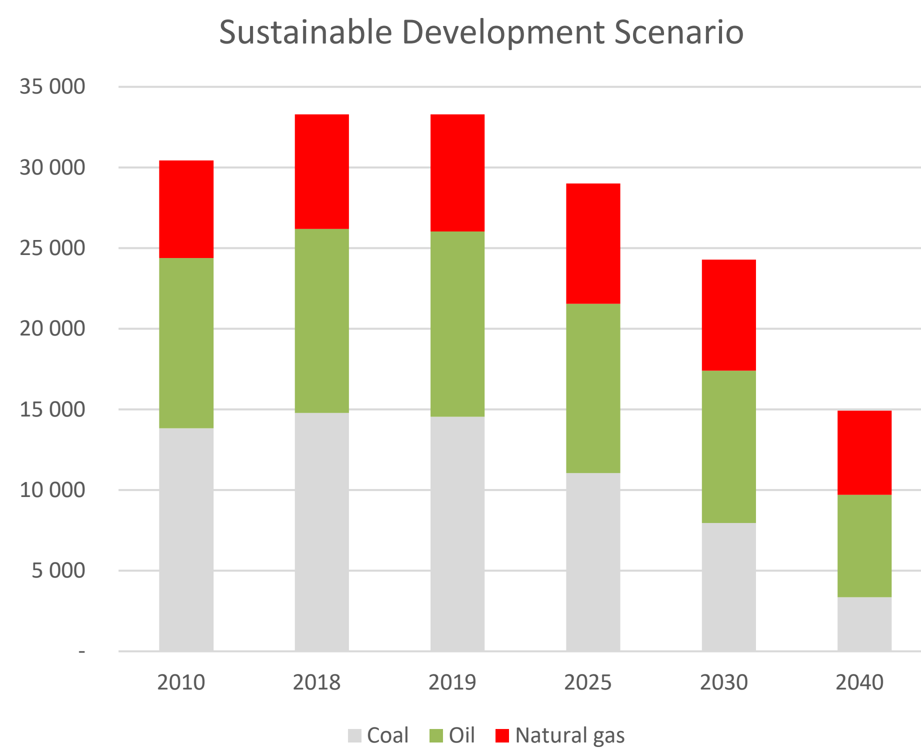




Energy related CO2 outlook

- Global CO2 emissions stopped to increase and remains similar level until 2040 in STEPS
- Global CO2 emissions declines first lead by decline of coal then oil and gas, by 50% in 2040,in SDS



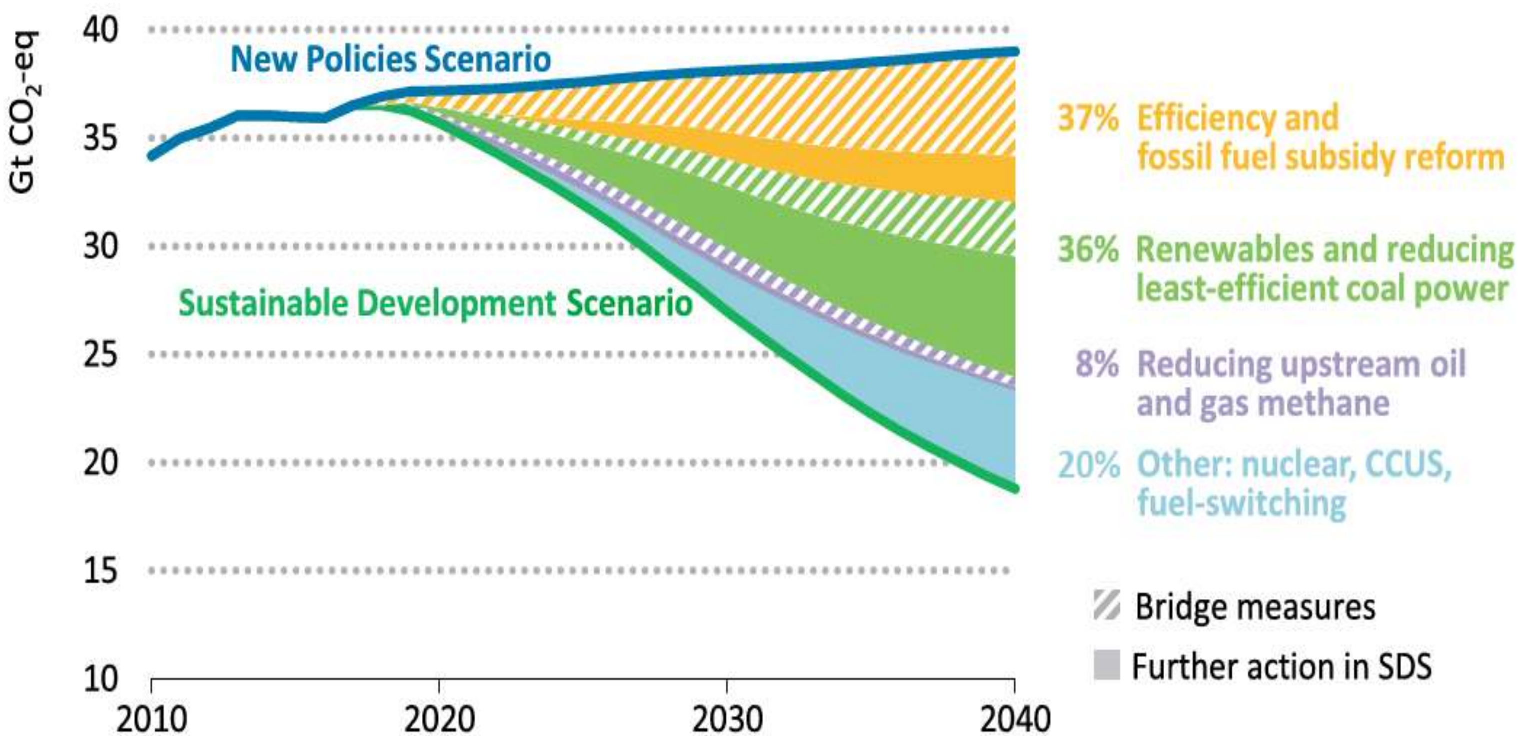


Source: IEA “Word Energy Outlook 2020”

GAP BETWEEN 2DEGREE SCENARIO AND REALITY(NDC)

Gap between Reality and "2 Degree Scenario"

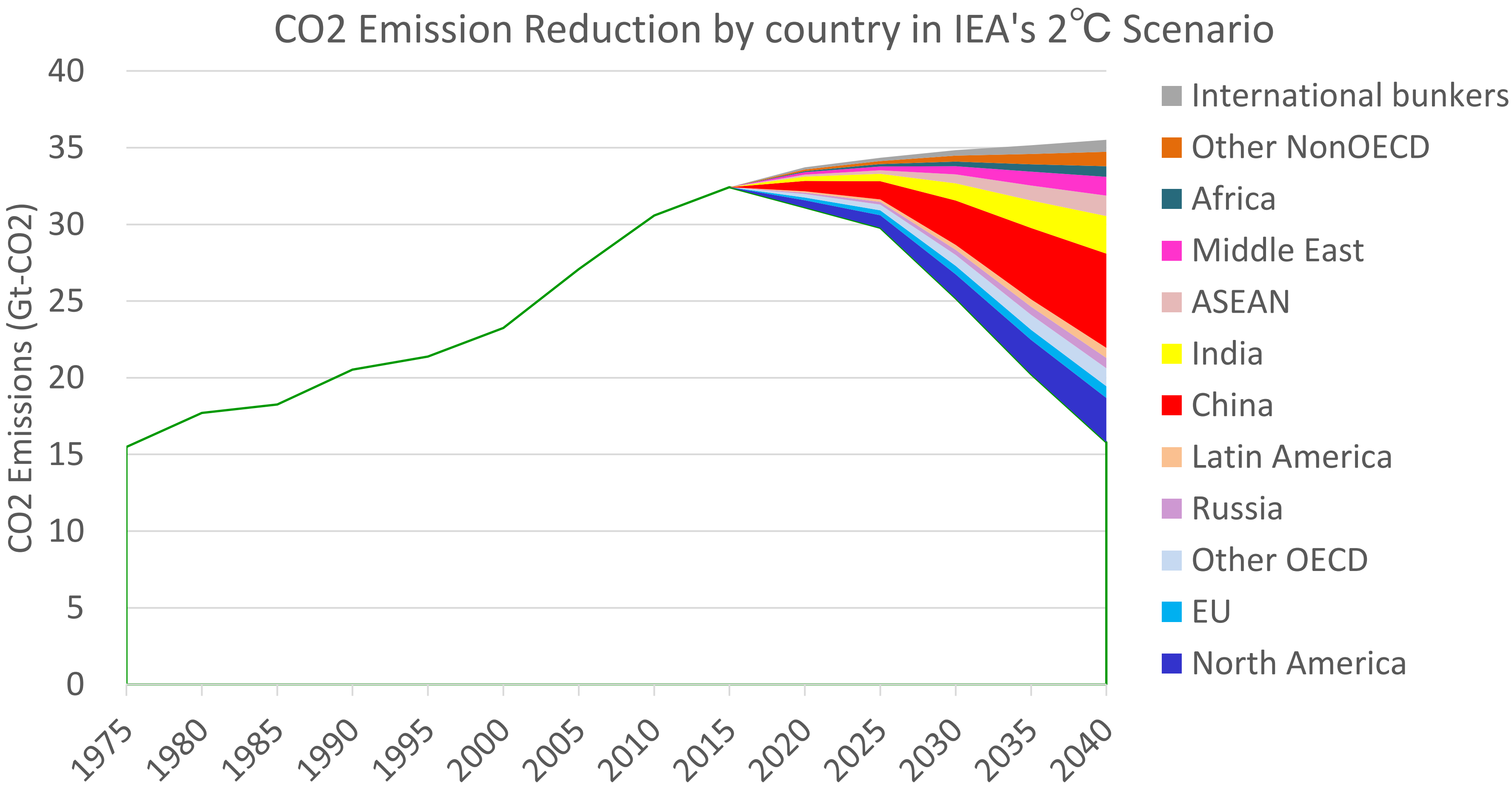
- International Energy Agency (IEA) forecasts the gap of the world energy related CO2 emissions between likely scenario and 2℃ scenario in the figure below.
- To implement 2℃ scenario, the world CO2 emissions should start decline from now and halve the emission of likely scenario in 2040 by using all applicable technologies.



Source: IEA World Energy Outlook 2019

Who should reduce?

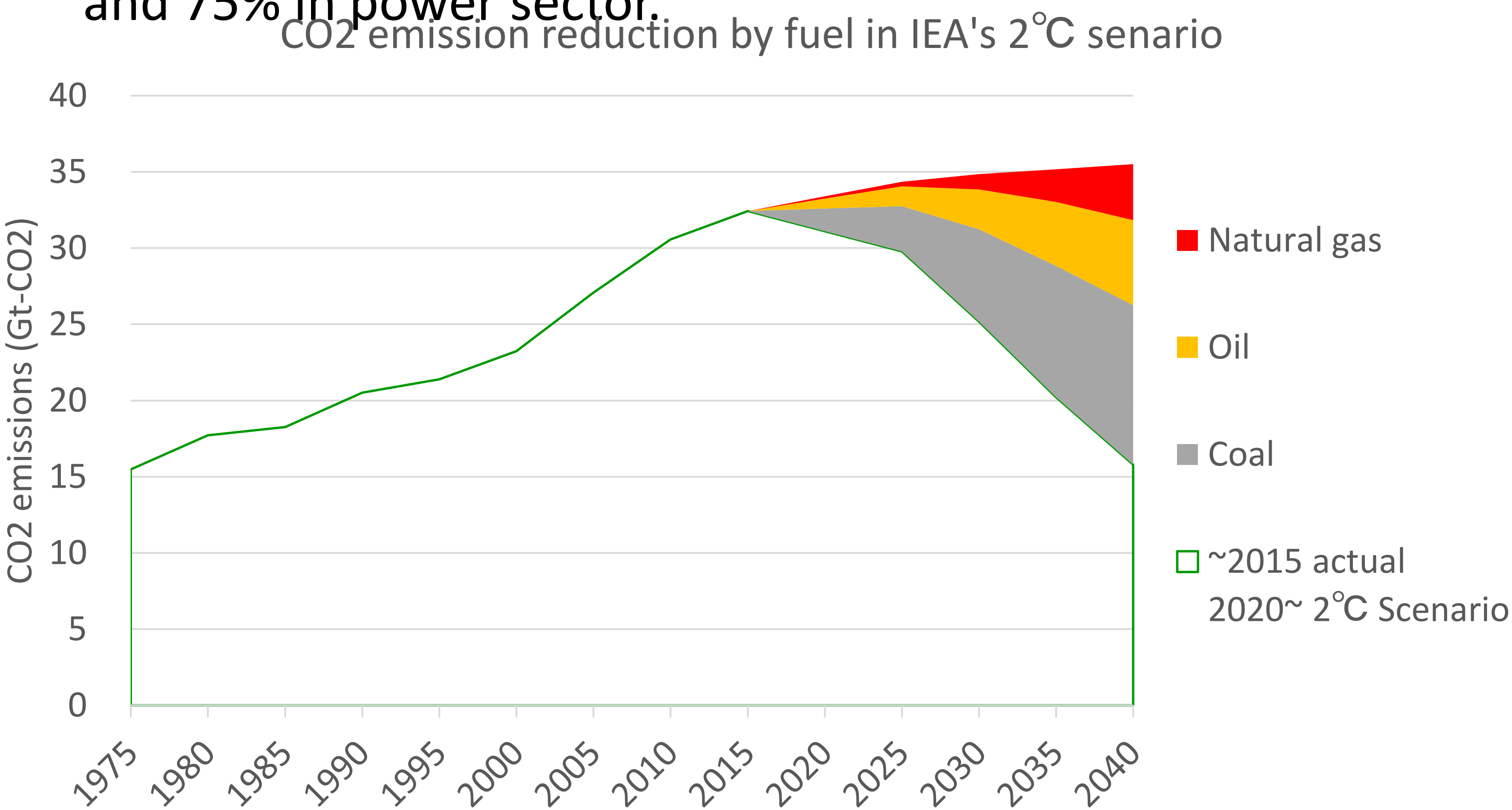
- To implement 2℃ scenario, Non-OECD is responsible of 75% of total necessary reduction by 2040.
- Asia needs to bear the 50% of total necessary reduction by 2040, while EU only needs to bear 5%.



Data source: IEA World Energy Outlook 2019

What to reduce?

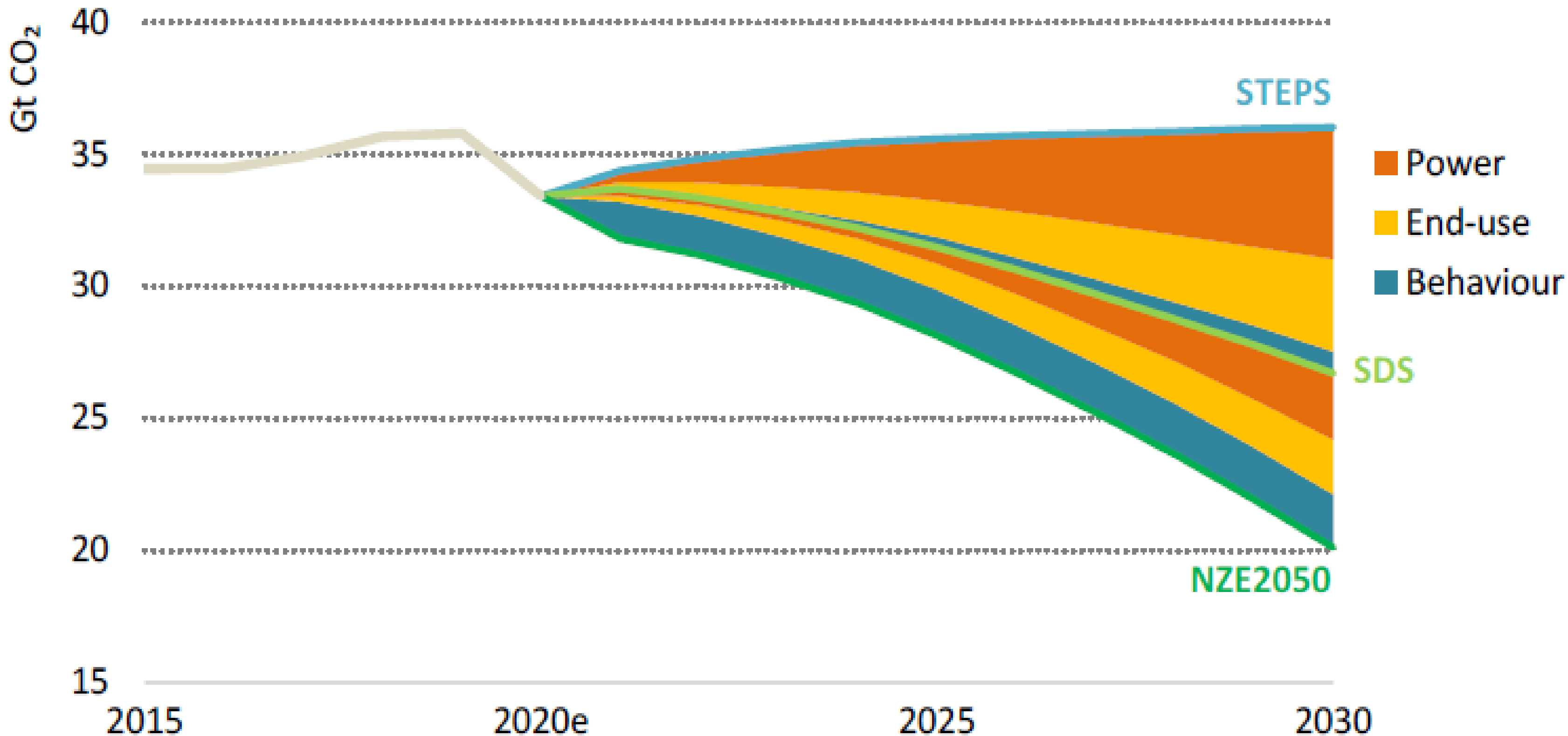
- To implement 2℃ scenario, all the fossil fuel should be reduced compared to likely scenario.
- Coal should be reduced 60% of today's total consumption and 75% in power sector.



Data source: IEA World Energy Outlook 2019

Gap of CO2 emission between scenarios

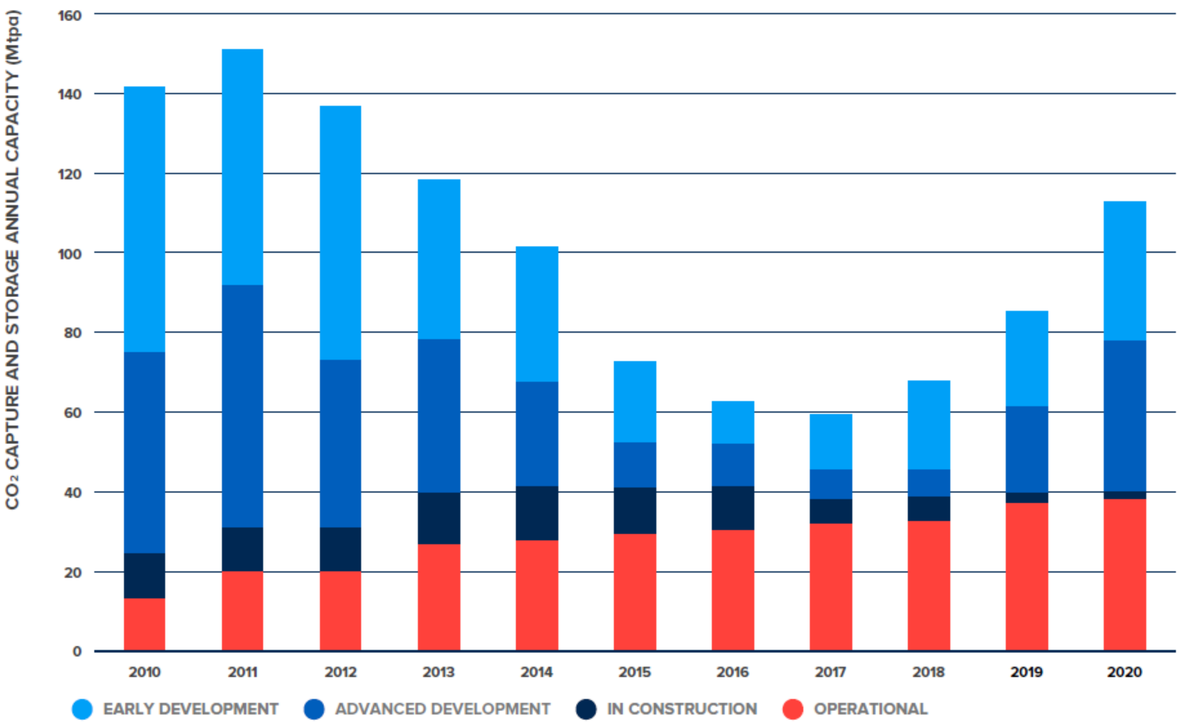
Figure 4.1 ▷ Energy and industrial process CO_2 emissions and reduction levers in the scenarios



An unparalleled transformation of the energy sector and major behaviour changes in the next ten years would be needed to achieve global net-zero emissions by 2050

Source: IEA "Word Energy Outlook 2020"

Progress in CCS



THE CAPACITY OF FACILITIES WHERE OPERATION IS CURRENTLY SUSPENDED IS NOT INCLUDED IN THE 2020 DATA.

FIGURE 4 **PIPELINE OF COMMERCIAL CCS FACILITIES FROM 2010 TO 2020: CCS CAPACITY**[a]

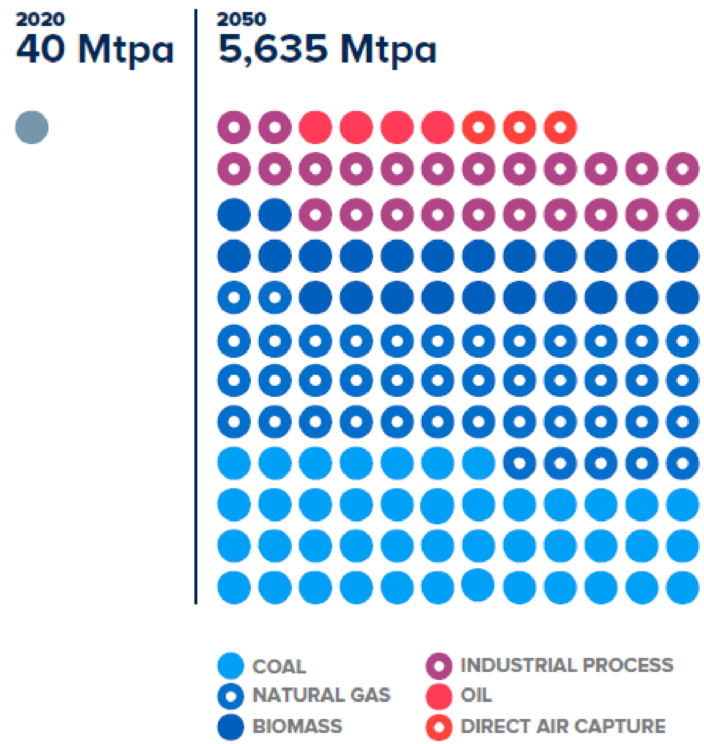
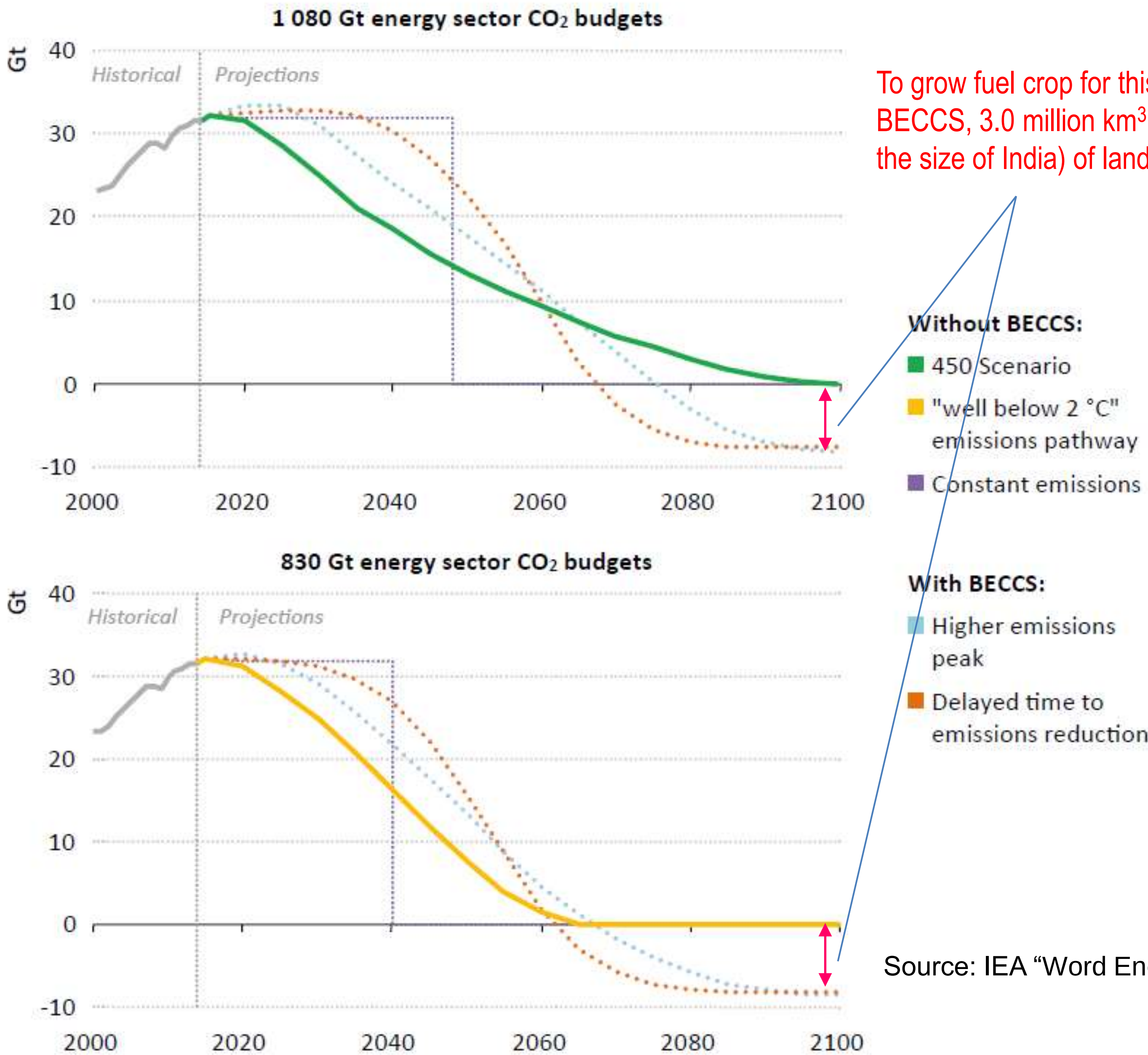


FIGURE 2 **CO_2 CAPTURE CAPACITY IN 2020 AND 2050 BY FUEL AND SECTOR IN THE IEA SUSTAINABLE DEVELOPMENT SCENARIO**[b]

Includes CO_2 captured for use (369 Mtpa) and storage (5,266 Mtpa) in 2050

Source: GCCSI “Status report of CCS, 2020”

2℃ and “well below 2℃”

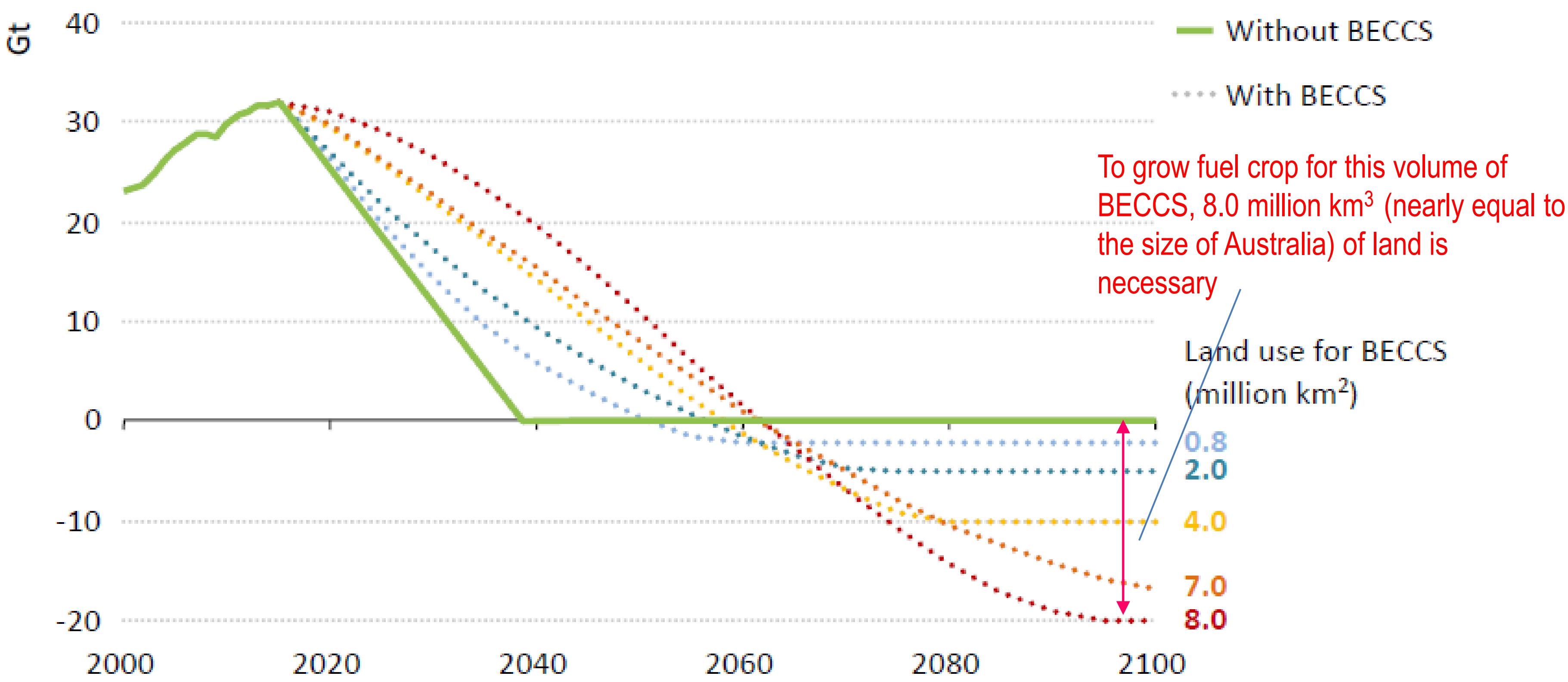


To grow fuel crop for this volume of BECCS, 3.0 million km^3 (nearly equal to the size of India) of land is necessary

Source: IEA “Word Energy Outlook 2016”

… and "1.5°C"

Figure 8.16 ▷ Energy sector CO_2 emission pathways consistent with a 1.5 °C temperature rise



Source: IEA "Word Energy Outlook 2016"

INTERNATIONAL CLIMATE POLICY (UNFCCC NEGOTIATION HISTORY, MAJOR COP DECISIONS AND PARIS AGREEMENT)

Major International Forum for Climate Change Policy

☐ United Nation Framework Convention on Climate Change

- Objective (Article 2) : to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.
- 192 parties (countries and region (EU)) that ratified UNFCCC
- Decision is only made by consensus
- Annual conference of parties (COP) in Nov/Dec, and semi annual meetings of subsidiary bodies (SBI, SBSTA and temporally Ad-hoc meetings)
- Annual meeting under Kyoto Protocol and Paris Agreement are held in pallarel during COP

☐ Other UN meetings

– United Nation Summit

☐ G8 (G7), G20

COP Chronology

Year	Meeting	Venue	Major outcome
1992	UN summit	Rio de Janeiro	adoption of UN Framework Convention on Climate Change (UNFCCC)
1994			Effect of UNFCCC
1997	COP3	Kyoto	Adoption of Kyoto Protocol
2000	COP6	Bonn	US' withdrawal from Kyoto Protocol
2001	COP7	Marakech	Agreement on rules for Kyoto Protocol
2005	COP11	Montreal	Effect of Kyoto Protocol
2007	COP13	Bali	Agreement on "post 2012 framework by 2012"
2009	COP15	Copenhagen	Failure to agree on post 2012 framework
2010	COP16	Cancun	Agreement to continue long term vision and 2020 voluntary target
2011	COP17	Darbun	Agreement on "post 2020 framework with all parties' contribution by 2015"
2012	COP18	Doha	Agreement on work program for post 2020 framework
2014	COP20	Lima	Start of negotiation on post 2020 framework text
2015	**COP21**	**Paris**	**Adoption of Paris Agreement**
2016	COP22	Marakech	Effect of Paris Agreement
2018	COP24	Katowice	Agreement on major rules for Paris Agreement
2019	COP25	Madrid	Agreement on pending rules for Paris Agreement (including Article 6)

Negotiation group in UNFCCC COP

Developing countries' groups

- Group of 77+China (G77+China) – a large alliance of 134 developing nations
- Least Developed Countries (LDCs) – a group of the world's poorest nations, which evolves as economies change
- Alliance of Small Island States (AOSIS) – a group of 44 small islands and low-lying coastal states
- Like-Minded Developing Countries (LMDCs) – a group of developing countries, representing 3.5bn people, with a strong focus on ensuring rich countries bear most responsibility for tackling climate change
- BASIC (Brazil, South Africa, India and China) – a coalition of four major emerging economies
- Bolivarian Alliance for the Americas (ALBA) – a Latin American and Caribbean alliance with socialist leanings

Regional developing countries' groups

- African Group – One of the UN's five regional negotiating groups, with 54 member states
- Arab Group – formally the League of Arab States, a regional organisation formed in 1945

Developed countries' group

- European Union (EU) – the 28 member states of the EU, with negotiations led by DG-Clima
- Umbrella Group (Australia, Belarus, Canada, Iceland, Israel, Japan, New Zealand, Kazakhstan, Norway, the Russian Federation, Ukraine and the United States)– a cross-continent group of countries

Source: Climate policy info hub

Paris Agreement in comparison with Kyoto Protocol

	Kyoto Protocol	Paris Agreement
What are to be done	Mitigation	Mitigation, Adaptation, Finance support, Review
Who are to mitigate	Developed countries	All parties
How to set mitigation target	Decided by COP (top-down)	Decided by each party (bottom-up)
What are mandated	Compliance of the target (penalty for no compliance)	Efforts to aim the target (compliance of the target is not mandate)
Emission coverage	26% (to global energy related CO2 between 2008-2012)	100%
Long term vision	No long term vision	Holding temperature increase well below 2 degree
Adaptation	―	Necessity for developing countries
Finance support	―	Mandate for developed countries to provide to developing countries
Transparency	―	All parties shall submit NDC and follow review process
Review	Kyoto Protocol shall be reviewed to decide new target for next commitment period	Each party shall submit new NDC in every 5 years

Overview of Paris Agreement

	Relevant text in Paris Agreement	Legal binding force
Long term target (Article 2)	This Agreement aims (…) to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by: (a) Holding the increase in the global average temperature to well below 2° C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5° C above pre-industrial levels	Not mandate
Pathway for the long term target (Article 3, Paragraph 1)	In order to achieve the long-term temperature goal set out in Article 2, (…) Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.	Not mandate

Overview of Paris Agreement

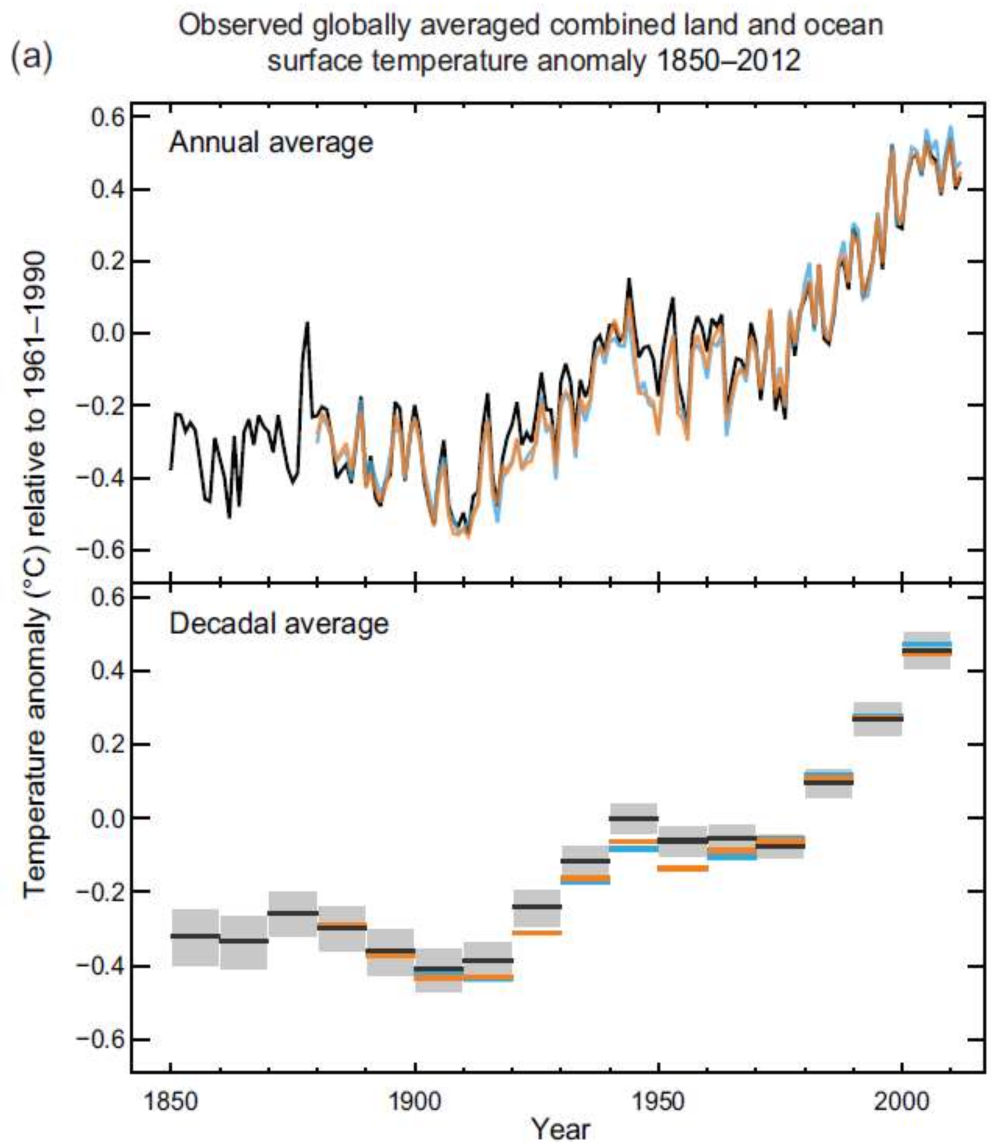
	Relevant text in Paris Agreement	Legal binding force
Short term target for all parties (Article 3, Paragraph 2)	Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.	Mandate: NDC preparation, communication, maintenance and pursuing domestic mitigation measures (achieving the objectives is not mandate)
Support to developing countries (Article 3, Paragraph 5)	Support shall be provided to developing country Parties for the implementation of this Article, in accordance with Articles 9, 10 and 11, recognizing that enhanced support for developing country Parties will allow for higher ambition in their actions.	Mandate
Mechanism to check progress of domestic measures (Article 13, Paragraph 7)	Each Party shall regularly provide the following information: (b) Information necessary to track progress made in implementing and achieving its nationally determined contribution under Article 4.	Mandate
Review process to check progress toward long term target (Article 14, Paragraph 1)	The Conference of the Parties serving as the meeting of the Parties to this Agreement shall periodically take stock of the implementation of this Agreement to assess the collective progress towards achieving the purpose of this Agreement and its long-term goals (referred to as the "global stocktake").	Mandate

CLIMATE CHANGE SCIENCE (IPCC AR5 AND SPECIAL REPORT 1.5℃)

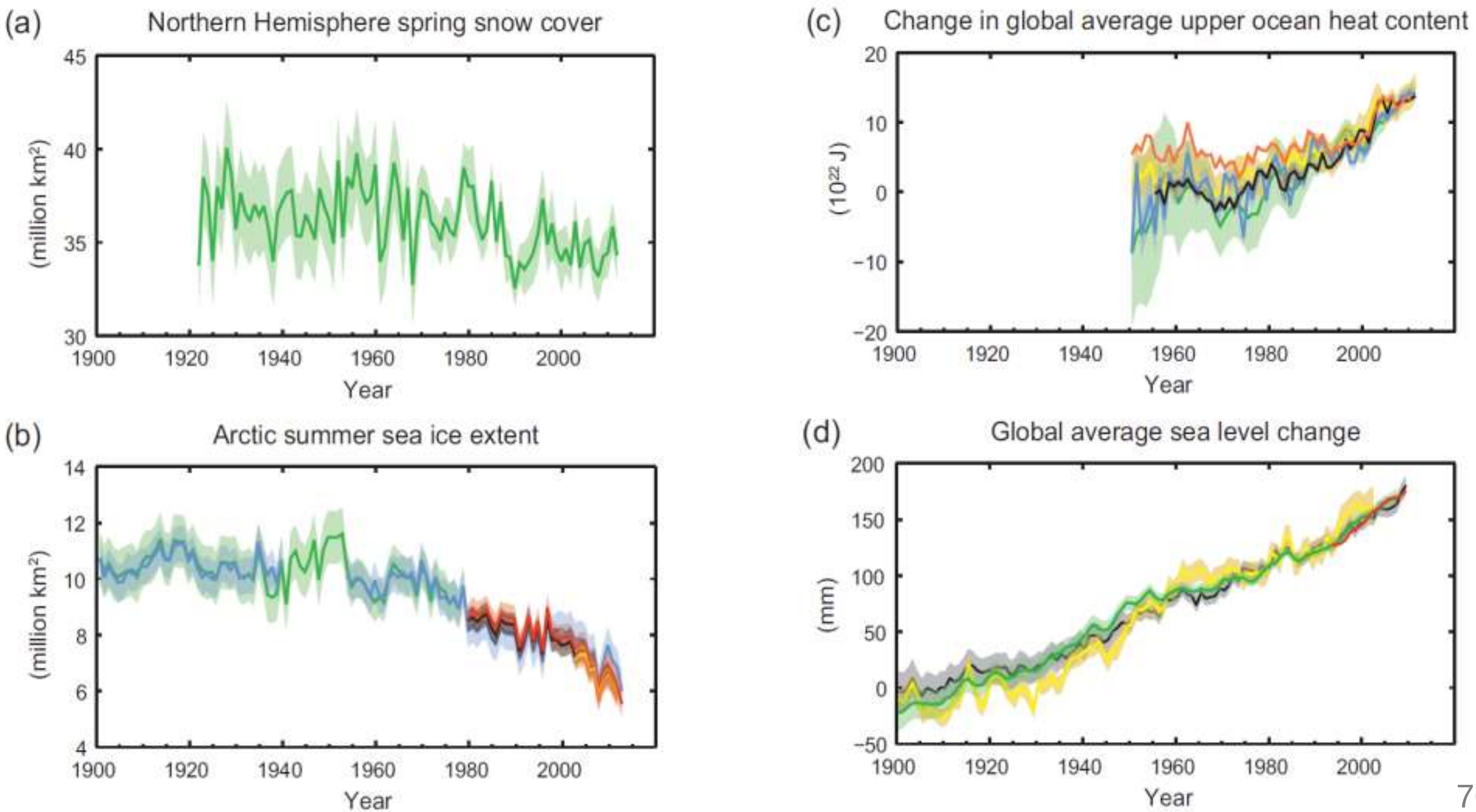
Scientific base for climate change

- The Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988.
- The objective of the IPCC is to provide governments at all levels with scientific information that they can use to develop climate policies.
- Since 1988, the IPCC has had delivered five Assessment Reports, the most comprehensive scientific reports about climate change.
- Three working groups are in charge of Assessment Report based on the latest academic findings;
  - Working Group I The Physical Science Basis
  - Working Group II Impacts, Adaptation and Vulnerability
  - Working Group III Mitigation of Climate Change
- Each Assessment Report (some thousands pages) and Synthesis Report (a couple of hundreds pages) are summarized into Summary for Policymakers (SPM, 20-30 pages) that were reviewed by government officials.

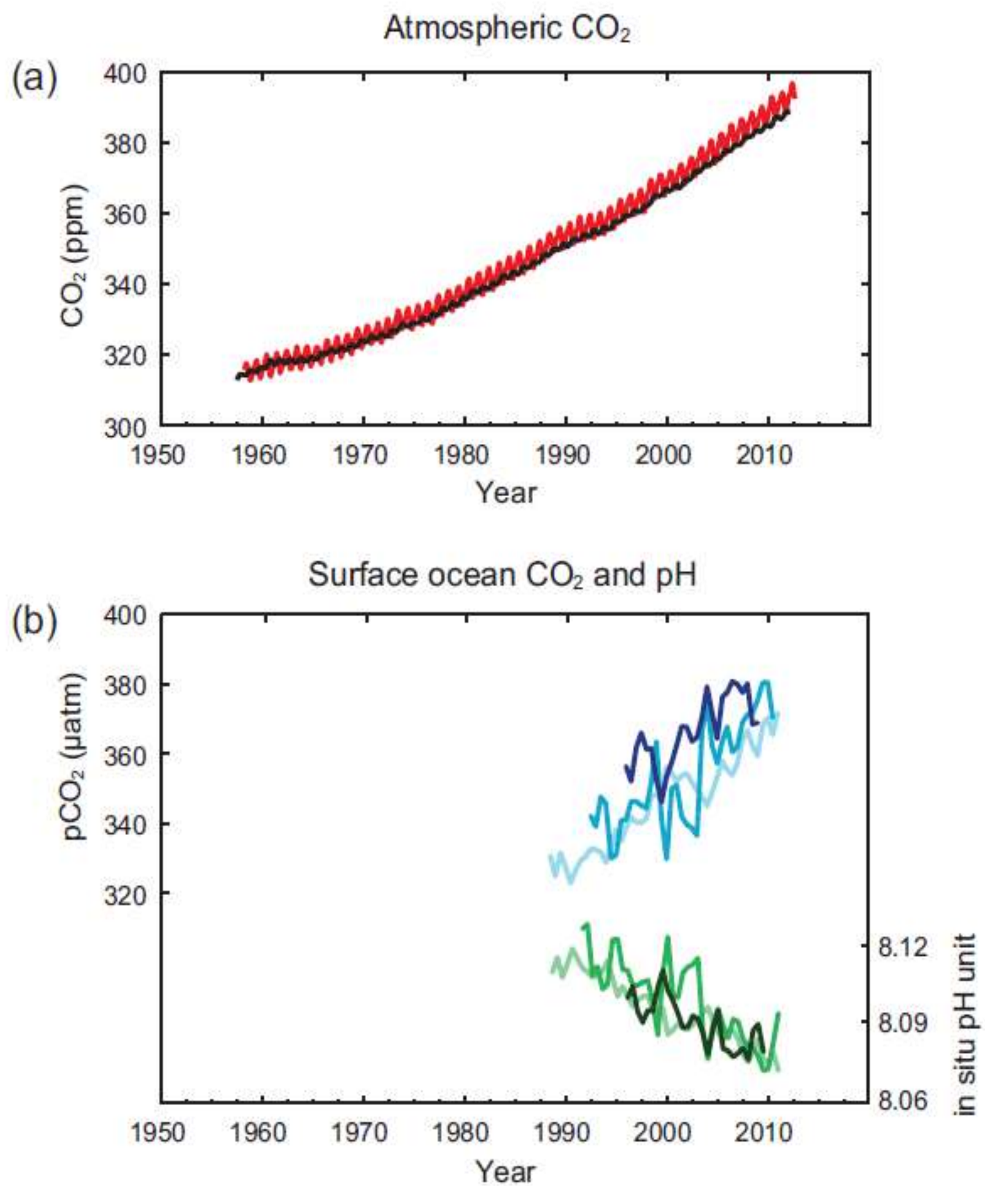
WG1 AR5 SPM: Figure SPM1



WG1 AR5 SPM: Figure SPM3

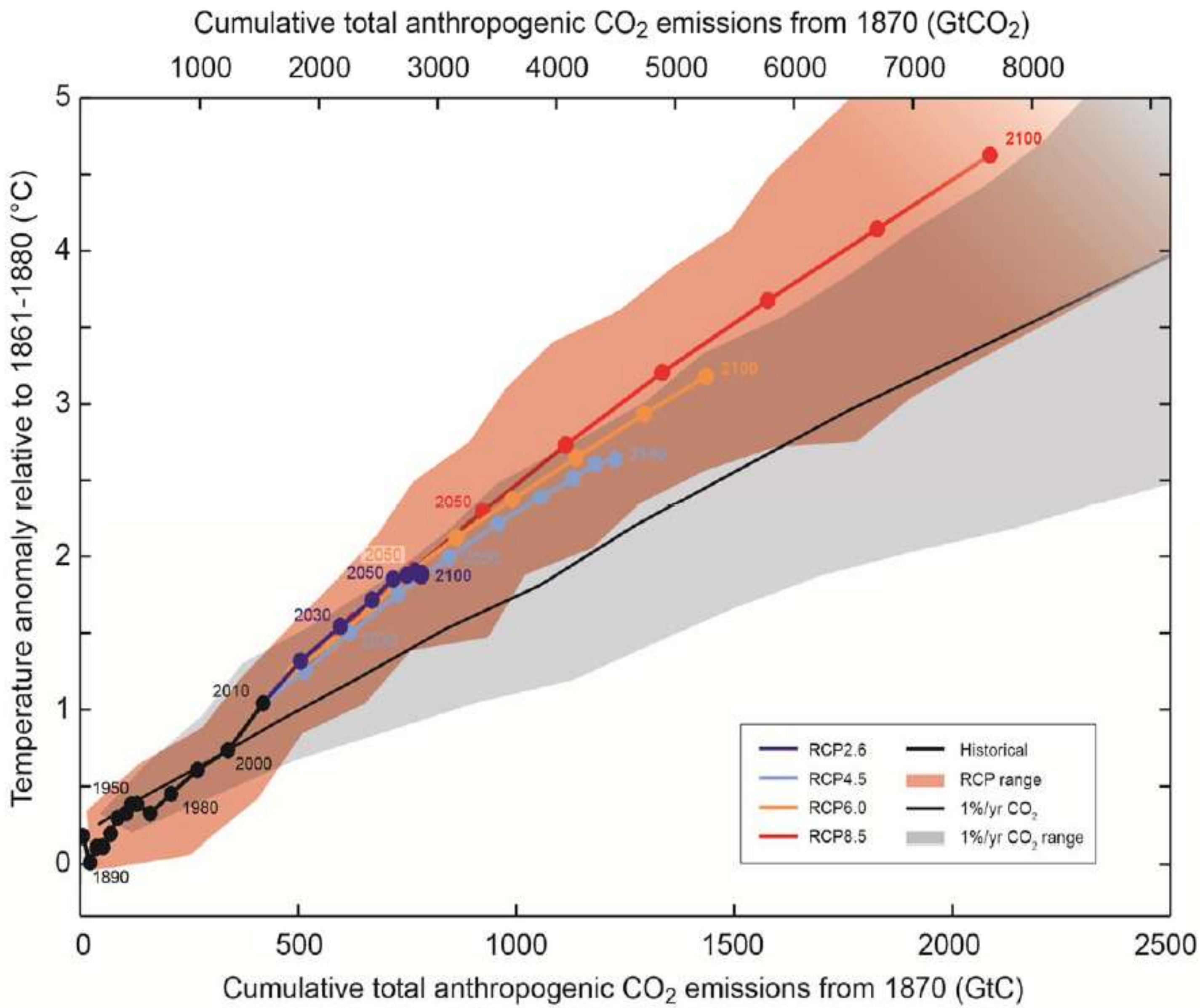


WG1 AR5 SPM: Figure SPM4

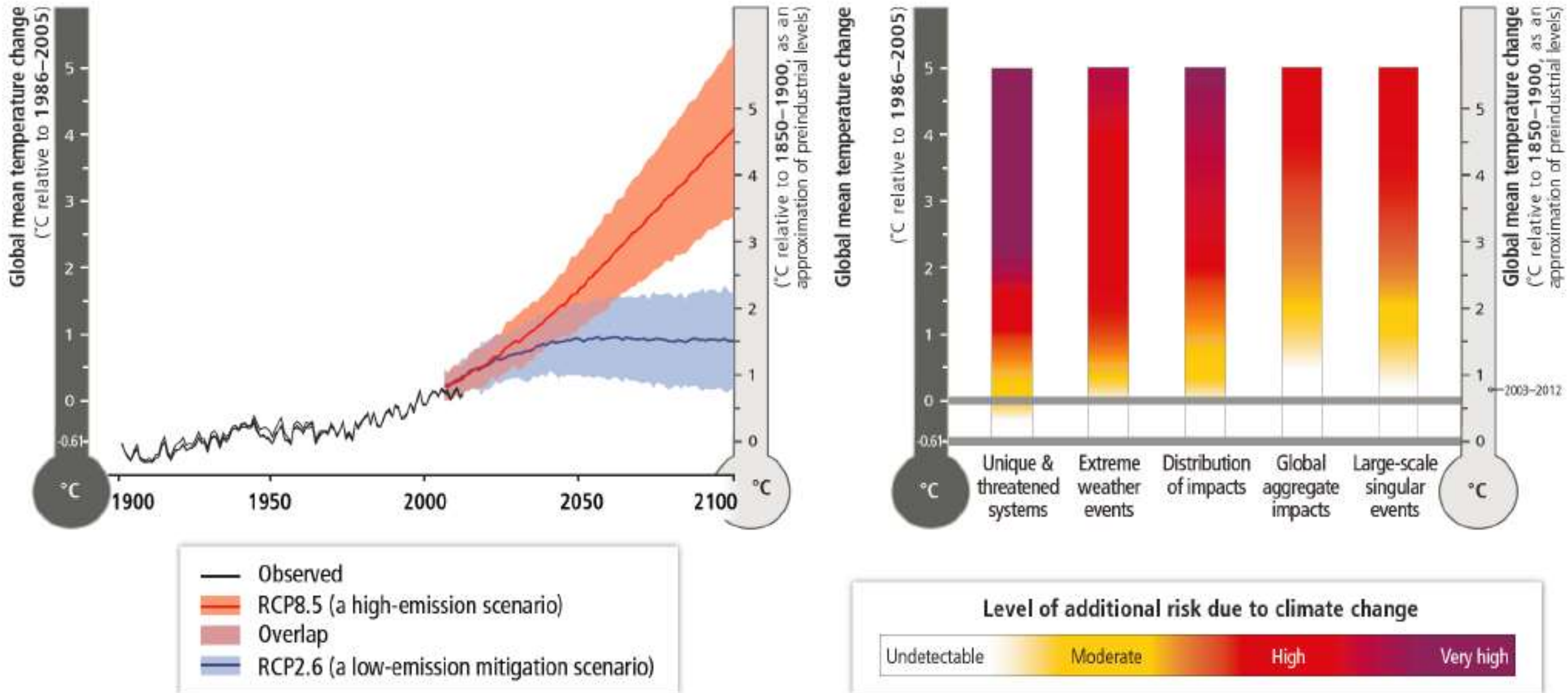


WG1 AR5 SPM: Figure SPM10

Figure SPM.10 [FIGURE SUBJECT TO FINAL COPYEDIT]



WG2 AR5 SPM: Assessment Box SPM.1 Figure 1.



WG2 AR5 SPM: Figure SPM. 5

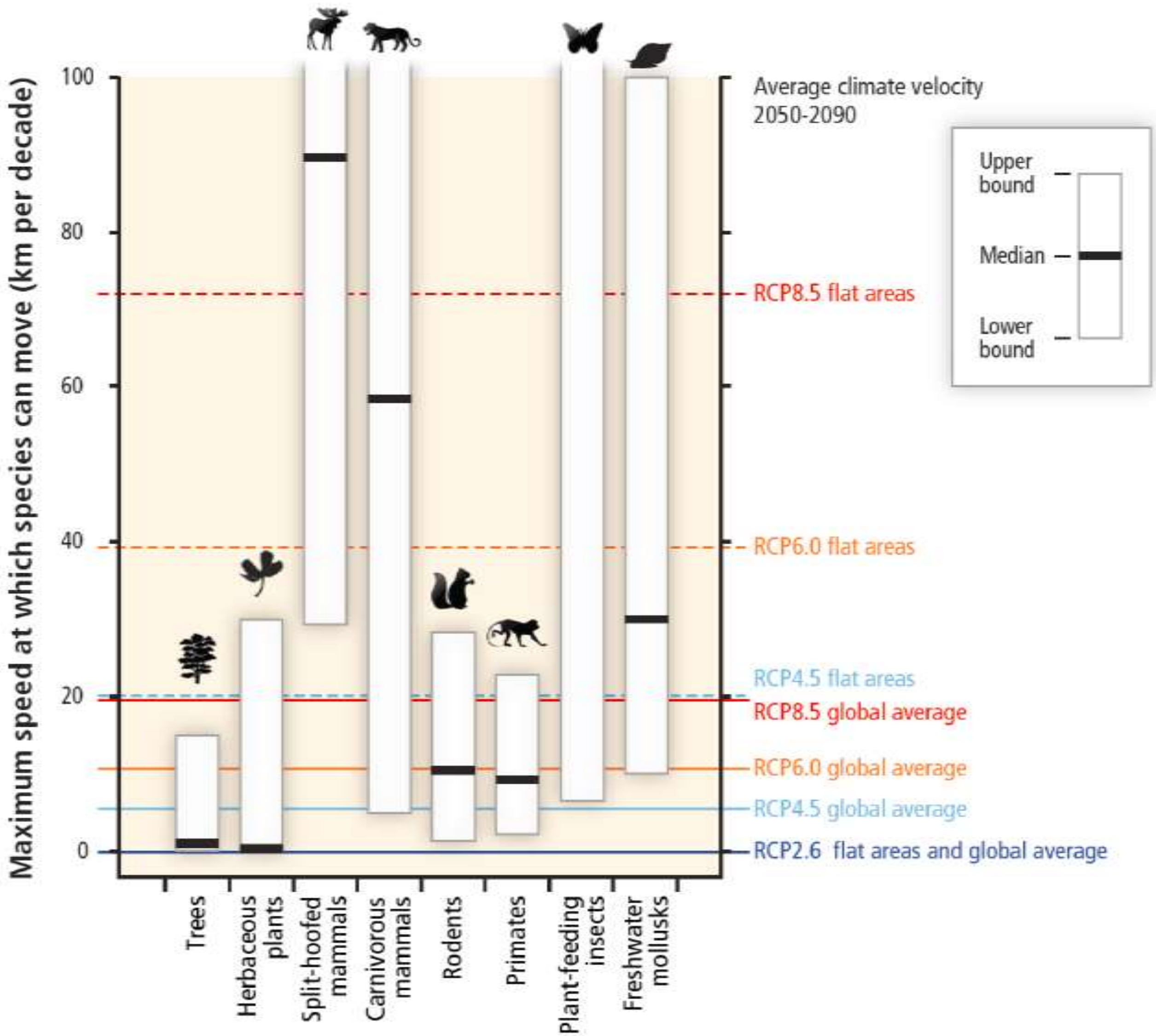


Figure SPM.5.

WG2 AR5 SPM: Figure SPM. 2

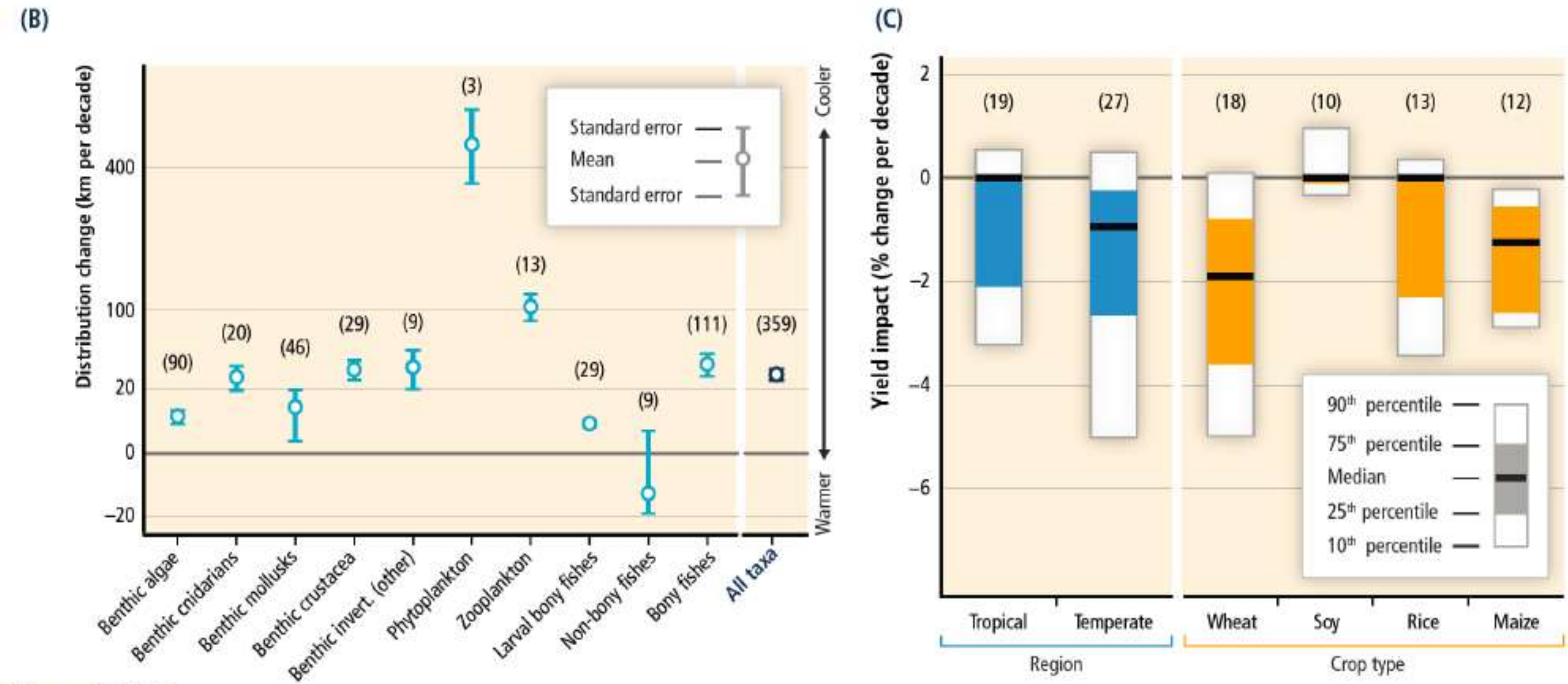


Figure SPM.2.

WG3 AR5 SPM: Figure SPM. 4

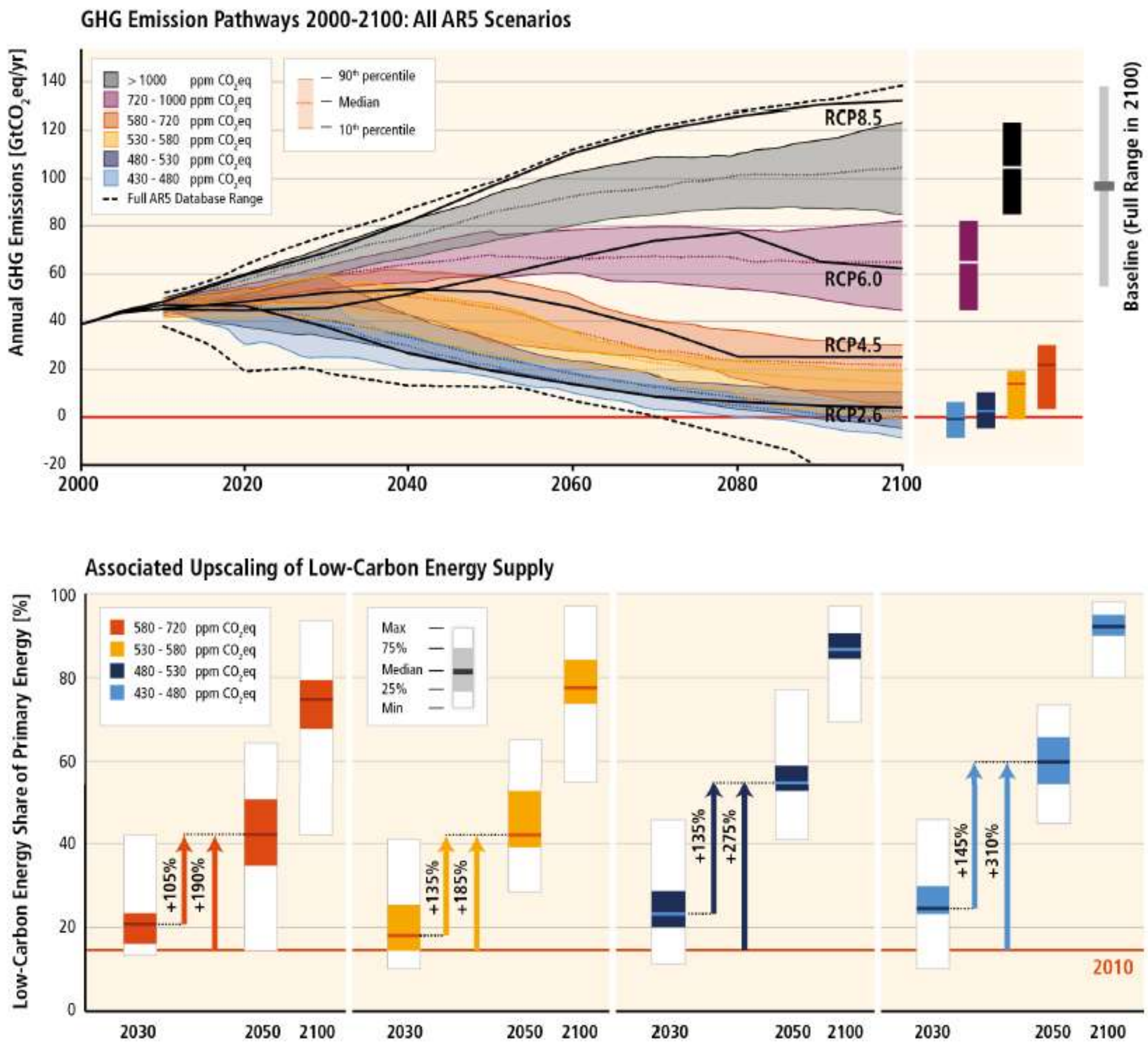
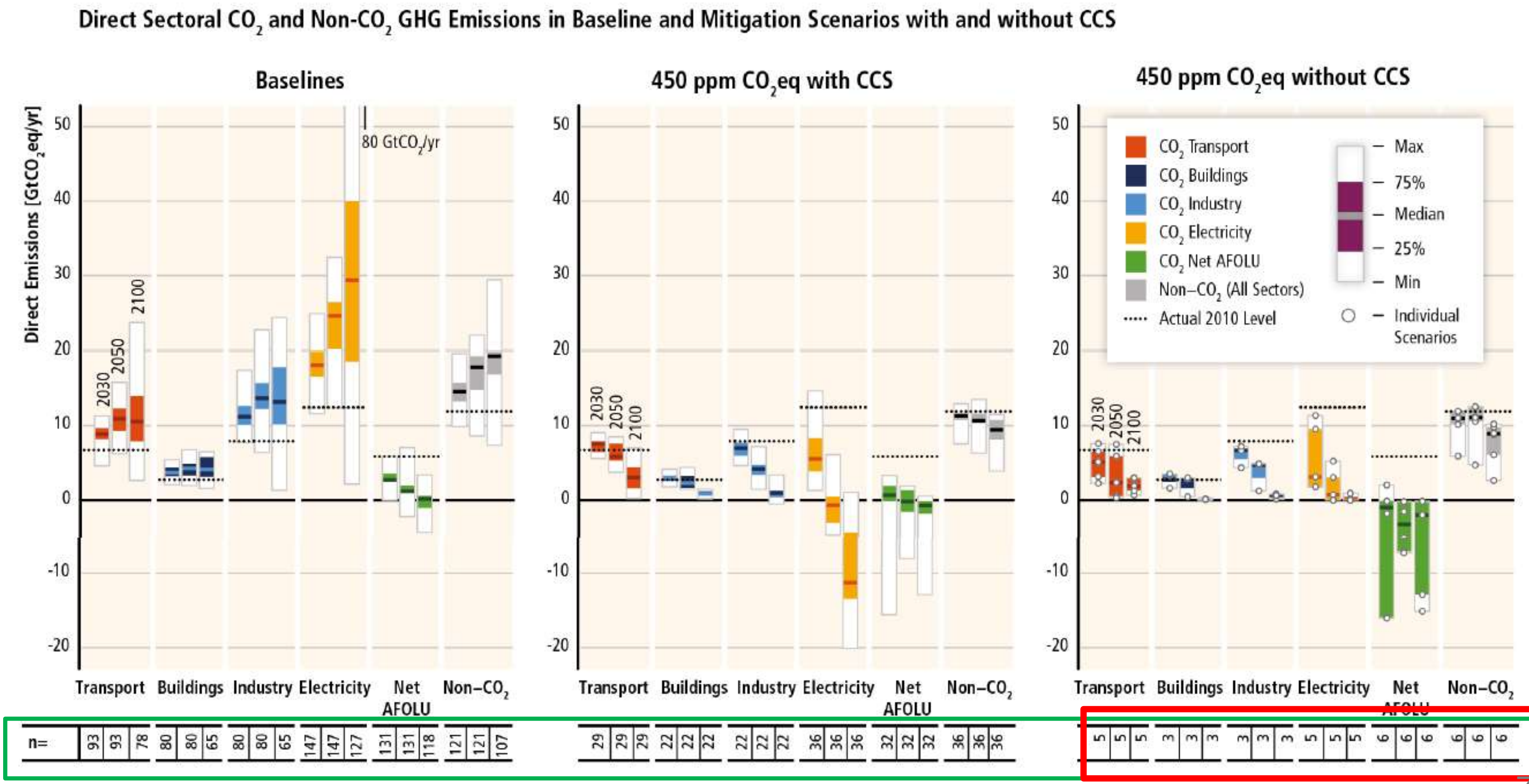


Figure SPM.4. Pathways of global GHG emissions ($GtCO_2eq/yr$) in baseline and mitigation scenarios

WG3 AR5 SPM: Figure SPM 7



AR5 WG3 Technical Summary: Figure TS.12

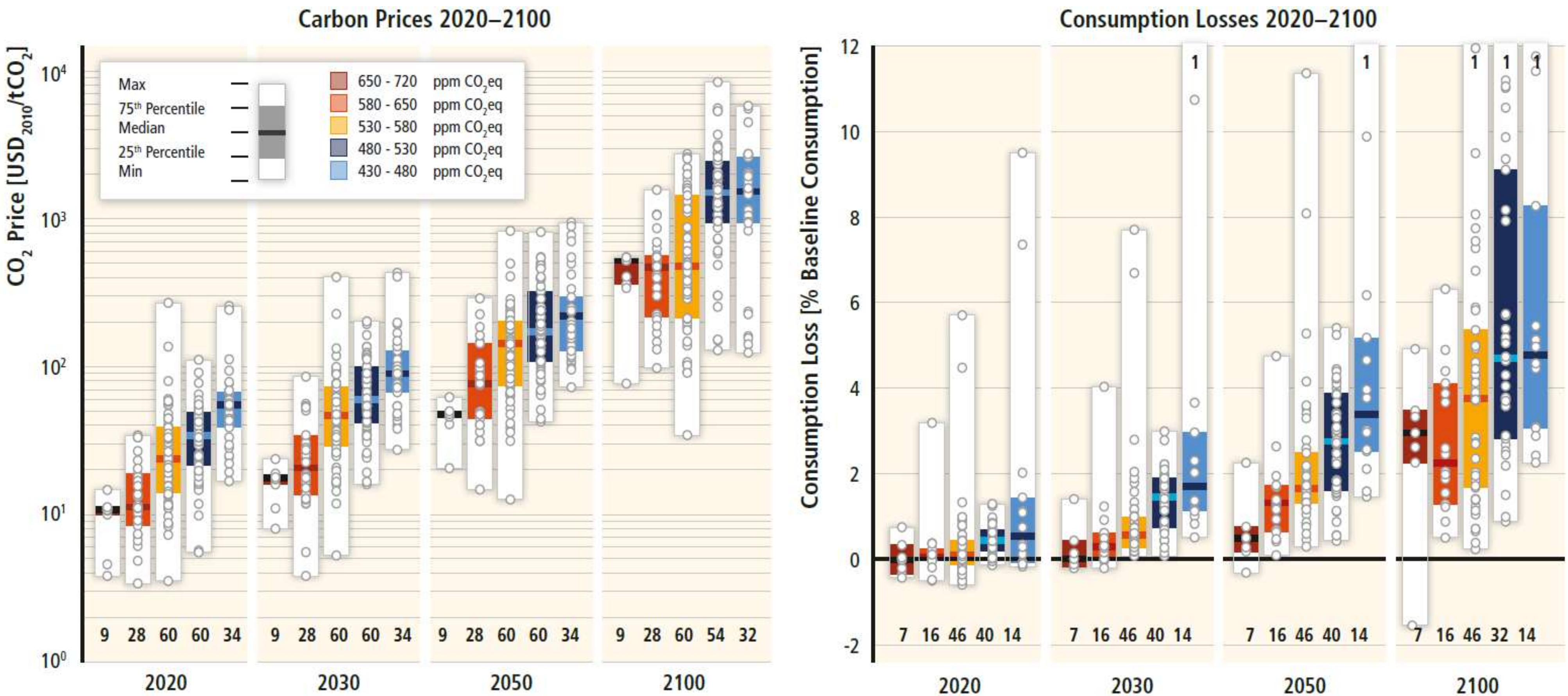
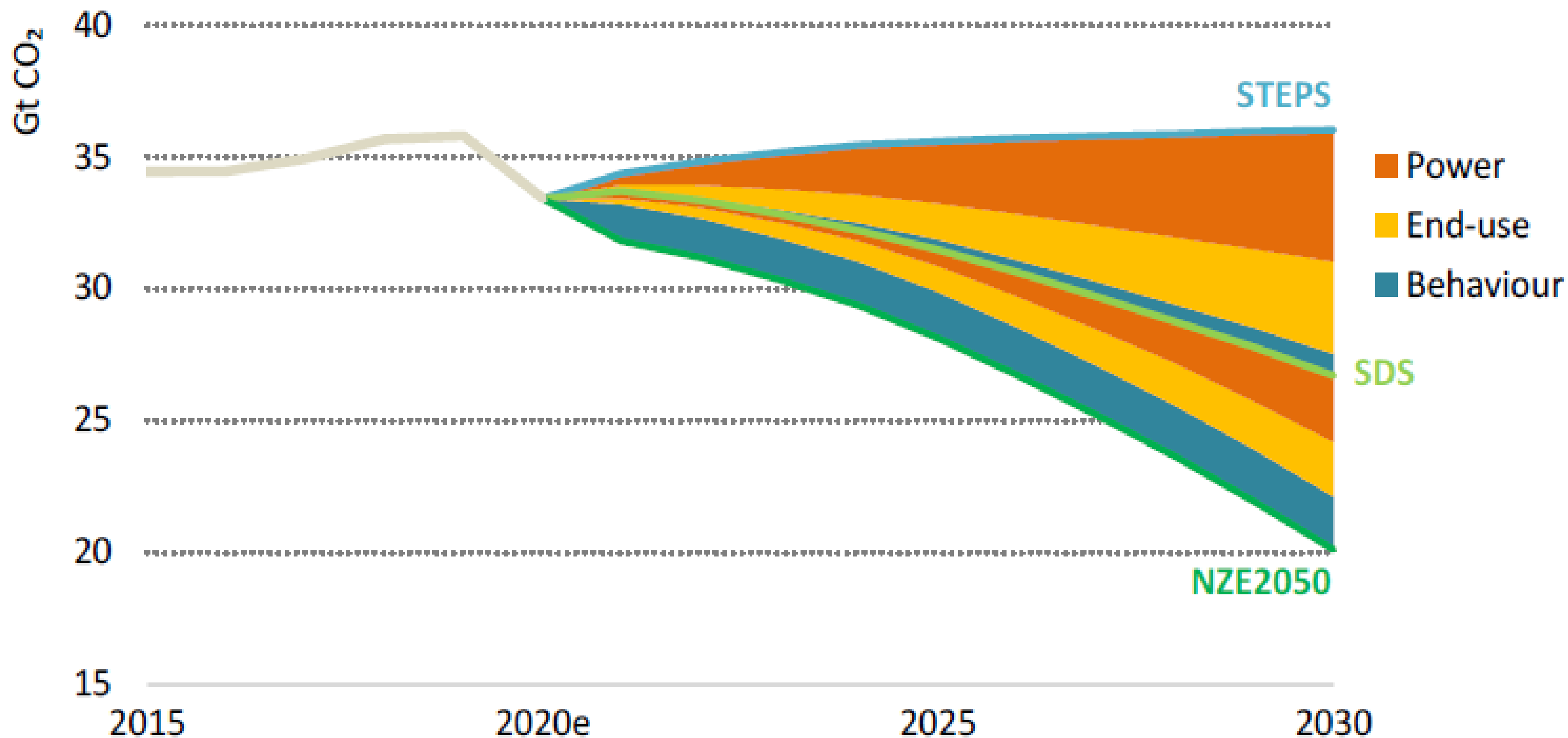


Figure TS.12 | Global carbon prices (left panel) and consumption losses (right panel) over time in cost-effective, idealized implementation scenarios. Consumption losses are expressed as the percentage reduction from consumption in the baseline. The number of scenarios included in the boxplots is indicated at the bottom of the panels. The 2030 numbers also apply to 2020 and 2050. The number of scenarios outside the figure range is noted at the top. Note: The figure shows only scenarios that reported consumption losses (a subset of models with full coverage of the economy) or carbon prices, respectively, to 2050 or 2100. Multiple scenarios from the same model with similar characteristics are only represented by a single scenario in the sample. [Figure 6.21]

Behavioural changes by WEO2020

Figure 4.1 ▷ Energy and industrial process CO_2 emissions and reduction levers in the scenarios

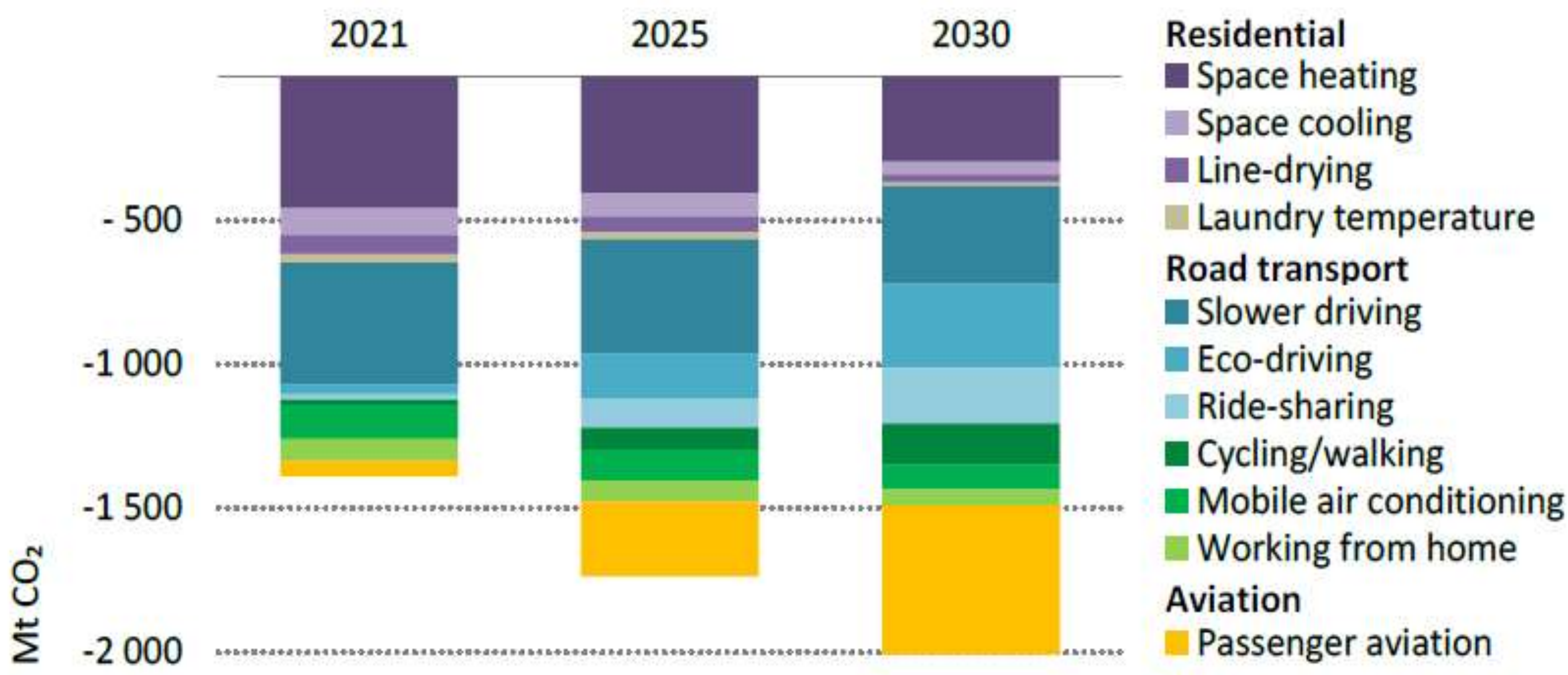


An unparalleled transformation of the energy sector and major behaviour changes in the next ten years would be needed to achieve global net-zero emissions by 2050

Source：IEA World Energy Outlook 2020

Behavioural changes by WEO2020

Figure 4.15 ▷ Impact of behaviour changes on CO_2 emissions in the NZE2050



Some changes in behaviour could happen right away; others would need to be guided by policy, supported by infrastructure, and would ramp up over time

Source：IEA World Energy Outlook 2020

Behavioural changes by WEO2020

Table 4.1 ▷ Behaviour change measures and impact on CO_2 emissions in the NZE2050 to 2030

Behaviour change		Emissions savings ($Mt\ CO_2$) 2021	2025	2030	Cumulative savings ($Mt\ CO_2$) 2021-30	Share in 2030
Space heating	Reduce space heating temperature by 3 °C.	460 33%	400 23%	300 15%	4 340 23%	11% of residential emissions. % of total savings.
Space cooling	Raise air conditioning temperature by 3 °C.	95 7%	95 5%	45 2%	860 5%	2% of residential emissions. % of total savings.
Line-drying	Line-drying instead of tumble-drying during summer months.	65 5%	55 3%	30 1%	550 3%	1% of residential emissions. % of total savings.
Laundry temperature	Wash on average 10 °C colder.	30 2%	25 1%	15 1%	270 1%	1% of residential emissions. % of total savings.
Driving more slowly	Reduce driving speed by 7 km/h.	420 30%	400 23%	340 17%	4 280 23%	7% of road transport emissions. % of total savings.
Eco-driving	Avoid sudden acceleration, stops or idling; early upshifting.	30 2%	160 9%	290 14%	1 670 9%	6% of road transport emissions. % of total savings.

Source：IEA World Energy Outlook 2020

Behavioural changes by WEO2020

Behaviour change		Emissions savings ($Mt\ CO_2$) 2021	2025	2030	Cumulative savings ($Mt\ CO_2$) 2021-30	Share in 2030
Ride-sharing	Share all urban car trips.	20	100	190	1 100	9% of passenger car emissions.
		2%	6%	10%	6%	% of total savings.
Cycling and walking	Cycle or walk all car trips that would take less than ten minutes to cycle.	15	75	140	820	7% of passenger car emissions.
		1%	4%	7%	4%	% of total savings.
Mobile air conditioning	Raise air conditioning temperature in cars by 3 °C.	120	110	90	1 160	4% of passenger car emissions.
		9%	6%	4%	6%	% of total savings.
Working from home	20% of global workforce works from home 3 days of the week.[7]	80	75	55	800	3% of passenger car emissions.
		6%	4%	3%	4%	% of total savings.
Passenger aviation	Total passenger aviation.	50	260	520	2 850	60% of aviation emissions.
		4%	15%	26%	15%	% of total savings.
	Replace all flights less than 1 hour.	10	50	100	550	11% of aviation emissions.
	Replace three-quarters of all business flights.	25	120	240	1 340	28% of aviation emissions.
	Replace three-quarters of long-haul flights.	35	170	350	1 910	40% of aviation emissions.
Total		1 390	1 750	2 010	18 700	

Source：IEA World Energy Outlook 2020

Behavioural change in diet by IPCC Special Report CCL

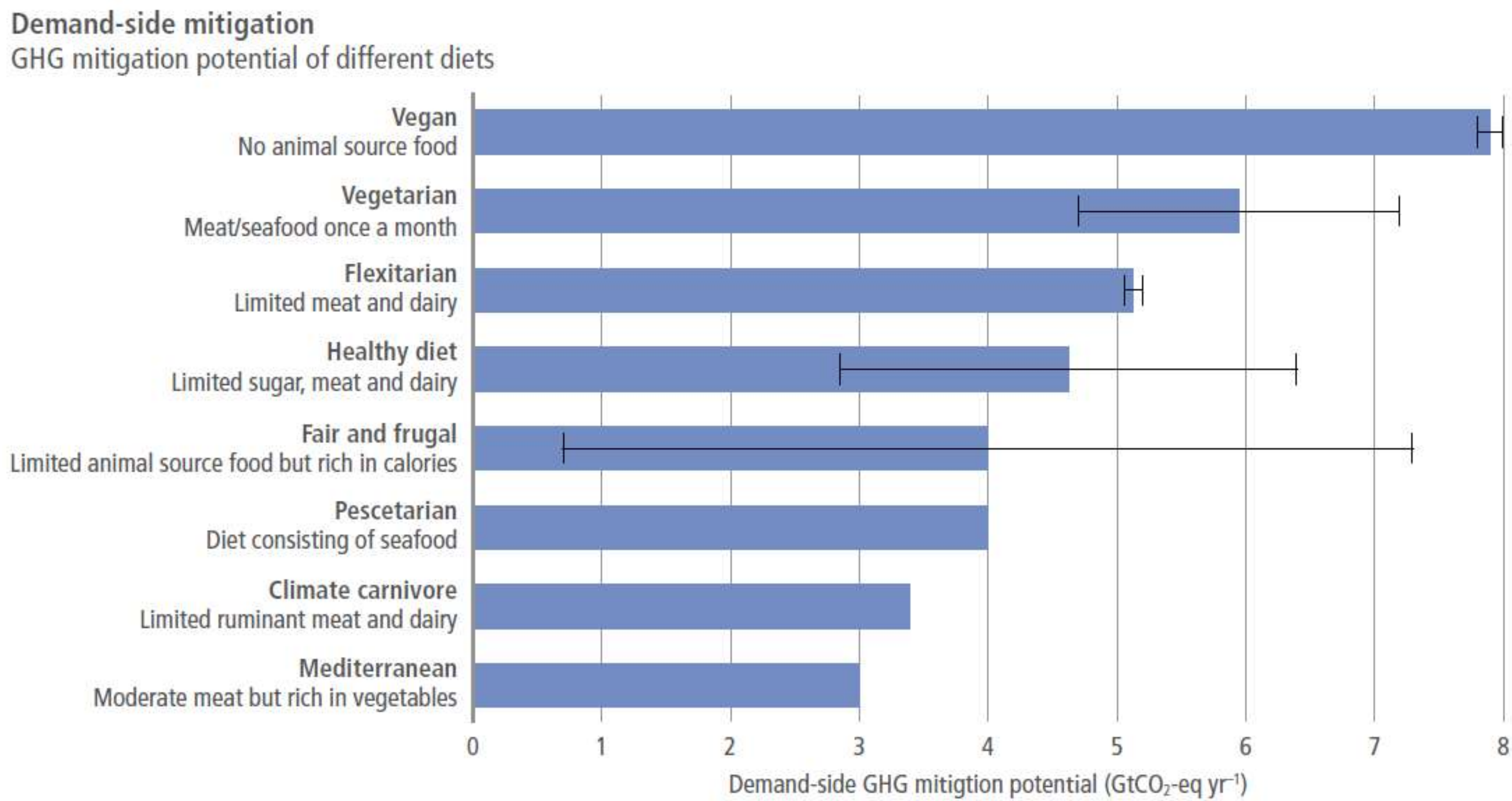
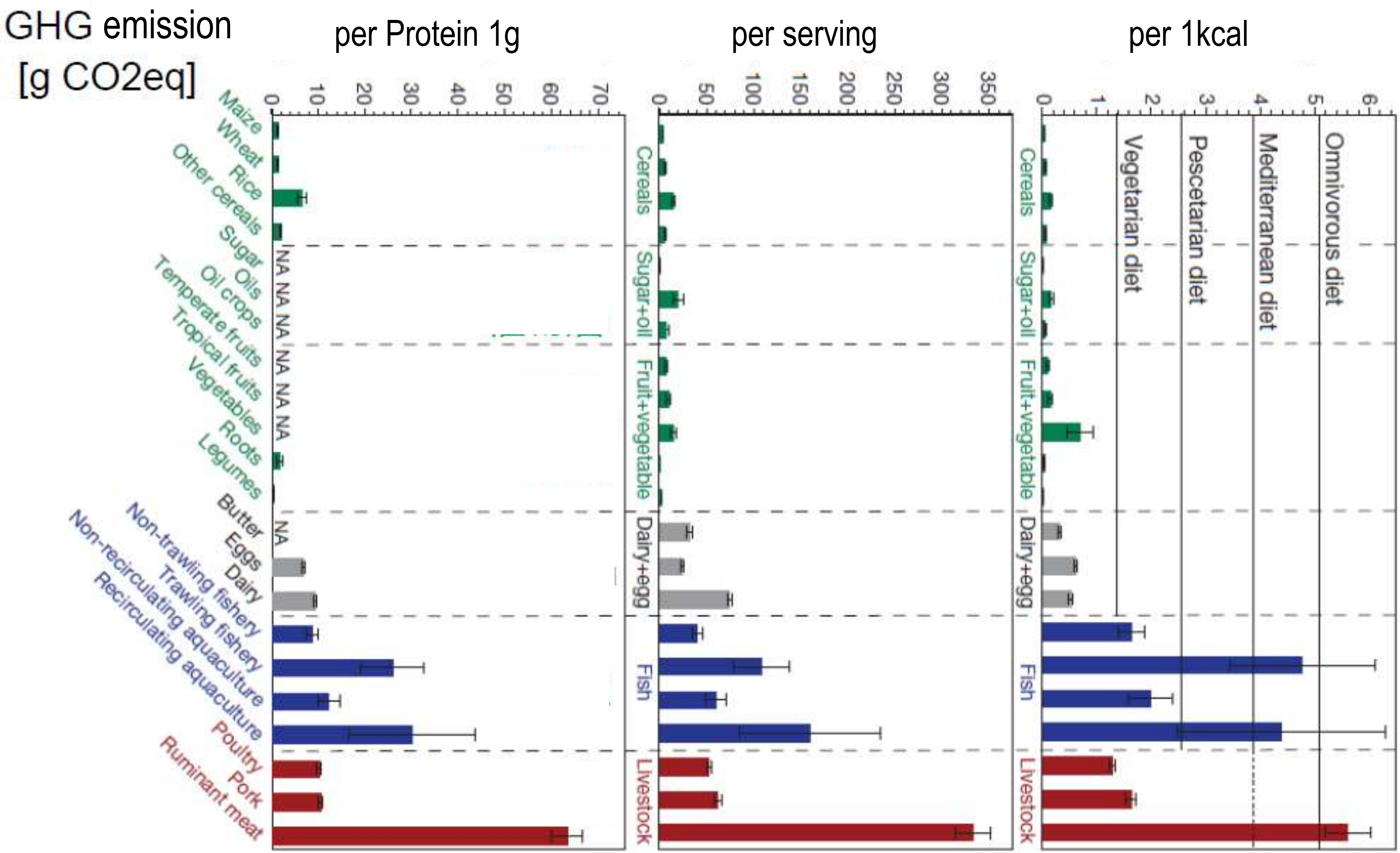


Figure 5.12 | Technical mitigation potential of changing diets by 2050 according to a range of scenarios examined in the literature. Estimates indicate technical potential only and include additional effects of carbon sequestration from land-sparing. Data without error bars are from one study only.

Source：IPCC Special Report on Climate Change and Land(2019)

Example of estimated carbon footprint of food

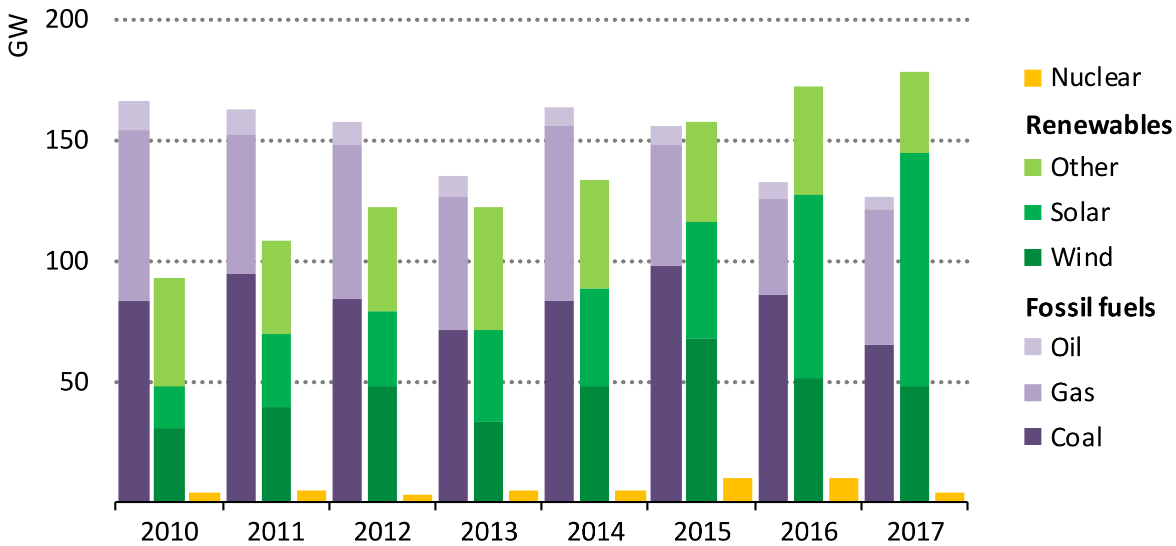


Tilman, D. and M. Clark (2014). "Global diets link environmental sustainability and human health." Nature 515(7528): 518-522.

Source：Osamu Kimura, 36th Energy and Resource Conference

POWER SECTOR LOW CARBONIZATION: VARIABLE RENEWABLE ENERGY AND FLEXIBILITY

Global growth of Renewable in Power Sector



Annual power generation capacity additions, 2010-2017

- Renewables power capacity is growing while fossil power capacity is declining after 2014 in terms of capacity additions.
- Solar alone exceeded coal in 2016.
- Wind and solar are on the rise having overtaken fossil fuels in 2017.

Global power generation portfolio by type (upper) and power generation by type (lower)

- In terms of total power generation, fossil fuels power is still dominating in both in share and absolute terms.
- Recent growth of wind and solar PV is remarkable, however, hydro power remains as the major source of renewable power.

Source：IEA, “World Energy Outlook 2018”

Flexibility as the key feature of future-ready power systems

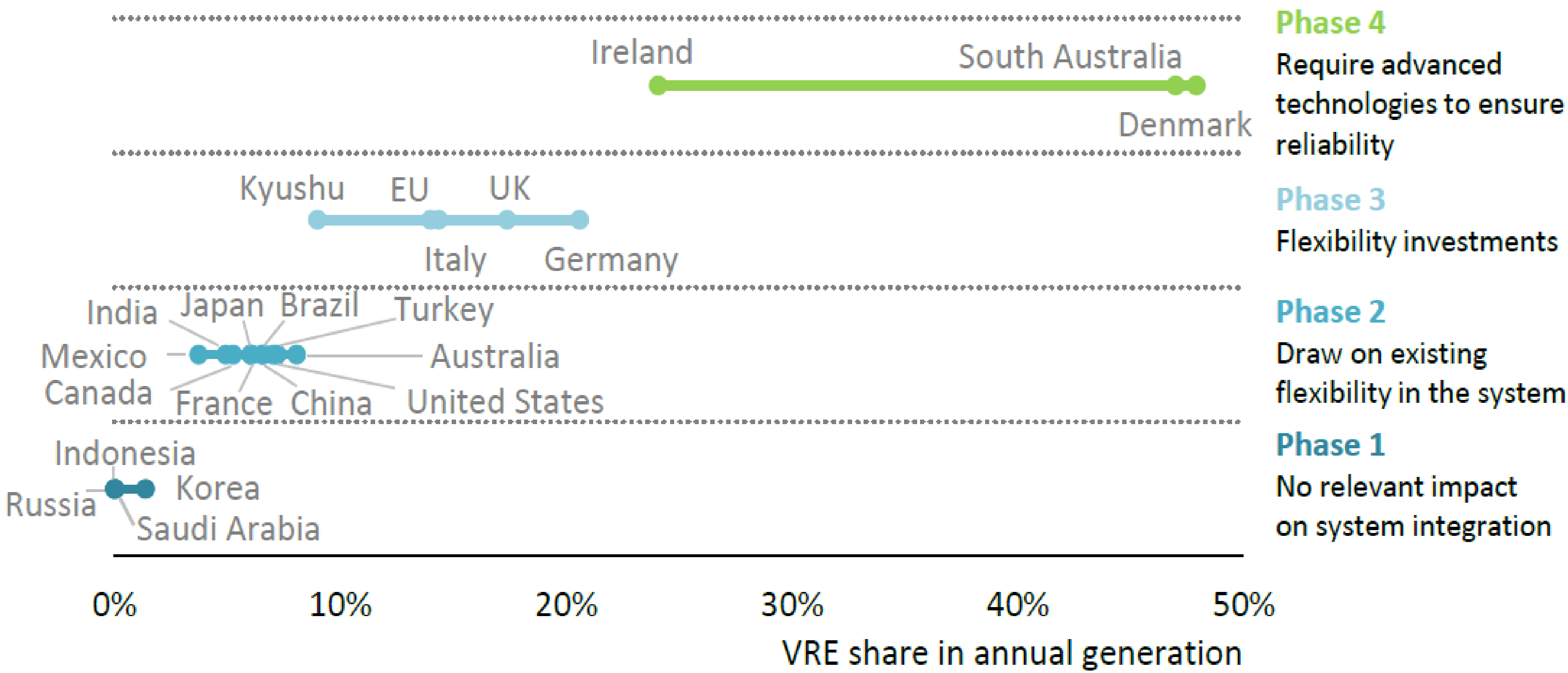
Variable renewable energy requires sufficient power system flexibility

Flexibility requires both technologies and effective regulation/markets.

VRE integration phase in selected countries

- IEA categorized VRE integration phase based on VRE penetration level and restrictions of respective power system.

Annual share of VRE generation and related VRE integration phase in selected regions/countries, 2017



Source：IEA, "World Energy Outlook 2018"

VRE integration phase and impact

POWER

Characteristics and key challeges in different phase of VRE integration

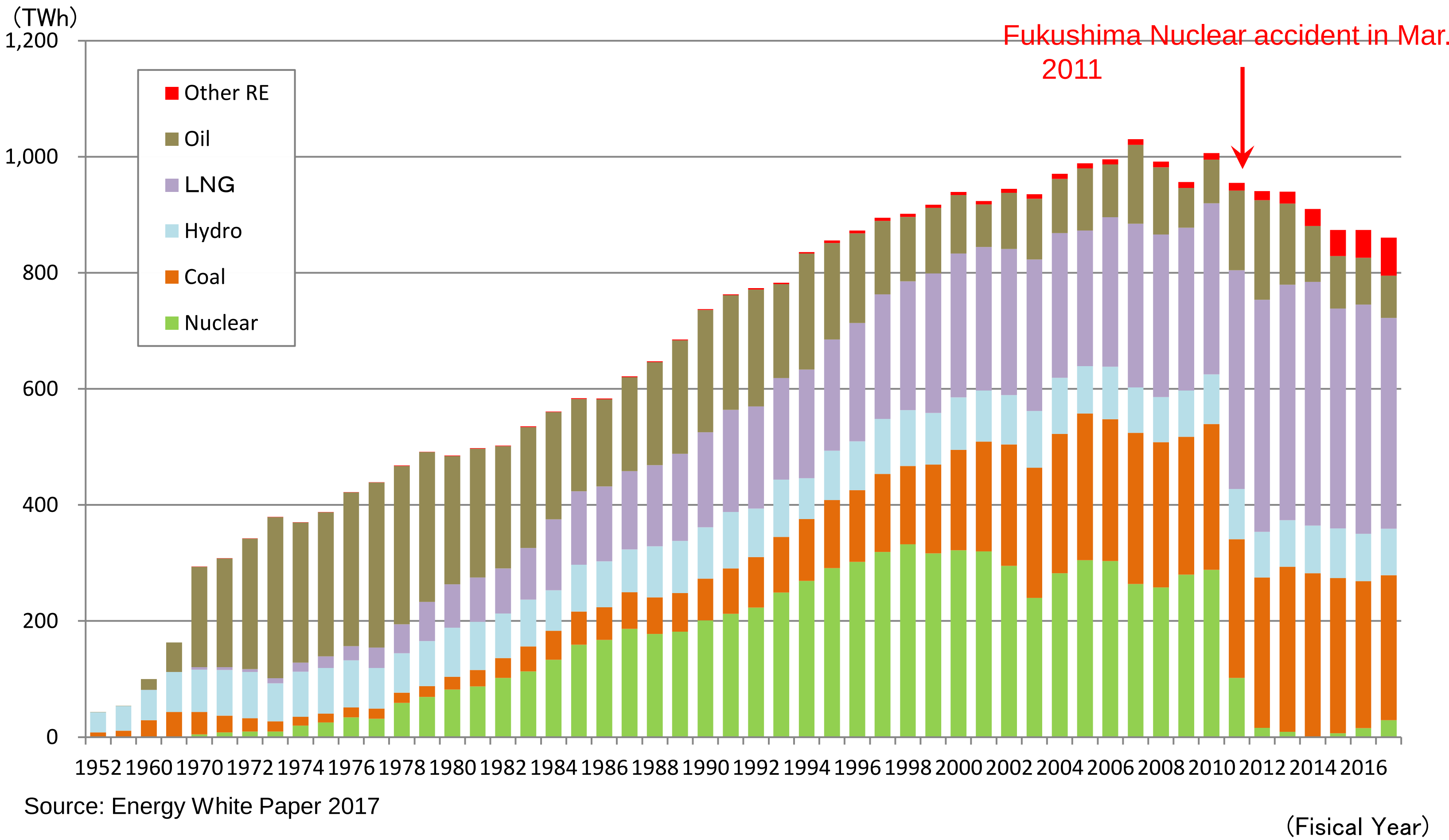
	Attributes (incremental with progress through the phases)			
	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
Characterisation from a system perspective	VRE capacity is not relevant at the all-system level	VRE capacity becomes noticeable to the SO	Flexibility becomes relevant with greater swings in the supply/demand balance	Stability becomes relevant. VRE covers nearly 100% of demand at times
Impacts on the existing generator fleet	No noticeable difference between load and net load	No significant rise in uncertainty and variability of net load, but small changes to operating patterns	Greater variability of net load. Major differences in operating patterns;	No power plants are running around the clock; all plants adjust output to VRE output
Impacts on the grid	Local grid condition near points of connection, if any	Likely to affect local grid conditions; congestion is possible, driven by shifting power flows	Significant changes in power flow patterns across the grid; increased two-way flows between HV and LV grids	Requirement for grid-wide reinforcement, and improved ability of the grid to recover from disturbances
Challenges depend mainly on	Local conditions in the grid	Match between demand and VRE output	Availability of flexible resources	Strength of system to withstand disturbances

Source：IEA, “System Integration of Renewables, an update on Best Practice (2018)”

POWER SECTOR LOW CARBONIZATION: CASE STUDY IN JAPAN

Japan's Electricity Supply by Energy Resources

- After the oil crises in the 1970s, Japan's energy policy targeted achieving a well balanced energy portfolio and it was about to realize it in 2010.
- But nuclear generation has suddenly ceased after Fukushima nuclear accident in 2011.3.11. Single accident affects all nuclear plants.



Source: Energy White Paper 2017

[2010FY ⇒ 2017FY]

Other Renewables
1.1⇒7.6%

Oil & Petro
7.5⇒8.5%

LNG
29.3⇒42.2%

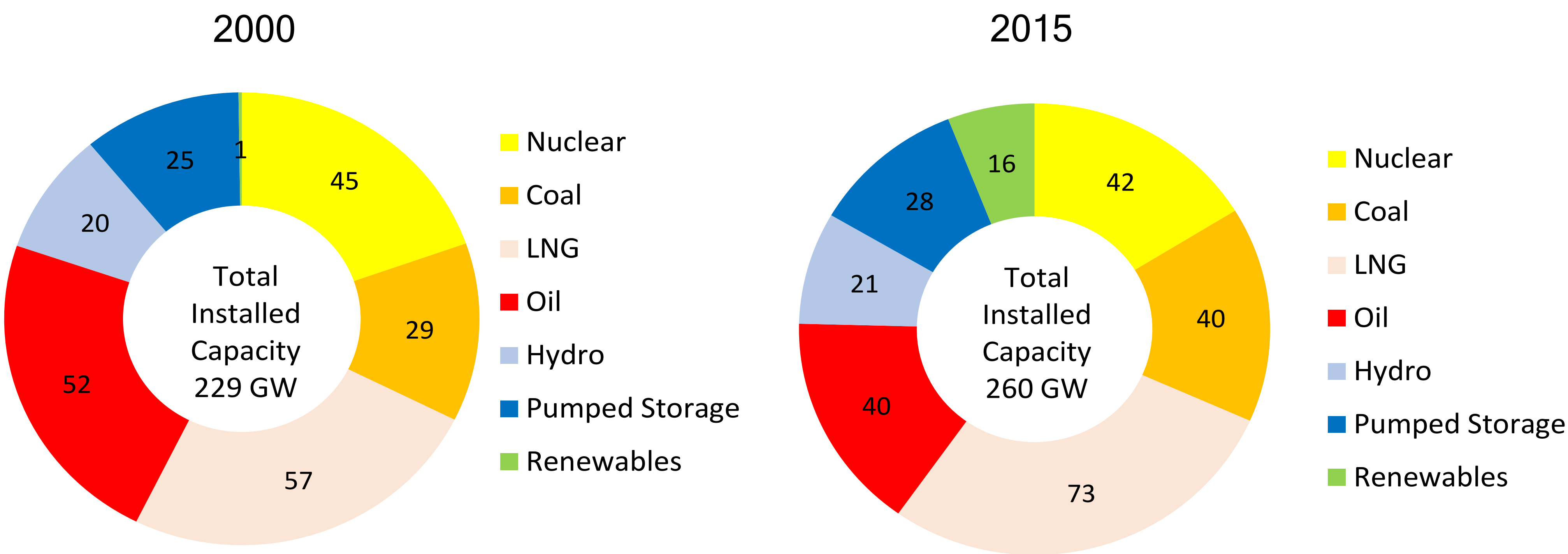
Hydro & Pumped Storage
8.5⇒9.3%

Coal
25.0⇒29.0%

Nuclear
28.6⇒3.4%

Japan's Power Generation Capacity Portfolio

- From 2000 to 2015, installed capacity of RE has remarkably increased, though most of solar PV and wind farms are owned by new entrants and not presented in the pie charts.
- Existence of 28GW pumped storage hydro (PSH) is a unique aspect of Japan's power generation capacity portfolio.



Power generation capacity by type in Japan (excluding new entrants)

Source: Energy White Paper 2018

Growth of Renewables

- RE promotion policy started with RPS in 2003 supplemented by Excess Electricity Purchasing Scheme in 2009. In 2012 they were replaced by Feed-in Tariff that triggered a surge of solar PV.

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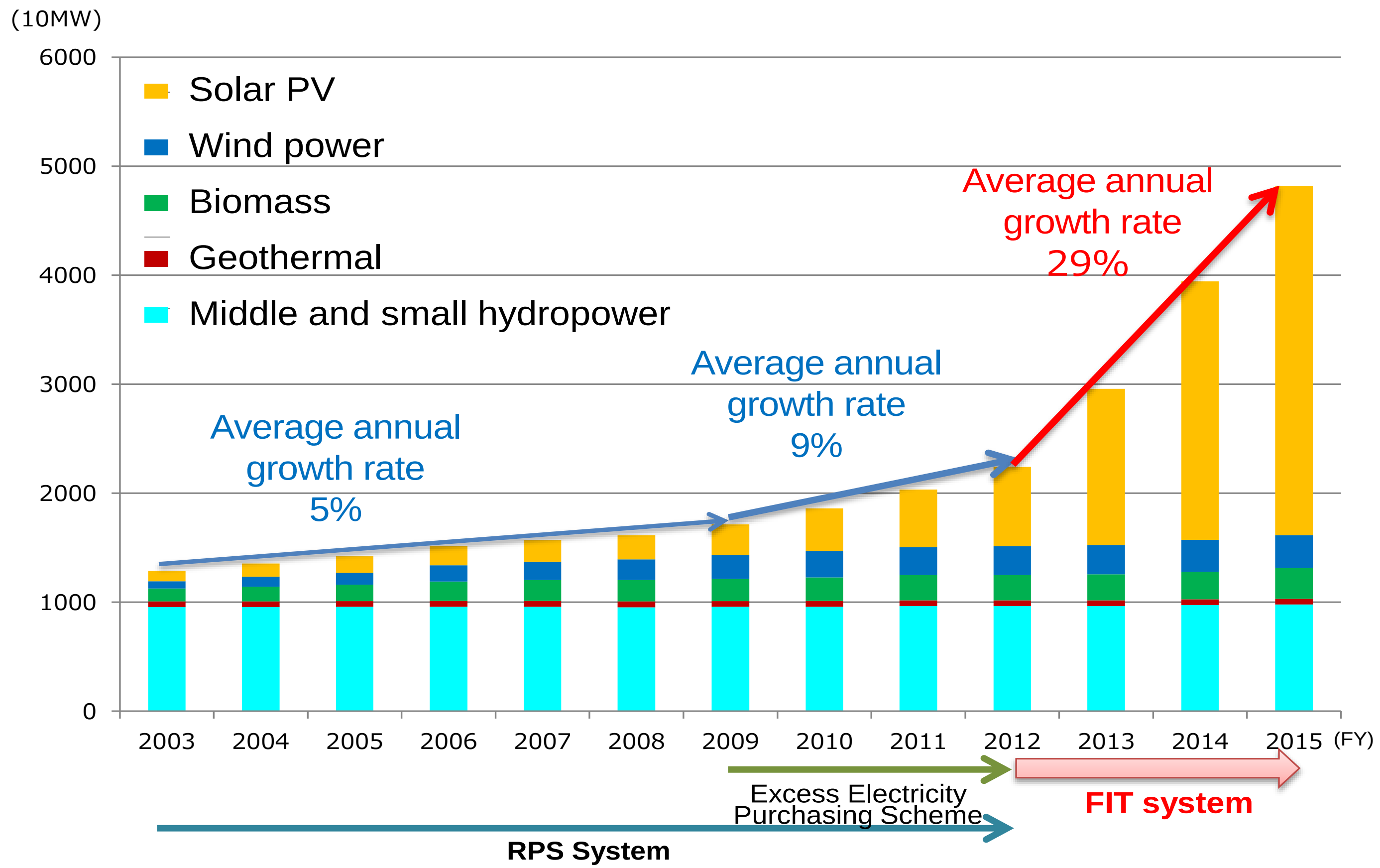
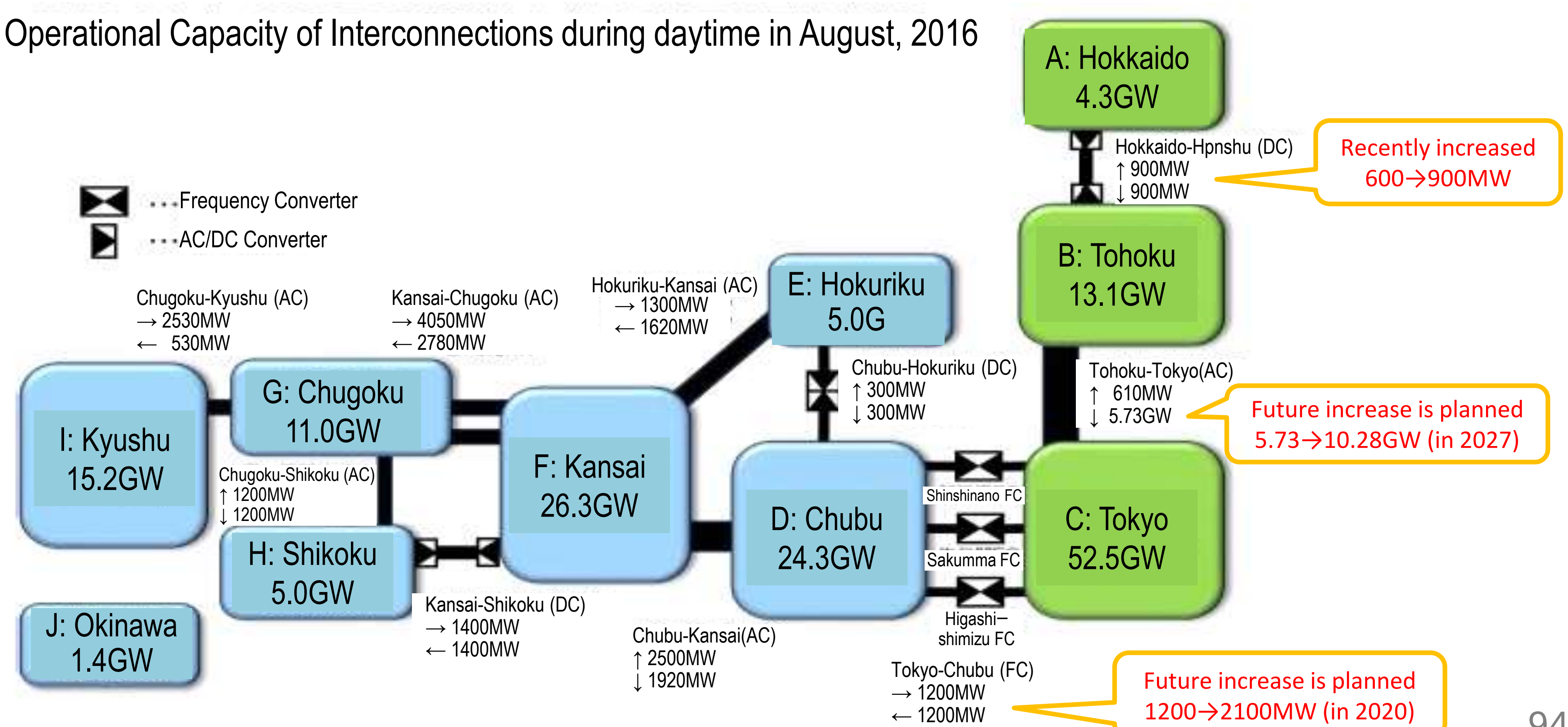


Change in power generation capacity of renewables in Japan

Source: presentation of Ministry of Economy, Trade and Industry

Power System in Japan

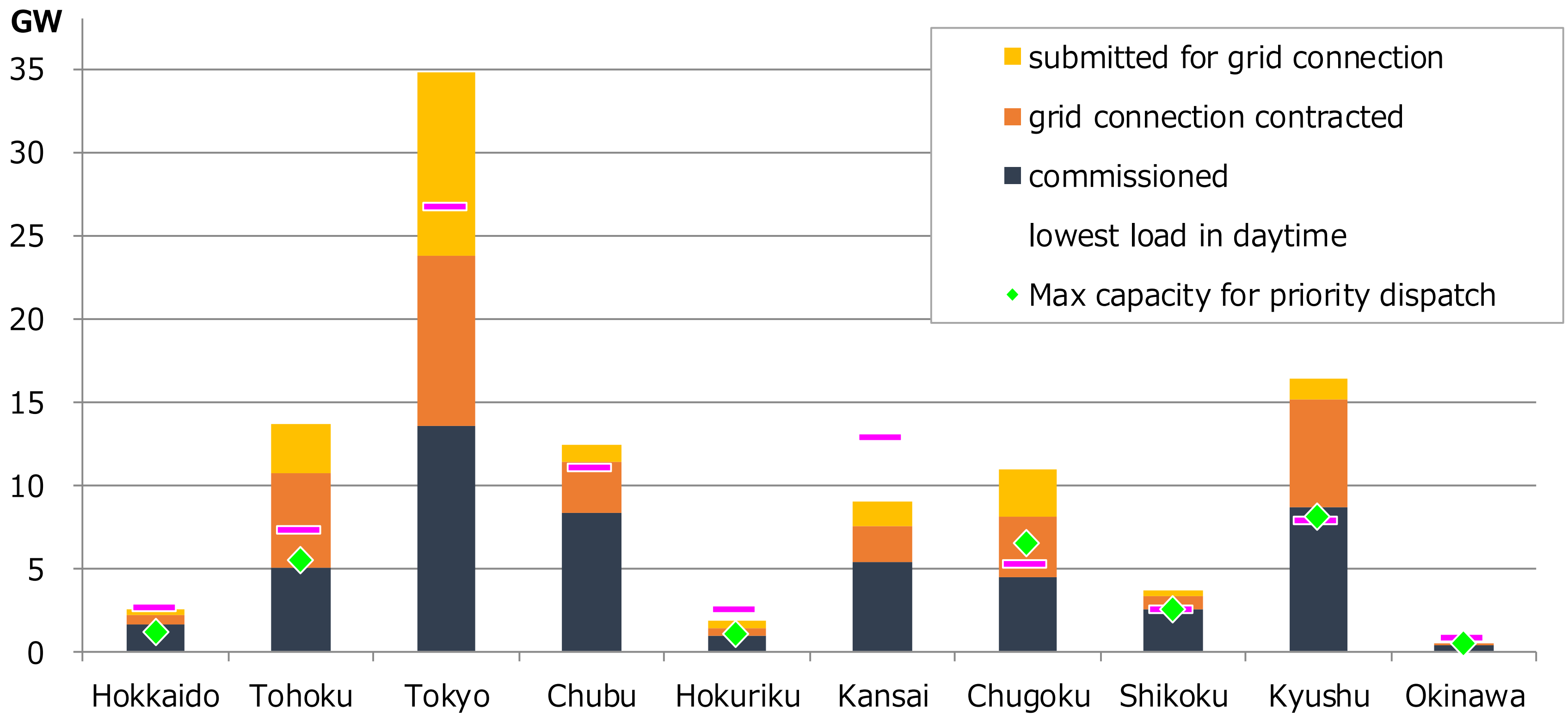
- Japan's power system consisting of 10 grids is divided between East (50Hz) and West (60Hz) in frequency.
- 9 grids going through four main islands are connected with interconnections and FCs like "fishbone", which is totally different from the meshed network in the US or Europe.
- Interconnections between grids vary in number, capacity and type(AC/DC).



Source: OCCTO

Solar PV penetration under FIT by grid

- In Kyushu, the commissioned solar PV is over the maximum capacity for grid connection.
- In Tohoku, the sum of commissioned and EIA completed is about to exceed the maximum capacity for grid connection.

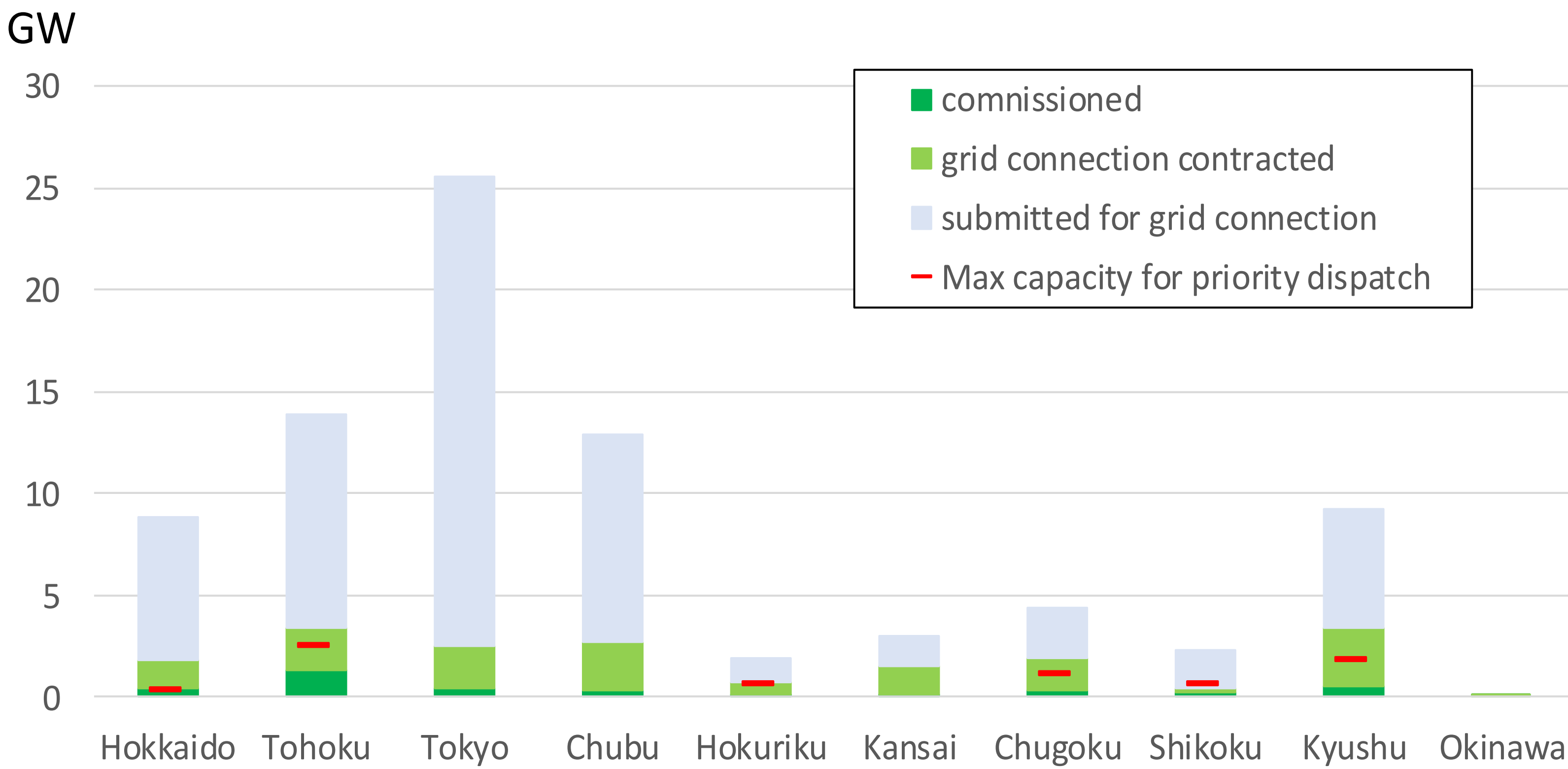


Capacity of solar PV certified under FIT by grid (as of June 2019)

Source: based on data on "Renewable energy information disclosure website" (METI)

Wind penetration under FIT by grid

- In Hokkaido, commissioned wind is over the maximum capacity for grid connection.
- In Tohoku, the sum of commissioned and EIA completed is about to exceed the maximum capacity for grid connection.



Capacity of wind farm certified under FIT by grid (as of June 2019)

Source: based on data on “Renewable energy information disclosure website” (METI)

Model Description

- The analysis used a production cost model customized for Japan's power system.
- Objective function: Minimizing generation cost (fuel cost plus start-up cost) of the total power system of interconnected 9 power grids and one isolated grid for 8760 hours.

$$\min\left(\sum_{ig=1}^{Ngrid}\sum_{i=idx_{ig}}^{idx_{ig}+NG_{ig}-1}(F(P_i))\right)=\min\left(\sum_{ig=1}^{Ngrid}\sum_{i=idx_{ig}}^{idx_{ig}+NG_{ig}-1}(b_i\cdot P_i+c_i\cdot U_i+startup\cdot ST_i)\right)$$

- As a nature of production cost simulation, it does not take fixed cost (capital cost nor depreciation) into account.
- Limiting conditions
  - Balance between demand and supply
  - Balance between variability and available flexibility (LFC* capacity)
  - Upper and lower limit of hourly output in each power generation unit
  - Capacity of interconnection for energy interchange

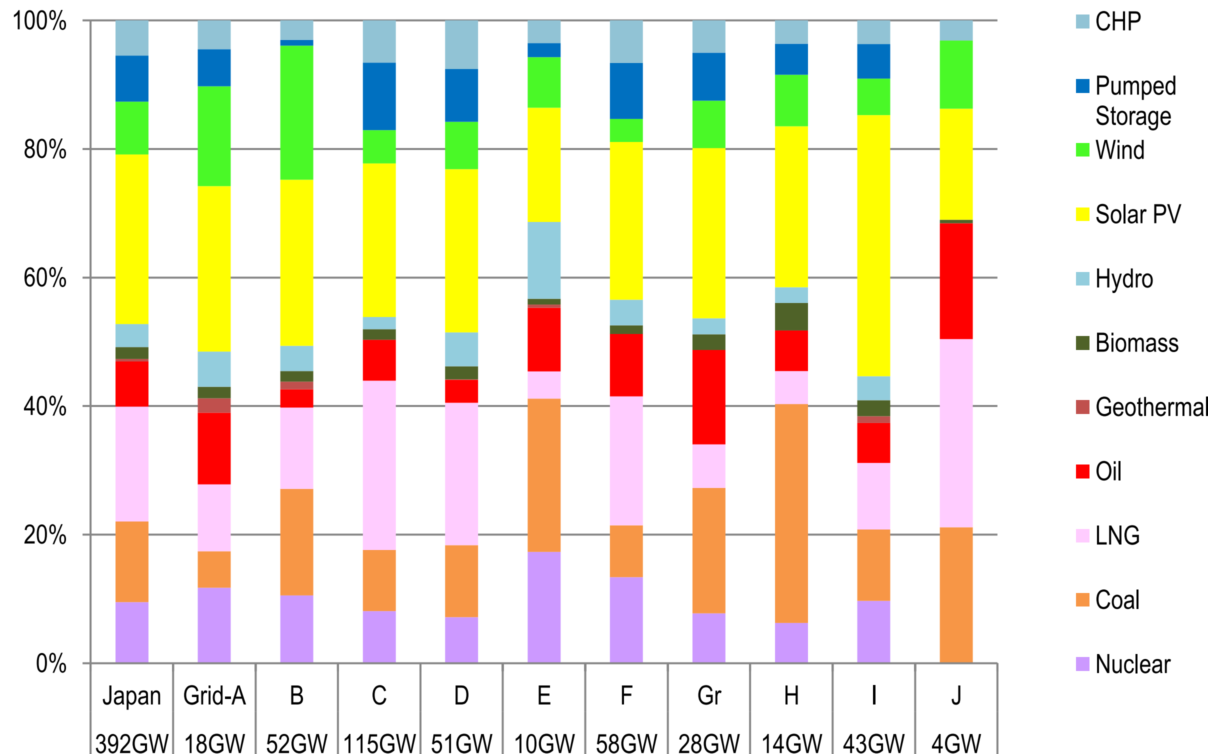
* LFC (Load Frequency Control) balancing capacity able to regulate variability in a few to 15 minutes .

Calculation Condition

- The total capacity of solar PV (103GW) and wind (32GW) in 2030 assumed to represent "massive VRE deployment "
- Solar PV and wind distribution by grid assumed to reflect the current unevenness
- Other type of power generation capacity in 2030 assumed in line with Long Term Energy Demand and Supply Outlook 2015

VRE capacity by grid

GRID	PV(GW)	Wind(GW)
A: Hokkaido	4.5	2.7
B: Tohoku	13.5	10.9
C: Tokyo	27.4	5.9
D: Chubu	12.9	3.7
E: Hokuriku	1.8	0.8
F: Kansai	14.2	2.1
G: Chugoku	7.5	2.1
H: Shikoku	3.6	1.1
I: Kyushu	17.3	2.4
J: Okinawa	0.6	0.4
Total	103.4	32.2



Power generation capacity by type by grid

Cases for Flexibility Evaluation

- The impact by availability of source of flexibility to VRE utilization and operation cost were analyzed.
  - Coal-fired power plants' LFC capacity
  - Pumped storage hydro
- Priority dispatch for VRE, a known measure to support VRE, was also analyzed for comparison

Analyzed case and available source of flexibility

Case	Available Source of Flexibility		
	Energy Transmission by Interconnections	LFC service from Coal-fired PP	Pumped Storage Hydro
Current situation in Japan	✔	*Not fully*	✔
Base Case (Base)	✔	✔	✔
without Interconnection (E0)	No	✔	✔
without Coal LFC (C0)	✔	No	✔
without PSH (P0)	✔	✔	No
without flexibilities above (F0)	No	No	No

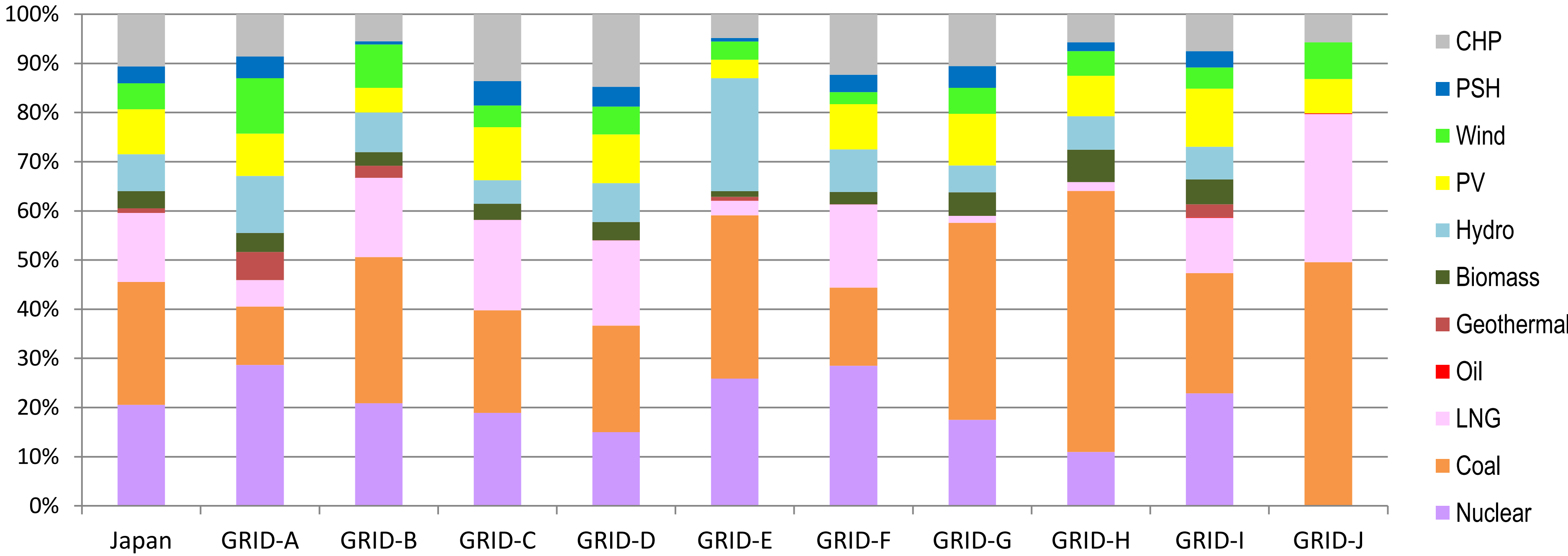
Result of Analysis: Power Generation Mix

- The power generation mix in Base Case by energy type shows;

  Nuclear: Coal: Gas: Oil: Renewables = 21%: 23%:27%:1%:28%

*Gas includes CHP, and Renewables includes PSH as in line with Long Term Energy Demand and Supply Outlook 2015

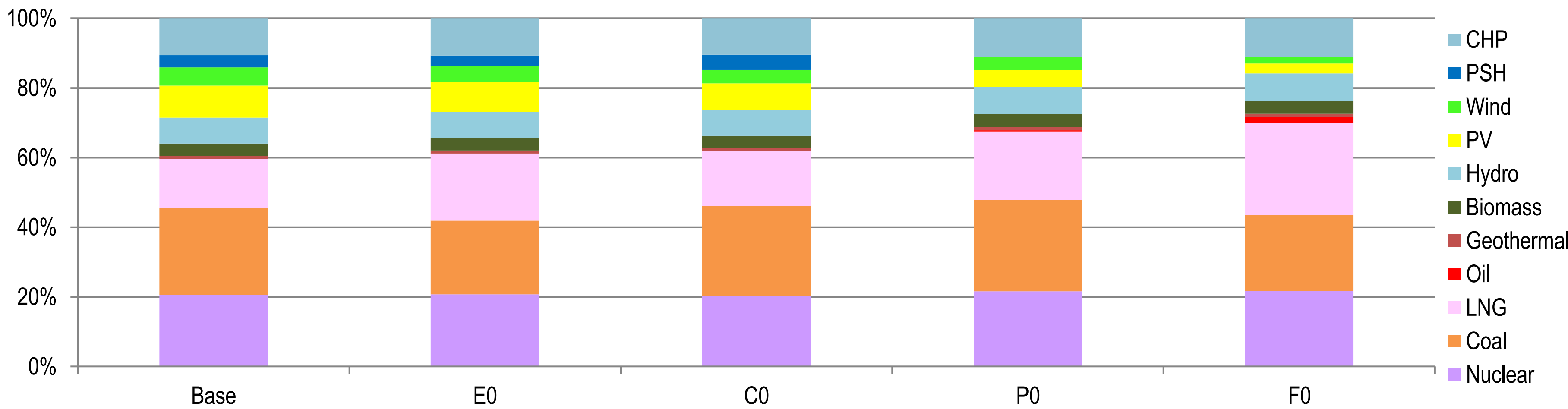
- The power generation mix varies by grid, mainly due to capacity portfolio in each grid but also due to conditions in neighboring grids.



Power generation mix in Japan total and by grid in Base Case

Result of Analysis: Power Generation Mix

- The power generation mix varies by case.
- When Coal LFC or PSH is not available, LNG power generation increase.
- When flexibility is not available, the share of VRE is reduced significantly from 14% in Base to 5%.

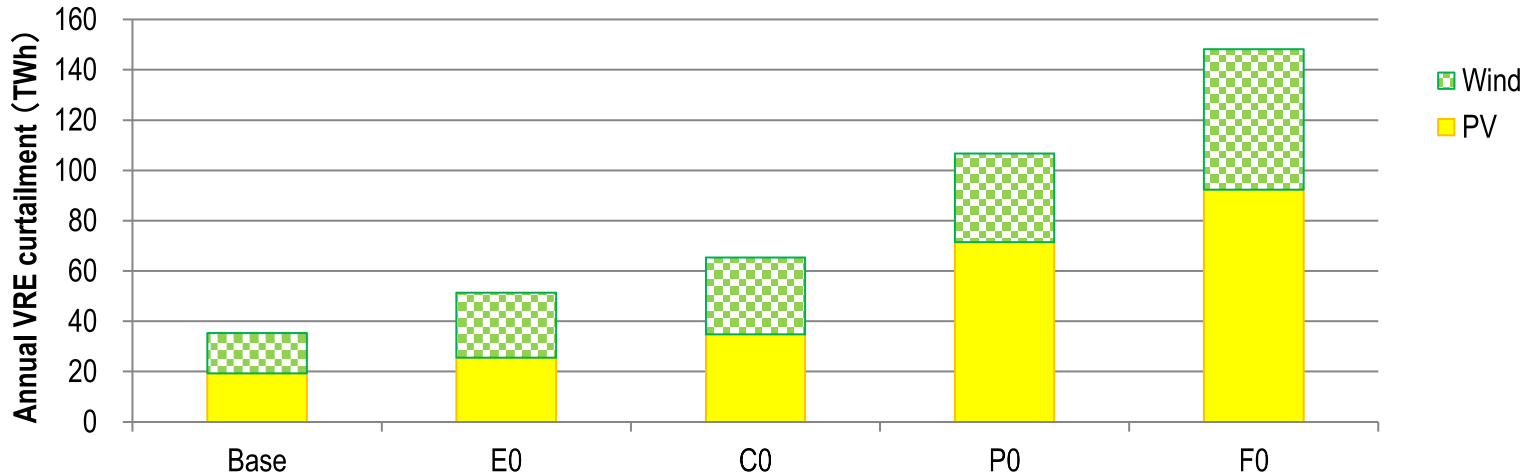


	Base	E0	C0	P0	F0
VRE	14%	13%	12%	9%	5%
Renewables	30%	28%	28%	21%	17%
Fossil	50%	51%	52%	57%	61%

Power generation mix and share of selected indicators by case and by grid

Result of Analysis: VRE Curtailment

- Each source of flexibility affects VRE curtailment, for both of Wind and Solar PV.
- The impact vary, interconnection < coal LFC < pumped storage hydro.
- Unavailability of PSH largely increases curtailment solar PV because PSH works to storage to accumulate PV's surplus power generation in daytime as well as providing flexibility.
- Unavailability of all sources of flexibility causes 75% curtailment of VRE power.

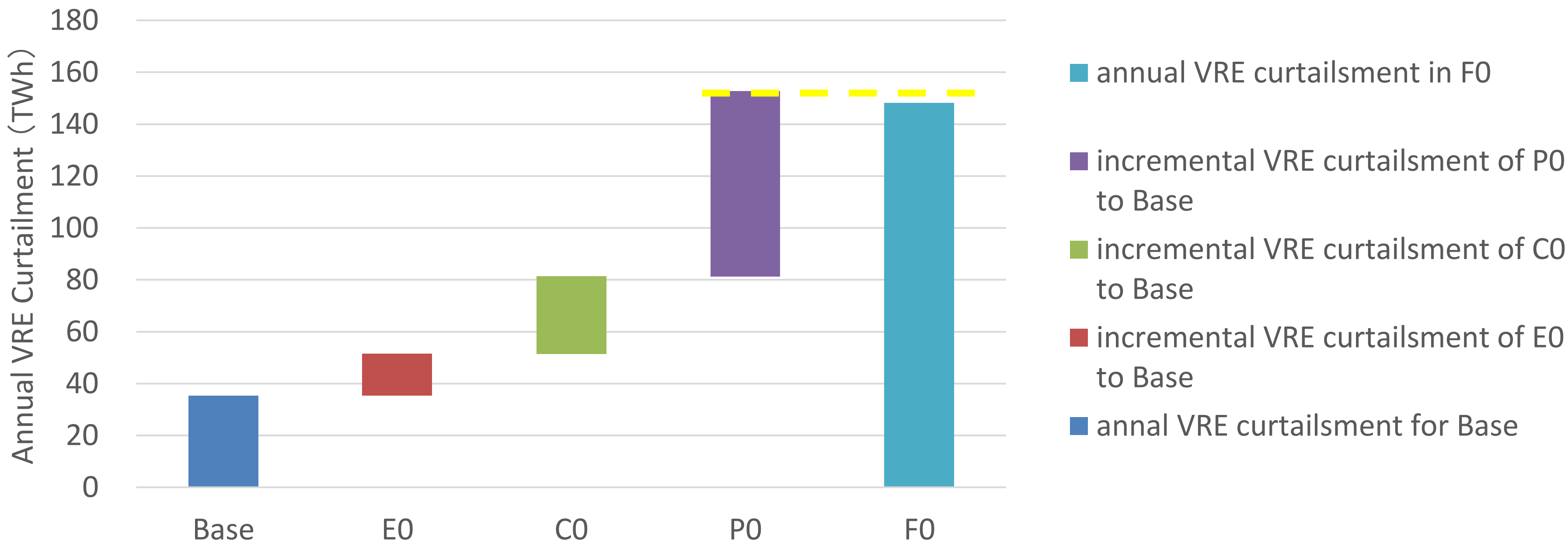


	Base	E0	C0	P0	F0
Curtailment ratio: Wind	21%	34%	41%	47%	74%
Curtailment ratio: Solar PV	16%	21%	28%	58%	75%

VRE curtailment (upper figure) and VRE share in total power generation (lower table) by case

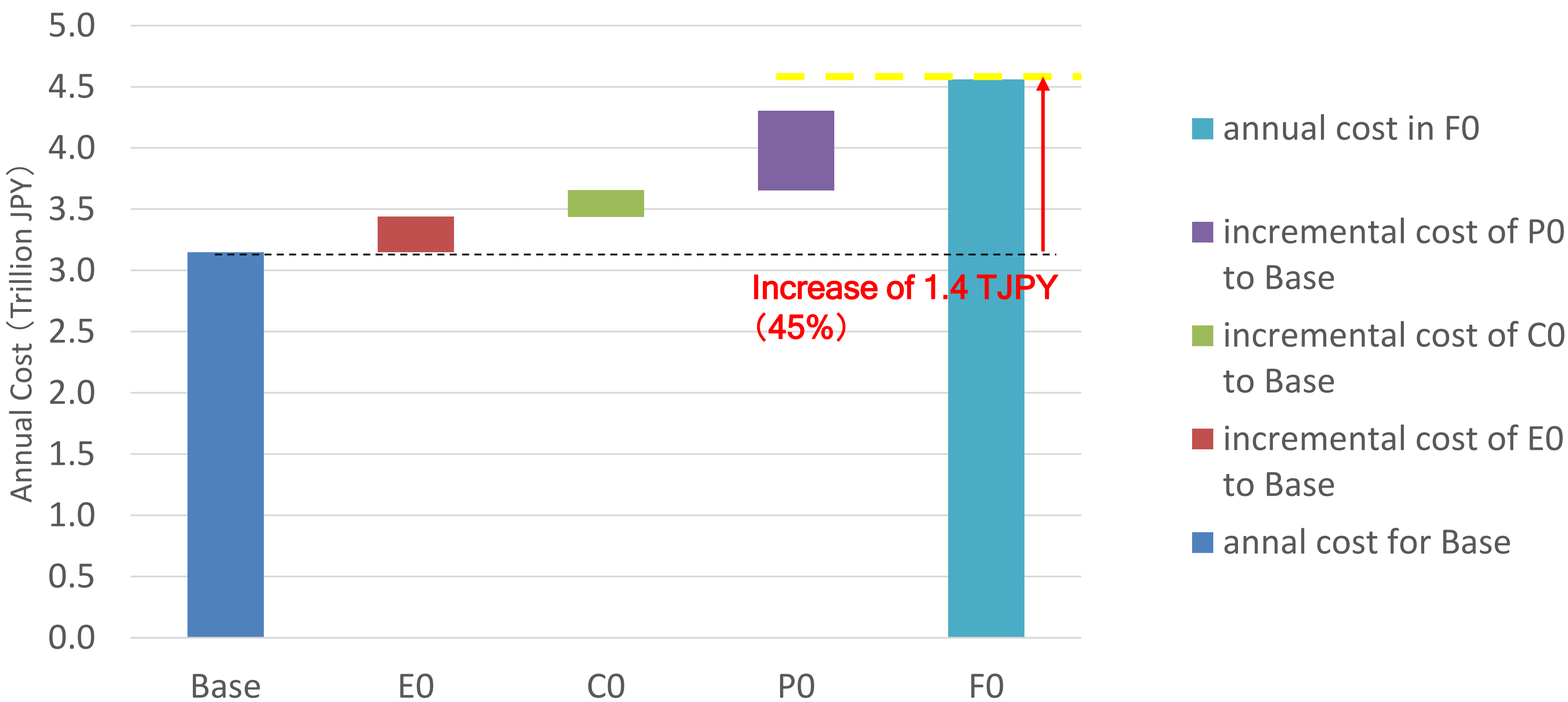
Flexibility and VRE curtailment

- The sum of VRE curtailment for base and total incremental VRE curtailment by each unavailable flexibility almost equals the VRE curtailment for F0, no-flexibility available case.
- It means the impact of each flexibility is independent, so no offset in the total impact.



Flexibility and cost

- The sum of annual cost for base and total incremental annual cost by each unavailable flexibility almost equals the annual cost for F0, no-flexibility available case.
- It means the impact of unavailability of multiple flexibility has negative synergetic affect.



Useful source of Information

- Energy
  - –IEA: Executive summary of WEO, many free publication
  - –DOE/EIA: “International Energy Outlook”, energy statistic and outlook for USA and the world.
  - –IEEJ (The Institute of Energy Economics, Japan 日本エネルギー経済研究所) “IEEJ Energy Outlook”, energy statistic and outlook for Asia and the world.
  - –Eurostat: economic (including energy) statistic in EU
- Climate Change
  - –UNFCCC (policy)
  - –IPCC (science)
  - –UNEP (gap report)

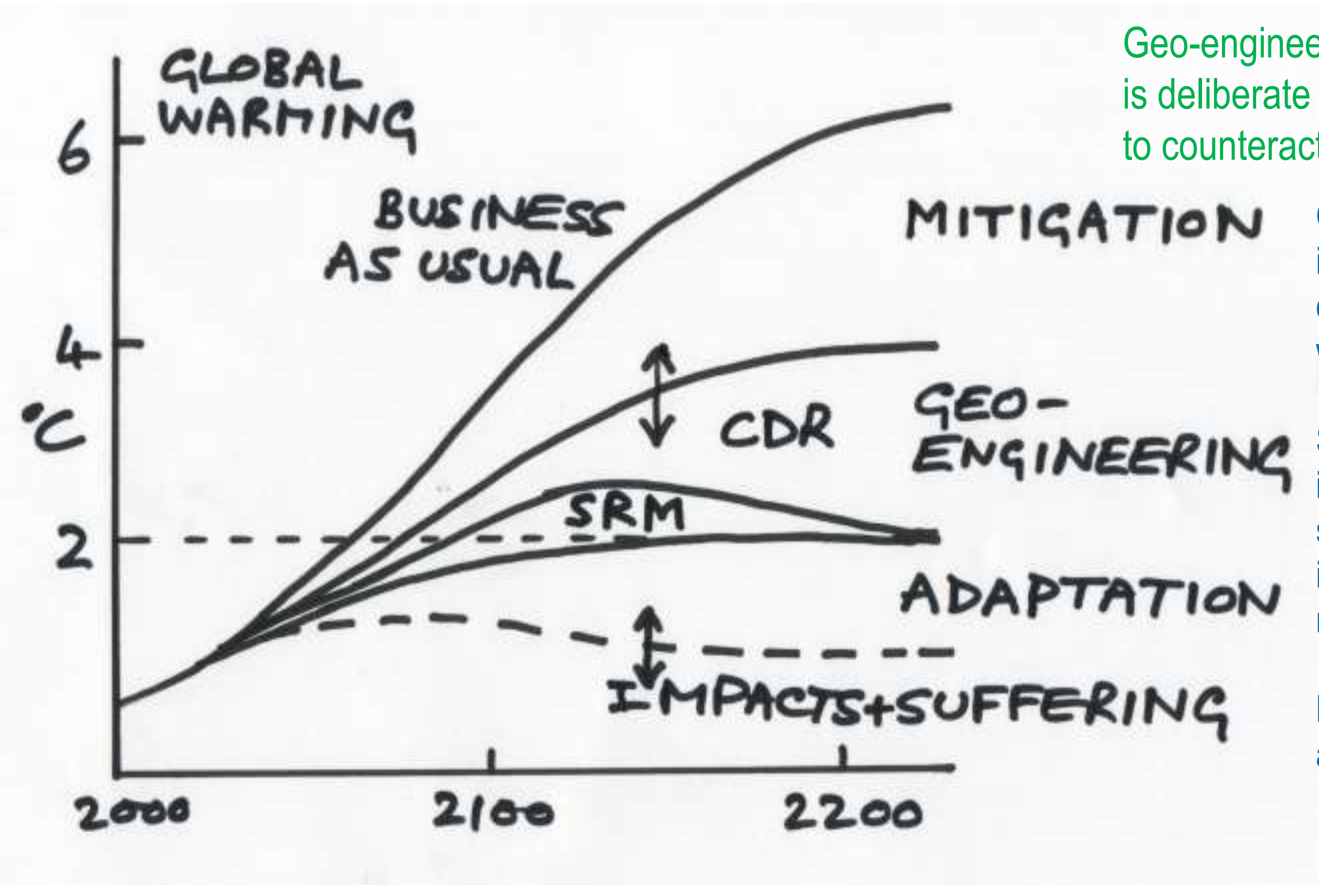
http://www.jpower.co.jp/english

… and some more

- Which country's reduction in energy related CO2 since 2000 is the largest in the world?
- What is the priority of climate change in 17 SDGs?

Napkin diagram of multiple responses to climate change

- Simple sketch of "how global mean temperature might evolve over the next two centuries, both with and without any active climate response, and phased implementation of both SRM and CDR. "
- and "how one might attempt to limit the rise of global mean temperature to some specific level using such a combination of responses. "



Geo-engineering (Climate Engineering) = CDR + SRM, is deliberate intervention in the Earth's climate system to counteract anthropogenic climate change.

CDR: Carbon Dioxide Removal
is to remove GHG from the atmosphere, including direct air capturing (DAC) and biomass energy with carbon capture and storage (BECCS)

SRM: Solar Radiation Management
is to reduce incoming solar radiation by reflecting sunlight back into space to cool the planet, including stratospheric aerosol injection (SAI) and marine cloud brightening.

BECCS is classified as both means of mitigation and geo-engineering.

Source :J. G. Shepherd, The "napkin diagram" of multiple responses to climate change