Syllabus_Energy Economics and Policy

Energy and Economy

Introduction to different forms of energy; Understanding energy-economy linkages; Accounting energy balance; Understanding energy intensity and efficiency; Tradeoffs between energy-environment, Role of globalization and urbanization on energy demand

Economics of Non-renewable Energy

Economics of coal, petroleum and natural gas; Pricing of exhaustible energies - theories and practical issues; Regulation of fossil fuels energy markets

Economics of Renewable Energy

Drivers and sources of renewable energy; Economics of renewable energy supply; Developing markets for renewable energies

Environmental Implications of Energy

Energy-economic growth-environment Interactions; Income inequality-energy-pollution linkages; Climate change and environmental Kuznets Curve; Pollution haven hypothesis; Analysis on energy mixclimate change-market failure; natural resources management, The Clean Development Mechanism

Current Energy Issues and Policies

Current energy market trend and challenges; Energy policies in selected countries; Energy governance in India; Policy and institutional arrangement for energy efficiency and management in developing countries; Promoting clean energy usage for sustainable development goals

Suggested Readings

1.Griffin, J. M., & Steele, H. B. (2013). Energy economics and policy. Elsevier.

2.Tietenberg, T. Environmental and Natural Resource Economics, seventh edition, Addison Wesley, 2006

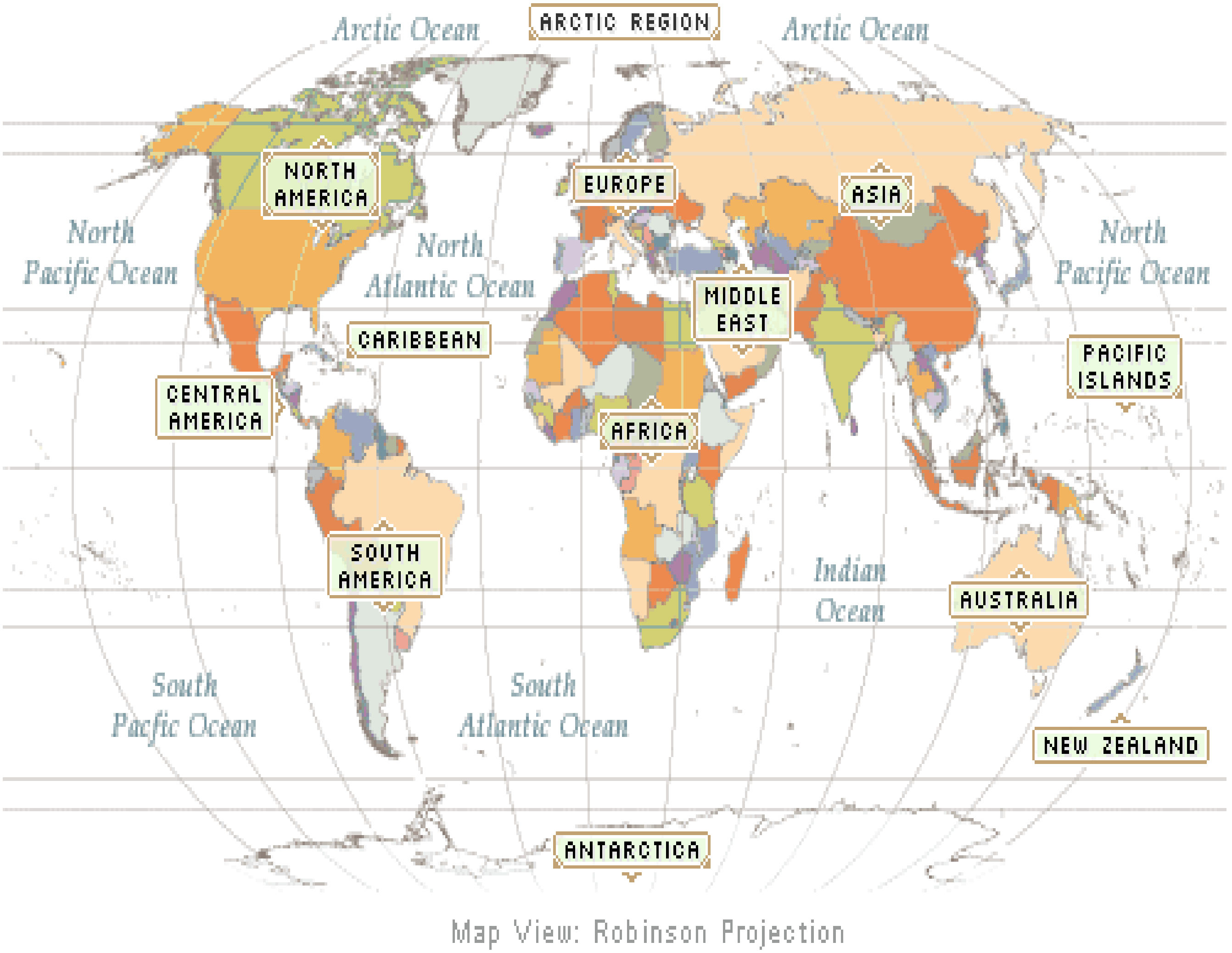
3.Munasinghe, M. and P. Meier, Energy Policy Analysis and Modelling. U.K.: Cambridge University Press, 1993

4. Ristinen, R. and J. Kraushaar, Energy and the Environment, John Wiley and Sons, 1998.

5. Wright, R.T., Environmental Science: Towards Sustainable Future, Pearson, Eleventh Edition, 2011

Country Maps: The Middle East

1. Bahrain
2. Cyprus
3. Egypt
4. Iran
5. Iraq
6. Israel
7. Jordan
8. Kuwait
9. Lebanon
10. Oman
11. Qatar
12. Saudi Arabia
13. Syria
14. Turkey
15. United Arab Emirates
16. Yemen



https://www.infoplease.com/atlas/middle-east

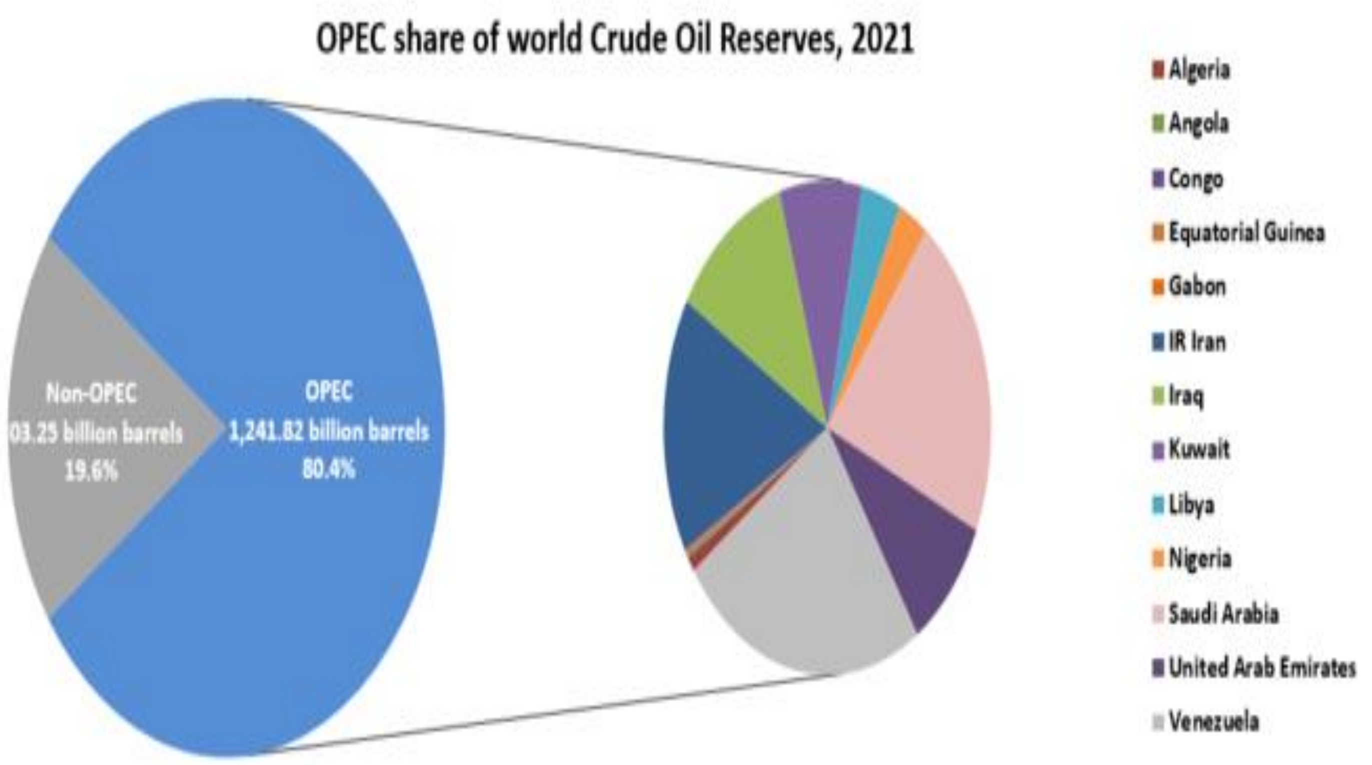
FIGURE 1.3 Map of the Middle East. Major oil pipelines are shown as broken lines. Major oil fields are indicated by small black spots of irregular shape.

Organization of the Petroleum Exporting Countries (OPEC, 1960, Iraq)

1. Iran (1960)
2. Iraq (1960)
3. Kuwait (1960)
4. Saudi (1960)
5. Arabia (1960)
6. Venezuela (1960)
7. Qatar (1961)
8. Indonesia (1962)
9. Libya (1962)
10. the United Arab Emirates (1967)
11. Algeria (1969), Nigeria (1971)
12. Ecuador (1973)
13. Gabon (1975)
14. Angola (2007)
15. Equatorial Guinea (2017)
16. Congo (2018)

- “any country with a substantial net export of crude petroleum, which has fundamentally similar interests to those of Member Countries, may become a Full Member of the Organization”
- Currently, the Organization has a total of 13 Member Countries

https://www.opec.org/opec_web/en/about_us/25.htm



OPEC proven crude oil reserves , at end 2021 (billion barrels, OPEC share)

Venezuela	303.47	24.4%	United Arab Emirates	111.00	8.9%	Algeria	12.20	1.0%	Equatorial Guinea	1.10	0.1%
Saudi Arabia	267.19	21.5%	Kuwait	101.50	8.2%	Angola	2.52	0.2%			
IR Iran	208.60	16.8%	Libya	48.36	3.9%	Gabon	2.00	0.2%			
Iraq	145.02	11.7%	Nigeria	37.05	3.0%	Congo	1.81	0.1%			

https://www.opec.org/opec_web/en/data_graphs/330.htm

Percentage of World Crude Oil Production by Country, 1850-1984

	United States	Russia	Indonesia	Mexico	Venezuela	Middle East	Africa	Other
1860	98							2
1865	92	2						6
1870	91	3						6
1875	91	5						4
1880	88	10						2
1885	60	34						6
1890	60	37						3
1895	51	44	1					4
1900	43	52	2					3
1905	63	25	4					8
1910	64	27	4	1				4
1915	65	14	3	8				10
1920	64	4	3	23				6
1925	71	5	2	12	2	3		5
1930	64	8	2	3	10	3		10
1935	60	9	2	2	9	4		14
1940	63	10	3	2	10	4		8
1945	66	6	1	2	12	7		6
1950	52	7	1	2	15	15		8
1955	45	9	2	2	14	19		9
1960	35	14	2	1	14	23	1	10
1965	27	16	2	1	12	25	6	11
1970	22	17	2	1	8	30	13	7
1975	16	18	2	1	4	36	16	7
1980	14	20	3	3	4	30	16	10
1984	16	22	3	5	3	20	6	25

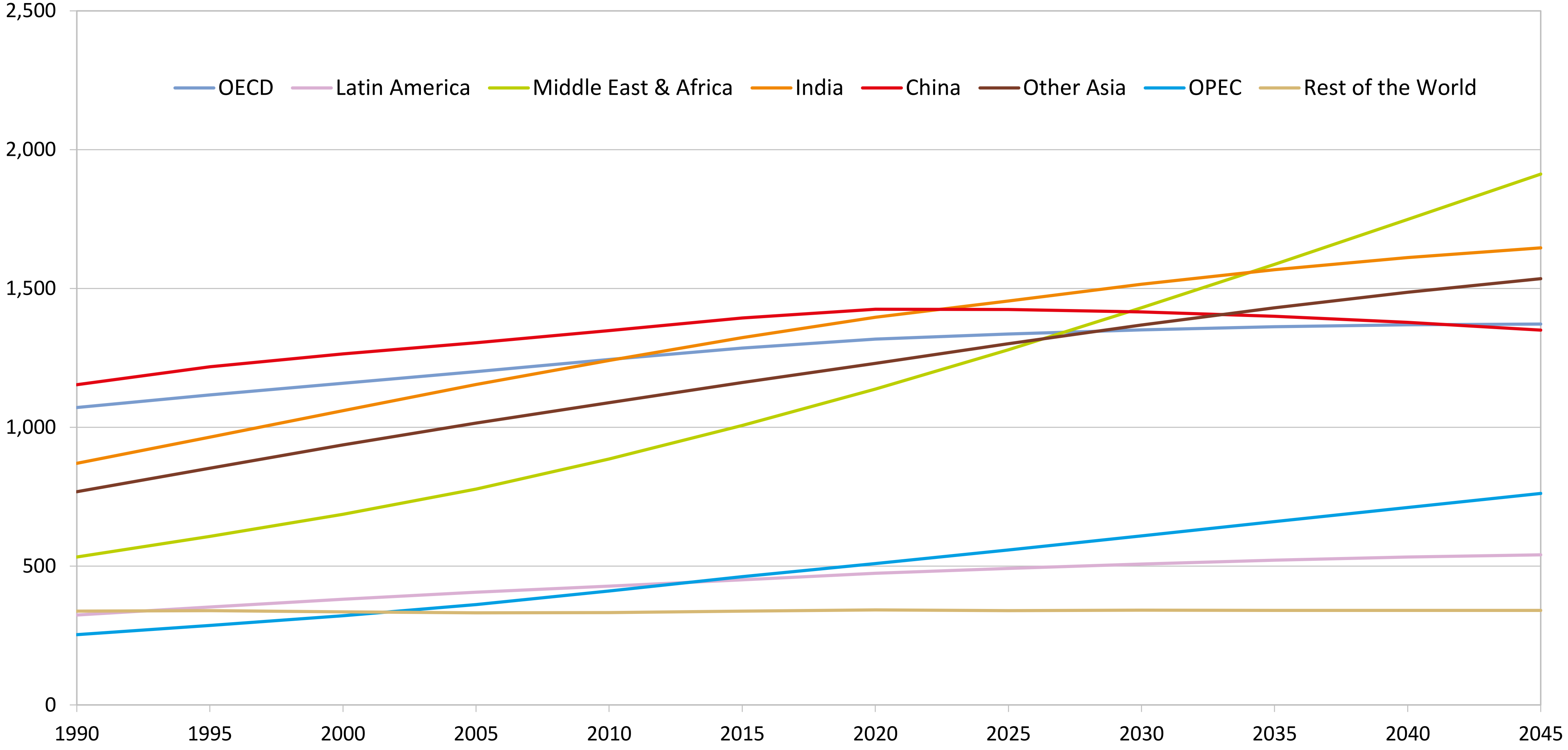
SOURCES: 1860–1920: U.S. Bureau of Mines; 1925–1965: Energy in the World Economy*; 1970–1984: Monthly Energy Review.*

Percentage of Government Owned Oil Production for Selected Years in OPEC Countries

Country	1970	1972	1974	1976	1978	1980
Saudi Arabia	.9	.7	58.5	58.7	58.7	97.7
Iran	4.5	5.0	96.2	96.2	94.6	100
Kuwait	1.2	1.2	55.1	90.6	94.1	90.6
Iraq	0	53.8	77.2	100	100	100
Libya	0	3.6	60.7	64.2	65.7	67.5
U.A.E.	0	0	49.5	62.1	64.4	64.4
Venezuela	1.2	1.9	2.5	100	100	100
Qatar	0	0	60.0	78.5	99.4	100
Nigeria	0	0	54.9	55.1	54.9	71.1
Indonesia	11.7	16.2	30.5	36.6	44.6	45.7
Algeria	14.6	76.9	88.2	90.5	89.1	93.7
Ecuador	—	1.3	25.4	25.5	62.9	62.7
Gabon	0	0	0	0	0	0

SOURCE: OPEC Annual Statistical Yearbook.

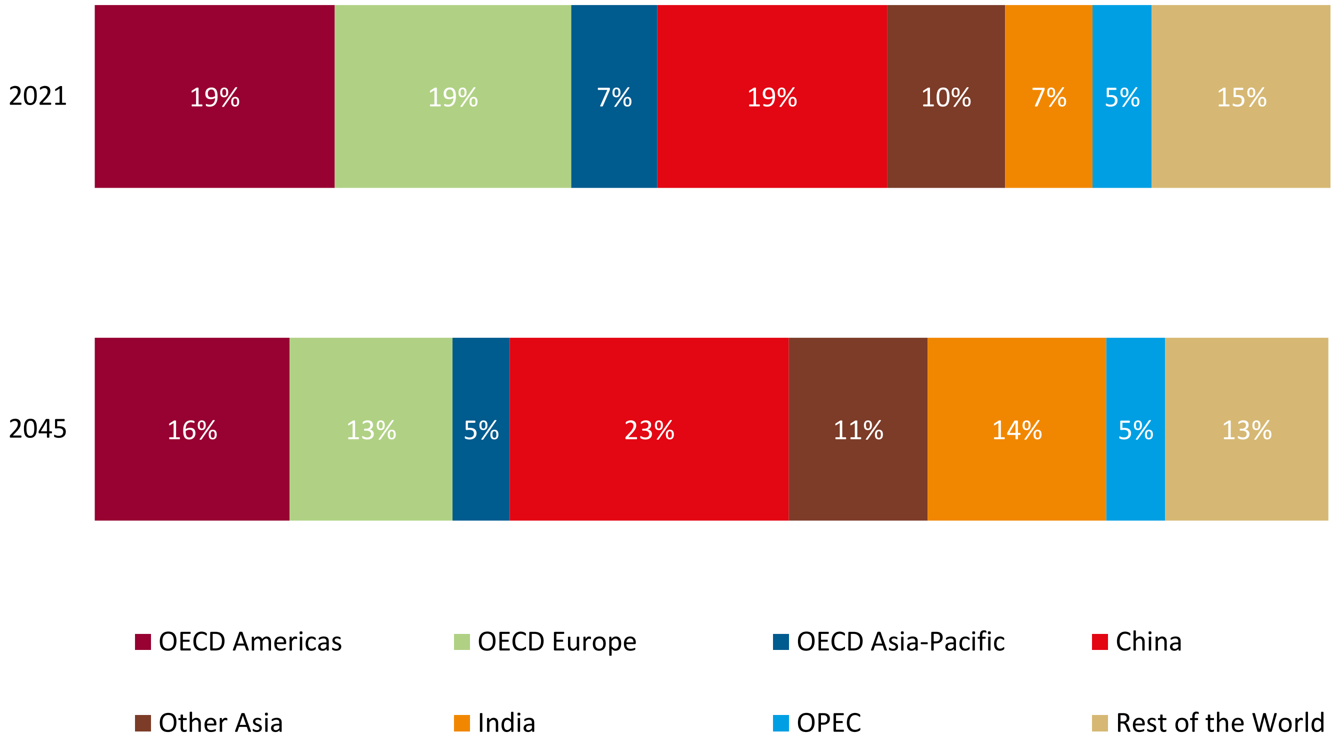
World population trends, 1990-2045 (Millions)



Source: UN, OPEC

Distribution of the global economy, 2021 and 2045 (%)

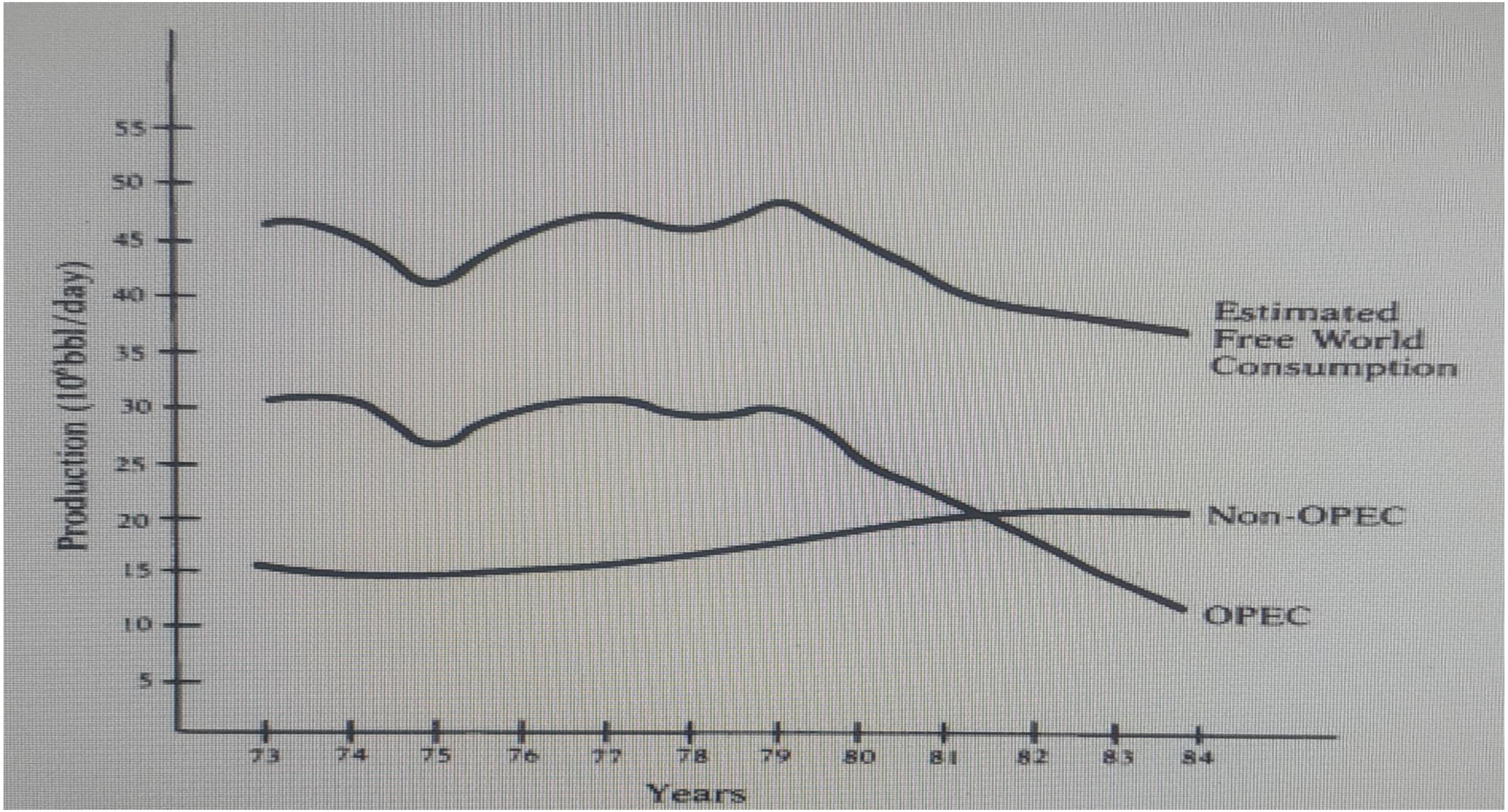
	2045	2021
OECD Americas	15.81%	19.45%
OECD Europe	13.21%	19.18%
OECD Asia-Pacific	4.62%	6.96%
China	22.63%	18.63%
Other Asia	11.25%	9.58%
India	14.47%	7.10%
OPEC	4.78%	4.78%
Rest of the World	13.23%	14.60%



Implications for OPEC

- Urbanised Asia is the key to growth of OPEC region.
- Growth performance in OPEC appears to be stagnant.
- It is a concern for OPEC if no growth in long-run.
- Resources depletion or low oil generation could be a reason for no growth.
- The countries in OPEC region may think of oil diversification for society welfare.
- Massive renewable energy investment is required on the ground of environmental quality and domestic consumption.

CHANGING PUBLIC PERCEPTIONS OF THE "ENERGY PROBLEM"



Real U.S. and World Crude Oil Prices, 1955-1982 [PRE-AND POST-OPEC]

- Rising energy price started in 1973
- We still live in a world of high-priced oil
- It is due to higher demand for oil
- Oil supply disruption in OPEC region
- Price escalations due to labour problems in oil fields interrupted production

Year	Real U.S. Price ($/bbl)	Real World Price ($/bbl, hereafter barrel)
1955	2.97	1.75
1965	2.70	1.43
1970	2.50	1.21
1971	2.37	.94
1972	2.34	1.14
1973	**2.26**	**1.23**
1974	**2.53**	**1.89**
1975	**3.85**	**6.15**
1976	**4.10**	**5.73**
1977	**4.05**	**6.02**
1978	**4.06**	**6.27**
1979	**3.96**	**5.85**
1980	**5.00**	**7.98**
1981	**7.52**	**11.22**
1982	**10.02**	**11.07**

Source: Griffin, J.M. & Steele, H. B. (1986). Energy Economics and Policy. Page no. 16

“Energy problem” becomes a history

- Increasing oil consumption is stable.
- Gap between oil demand and supply is higher.
- Energy problem occurs with supply uncertainty.
- OPEC monopoly action of reducing oil supply drives such gap, resulting for oil price rise.
- Poor economies can not create pressure on OPEC in reducing oil price.
- Because poor economies are beneficiary of remittances, commodity export and oil import.
- Cartel formation among poor economies may not be effective due to their insignificant share of import.

Way out for ‘‘energy problem’’

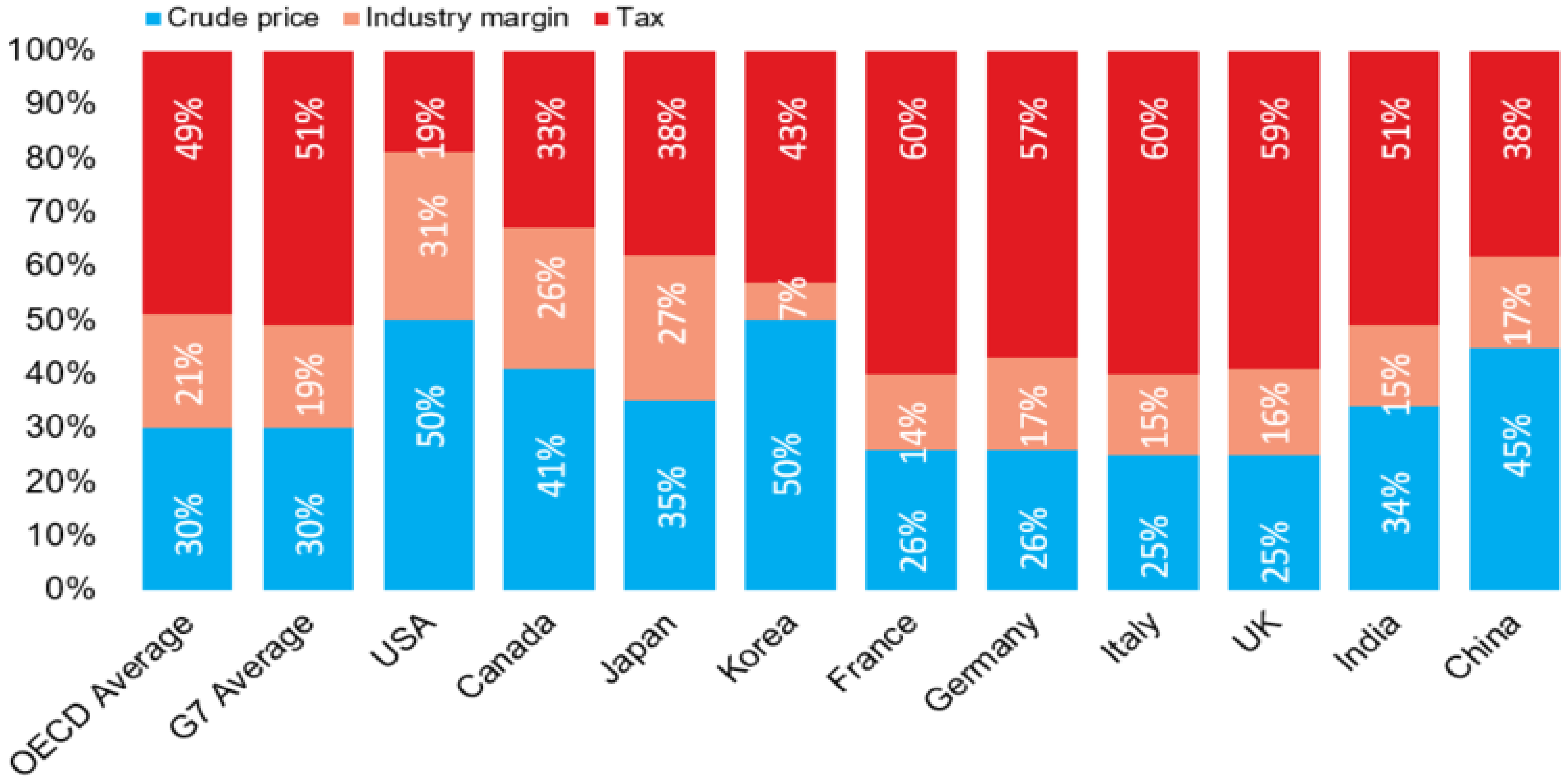
- Monopoly action of OPEC region is checked with oil supply reduction.
- Accept the energy issue with public opinion.
- So public opinion matters a lot.
- Reduce oil dependency.
- Energy diversification may be an option for solving energy problem.
- Easy option for advanced economies due to wealth reserve.
- Poor economies may think of energy efficiency.

Total World Crude Oil Reserves by Region in 1975 and 1984, in Billions of Barrels of Proved Reserves

OPEC areas:		
Saudi Arabia	152	169
Other Middle East	208	201
Other OPEC	90	81
Total OPEC	450	451
North America	40	82
Western Europe	25	23
Rest of Noncommunist World	40	29
Total Non-OPEC	105	134
Total, All Noncommunist Areas	555	585
Communist Areas	103	85
Total World	658	670

SOURCE: *Oil and Gas Journal, Year-end Summary Issues, 1975 and 1984.*

Who gets what from a litre of oil in 2021



https://www.opec.org/opec_web/en/data_graphs/333.htm

WHY ENERGY ECONOMICS AND POLICY?

- **THE DIMENSIONS OF THE ENERGY PROBLEM**

- Arab Oil Embargo between 1973-1983 [Currently 13 member countries]
- OPEC Monopoly
- Oil prices hike in 1973: energy crisis
- Inflation & unemployment in Non-OPEC countries
- Environmental threat in Non-OPEC countries

The Role of Energy in Economic Development

❑ Role of Energy

- Energy is an input in economic activities.
- Energy consumption matters for households, firms and governments.
- Energy is the driver of economic growth (*energy-led economic growth hypothesis, Apergis and Tang, 2013*).

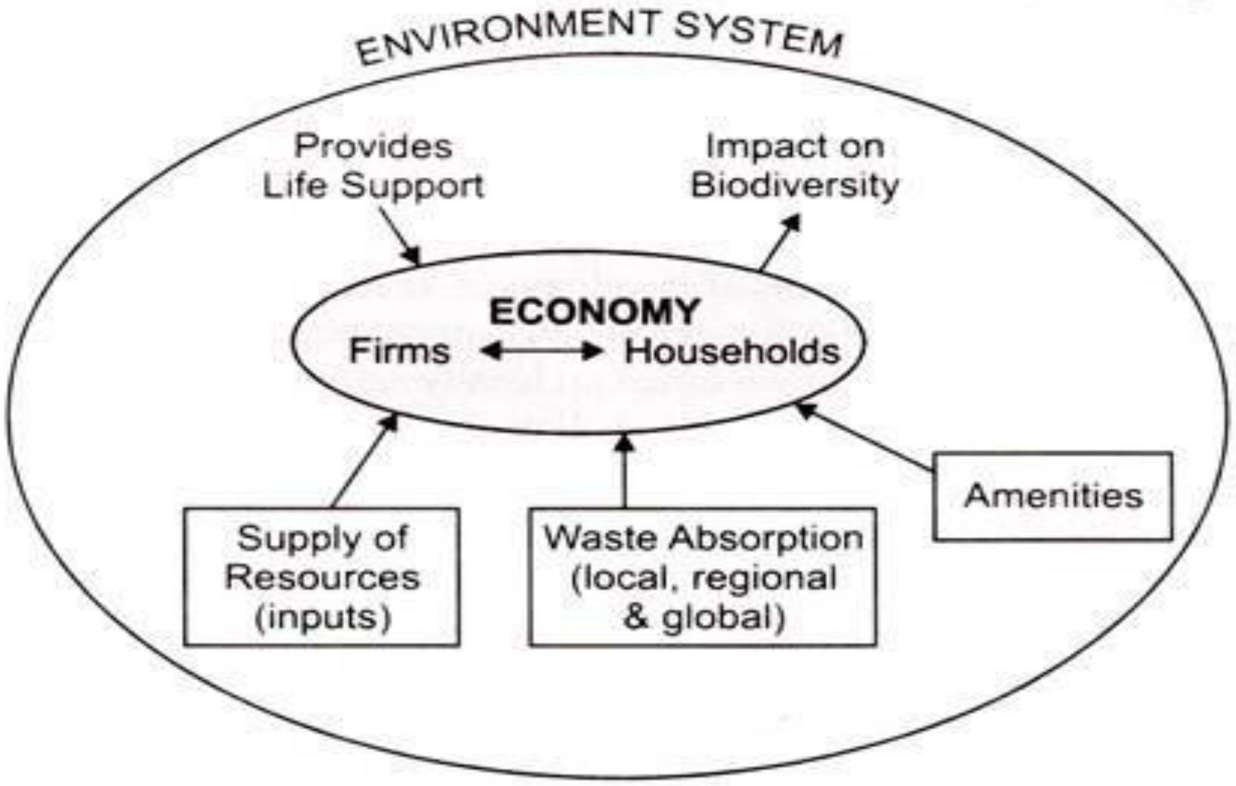


Fig. 56.1. *Economy–environment linkages or relations*

https://adamasuniversity.ac.in/man-economy-and-nature-why-study-environmental-economics/

Causality Results (Apergis and Tang, 2013; Energy Economics Journal)

- Validity of energy-led growth hypothesis for 85 countries (developed, developing and less developing)
- Though results are mixed among countries, but we do find a systematic pattern.
- Energy-led growth hypothesis remains valid at least in the 46 out of 85 selected countries.
- Both developed and developing countries are more likely to support the energy-led growth hypothesis compared to the less developed economies.
- Energy conservation policies should only focus on low income countries as these policies may not retard the process of economic growth

Causality Results

No	Countries	Income group	Energy consumption Granger-causes economic growth		
			Bivariate model	Trivariate model	Multivariate model
1.	Algeria	Upper middle			✓
2.	Argentina	Upper middle	✓	✓	✓
3.	Australia	High	✓	✓	✓
4.	Austria	High	✓	✓	✓
5.	Bangladesh	Low			✓
6.	Belgium	High	✓	✓	✓
7.	Benin	Low			✓
8.	Bolivia	Lower middle		✓	✓
9.	Brazil	Upper middle	✓	✓	✓
10.	Brunei	High			✓
11.	Cameroon	Lower middle			✓
12.	Canada	High	✓	✓	✓
13.	Chile	Upper middle	✓	✓	✓
14.	China	Lower middle			✓
15.	Colombia	Upper middle	✓	✓	✓
16.	Congo dem. Rep	Low			✓
17.	Congo Rep.	Lower middle	✓	✓	✓
18.	Costa Rica	Upper middle			✓
19.	Cote d'Ivoire	Lower middle			✓
20.	Cuba	Upper middle	✓	✓	✓
21	Cyprus	High			✓
22	Denmark	High	✓	✓	✓
23	Dominican Republic	Upper middle	✓		✓
24	Ecuador	Lower middle	✓	✓	✓
25	Egypt	Lower middle			✓
26	El Salvador	Lower middle	✓	✓	
27	Finland	High	✓	✓	✓
28	France	High		✓	✓
29	Gabon	Upper middle		✓	
30	Germany	High			
31	Ghana	Low		✓	✓
32	Greece	High	✓	✓	✓
33	Guatemala	Lower middle		✓	✓
34	Honduras	Lower middle			✓
35	Hong kong	High	✓	✓	✓
36	Hungary	High			
37	Iceland	High	✓		✓
38	India	Lower middle	✓	✓	✓
39	Indonesia	Lower middle	✓	✓	✓
40	Iran	Upper middle	✓	✓	✓
41	Ireland	High	✓		✓
42	Israel	High		✓	✓
43	Italy	High	✓	✓	✓
44	Jamaica	Upper middle			✓
45	Japan	High	✓	✓	✓
46	Jordan	Lower middle	✓		✓
47	Kenya	Low	✓	✓	✓
48	Korea	High	✓	✓	✓
49	Luxembourg	High			✓
50	Malaysia	Upper middle	✓	✓	✓
51	Malta	High			✓
52	Mexico	Upper middle	✓	✓	✓
53	Morocco	Lower middle			
54	Nepal	Low			✓
55	Netherland	High		✓	✓
56	New Zealand	High			
57	Nigeria	Lower middle			✓
58	Norway	High	✓	✓	✓
59	Oman	High	✓	✓	✓
60	Pakistan	Lower middle	✓	✓	✓
61	Panama	Upper middle		✓	
62	Paraguay	Lower middle	✓	✓	✓
63	Peru	Upper middle	✓	✓	✓
64	Philippines	Lower middle	✓	✓	✓
65	Portugal	High	✓		✓
66	Saudi Arabia	High	✓	✓	✓
67	Senegal	Lower middle		✓	
68	Spain	High	✓	✓	✓
69	Sri Lanka	Lower middle			
70	Sudan	Lower middle			✓
71	Sweden	High		✓	✓
72	Switzerland	High		✓	
73	Syrian Arab Rep	Lower middle		✓	✓
74	Thailand	Lower middle	✓	✓	✓
75	Togo	Low			
76	Trinidad and Tobago	High			
77	Tunisia	Lower middle	✓	✓	✓
78	Turkey	Upper middle	✓	✓	✓
79	UAE	High	✓	✓	✓
80	UK	High	✓	✓	✓
81	USA	High	✓	✓	✓
82	Uruguay	Upper middle	✓	✓	✓
83	Venezuela	Upper middle	✓	✓	✓
84	Zambia	Low			✓
85	Zimbabwe	Low			

❑ The services that environment provides

- Flow resources
- Stock resources

✓ Flow resources: no link between current use and future availability

- Solar radiation-if a roof has a solar water heater on it, amount of water heating today

- Same water heating can be done tomorrow

- Renewable resources-biotic, plant & animal populations

- Capacity to grow over time via biological reproduction

✓ <u>Stock resources</u>: current use does affect future availability

- stocks of minerals-coal, oil [non-renewable-abiotic]
- Don’t have capacity to grow over time
- No positive constant rate of use
- Exhaustible or depletable resources
- Resources are exhaustible if harvested too long exceeding their generation capacities
- If harvest exceeds natural growth, unsustainable resources or declining stock size
- No natural reproduction except geological timescales

Renewable & exhaustible resources

- ❑ How they are managed?
- ❑ How they should be managed?

❖ Renewable resource:

- It regenerates itself
- Examples-fish and trees
- Fishery-catch a number of fish and leave the rest to grow naturally
- Fish stock does not die with reproduction

❖ Exhaustible resource [Gray, 1914; Hotelling, 1931]:

- It is fixed in overall quantity
- Usage in a given time is less available for other time
- Does not have regenerating capability
- Examples-coal and oil [fossil fuels] & minerals

❖ Management Issue:

- Fish & trees are exhaustible if not managed in a sustainable way.

Advantages of Renewable and Non-Renewable Energies

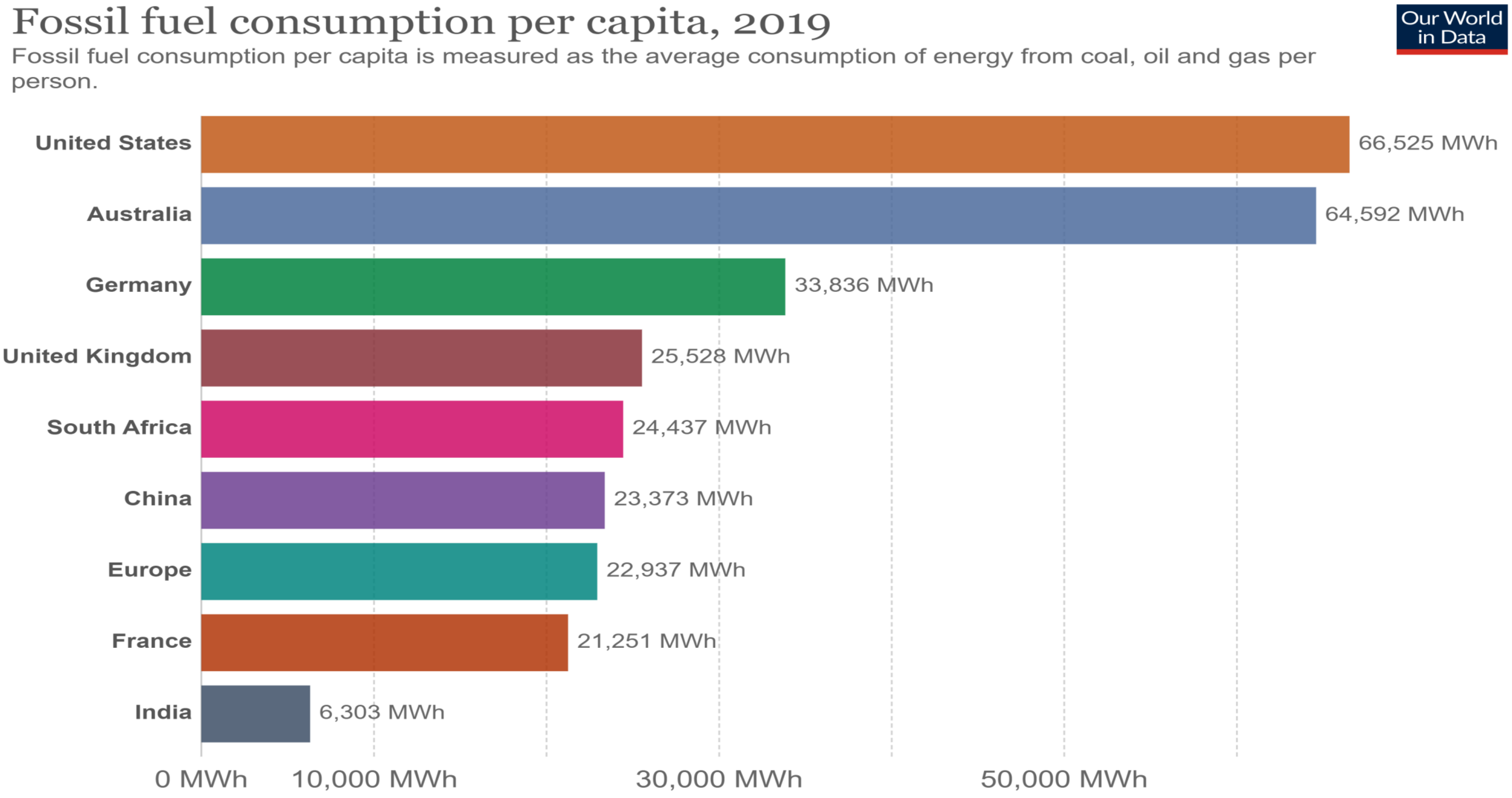
Renewable Energy	Non-Renewable Energy
✓ Operating cost is low.	✓ It is affordable and easily available.
✓ Environmental Friendly.	✓ Easy to use and more reliable in the short-run.
✓ Clean energy and more can be produced in the long-run.	✓ More can be produced in the short-run.
✓ Produces Low carbon emissions and stimulates green economy.	✓ known for its quick exploration.
✓ Infinite	✓ Expandable in response to human effort

Dis-advantages of Renewable and Non-Renewable Energies

Renewable Energy	Non-Renewable Energy
✓ Expensive in the short-run, and less reliable and becomes affordable in the long-run.	✓ Eventually run out, becomes scarce and also becomes expensive.
✓ Not effective of producing energy in massive scale, particularly in the short-run.	✓ Threatening to the natural environment.
✓ It can be noisy and requires more space.	✓ Dirty Energy.
✓ Finite at a given time	✓ Finite

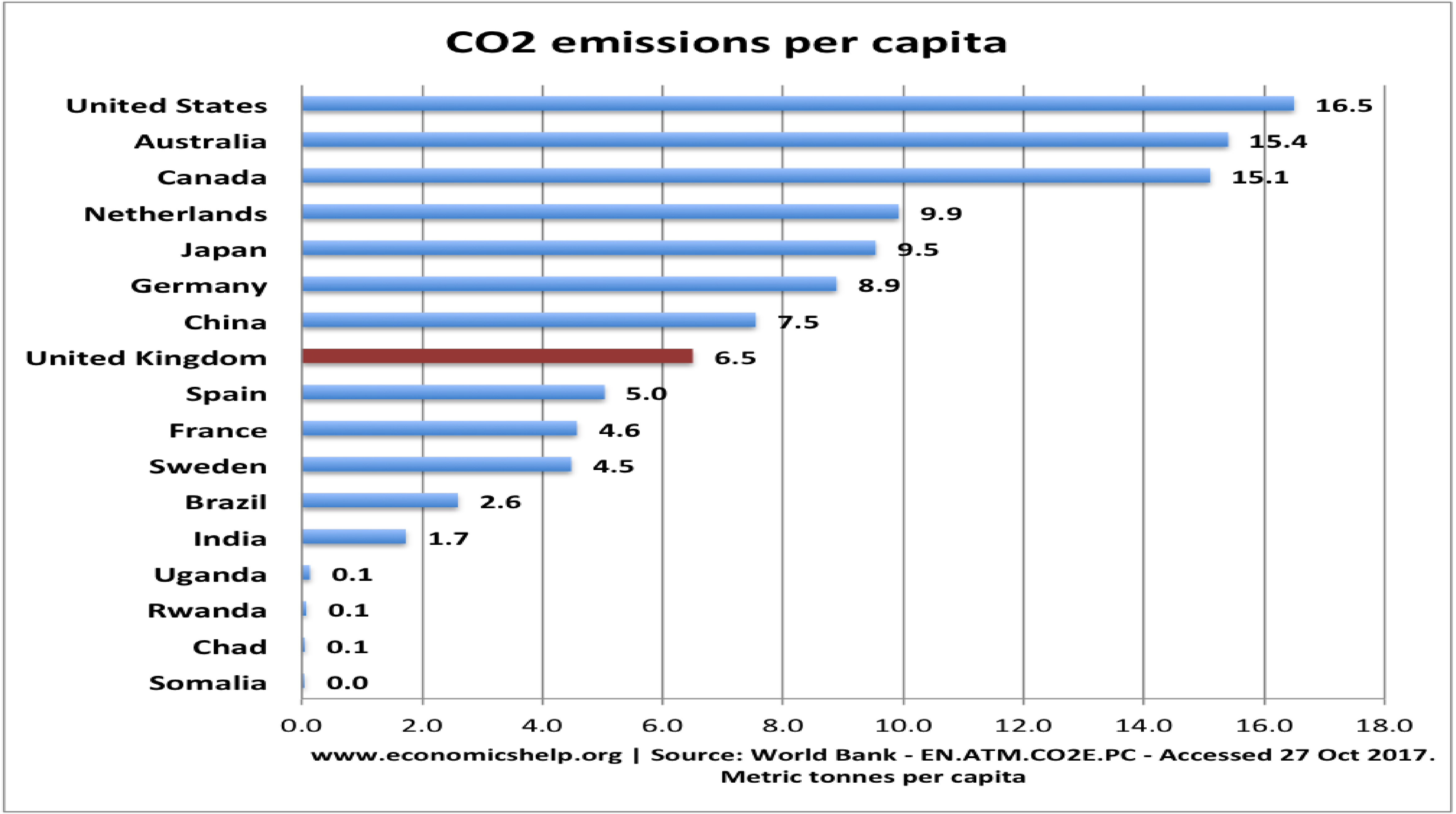
Fossil fuel consumption per capita, 2019

Fossil fuel consumption per capita is measured as the average consumption of energy from coal, oil and gas per person.

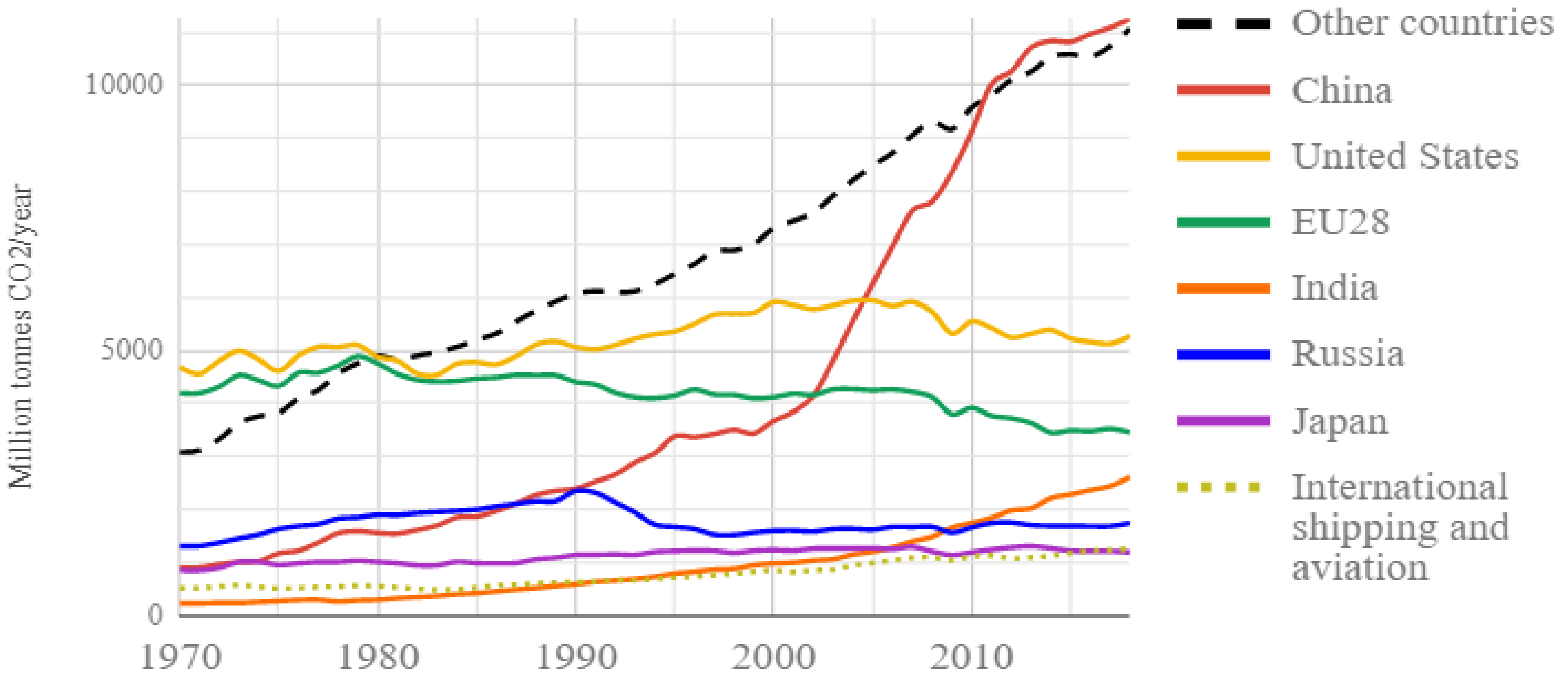


Source: Our World in Data based on BP Statistical Review of World Energy

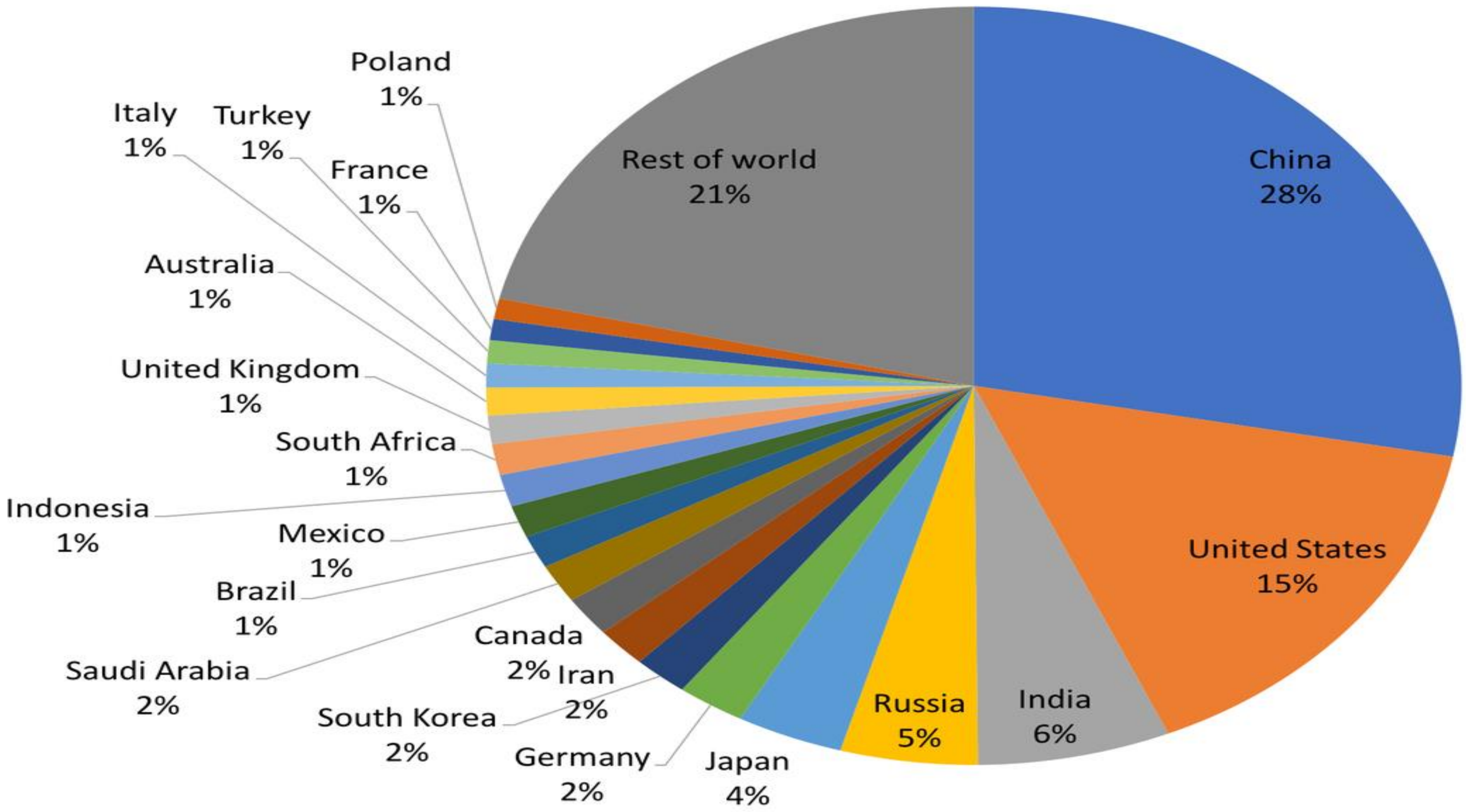
OurWorldInData.org/energy • CC BY


CO2 emissions per capita
United States
Australia
Canada
Netherlands
Japan
Germany
China
United Kingdom
Spain
France
Sweden
Brazil
India
Uganda
Rwanda
Chad
Somalia
16.5
15.4
15.1
9.9
9.5
8.9
7.5
6.5
5.0
4.6
4.5
2.6
1.7
0.1
0.1
0.1
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
www.economicshelp.org | Source: World Bank - EN.ATM.CO2E.PC - Accessed 27 Oct 2017.
Metric tonnes per capita

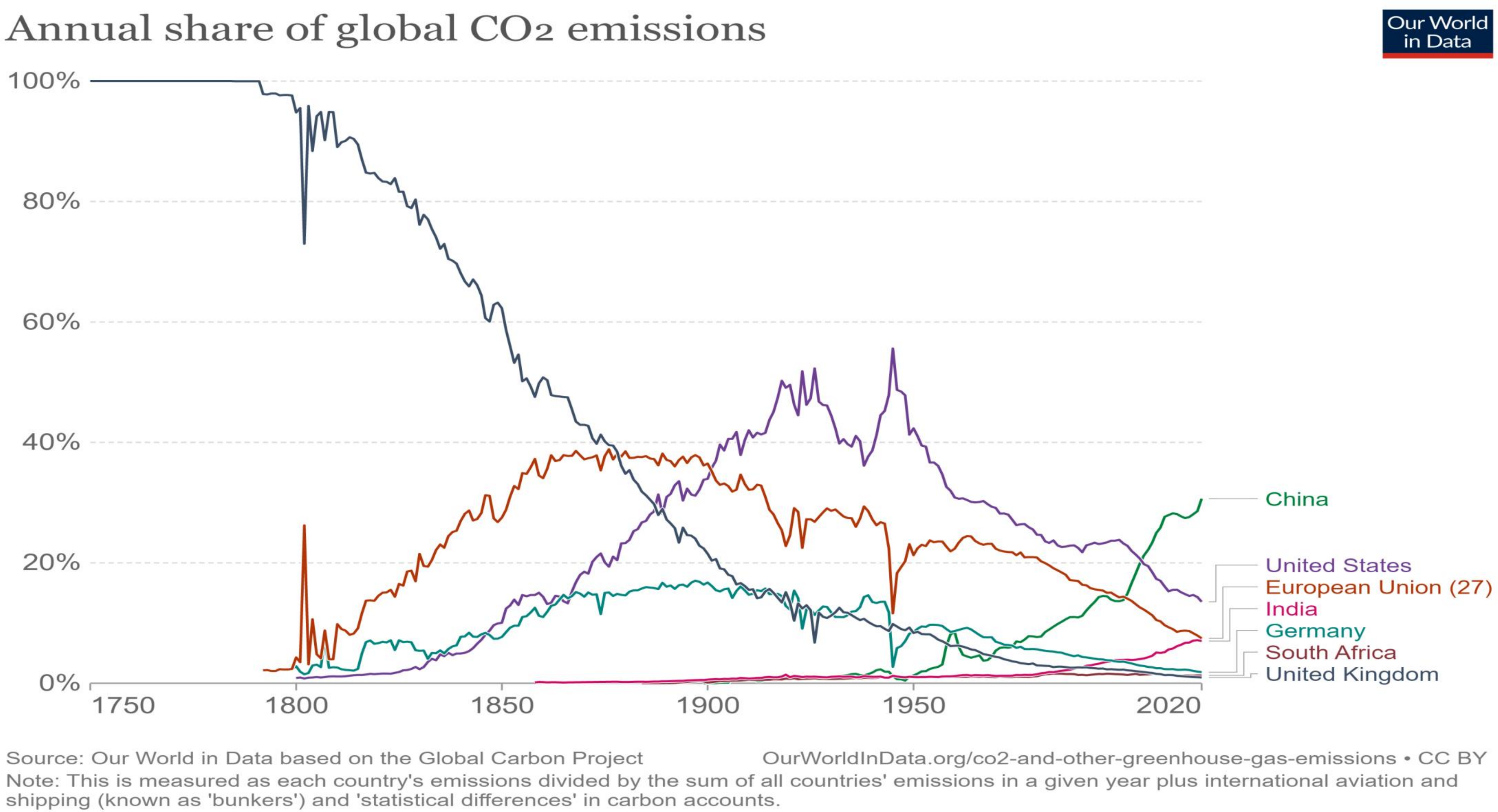
World fossil carbon dioxide emission 1970-2018



Share of global carbon dioxide emissions from fuel combustion (2015)

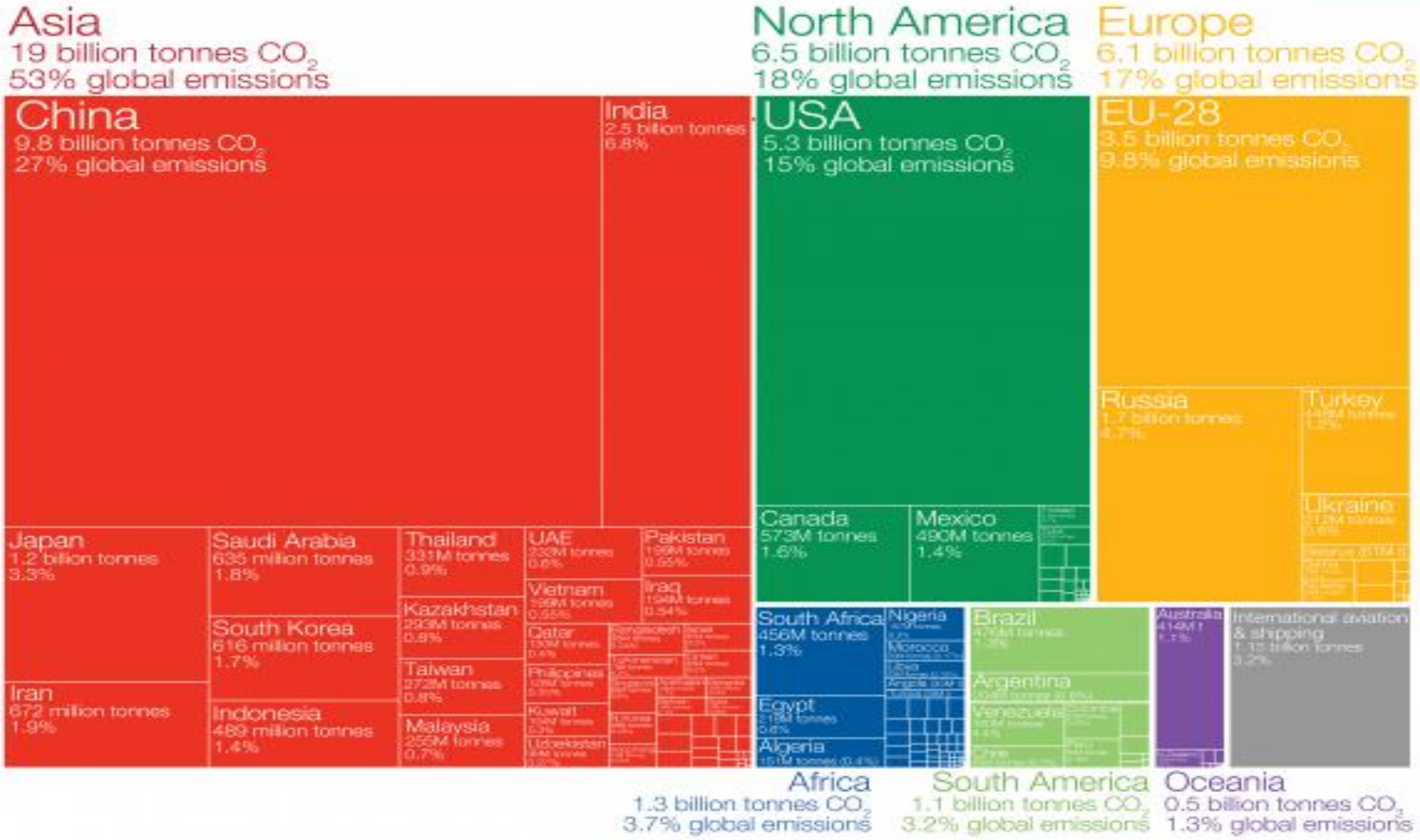


Data: IEA
Image: Union of Concerned Scientists


Annual share of global CO2 emissions
Our World in Data
100%
80%
60%
40%
20%
0%
1750
1800
1850
1900
1950
2020
China
United States
European Union (27)
India
Germany
South Africa
United Kingdom
Source: Our World in Data based on the Global Carbon Project
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY
Note: This is measured as each country's emissions divided by the sum of all countries' emissions in a given year plus international aviation and shipping (known as 'bunkers') and 'statistical differences' in carbon accounts.

Who emits the most CO_2?

Global carbon dioxide (CO_2) emissions were 36.2 billion tonnes in 2017.



Shown are national production-based emissions in 2017. Production-based emissions measure CO_2 produced domestically from fossil fuel combustion and cement, and do not adjust for emissions embedded in trade (i.e. consumption-based).

Figures for the 28 countries in the European Union have been grouped as the 'EU-28' since international targets and negotiations are typically set as a collaborative target between EU countries. Values may not sum to 100% due to rounding.

Data source: Global Carbon Project (GCP).
This is a visualization from OurWorldinData.org, where you find data and research on how the world is changing.

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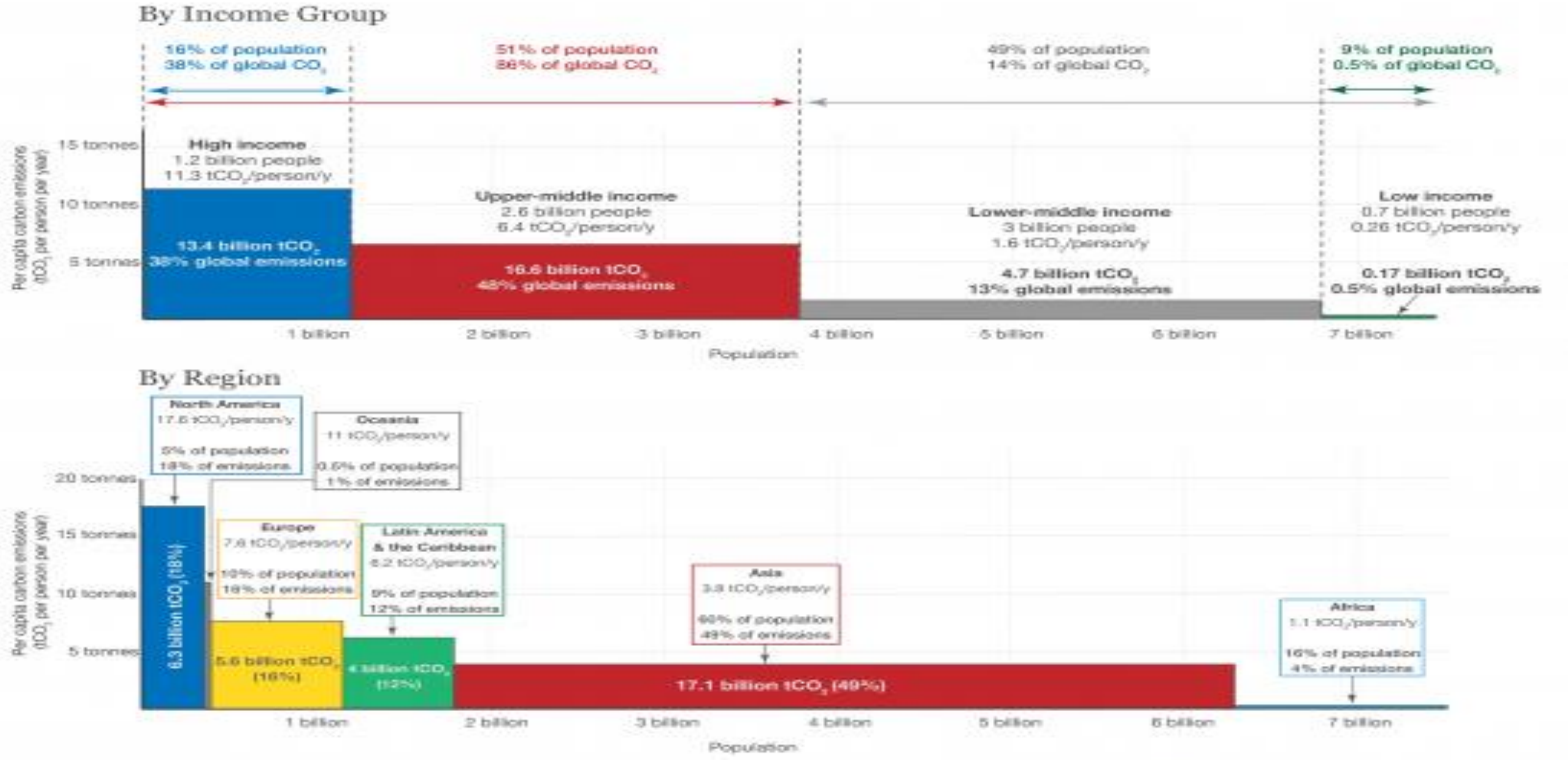
Global CO_2 emissions by income and region

Breakdown of global carbon dioxide (CO_2) emissions in 2016 by World Bank income group (top) and world region (bottom). This is shown based on average per capita emissions (y-axis) and population size (x-axis), with the area of the box representing total annual emissions in 2016.

- Emissions represent domestic production (not accounting for embeddded emissions in traded products), and do not include cross-boundary emissions such as international aviation & shipping.
- Aggregation by income is based on the total emissions of countries within each of the World Bank's income groupings. It reflects average national incomes rather than the distribution of incomes within countries. E.g. 'Low income' reflects the total emissions of all countries defined as low income, rather than the emissions of global individuals defined as low income. If defined on the basis of individuals (without country contexts), the global inequality would be even larger.



Source: Our World in Data based on data from the Global Carbon Project, UN Population Division (2019) & World Bank income groups.
This is a visualization from OurWorldinData.org, where you find data and research on how the world is changing.

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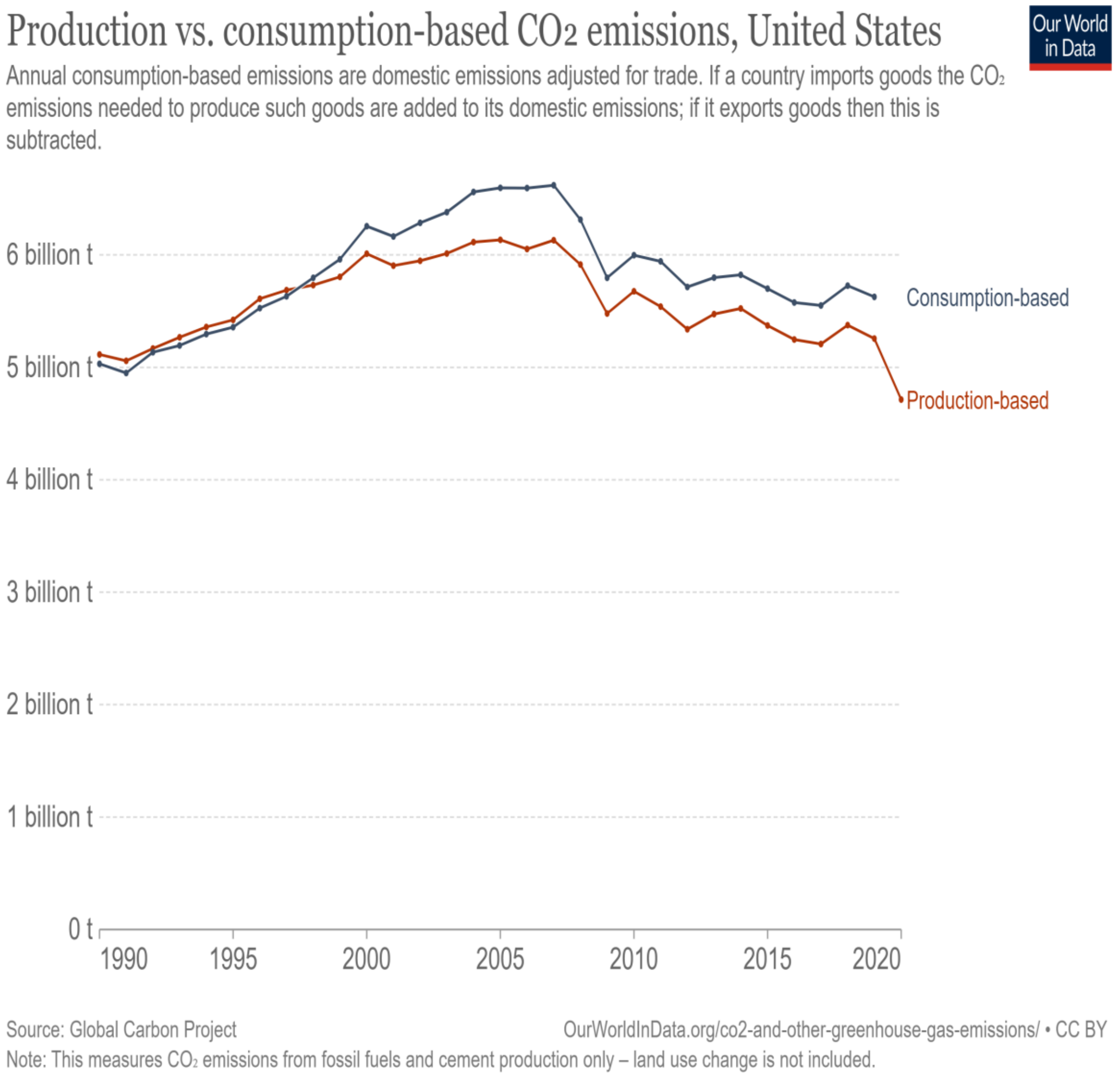
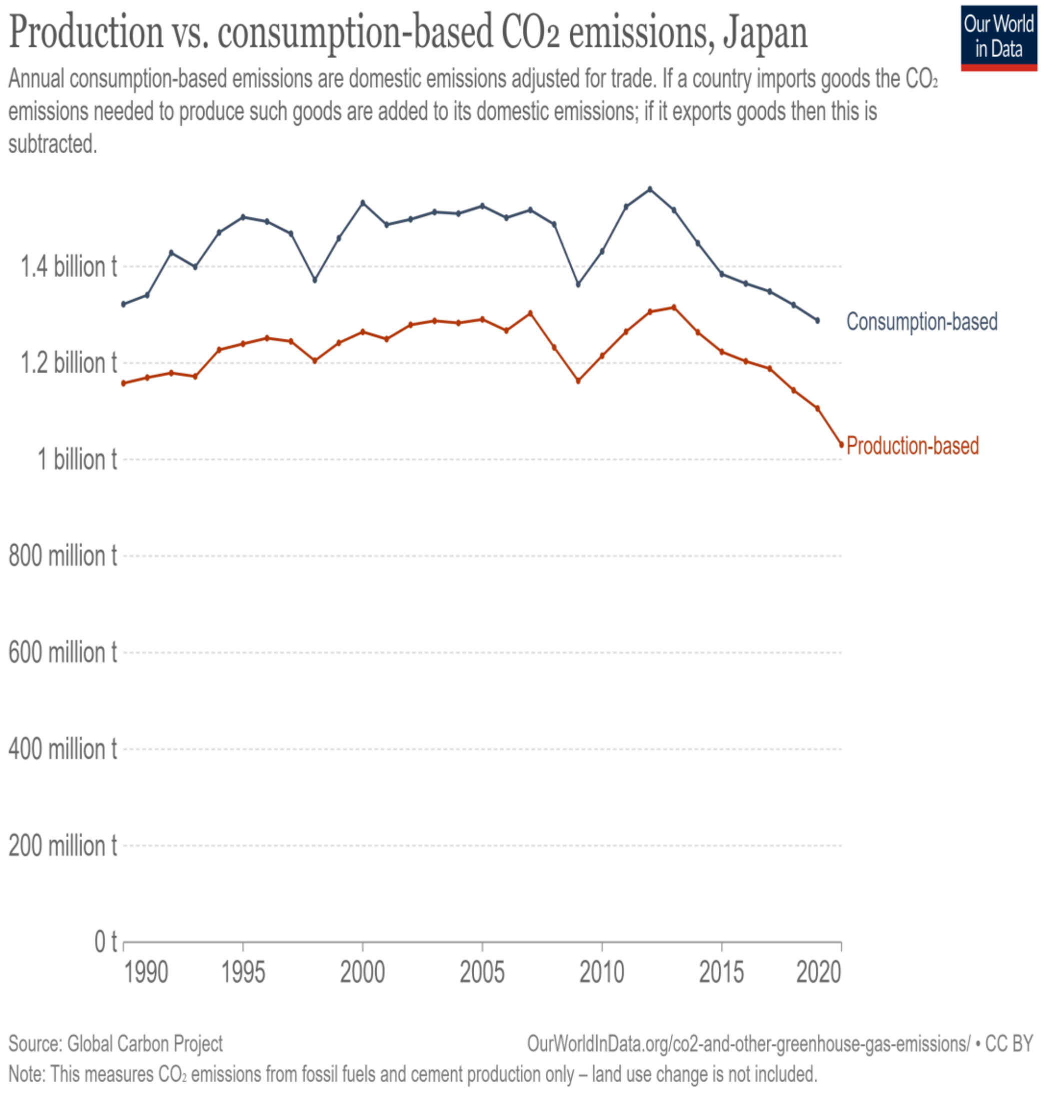
Global Pollution Inequalities

Income or regional group	Share of population (%)	Share of production-based CO_2 emissions (%)	Share of consumption-based CO_2 emissions (%)
High income [83 countries]	16%	39%	**46%**
Upper-middle income [56 countries]	35%	**48%**	41%
Lower-middle income [50 countries]	40%	13%	13%
Low income [28 countries]	9%	0.4%	0.4%
North America [40 countries]	5%	17%	**19%**
Europe [50 countries]	10%	16%	**18%**
Latin America & the Caribbean [33 countries]	9%	6%	6%
Asia [50 countries]	60%	**56%**	52%
Africa [57 countries]	16%	**4%**	3%
Oceania [23 countries]	0.5%	1.3%	1.3%

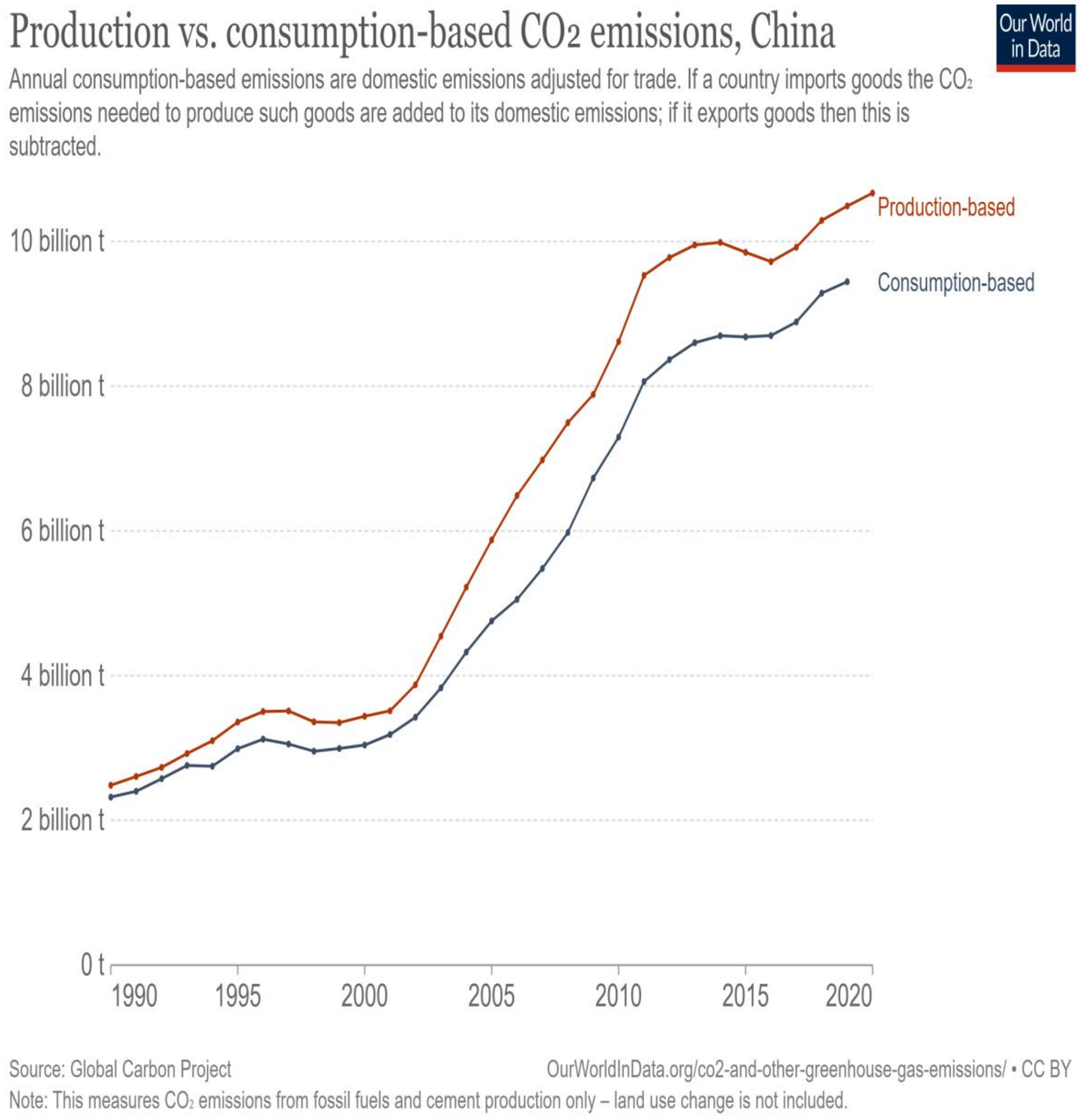
https://ourworldindata.org/co2-emissions

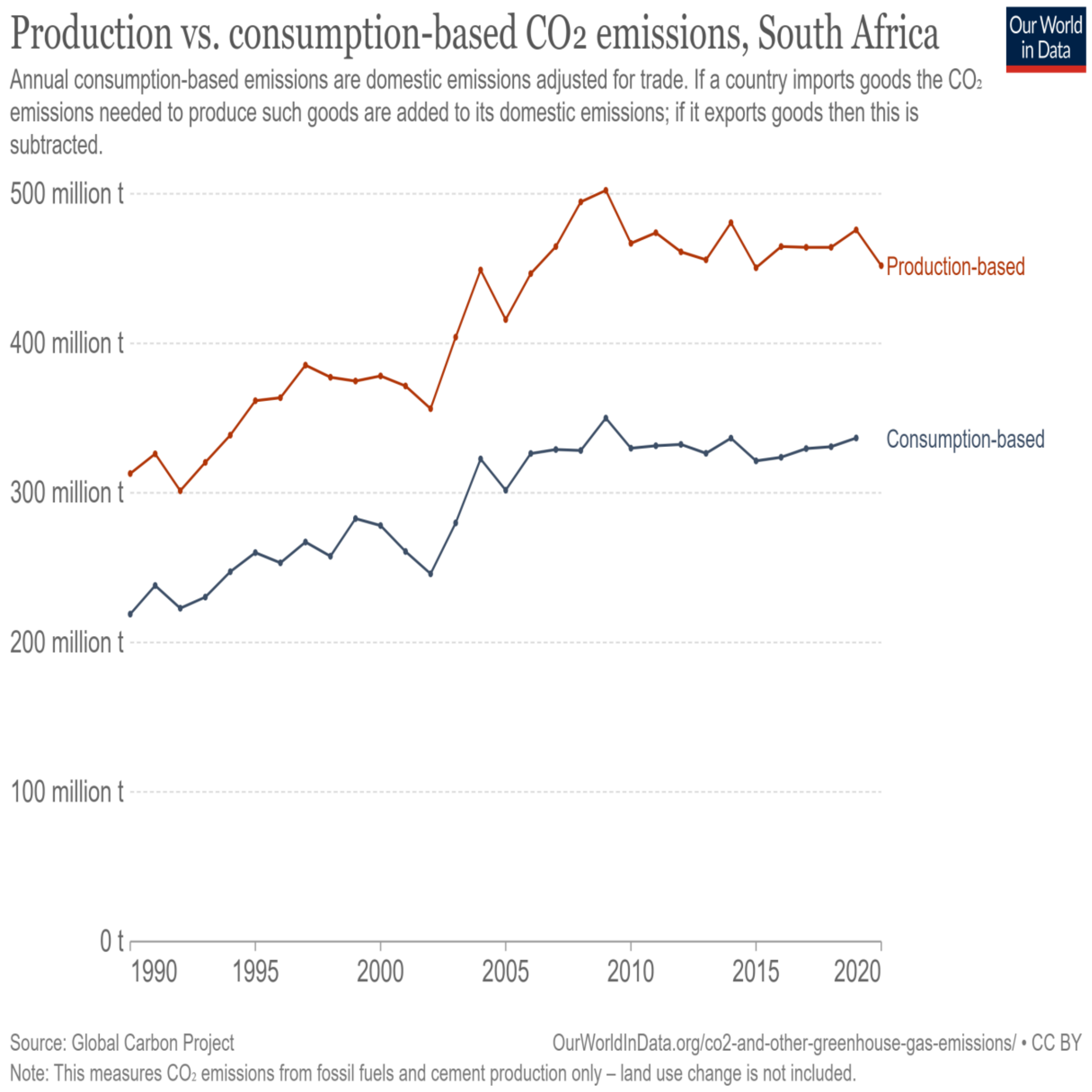
High Income Countries





Upper-Middle Income Countries





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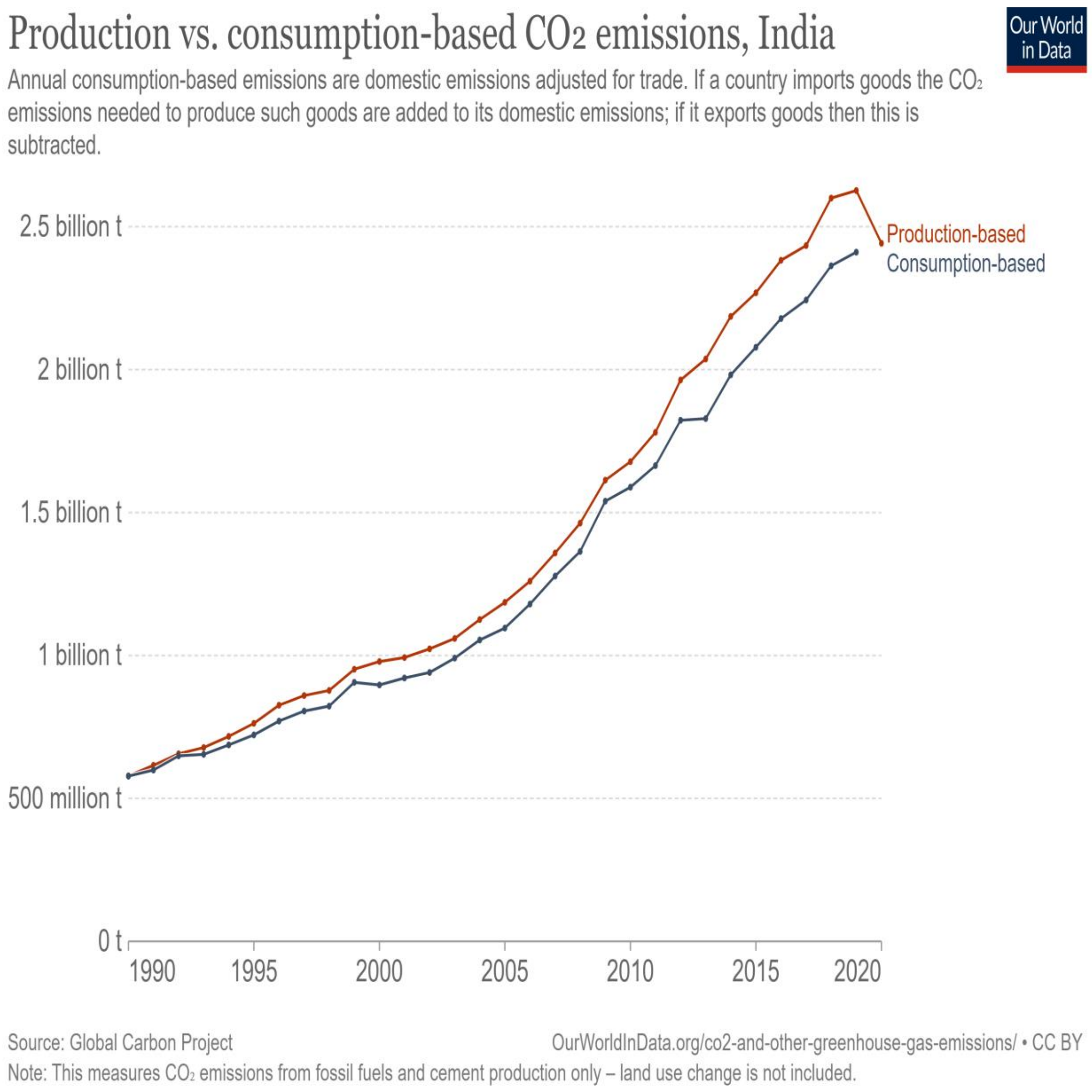
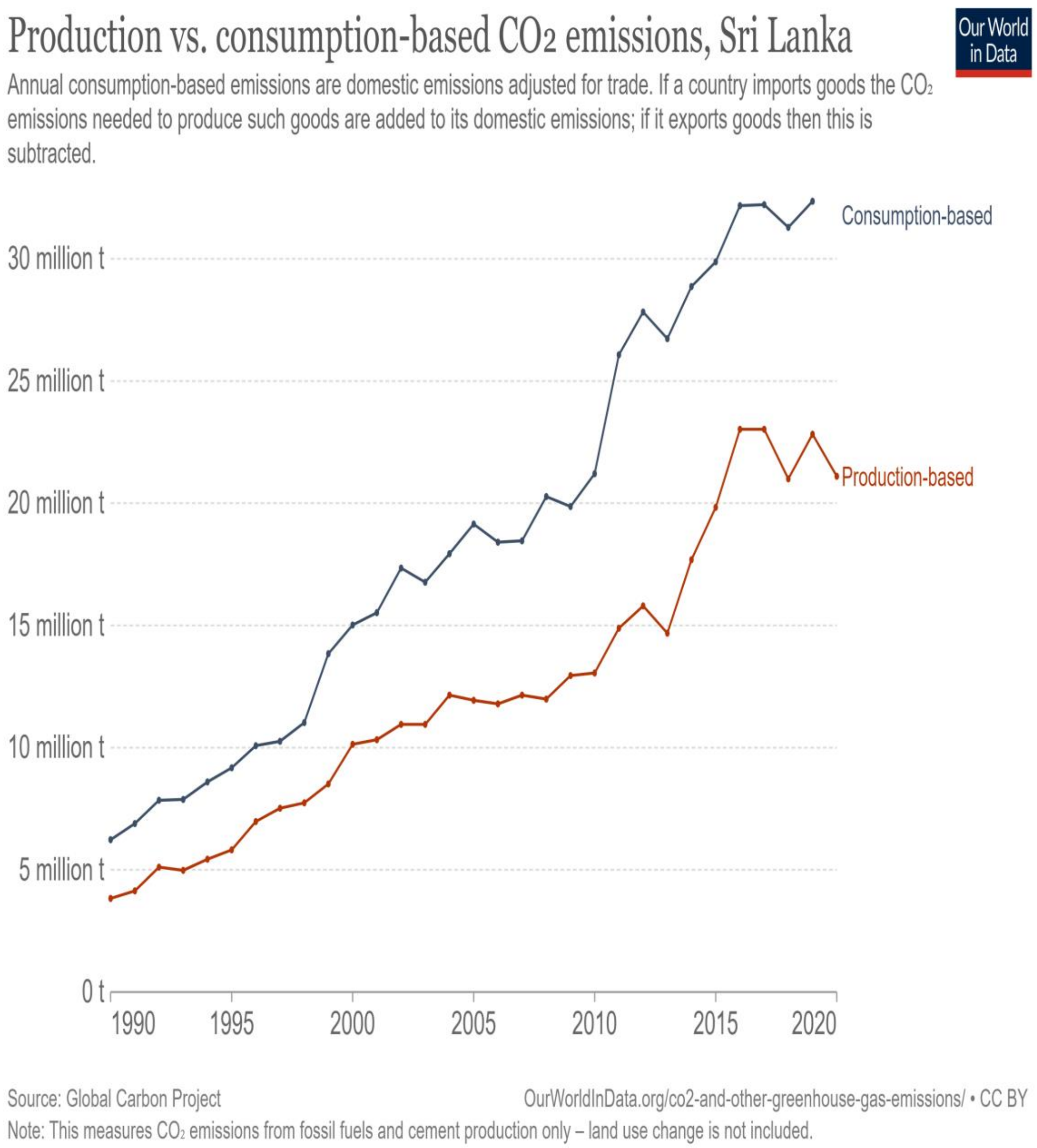
Lower-Middle Income Countries





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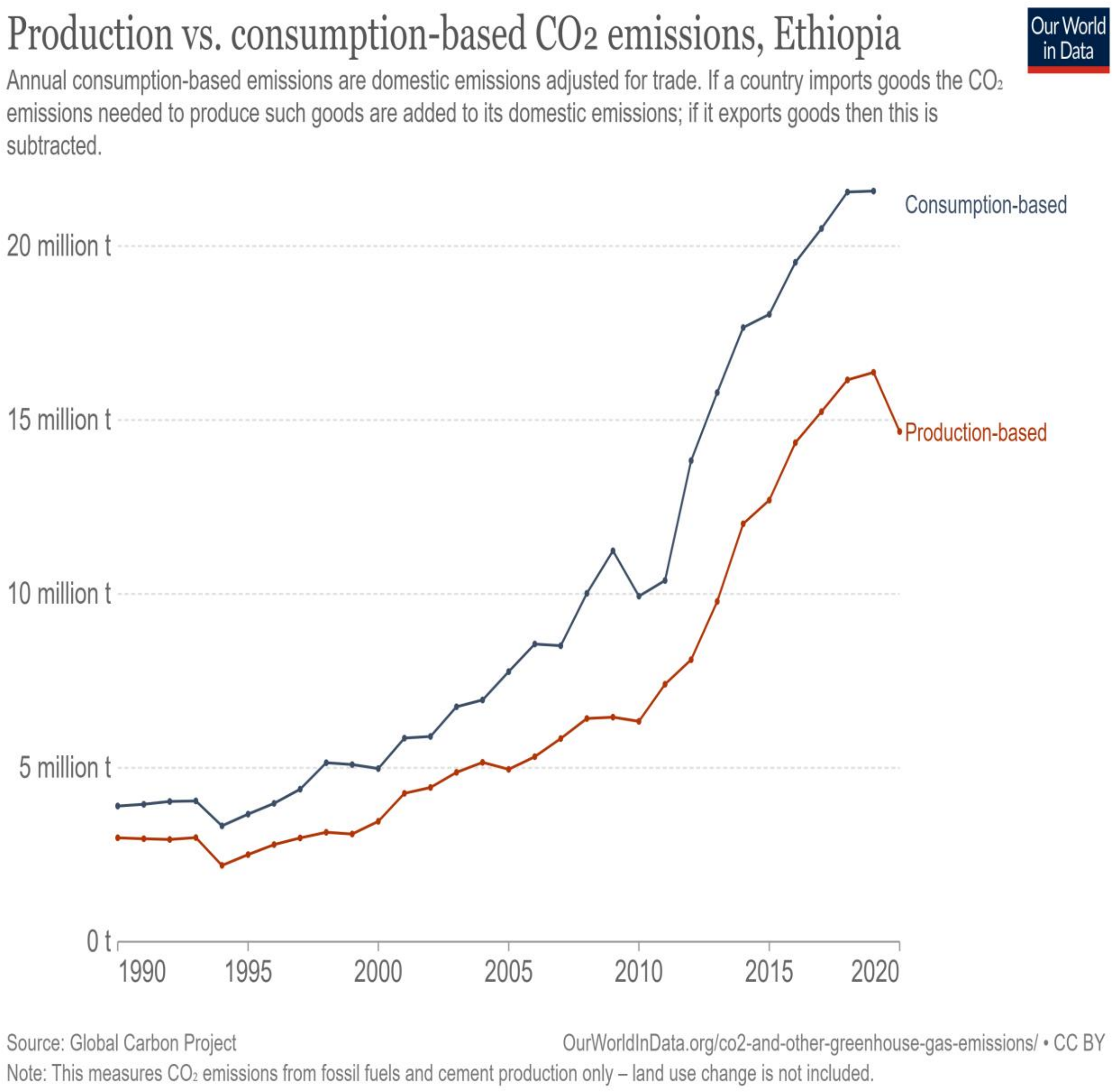
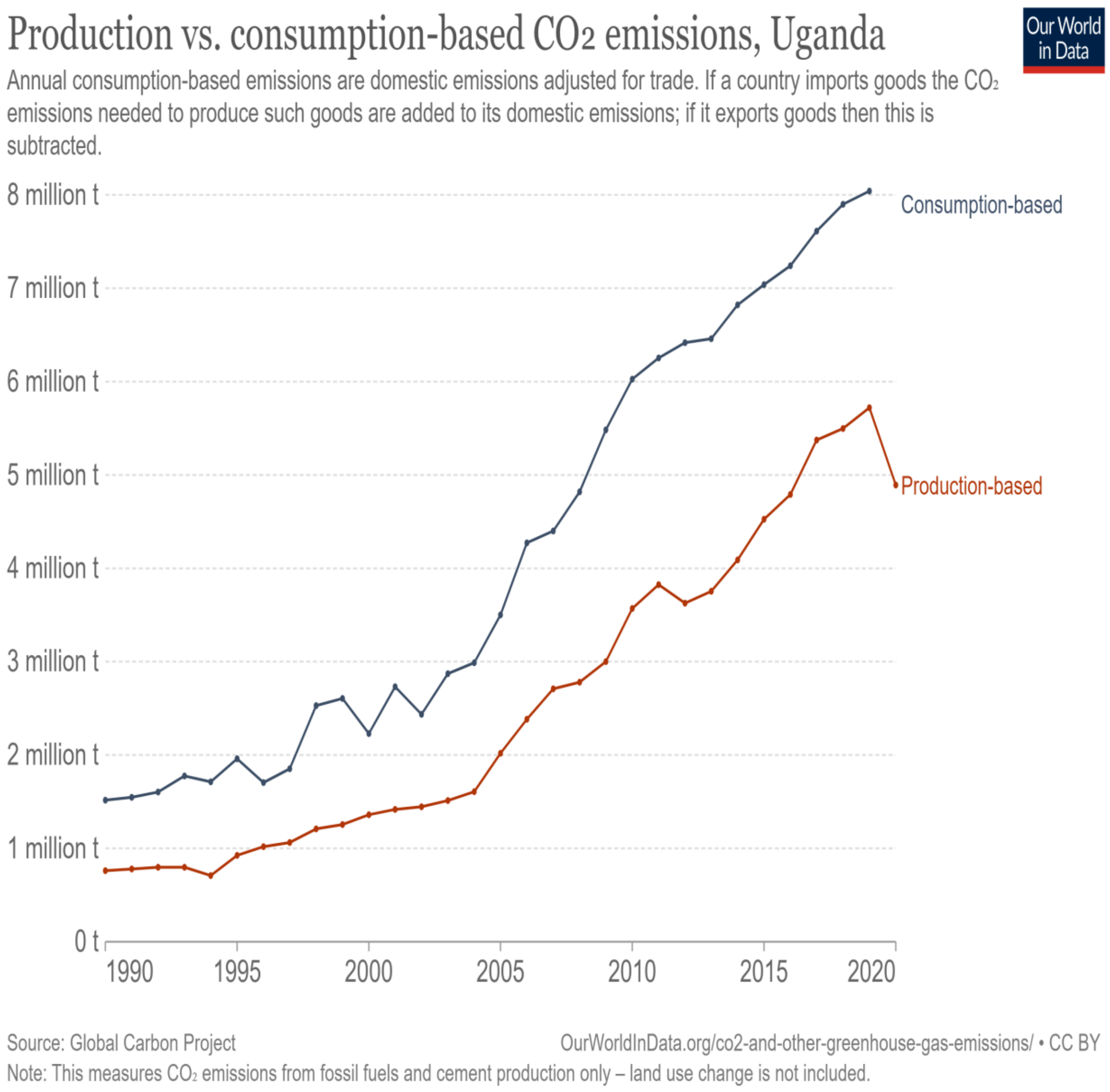
Low Income Countries



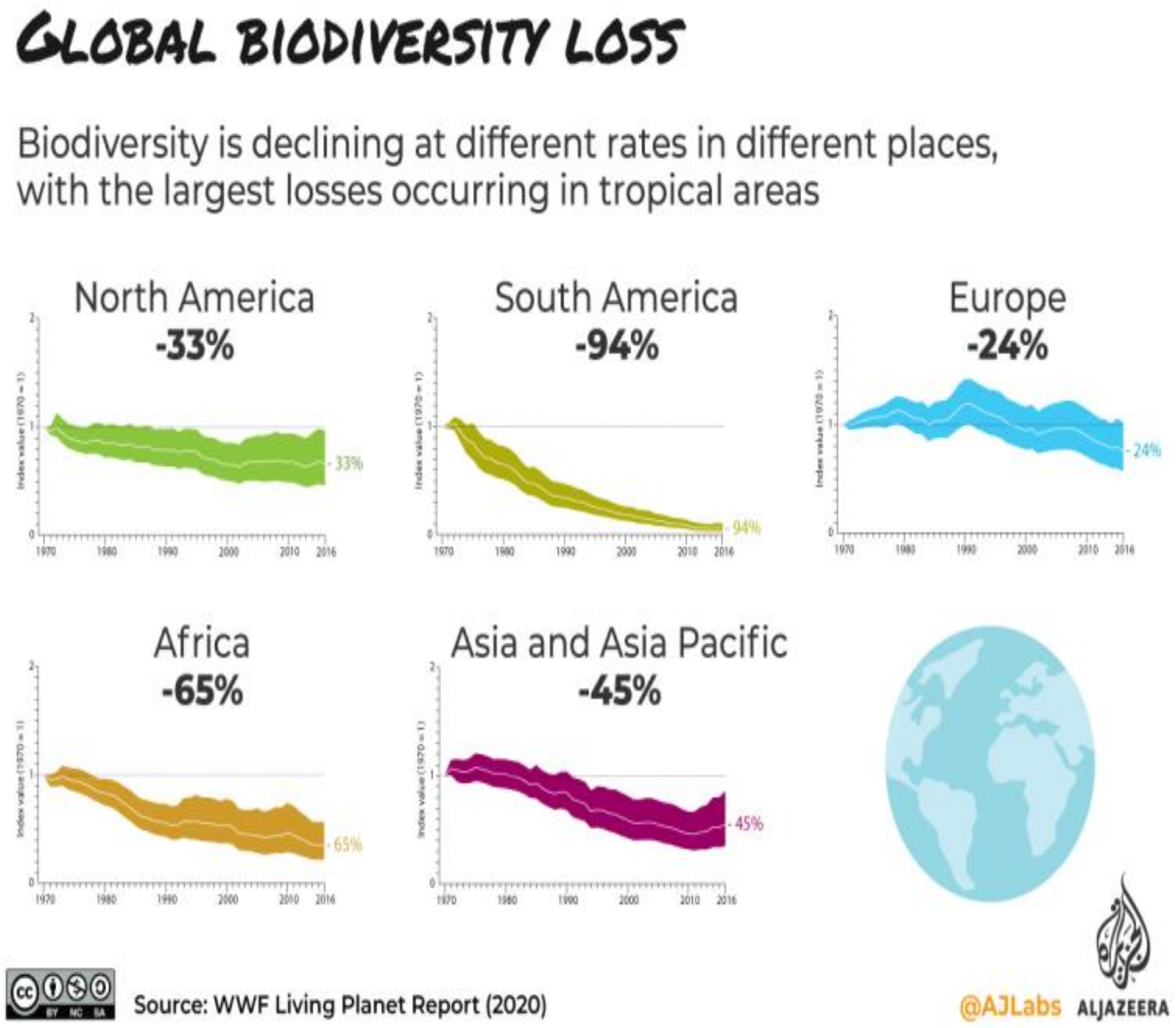


https://ourworldindata.org/grapher/production-vs-consumption-co2-emissions?country=~UGA

❑ Environmental Consequences

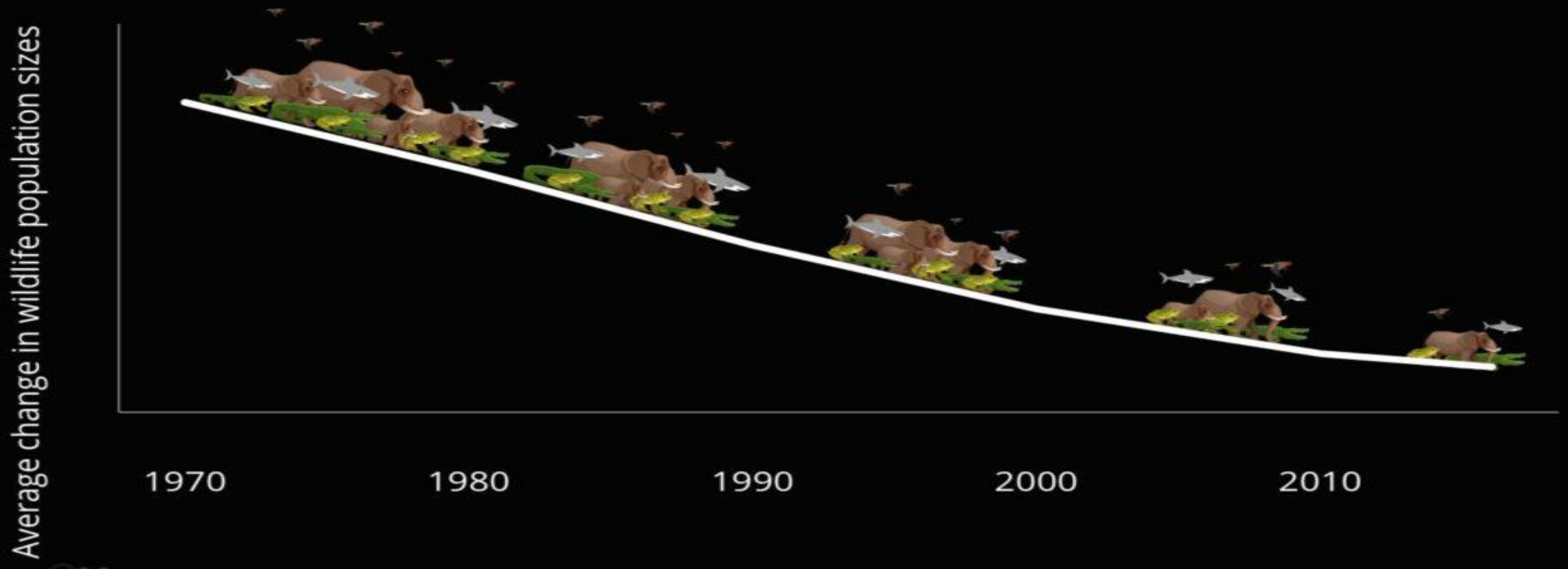
- Planet is becoming hotter because of fossil fuels extraction and usage.
- Excessive energy usage creates ‘‘anthropogenic carbon emissions’’.
- Pollution level in the atmosphere is increasing due to ‘‘human activities’’.
- Environmental change caused by ‘‘people’’.

- ✓ Growing economic growth with massive fossil fuels consumption accounts for the depreciation of the natural assets.
- ✓ Then sustainable development will be at risk if planetary system is destroyed.
- ✓ The life would also cease to exist.
- ✓ We need to protect the health of natural assets as nature is our home.



THE LIVING PLANET INDEX

The population sizes of mammals, birds, fish, amphibians and reptiles have seen an alarming average drop of 68% since 1970.



Interaction Between the Capitals

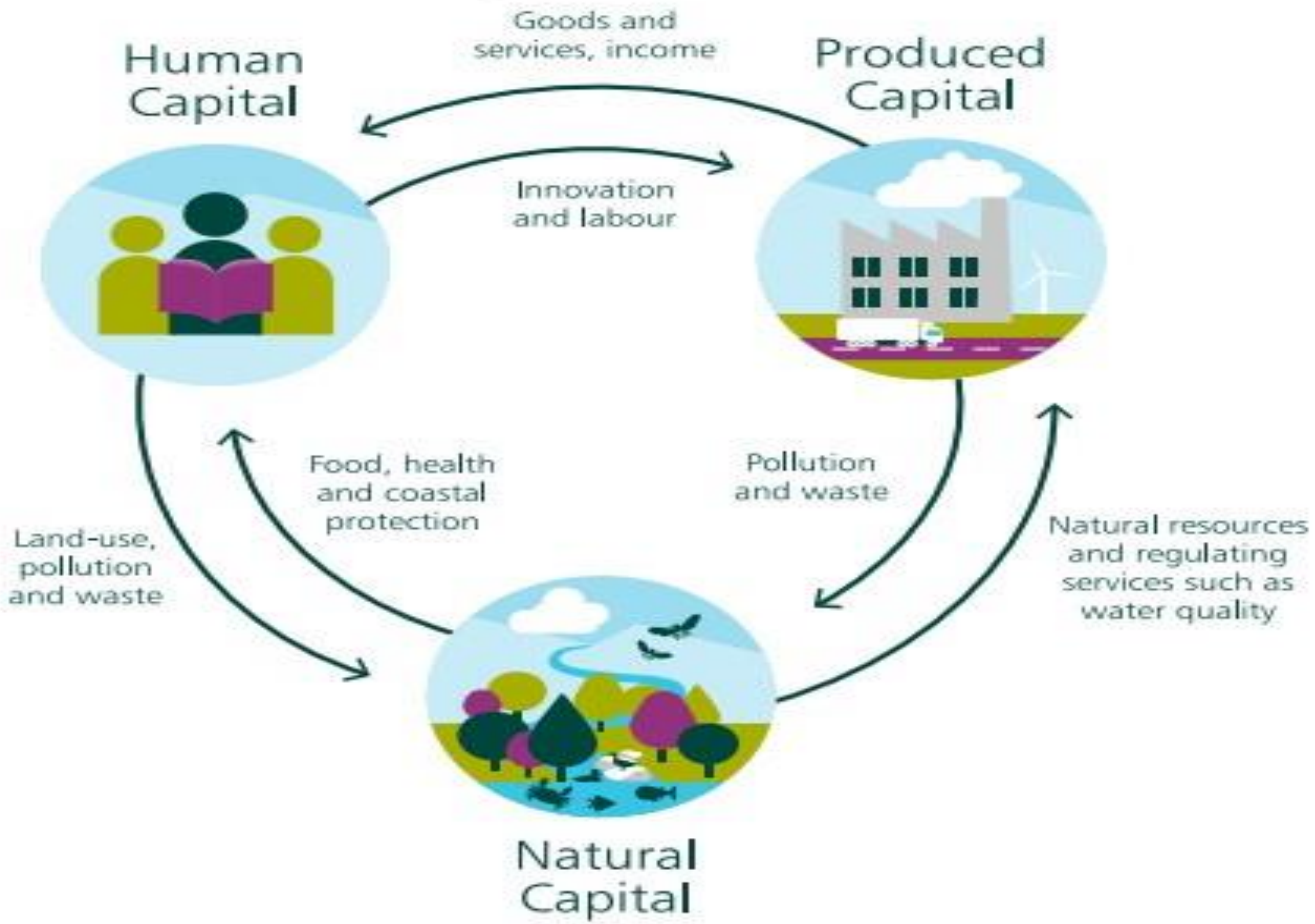


Figure 4.8 Global Wealth Per Capita, 1992 to 2014

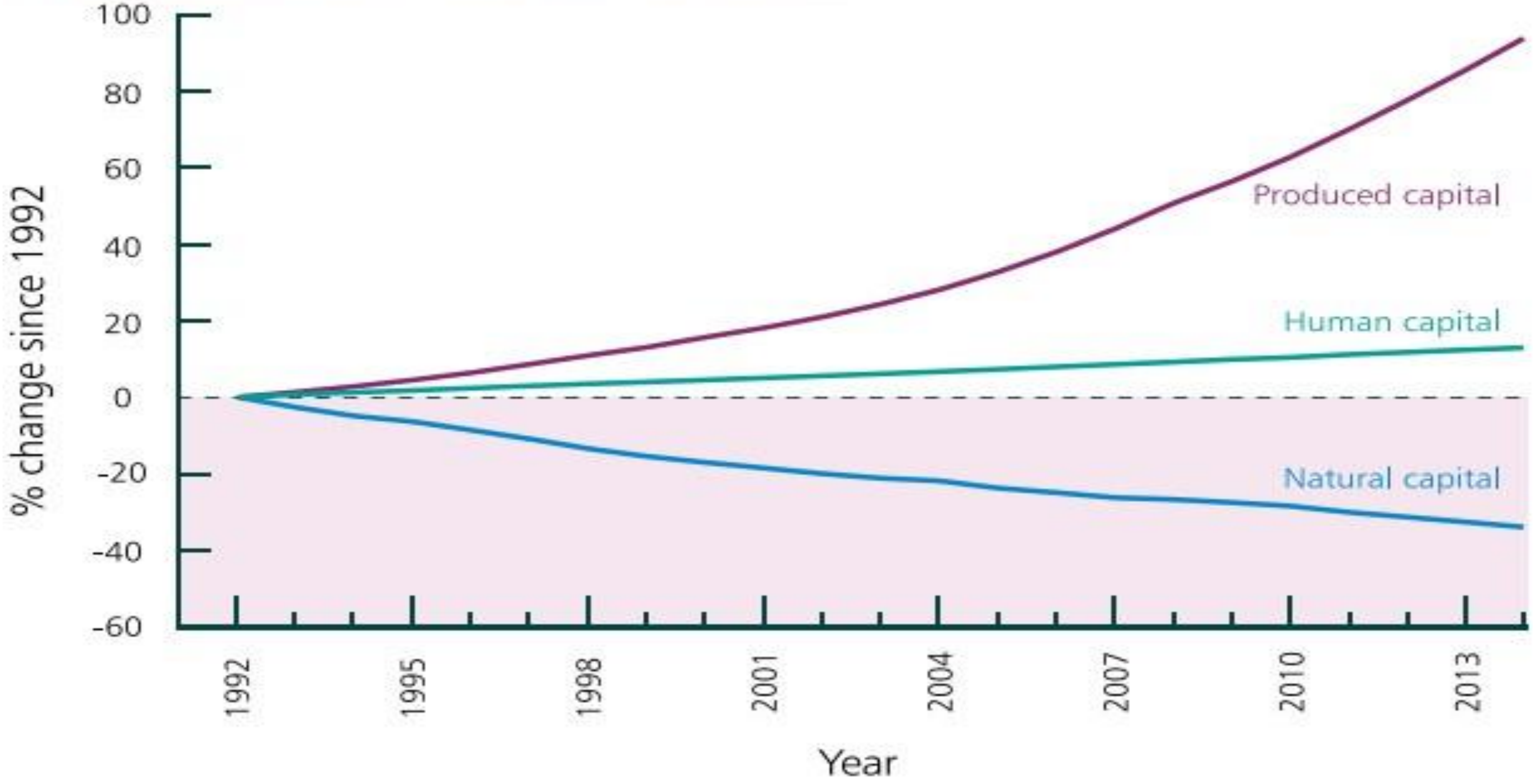
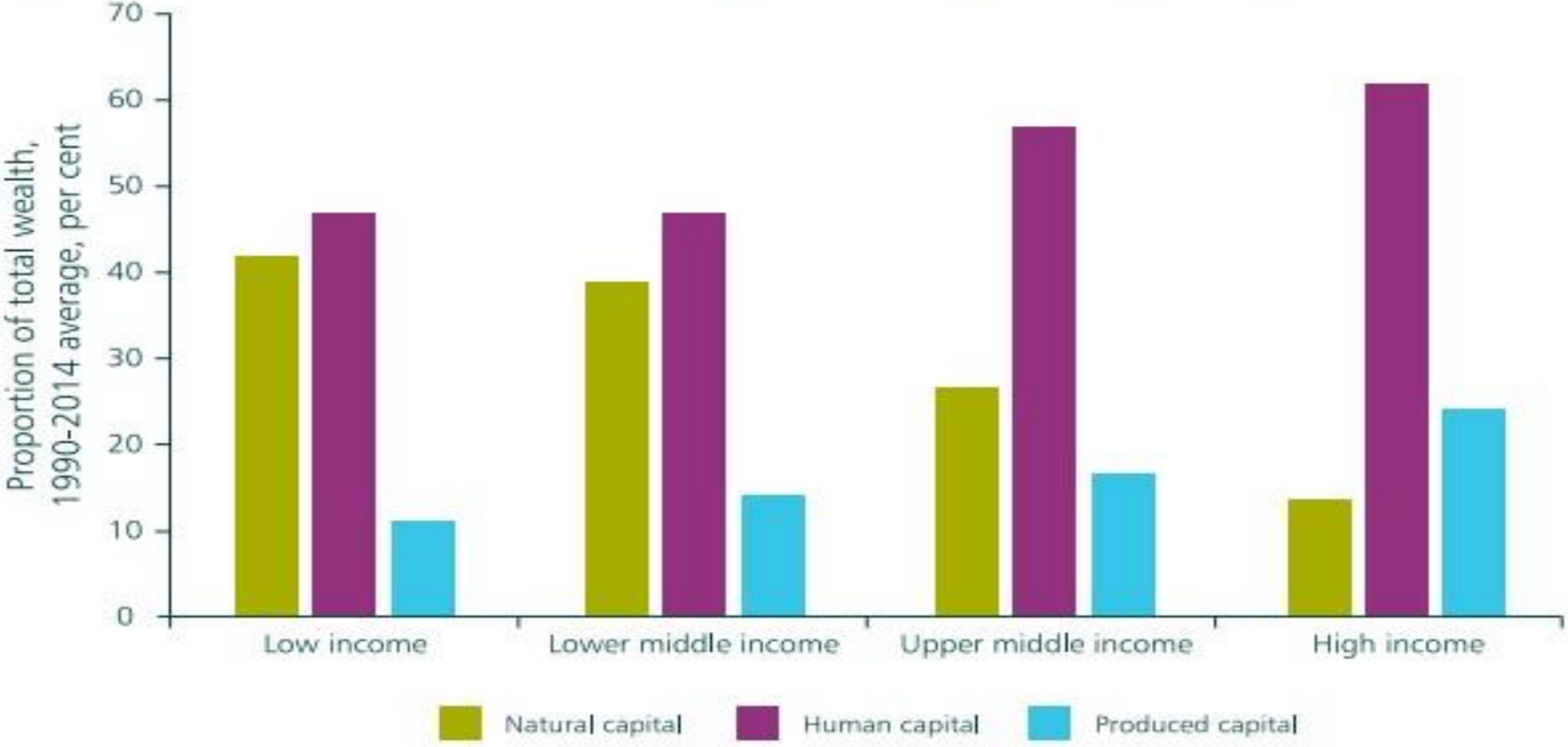


Figure 14.3 Inclusive Wealth of Countries by Income Group and Capital Type



Source: Based on Managi and Kumar (2018) and Review calculations.

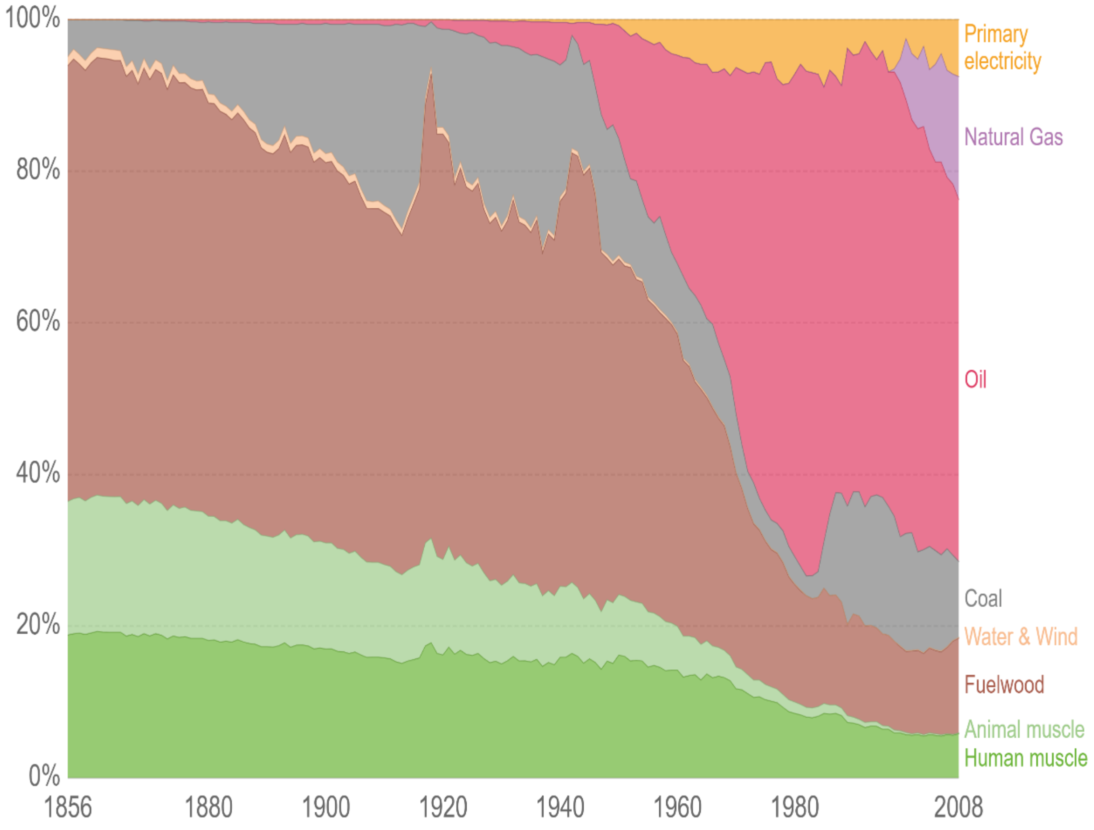
Table 1: Distribution of Energy Sources for Japan

Year	Wood	Coal	Oil	Natural Gas	Hydro	Nuclear
1880	85%	14%	1%			
1900	39%	57%	4%			
1940	10%	66%	8%		16%	
1970		22%	71%	1%	6%	0%
1990		18%	57%	10%	5%	10%
2010		23%	43%	17%	4%	13%

Source: Adopted from the book of Nersesian (2016)

Long-term energy transitions, Portugal

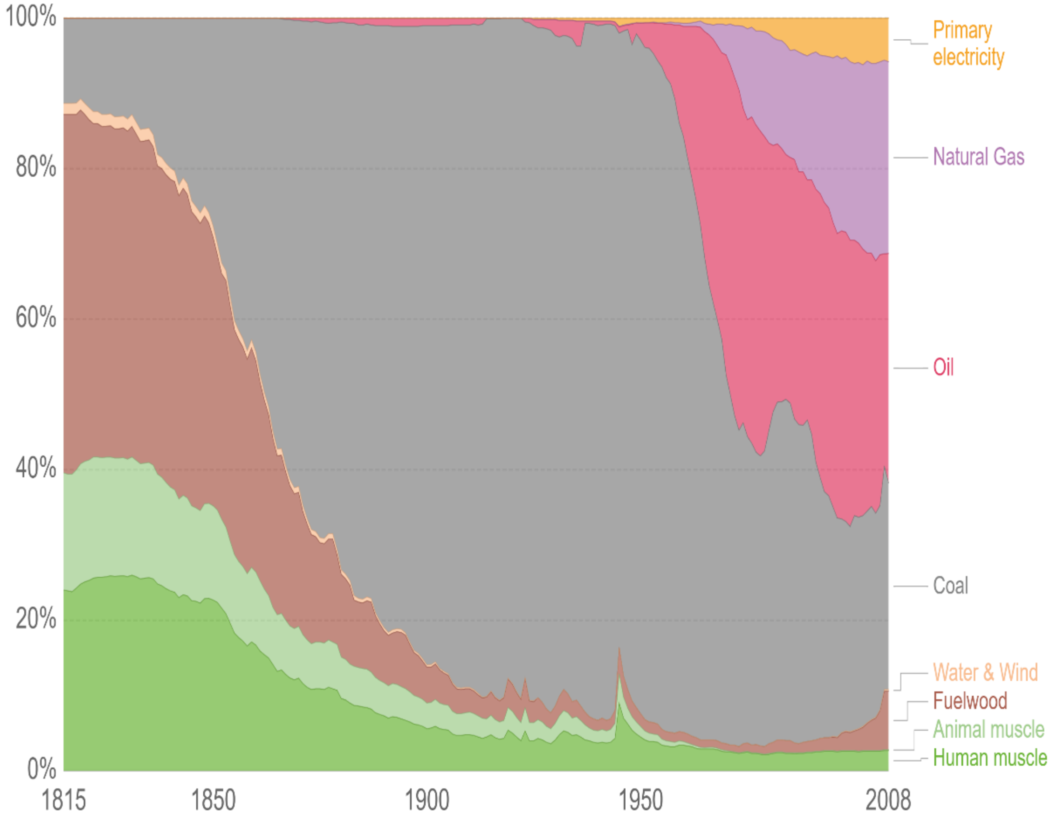
Share of primary energy by source over the long-term, measured as the percentage of total energy consumption. Primary electricity includes: hydropower, nuclear power, wind, photovoltaics, tidal, wave and solar thermal and geothermal (only figures for electricity production are included).



Source: Joint Center for History and Economics, Harvard University and University of Cambridge. Energy History.
OurWorldInData.org/energy-production-and-changing-energy-sources/ • CC BY

Long-term energy transitions, Germany

Share of primary energy by source over the long-term, measured as the percentage of total energy consumption. Primary electricity includes: hydropower, nuclear power, wind, photovoltaics, tidal, wave and solar thermal and geothermal (only figures for electricity production are included).



Source: Joint Center for History and Economics, Harvard University and University of Cambridge. Energy History.
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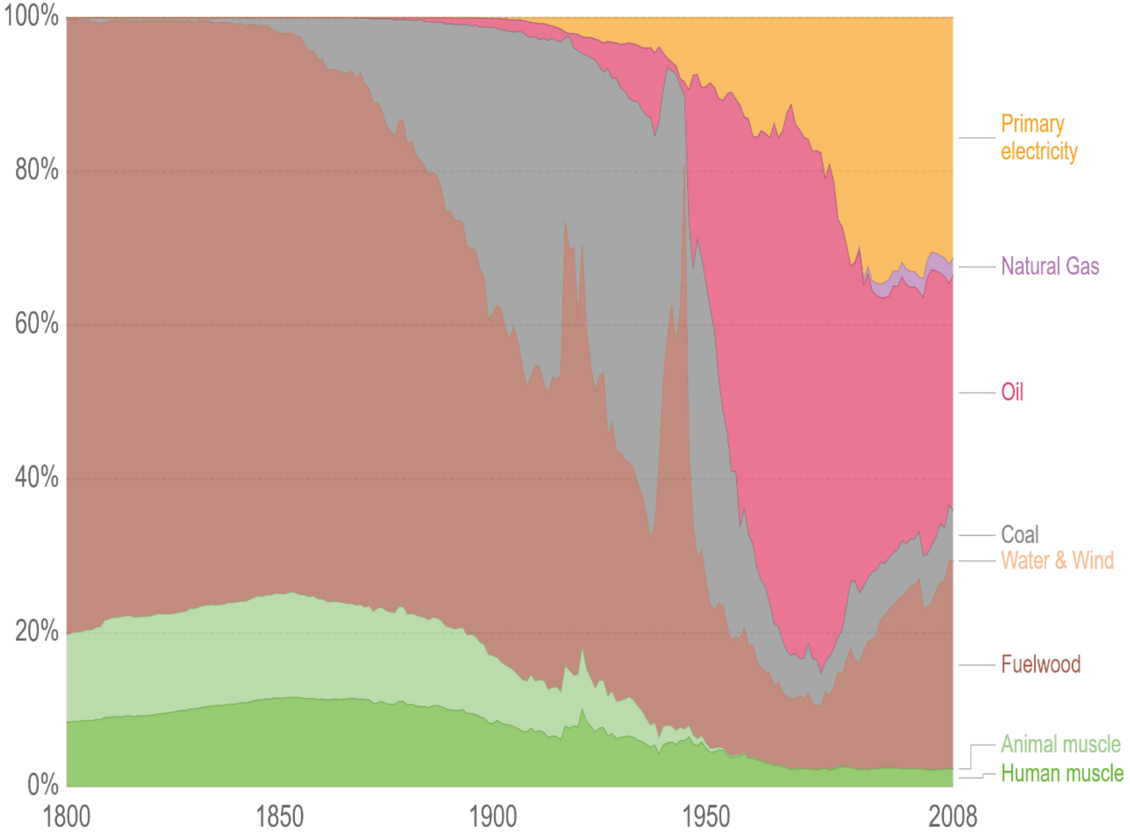
Long-term energy transitions, Sweden

Our World in Data

Share of primary energy by source over the long-term, measured as the percentage of total energy consumption. Primary electricity includes: hydropower, nuclear power, wind, photovoltaics, tidal, wave and solar thermal and geothermal (only figures for electricity production are included).



Source: Joint Center for History and Economics, Harvard University and University of Cambridge. Energy History.
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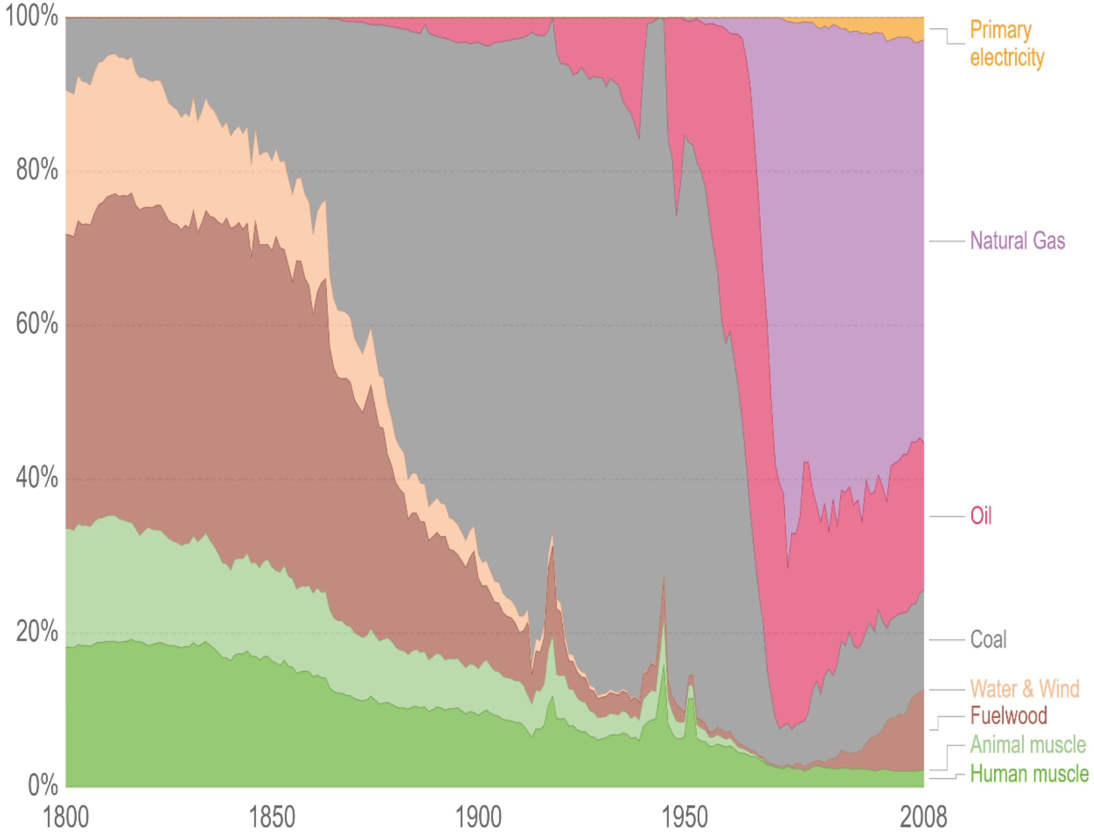
Long-term energy transitions, Netherlands

Our World in Data

Share of primary energy by source over the long-term, measured as the percentage of total energy consumption. Primary electricity includes: hydropower, nuclear power, wind, photovoltaics, tidal, wave and solar thermal and geothermal (only figures for electricity production are included).



Source: Joint Center for History and Economics, Harvard University and University of Cambridge. Energy History.
OurWorldInData.org/energy-production-and-changing-energy-sources/ • CC BY

Table 2: Share of Renewable Energy in Total Energy in BRICS economies (%)

Countries	1990	1995	1997	2000	2004	2006
Brazil	63	61	58	49	49	48
China	24	21	21	22	17	15
India	48	44	42	43	40	39
Russia	2	2	2	2	2	2
South Africa	9	9	9	9	9	9

Source: International Energy Agency (IEA), 2009

The Top 10 Countries Relying on Fossil Fuels

Country	% of Energy Consumed From Fossil Fuels (2009-2018)	Most Used Fossil Fuel (2009-2018)
Oman	100%	Gas
Saudi Arabia	100%	Oil
Trinidad and Tobago	100%	Gas
Kuwait	100%	Oil
Qatar	99.9%	Gas
United Arab Emirates	99.9%	Gas
Hong Kong	99.9%	Oil
Algeria	98.8%	Gas
Singapore	98.8%	Oil
Israel	98.1%	Oil

Source: https://ourworldindata.org/energy

The Top 10 Countries Using Alternative Energy Sources

Country	% of Energy Consumed From Alternative Energy Sources (2009-2018)	Most Used Alternative Energy Source (2009-2018)
Iceland	81.6%	Hydropower
Norway	67.5%	Hydropower
Sweden	65.3%	Hydropower
Switzerland	50.5%	Hydropower
France	47.0%	Nuclear
Finland	39.5%	Nuclear
New Zealand	37.2%	Hydropower
Brazil	37.2%	Hydropower
Canada	34.8%	Hydropower
Austria	31.7%	Hydropower

Source: https://ourworldindata.org/energy

CO2 emissions (metric tons per capita) for Top 10 Fossil Fuel and 10 Alternative Energy Consuming Countries

Country	2009	2010	2011	2012	2013	2014	2015	2016
Oman	14.29	15.59	16.61	17.05	16.47	15.20	15.32	14.16
Saudi Arabia	17.61	18.90	17.68	19.37	18.00	19.44	20.40	17.36
Trinidad and Tobago	33.98	36.08	35.12	33.77	34.37	33.96	33.75	31.84
Kuwait	30.94	29.95	27.35	30.01	26.88	23.94	24.24	24.95
Qatar	41.82	39.05	39.50	42.86	36.38	43.52	41.64	38.90
United Arab Emirates	21.25	18.55	19.18	24.04	23.99	24.54	21.02	22.04
Hong Kong	5.98	5.73	6.13	6.01	6.20	6.32	5.84	5.94
Algeria	3.43	3.31	3.30	3.47	3.52	3.73	3.85	3.69
Singapore	11.75	11.48	9.02	9.41	10.39	10.35	11.10	6.69
Israel	8.61	9.03	8.90	9.54	8.19	7.65	7.90	7.62
Iceland	6.44	6.16	5.89	5.84	5.86	6.05	6.00	6.15
Norway	11.46	10.10	8.55	8.86	9.49	9.32	9.09	7.83
Sweden	4.63	5.54	5.47	4.94	4.67	4.48	3.89	4.35
Switzerland	5.39	5.00	4.69	4.73	4.99	4.35	4.30	4.11
France	5.43	5.42	5.07	5.07	5.06	4.57		
Finland	10.00	11.54	10.51	9.05	8.67	8.64	7.77	8.34
New Zealand	7.52	7.29	7.18	7.74	7.52	7.68	7.59	7.32
Brazil	1.89	2.14	2.22	2.35	2.50	2.63	2.46	2.24
Canada	15.82	15.50	15.22	14.91	14.79	15.25	15.38	15.09
Austria	7.52	8.07	7.75	7.39	7.37	6.89	7.08	7.03

Source: World Development Indicators, The World Bank

Need for energy transition or diversification

- Climate breakdown requires energy transition
- Gradual substitution of fossil fuels
- Fossil fuels intensity drives economic activities
- Commentary between fossils and clean sources applicable to developing countries
- Substitution is viable for advanced economies

Published Case Study1: Do alternative energy sources displace fossil fuels?

- The study of York (2012) published in Nature Climate Change, 2(6), 441.
- Annual time series data of 1960-2009 for 132 countries.
- The dependent variable is Fossil-fuel electricity production per capita (kWh, hereafter kilowatt hours).
- These data are sourced from International Fossil-fuel energy use per capita (kilotonnes oil).
- The Model 1 and Model 2 consider GDP per capita as control variable only (in inflation adjusted US dollars).
- In Models 3 & 4:
- Urbanization,
- % of the GDP from the manufacturing sector, and
- the age-dependency ratio (the ratio of dependent aged people, those under 15 and over 64), non-dependent-aged people (those 15-64 years of age).

Table 1. Non-fossil-fuel displacement coefficients for models of electricity production and energy use from fossil-fuel sources

	Fossil-fuel electricity production per capita (kWh)		Fossil-fuel energy use per capita (kilotonnes oil equivalent)	
	Model 1	Model 2	Model 3	Model 4
Displacement coefficient for non-fossil-fuel energy sources per capita	-0.089*	-0.079*	-0.128*	-0.219*
Nations/Countries	132	128	132	128
Nation Years (Data: 1960-2009)	4,334	3,267	4,336	3,269

Note: Each coefficient represents the effect on fossil-fuel use from the addition of one unit of energy from non-fossil-fuel sources. In models 1 and 3, energy demand is controlled for using GDP per capita. In models 2 and 4, energy demand is controlled for using GDP per capita, urbanization (% of the population living in the urban area, manufacturing (% of GDP from the manufacturing sector) and the age-dependency ratio (the ratio of dependent-age people those under 15 and over 64, non-dependent-age people those 15-64 years of age).
*Statistically significant at the 0.05 alpha level. Source: Adopted from York (2012)

Analysing Fossil-Fuel Displacement

- **In Model 1**, **displacement coefficient of -0.089** indicates that each kilowatt hour of non-fossil-fuel electricity that is generated displaces at best only 0.089 kilowatt hours (kWh) of fossil-fuel-generated electricity.

- Therefore, to **displace 1 kWh of fossil-fuel electricity** requires generating more than 11 kWh (1/0.089=11.236) of non-fossil-fuel electricity.

- **In Model 2**, electricity production from non-fossil-fuel sources has a significant coefficient of 0.079.

- This coefficient indicates that close to 13 kWh (1/0.079=12.658) of non-fossil electricity are needed to **displace 1 kWh of fossil-fuel** electricity.

- Models 3 and 4 examine the total national energy use (that is, electricity plus other uses) per capita from fossil-fuel sources (in kilotonnes oil equivalent).

- **In Model 3**, the coefficient for energy use from non-fossil-fuel sources is **-0.128**, indicating that it takes nearly **eight units (1/0.128=7.813) of non-fossil energy to displace one unit of fossil-fuel total energy**.

- **In Model 4**, Energy use from non-fossil-fuel sources has a significant coefficient of **-0.219**, the **strongest coefficient of any model**. This coefficient indicates that more than 4.5 units (1/0.219=4.566) of non-fossil-fuel energy are required to displace one unit of fossil-fuel energy.

Table 2. Nuclear, hydro and non-hydro renewable sources (non fossil-fuels)* displacement coefficients for models of electricity production from fossil-fuel sources

	Fossil-fuel electricity production per capita (kWh)	
	Model 5	Model 6
Displacement coefficient for nuclear energy per capita	-0.221*	-0.163*
Displacement coefficient for hydropower per capita	-0.099*	-0.086*
Displacement coefficient for non-hydro renewable sources per capita	0.048	0.018
Nations	132	128
Nation years	4,334	3,267

Note: In model 5, energy demand is controlled for using GDP per capita. In model 6, energy demand is controlled for using GDP per capita, urbanization, manufacturing and the age-dependency ratio. *Statistically significant at the 0.05 alpha level. It is non-carbohydrate energy sources which do not emit carbon when generated (hydropower, geothermal and solar power, combustible renewable and waste).

Results Discussion

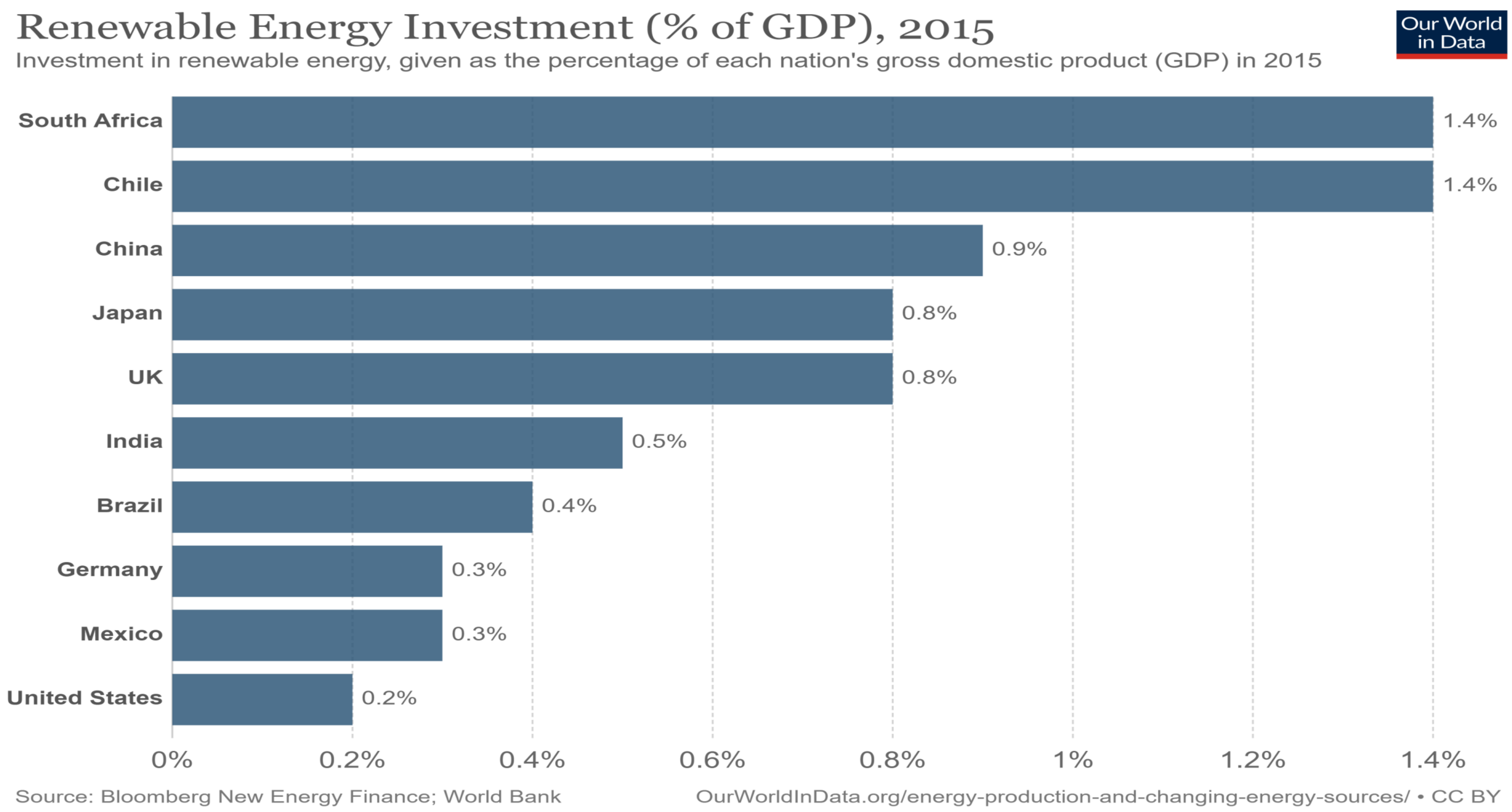
- Model 5 indicates that nuclear power displaces more fossil-fuel electricity than other sources, but
- still not a substantial amount, with a coefficient of -0.221. Hydropower displaces less, with a coefficient of -0.099.
- Non-hydro renewable sources have a positive coefficient, indicating the opposite of displacement, but
- this coefficient is not significantly different from 0, indicating that renewables tend to simply be added to the energy mix without displacing fossil fuels.
- Model 6 indicates a similar pattern, where nuclear power displaces the most fossil-fuel electricity, with a coefficient of -0.163, hydropower displaces less, with a coefficient of -0.086, and
- non-hydro renewables do not displace, with a non-significant coefficient of 0.018.

Justification for the results

- The lack of a significant displacement effect from non-hydro renewables is not necessarily that surprising,
- Small proportion of non-fossil-fuel sources (less than 4% of the world total).
- As they have been deployed only on a small scale.
- Hydroelectric dams are often developed for flood control, irrigation and navigation, with the electrical output being merely one of the purposes.
- In contrast, nuclear power plants are typically developed primarily for electricity generation.
- Do alternative energy sources displace fossil fuels? is yes, but only very modestly.
- The failure of non-fossil energy sources to displace fossil ones is probably
- because of their long-standing prevalence and existing infrastructure and to the political and economic power of the fossil-fuel industry.

Yorks' research observation

- Growth dynamics in pursuit of profit but not a concern for conservation.
- It's an addition to total energy but not a transition
- Need to replace fossil fuels if we are to avert to climate crisis (York and Bell, 2019).
- He argues for a shift in policy, rather than pursuing technological change only.
- However, bringing more green technologies do not actually decrease our use of fossil fuels.
- "If we are to truly solve the challenges our environment is facing in the future, we need to consider our own behaviors and attitudes."


Renewable Energy Investment (% of GDP), 2015
Investment in renewable energy, given as the percentage of each nation's gross domestic product (GDP) in 2015
Our World in Data
South Africa
1.4%
Chile
1.4%
China
0.9%
Japan
0.8%
UK
0.8%
India
0.5%
Brazil
0.4%
Germany
0.3%
Mexico
0.3%
United States
0.2%
0%
0.2%
0.4%
0.6%
0.8%
1%
1.2%
1.4%
Source: Bloomberg New Energy Finance; World Bank
OurWorldInData.org/energy-production-and-changing-energy-sources/ • CC BY

Energy transitions or additions?

- **Energy transitions (Grayson, 2017; Smil, 2017; York & Bell, 2019)**

- **Change in the composition (structure) of primary energy supply**
- **Gradual shift from a specific pattern of energy provision to a new state of an energy system**
- **Coal surpassed biomass-energy transitions and petroleum overtook coal-energy additions (York & Bell, 2019)**

- **Why energy transitions?**

- **Rising demand, energy intensity and climate change triggered energy transitions**
- **Societies need a transition in how they produce and consume energy.**
- ***"Transitions from fossil fuels"* (dirty) to new energy (clean) has risen to dominance (Grayson, 2017)**
- **The transition from fossil fuels is well under way.**
- **Each year sees an increase in the amount of electricity generated from renewable sources (Grayson, 2017 sourced from Nature).**
- **Energy transitions are initiated in pursuit of energy security.**
- **Towards low-carbon system as a way to mitigate climate change**

Historical pattern of energy additions or energy transitions

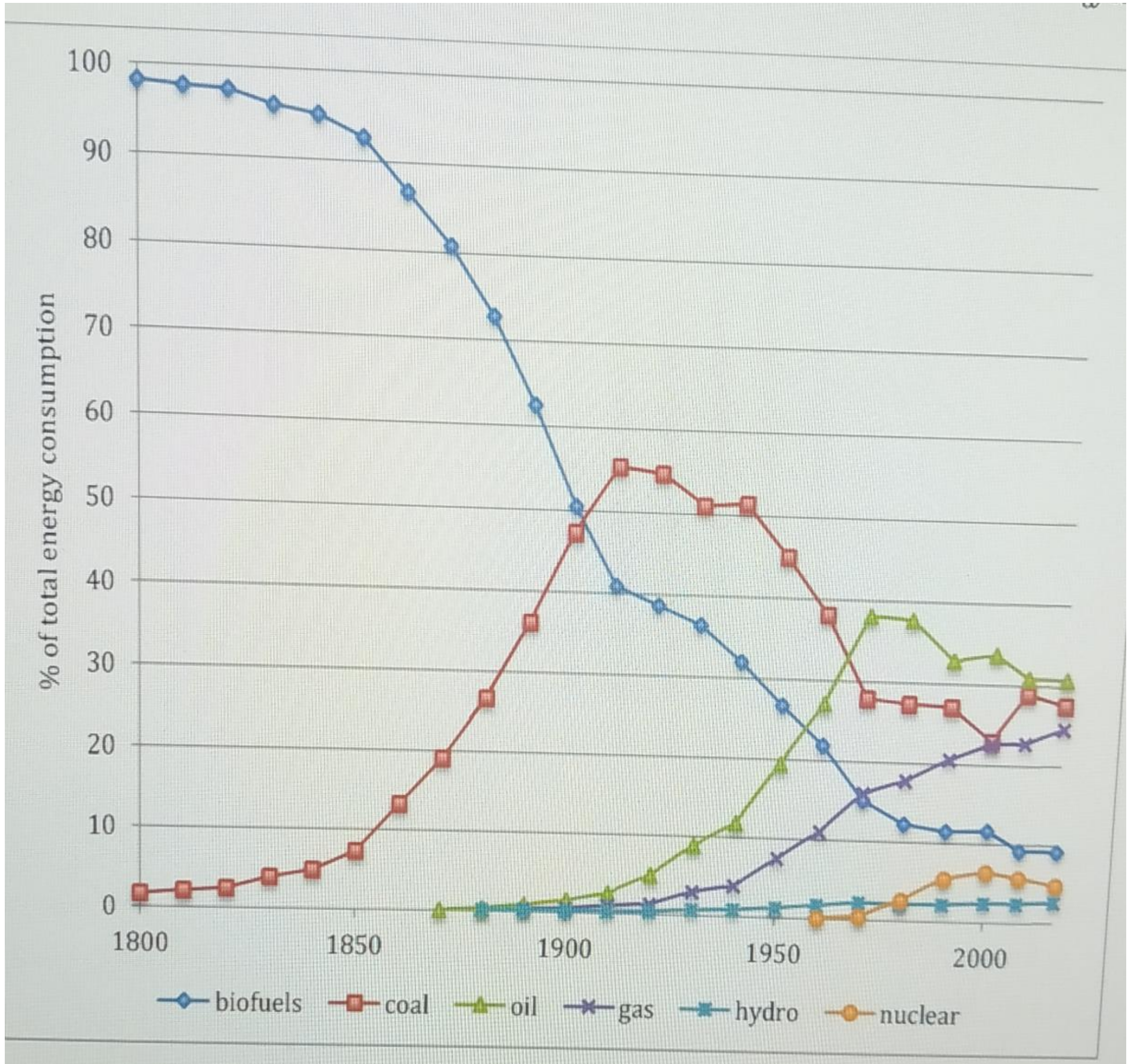


Fig. 1. Percentage of global energy consumption from various sources.1800–2017.

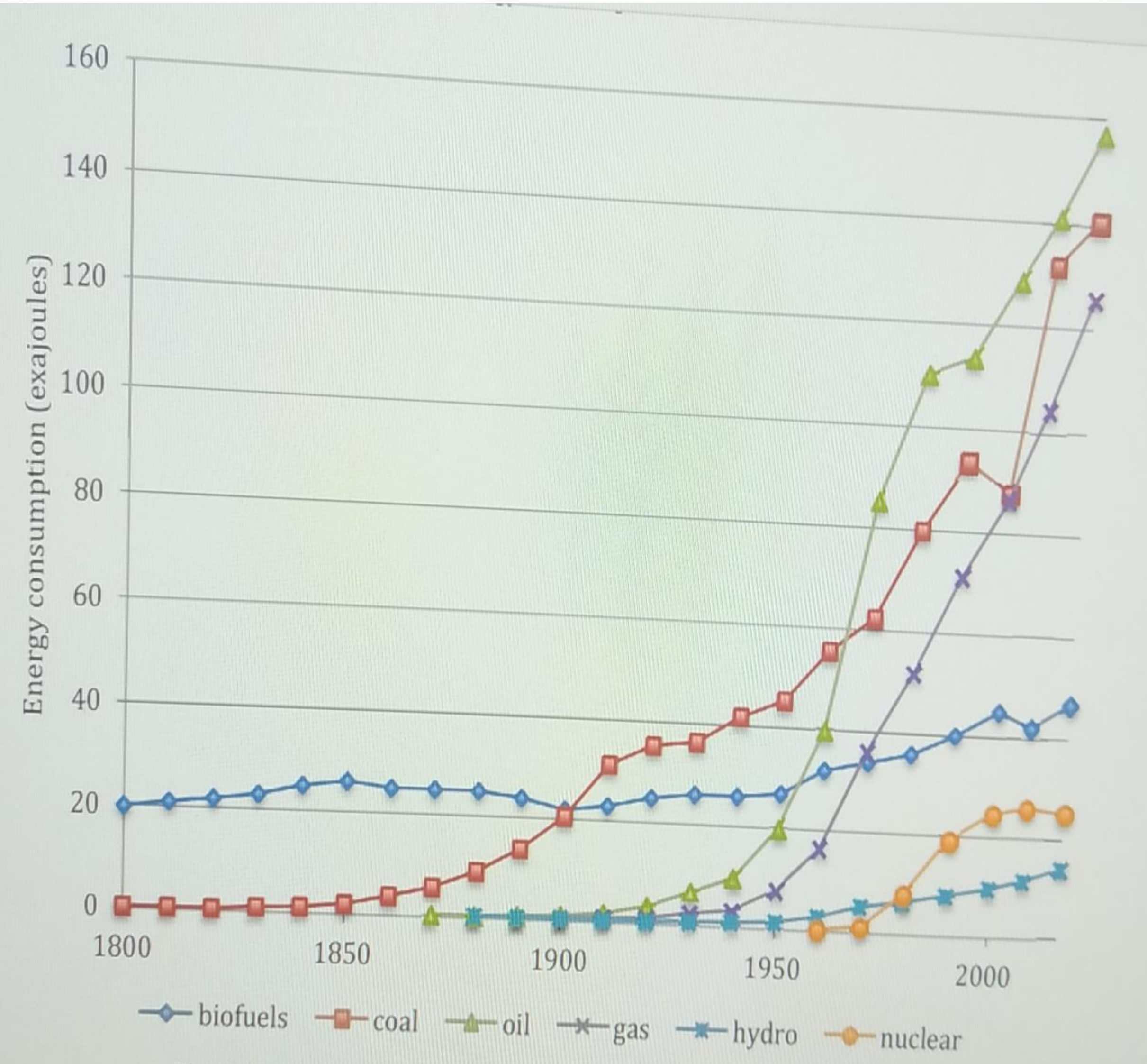
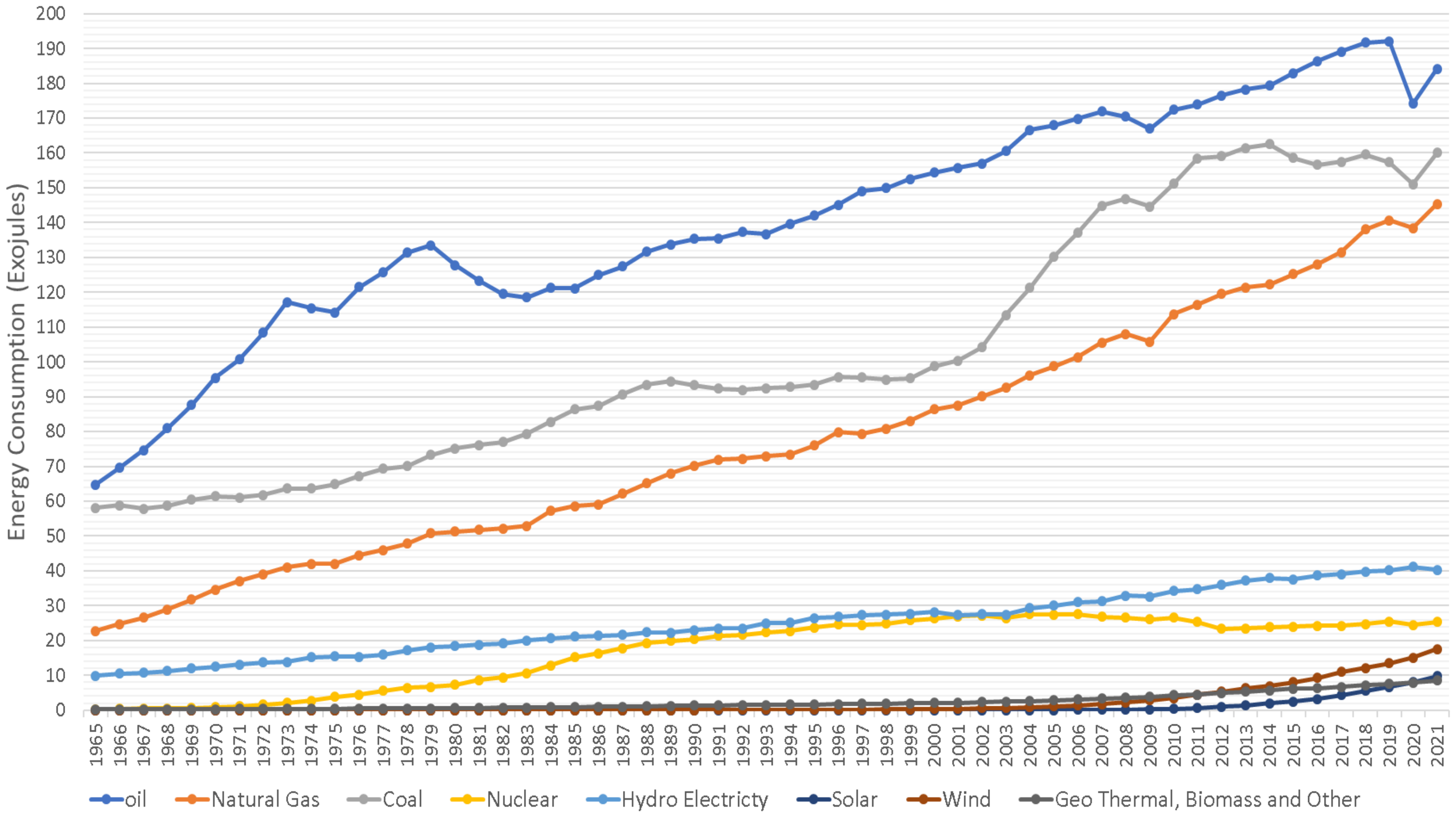


Fig. 2. Global energy consumption (exajoules) by source.1800–2017.

Source: Adopted from York and Bell, 2019

https://commons.wikimedia.org/wiki/Data:Global_primary_energy_share_(Smil_%26_BP)_(OWID_3110).tab

Recent pattern of primary energy at global level



Source: British Petroleum (BP) Statistics

Case Study: Indian States' Electricity Transition (SET)

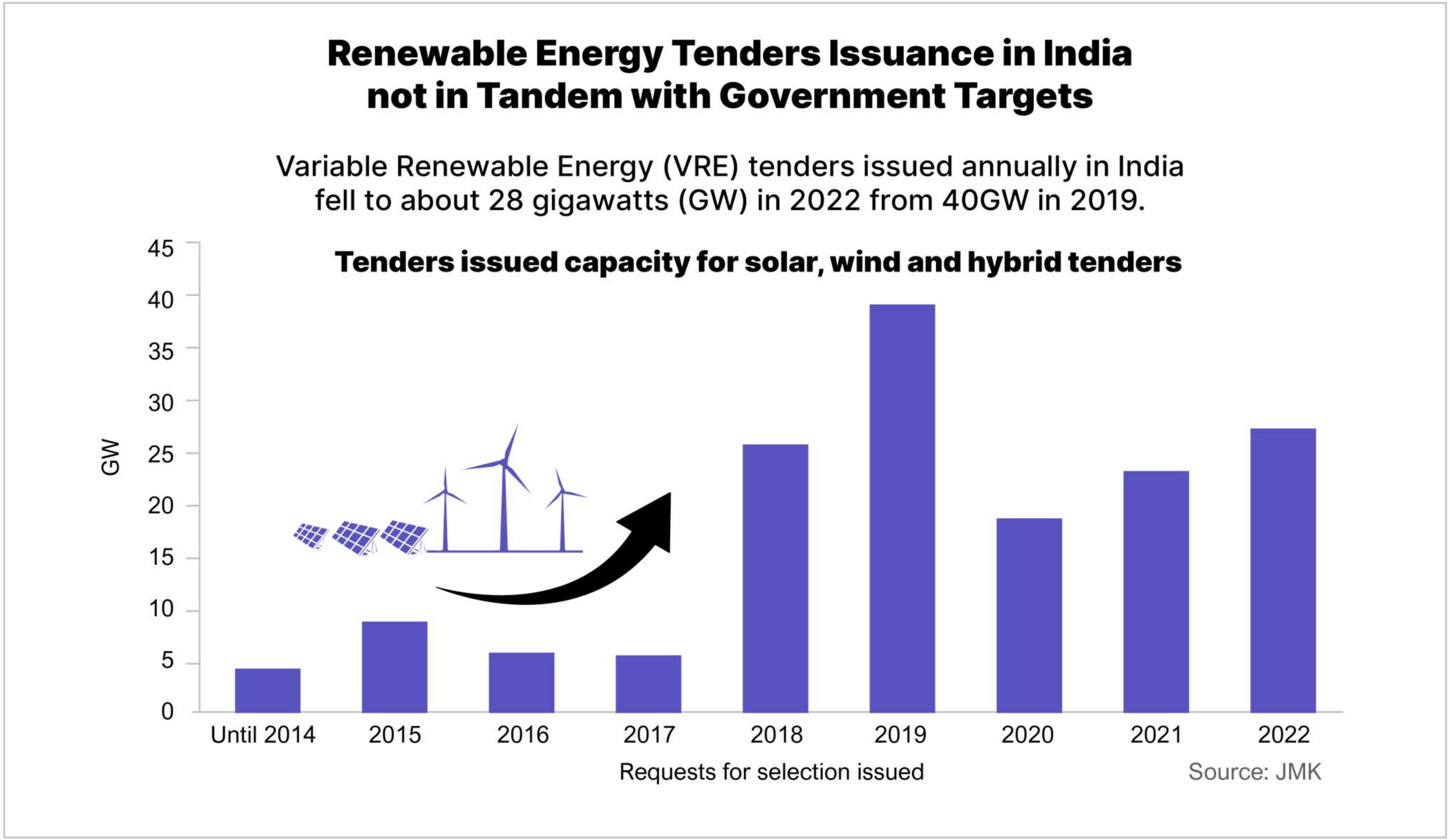
- India, now with the G20 Presidency, will be key to the electricity transition.
- It ranks 8th in the Climate Change Performance Index (CCPA) 2023 and
- earned high ratings in the Green House Gases (GHG) Emissions and Energy Use categories
- a medium for Climate Policy and Renewable Energy.

https://ieefa.org/resources/indian-states-electricity-transition-set

Report from Institute for Energy Economics and Financial Analysis

India’s global commitments

- India’s global commitments, made at the COP26 climate conference in 2021, includes 500 gigawatts of non-fossil electricity capacity.
- 50% cumulative electric power installed from non-fossil fuel resources, reducing carbon emissions by one billion tonnes and reducing emissions intensity of its gross domestic product by 45%.
- The government has set a deadline of 2030 to achieve all these targets as well as achieve net zero by 2070.



https://ieefa.org/articles/india-needs-increase-renewables-tender-issuance-meet-clean-energy-targets

- **We analysed 16 Indian states that account for 90% of the country’s annual power requirement on four key dimensions of electricity transition.**

- We identified and finalised these dimensions through several expert consultations.

❑The dimensions are:

1) **Decarbonisation** -state’s preparedness to shift away from fossil-based power

2) **Performance of the power system** -state’s ability to incentivise greener market participation

3) **Readiness of the power ecosystem-**state’s power system reliability to ensure electricity supply for the transition

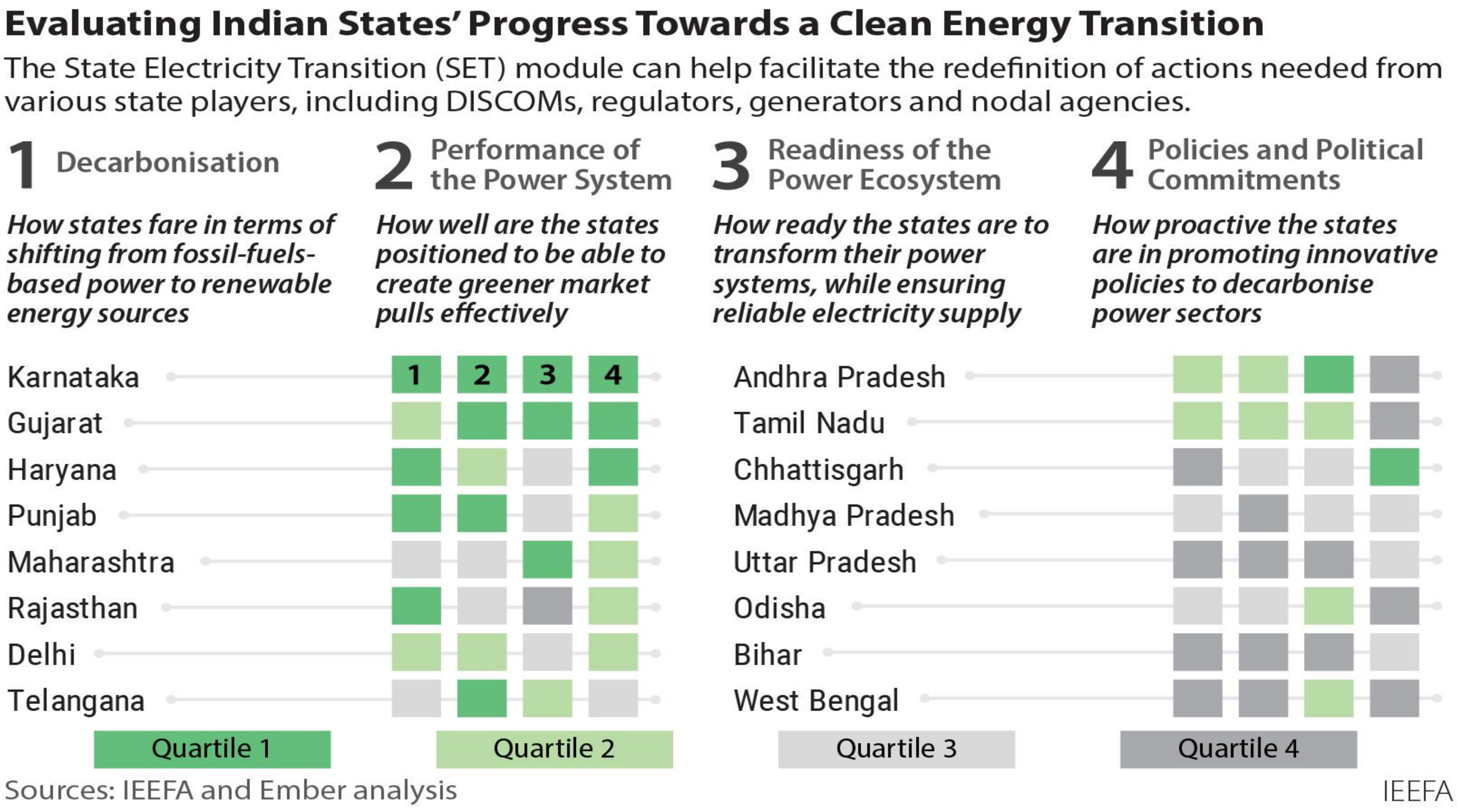
4) **Policies and political commitments** -state’s policies to push for power sector decarbonisation

- While India’s revised Nationally Determined Contribution (NDC) targets put it on the right path for transitioning its electricity sector,

- it needs the cooperation of its states.

- Renewable energy-rich states are not utilising their renewable energy generation potential.

Macro Performance of 16 States on Electricity Transition Dimensions



❑Key messages:

- Indian states have shown notable clean electricity transition performance.

- The performance of states like Karnataka, Gujarat, Haryana, and Punjab, which have demonstrated considerable efforts in overall preparedness and committed capabilities to promote clean electricity.

- This indicates the progress of Indian states towards a clean electricity transition.

- Few other states (Odisha, Bihar and West Bengal) are in the bottom list performance because they depend on coal

- State energy departments also need to strengthen electricity infrastructure for better integration of renewables.
- States must also increase participation in green market mechanisms and have more favourable policies for the same.
- States must also improve data transparency for better evaluation of their progress to take corrective measures.
- Finally, states must also bridge the gap between electricity transition policy intent and implementation.

Dealing with climate change and global warming Issues

- ✓ What the tool of choice should be?
- ✓ How the problems should be approached?
- ✓ How humankind uses energy for its needs and reconciles it with social, environmental, and economic interests.
- ✓ Nationalising fossil fuels companies as we are in extreme times (Gowan, 2018)
- ✓ Immediate calls for fair energy transitions
- ✓ The current energy transitions should not be viewed through just one lens.
- ✓ It is not merely an issue of technology or resource availability
- ✓ It is about history, democracy, economics and society (Grayson, 2017; York, 2012, York & Bell, 2019).

How can we speed up the transition to renewable energy?

- **Our vision is for a clean, green, and equitable energy future.**
- **The world needs at least a nine-fold increase in renewable energy production to meet the Paris Agreement climate goals and much more to achieve net zero emissions by 2050.**
- **The rapid transition to renewable energy will be good for people and the planet.**
- **But the land-use footprint for this buildout will be large because renewable energy infrastructure requires a lot of land—especially onshore wind and large-scale solar installations.**
- **This raises the potential for land-use conflicts over renewable energy.**
- **We need to go smart to go fast—deploying renewable energy in ways that support goals for climate, conservation, and communities.**

Pollution Potential of Alternative Energy Sources

- Alternative energy will suppress fossil-fuel energy production in equal proportion is clearly wrong.

- Non-fossil-fuel energy sources contribute to serious environmental impacts of their own.

- The recent disaster at the Fukushima Dai-Ichi nuclear power plant in Japan (March, 2011) is enough

- to highlight the risks associated with expanding nuclear power plant,

- risks stemming from long-term nuclear waste disposal and the environmental damage caused by uranium mining (Nature Climate Change, 2011).

- ✓ Major earth-quake and tsunami severely damaged the plant,
- ✓ highlights the threats created for societies by the technologies they rely on and raises questions what can be learned and how societies handle risky technologies and disasters.

- Hydroelectric power:

- It is not entirely without environmental impacts.
- It’s air pollution impact is zero because it is derived from the energy of falling water and no fuels are burned.
- It destroys river/aquatic ecosystems and threatens the survival of fish and other aquatic species (Stone, 2011).
- Water pollution can be avoided by proper design of installations.

- Solar and wind power: It has less environmental threats than nuclear power and hydropower.

- It requires large amounts of material;
- It requires large areas of land to produce substantial amounts of energy (Smil, 2003).
- In short, all energy sources have environmental costs.
- This implies that the concept of green energy does not exist at all.

Understanding the Jevons Paradox (1865) and Its Implications on the environment

- **Energy Intensity (EI)**= Energy Consumption (EC)/Gross Domestic Product (GDP) ---------(1)
- **Energy Efficiency (EE)**=GDP/EC -----------------(2)
- Energy Efficiency is typically measured as economic output (GDP) per unit of energy.
- Energy intensity is simply the inverse of efficiency (e.g. intensity is units of energy consumed per unit of economic output produced).

W. Stanley Jevons’ Paradox (1865) in his book “Coal Question”

- Economical use of fuel is equivalent to diminished consumption.
- Jevons paradox is known as the rebound effect (Herring and York, 2006).
- Greater energy efficiency, while in the short-run producing energy savings.
- It may in the long-run result in higher energy use.

- The expansion of fuel using activities is less than 100% of the improvement in efficiency) then

✓ energy efficiency lowers energy consumption

- The expansion of fuel using activities is greater than 100% of the improvement in efficiency) then

✓ energy efficiency increases energy consumption

❑ For example:

- Profits gained by lowering the costs of production were often reinvested, further increasing the scale of production.

- The lower costs that came with increasing efficiency also made goods affordable to more people, and latent demand increased commodity consumption.

- Thus, improvements in efficiency often led to an overall increase of resource consumption because **the scale of production increased more rapidly than efficiency improved**.

Case Study Example: Understanding the Jevons paradox

- Jevons association is common within the frameworks of time series and panel analysis.
- A positive correlation between efficiency and resource consumption) and,
- the causal relationships that underlie this association.

TABLE-1* (Adopted from York and McGee, 2015)
Correlations of energy use per capita and total with energy efficiency (GDP/energy use) for **time-series in China (1971–2011) and across nations (2010).**
*Note: *** p < .001, † p < .05*

	Unlogged Variables (Pearson's r)	Logged Variables (Pearson's r)
China, 1971–2011 (N = 41)		
Energy use p.c. and GDP/ energy use	.892***	.910***
Energy use total and GDP/ energy use	.915***	.945***
Cross-national (N = 131)		
Energy use p.c. and GDP/ energy use	.158†	.360***
Energy use total and GDP/ energy use	.007	.071

TABLE-2 **(Adopted from York and McGee, 2015)**

Random-effects generalized least squares panel regression elasticity models of factors influencing change in energy use per capi electricity consumption per capita, and CO_2 emissions per capita, 1960–2010.

	Δ Energy use p.c. Coefficient (S.E.)	Δ Elec. cons. p.c. Coefficient (S.E.)	Δ CO2 emissions p.c. Coefficient (S.E.)
Efficiency	.092*** (.010)	.111*** (.011)	.221*** (.017)
Δ GDP per capita	1.234*** (.189)	1.243*** (.222)	1.327*** (.297)
Δ (GDP p.c.)2	−.044*** (.012)	−.049** (.014)	−.041* (.019)
Δ Urbanization	.297* (.133)	.124 (.165)	.355 (.187)
Δ Manufacturing	.064** (.023)	.088** (.028)	.076* (.032)
R2 (overall)	.453	.435	.255
N	602/122	594/121	925/168

Why does Green growth matter?

- OECD (2011): green growth is about

✓ Fostering economic growth and development.

✓ Providing environmental services on which our well-being relies.

✓ Reducing environmental risks and ecological scarcities (The United Nations Environment Programme, 2011).

✓ Green economy is low carbon, resource efficient, and socially inclusive (**Hallegatte et al., 2012**).

✓ Green growth occurs if negative externality corrected [**Porter & Linde, 1995**]

Transition to a green economy

- "Green growth means
  - fostering economic growth and development
  - while ensuring that natural assets continue to provide the
  - resources and environmental services on which our well-being relies" (OECD 2011, p. 9).

- ✓ Enhance energy and resource efficiency.
- ✓ Prevent the loss of biodiversity and ecosystem services.
- ✓ Rebuild natural capital as a critical economic asset and as a source of public benefits.
- ✓ This is important for poor people whose livelihoods and security depend on nature.