ROMA TRE
UNIVERSITÀ DEGLI STUDI
Dipartimento di Scienze

ORDINE DEI GEOLOGI DEL LAZIO

SAPIENZA
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Dipartimento di Scienze della Terra

UNIVERSITÀ DEGLI STUDI ROMA TRE
SAPIENZA UNIVERSITÀ DI ROMA
ORDINE DEI GEOLOGI DEL LAZIO
presentano
LA GEOLOGIA NEL MONDO DEL LAVORO

Una transizione energetica sostenibile
Le Scienze della Terra e i sistemi energetici

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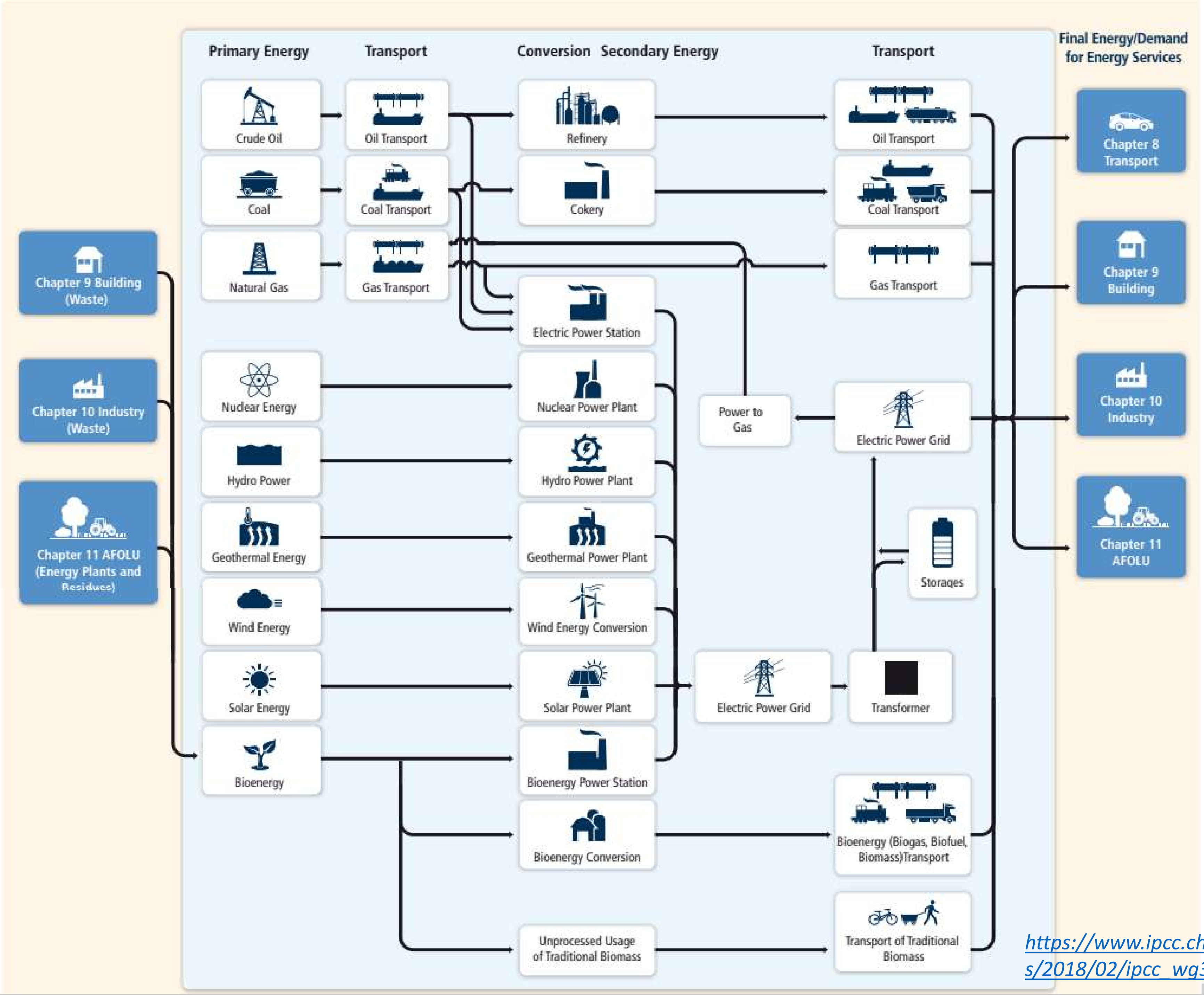
7 marzo 2024

https://www.socgeol.it/N5518/il-ruolo-delle-geoscienze-nella-transizione-energetica.html

What is an Energy System?

Glossary – Energy Syst



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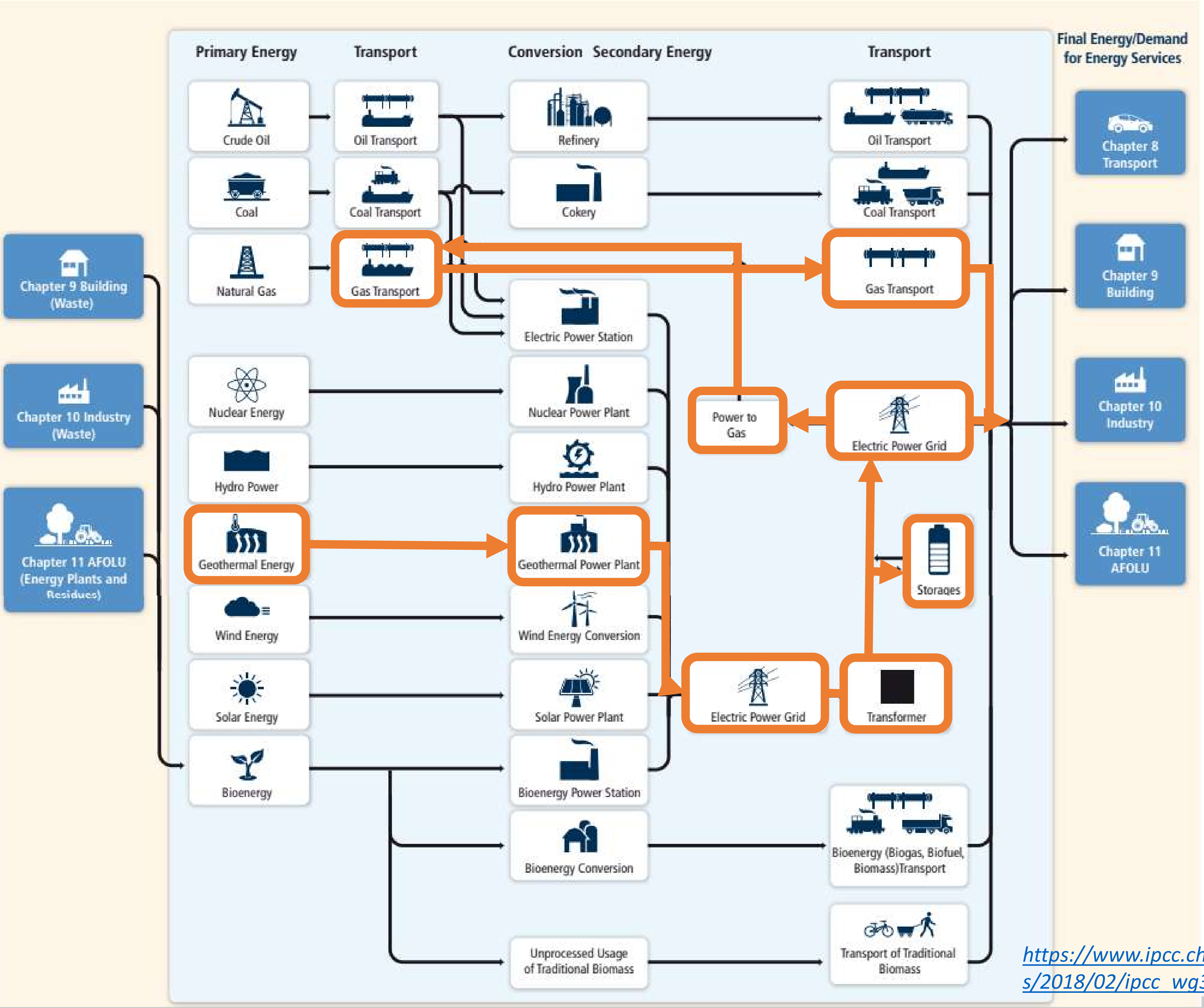
Glossary – Energy Syst



https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf

Sustainability/ Sustainable Sostenibilità/Sostenibile

Oxford Learner's Dictionaries

Sustainability */səˌsteɪnəˈbɪləti/ /səˌsteɪnəˈbɪləti/ noun*

- the use of natural products and energy in a way that does not harm the environment
- the ability to continue or be continued for a long time

Sustainable /səˈsteɪnəbl/ /səˈsteɪnəbl/ *adjective*

- involving the use of natural products and energy in a way that does not harm the environment
- *a company well-known for its commitment to environmental sustainability*
- *an environmentally sustainable society*

TRECCANI

Sostenibilità */so·ste·ni·bi·li·tà/ sostantivo femminile*

- possibilità di essere mantenuto o protratto con sollecitudine e impegno o di esser difeso e convalidato con argomenti probanti e persuasivi.
- possibilità di essere sopportato, spec. dal punto di vista ecologico e sociale.

Sostenìbile */ so·ste·ni·bi·le / aggettivo*

- che si può sostenere: *una tesi difficilmente sostenibile*.
- che può essere affrontato: *una spesa s.*; *questa situazione non è più s*.
- compatibile con le esigenze di salvaguardia delle risorse ambientali: *energia s.*; *sviluppo s.*

No universally agreed definition of sustainability: many different viewpoints on this concept and on how it can be achieved.

Sustainable = an adjective for something that is able to be sustained, i.e, something that is "bearable" and "capable of being continued at a certain level".

Sustainability = **sustain + able + ity**. To sustain = "to give support to", "to hold up", "to bear" or "to keep up".

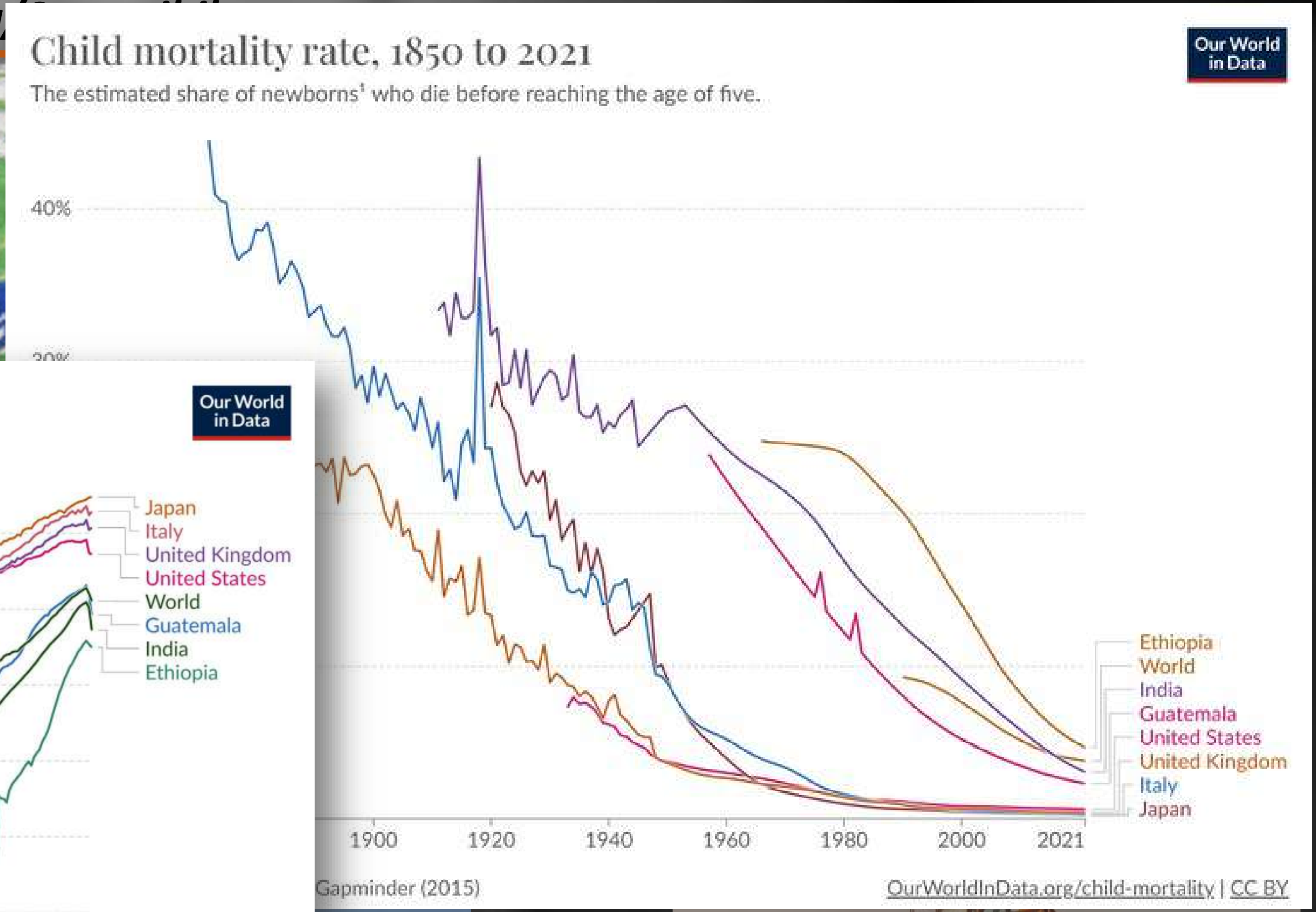
Sustainability can perhaps be seen as **the process(es) by which something is kept at a certain level**.

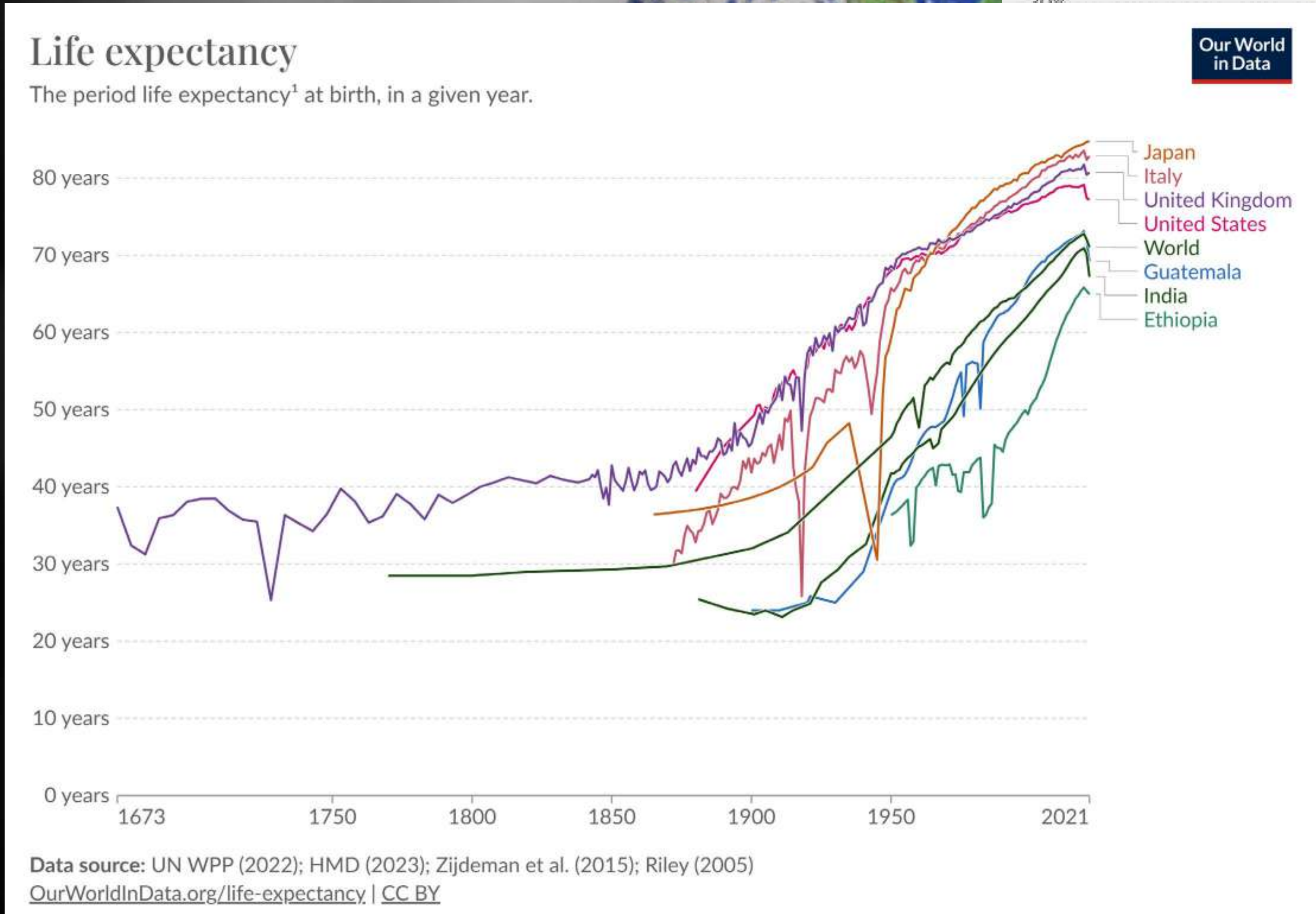
Nonetheless, nowadays, because of the environmental and social problems, societies around the world are facing, sustainability has been increasingly used in a specific way.
Sustainability is usually defined as the **processes and actions through which humankind avoids the depletion of natural resources, in order to keep an ecological balance that doesn't allow the quality of life of modern societies to decrease.**

Sustainability/ Sustainable *Sostenibilità/Sostenibile*

Sustainability/ Sustainable *Sostenibilità/Sostenibile*

Sustainability/ Sustainable *Sostenibilità/...*





Sustainable development

1972. UN Stockholm Conference on the Human Environment. First hints on international environmental law. Final report: **Declaration on the human environment**, containing key principles:

- configuration of the environment as a legal asset, the protection of which is not subordinated to respect for other state interests;
- extension of environmental protection to spaces located outside state sovereignty, such as the open sea, extra-atmospheric space, Antarctica;
- international cooperation for environmental protection purposes

1983. UN report **"Our Common Future"** of the World Commission on Environment and Development (WCED) on the world environment and development situation. The report laid the foundations for the modern concept of sustainable development and for the finalization of sectorial treaties based on damage prevention and cross-border pollution

1992. UN Rio de Janeiro Conference. Compatibility between economic development and environmental protection, with the extension of international cooperation on global environmental issues and the signing of universal agreements based on the precautionary principle

Sustainable development:

a development capable of ensuring the satisfaction of the needs of the present generation without compromising the possibility of future generations to make their own

«uno sviluppo in grado di assicurare il soddisfacimento dei bisogni della generazione presente senza compromettere la possibilità delle generazioni future di realizzare i propri»

1983: WCED report (World Commission on Environment and Development ; **Brundtland report**).
For the first time, the concept of sustainability is connected to the **compatibility between development of economic activities and environmental protection**. Proposals are made to **governments, international organizations and individual citizens**

A **new growth model** is proposed: a global development that does not alter the environment up to the point of compromising the possibility of future generations to meet their needs for the enjoyment of natural resources.

A **new way of managing economic relations between States**, which will have to guarantee a sustainable use of natural resources, **exploiting non-renewables** in such a way not to cause their rapid depletion **and renewables** taking due account of their regeneration capacity and impacts on the environment.

The concept of sustainable development must guide **international regulatory production** aimed at protecting the environment. Development policies can no longer be separated from considering tools and measures that protect nature and the ecosystem.

Sustainable development

TRECCANI
encyclopedia

Environmental and economic sciences: the condition for a development capable of guaranteeing the satisfaction of the needs of the current generation without compromising the possibility that future generations will satisfy their own.

Sustainability, in terms of environmental contents, derives from the study of **ecological systems**:
carrying capacity, self-regulation, resilience and resistance are crucial and influence the stability of an ecosystem.

A balanced ecosystem is implicitly sustainable; the greater its stability, the greater its self-regulation capacity with respect to internal and external factors which tend to alter its state of equilibrium. **Relations with the anthropic system are the most disturbing factor for an ecosystem.**

The **interaction between complex eco- and anthropic systems** increases the probability of disturbances and the risk of non-linear reactions, which are irreversible alterations of the balance of an ecosystem, bringing it towards the load capacity (or recovery) threshold values of the system itself.

The response and regulation capacity of the systems affected by the perturbations increases as the structural and functional variety of the system increases.

Definitions

Sustainable development

TRECCANI *encyclopedia*

Environmental and economic sciences: the condition for a development capable of gua needs of the current generation without compromising the possibility that future gener

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Agenda 2030 & the SDGs

- **1992, Earth Summit, Rio de Janeiro***:* >178 countries adopt **Agenda 21**, a global action plan to build a global partnership for sustainable development, to improve human life and protect the environment.
- **2000: New York.** *A*doption of the *Millennium Declaration* with 8 **Millennium Development Goals** (MDGs) developed to reduce extreme poverty by 2015.
- **2002: UN World Summit, Johannesburg***:* the **Declaration on Sustainable Development** reaffirms the commitment of the global community to eradicate poverty and protect the environment**.**
- **2012: United Nations Conference on Sustainable Development (Rio + 20):** adoption of the document "**The Future We Want**" with the establishment of the United Nations high-level political forum on sustainable development.
- **2013***:* the General Assembly establishes an open working group of 30 members to develop GDS proposal
- **2015**: the General Assembly (Paris) adopts the *2030* ***Agenda for sustainable development***, with *17 SDGs*.

"The **2030 Agenda for Sustainable Development** provides a shared model for peace and prosperity for people and the planet, now and in the future".

17 Sustainable Development Goals: an urgent **call to action** recognizing that *ending poverty* must go hand in hand with strategies that *improve health and education*, *reduce inequality* and *stimulate economic growth*, *tackling climate change* and *preserving oceans and forests*.

Agenda 2030: 17 Goals + 169 Targets + 242 Indicators

NO POVERTY: End poverty in all its forms

ZERO HUNGER: End hunger, achieve food security, improve nutrition and promote sustainable agriculture

GOOD HEALTH AND WELL-BEING. Ensure healthy lives and promote well-being for all at all ages

QUALITY EDUCATION. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

GENDER EQUALITY. Achieve gender equality and empower all women and girls

CLEAR WATER AND SANITATION. Ensure availability and sustainable management of water and sanitation for all

AFFORDABLE AND CLEAN ENERGY. Ensure access to affordable, reliable, sustainable and modern energy for all

DECENT WORK AND ECONOMIC GROWTH. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work conditions for all

Agenda 2030: 17 Goals + 169 Targets + 242 Indicators

INDUSTRY INNOVATION AND INFRASTRUCTURE. Build resilient infrastrucures, promote inclusive and sustainable industrialization and foster innovation

REDUCE INEQUALITIES. Reduce inequalities within and among countries

SUSTAINABLE CITIES AND COMMUNITIES. Make cities and human settlements inclusive, safe, resilient and sustainable

RESPONSIBLE CONSUMPTION AND PRODUCTION. Ensure sustainable consumption and production patterns

CLIMATE ACTION. Take urgent action to combat climate change and its impacts

LIFE BELOW WATER. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

LIFE ON LAND. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and biodiversity loss

PEACE, JUSTICE AND STRONG INSTITUTIONS. Promote peaceful and inclusive societies, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

PARTNERSHIP FOR THE GOAL. Strenghten the means of implementation and revitalize the Global Partnership for Sustainable Development

Goals – Targets - Indicators

7 AFFORDABLE AND CLEAN ENERGY

Ensure universal access to affordable, reliable and modern energy services

targets | indicators

Goals and targets (from the 2030 Agenda for Sustainable Development)	*Indicators*
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all	
7.1 By 2030, ensure universal access to affordable, reliable and modern energy services	7.1.1 Proportion of population with access to electricity 7.1.2 Proportion of population with primary reliance on clean fuels and technology
7.2 By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1 Renewable energy share in the total final energy consumption
7.3 By 2030, double the global rate of improvement in energy efficiency	7.3.1 Energy intensity measured in terms of primary energy and GDP
7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology	7.a.1 International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems
7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support	7.b.1 Investments in energy efficiency as a proportion of GDP and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services

1. **Access to electricity**
2. **Access to clean cooking**
3. **Growth of renewables in the energy mix**
4. **Improving of energy intensity**

stainabledevelopment.un.org/topics/sustainabledevelopmentgoals
https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202019%20refinement_Eng.pdf

Goals – Targets - Indicators

7 AFFORDABLE AND CLEAN ENERGY

Ensure universal access to affordable, reliable and modern energy services

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stainabledevelopment.un.org/topics/sustainabledevelopmentgoals

https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202019%20refinement_Eng.pdf

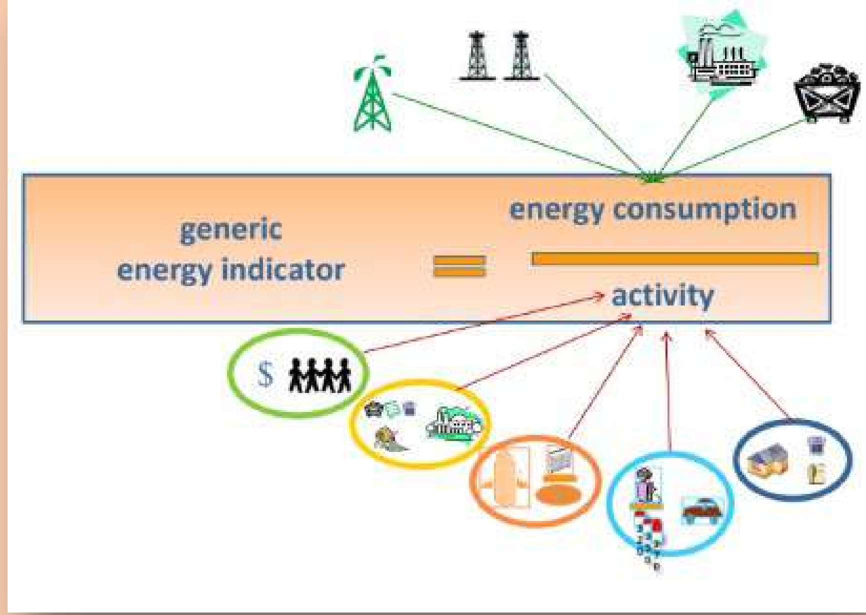
Goals – Targets - Indicators

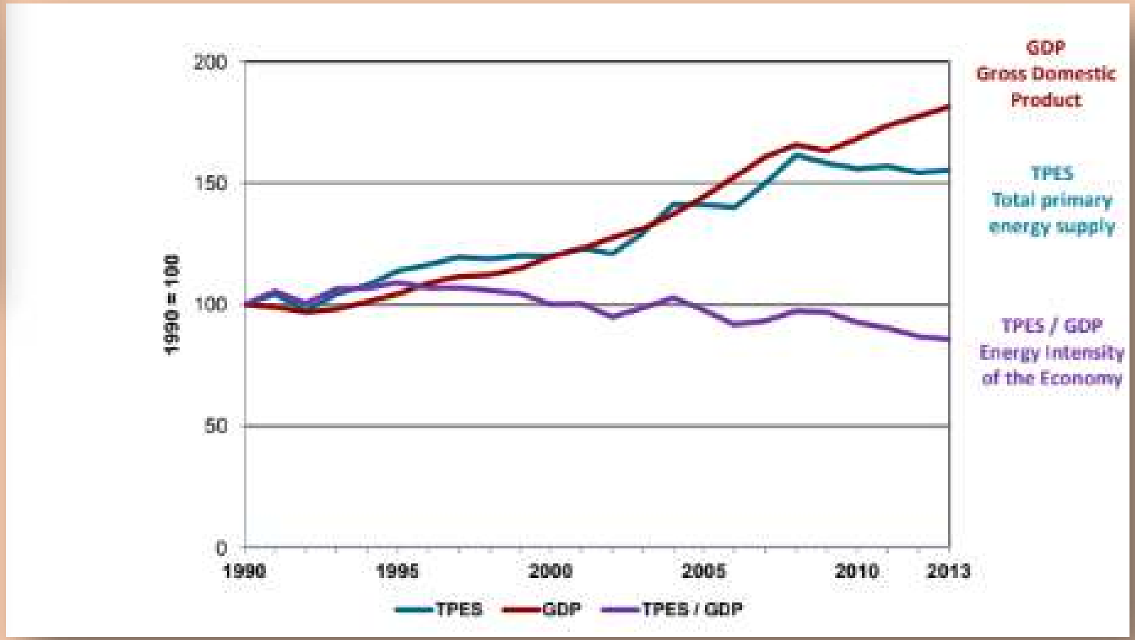
1. **Access to electricity**
2. **Access to clean cooking**

...nsity

Energy Intensity: energy (TPES) per unit activity (GDP).

Variable due to several reasons: e.g. changes in economic structure, climate, ...





...developmentgoals

https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202019%20refinement_Eng.pdf

What other goals/targets may be involved in Goal7?

7 AFFORDABLE AND CLEAN ENERGY

Ensure universal access to affordable, reliable and modern energy services

SDG & Ene

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7 AFFORDABLE AND CLEAN ENERGY

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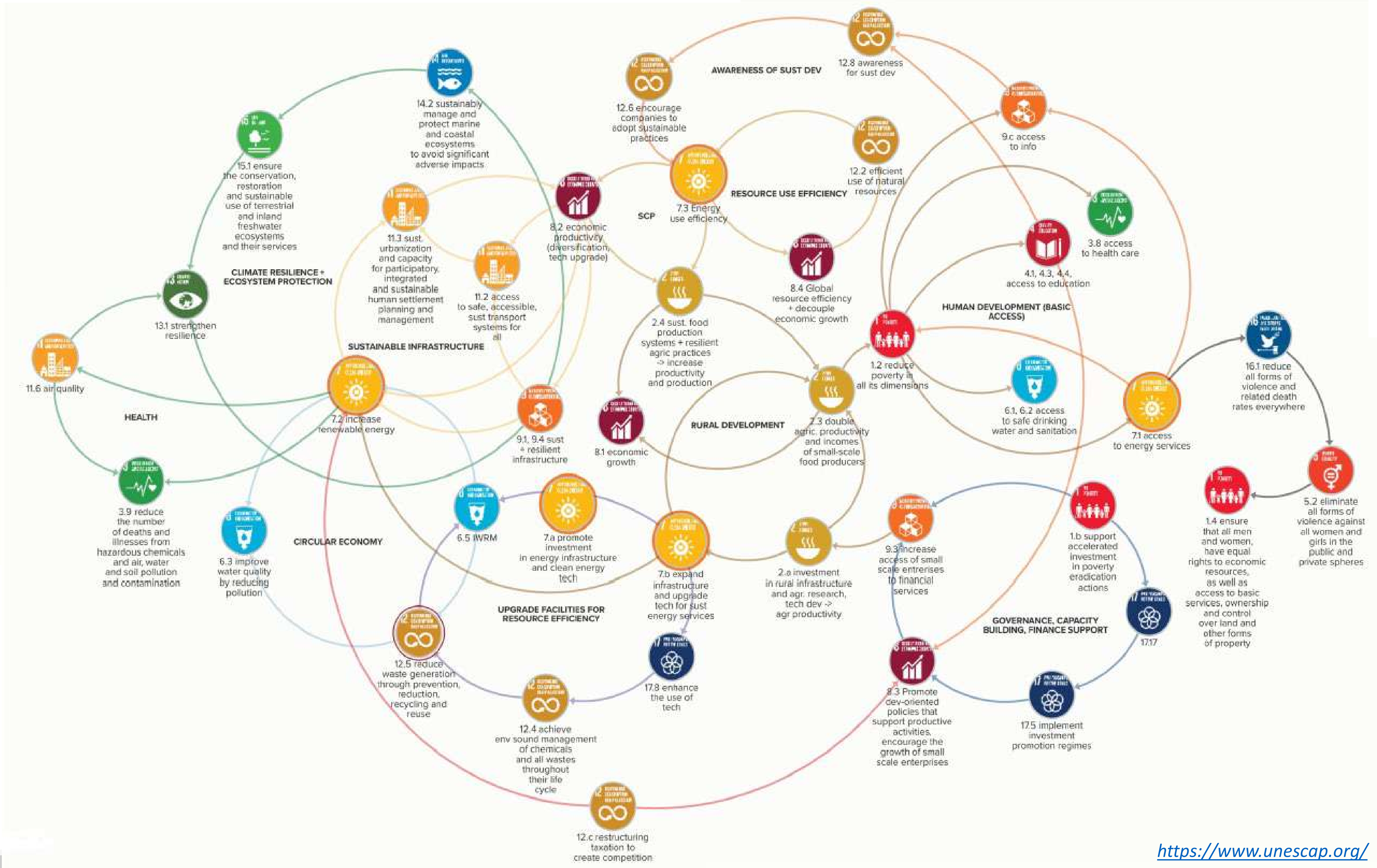


https://www.unescap.org/

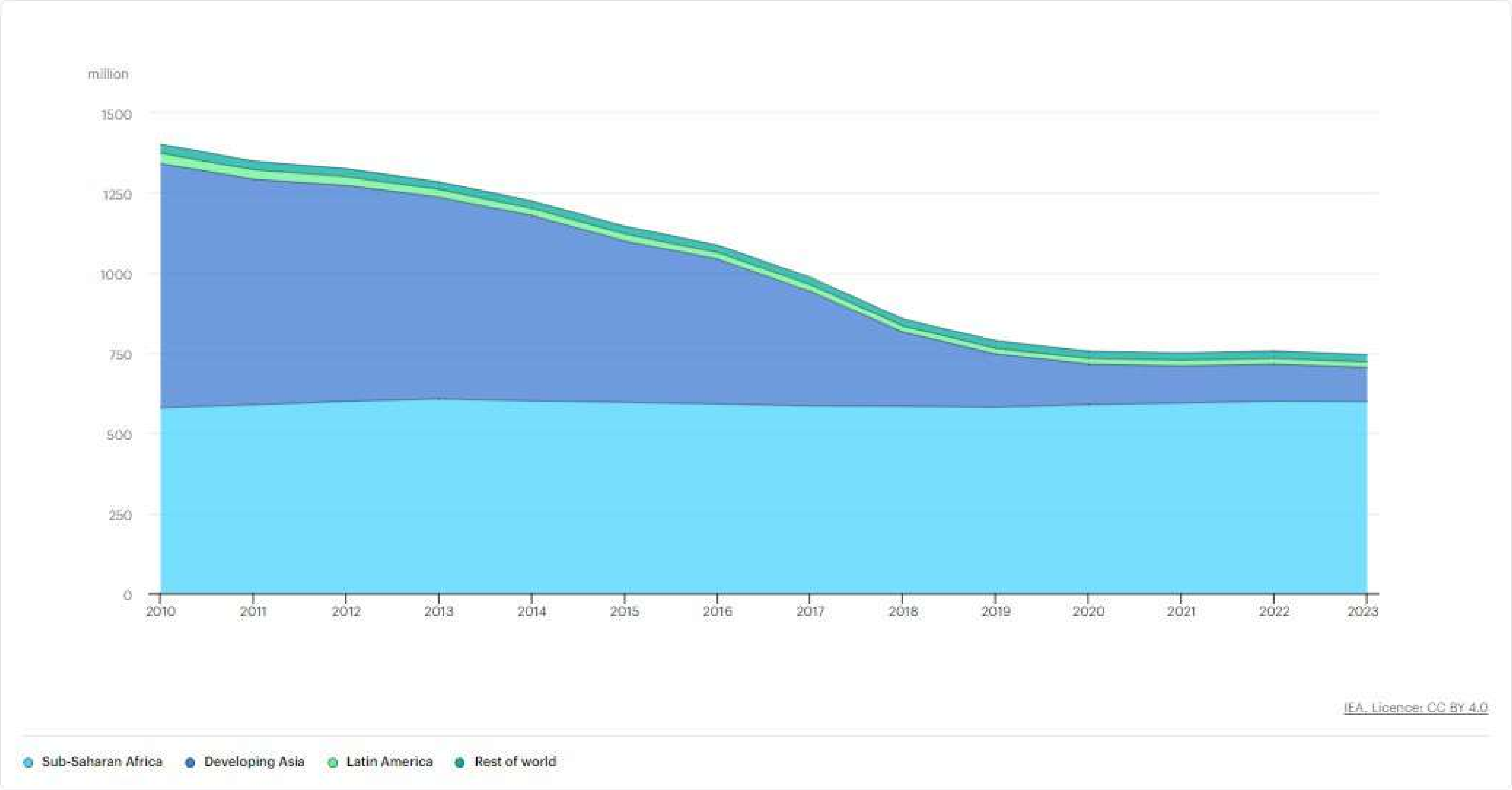
Access to electricity-1

760 million people without access

2022: the number of people without electricity access dropped to 760 million, a record in recent years.

Progress is irregular, with 80% of the 760 million people who gained access since 2010 concentrated in Asia.

Efforts should step up in Africa if we are to reach universal access to electricity by 2030.

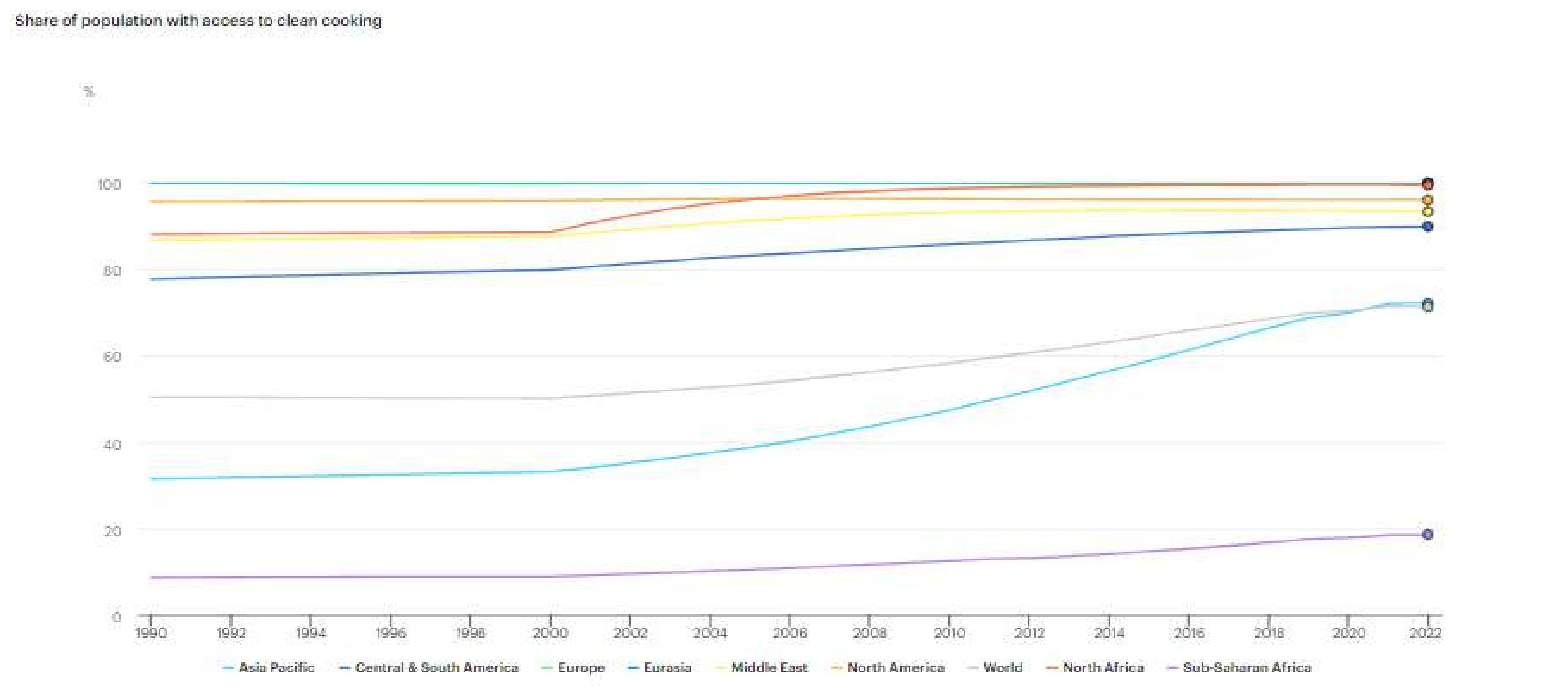


Access to clean cooking-1

2 billion people without access

Over **2 billion people in 2022** do not have access to clean cooking facilities, relying on solid biomass, kerosene or coal as their primary cooking fuel.

Recent decades saw a decline in the number of people without access to clean cooking globally, from 2.9 billion in 2010, but the Covid-19 pandemic and global energy crisis threaten to reverse the situation



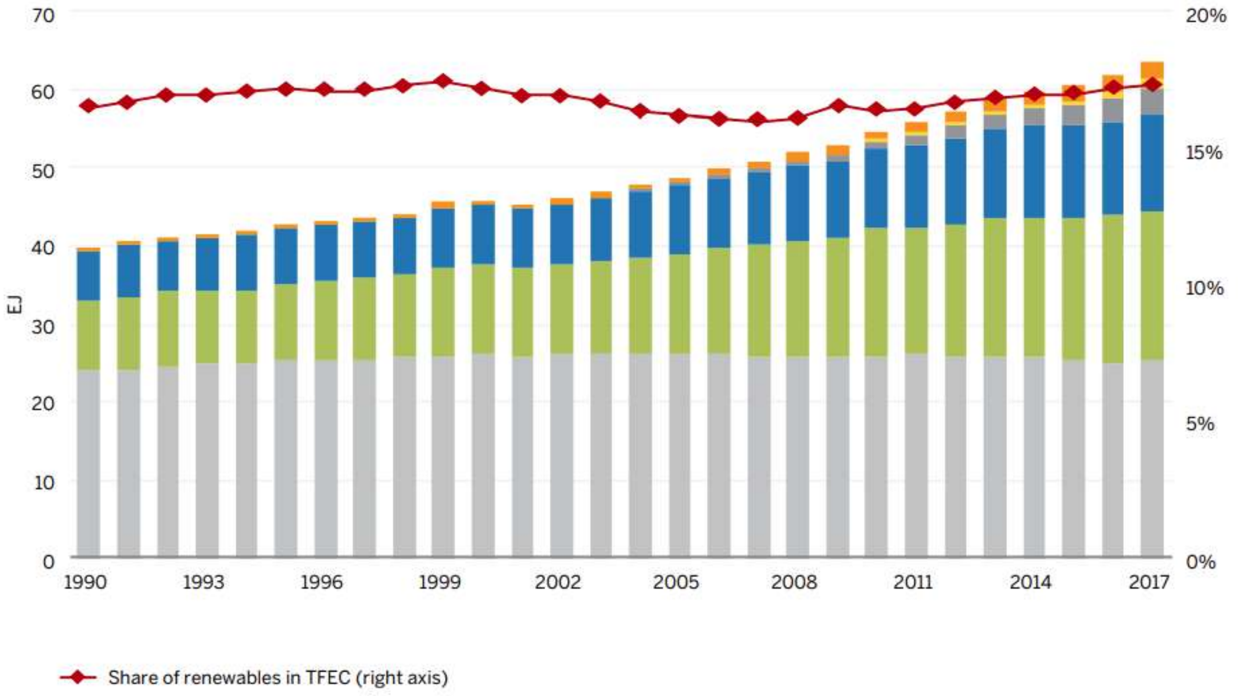
Renewables-1

2022: “Modern” renewables are @ 12.7% of total final energy consumption

The share of renewable energy has slowly increased from 2007, after a period of modest decline, due to strong growth in coal consumption in China. In 2016 it recovered to the same level as in 2000.

Overall, bioenergy accounts for 70% of global renewable energy consumption, followed by hydropower.

FIGURE 3.1 • Renewable energy consumption by technology, and share in total energy consumption, 1990–2017

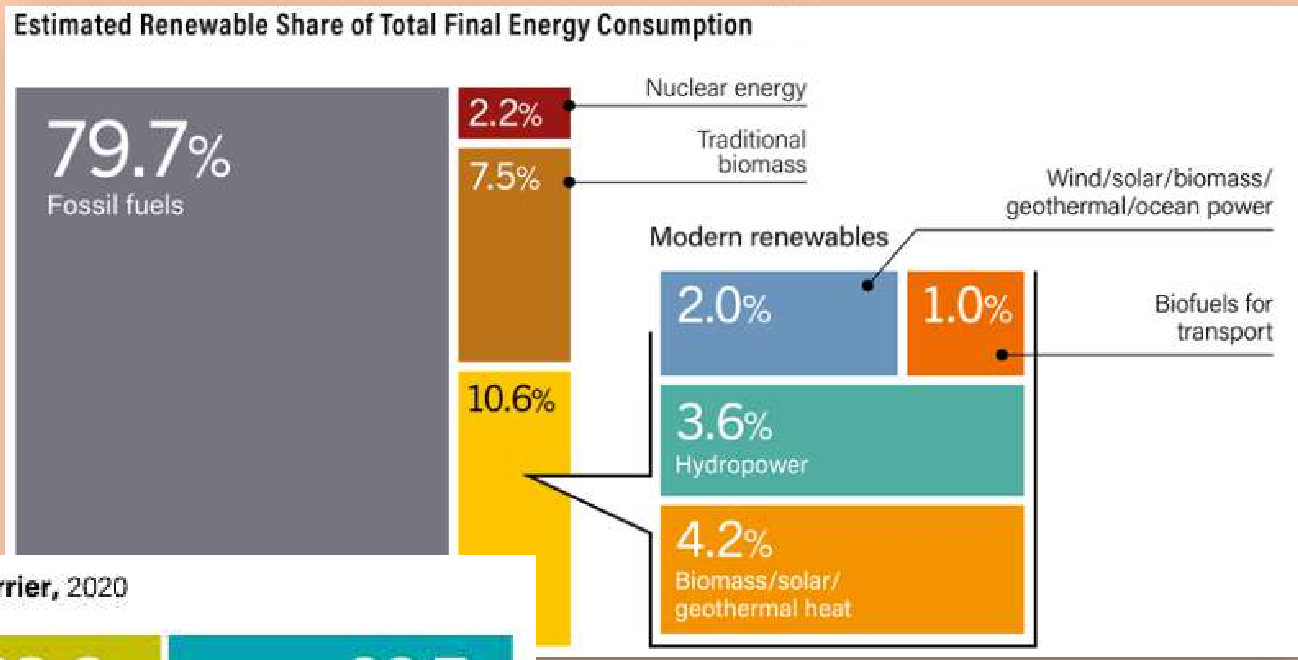


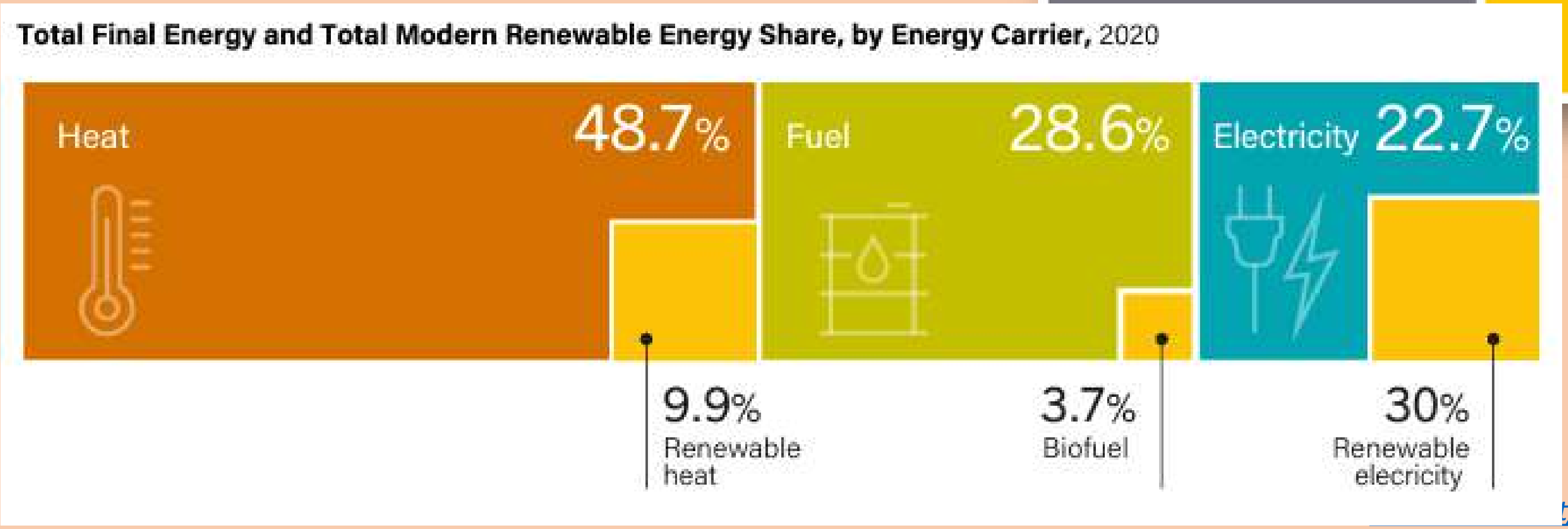
Source: IEA and UNSD.

Including traditional REN

2020: 19.1%
2018: 17.3%
2017: 17.5%

Modern renewables: renewable technologies with exception to traditional biomass. These include **hydropower**, **solar**, **wind**, **geothermal** and **modern biofuel** production (including modern forms of waste-to-biomass conversion).





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7 AFFORDABLE AND CLEAN ENERGY

Ensure universal access to affordable, reliable and modern energy services

Progresses 2010-2012

Access to electricity: Not on track to reach universal access by 2030.

2010-2021- Access to electricity growth 0.7% per year (84% to 91% of the world's population).

2019-2021 - The annual growth slowed to 0.6%.

To bridge the gap the growth must be 1% per year from 2021 onward.

Access to clean cooking: If current trends continue, almost six out of ten people without access to clean cooking in 2030 would reside in Sub-Saharan Africa. With the ongoing impact of COVID-19 and soaring energy prices, 100 million people who recently transitioned to clean cooking may revert to using traditional biomass.

Renewable energy: to be on track with the Delta<1.5°c in the century, the share of renewables must reach 33–38% in 2030 (60-65% in electricity generation). Greater effort is needed to increase the use of renewables in transport and heating, both directly (use of bioenergy, solar thermal and geothermal, and ambient heat) and indirectly (electrification), while progressing on energy conservation.

Energy efficiency: progress between 2010 and 2020 averaged 1.8%/y. Improvement in energy intensity must now exceed 3.4%/y globally from 2020 to 2030

INDICATOR	2010	LATEST YEAR
7.1.1 Proportion of population with access to electricity	**1.1 billion** people without access to electricity	**675 million** people without access to electricity (2021)
7.1.2 Proportion of population with primary reliance on clean fuels and technology for cooking	**2.9 billion** people without access to clean cooking	**2.3 billion** people without access to clean cooking (2021)
7.2.1 Renewable energy share in total final energy consumption	**16%** share of total final energy consumption from renewables	**19.1%** share of total final energy consumption from renewables (2020)
7.3.1 Energy intensity measured as a ratio of primary energy and GDP	**5.53 MJ/USD** primary energy intensity	**4.63 MJ/USD** primary energy intensity (2020)
7.a.1 International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems	**11.9 USD billion** international financial flows to developing countries in support of clean energy	**10.8 USD billion** international financial flows to developing countries in support of clean energy (2021)

Energy statistics – World outlook - IPPC

Table 2.6 | Global primary energy supply of 1.5°C pathways from the scenario database (Supplementary Material 2.SM.1.3).
Values given for the median (maximum, minimum) across the full range of 85 available 1.5°C pathways. Growth Factor = [(primary energy supply in 2050)/(primary energy supply in 2020) – 1]

	Median (max, min)	Count	Primary Energy Supply (EJ)			Share in Primary Energy (%)			Growth (factor) 2020-2050
			2020	2030	2050	2020	2030	2050	
Below-1.5°C and 1.5°C-low-OS pathways	total primary	50	565.33 (619.70, 483.22)	464.50 (619.87, 237.37)	553.23 (725.40, 289.02)	NA	NA	NA	–0.05 (0.48, –0.51)
	renewables	50	87.14 (101.60, 60.16)	146.96 (203.90, 87.75)	291.33 (584.78, 176.77)	14.90 (20.39, 10.60)	29.08 (62.15, 18.24)	60.24 (87.89, 38.03)	2.37 (6.71, 0.91)
	biomass	50	60.41 (70.03, 40.54)	77.07 (113.02, 44.42)	152.30 (311.72, 40.36)	10.17 (13.66, 7.14)	17.22 (35.61, 9.08)	27.29 (54.10, 10.29)	1.71 (5.56, –0.42)
	non-biomass	50	26.35 (36.57, 17.78)	62.58 (114.41, 25.79)	146.23 (409.94, 53.79)	4.37 (7.19, 3.01)	13.67 (26.54, 5.78)	27.98 (61.61, 12.04)	4.28 (13.46, 1.45)
	wind & solar	44	10.93 (20.16, 2.61)	40.14 (82.66, 7.05)	121.82 (342.77, 27.95)	1.81 (3.66, 0.45)	9.73 (19.56, 1.54)	21.13 (51.52, 4.48)	10.00 (53.70, 3.71)
	nuclear	50	10.91 (18.55, 8.52)	16.26 (36.80, 6.80)	24.51 (66.30, 3.09)	2.10 (3.37, 1.45)	3.52 (9.61, 1.32)	4.49 (12.84, 0.44)	1.24 (5.01, –0.64)
	fossil	50	462.95 (520.41, 376.30)	310.36 (479.13, 70.14)	183.79 (394.71, 54.86)	82.53 (86.65, 77.73)	66.58 (77.30, 29.55)	32.79 60.84, 8.58)	–0.59 (–0.21, –0.89)
	coal	50	136.89 (191.02, 83.23)	44.03 (127.98, 5.97)	24.15 (71.12, 0.92)	25.63 (30.82, 17.19)	9.62 (20.65, 1.31)	5.08 (11.43, 0.15)	–0.83 (–0.57, –0.99)
	gas	50	132.95 (152.80, 105.01)	112.51 (173.56, 17.30)	76.03 (199.18, 14.92)	23.10 (28.39, 18.09)	22.52 (35.05, 7.08)	13.23 (34.83, 3.68)	–0.40 (0.85, –0.88)
	oil	50	197.26 (245.15, 151.02)	156.16 (202.57, 38.94)	69.94 (167.52, 15.07)	34.81 (42.24, 29.00)	31.24 (39.84, 16.41)	12.89 (27.04, 2.89)	–0.66 (–0.09, –0.93)

Issued October 2019

2.4.2 Energy Supply

Several energy supply characteristics are evident in 1.5°C pathways assessed in this section:

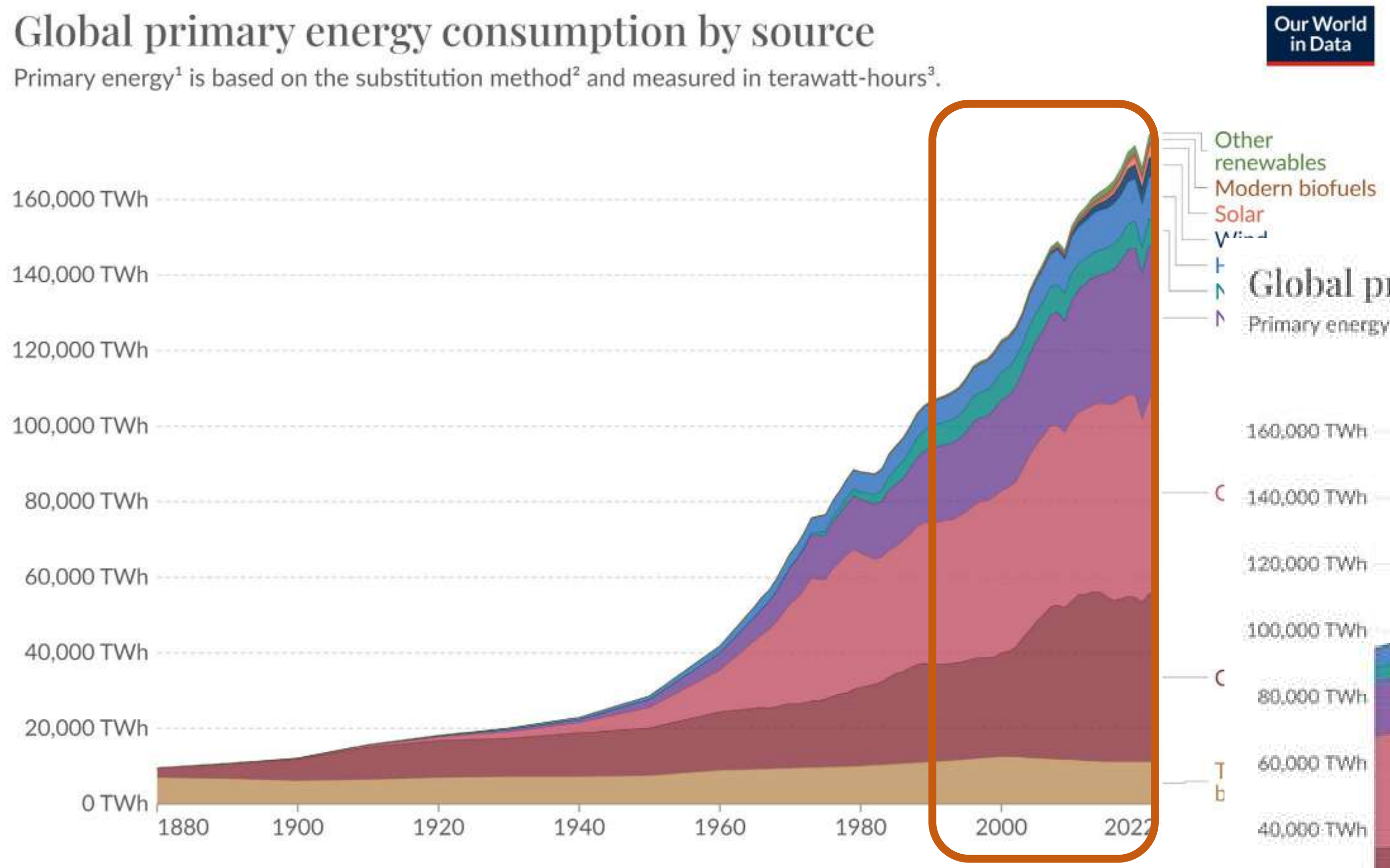
i. growth in the share of energy derived from low-carbon-emitting sources (incl. **REN, nuclear and fossil fuel with CCS**) (Section 2.4.2.1),

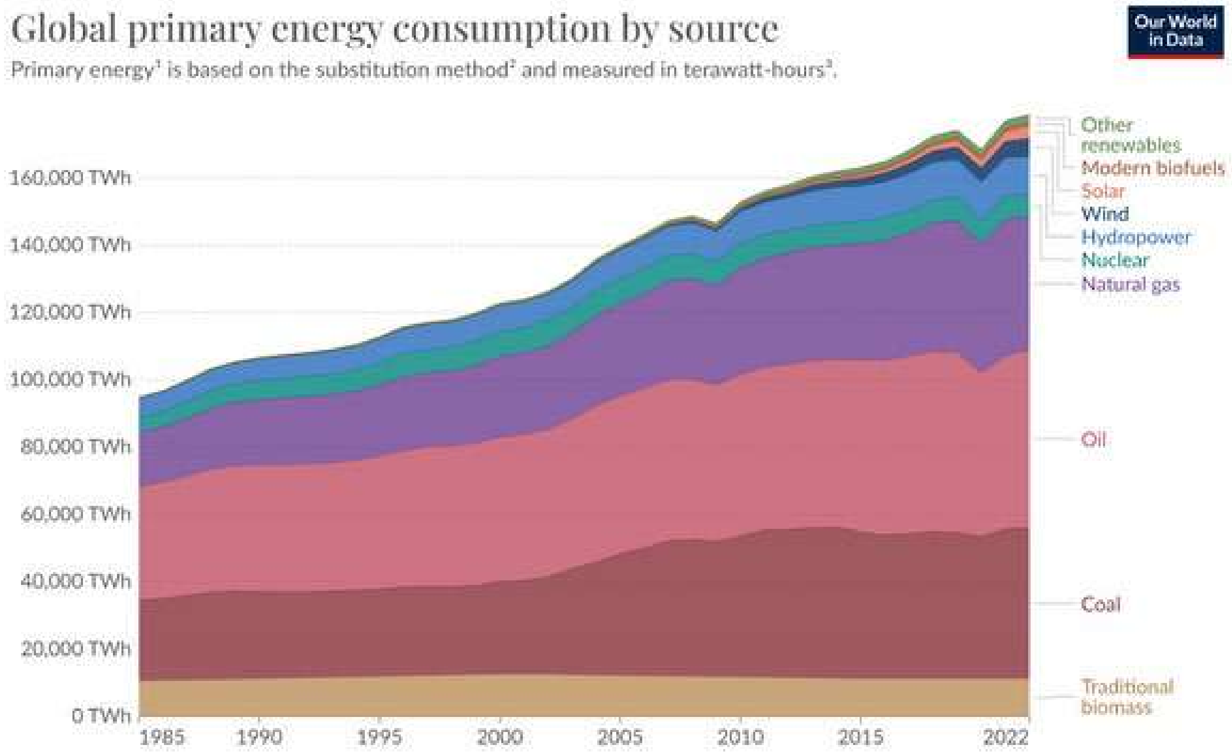
ii. rapid decline in the carbon intensity of electricity generation simultaneous with further electrification of energy end-use (Section 2.4.2.2),

iii. growth in the use of **CCS applied to fossil and biomass** carbon in most 1.5°C pathways (Section 2.4.2.3)

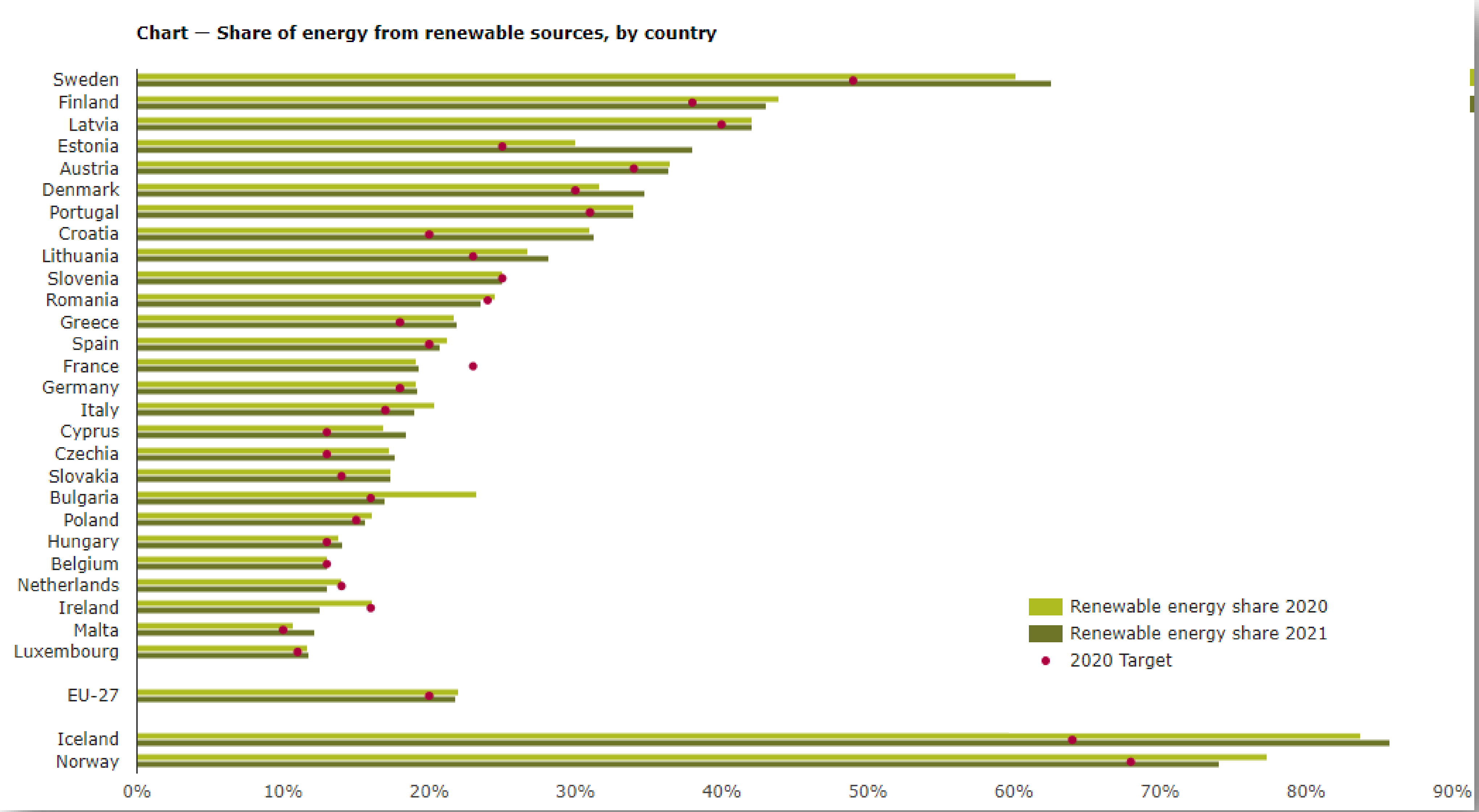
https://www.ipcc.ch/sr15/

Energy statistics - mondo





Energy statistics - EU



eurostat
Statistics Explained

Energy statistics - EU

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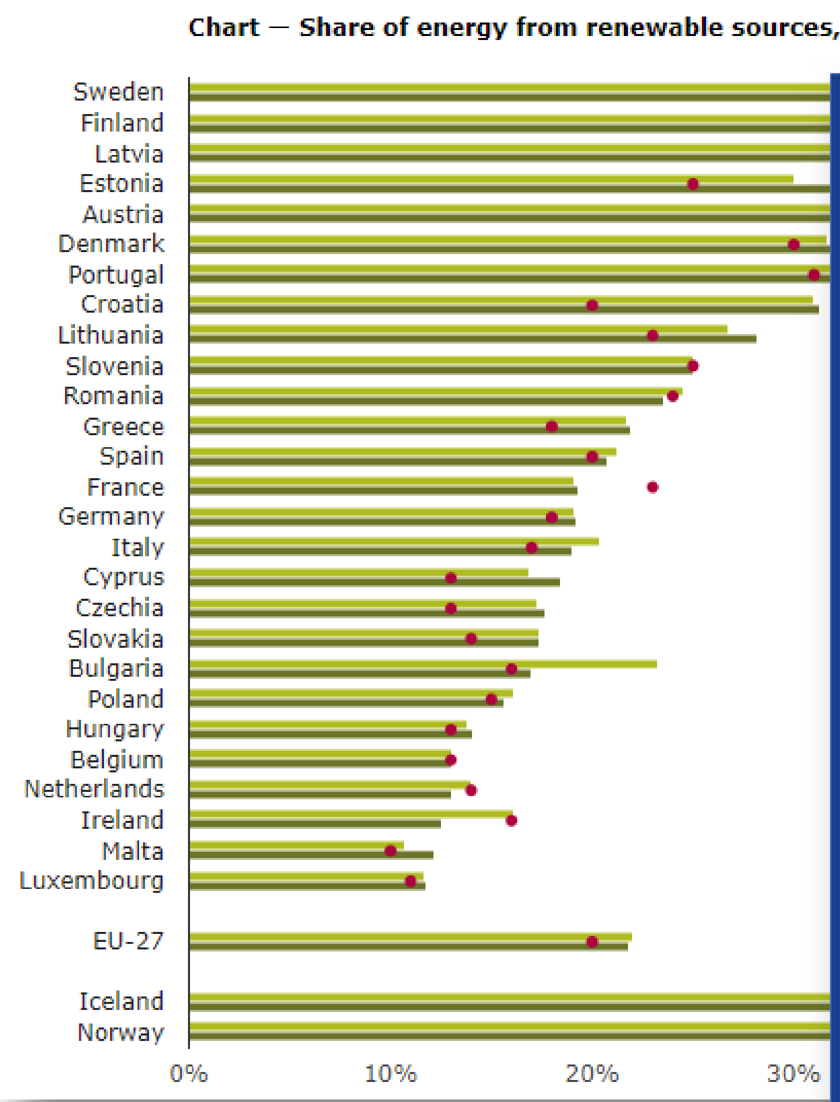
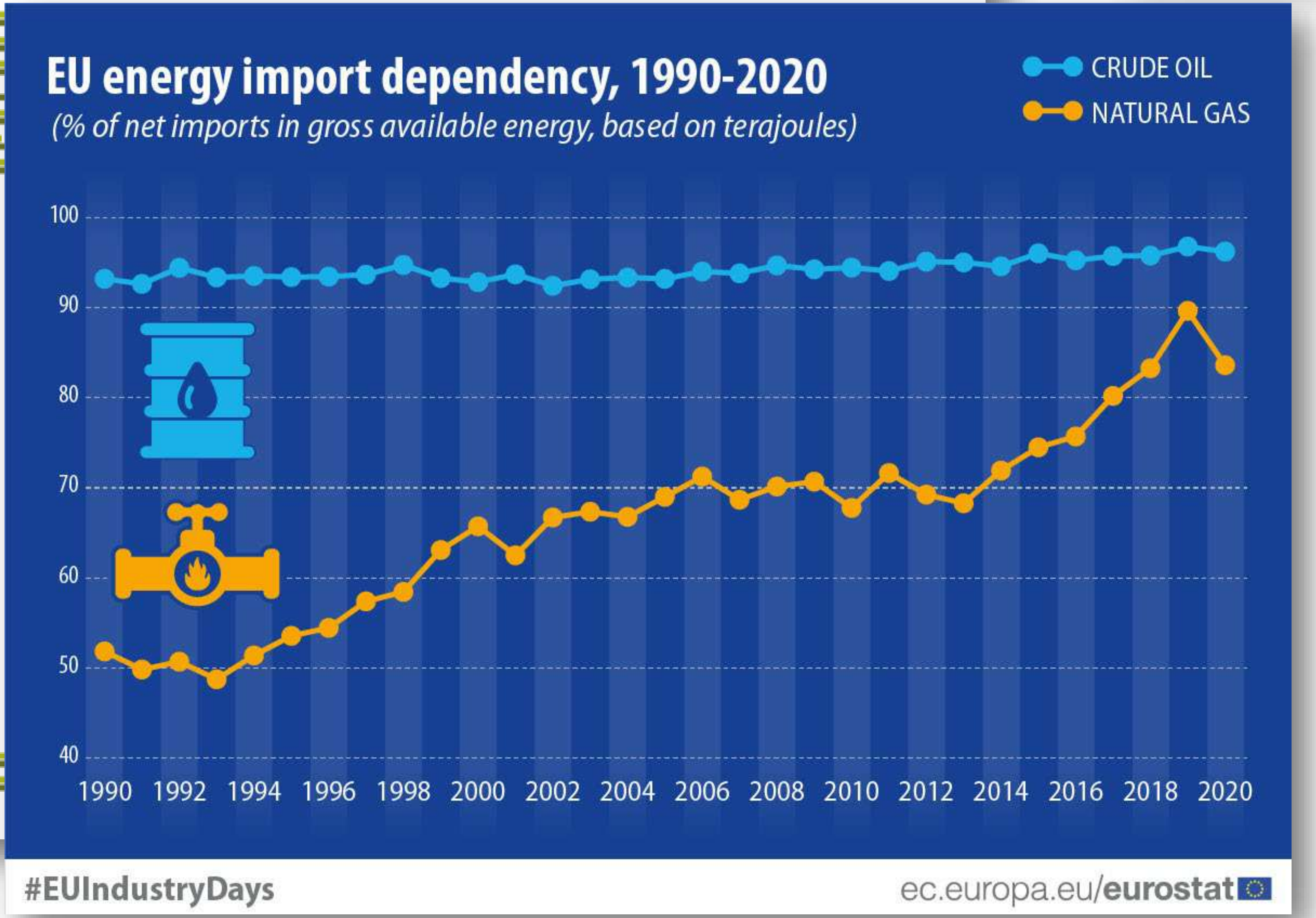
Statistics Explained





MINISTERO DELL'AMBIENTE E DELLA SICUREZZA ENERGETICA

DIPARTIMENTO ENERGIA

DIREZIONE GENERALE INFRASTRUTTURE E SICUREZZA

LA SITUAZIONE ENERGETICA NAZIONALE NEL 2022

Tabella 1: Il bilancio dell'energia in Italia – La disponibilità energetica lorda (ktep)

	2021	2022*								
	Totale	Combustibili solidi	Petrolio e prodotti petroliferi	Gas naturale	Rinnovabili e bioliquidi	Rifiuti non rinnovabili	Calore derivato	Energia elettrica	Totale	Var % (totale 2022/ totale 2021)
+ Produzione	36.676	-	4.525	2.544	25.558	1.126	-	-	33.752	-8,0%
+Saldo importazioni	144.188	7.857	77.847	59.452	2.632		-	4.075	151.8632	5,3%
- Saldo Esportazioni	29.339	248	27.995	3.779	604		-	379	33.005	12,5%
+ Variazioni scorte	4.653	182	1.094	2.114	45		-	-	3.435	-173,8%
=Disponibilità energetica lorda	156.179	7.427	53.282	56.104	27.540	1.126	-	3.696	149.175	-4,5%

Fonte: Ministero dell'ambiente e della sicurezza energetica - Bilancio Energetico Nazionale - Metodologia Eurostat - (*) Dati provvisori

Energy statistics - Italy

MINISTERO DELL'AMBIENTE E DELLA SICUREZZA ENERGETICA

DIPARTIMENTO ENERGIA

DIREZIONE GENERALE INFRASTRUTTURE E SICUREZZA

LA SITUAZIONE ENERGETICA NAZIONALE NEL 2022

Tabella 1: Il bilancio dell'energia in Italia – La disponibilità energetica lorda (ktep)

	2021	2022*
	Tota…	
+ Produzione	36.67…	
+Saldo importazioni	144.1…	
- Saldo Esportazioni	29.3…	
+ Variazioni scorte	4.65…	
=Disponibilità energetica lorda	156.1…	

Fonte: Ministero dell'am…

Tabella 6: Bilancio di copertura dell'energia elettrica (Miliardi di kWh)

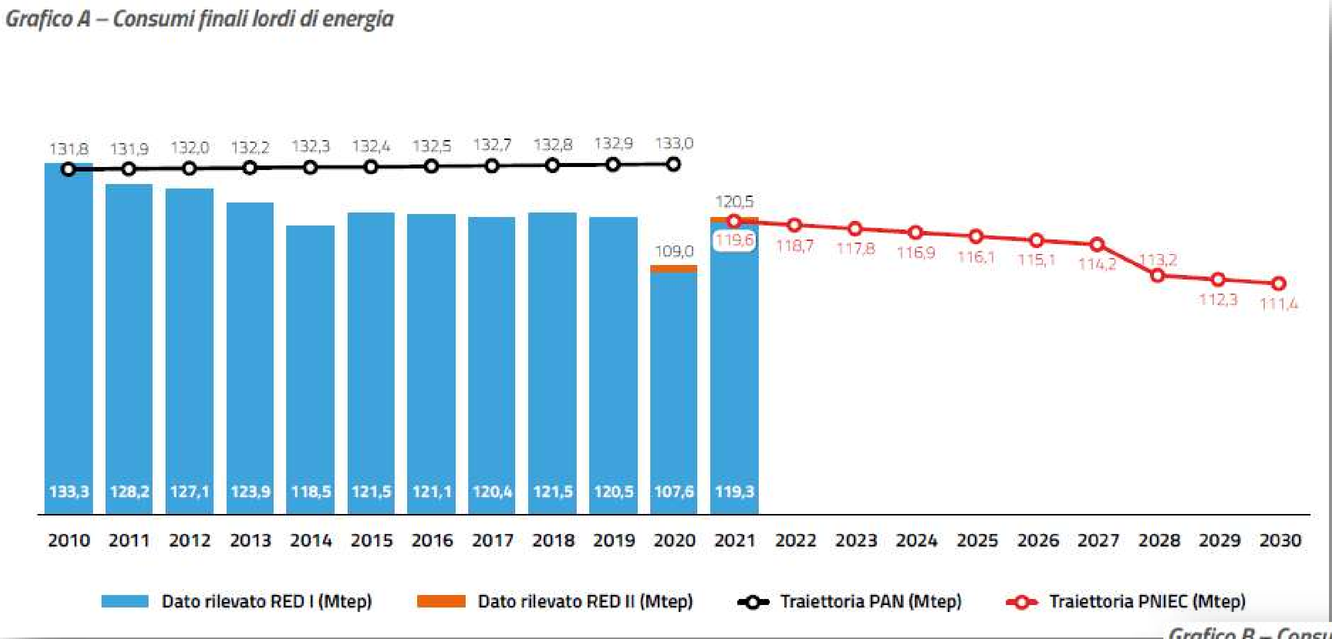
	2017	2018	2019	2020	2021	2022
Produzione lorda di energia elettrica (a)	294,0	288,0	292	278,6	286,9	284,2
di cui:						
idroelettrica (a)	36,2	48,8	46,3	47,6	45,4	28,2
geotermoelettrica	6,2	6,1	6,1	6	5,9	5,8
rifiuti urbani, biomasse, eolico, solare e altre rinnovabili	61,5	59,5	63,4	63,3	65	66,1
termoelettrica tradizionale	190,1	173,6	176,2	161,7	170,6	184,1
Saldo import-export	37,8	43,9	38,1	32,2	42,8	43,0
Disponibilità lorda	331,8	331,9	330,1	310,8	329,7	327,2
Assorbimenti dei servizi ausiliari e perdite di pompaggio	11,3	10,5	10,5	9,6	9,8	10,3
Energia Elettrica richiesta	**320,5**	**321,4**	**319,6**	**301,2**	**319,9**	**316,9**

* Dati provvisori   Fonte: TERNA

Energy statistics - Italy

Rapporto Statistico sulle Fonti Rinnovabili

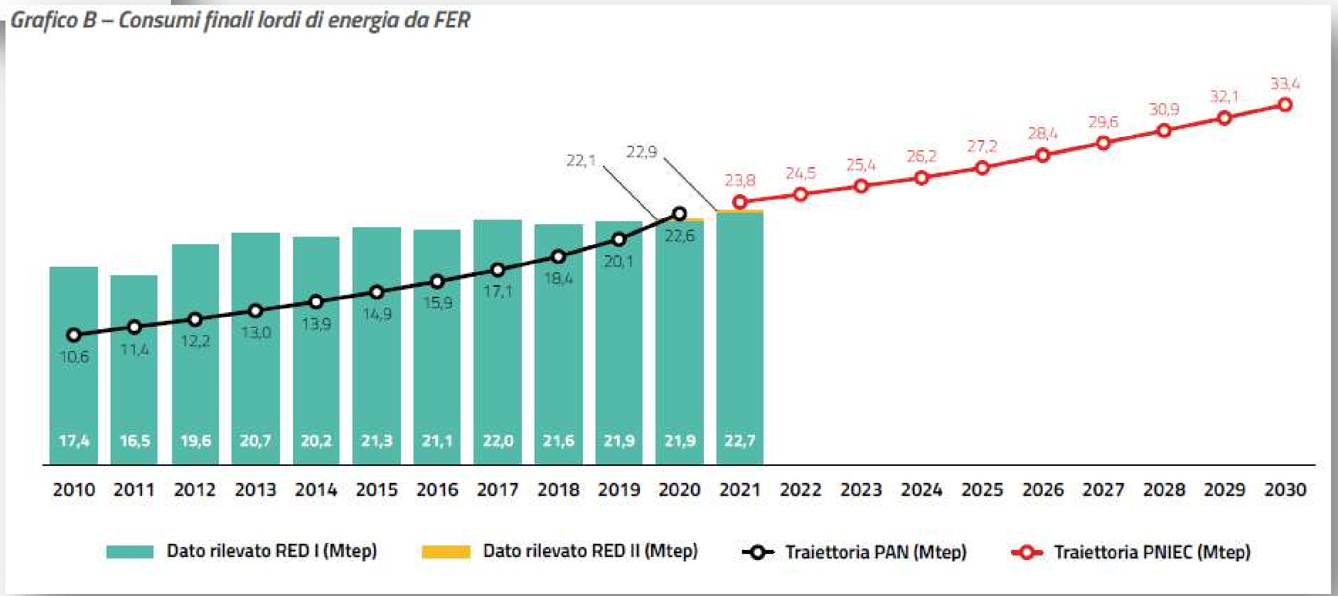
(GSE 2023, dati 2021, https://www.gse.it/dati-e-scenari/statistiche)



Renewable Energy Directive – RED (Directive 2009/28/EC: "Promotion of the use of energy from renewable sources".

The legal framework for the development of clean energy across all sectors of the EU economy, supporting cooperation between EU countries towards this goal. It implements the 2020 objectives defined for each EU Member State, the trajectories foreseen for achieving them and the main policies to be implemented.

- ***PAN: Piano d'Azione Nazionale per le energie rinnovabili.*** *Obiettivi al 2020*
- ***PNIEC: Piano Nazionale Integrato Energia e Clima.*** *Obiettivi nazionali al 2030 su efficienza energetica, fonti rinnovabili, riduzione delle emissioni di CO2, in tema di sicurezza energetica, interconnessioni, mercato unico dell'energia e competitività, sviluppo e mobilità sostenibile*



Energy statistics - Italy

Energy mix

Total energy supply, Italy, 2022

Total energy supply | Production | Electricity | Consumption

Energy mix

Emissions

CO2 emissions, Italy, 2021

310 Mt CO2

0.92%
of global emissions

↓26%
change since 2000

Emissions

https://www.iea.org/countries/italy

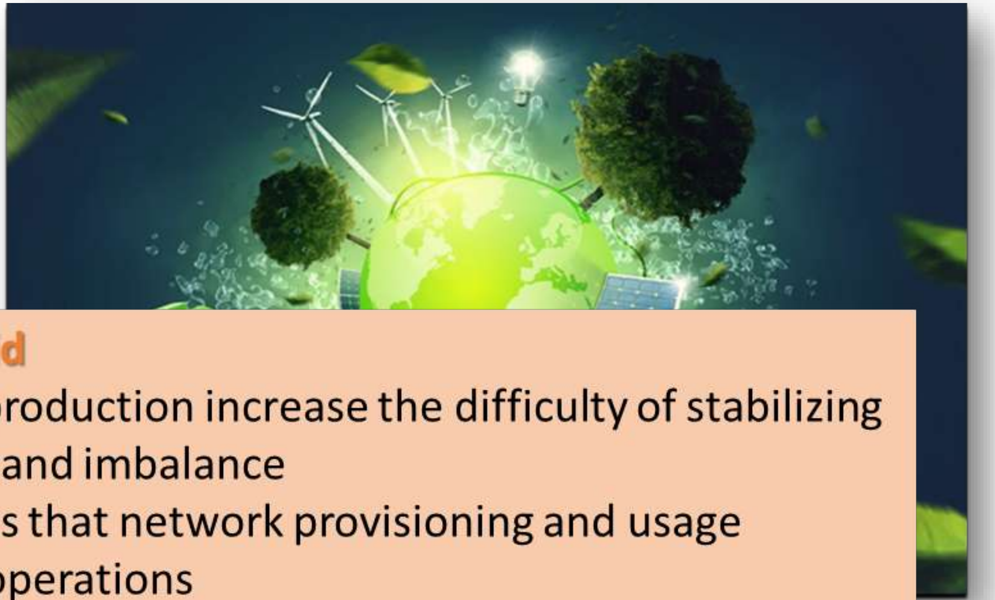
what future for a geologist in this changing world?

Traditional energy sources: the resource availability is homogeneous; the delivery of power/energy from their production plants can be modulated according to the demand

Renewable energy sources: the delivery of power/energy from their production plants is higly dependant on the resource availability/storage. **Intermittent energy sources**

Traditional energy sources: the resource availability is homogeneous; the delivery of power/energy from their production plants can be modulated according to t

Renewable energy sourc
production plants is higly
availability/storage. **Inter**

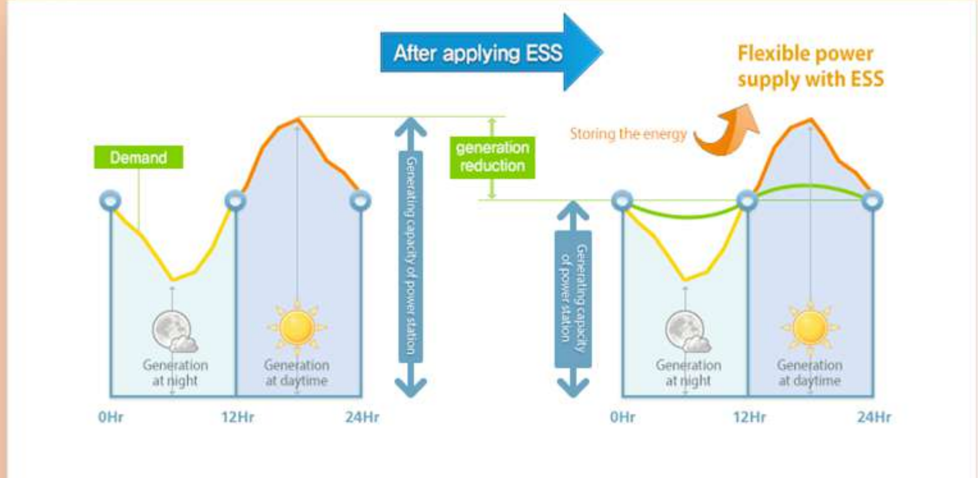


Difficulties with renewables integration in the grid

- Fluctuating sources and decentralized energy production increase the difficulty of stabilizing the power network, mainly due to supply/demand imbalance
- Unpredictable character of renewables requires that network provisioning and usage regulations be established for optimal system operations
- Peak supply of renewables (solar, wind) and demand of energy do not match and hence create a gap

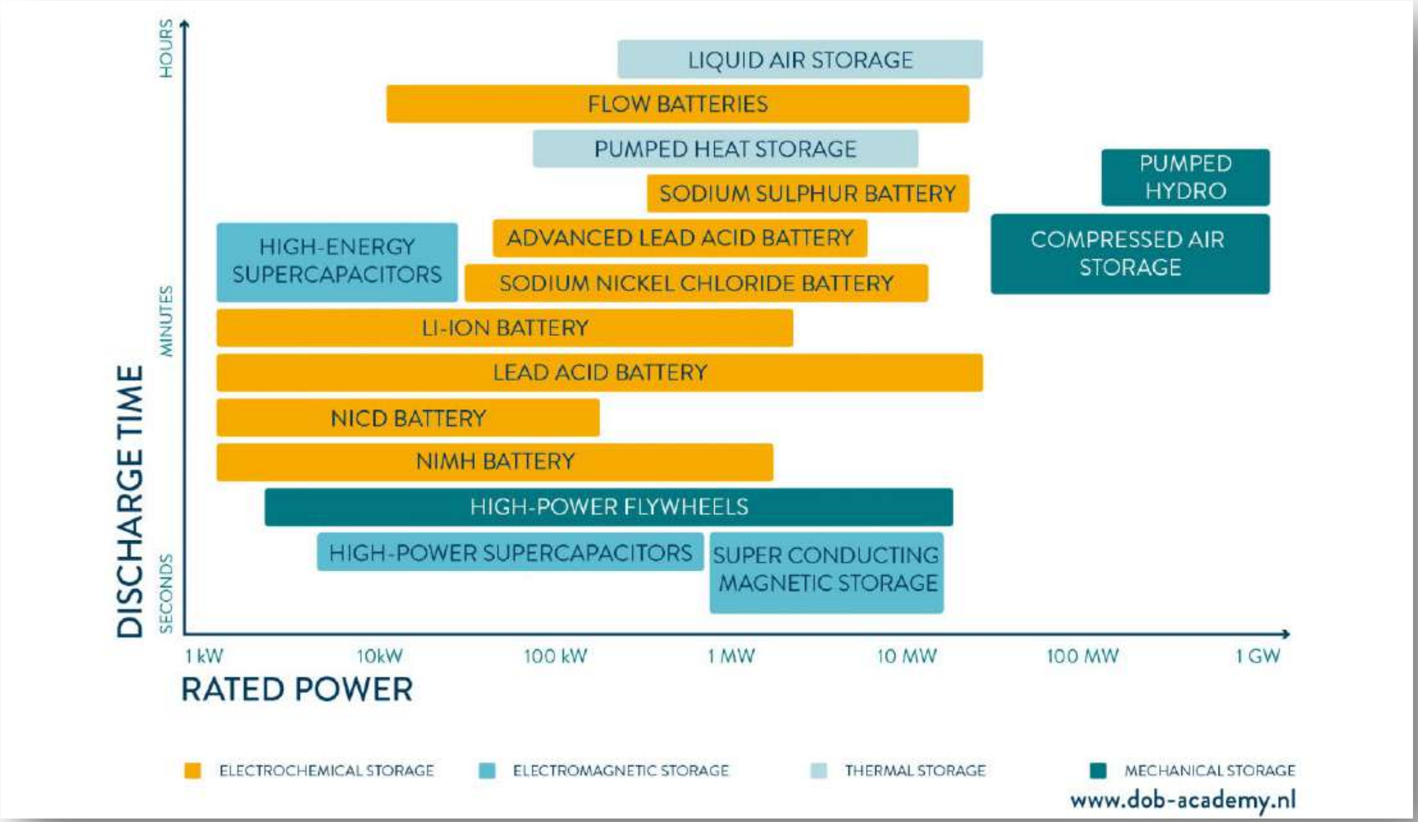
Energy Storage Systems - ESS

- Conversion of excess energy into a different form of energy, to be converted in electricity with minimum losses
- Increases the dispatch ability, makes power available on demand; by reducing the supply/demand gap reduces the nedd for newer power plants



Concept Map of Energy Storage System (ESS)

Energy storage



Intermittency of energy supply: increase of energy storage capabilities. This could include:

- advancement in **battery technologies**
- **subsurface air & thermal energy** and **pumped hydro**

Decarbonisation/transition of power generation, industry, transport and heating needs expansion in renewables and nuclear, many of which require **critical raw materials and metals** to manufacture (which rely on sources of minerals and metals e.g. lithium, cobalt, cadmium).

A **sustainable and secure supply of mined materials** is required

The Role of Geoscience in Decarbonisation

The Geological Society
serving science, profession & society

21 - 23 January 2019
The Geological Society, Burlington House
https://www.geolsoc.org.uk/Lovell19

Decarbonisation/transition of power generation, industry, transport and heating to meet climate change targets: a major challenge that intrinsically involves the subsurface and geoscience.

Renewables	increase in grid-scale energy storage to cover intermittency: greater efforts on more efficient batteries, pumped storage and compressed air energy storage
Civil nuclear	understanding of risks associated with natural hazards (seismicity); challenge of geological disposal of radioactive waste
Geothermal power, heating and cooling	assessment of resources and impacts
Hydrogen *(it is a vector, not a source!!!)*	development of technology; environmental and geological assessment for underground storage and transport
Carbon Capture and Storage (CCS)	definition of the reservoirs and volumes of potential storage; risks assessment associated with natural and induced hazards (seismicity, …)
Natural gas	the **energy resource for the transition** needs environmental and resources assessment

All require **geological studies**: investigating the geological origin and prospectivity of transition metals and rare earth elements for batteries; for siting of power station, dams and tunnels in pumped water storage; geological studies for CCS; detailed characterisation of the subsurface for radio- waste disposal.

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Scientific and technological challenges for Geosciences in the Energy Transition

- ✓ **Characterise** the physical properties, chemistry and structure of the subsurface to determine feasibility of various subsurface storage and infrastructure projects.
- ✓ **Improve** understanding of how the properties of the subsurface respond to changing physical and chemical conditions, e.g. during cyclical pressurisation and depressurisation of hydrogen or thermal fluids.
- ✓ **Assess** the origin, distribution and extractability of subsurface critical raw materials needed for decarbonisation.
- ✓ **Develop** and design effective and cost-efficient monitoring techniques for various uses of the subsurface.
- ✓ **Improve** scientific understanding on how fluids flow in the subsurface (HC, thermal energy storage, geothermal resources).

Critical to the success of the decarbonisation initiative is **knowledge and data sharing** across geographical borders, between industries, and by all "subsurface stakeholders".

There are key geoscientific lessons to be learned across planning, exploration, exploitation, decommissioning and remediation

The Role of Geoscience in Decarbonisation

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The opportunity for Geosciences in the Energy Transition

Europe is well placed to develop subsurface decarbonisation technologies. It has an excellent base of worldclass universities, research institutes, and **the experience of Oil&Gas companies**.
A combination of state-of-the-art technology, improvements to efficiency and low-carbon fuel switching will be needed to achieve the ambitious decarbonisation targets.

However, for some industrial processes, such as steel manufacturing, cement production, and refining, subsurface carbon-capture technologies are the only viable decarbonising solution.

According to IPCC, **negative emissions** can only realistically be achieved adding **nuclear and carbon capture and storage (CCS)**

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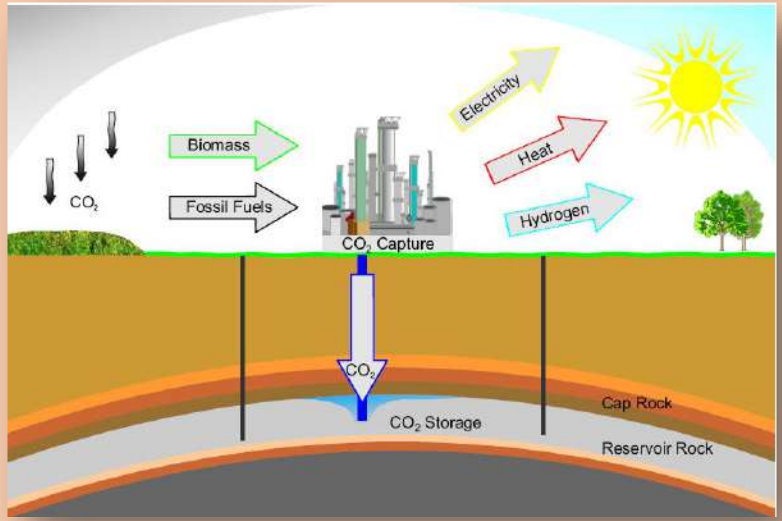
However, fo
carbon-cap
realistically

CCS - Carbon Capture & Storage

The quantity of CO_2 to be stored via CCS over this century in 1.5°C pathways ranges, depending by different scenarios, from zero to >1,200 $GtCO_2$.

The **2005 IPCC Special Report on Carbon Dioxide Capture and Storage** found that, worldwide, it is likely that there was a technical potential of at least about 2,000 $GtCO_2$ of storage capacity in geological formations, with possible additional potential for geological storage in saline formations.



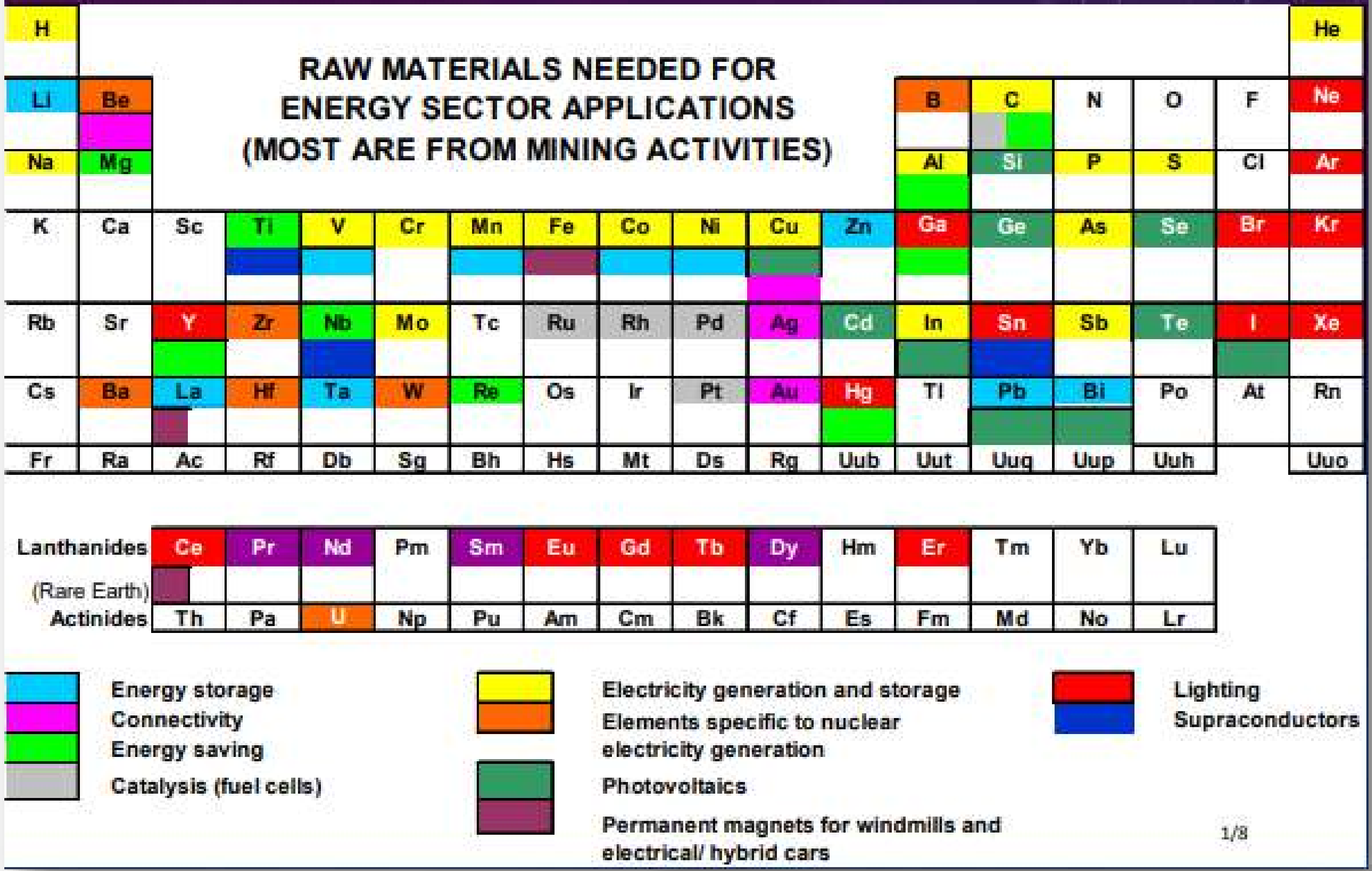
The **cumulative demand for CO_2 storage was small compared to a practical storage capacity estimate worldwide**.

The global potential storage capacity is estimated today from 8,000 to 55,000 $GtCO_2$,which is sufficient at a global level for this century.

The storage capacity of all of these global estimates is likely to be larger than the cumulative CO_2 stored via CCS in 1.5°C pathways over this century

Mining

Most elements in the periodic table are essential to the innovative technologies required to address mankind's energy problems



The **energy sector** contributes to the rapid demand growth for a **wide range of** minerals and metals.

The production of minerals and metals

- **requires energy** (currently about 10.5% of the global production),
- **generates emissions** (CO2, sulfur and nitrogen oxydes, particulate matter, mercury from coal production, radionucleides from coal combustion and rare earth production…).

http://www.mineralinfo.fr/sites/default/files/upload/ancre_rapport_2015-ressources_minerales_et_energie_0.pdf

Energy transition and Geology

Mining

nature reviews materials

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nature › nature reviews materials › comment › article

Comment | Published: 24 May 2021

Mining our green future

Richard Herrington

Nature Reviews Materials **6**, 456–458 (2021) | Cite this article

The green energy revolution is heavily reliant on raw materials, such as cobalt and lithium, which are currently mainly sourced by mining. We must carefully evaluate acceptable supplies for these metals to ensure that green technologies are beneficial for both people and planet.

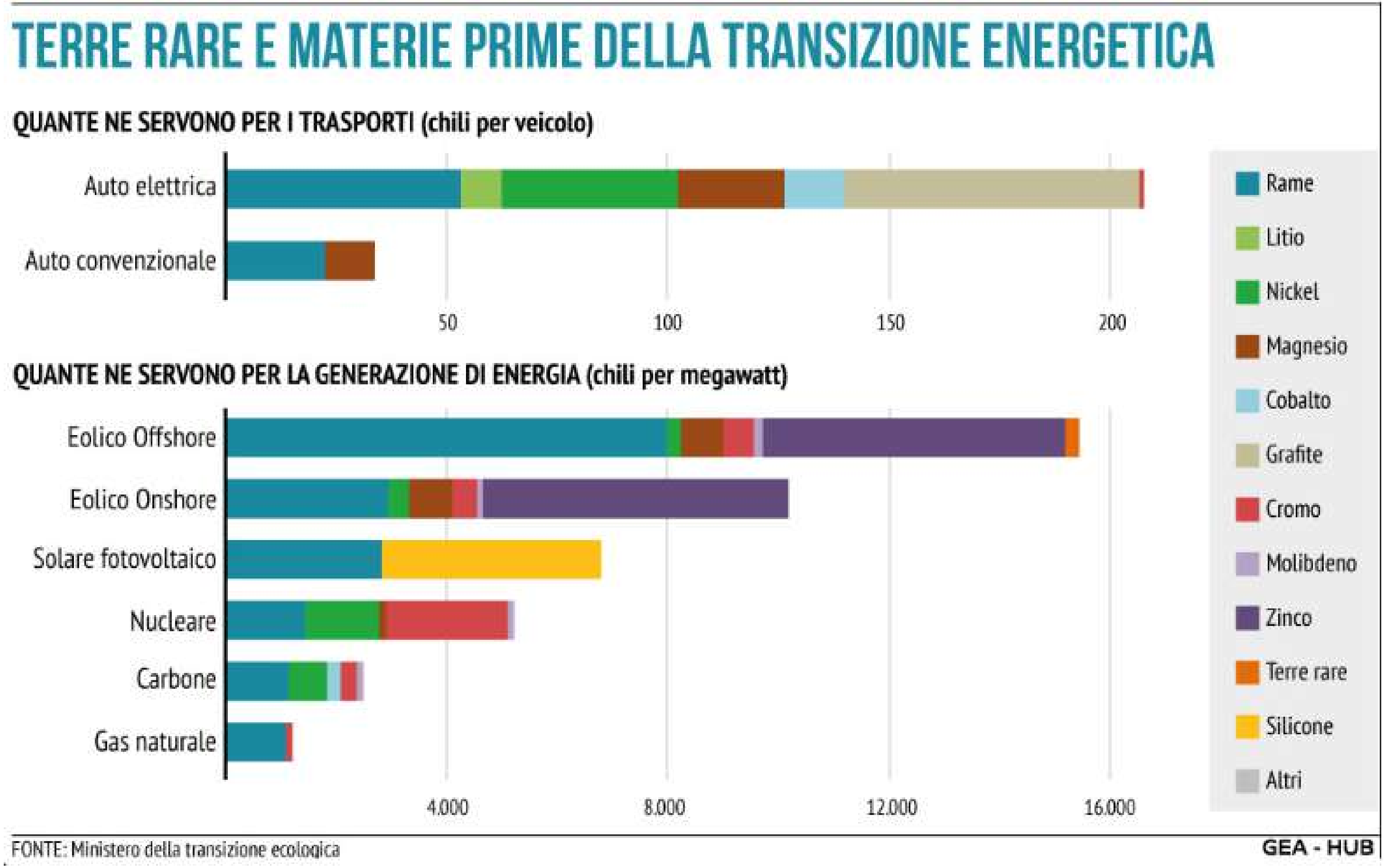
Table 1 | **Anticipated increase in demand for the 12 most needed commodities for delivering a green energy future**

Commodity	% increase in demand in 2050 compared with 2018
Graphite	494
Cobalt	460
Lithium	488
Indium	231
Vanadium	189
Nickel	99
Silver	56
Neodymium	37
Lead	18
Molybdenum	11
Aluminium	9
Copper	7

Data source: World Bank Report in 2020

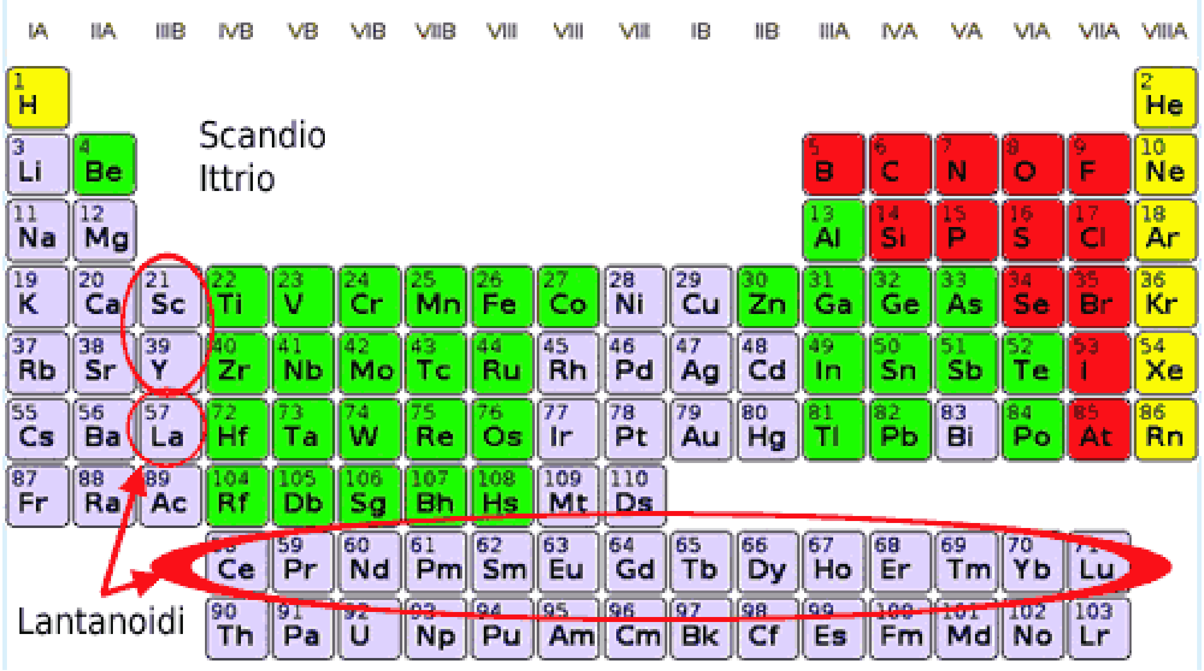
Mining

Mining



Elaborato da https://www.iea.org/articles/clean-energy-progress-after-the-covid-19-crisis-will-need-reliable-supplies-of-critical-minerals

Rare Earth Elements

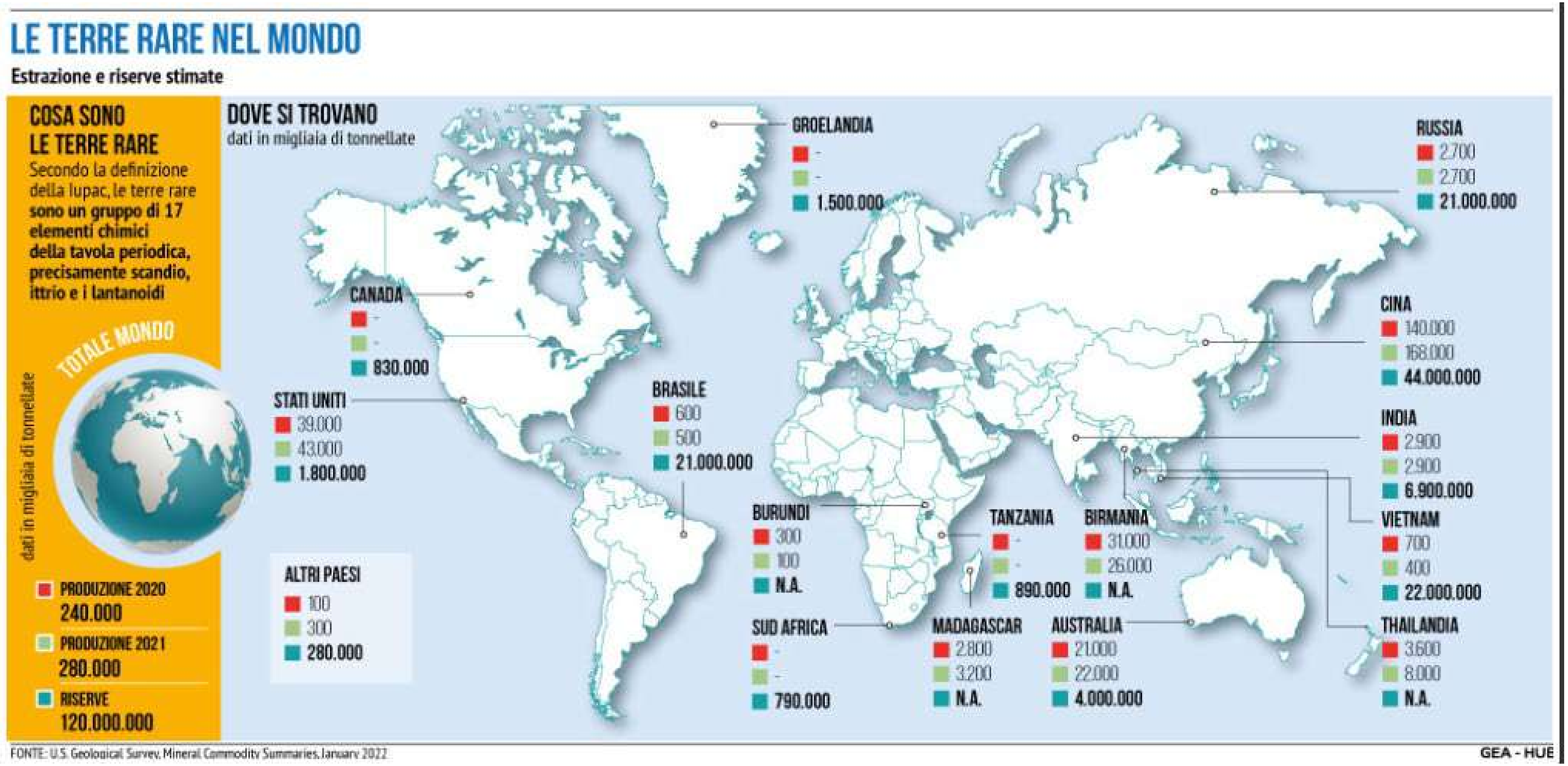


Permettono la produzione e il funzionamento di oggetti della quotidianità: si trovano all'interno di smartphone, touchscreen, lampade, hard disk. Sono anche alla base di fibre ottiche e laser, di molte apparecchiature mediche, nelle batterie per le auto elettriche. Costituiscono magneti permanenti, sensori elettrici, convertitori catalitici indispensabili per la produzione di tecnologie green come turbine eoliche e pannelli fotovoltaici.

Preziose e fondamentali per lo sviluppo della tecnologia verde e non solo: le **Terre rare**, anche definite con l'acronimo **REE** (**Rare Earth Elements**), sono 17 metalli presenti nella tavola periodica degli elementi chimici, con colori che variano dal grigio all'argento.

Includono lo **scandio** (Sc) e l'**ittrio** (Y), più l'intera serie dei lantanidi, gli elementi chimici dal numero atomico dal 57 al 71. Nell'ordine: **lantanio** (La), **cerio** (Ce), **praseodimio** (Pr), **neodimio** (Nd), **promezio** (Pm), **samario** (Sm), **europio** (Eu), **gadolinio** (Gd), **terbio** (Tb), **disprosio** (Dy), **olmio** (Ho), **erbio** (Er), **tulio** (Tm), **itterbio** (Yb), **lutezio** (Lu). Le loro straordinarie proprietà magnetiche e conduttive ne implementano l'utilizzo in svariati ambiti, dall'industria elettronica e tecnologica a quella aereonautica e militare.

Mining

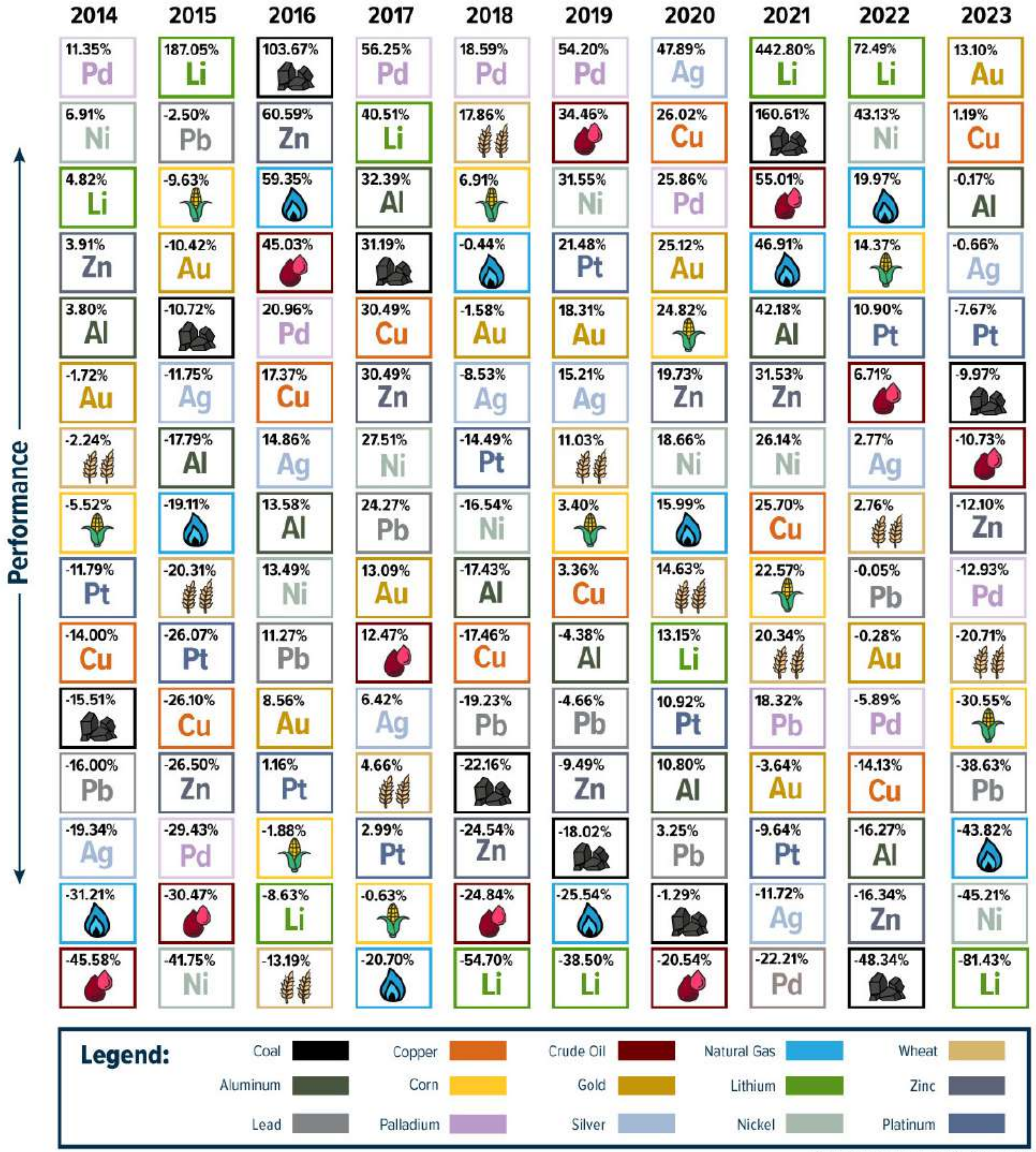


Elaborato da https://www.iea.org/articles/clean-energy-progress-after-the-covid-19-crisis-will-need-reliable-supplies-of-critical-minerals

Mining

THE PERIODIC TABLE OF COMMODITIES RETURNS 2023

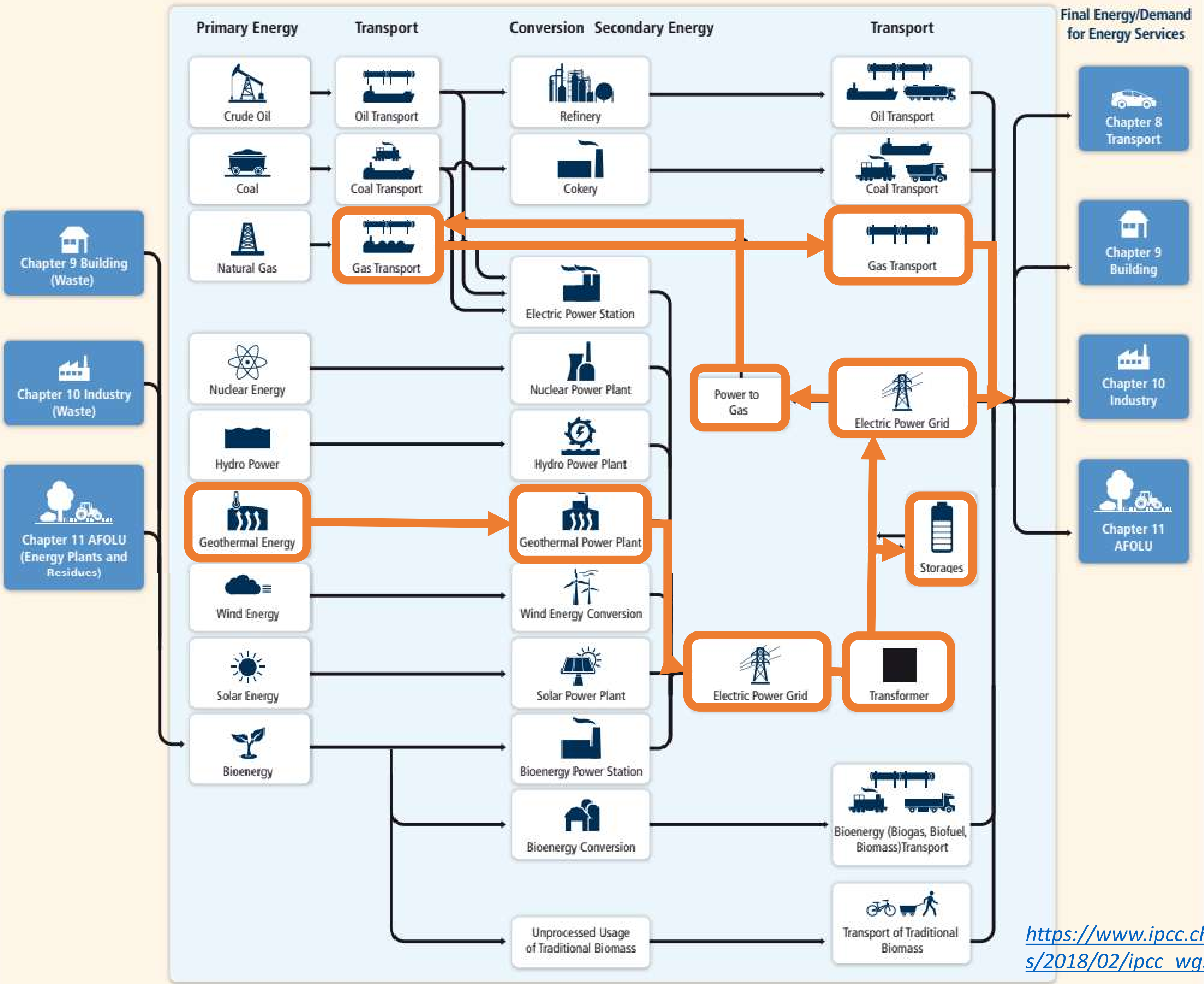
Natural resources are vital for global progress and prosperity, but their prices can fluctuate significantly over time, as demonstrated in a table highlighting price movements over the past decade. This volatility aligns with the principle of mean reversion, where returns tend to revert to their average levels. The prices of commodities exhibit both seasonal and cyclical patterns historically. Therefore, investing in natural resources necessitates a diversified portfolio managed by professionals knowledgeable about these assets and their global trends. However, diversification doesn't eliminate market risks or ensure profits, and past performance doesn't predict future outcomes.



Source: Bloomberg and U.S. Global Investors

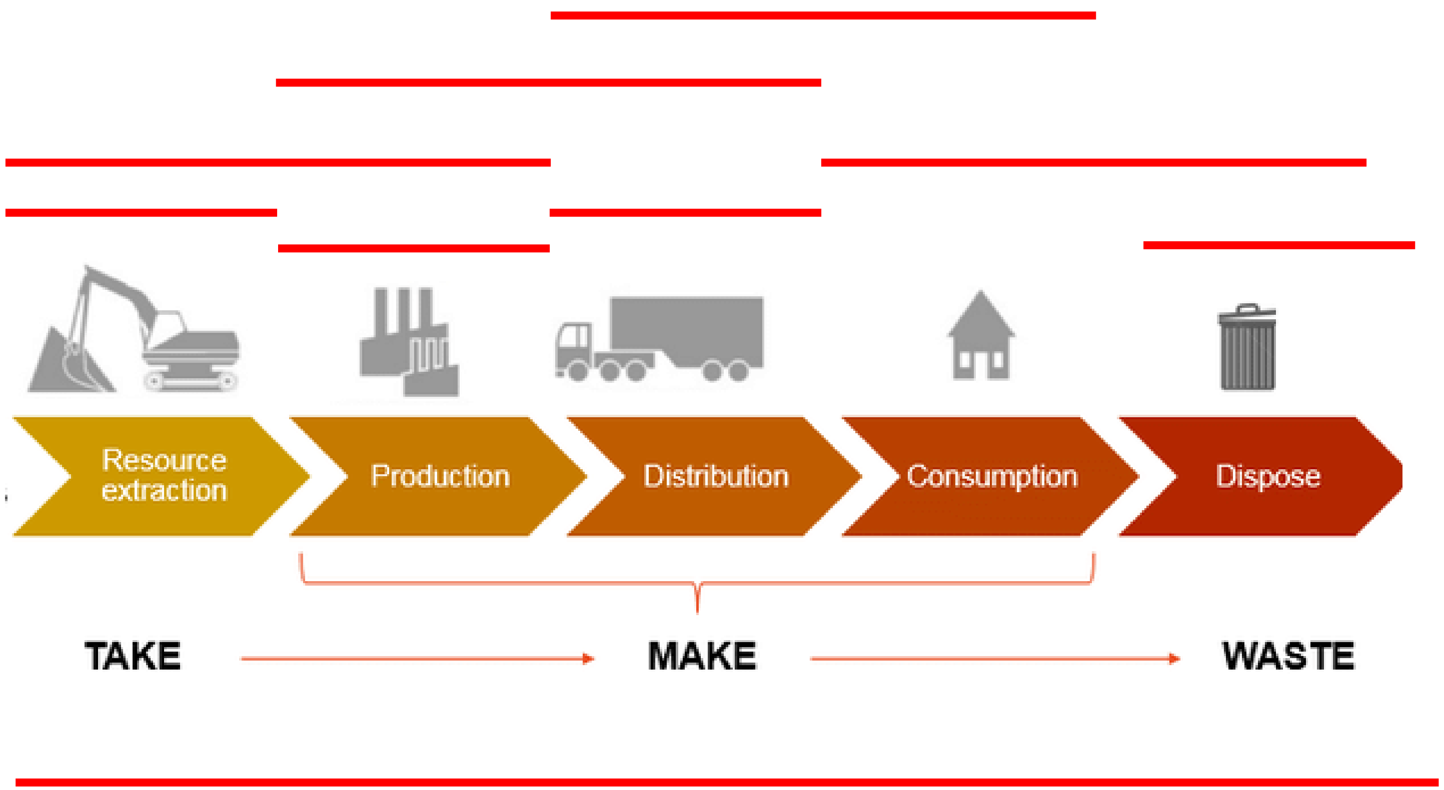
Life Cycle Assessment

Energy Systems



https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf

Impact Assessment



Environmental Assessment Standard approach

LIFE CYCLE

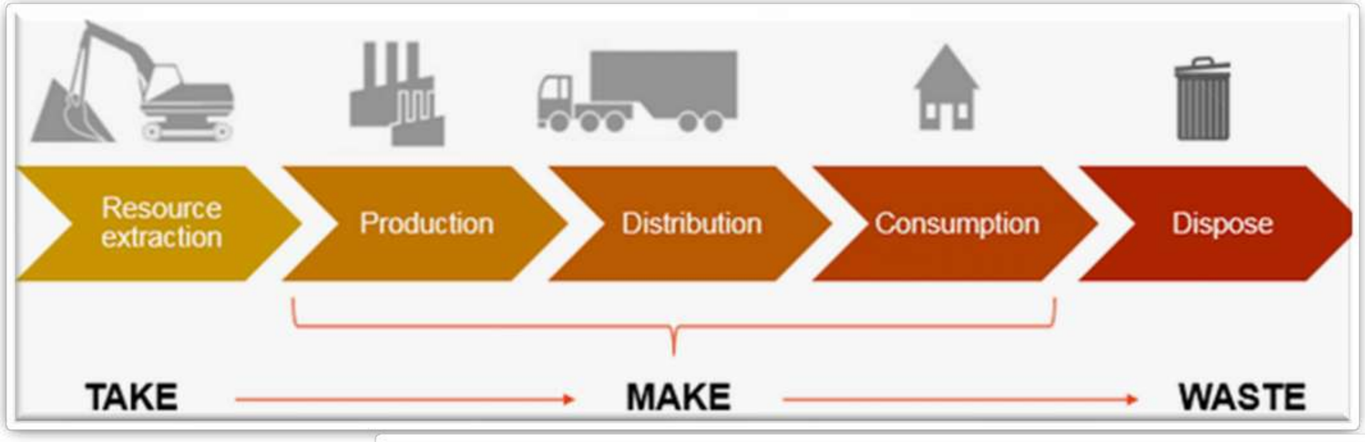
Life Cycle Assessment

Life-cycle assessment (**LCA**, also known as **life-cycle analysis**, **cradle-to-grave analysis, Ecobalance**):

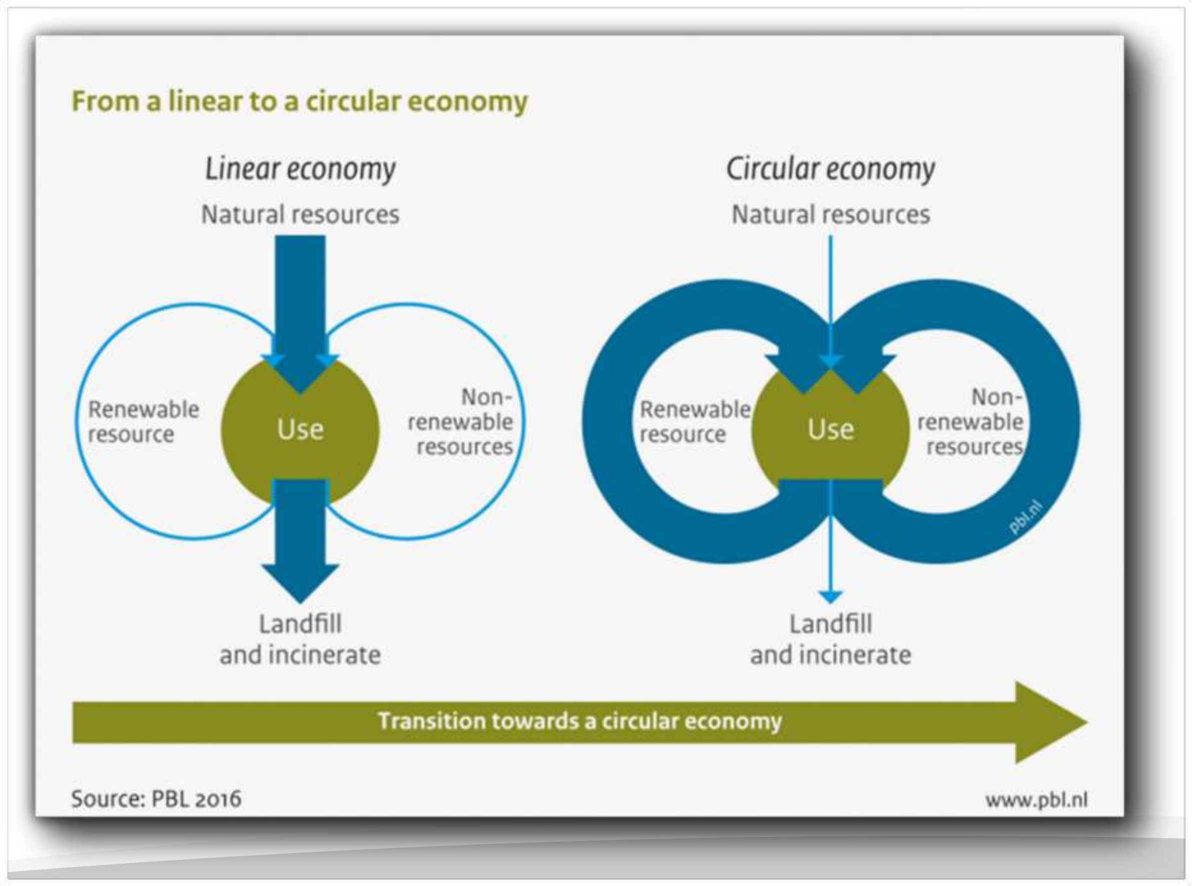
the evaluation of some aspects - often the environmental aspects - of a product system through all stages of its life cycle. It represents a family of tools and techniques designed to help in environmental management and, longer term, in sustainable development.

European Environmental Agency (1997)"Life Cycle Assessment, A guide to approaches, experiences and information sources"

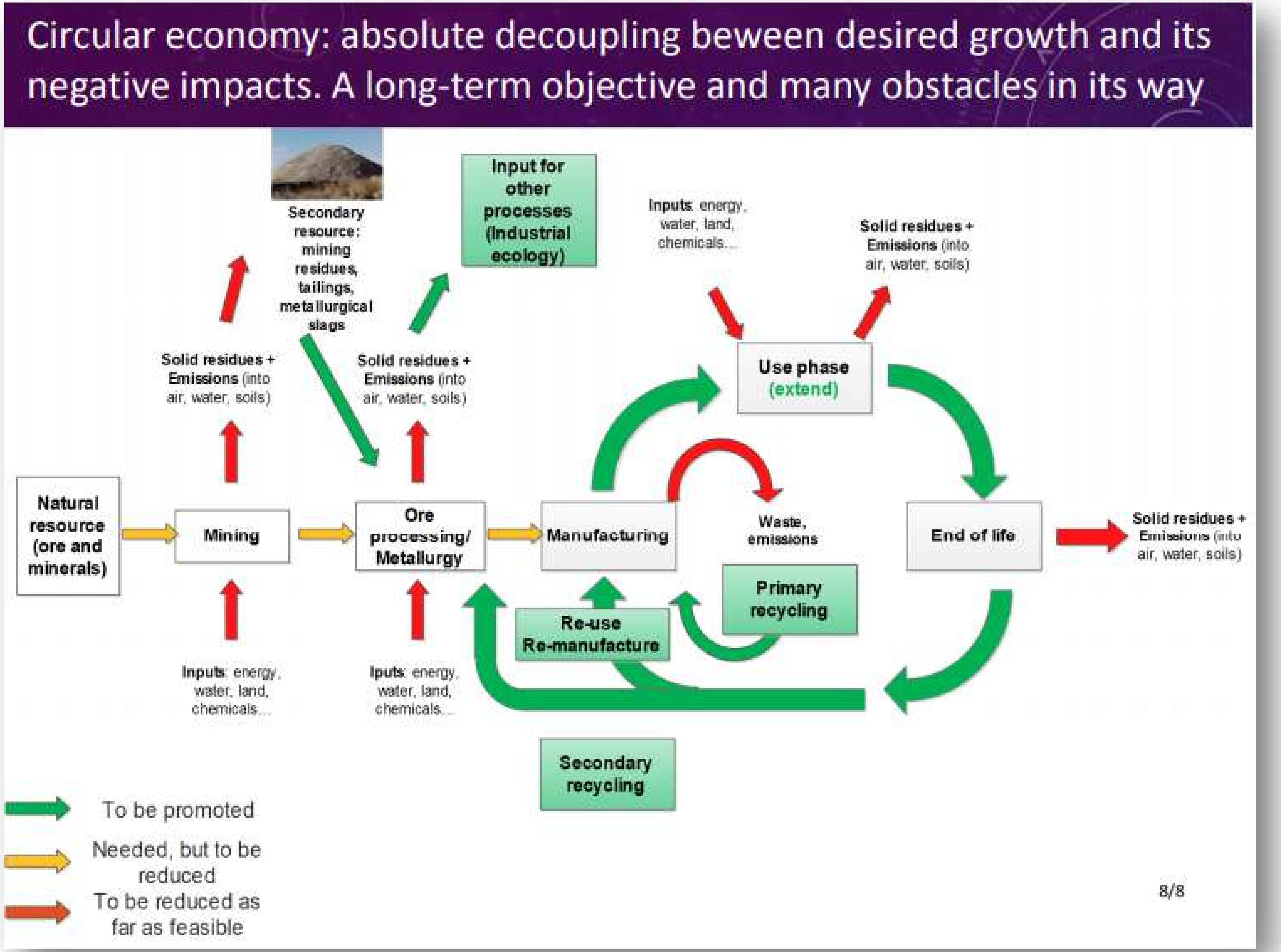
Life Cycle Assessment



LINEAR ECONOMY



CIRCULAR ECONOMY

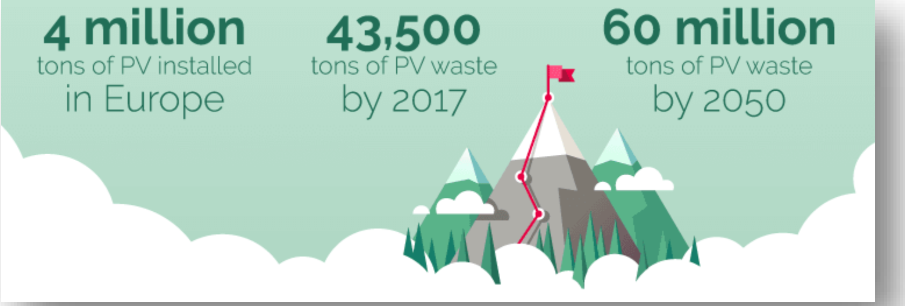


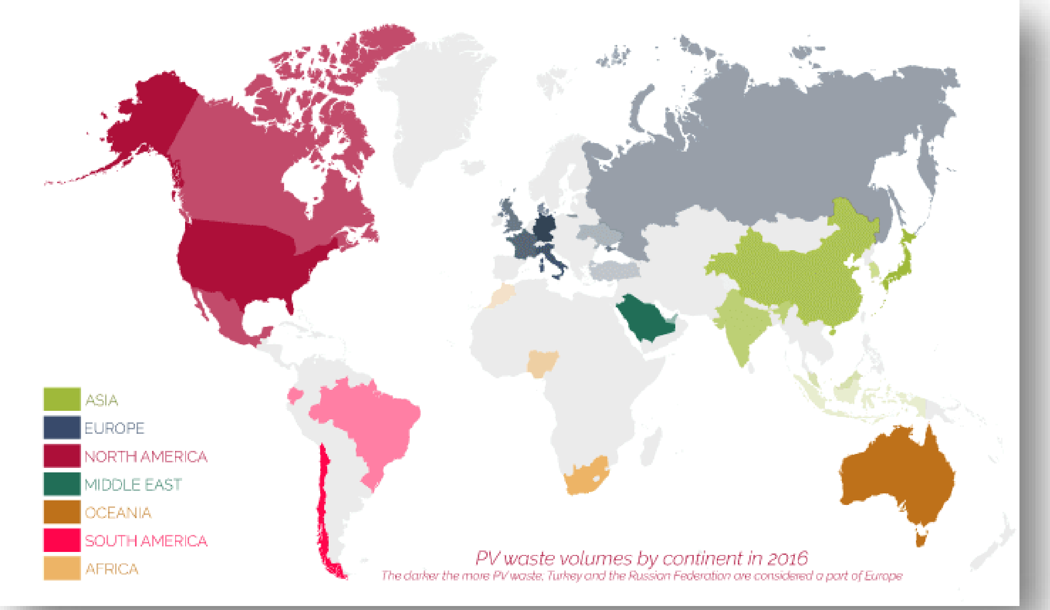
http://www.mineralinfo.fr/sites/default/files/upload/ancre_rapport_2015-ressources_minerales_et_energie_0.pdf

Example

An LCA view of solar panels

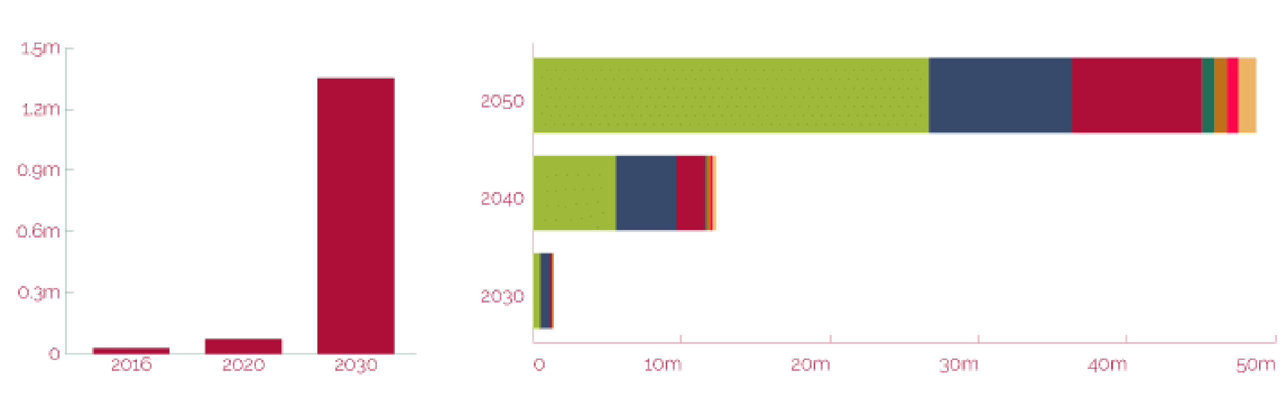
PV panel from raw material extraction to end-of-life reuse, recycle and disposal





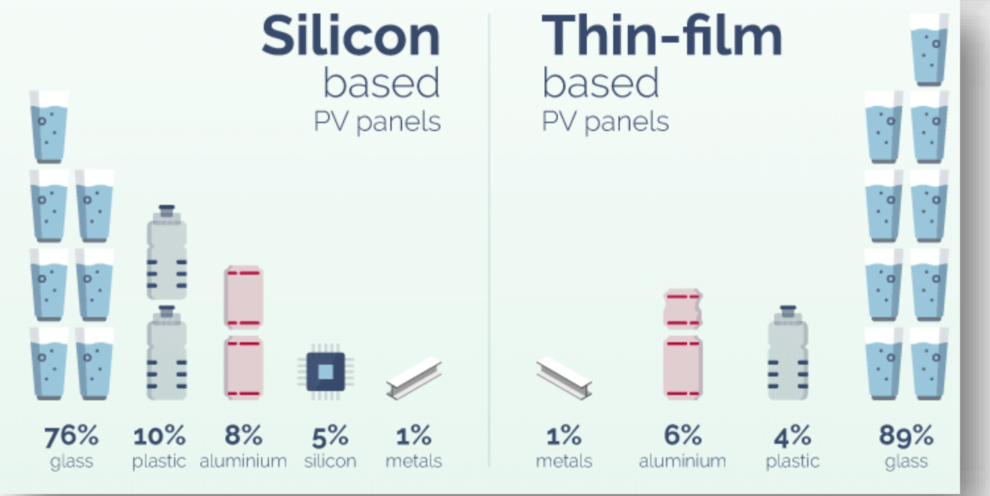
PV waste volumes by continent in 2016

The darker the more PV waste. Turkey and the Russian Federation are considered a part of Europe

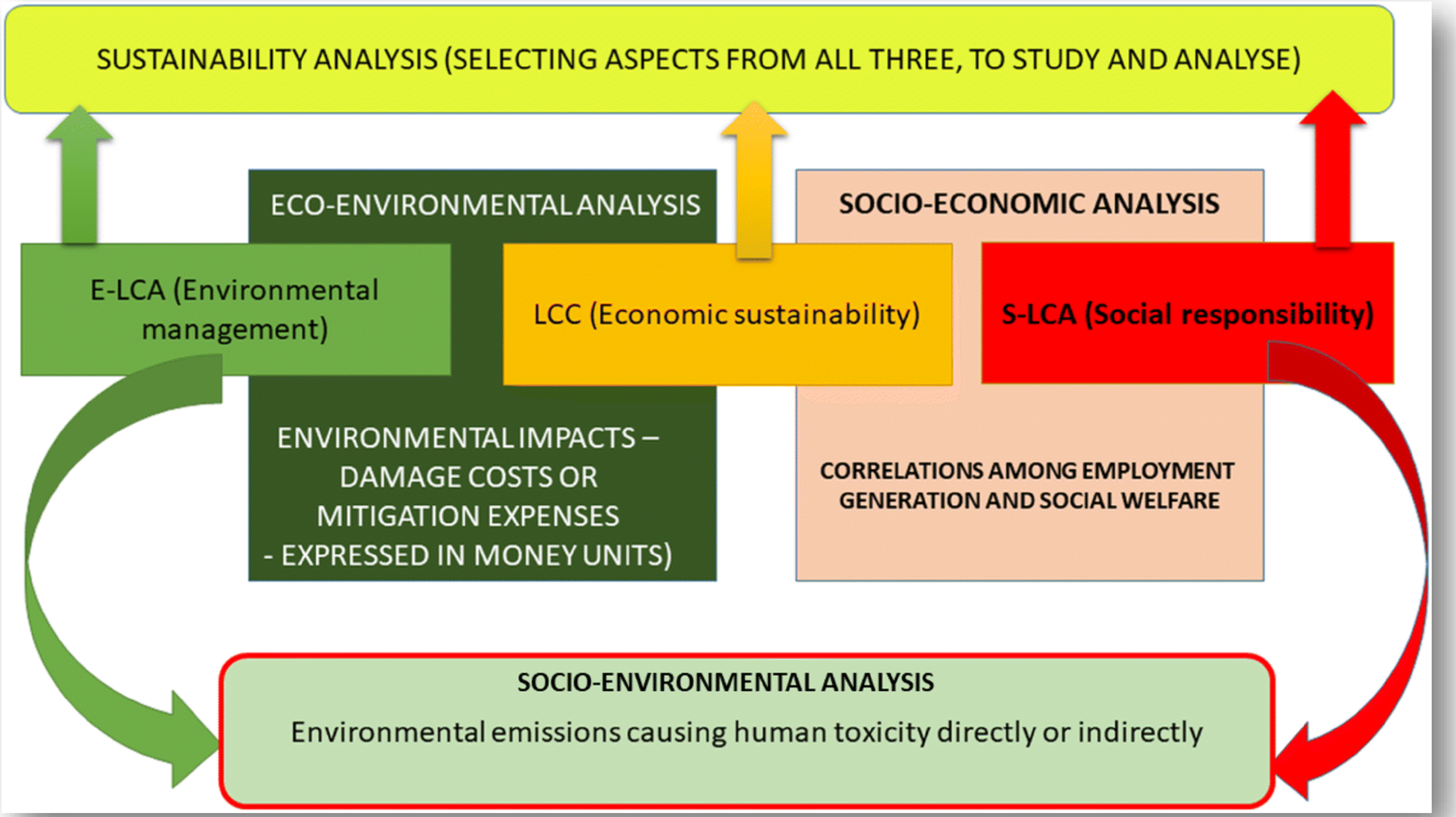


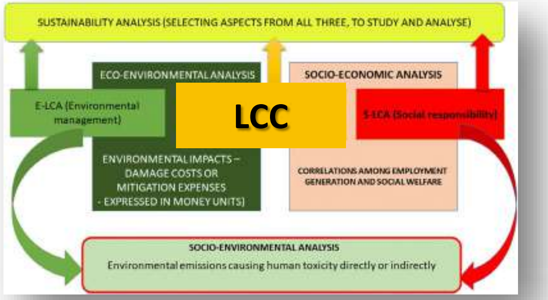
Estimated PV waste increase (t)

Estimated PV waste volumes by continent in the coming decades (t)



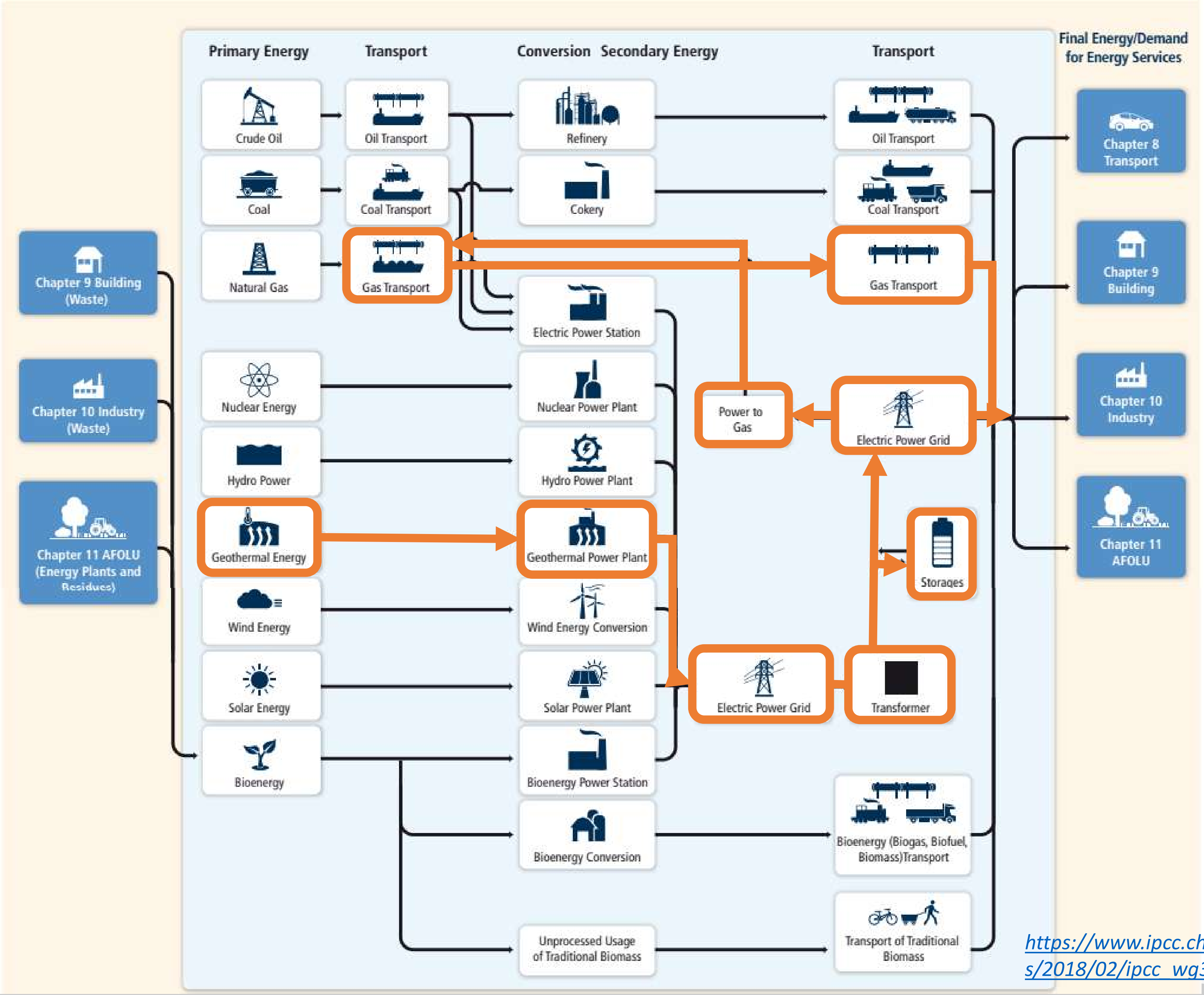
Is LCA a sufficient tool to analyze the full spectrum of the impacts of a policy/product on the environmental, economic, social sphere??


SUSTAINABILITY ANALYSIS (SELECTING ASPECTS FROM ALL THREE, TO STUDY AND ANALYSE)
ECO-ENVIRONMENTAL ANALYSIS
SOCIO-ECONOMIC ANALYSIS
E-LCA (Environmental management)
LCC (Economic sustainability)
S-LCA (Social responsibility)
ENVIRONMENTAL IMPACTS – DAMAGE COSTS OR MITIGATION EXPENSES - EXPRESSED IN MONEY UNITS)
CORRELATIONS AMONG EMPLOYMENT GENERATION AND SOCIAL WELFARE
SOCIO-ENVIRONMENTAL ANALYSIS
Environmental emissions causing human toxicity directly or indirectly



LCC elements

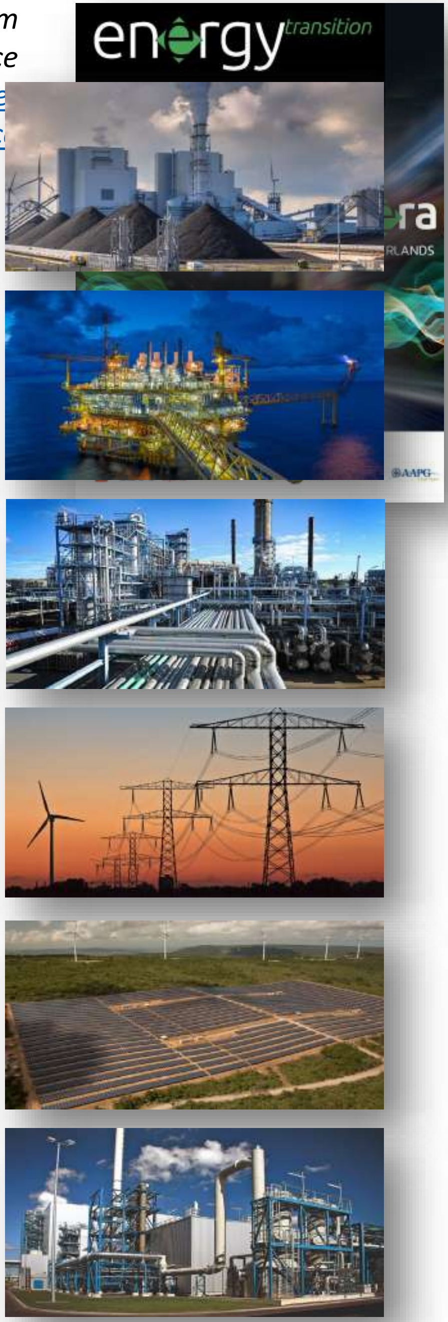
PREPARATION COSTS			SUSTAINMENT COSTS		
RDI Costs	Replication Cost	Cost of Investments	Costs of Schedule and Non-Schedules Maintenance	Cost of Use of Facilities	Disposal Costs
Non-Recurring	Recurring	Non-Recurring	Recurring	Recurring	Recurring
Occurs only once for all units produced	Occur for each unit produced	Occur for every installation of each unit	Occur for each unit installed and for each maintenance cycle	Occur for each unit installed and for each operation cycle	Occur only once for each unit installed
TSR Technology and Systems Research	PSP Production of Systems and Products	Installation Project	ILS Integrated Logistic Support	Operation	Legal Permission
SCR Systems Concepts Research	Factory Acceptance Tests	Design and Construction of Infrastructure	Replacement and Renovation	Training for Continued Operation	Demolition and Disposal
DSP Development of Systems and Products	Qualification and Certification	Improvement of Equipment and Infrastructure	Modification of Systems and Equipment	Consumption of Energy , Water, Communications and Other	Repairs and Restorations
SPA Systems and Products Assurance		Improvement of Utilities	Materials, Labor-Work, Charges	Supply of Materials and Consumables	Depreciation
Trading and Contracting		Systems Integration and Commissioning	Transportation and Insurance	Rents	Improving the Environmental Sustainability
		Initial Preparations for Operation		Outsourced Services	
Management and Documentation	Management and Documentation	Management and Documentation	Management and Documentation	Management and Documentation	Management and Documentation
TCA TOTAL COST OF ACQUISITION				COO COST OF OPERATION	
TCO TOTAL COST OF OWNERSHIP					



https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf

Energy transition and Geology

AAPG Energy Transition Forum
A New Era in Geoscience
[https://energytransition.aapg.org/2018/About/About-the Conferenc](https://energytransition.aapg.org/2018/About/About-the)



Geosciences drivers underpinning the transition:

The **hydrocarbon era** is not over soon: fossil fuel use might flatten from 2035, with oil and coal in decline but gas use continuing to expand.

- **Coal demand**: peak expected in next 10y, with a rapid shift toward gas. Gas is a viable and profitable alternative to coal.
- **Oil demand**: expected to peak in the next 15-20y. Decline won't be for lack of supply: technological and economic competition for oil is coming, with a shift from oil-based transport to electricity-based transport. The question is "when" rather than "if".
- **Gas demand**: will continue to grow to 2040, due to its affordability relative to other fuels, technologies and policies.
- **Electrification**, particularly in buildings and road transport, underlies an acceleration of electricity demand. Energy intensity is improving across regions and end-use sectors with the switches to more efficient fuels and technologies. Strong improvements in economics of electric vehicles trigger rapid uptake. In a disrupted case, electricity demand growth could be boosted to 2.9%/y.
- **Renewables**' cost decline accelerates, out-competing new-built fossil capacity today and existing capacity in 5-10 years causing electricity demand to grow four times faster than all other fuels.
- **CCS & Nuclear** can play a prominent role in the Energy Transition, but face much resistance from communities. Technological, political and social constraints are the challenge.

AAPG Energy Transition Forum
A New Era in Geoscience
https://energytransition.aapg.org/2018/About/

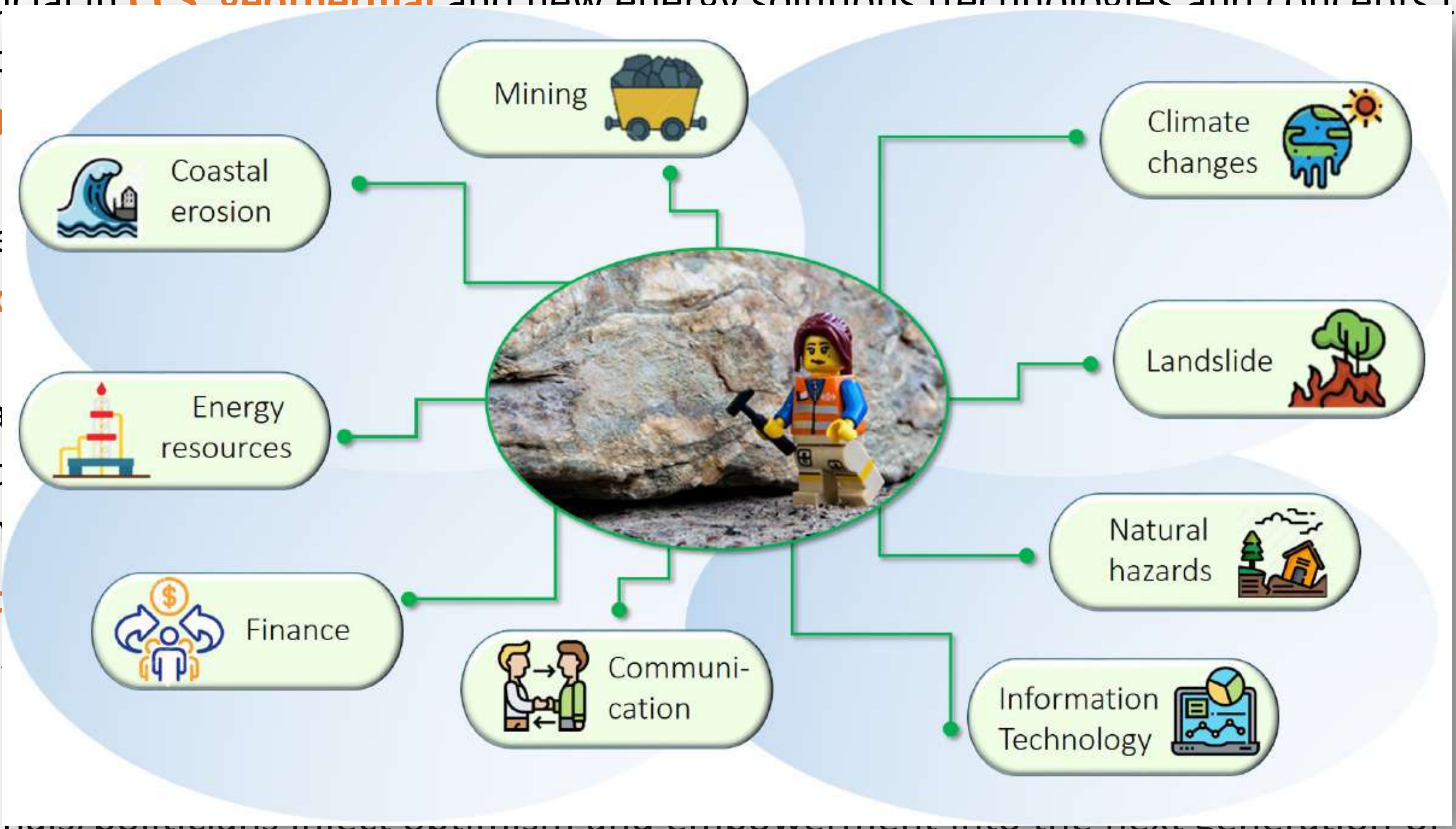
Geosciences in the Energy transition.

- **Natural energy resources**: a primary role for **oil** and mainly **gas** E&P– certainly until 2050 - 2060. Crucial in **CCS**, **geothermal** and new energy solutions (technologies and concepts to be developed;
- The **2050 2°c economy** will generate a huge demand for **new metals and minerals**: + 200% for aluminum, iron, lead and nickel; +1000% for cobalt, lithium, manganese. Challenge? Very little understanding of geology means huge demand for skill sets;
- The **mix of skills** of a geoscientists is unique, particularly in **managing data** and **solving complex problems**. There will be a need for **multiskilled people**, able to integrate geological knowledge with IT, economy and social sciences. Geoscientists have much to contribute because of way they think, used to dealing with complex environments, good at systems thinking and without full data sets;
- **Universities** need to proactively reinforce the message that petroleum/underground geologists are still needed in the future; they need to **adapt the curriculum** and how the profession is promoted;
- The **next generation** is already hugely **environmentally aware:** important that senior professionals/politicians inject optimism and empowerment into the next generation of decision makers;
- We have to develop the **ability to speak** easy and, more important, the **ability to listen** to the requests and doubts of the local communities. This is the only way for a correct **dissemination of knowledge**.

AAPG Energy Transition Forum
A New Era in Geoscience
https://energytransition.aapg.org/2018/About/

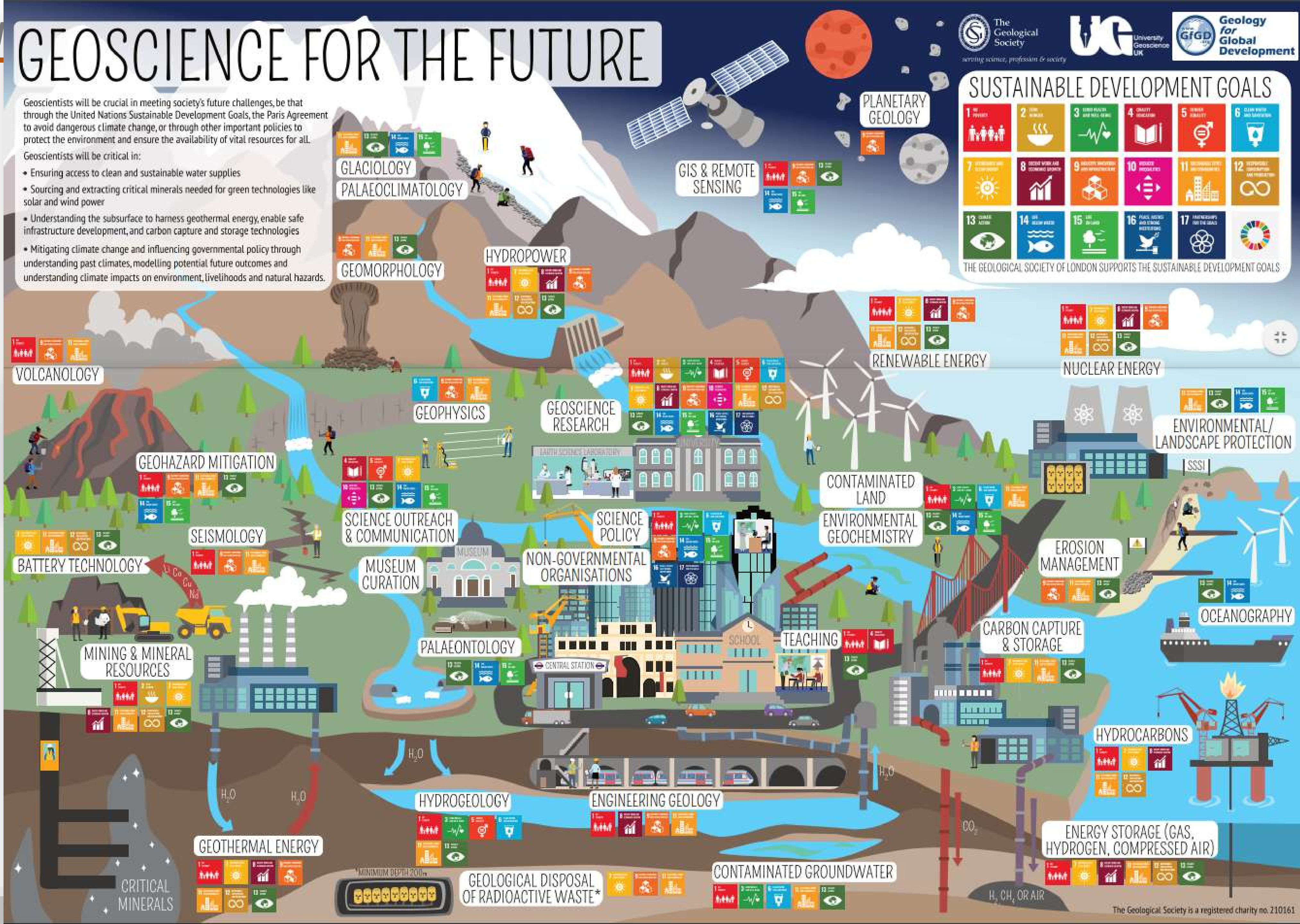
Geosciences in the Energy transition.

- **Natural energy resources**: a primary role for **oil** and mainly **gas** E&P– certainly until 2050 - 2060. Crucial in **CCS**, **geothermal** and new energy solutions (technologies and concepts to be develo
- The **2050** 200% for Challenge
- The **mix** **complex** geologica contribut at system
- **Universit** geologist professio
- The **next** professio… decision makers;
- We have to develop the **ability to speak** easy and, more important, the **ability to listen** to the requests and doubts of the local communities. This is the only way for a correct **dissemination of knowledge**.



Geosciences in the changing world

To sum up:



Le geoscienze saranno fondamentali per:

- **Garantire** l'accesso a forniture idriche pulite e sostenibili
- **Esplorare e produrre** i minerali critici necessari per tecnologie pulite come l'energia solare ed eolica
- **Comprendere** il sottosuolo per sfruttare O&G e l'energia geotermica; **consentire** lo sviluppo di infrastrutture sicure e di tecnologie CCS
- **Mitigare** i cambiamenti climatici influenzando le politiche governative attraverso la comprensione del passato, la modellazione di scenari futuri e degli impatti climatici sull'ambiente, sulla vita e sugli eventi naturali