

“ Il riscaldamento globale e le sue cause: produzione di energia oggi e domani ”

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Maurizio Fermeglia – Università di Trieste



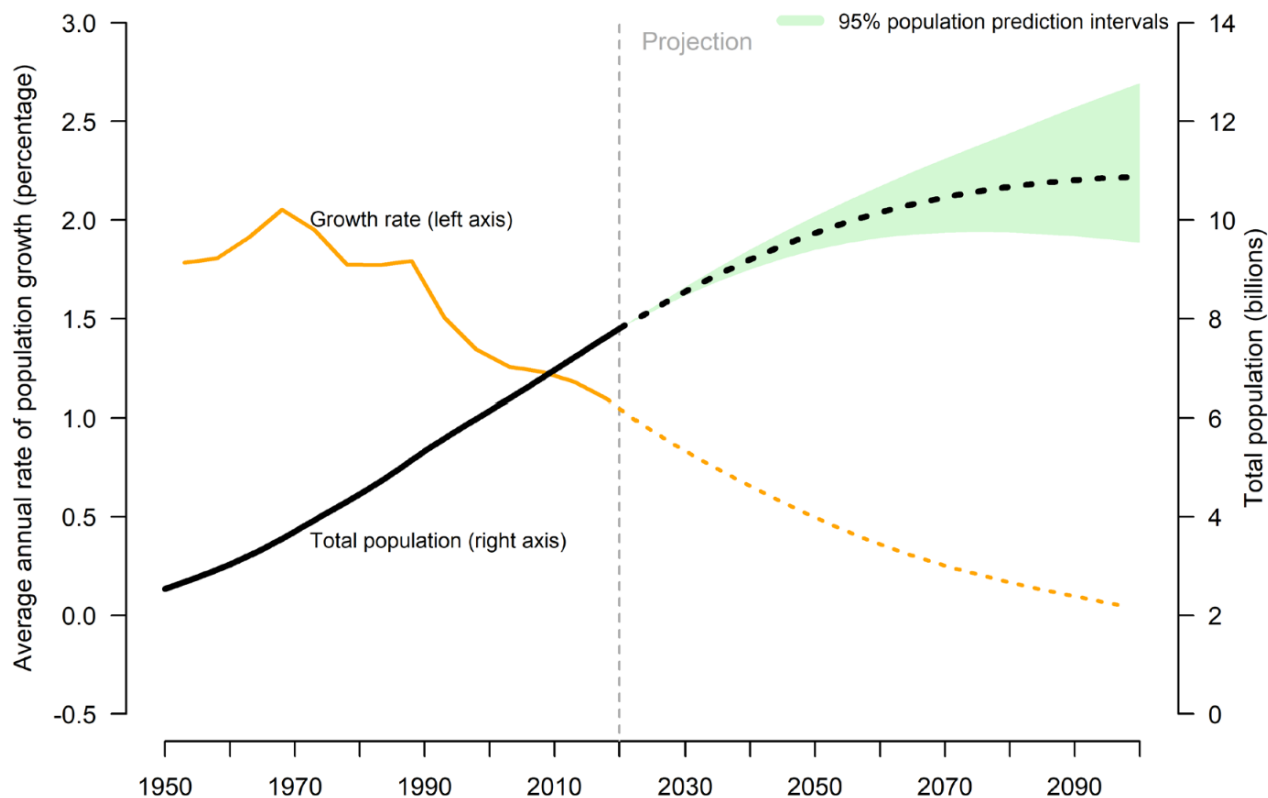
Argomenti da affrontare



- ➔ • Il Riscaldamento Globale: una emergenza mondiale
 - La concentrazione di CO₂ in atmosfera
 - Gli effetti del riscaldamento globale
- Le cause del riscaldamento globale: produzione di energia oggi e domani
 - Le fonti di energia
 - Indicatori per prendere decisioni
- Conclusioni



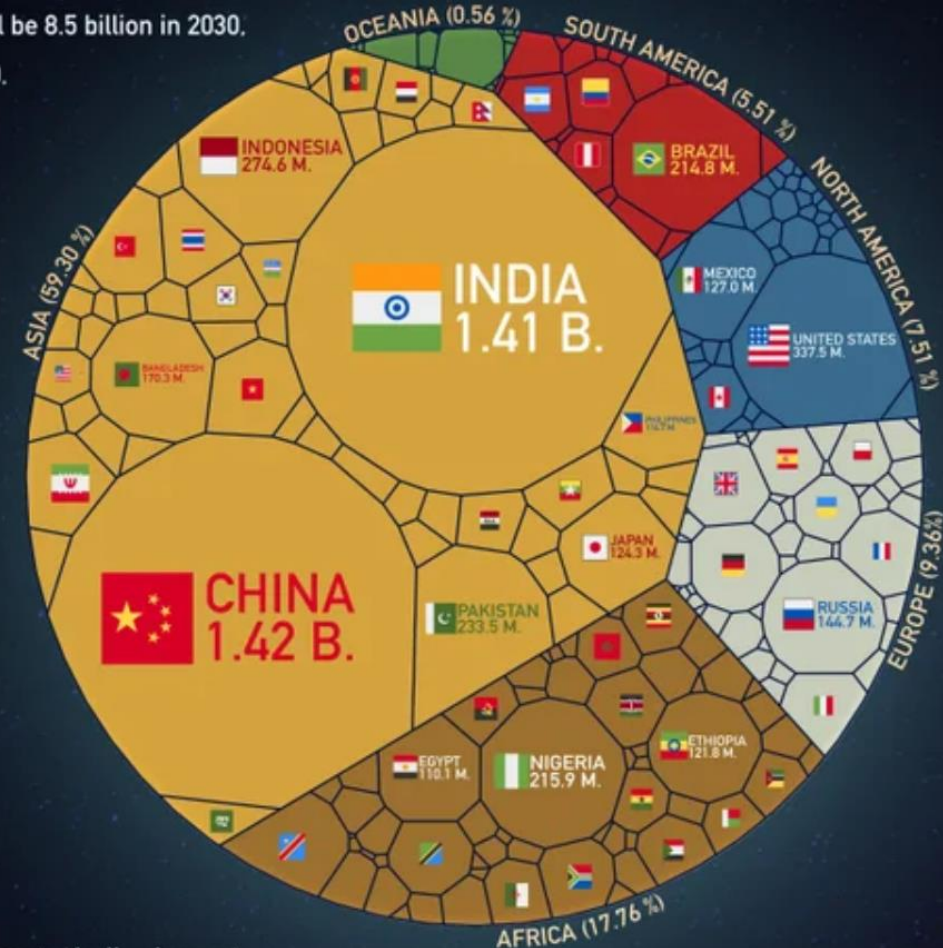
Il 22 novembre 2022 abbiamo raggiunto gli 8 miliardi di abitanti sulla terra



According to World Population Prospects,

India's population will surpass China's in 2023.

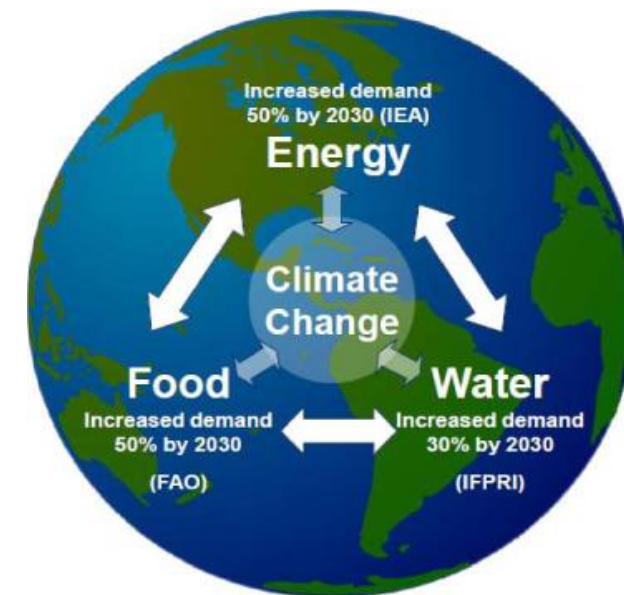
Earth's population will be 8.5 billion in 2030,
and 9.7 billion by 2050.



La tempesta perfetta di John Beddington



- Aumento **popolazione globale** (da 6.8 miliardi a 8.3 miliardi).
- Richiesta di **cibo** aumentata del 50%, ma produzione non adeguata
- Richiesta di **energia** aumentata del 60% ma produzione non adeguata
- Domanda globale di **acqua** aumentata del 30%, problemi di approvvigionamento acqua potabile
- Riduzione delle **emissioni di gas serra** inferiori alle aspettative - cambiamenti climatici sempre più evidenti
- Scarsità di cibo, energia ed acqua portano a **tensioni internazionali e migrazioni**



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News > Science

World faces 'perfect storm' of problems by 2030, chief scientist to warn

Food, water and energy shortages will unleash public unrest and international conflict, Professor John Beddington will tell a conference tomorrow



AMBIENTE

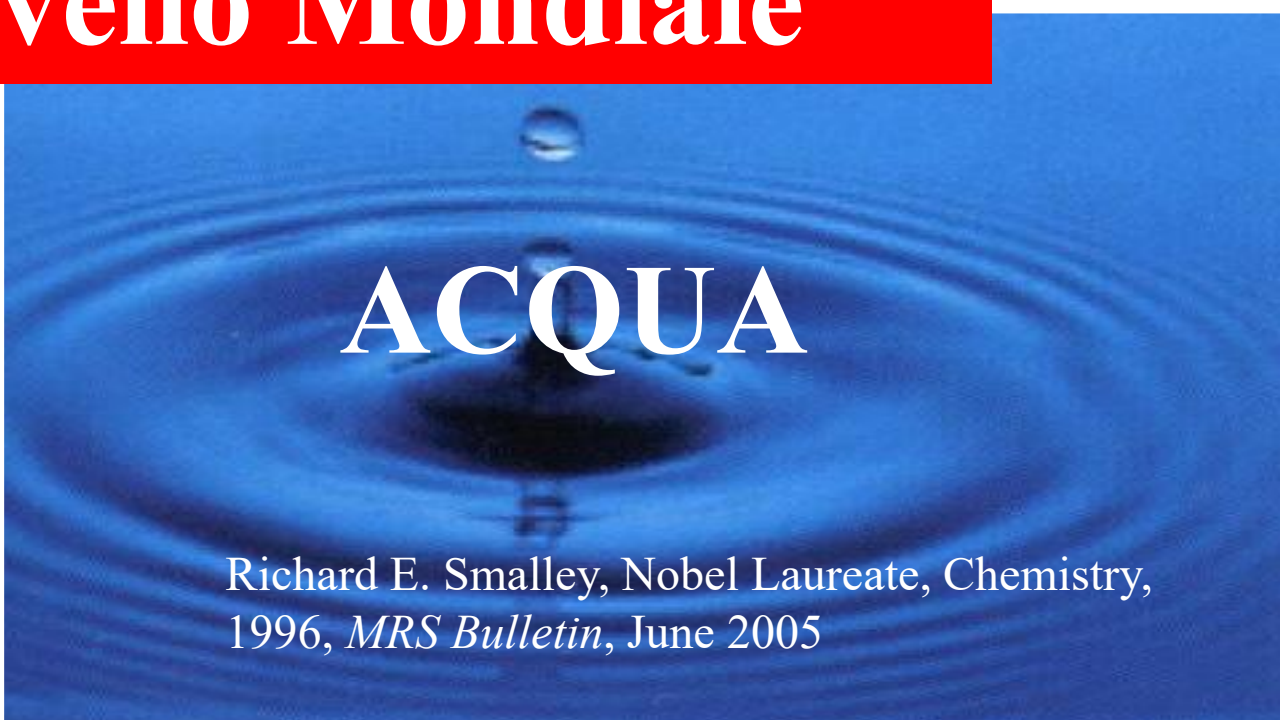


CIBO

4 Emergenze a livello Mondiale



ENERGIA



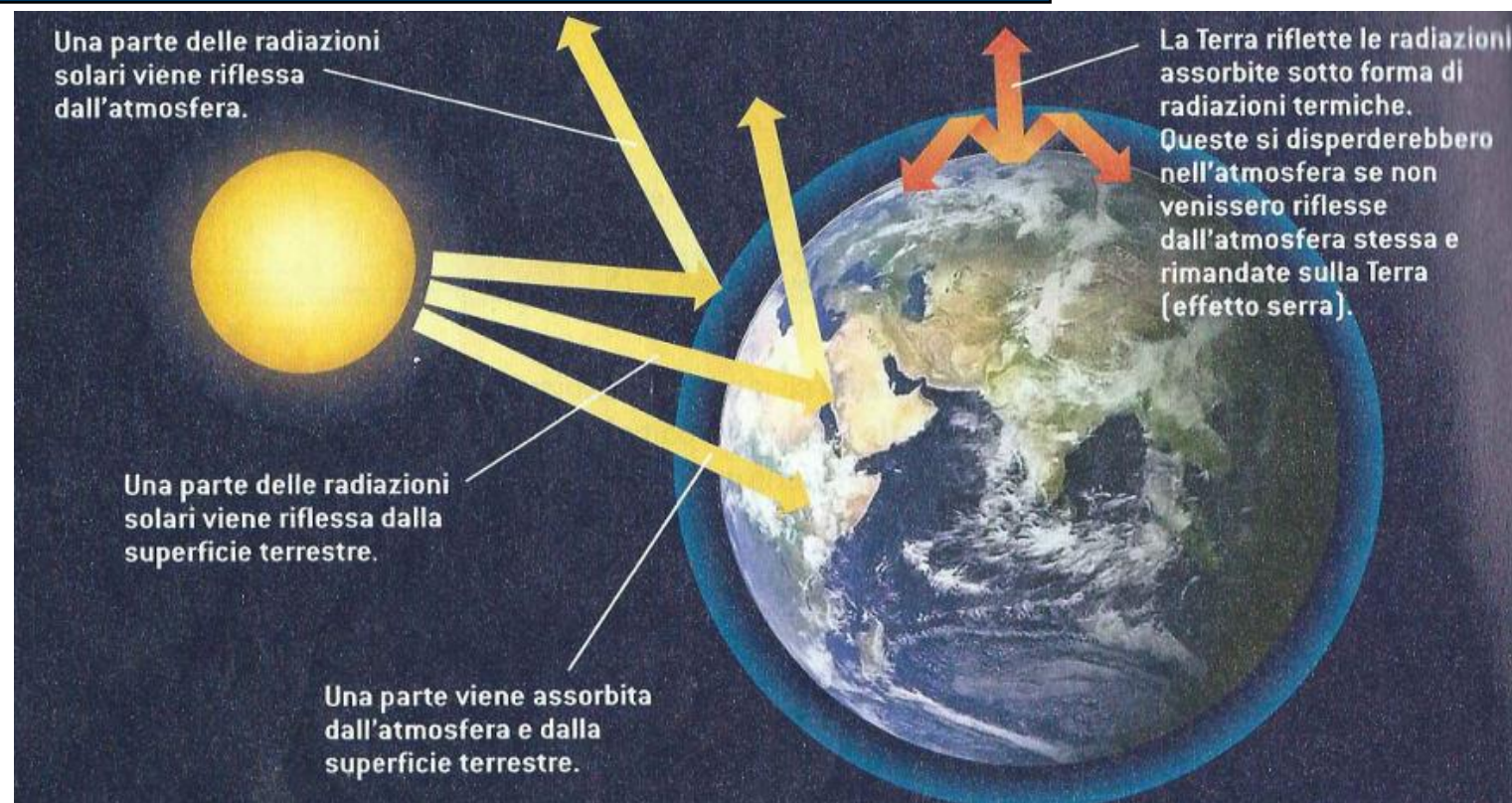
ACQUA

Richard E. Smalley, Nobel Laureate, Chemistry,
1996, *MRS Bulletin*, June 2005

L'effetto serra



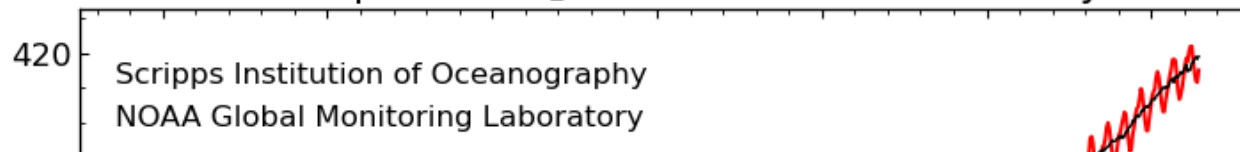
- **1824: Jean Baptiste Joseph Fourier** predice **effetto serra**.
- **1856: Eunice Newton Foote** dimostra in laboratorio l'effetto serra (vap. H₂O e CO₂) nella **cattura dei raggi solari**
- **1896: Svante Arrhenius** calcola che l'effetto serra porta a **riscaldamento globale**
- **1938 - Guy Stewart Callendar** **prima prova del riscaldamento globale**
- **2007 - IPCC** **responsabilità umana per CO₂ è 90%**.
- **2021 - IPCC** **La temperatura continuerà ad aumentare** almeno fino a metà secolo qualsiasi sia lo scenario di emissioni



Effetto: variazioni della concentrazione di gas serra in atmosfera



Atmospheric CO₂ at Mauna Loa Observatory



Sep. 13, 2023

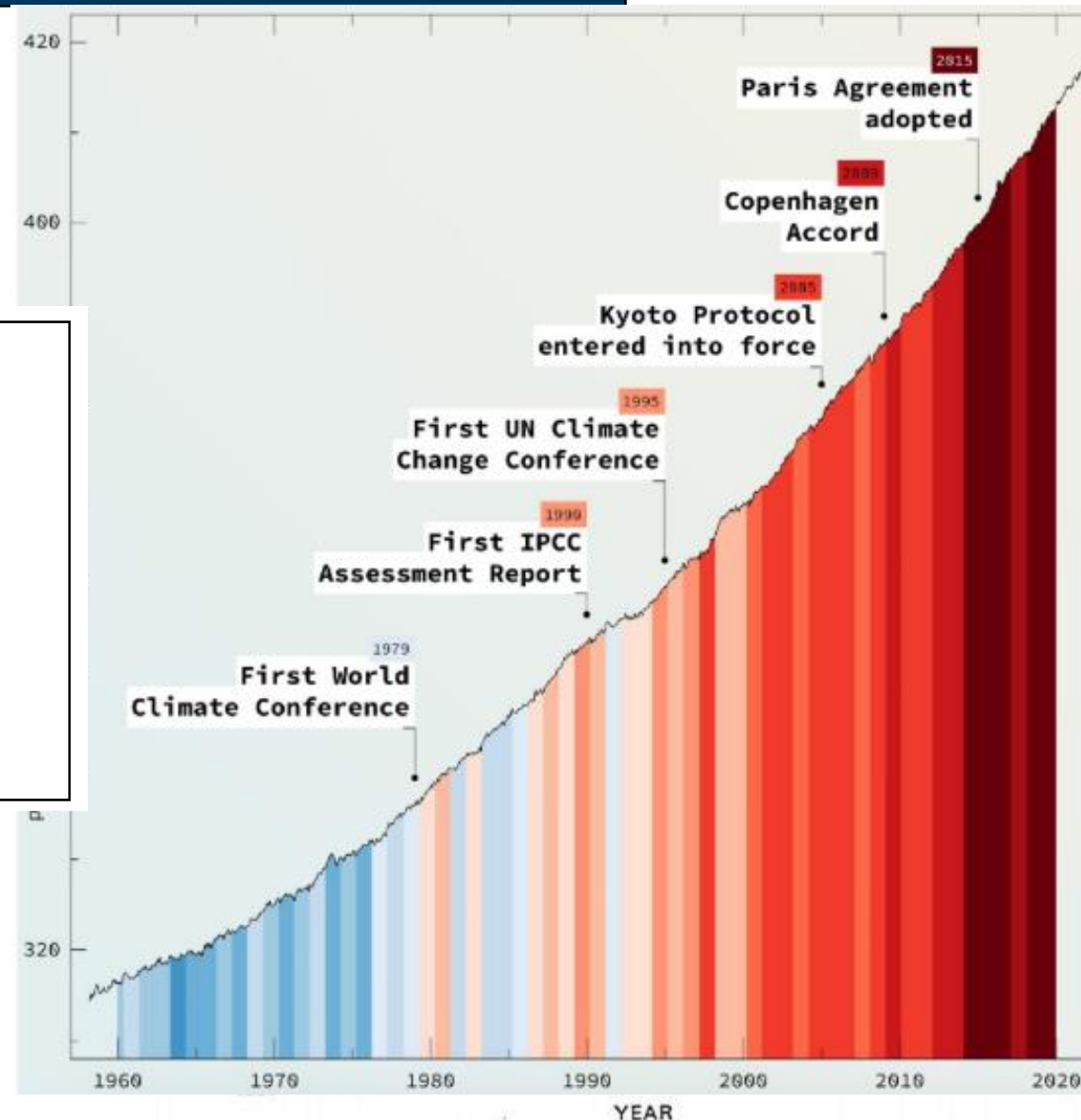
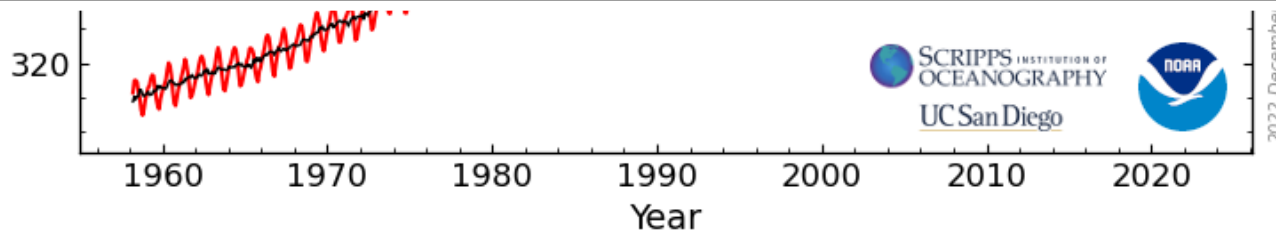
418.69 ppm

Sep. 16, 2022

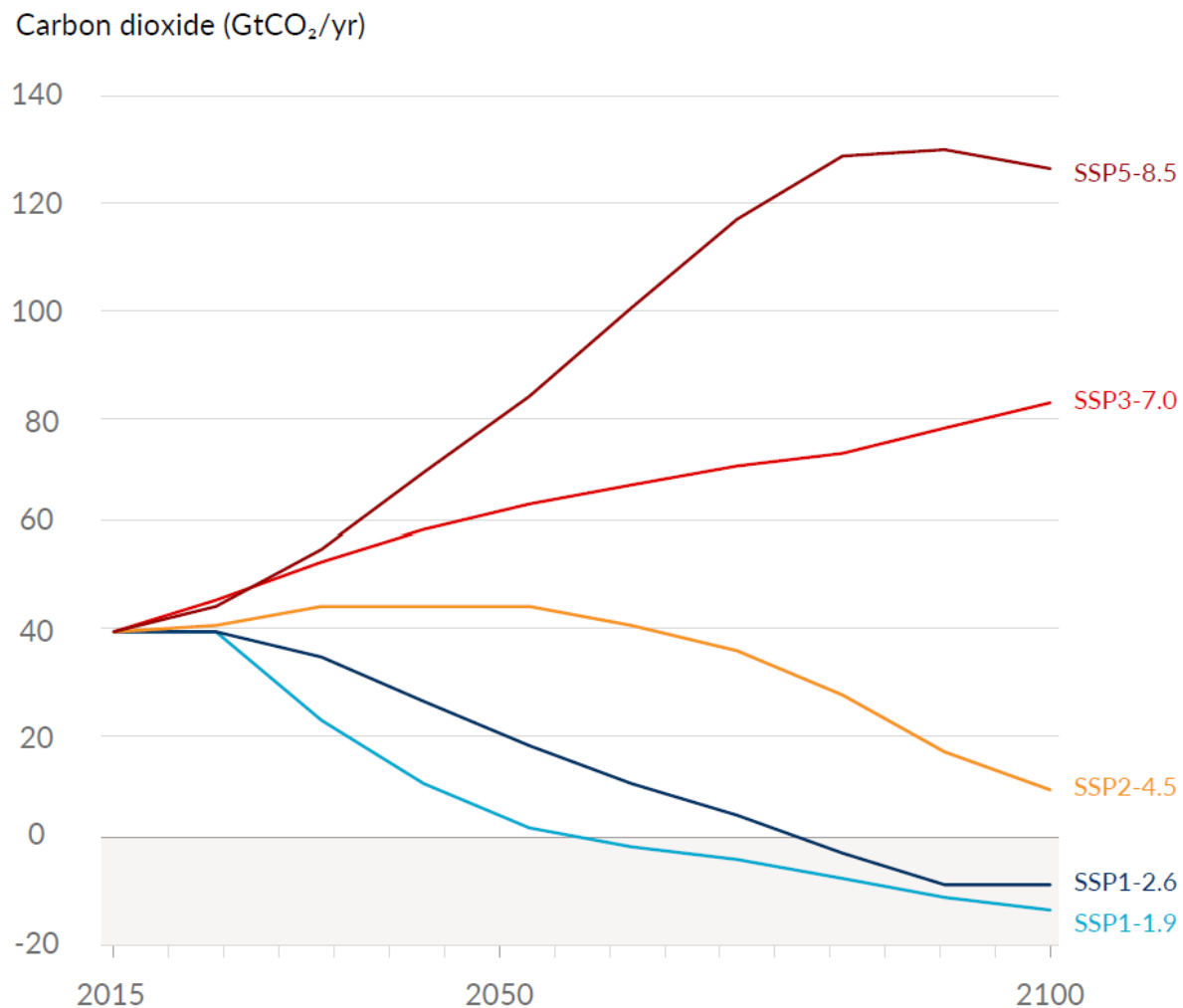
416.15 ppm

1 Year Change

2.54 ppm (0.61%)

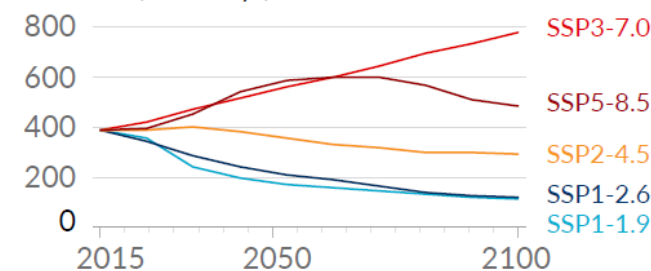


IPCC 2021: future emissioni annuale di CO₂ ed altri gas per diversi scenari climatici futuri

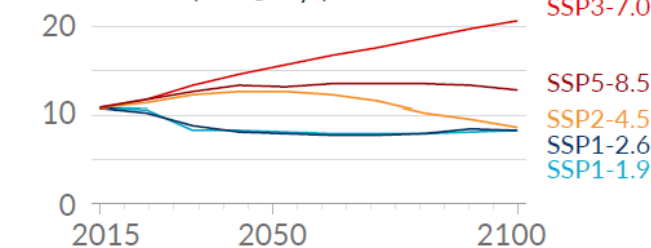


Selected contributors to non-CO₂ GHGs

Methane (MtCH₄/yr)

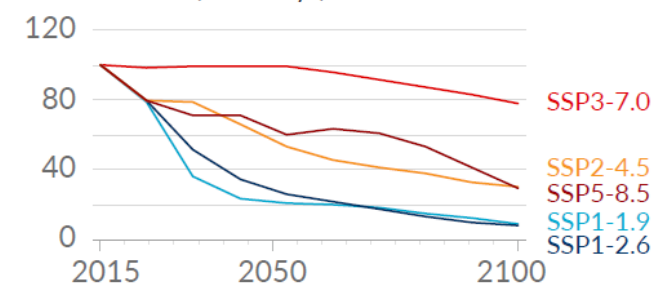


Nitrous oxide (MtN₂O/yr)



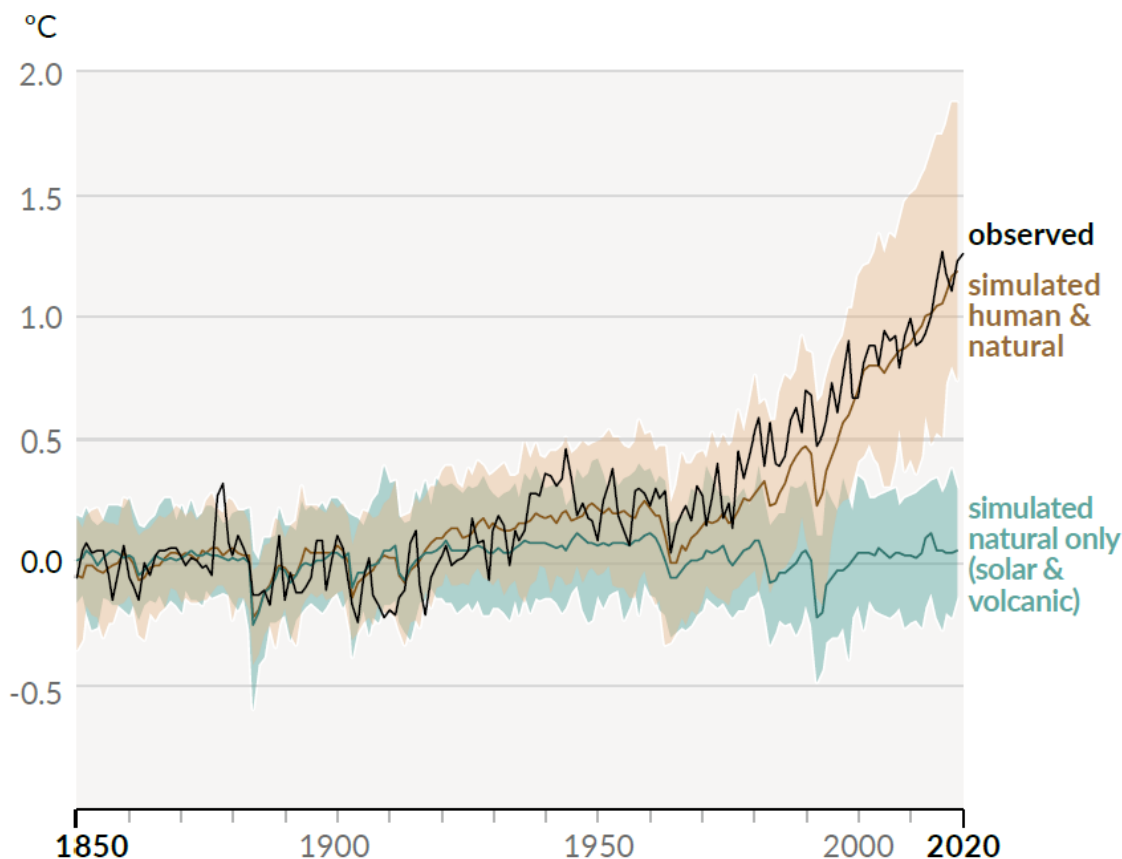
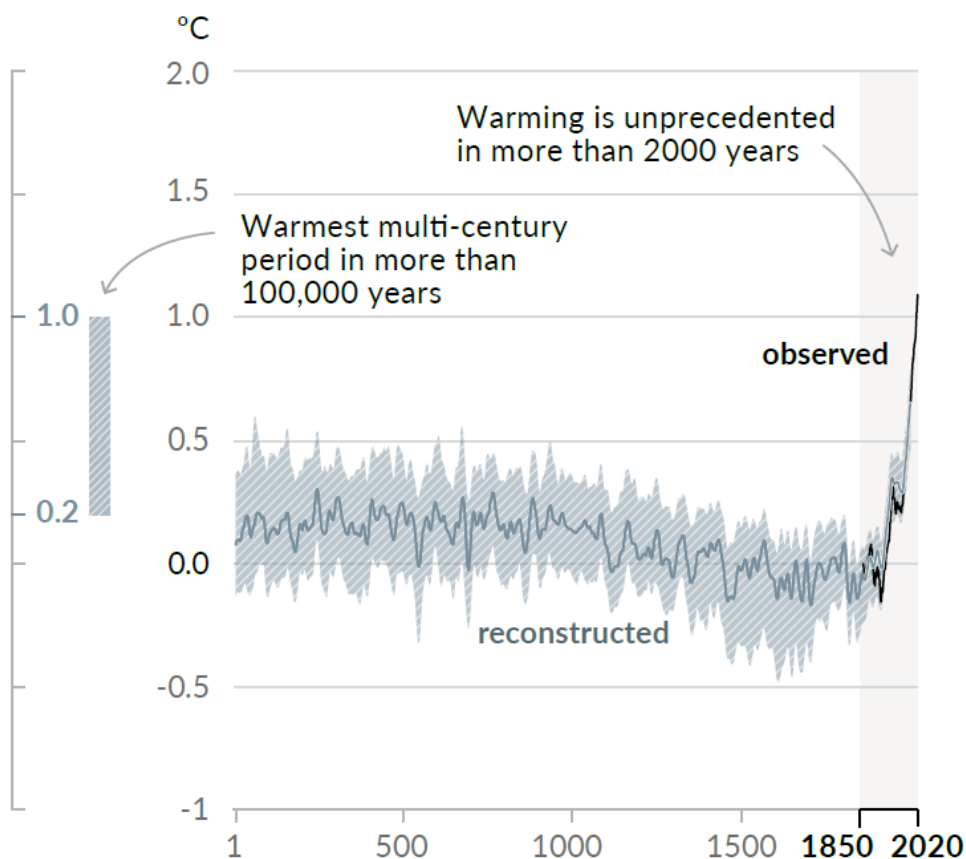
One air pollutant and contributor to aerosols

Sulfur dioxide (MtSO₂/yr)

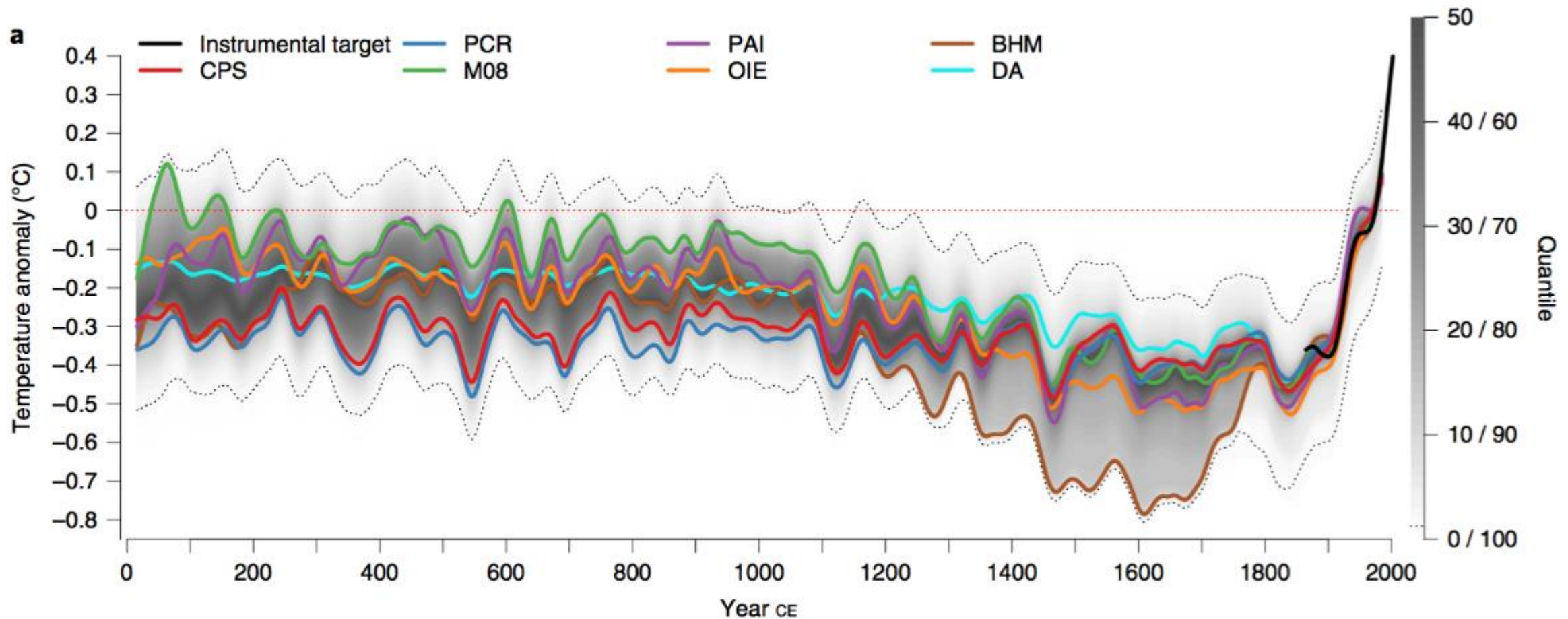


IPCC 2021: Temperatura della terra è aumentata di circa 1.2° negli ultimi 100 anni

- Sono gli esseri umani che hanno riscaldato il clima del pianeta ad una velocità senza precedenti negli ultimi 2000 anni.

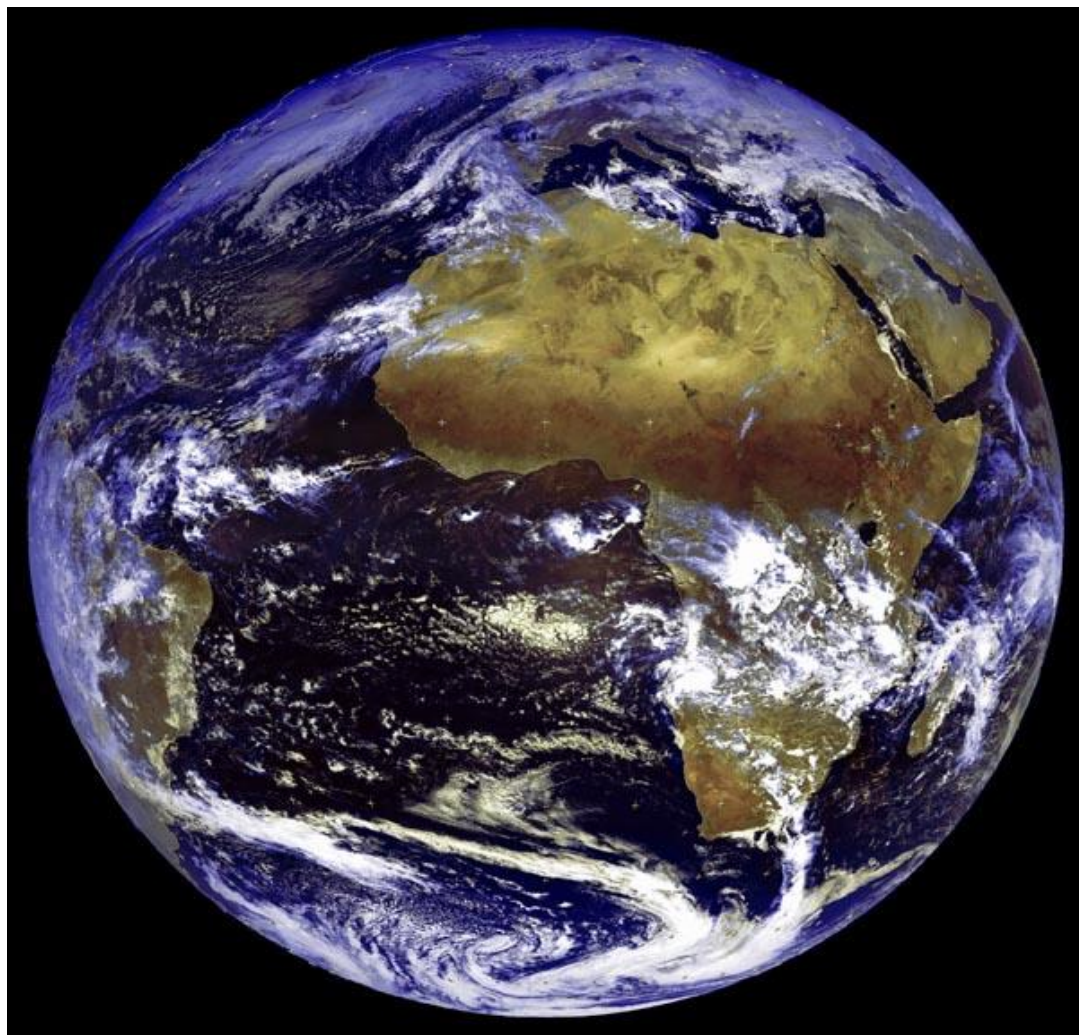


Quanto e' anomalo quello che sta succedendo? Ultimi 2000 anni.

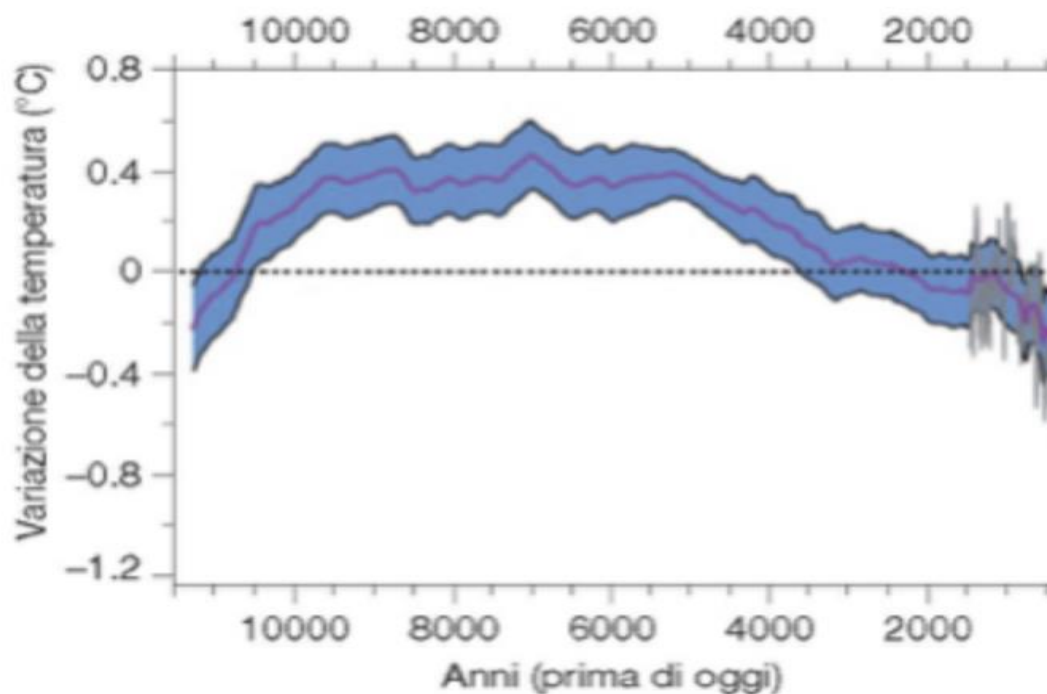


PAGES2K, Nature, Geoscience 2019

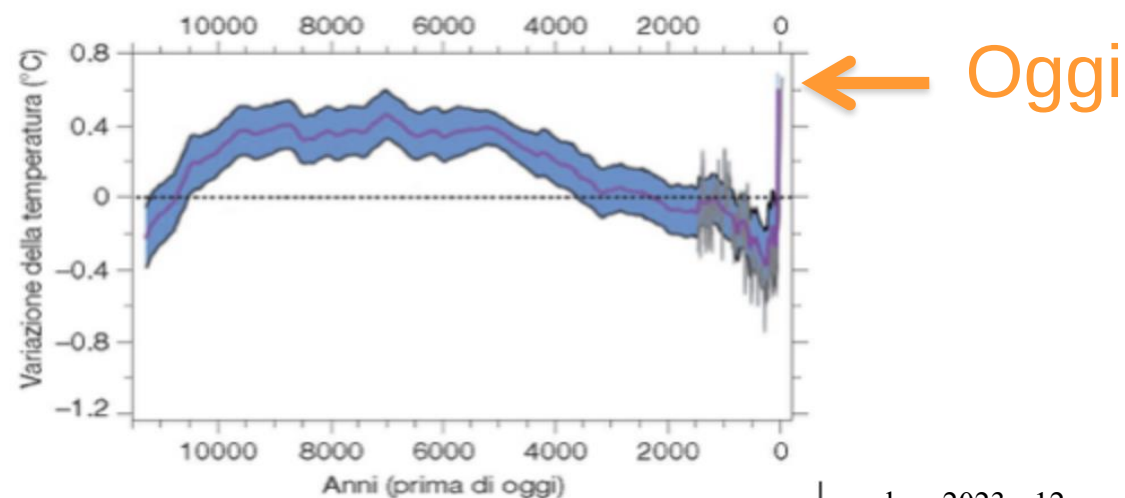
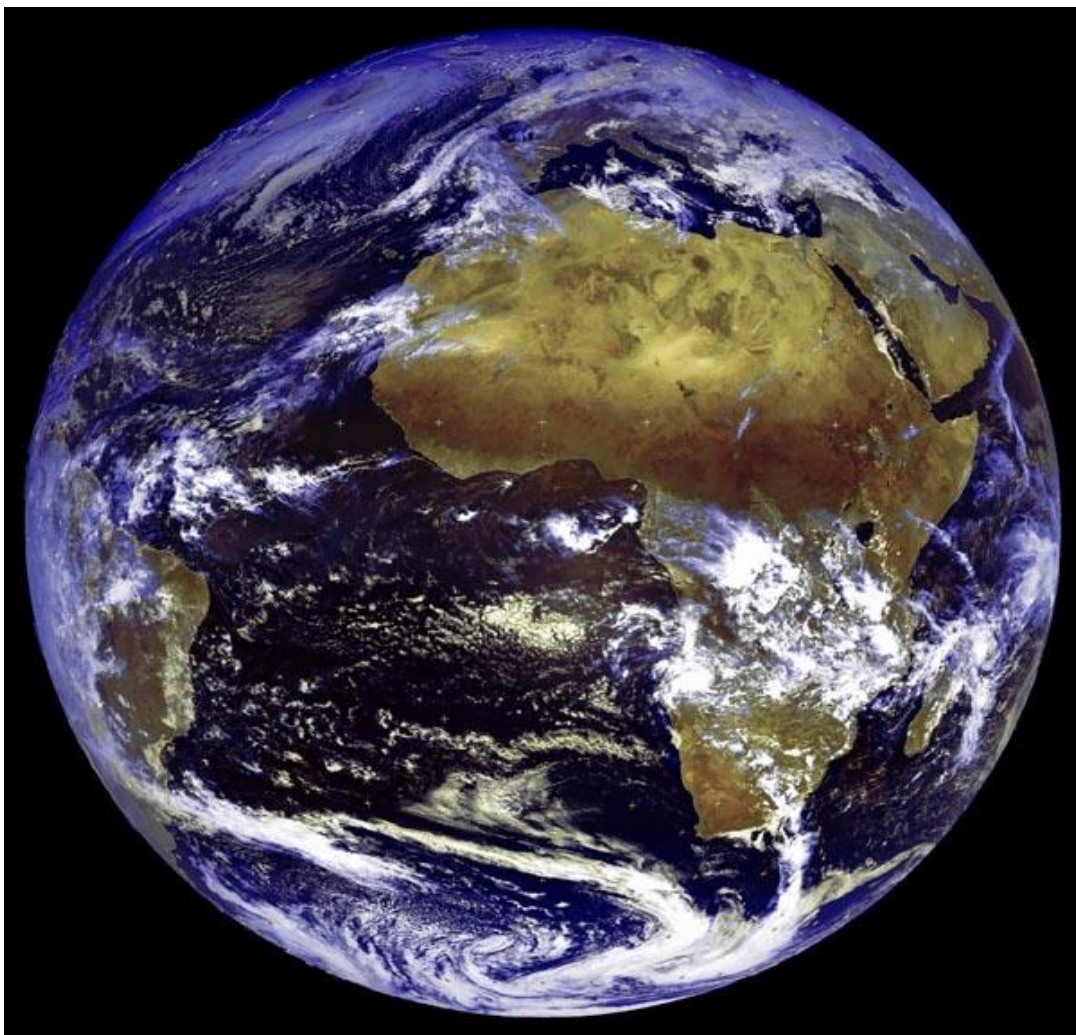
Le temperature “normali” del pianeta



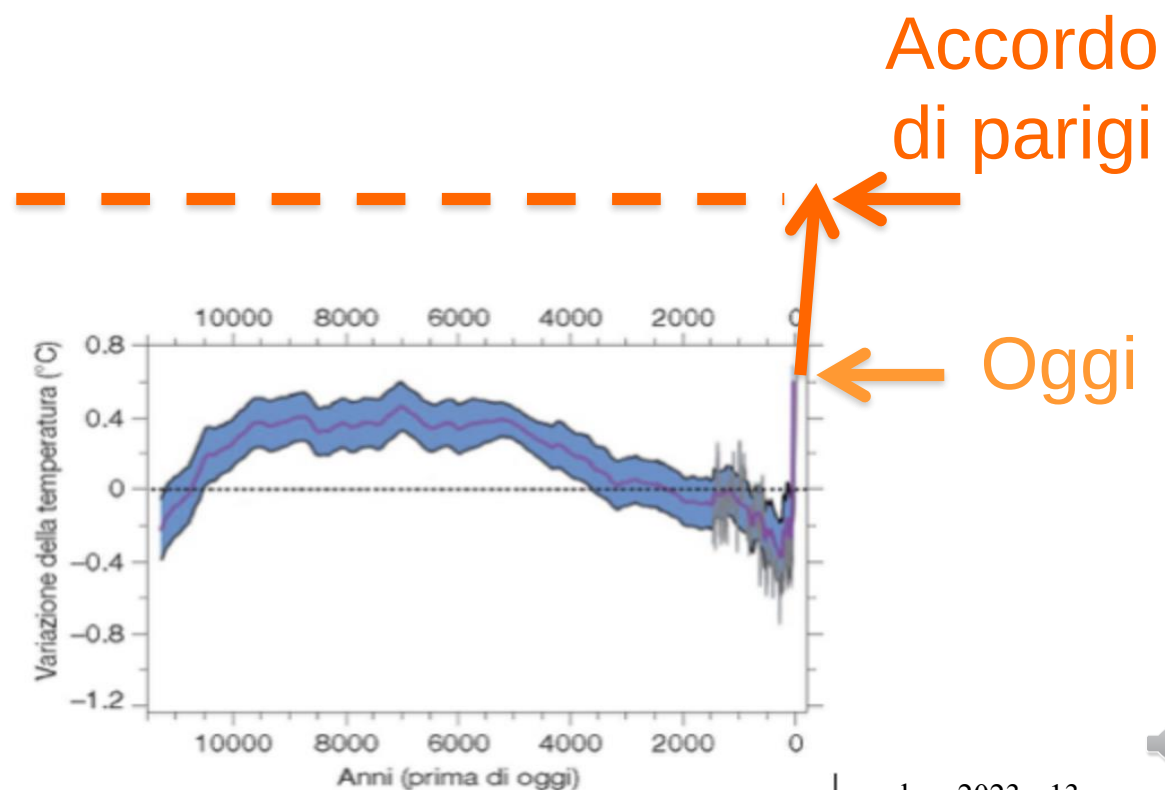
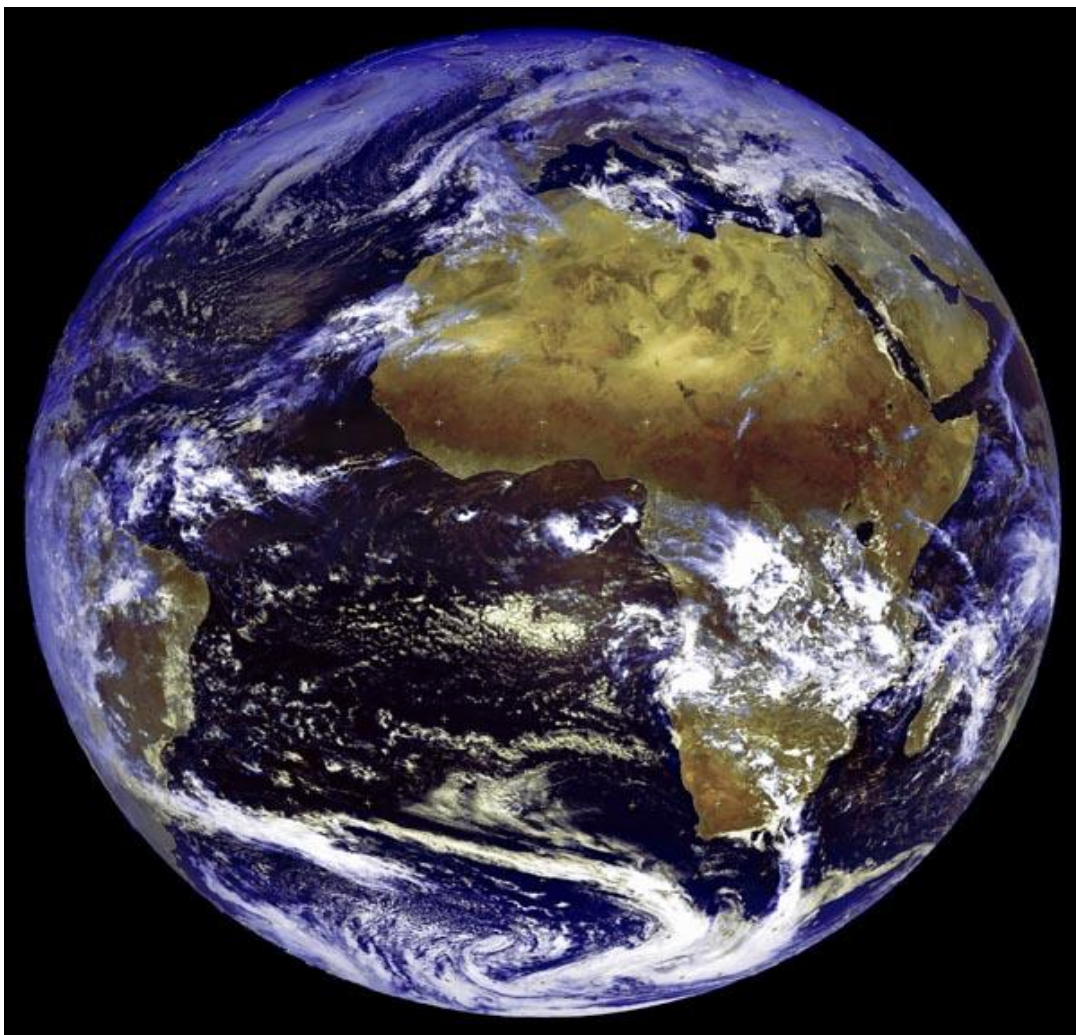
Marcott et al. 2013; Science



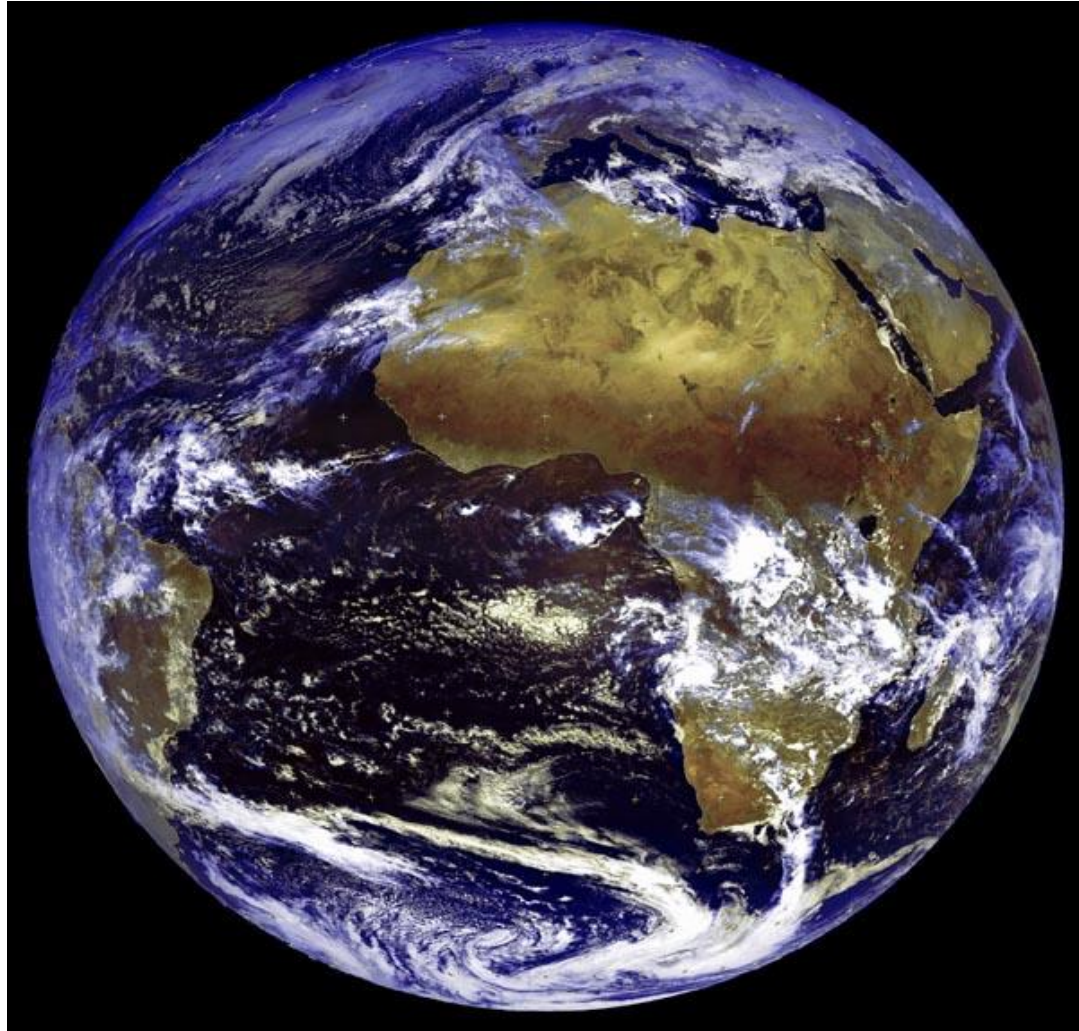
Ora il pianeta ha una febbre “anomala”



Che potrebbe crescere sempre di piu'



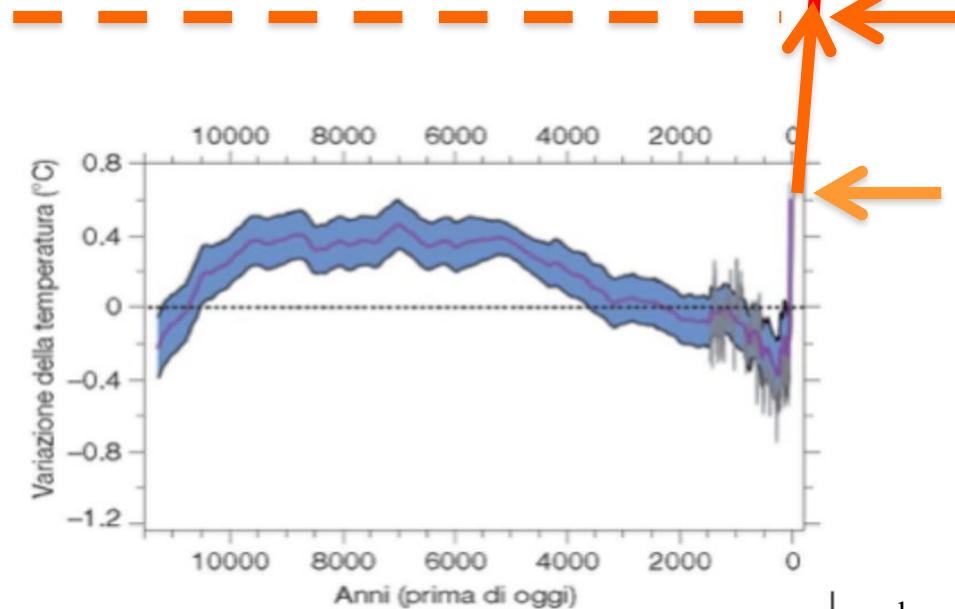
Fino a livelli non sopportabili per la società'



Business
as usual

Accordo
di parigi

Oggi



RCP8.5, at the end of 21 century, EURO-CORDEX

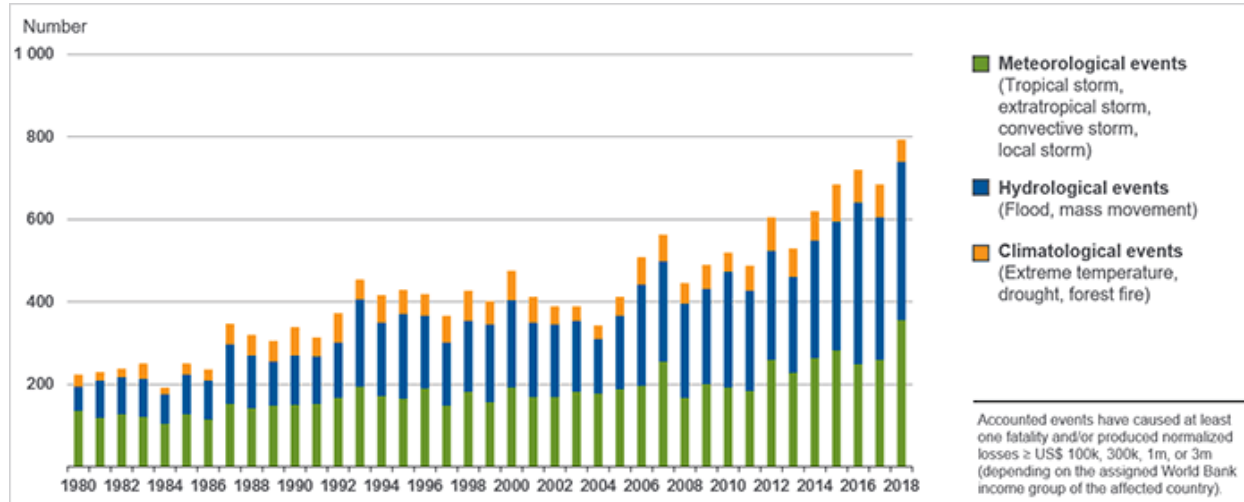


I cambiamenti climatici influenzano molteplici settori della società' (e della nostra vita)



Aumento di eventi meteoclimatici "catastrofici"

Scioglimento dei ghiacciai e crisi dell'acqua



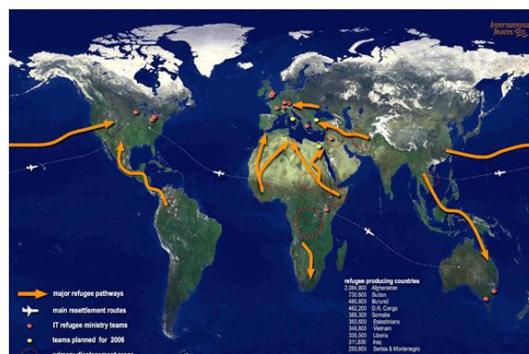
Lungo addio il ghiacciaio dei Forni negli scatti di Vittorio Sella, Ardito Desio e Claudio Smiraglia. Nell'ultima immagine, la simulazione dell'aspetto della montagna nel 2050 (Comitato Glaciologico Italiano)

Salute

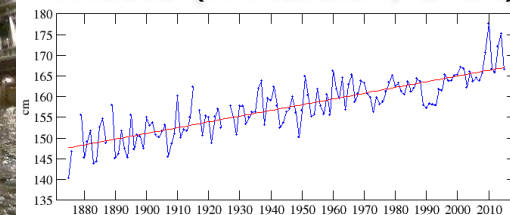
Migrazioni di massa

Biodiversita'

Innalzamento del livello del mare e distruzione delle zone costiere (circa 25 cm dal 1900)



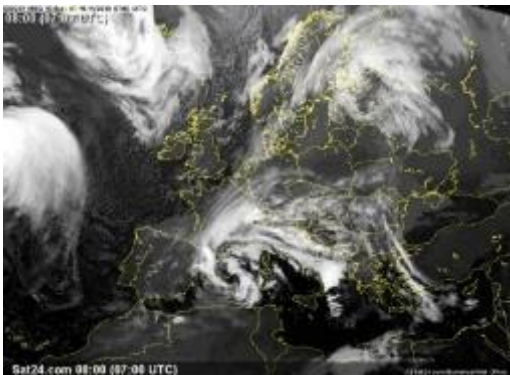
Livello del mare a Trieste (F. Raicich, CNR)



Anche in Italia siamo in emergenza climatica: enormi anomalie climatiche negli ultimi anni



Sardegna 2013; Genova 2011, 2014;
Vicenza 2010; Livorno 2017; Sicilia 2021;
Marche 2022; Emilia Romagna 2023



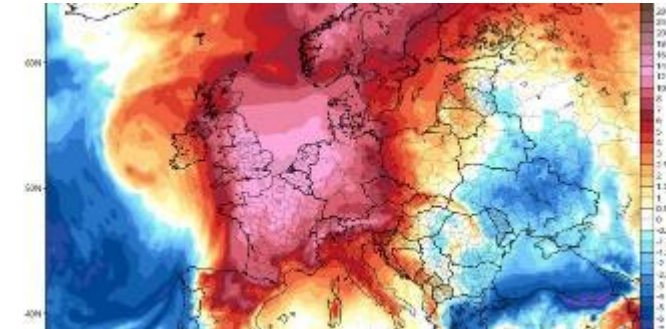
Monte Bianco 2021
Marmolada 2022



Tempesta VAIA 2018



Ondate di calore record in
Europa nel 2019, 2022



Siccità 2022



Fusione dei ghiacciai



1985

2007

The glacier was here in
Le glacier était ici en

1982

100 anni fa

OGGI

<http://climate.nasa.gov/sof/>

Quel (poco) che resta del ghiacciaio del Canin in Alpi Giulie

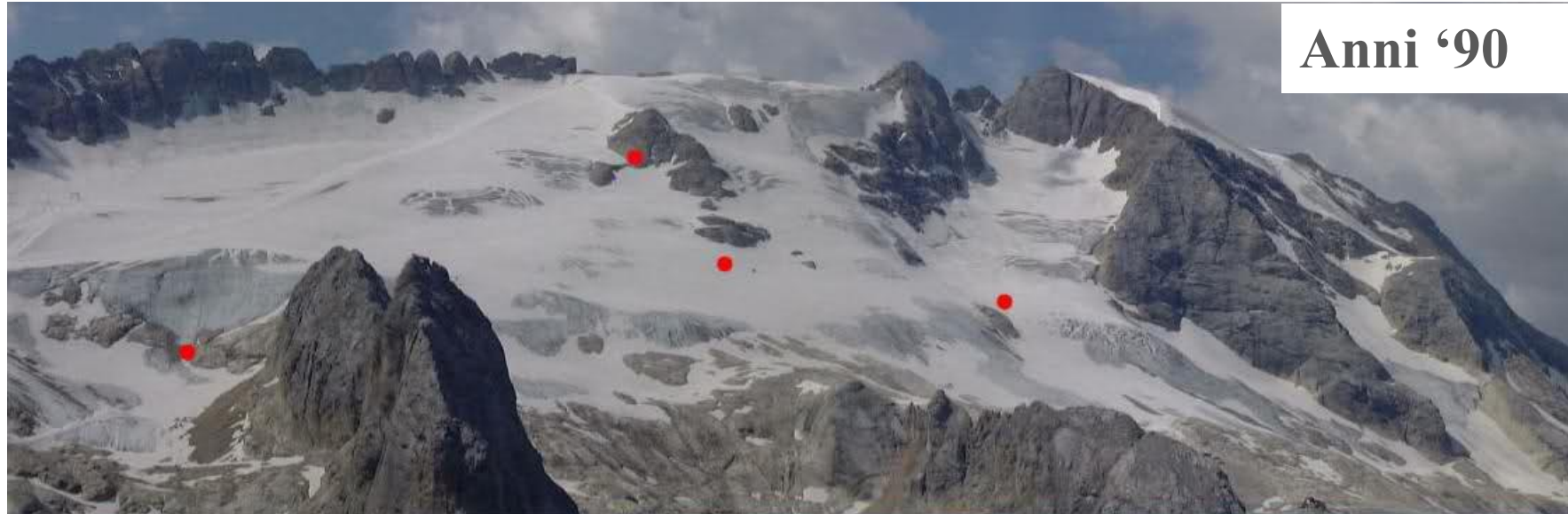


Foto: Roberto Valenti 2019

La Meringa del Gran Zebrù ...



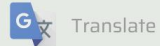
Il ghiacciaio della Marmolada... già un morto che cammina



Fusione dei ghiacciai porta anche a qualche sorpresa ...



Environmental



Cambiamento climatico

Caldo record: allerta di Legambiente per la fusione dei ghiacciai

22 Agosto 2023

R

La Repubblica

✓ Seguiti

Adamello, tracce della nube di Chernobyl vicine alla superficie. Gli esperti: “Vuol dire che ci siamo mangiati 30 anni di ghiacciaio”

Storia di Tiziana De Giorgio • 3 h fa



Fusione del permafrost



Le frane in quota

2011

Pale di San Martino/Sass Maor
30 mila metri cubi di roccia



2018

Carè Alto
300 mila
metri cubi



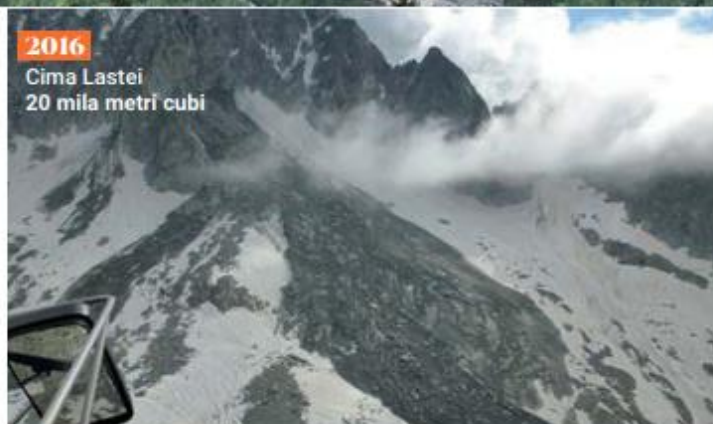
2022

Latemar
1.000 metri cubi



2016

Cima Lastei
20 mila metri cubi



2022

Molveno/Valle delle Seghe
20 mila metri cubi



Source: International Permafrost Association, 1998.
Active-Layer Permafrost System (CAPS), version 1.0.

Argomenti da affrontare



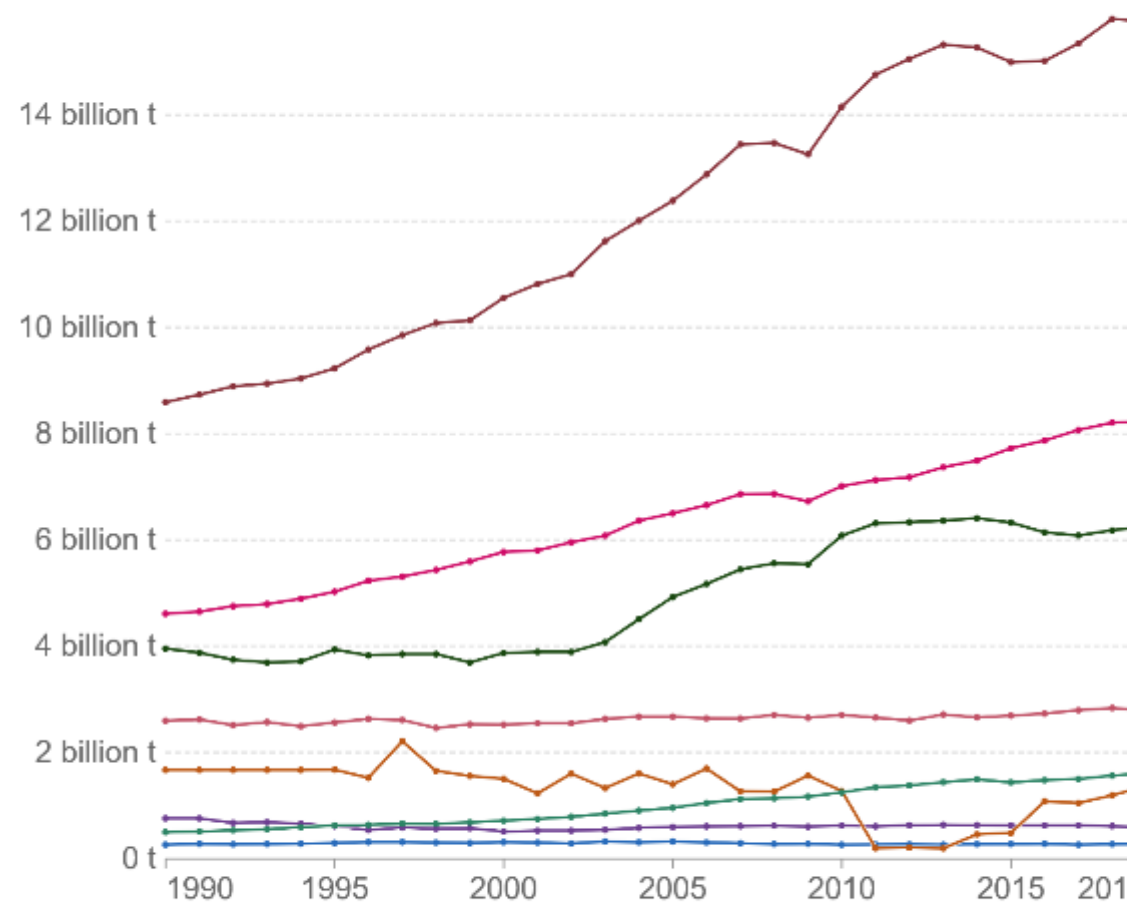
- Il Riscaldamento Globale: una emergenza mondiale
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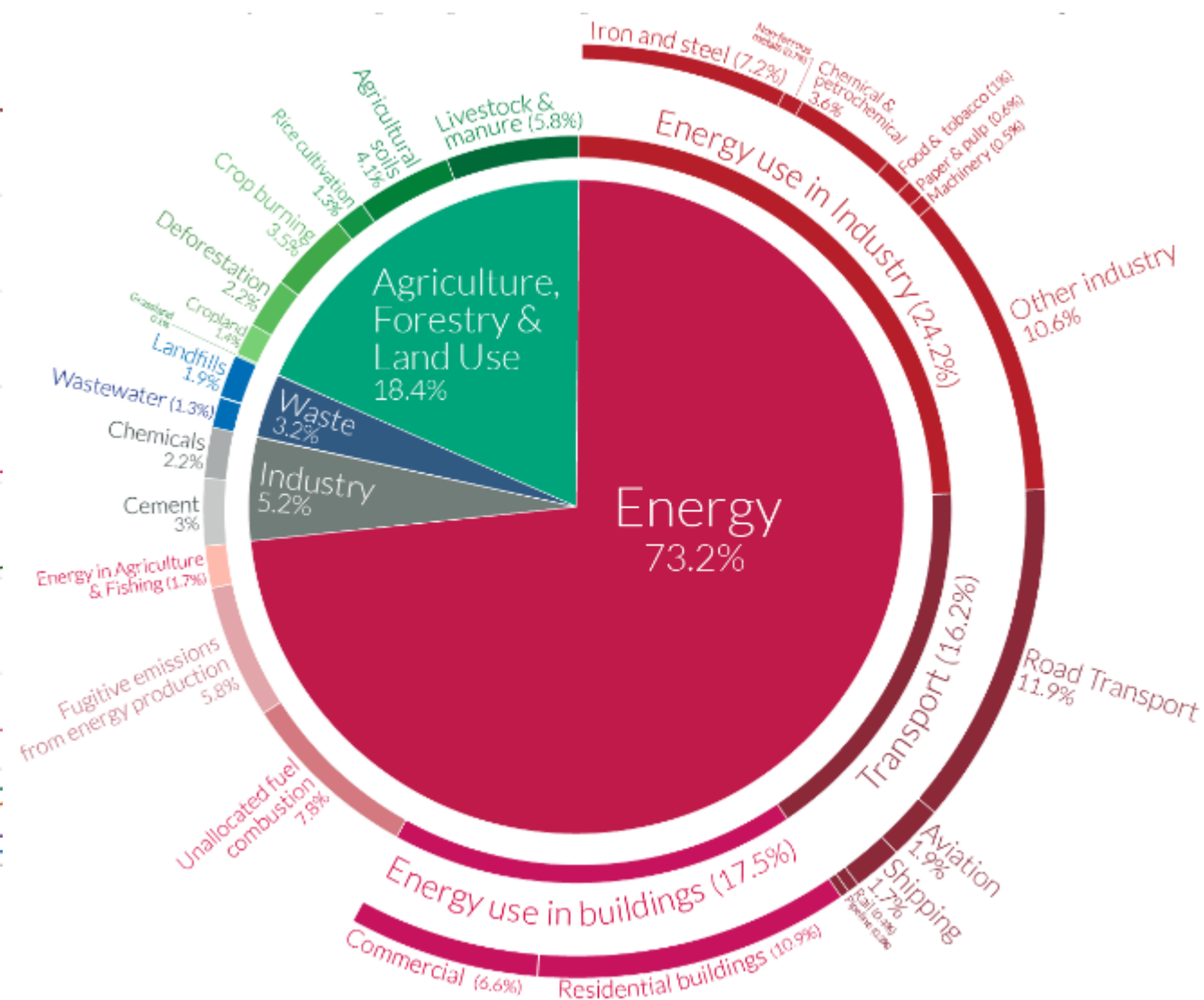
Da dove vengono le emissioni?



CO₂ emissions by sector, World



Source: Our World in Data based on Climate Analysis Indicators Tool (CAIT).
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY



Energia: quanta e come ... un pioniere ...

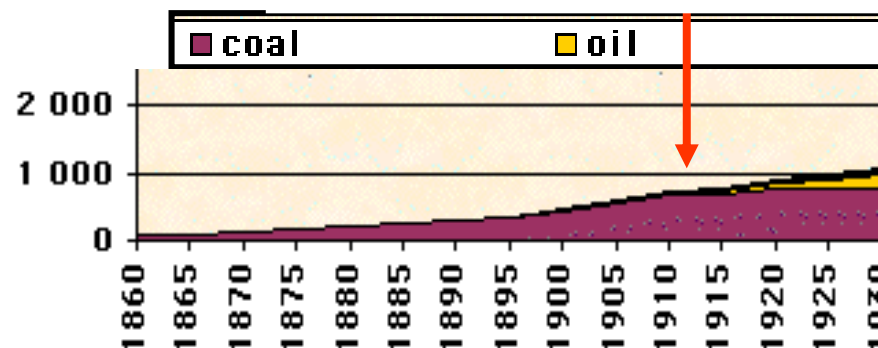


"...if our black and nervous civilization, based on coal, shall be followed by a quieter civilization based on the utilization of solar energy, that will not be harmful to progress and to human happiness."

SCIENCE

1912
~ 1 TW

Mtoe/anno



FRIDAY, SEPTEMBER 27, 1912

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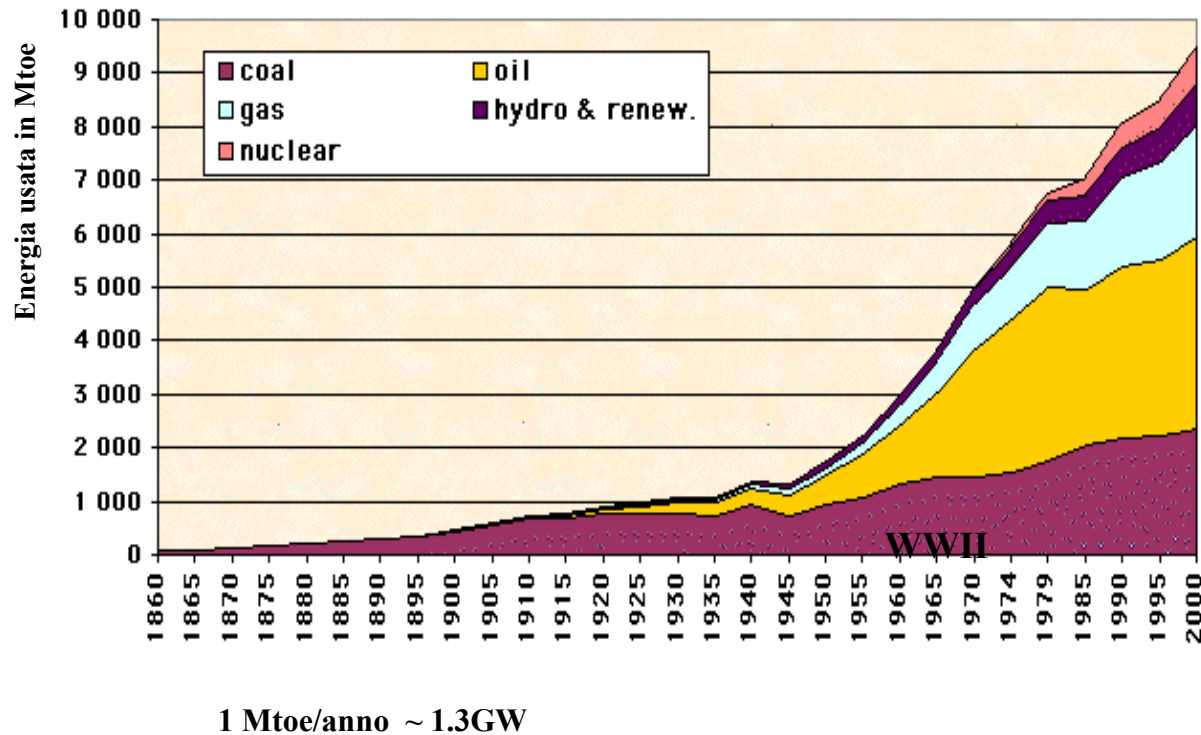
THE PHOTOCHEMISTRY OF THE FUTURE¹

MODERN civilization is the daughter of coal, for this offers to mankind the solar energy in its most concentrated form; that is, in a form in which it has been accumulated in a long series of centuries. Modern man uses it with increasing eagerness and thoughtless prodigality for the conquest of the world and, like the mythical gold of the Rhine, coal is to-day the greatest source of energy and wealth.

Ma dopo il 1912 ... nessuna buona notizia!

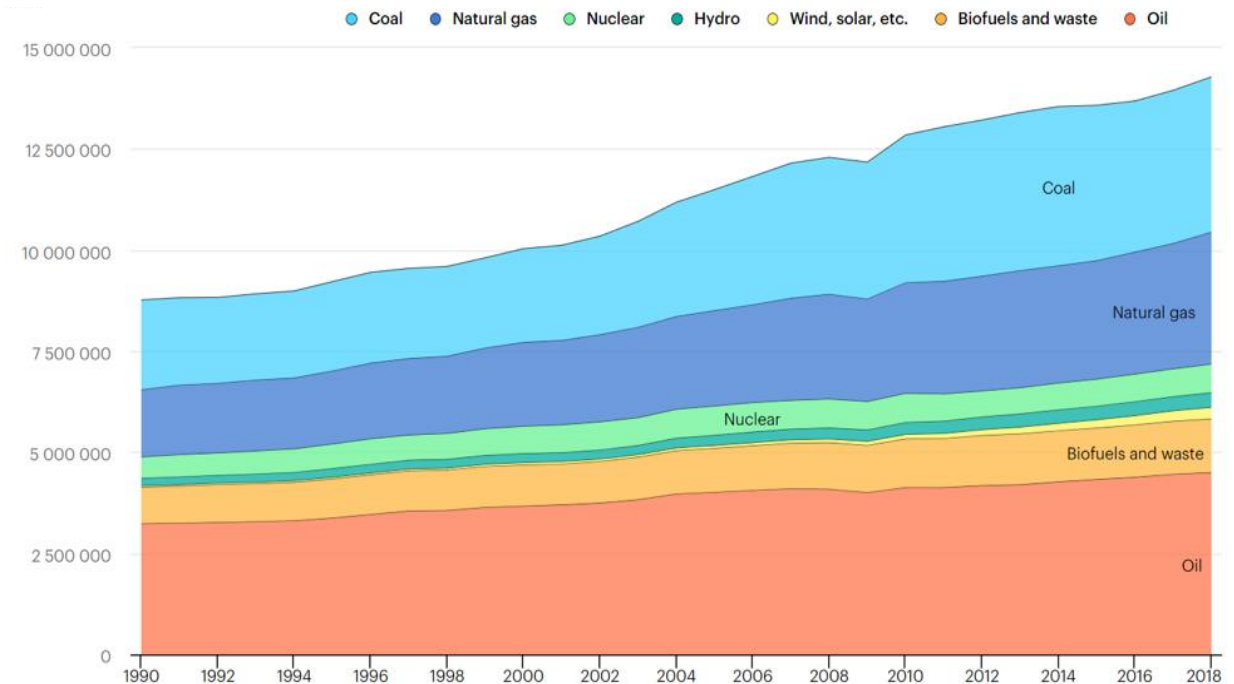


Nel 2000 12.3 TW

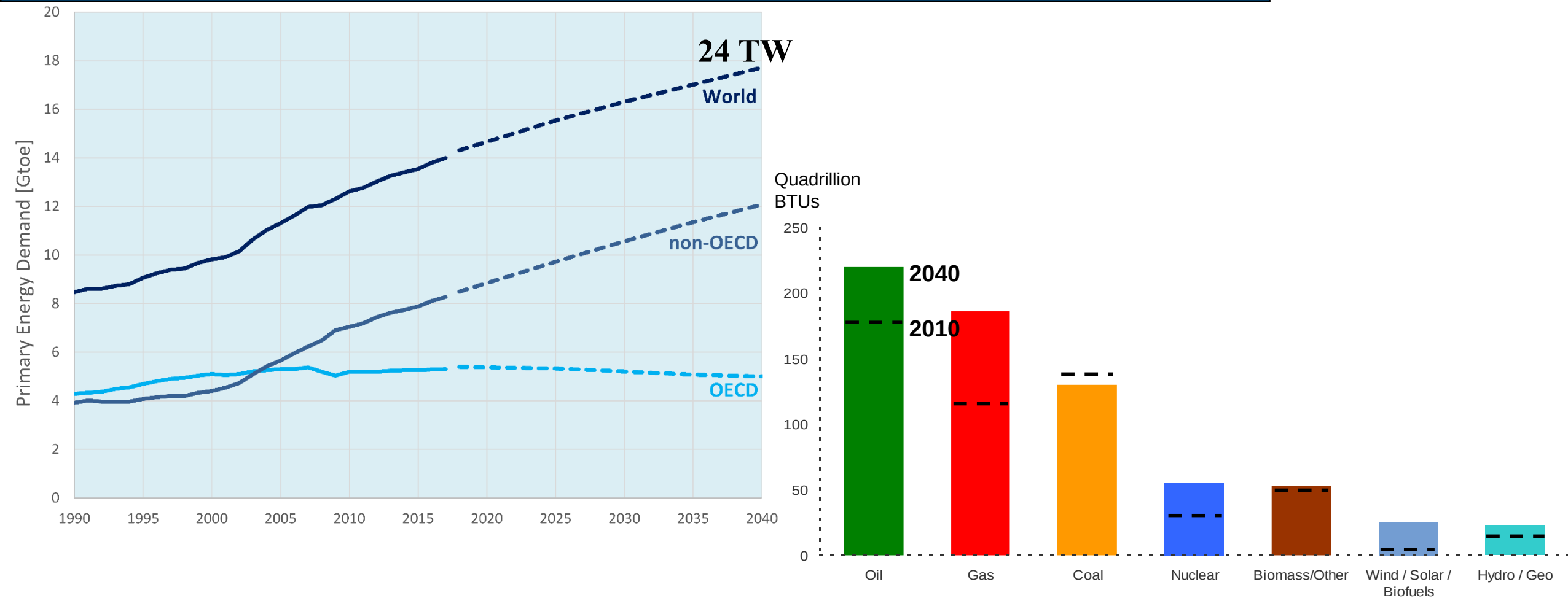


Nel 2018 19 TW

Total energy supply (TES) by source, World 1990-2018



Consumo primario di energia dal 1990 al 2040

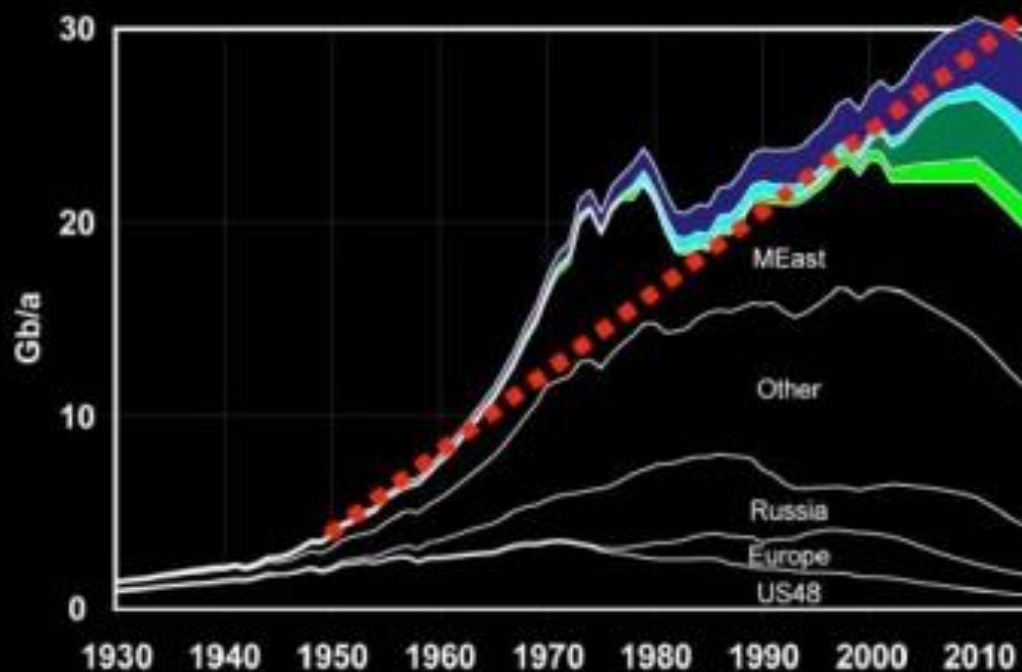


Fonte: The Outlook for energy: a view of 2040, Exxon

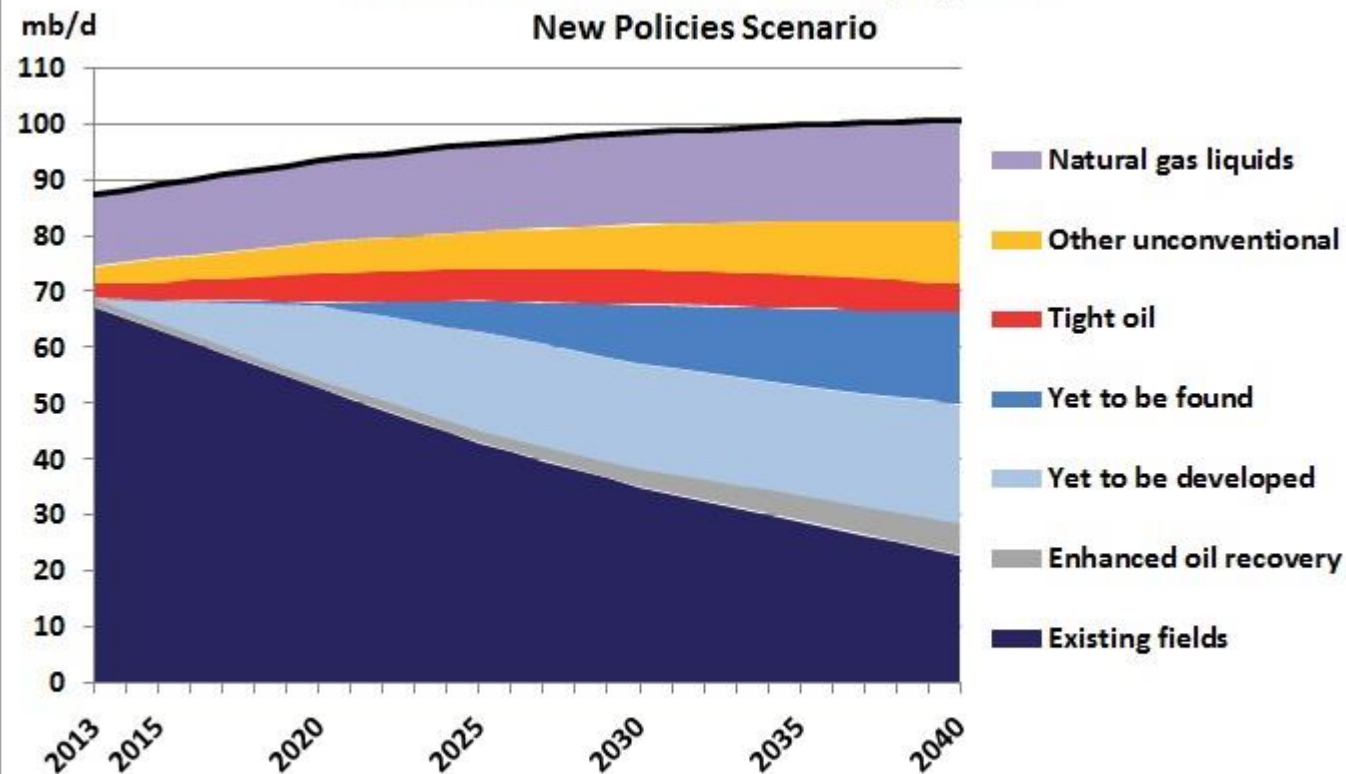
Previsioni di produzione di combustibili fossili



Trend line for world oil consumption.
Not sustainable with known reserves
and best conventional production.



IEA WEO 2014 crude oil and NGL projection
New Policies Scenario



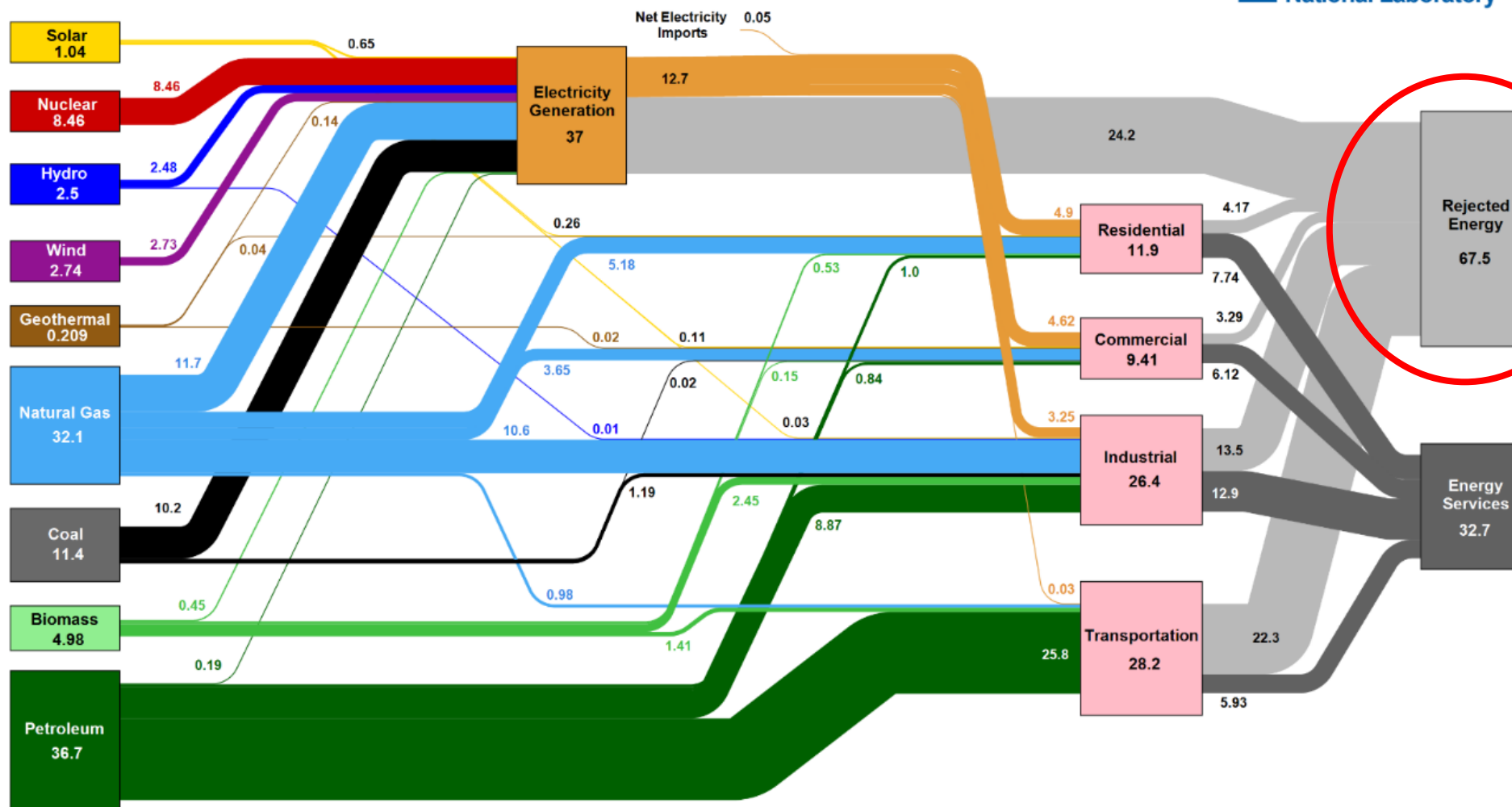
Data: IEA World Energy Outlook November 2014, table 3.6

Dalle fonti di energia ai servizi: il sistema energetico USA



Estimated U.S. Energy Consumption in 2019: 100.2 Quads

Lawrence Livermore
National Laboratory

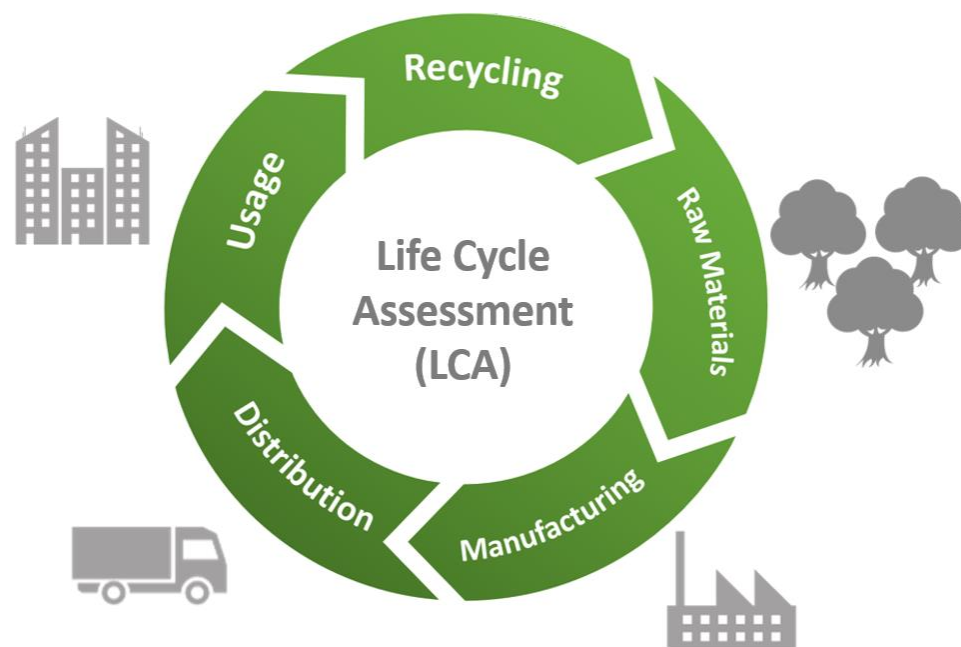


Agire sulla riduzione della domanda ha l'effetto più sensibile!

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

Indicatori su cui basare le decisioni

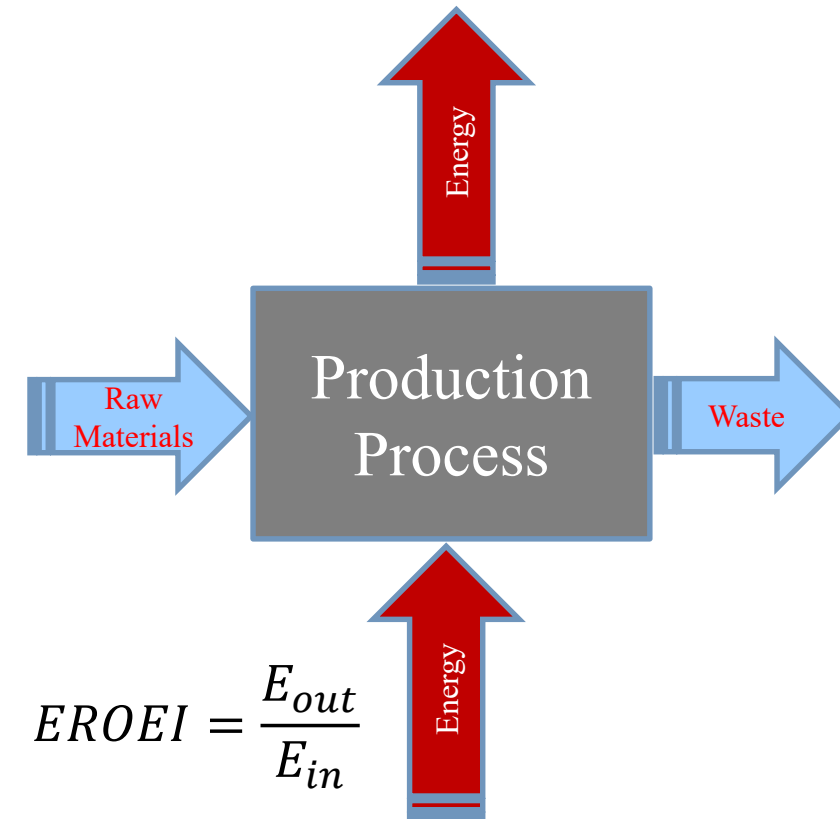
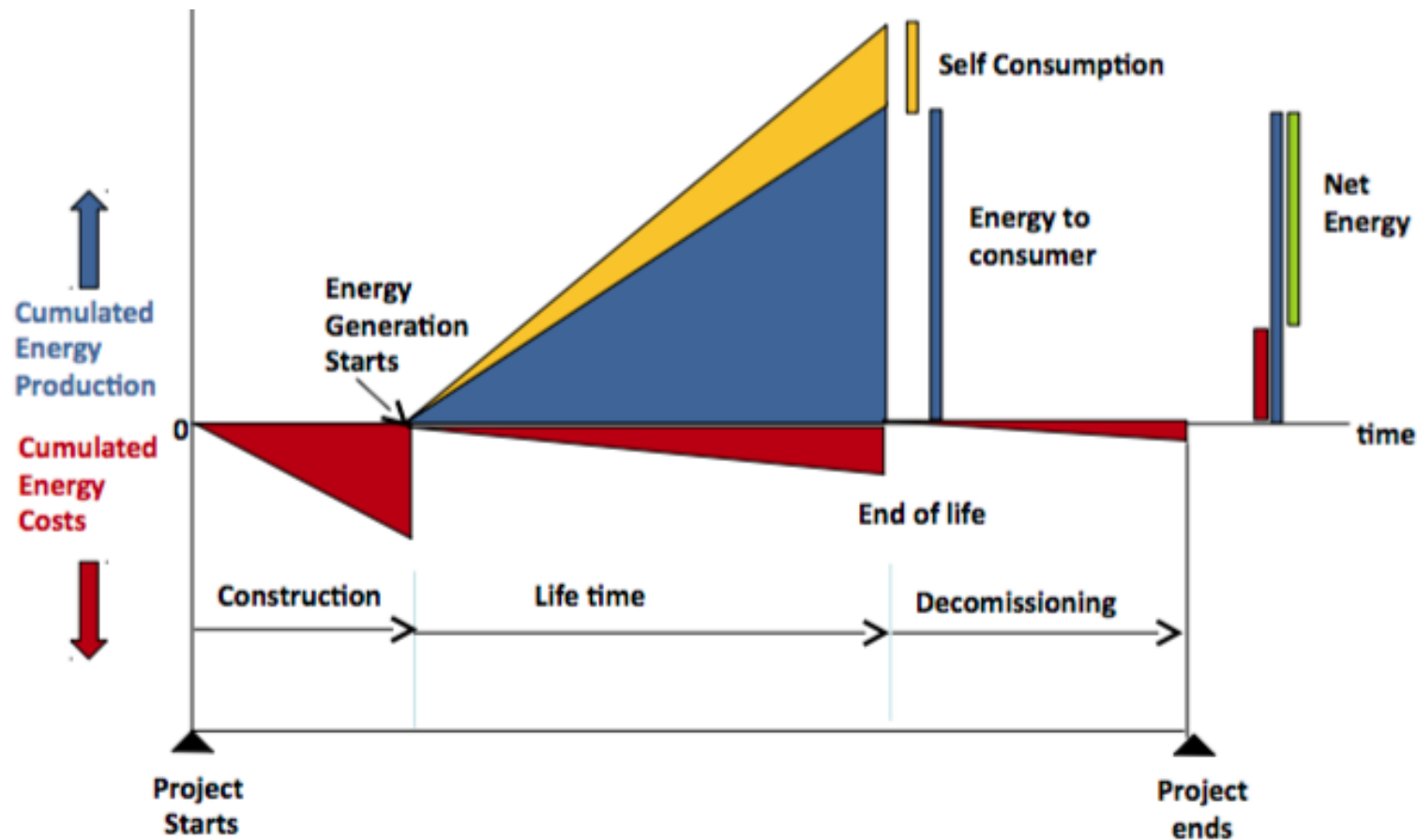
- Ritorno dell'investimento energetico – EROEI e indicatori da esso derivati (ESOEI – EROC)
- Costo dell'energia – LCOE
- Analisi del ciclo di vita - LCA



Ritorno dell'investimento energetico: EROEI



$$EROEI = \frac{\text{Energy to consumer}}{\text{Self Consumption}}$$



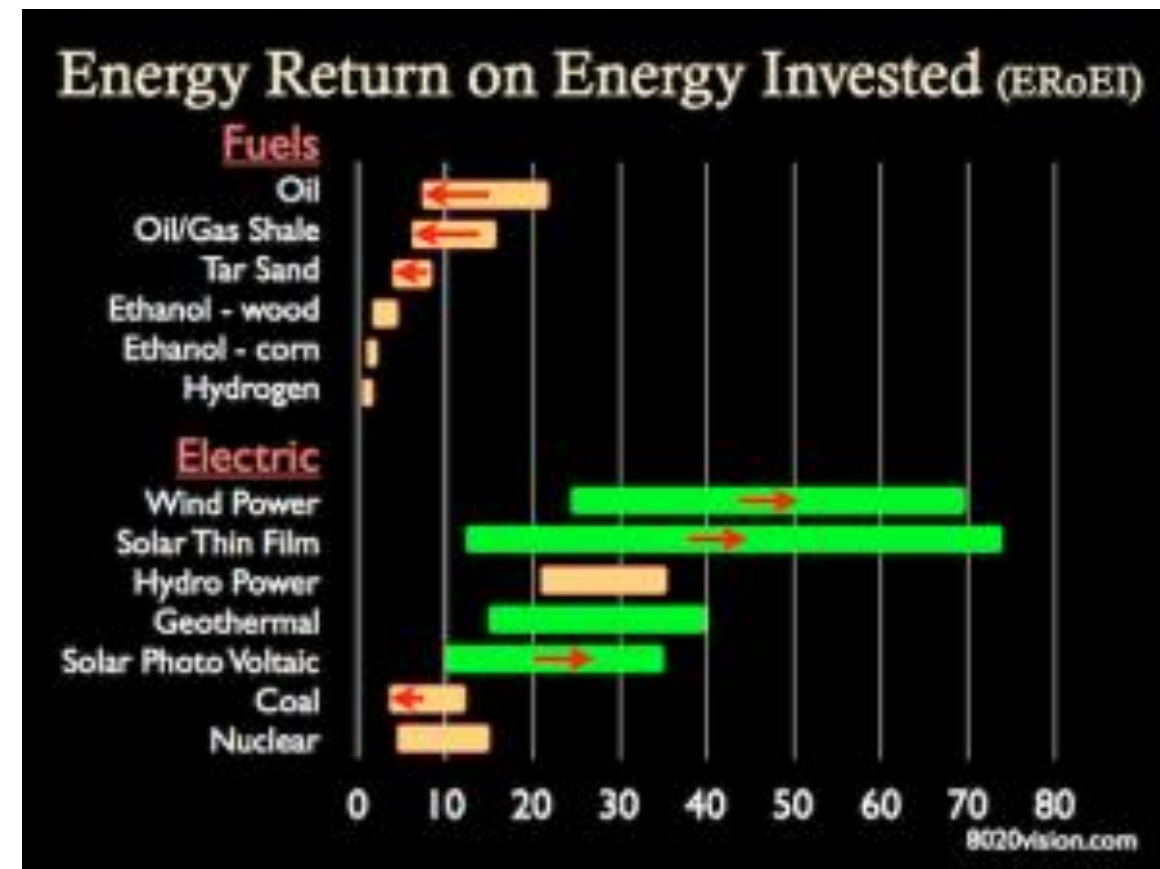
EROEI a confronto



Table 1 | Comparison of mean EROIs for different energy sources

Energy source			Optimistic EROI	Optimistic net energy percentage	
Coal	Thermal		46:1	98	Fonte: Nature
	Electricity		17:1	94	
	Electricity with CCS		13:1	92	
Oil	Thermal		19:1	95	
	Electricity		7:1	85	
Gas	Thermal		19:1	95	
	Electricity		8:1	88	
	Electricity with CCS		7:1	86	
Biofuels & waste	Solids	Thermal	25:1	96	
		Electricity	10:1	90	
	Gases and liquids	Thermal	5:1	80	
		Electricity	2:1	50	
Nuclear			14:1	93	
Hydroelectric			84:1	99	
Geothermal			9:1	89	
Wind			18:1	94	
Solar PV			25:1	96	
Solar thermal			19:1	95	

Fonte: King et al,
Nature Energy, 2018

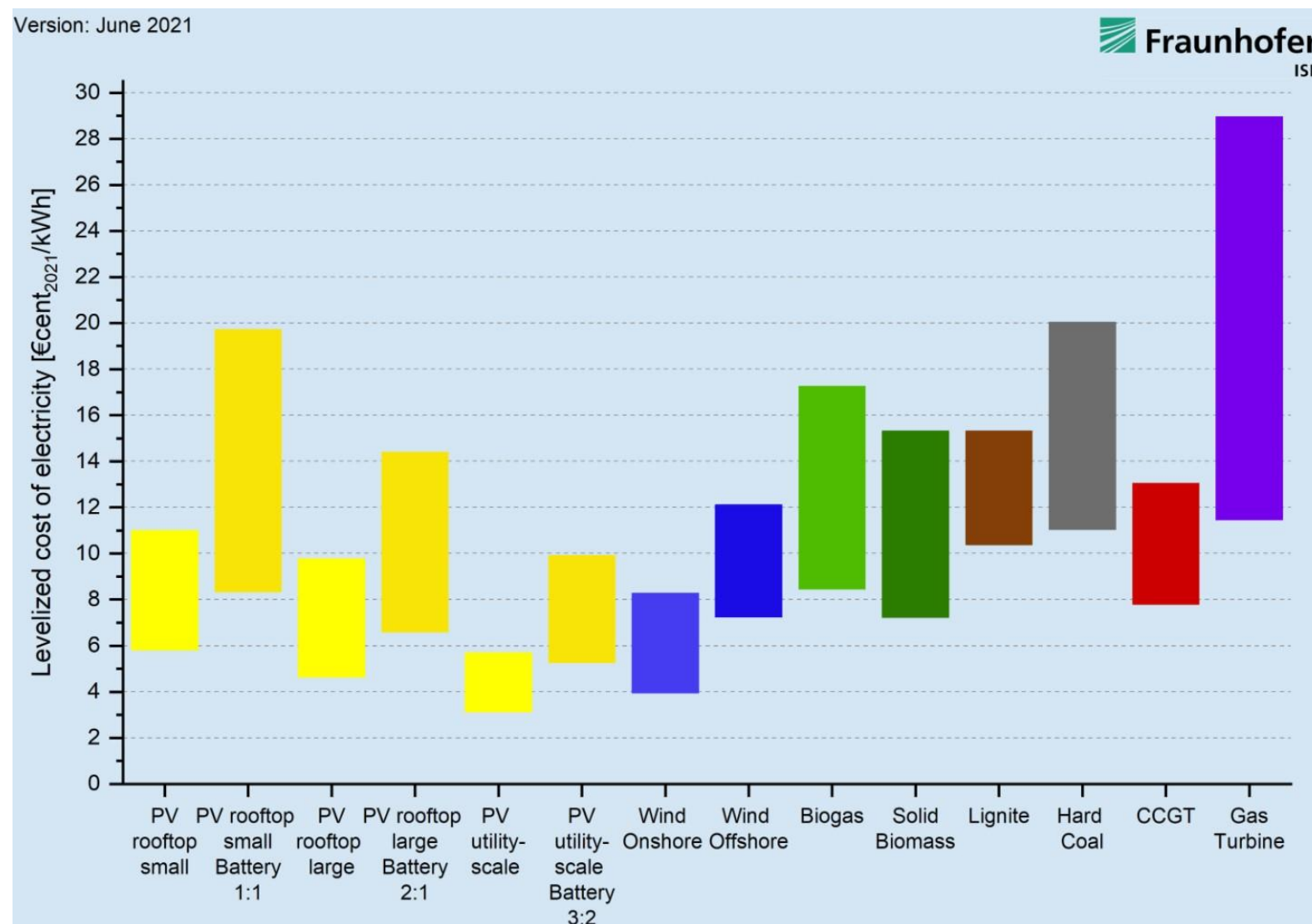


Fonte: Energy Sources: Energy Return on Energy Invested (ERoEI) — A Worthy Concept Difficult to Calculate, by S. Tom Bond on December 1, 2015



Prezzo livellato dell'energia (LCOE)

- Levelized cost of energy (in US\$/MWh) include:
 - l'ammortizzazione del capitale finanziario iniziale,
 - il ritorno sull'investimento,
 - il costo operativo, del combustibile,
 - Il costo della manutenzione.

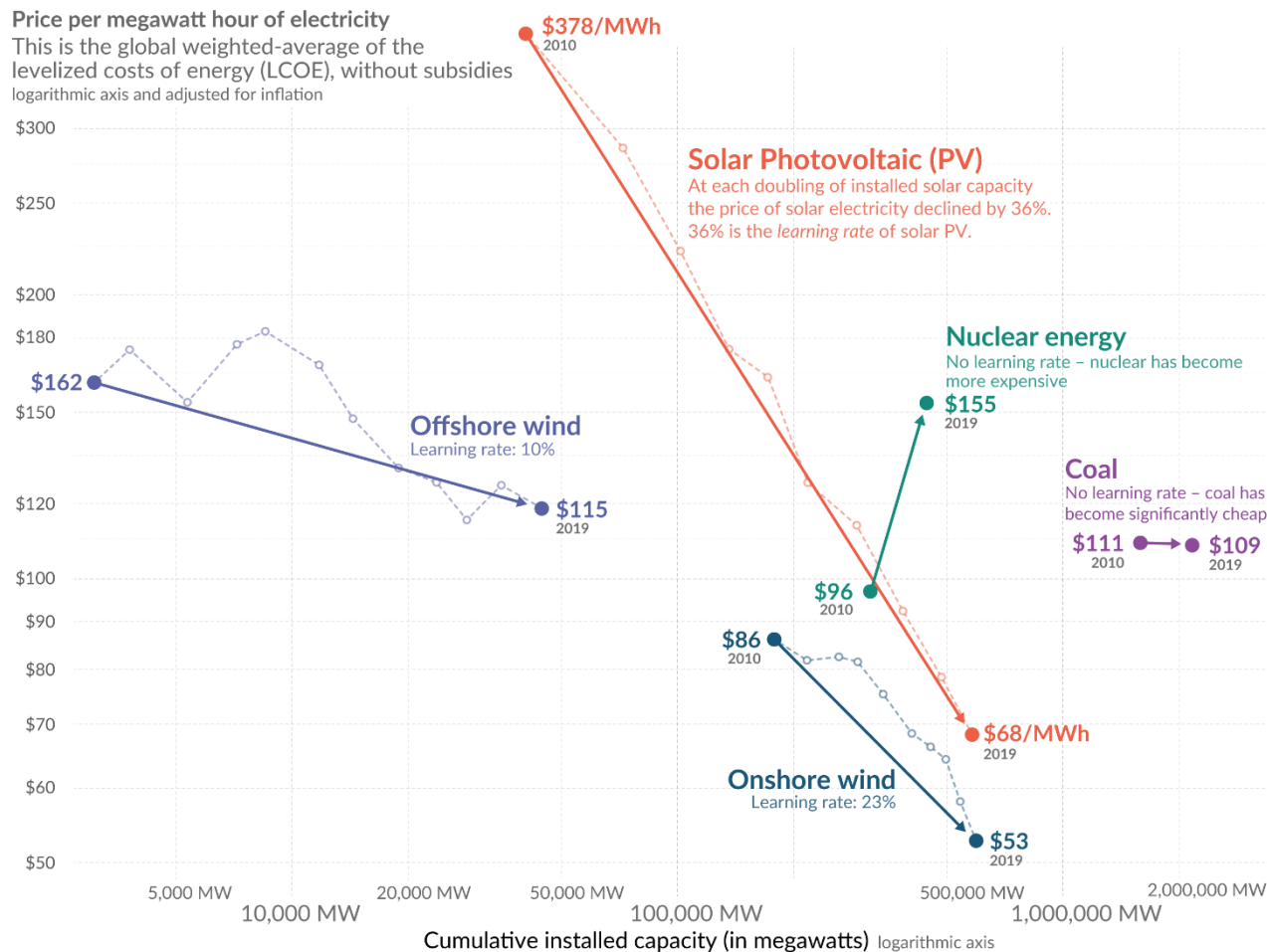


LCOE- dati IRENA 2020

Electricity from renewables became cheaper as we increased capacity – electricity from nuclear and coal did not

Price per megawatt hour of electricity

This is the global weighted-average of the levelized costs of energy (LCOE), without subsidies logarithmic axis and adjusted for inflation

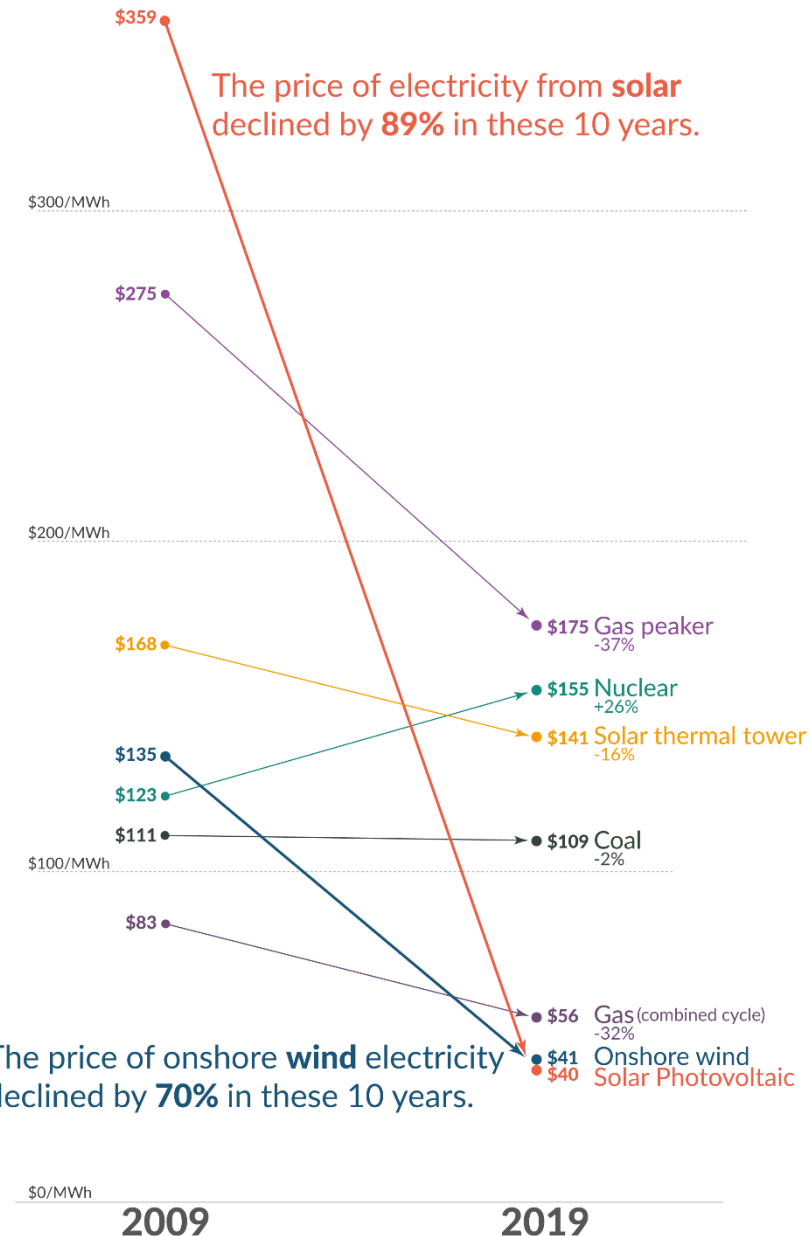


Source: IRENA 2020 for all data on renewable sources; Lazard for the price of electricity from nuclear and coal – IAEA for nuclear capacity and Global Energy Monitor for coal capacity. Gas is not shown because the price between gas peaker and combined cycles differs significantly, and global data on the capacity of each of these sources is not available. The price of electricity from gas has fallen over this decade, but over the longer run it is not following a learning curve.

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The price of electricity from new power plants
Electricity prices are expressed in 'levelized costs of energy' (LCOE). LCOE captures the cost of building the power plant itself as well as the ongoing costs for fuel and operating the power plant over its lifetime.

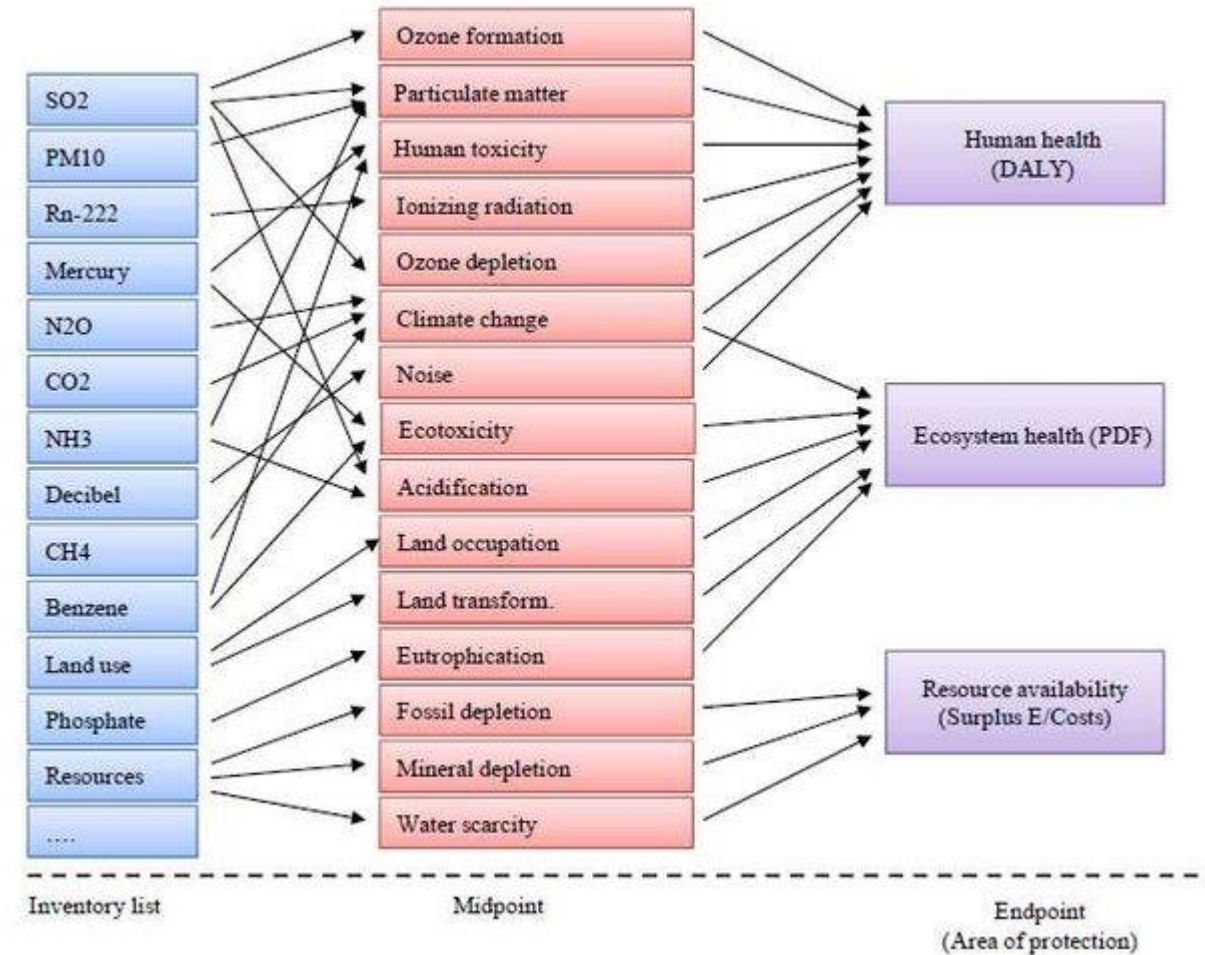
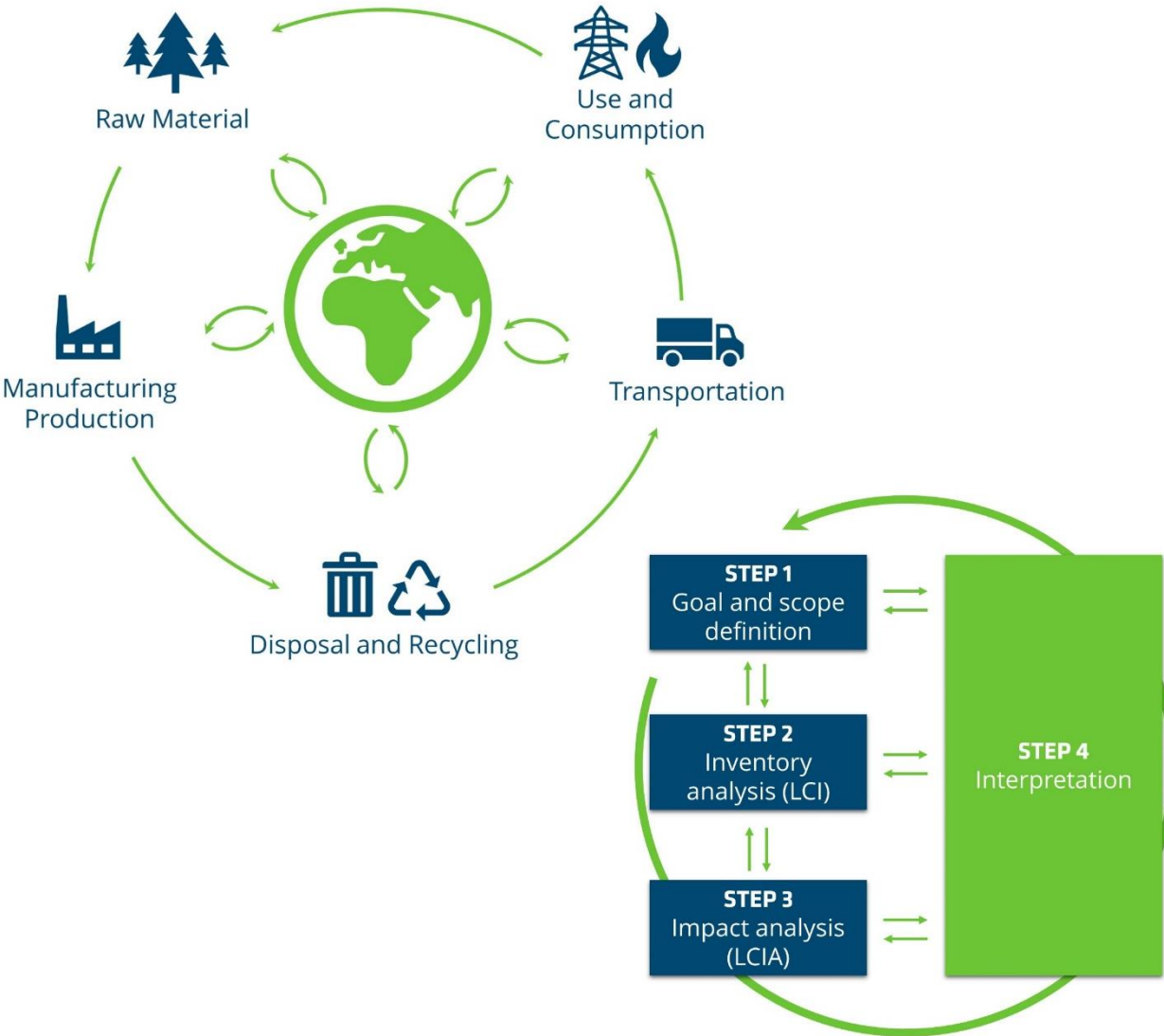


Data: Lazard Levelized Cost of Energy Analysis, Version 13.0

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Life Cycle Assessment - LCA



Argomenti da affrontare



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Alternative??



- Carbone?
 - Non ne parliamo
- Petrolio?
 - Trasporto e petrolchimica
- Gas con CCS?
 - Emissioni CO₂ sopra ai 100 g/kWh e fughe CH₄
 - impatto ambientale per solventi
 - EROEI si riduce ad 1/3
 - problemi stoccaggio ed uso CO₂
 - costi del gas e dipendenza geopolitica
- Idroelettrico?
 - Saturato
- Biomasse?
 - Solo marginali (no da biomassa legnosa)
 - basso EROEI
 - biodiversità e ambiente

- Nucleare
 - IV o III generazione ? SMR ?? Fusione ???
Scorie????
 - Sostenibilità economica (costi e tempi costruzione)
 - LCOE 155 \$/MWh (REN 40 \$/MWh) - Basso EROEI



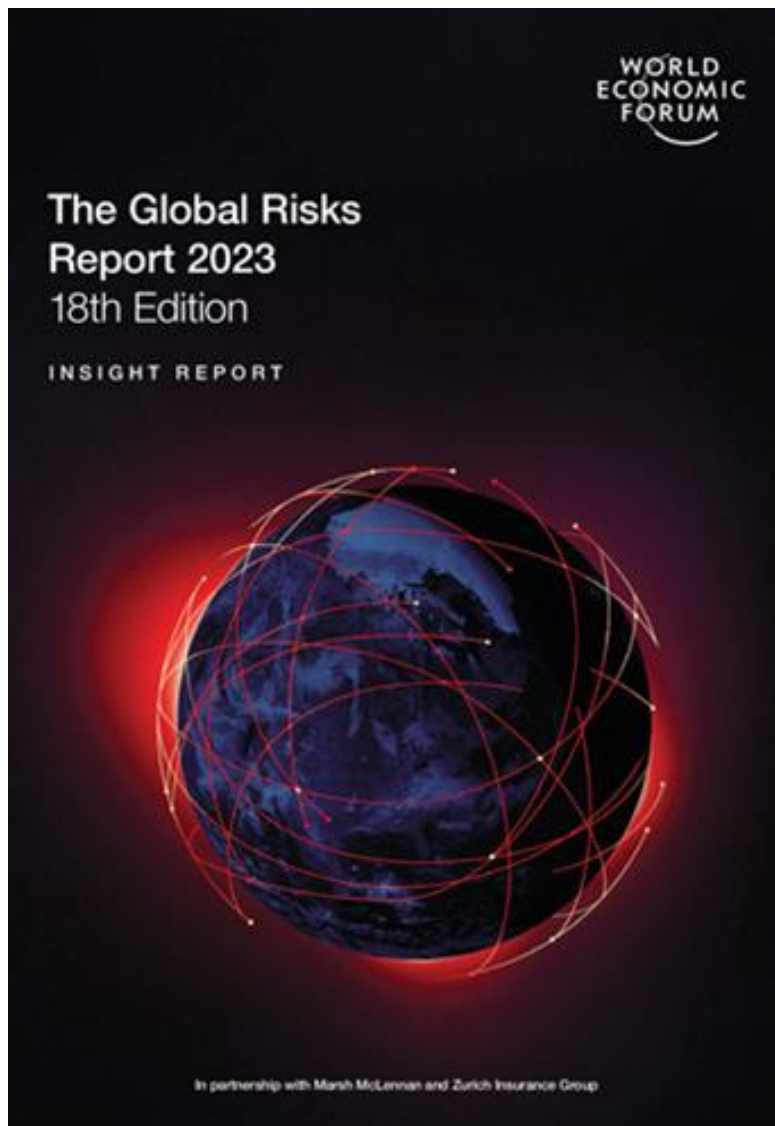
La terra è un sistema isolato ricordiamoci di Ciamician



- ... eccetto che per l'irraggiamento solare
- Solare e eolico
 - Buon EROEI
 - Ottimo LCOE
 - LCA competitivo (riciclo moduli)
 - No emissioni gas serra
 - No import, no costi materie prime
- Sistema 100% rinnovabile
 - Smart grids, batterie, idrogeno digitalizzazione
 - 70 GW elettrici da REN al 2030
- Il problema principale??
 - Tempo
 - No distrazioni



World Economic Forum: Global Risk Report 2023



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“ **The evidence is
clear:
The time for
action is now** ”

Climate Change 2022

Mitigation of Climate Change



La montagna di oggi è diversa da quella di 20 anni
... la montagna tra 20 sarà diversa da quella di oggi!!

