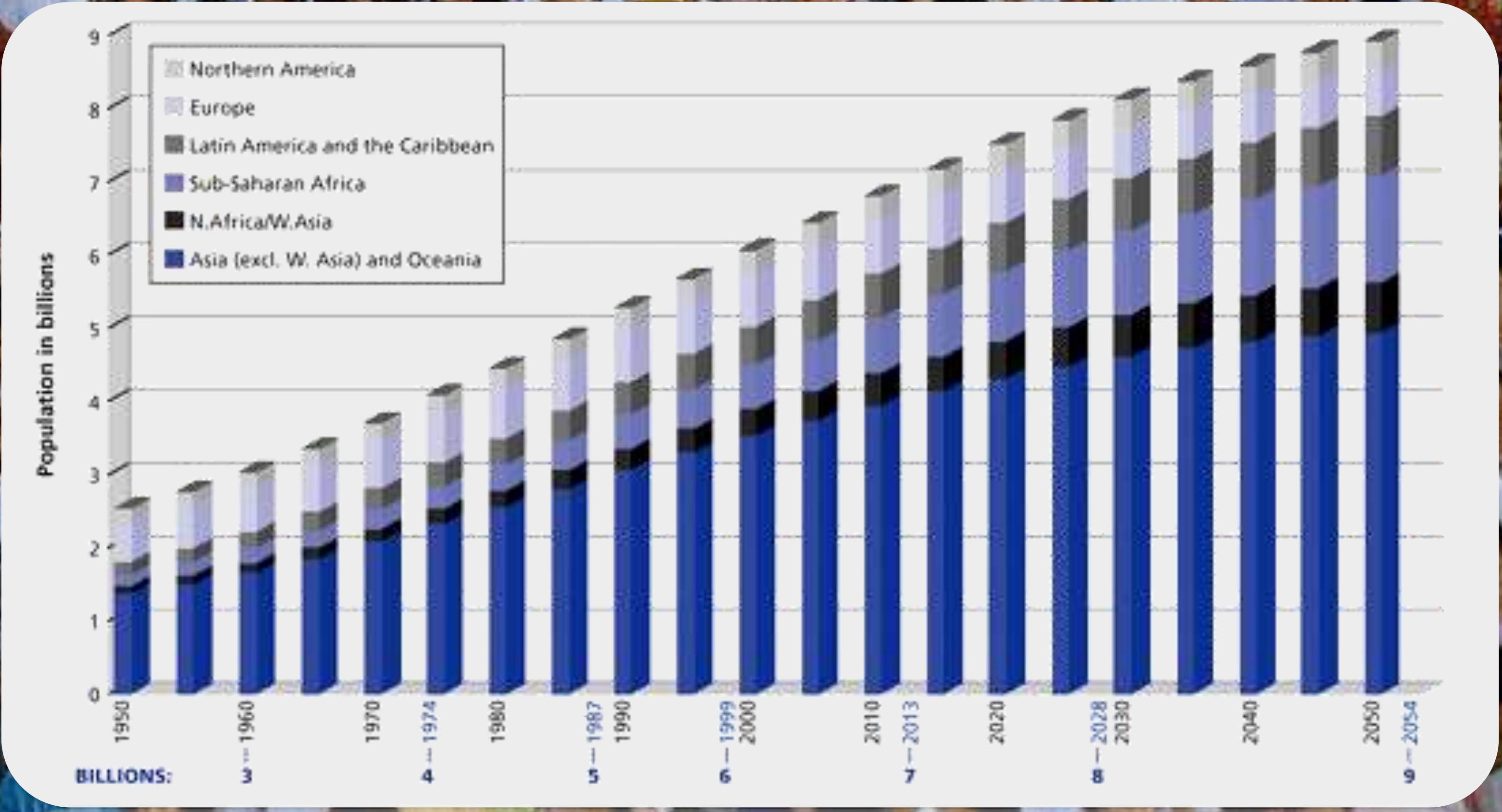
"Global warming, climate changes and their relationships with energy"

Maurizio Fermeglia

Maurizio.Fermeglia@units.it

World population grows …



The global risks landscape

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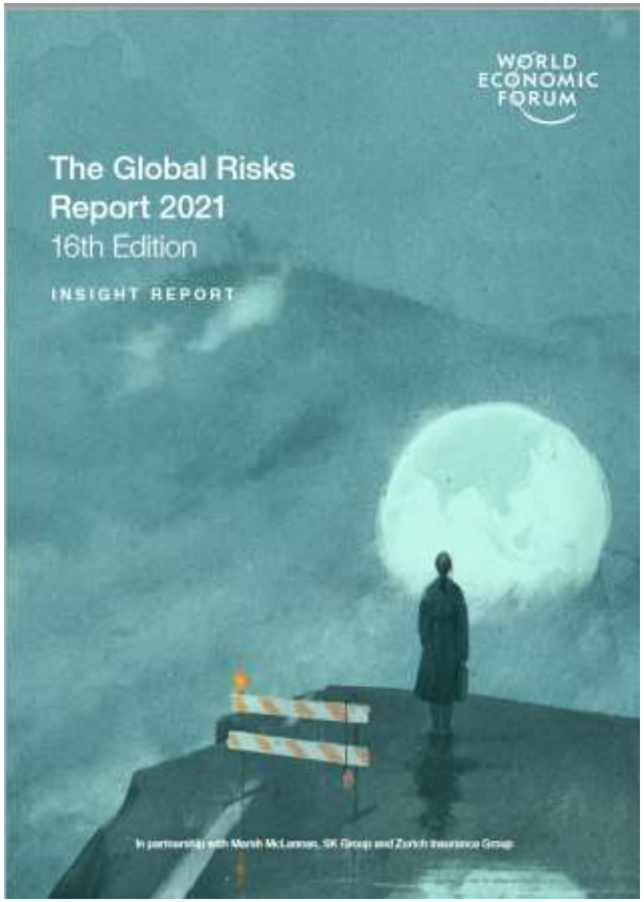
WORLD ECONOMIC FORUM

- Reviving economic growth (Economic)
- Reforming market capitalism (Economic)
- Facing up the importance of identity and community (societal)
- Managing technological change (technological)
- Protect and strengthen our system of global cooperation (geopolitical)
- Environmental related risk (environmental)



Source: The Global Risks Report 2021 16th Edition

Global risks network: what drives global risks?

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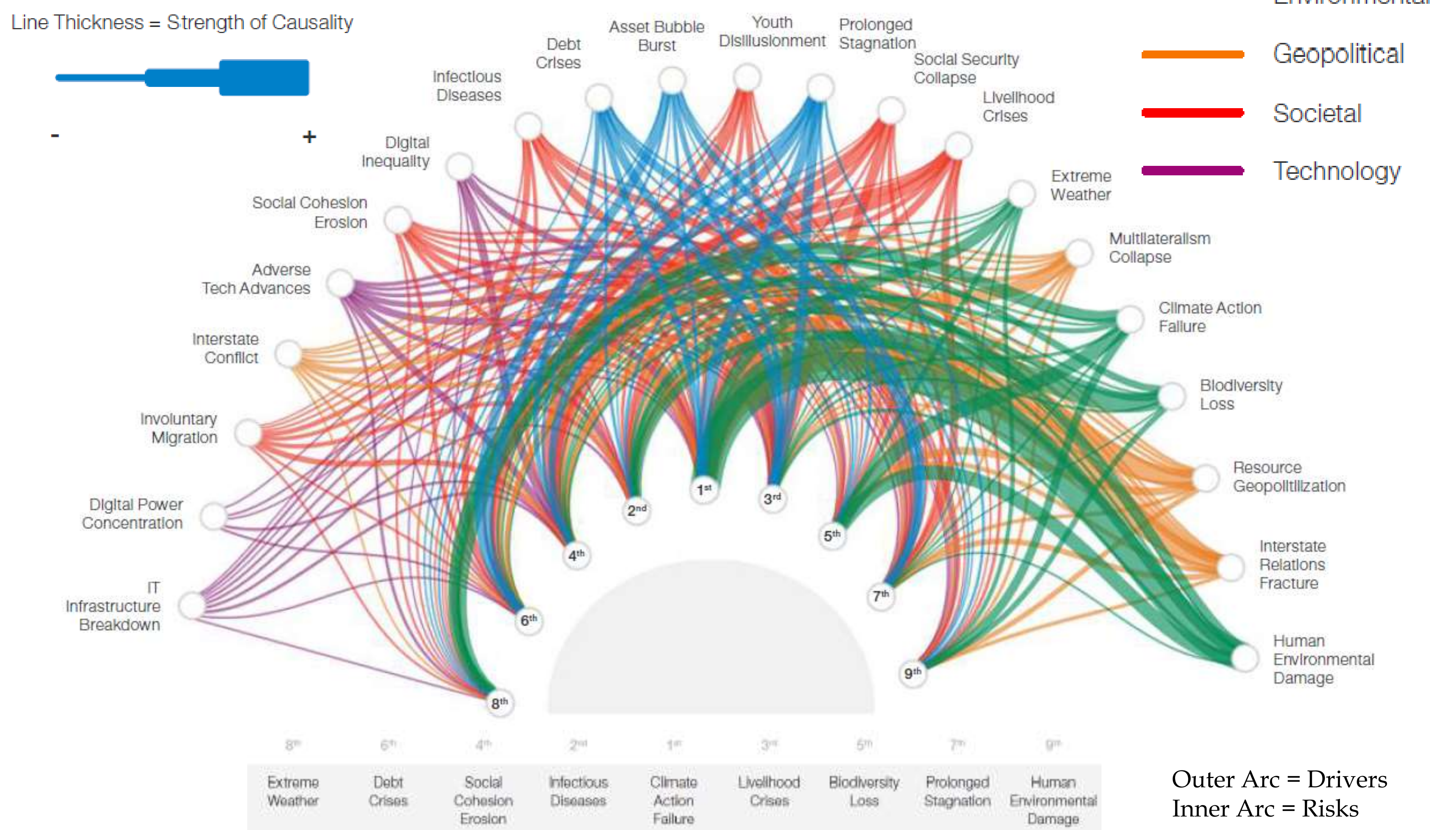

Outer Arc = Drivers
Inner Arc = Risks

Evolving risks landscape

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- Evoluzione dei rischi per probabilità

	1st	2nd	3rd	4th	5th	6th	7th
2021	Extreme weather	Climate action failure	Human environmental damage	Infectious diseases	Biodiversity loss	Digital power concentration	Digital inequality

	1st	2nd	3rd	4th	5th
2020	Extreme weather	Climate action failure	Natural disasters	Biodiversity loss	Human-made environmental disasters
2019	Extreme weather	Climate action failure	Natural disasters	Data fraud or theft	Cyberattacks
2018	Extreme weather	Natural disasters	Cyberattacks	Data fraud or theft	Climate action failure
2017	Extreme weather	Involuntary migration	Natural disasters	Terrorist attacks	Data fraud or theft
2016	Involuntary migration	Extreme weather	Climate action failure	Interstate conflict	Natural catastrophes
2015	Interstate conflict	Extreme weather	Failure of national governance	State collapse or crisis	Unemployment
2014	Income disparity	Extreme weather	Unemployment	Climate action failure	Cyberattacks
2013	Income disparity	Fiscal imbalances	Greenhouse gas emissions	Water crises	Population ageing
2012	Income disparity	Fiscal imbalances	Greenhouse gas emissions	Cyberattacks	Water crises

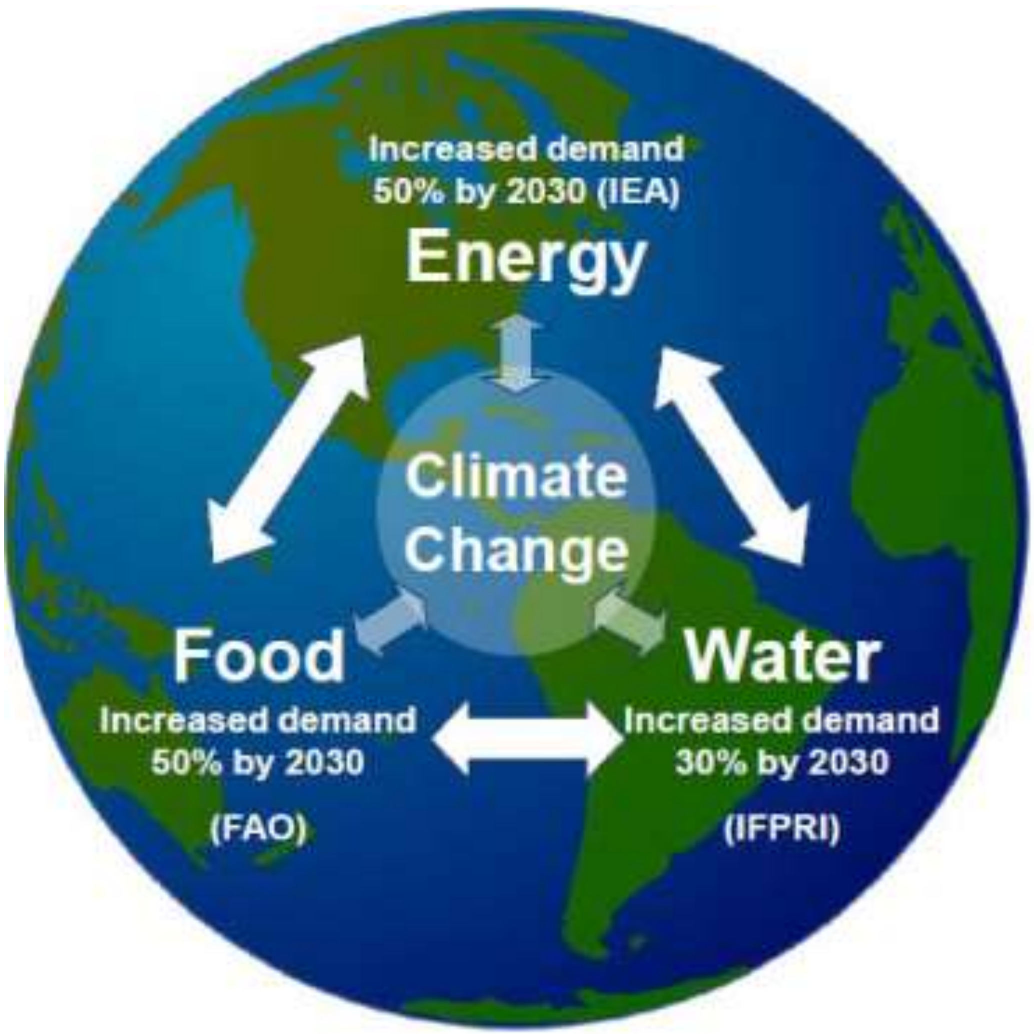
Evolving risks landscape

- Evoluzione dei rischi per imaptto

	1st	2nd	3rd	4th	5th	6th	7th
2021	Infectious diseases	Climate action failure	Weapons of mass destruction	Biodiversity loss	Natural resource crises	Human environmental damage	Livelihood crises

	1st	2nd	3rd	4th	5th
2020	Climate action failure	Weapons of mass destruction	Biodiversity loss	Extreme weather	Water crises
2019	Weapons of mass destruction	Climate action failure	Extreme weather	Water crises	Natural disasters
2018	Weapons of mass destruction	Extreme weather	Natural disasters	Climate action failure	Water crises
2017	Weapons of mass destruction	Extreme weather	Water crises	Natural disasters	Climate action failure
2016	Climate action failure	Weapons of mass destruction	Water crises	Involuntary migration	Energy price shock
2015	Water crises	Infectious diseases	Weapons of mass destruction	Interstate conflict	Climate action failure
2014	Fiscal crises	Climate action failure	Water crises	Unemployment	Infrastructure breakdown
2013	Financial failure	Water crises	Fiscal imbalances	Weapons of mass destruction	Climate action failure
2012	Financial failure	Water crises	Food crises	Fiscal imbalances	Energy price volatility

John Beddington's perfect storm



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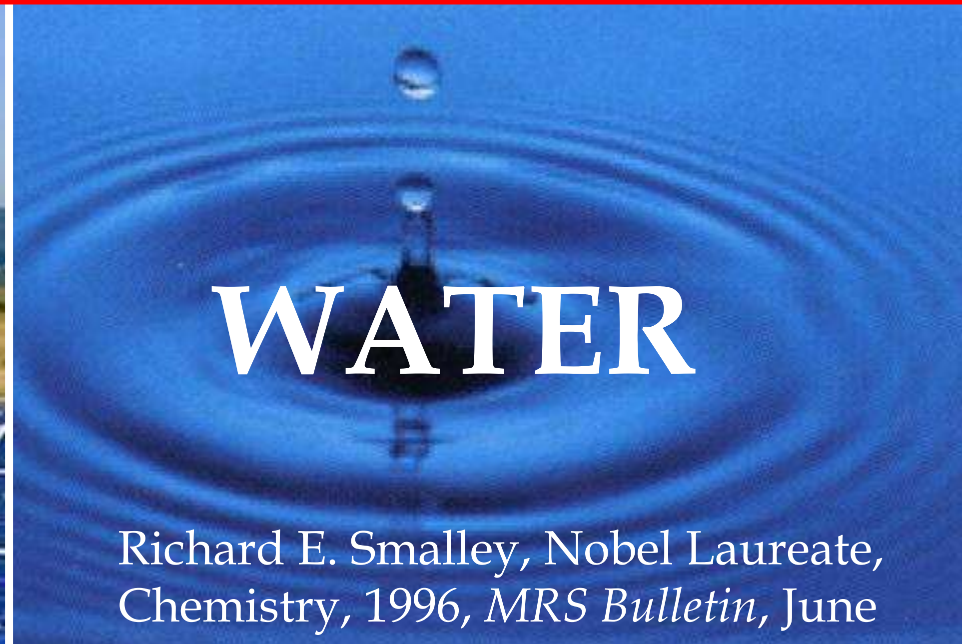
News › Science

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

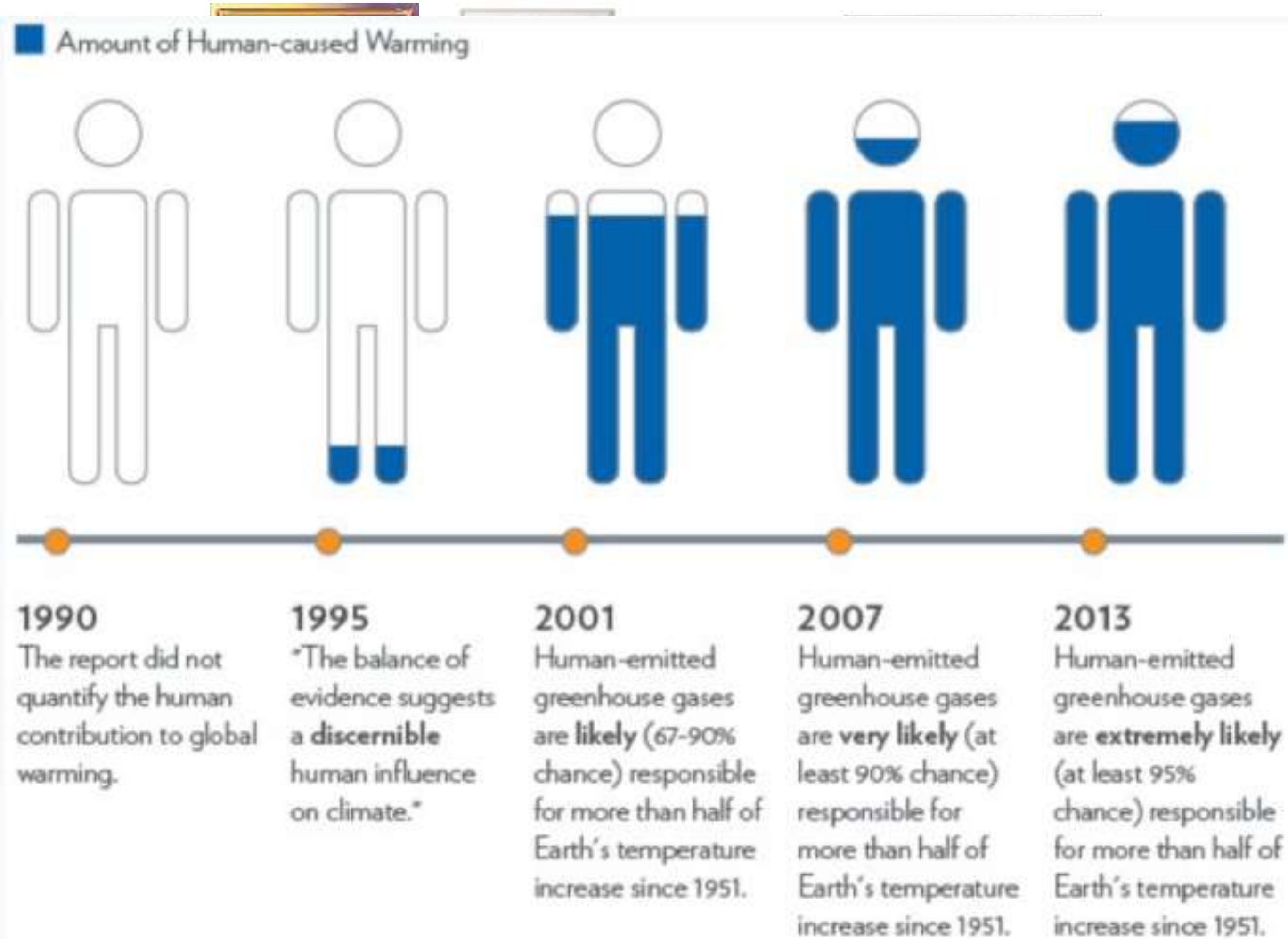
Food, water and energy shortages will unleash public unrest and international conflict, Professor John Beddington will tell a conference tomorrow

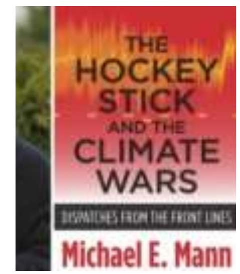
4 World Wide Emergencies



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

Timeline: the weathermen





- ***1824 -*** ***greenh***
- ***1896 -*** *effect w*
- ***1938 -*** ***global***
- ***1957 -*** ***oceans***
- ***1958 -*** *measu*
- ***1998 -***
- ***2007 – IPCC*** human responsibility of ***CO_2 growth is 90%.***
- ***2013 – IPCC*** human responsibility of ***CO_2 growth is 95%.***

NATIONAL GEOGRAPHIC ITALIA

Ricerca

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Gli impatti dei cambiamenti climatici saranno peggiori del previsto

Il rapporto IPCC (Intergovernmental Panel on Climate Change) manda un nuovo monito: dovremo affrontare le conseguenze del riscaldamento globale molto presto. Per contrastarlo servono cambiamenti enormi e immediati

The New York Times

Major Climate Report Describes a Strong Risk of Crisis as Early as 2040

EDITOR'S PICKS MAGAZINE

NEWS CLIMATE

Limiting global warming to 1.5 degrees versus 2 has big benefits, the IPCC says

Scientists hope a new climate report will jump-start policy decisions to reduce emissions

BY CAROLYN GRAMLING

CNN World » U.S. | Africa | Americas | Asia | Australia | China | Europe | Middle East | UK International Edition +

Planet has only until 2030 to stem catastrophic climate change, experts warn

By Brandon Miller and Jay Croft, CNN

Updated 2254 GMT (0654 HKT) October 8, 2018

The New York Times

A New York Clock That Told Time Now Tells the Time Remaining

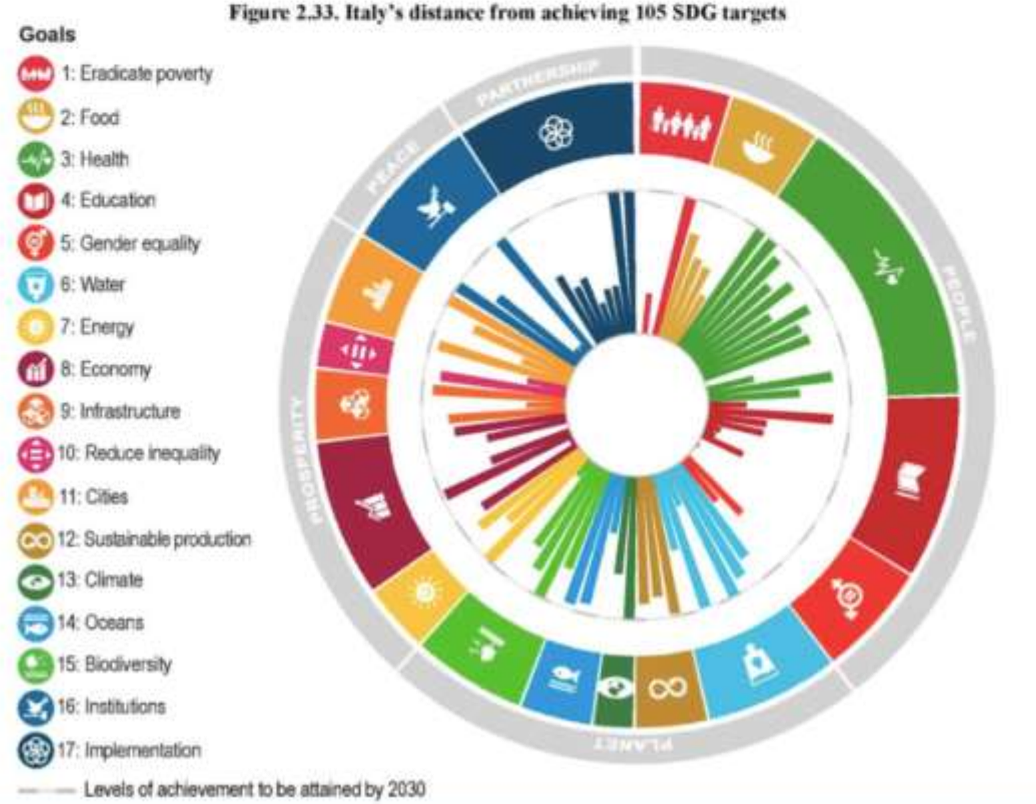
UN 17 SDG: Italy reached only 12 of the 105 targets!

POLITICA

Agenda 2030: l'Italia ha raggiunto solo 12 dei 105 target previsti

Cristina Da Roid 25 giugno 2019

Figure 2.33. Italy's distance from achieving 105 SDG targets



A pioneer …. (an Hero !!!)

UNIVERSITÀ DEGLI STUDI DI TRIESTE

SCIENCE

Friday, September 27, 1912

CONTENTS

THE PHOTOCHEMISTRY OF THE FUTURE[1]

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.

So far, human civilization has made use almost exclusively of fossil solar energy. Would it not be advantageous to make better use of radiant energy?

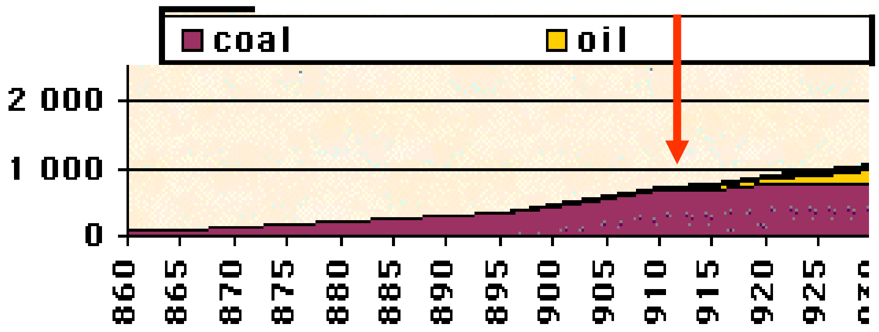
Giacomo Ciamician

Bologna

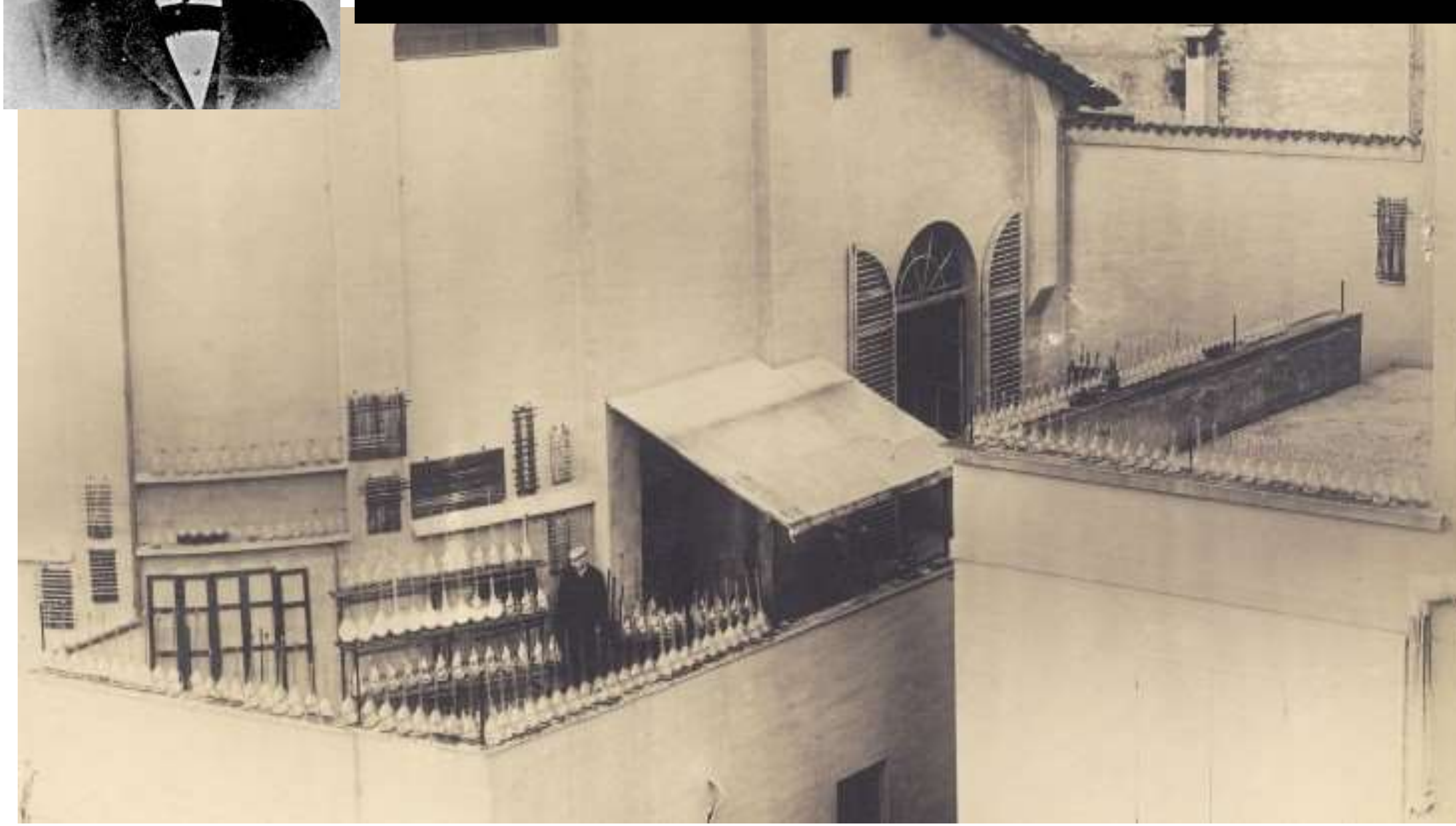
1912

~ 1 TW

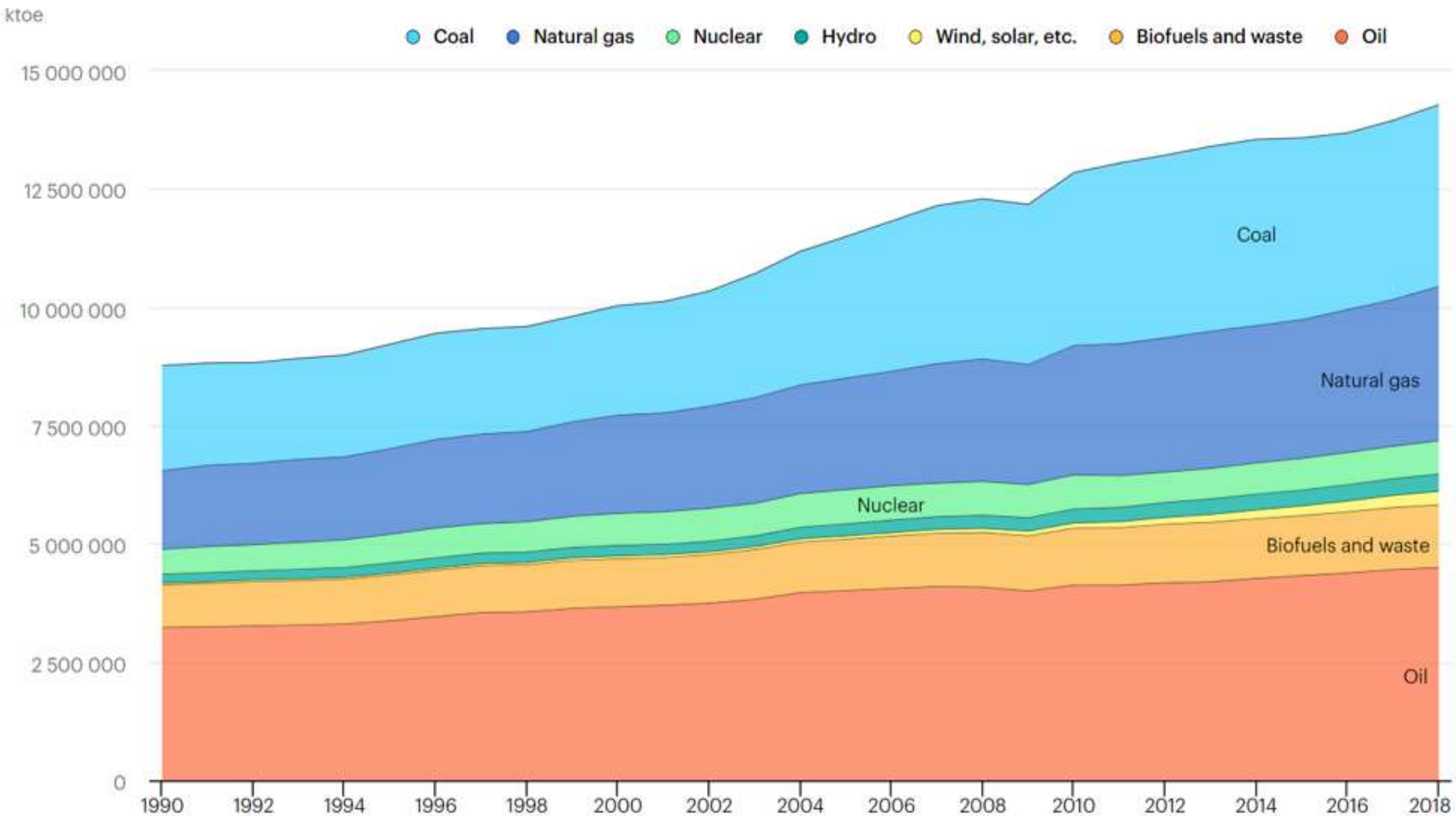
Mtoe/anno



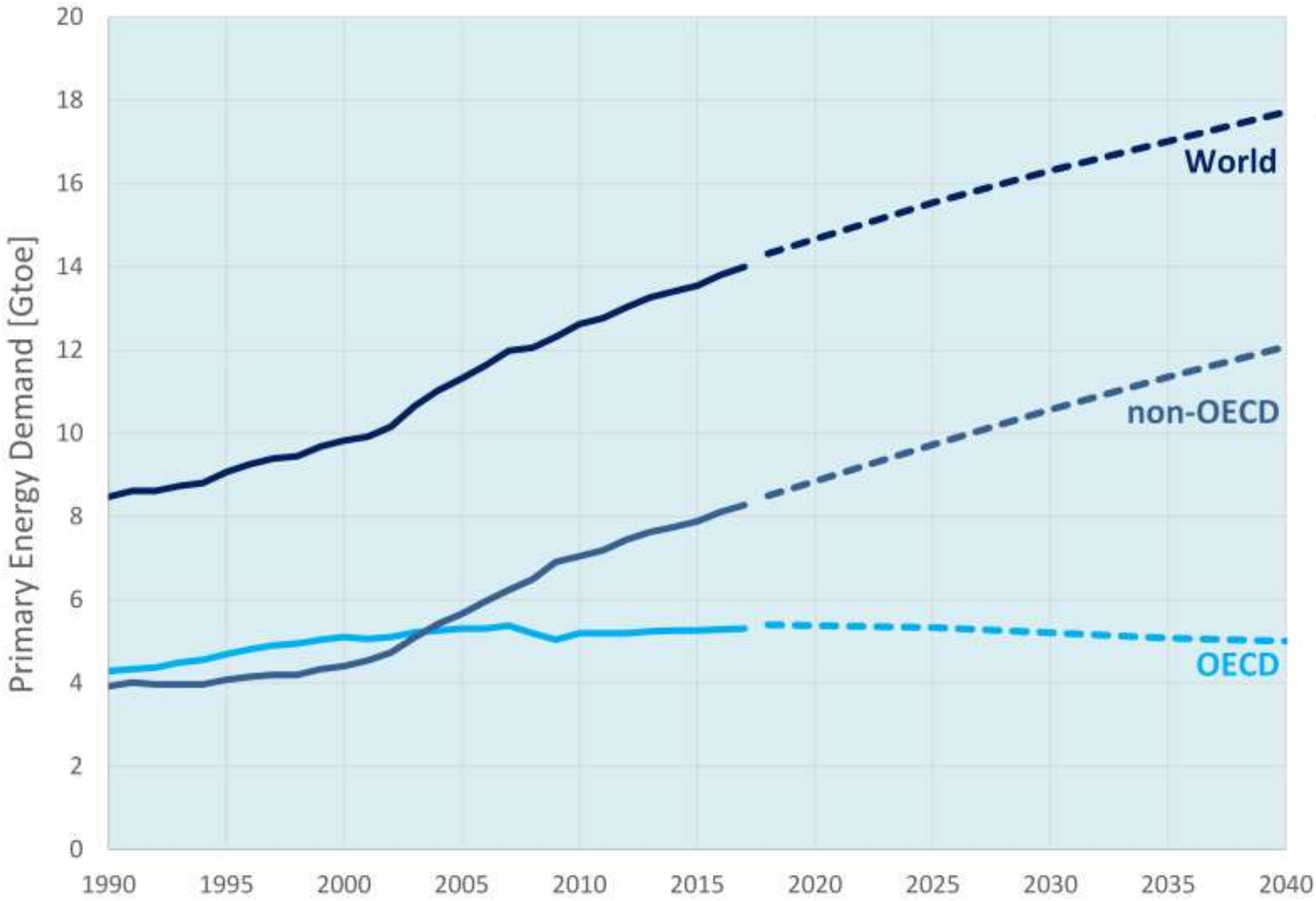
"…if our black and nervous civilization, based on coal, shall be followed by a quieter civilization based on the utilization of solar energy, that will not be harmful to progress and to human happiness."



Total energy supply (TES) by source, World 1990-2018; 2018= 19TW

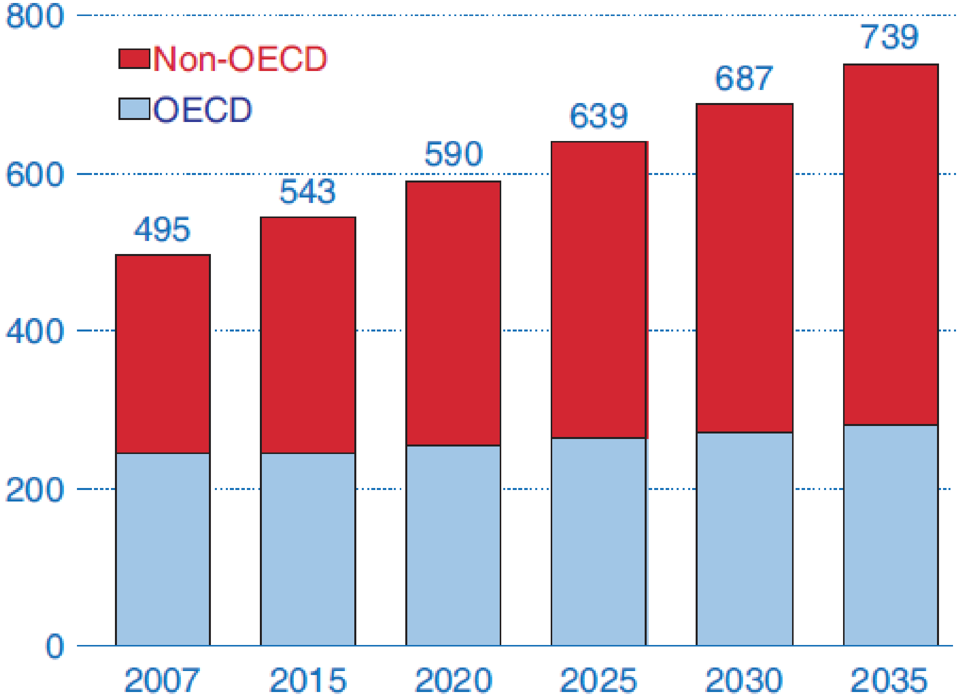


Primary energy consumption from 1990 to 2040

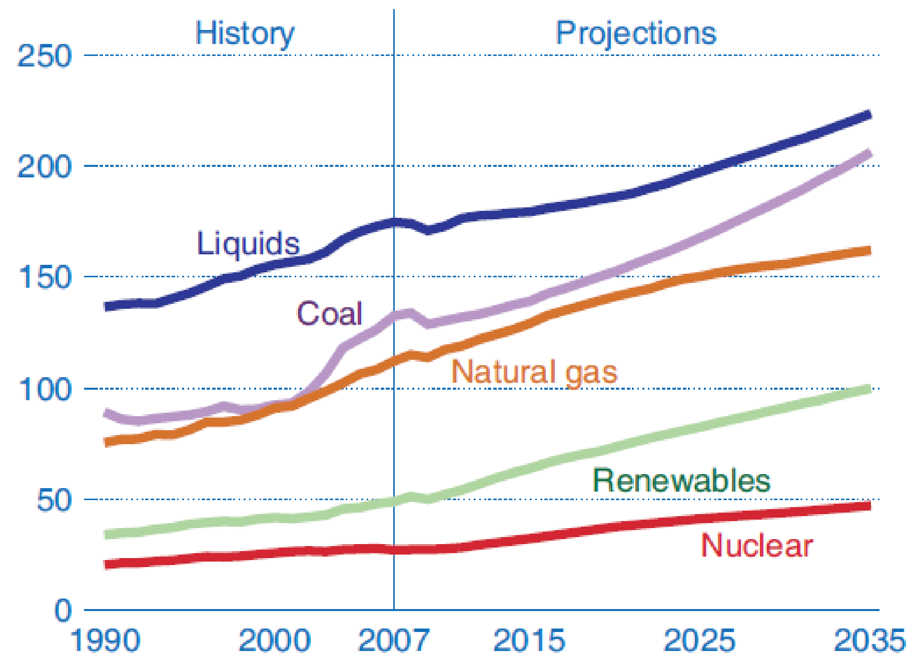


24 TW

Energy produced



In 2009: 474 exajoules (474×10^{18} J) equivalent to a 15 TW h/y

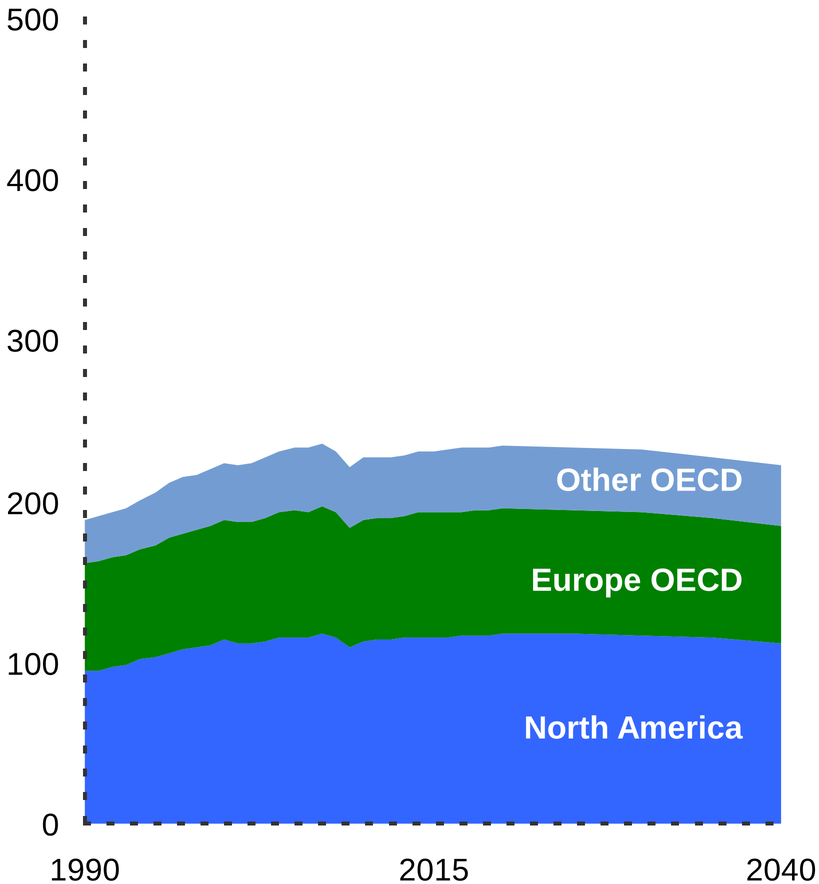


Source: IEO2010 see EIA Home Page (*http://www.eia.gov/oiaf/ieo/index.html*)

Data in QUAD. 1 QUAD (quadrillion BTU) = 1.055 EJ (10 E^{18} J) = 0.033 TW

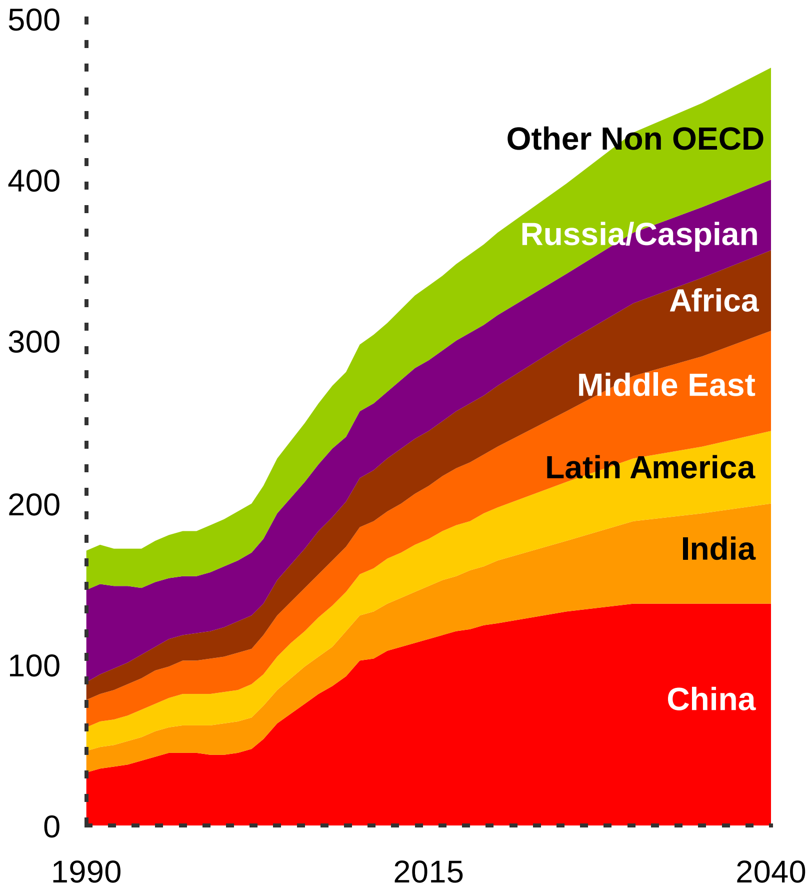
Global energy demand per region

- OECD
  - Quadrillion BTU - Quad



Non OECD

100 quad = 3.33 TW

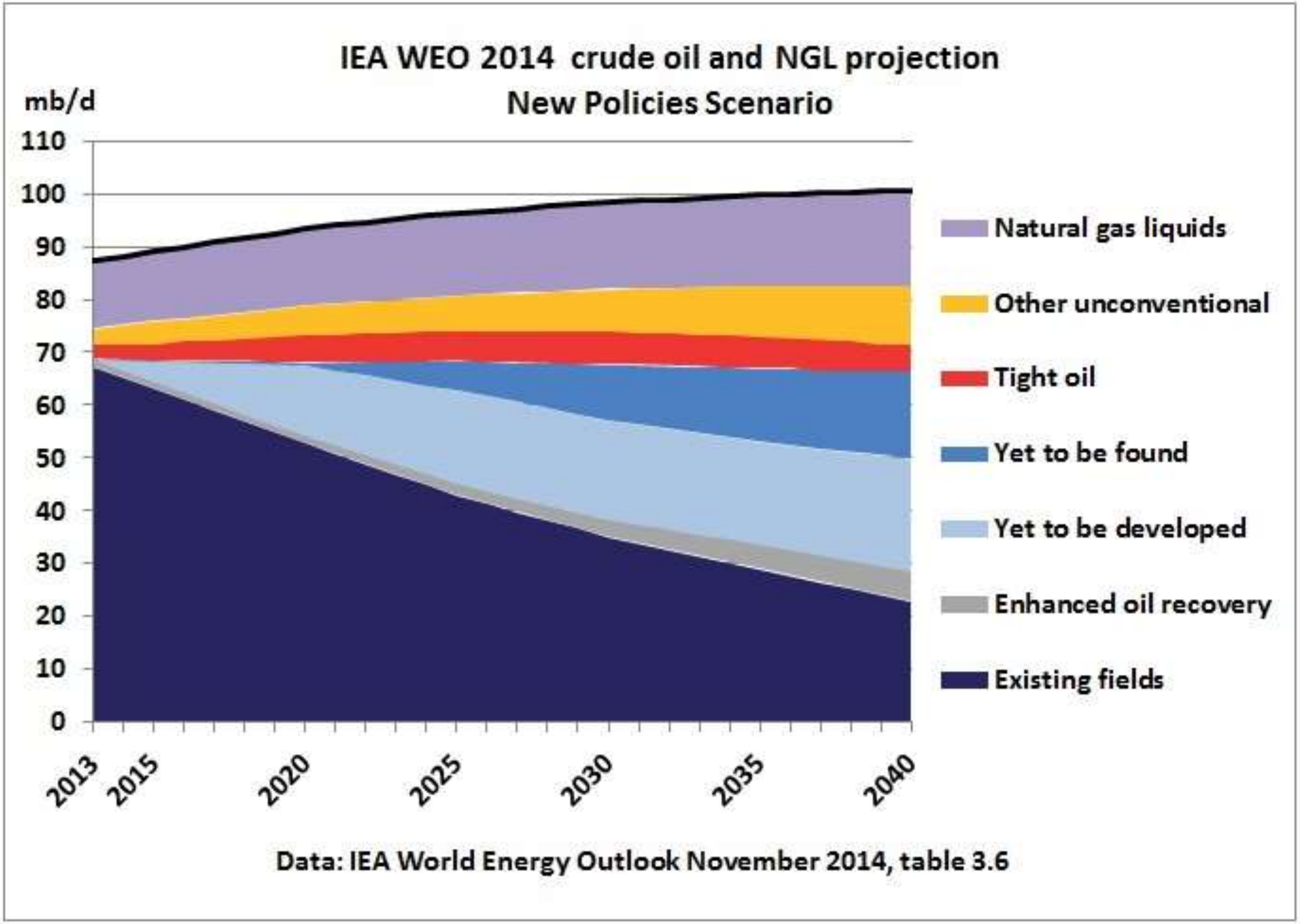


Source: The Outlook for energy: a view of 2040, Exxon

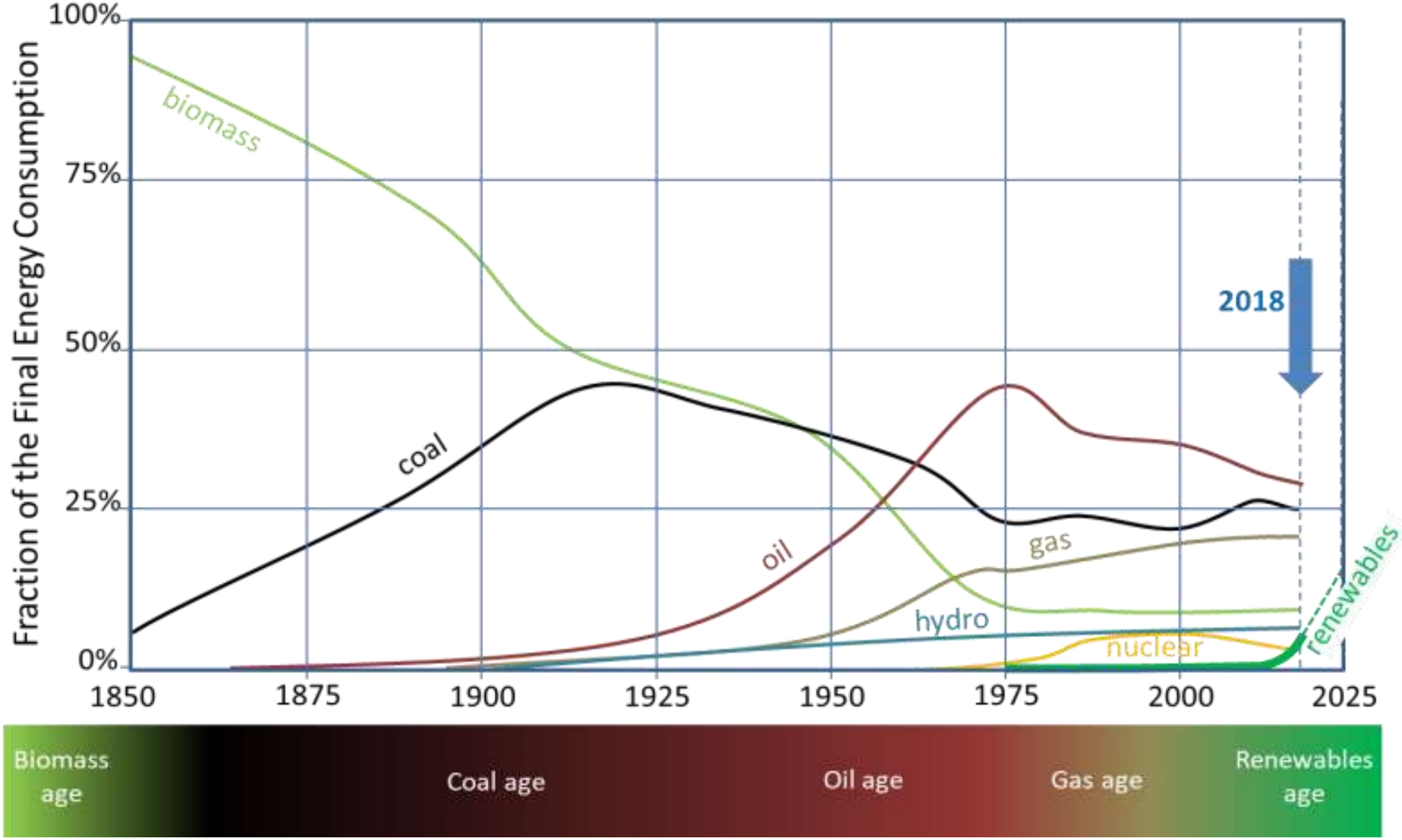
2010 474 exaJ = 15,000,000,000,000 Wh => 17 TW

2030 → 23 TW ; 2058 → 32 TW

Fossil fuels production: projection



Energetic transitions



Energy return on energy invested (EROEI)

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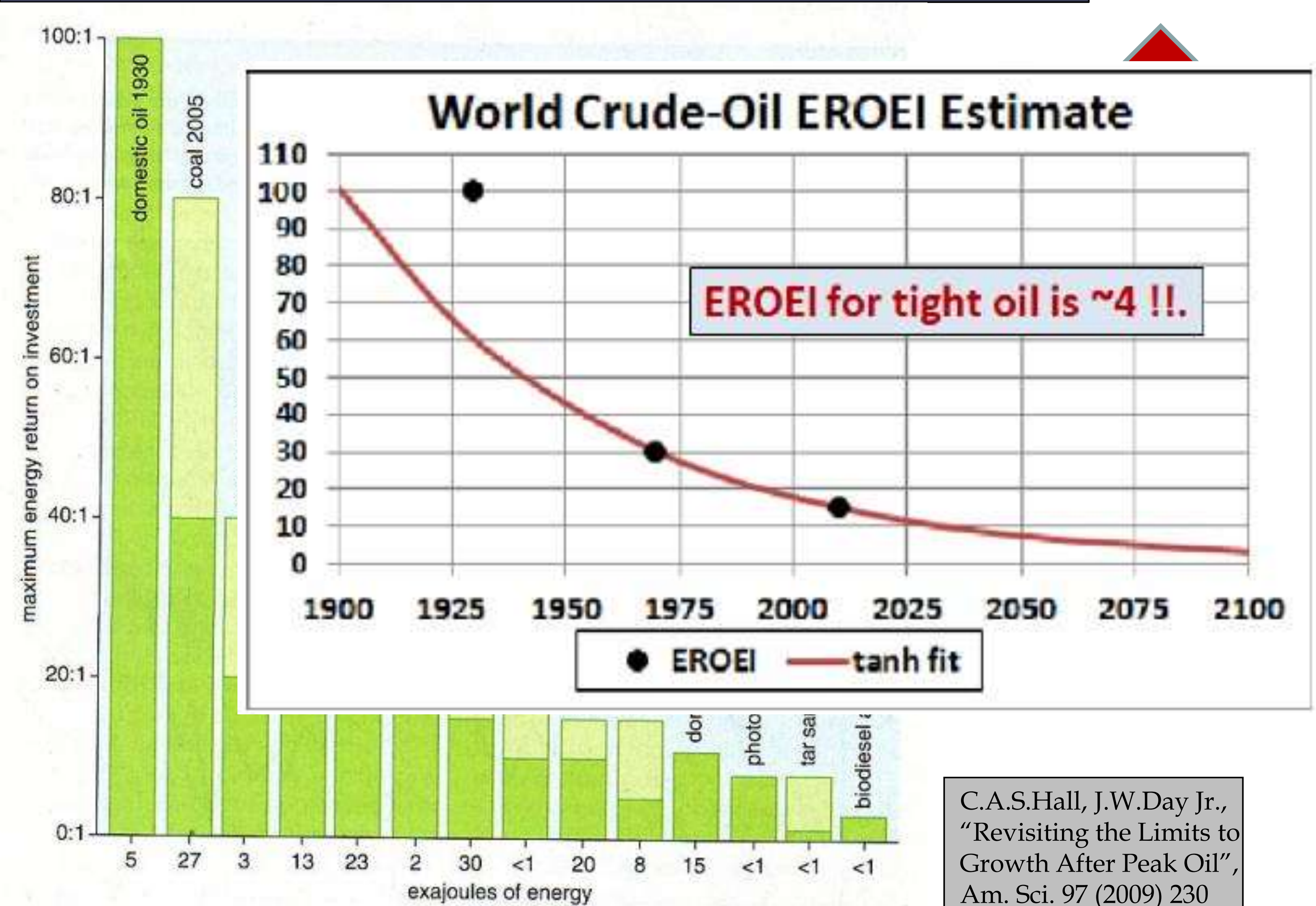
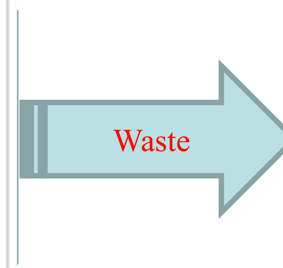


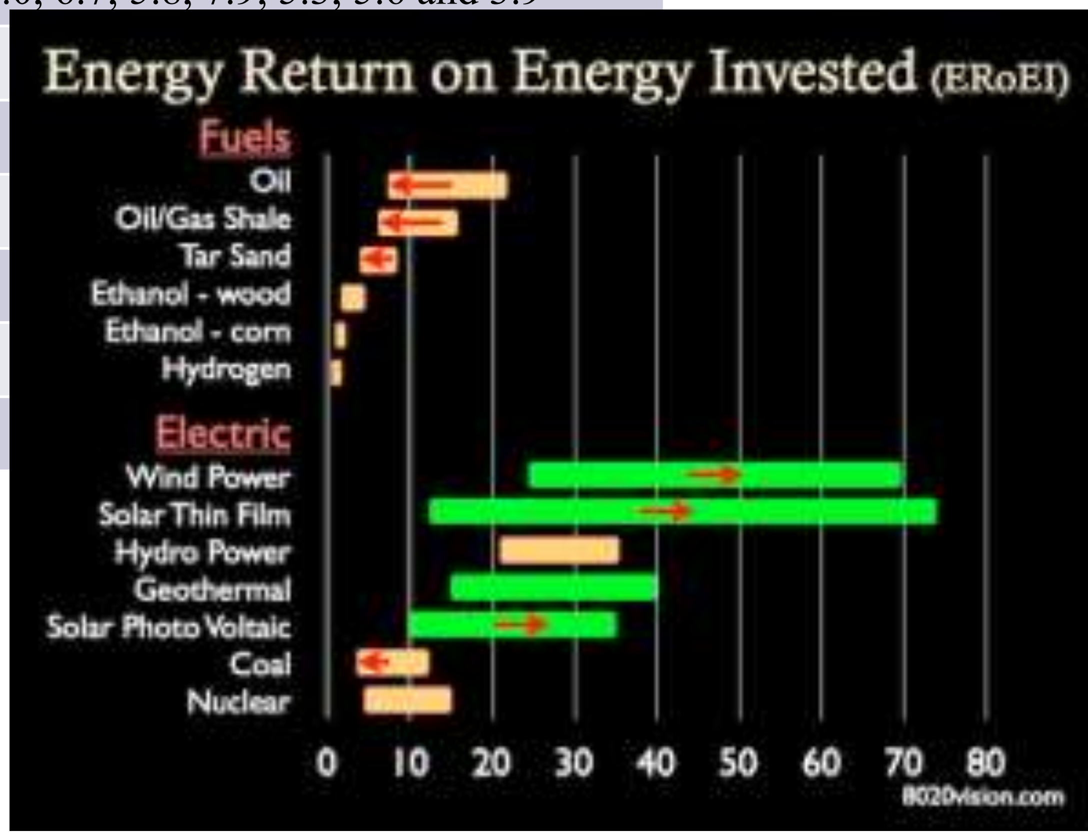


C.A.S.Hall, J.W.Day Jr., "Revisiting the Limits to Growth After Peak Oil", Am. Sci. 97 (2009) 230

Comparison of EROEI

Power Source	EROEI(actual)
Hydro	50, 43 and 205
Nuclear (centrifuge)	18.1, 18.4, 14.5, 13.6 and 14.8
Nuclear (diffusion)	6.0, 6.7, 5.8, 7.9, 5.3, 5.6 and 3.9
Coal	
Gas (piped)	
Gas (piped a lot or liquefied)	
Solar	
Solar PV	
Wind	

Source: The World Nuclear Association, 2011



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

EROEI: King et al. 2018

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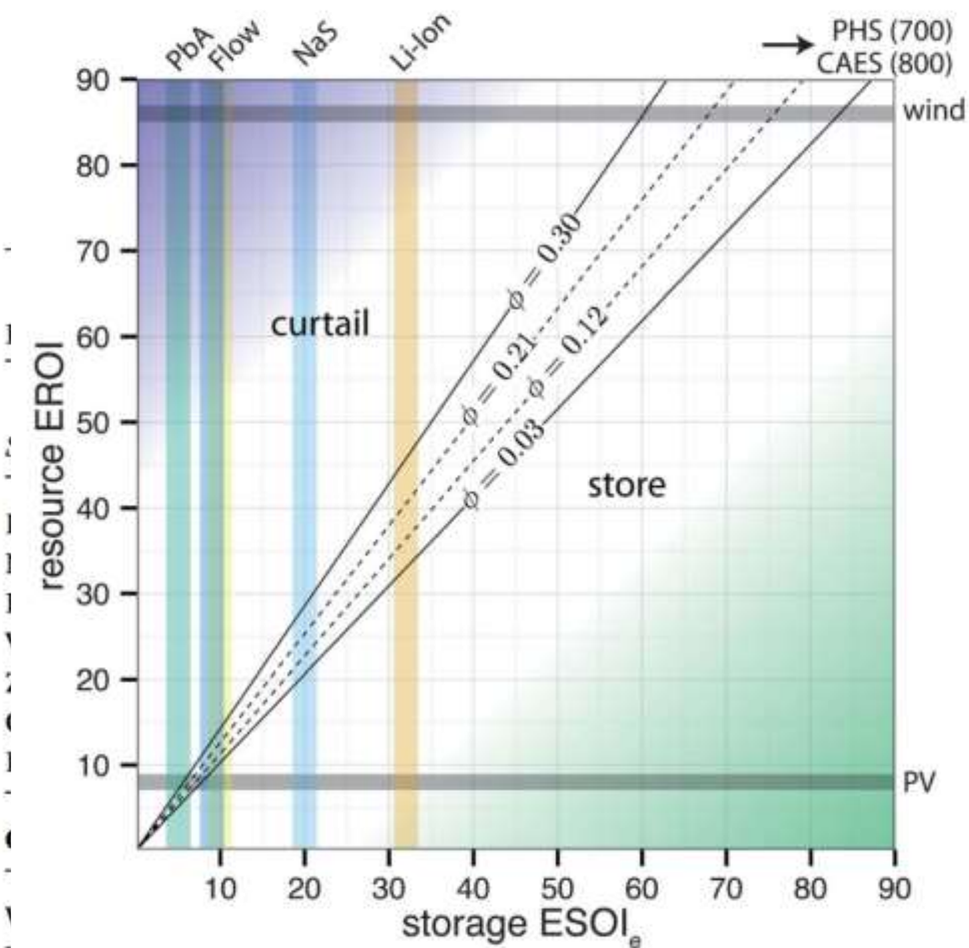
Table 1 | Comparison of mean EROIs for different energy sources

	Energy source		Optimistic EROI	Optimistic net energy percentage
Coal	Thermal		46:1	98
	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

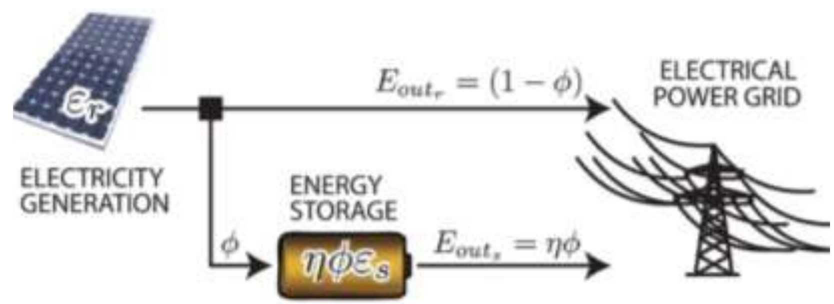
Source: King et al, Nature Energy, 2018

ESOEI: energy stored on energy invested

- ESOI - energy stored on energy invested



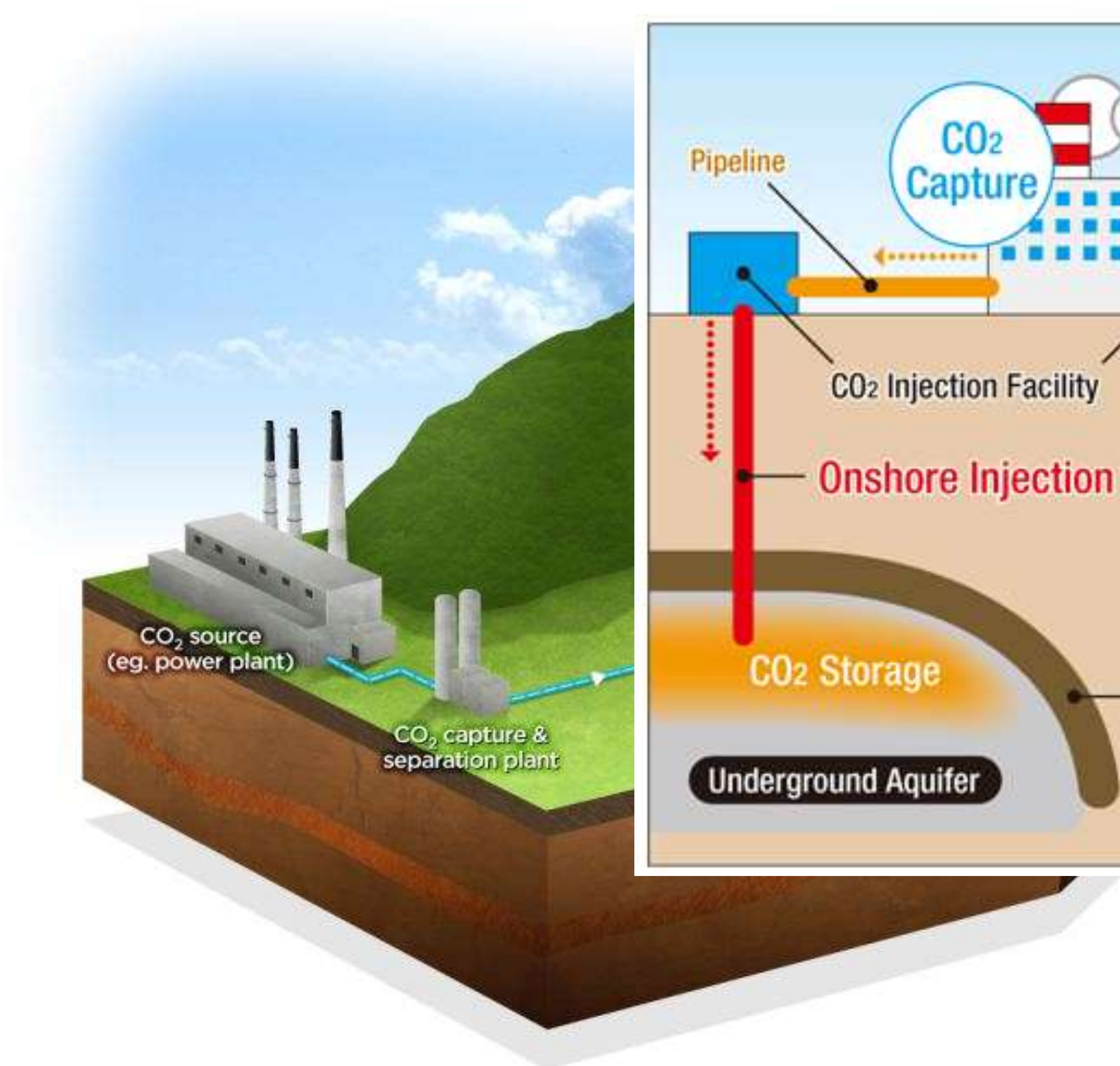
uity of renewables

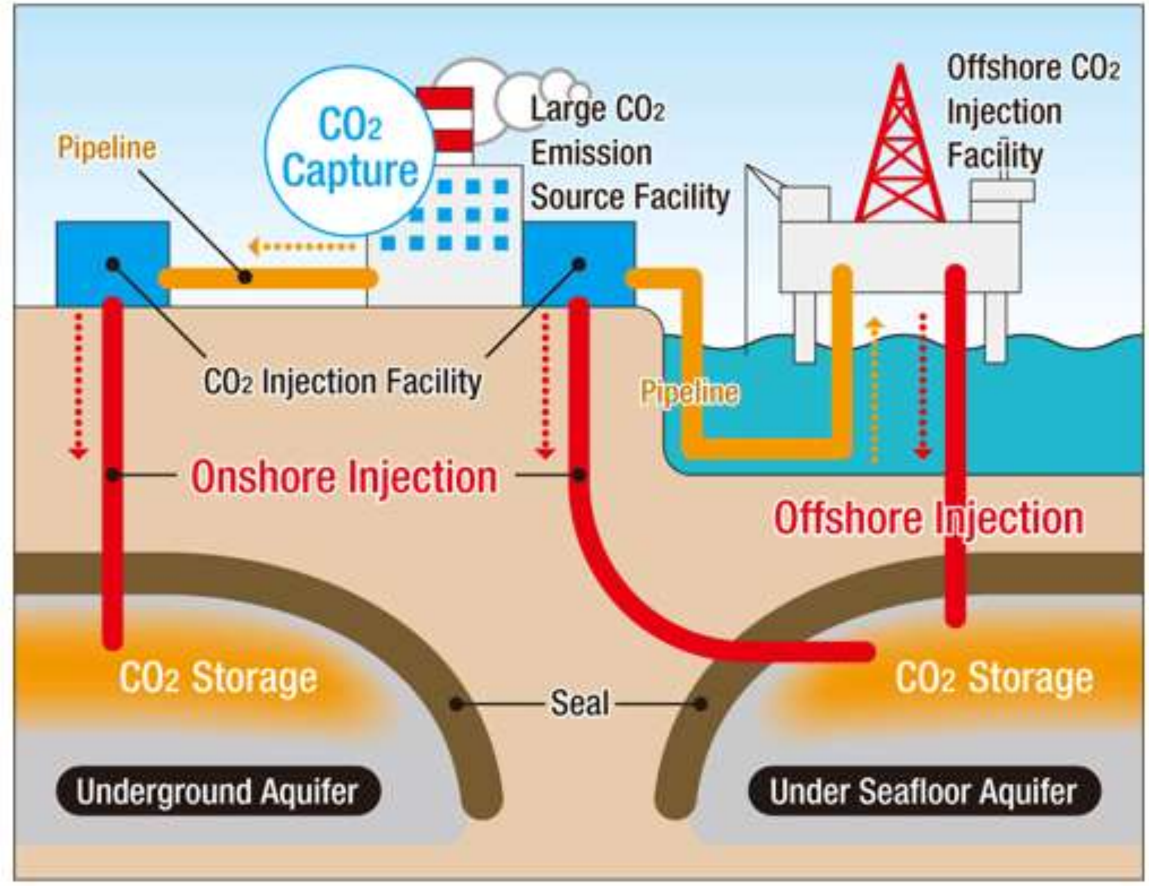


$$\mathrm{ESOI_{curt}} = (1-\phi)\mathrm{EROI}\left[\frac{\mathrm{kWh_e\ generated}}{\mathrm{kWh_e\ embodied}}\right].$$

$$\frac{\mathrm{ESOI_e}}{\mathrm{EROI}} \Rightarrow \begin{cases} \text{store if} > 1-\phi \\ \text{curtail if} < 1-\phi \end{cases}.$$

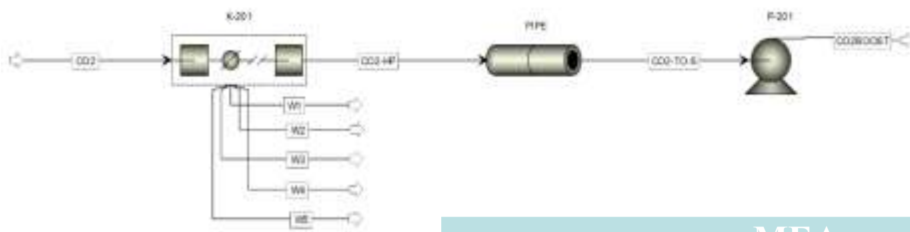
CO_2 Carbon capture and storage (CCS)

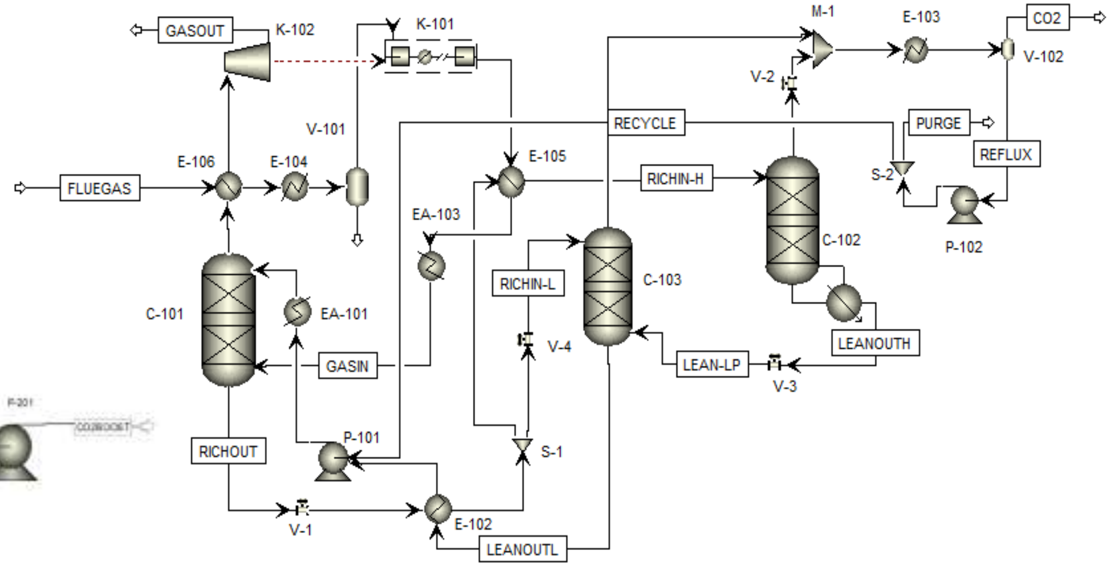




CCS is a chemical process

- Process simulation
- CO_2 transport





- Material and energy balances

MEA			HPC		
Blower (B-101)	20,945	kW_e	FG compressor (K-101 + K-102)	93,798	kW_e
Pump (P-101)	373	kW_e	Pumps (P-101+P-102)	1441	kW_e
CO2 compressor (K-201)	12,785	kW_e	CO2 compressor (K-201)	15,931	kW_e
Booster pump (P-201)	267	kW_e	Booster pump (P-201)	268	kW_e
Total auxiliaries	34,370	kW_e	Total auxiliaries	111,438	kW_e
Reboiler duty (C-102)	248,445	kW_{th}	Reboiler duty (C-102)	129,241	kW_{th}
	89,440	kW_e		46,527	kW_e
Total (auxiliaries + reboiler)	123,810	kW_e	Total (auxiliaries + reboiler)	157,965	kW_e

Information to be transferred to indicator calculations

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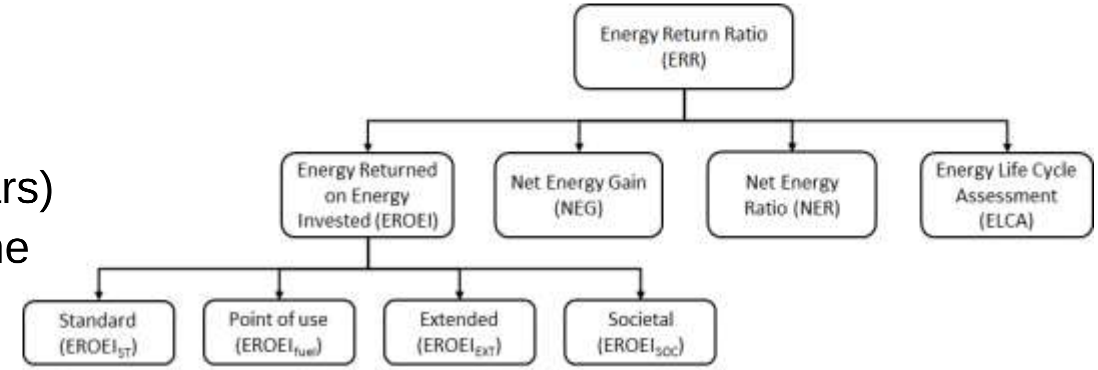
- From Process simulation SW

		MEA	HPC	EROEI	LCOE	LCA
Installed capacity (P_{inst})	kW_e	564,700	564,700	x	x	x
Energy for auxiliary[a]	%	7.8	21.4	x		x
Thermal energy[b]	%	84.2	91.75	x		x
Net power output (P)	kW_e	431,431	397,266	x	x	x
Total plant cost (TPC)	€	246,610,100 (CCS only)	522,848,300 (CCS only)		x	
		576,394,900 (CCS+NGCC)	852,663,100 (CCS+NGCC)	x		
Share of investment costs due to operation and maintenance ($s_{o\&m}$)	%	12.4	13.15	x		
Fixed operation and maintenance costs (FO&MC)	€/kW/year	67.28	143.18		x	
Variable operation and maintenance costs (VO&MC), cf = 0.4	€/kWh	0.020	0.030		x	
Variable operation and maintenance costs (VO&MC) cf = 0.85	€/kWh	0.009	0.014		x	
Total amount of solvent[c]	kg	53,317,213	9,691,908			x

Calculation of EROEI



- $EROEI = E_{out} / E_{in}$
- $E_{out} = P\ cf\ L$
  - P is the net power output
  - *L* is the plant life time (in years)
  - *cf* is the capacity factor for the energy production
- $E_{in} = E_{cap} + E_{o\&m} + E_f$
- $E_{cap} = P\ \varepsilon = (P\ TPC) / (P\ \varepsilon_c)$
  - TPC is the total plant cost
  - ε_c is the proportional factor between costs of energy and capital costs
- $E_{o\&m} = P\ \varepsilon\ L\ s_{o\&m}$
  - $s_{o\&m}$ is the share of the investment costs dedicated to operation and maintenance
  - ranging from 4% to 20% according to the different technology
- $E_f = (P\ cf\ L) / (\eta\ EROEI_{fuel})$
  - η is the global efficiency of the energy production plant
  - $EROEI_{fuel}$ is energy related to the production of the fuels, its extraction, intermediate storage, refining and transportation to the location of the plant

Sgouridis et al. 2019 – Nature Energy

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Table 1 | Normalized detailed performance characteristics of coal and natural gas plants with and without CCS

		IGCC (based on NETL Exhibit 3-101 and normalized for coal flow rate = 500,000 lb h^{-1})						PC (based on NETL Exhibit 4-58 and normalized for coal flow rate = 500,000 lb h^{-1})				NGCC (Exhibit 5-27)	
		1	1a (CCS)	2	2a (CCS)	3	3a (CCS)	4	4a (CCS)	5	5a (CCS)	6	6a (CCS)
Gross power output (kW_e)		800,812	753,576	802,465	726,645	843,933	723,675	666,014	546,916	708,621	585,699	564,700	511,000
Aux. power requirement (kW_e)		134,665	195,837	122,989	196,288	123,693	189,720	37,245	99,790	37,128	99,705	9,620	37,430
Net power output (kW_e)		666,148	557,739	679,475	530,357	720,240	533,955	628,770	447,126	671,493	485,994	555,080	473,570
Net plant efficiency (%)		39.0	32.6	39.7	31.0	42.1	31.2	36.8	26.2	39.3	28.4	50.2	42.8
Plant overnight unit cost (2007 US$ kW^{-1})		1,987	2,711	1,913	2,817	2,217	3,181	1,622	2,942	1,647	2,913	584	1,226
Total plant costs (million US$)		1,591	2,043	1,535	2,047	1,871	2,302	1,080	1,609	1,167	1,706	330	626
cf = 85%	E_{out} (GWh)	178,885	168,334	179,255	162,318	188,518	161,655	148,774	122,170	158,292	130,833	126,143	114,147
	$E_{cap\text{-}CCS}$ (GWh)		688		780		657		806		821		452
	E_{cap} (GWh)	2,425	2,425	2,339	2,339	2,851	2,851	1,646	1,646	1,778	1,778	503	503
	$E_{O\&M}$	2,910	3,736	2,807	3,743	3,421	4,209	1,975	2,942	2,134	3,120	603	1,146
	E_f (GWh)	7,908	7,908	7,785	7,785	7,720	7,720	6,970	6,970	6,944	6,944	2,888	2,888
	Fuel $EROEI_{th}$	58		58		58		58		58		87	
	$EROEI_{el}$ (equations (1) and (6))	**11.2**	**8.4**	**11.7**	**8.1**	**11.5**	**7.7**	**13.3**	**8.1**	**13.8**	**8.6**	**31.0**	**21.2**
	R (from equation (6))		1.48		1.51		1.23		1.92		1.77		2.61
cf = 55%	E_{out} (GWh)	115,749	108,922	115,988	105,029	121,982	104,600	96,266	79,051	102,424	84,657	81,622	73,860
	$E_{cap\text{-}CCS}$ (GWh)		688		780		657		806		821		452
	E_{cap} (GWh)	2,425	2,425	2,339	2,339	2,851	2,851	1,646	1,646	1,778	1,778	503	503
	$E_{O\&M}$	2,910	3,736	2,807	3,743	3,421	4,209	1,975	2,942	2,134	3,120	603	1,146
	E_f (GWh)	5,117	5,117	5,037	5,037	4,996	4,996	4,510	4,510	4,493	4,493	1,869	1,869
	Fuel $EROEI_{th}$	58		58		58		58		58		87	
	$EROEI_{el}$ (equations (1) and (6))	**9.2**	**6.7**	**9.6**	**6.4**	**9.2**	**6.1**	**11.2**	**6.5**	**11.6**	**6.9**	**27.0**	**17.3**
	R (from equation (6))		0.96		0.98		0.80		1.25		1.15		1.69
f_{op} (%)		16.3		21.9		25.9		28.9		27.6		14.7	
f_{cap} (%)		28.4		33.3		23.0		48.9		46.2		90.0	

The table shows the detailed simulated characteristics and lifetime energy flows of fossil-fuel power plants for 90% CRs, 85% and 55% cf, and 80 km pipeline to injection. These are used to calculate energy penalties and the corresponding EROEIs (in bold) based on equation (1) and confirming equation (6) in Methods. (Based on NETL simulations[26] and author calculations.)

EROEI: King et al. 2018

Table 1 | Comparison of mean EROIs for different energy sources

	Energy source		Optimistic EROI	Optimistic net energy percentage
Coal	Thermal		46:1	98
	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

From EROEI to EROC

Table 5 | EROC of combusting different fossil fuels

Energy source	EROI	Carbon emission factor[36] ($kgCO_2\ TJ^{-1}$)	EROC ($EJ\ GtCO_2^{-1}$)
Coal	46:1	94.6	10.3
Coal with CCS	9:1	9.5	65.1
Oil	19:1	73.3	12.9
Oil shale	7:1	107.0	8.0
Tar sands	4:1	107.0	7.0
Natural gas	19:1	56.1	16.9
Natural gas with CCS	4:1	5.6	101.9

CCS carbon emission factors are based on capturing 85% of CO_2 emissions, the midpoint of 80–90% range stated in the IPCC special report on CCS[32].

- Net energy per tons of CO_2
- Shows the performance of energetic sources subject to the constraints of climate change

Ratio of the net potential energy produced and carbon emissions

$$EROC = [(1 - 1/EROI)/(\text{carbon emission factor})]$$

Economics of PV. Grid parity is reached and LCOE is reduced

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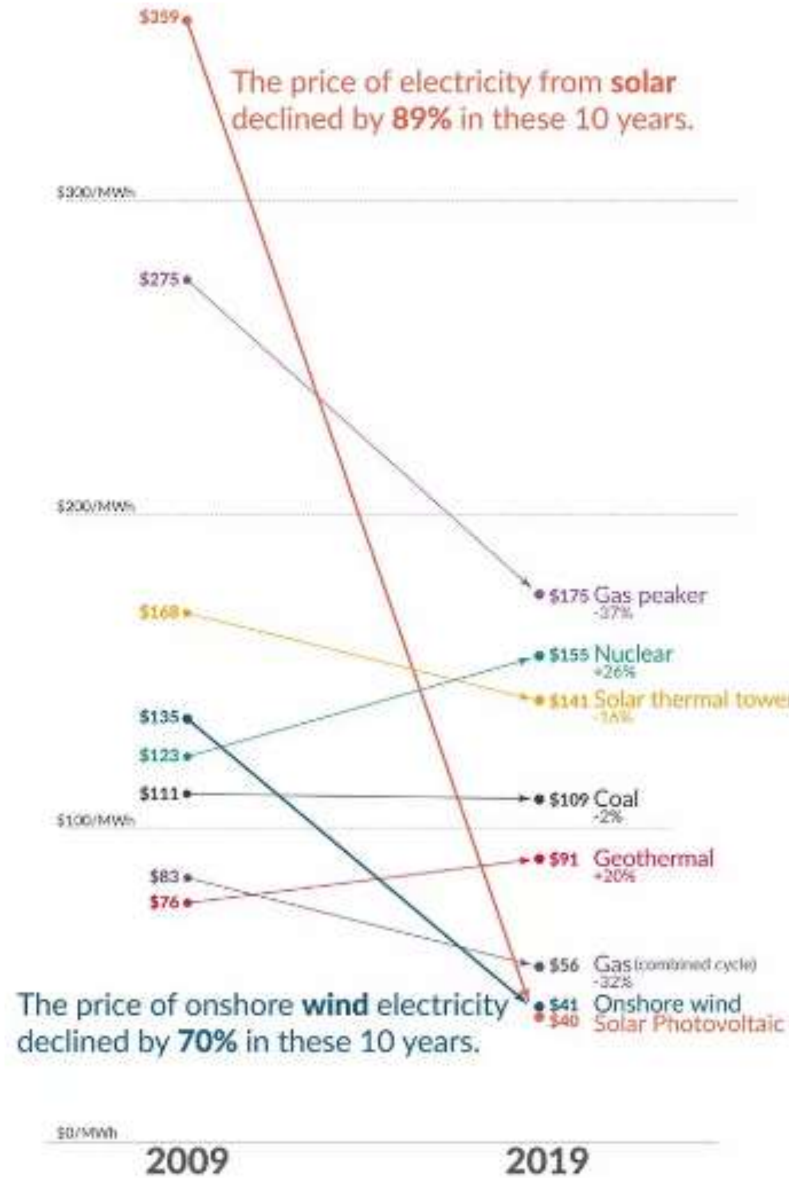
- Economical factors and policy contributed to favor PV diffusion.
- In Italy:
  - LCOE of PV lower than traditional primary energy resources
  - Among the first energy markets to achieve grid parity
  - Grid parity is possible without new technology now

Grid parity: Residential, commercial/industrial applications

Electricity price in Italy[28]	10–22 € cent/kWh
Photovoltaic LCOE[29]	5 -11.5 € cent/kWh
Fuel parity: Utility-scale	
Conventional power production (fossil and fissile)[19]	4.4–19.2 € cent/kWh
Photovoltaic LCOE[19]	3.2–4.4 € cent/kWh



Levelized Cost of Energy - LCOE

- $LCOE = \frac{OC \times P \times CRF + FO\&MC}{8760 \times cf} + VO\&MC$
  - OC [€/kW] is the overnight cost (cost per unit power produced),
  - P [kW] is the net power output of the plant,
  - *cf* [-] the capacity factor, while
  - FO&MC [€/kW/year] and VO&MC [€/kWh] are the fixed and the variable operation costs respectively.
  - CRF [−] the capital recovery factor,
- $CRF = \frac{i \times (i+1)^L}{(i+1)^L - 1}$
- The overnight cost is calculated as the ratio between the Total Plant Cost (TPC) relative to the CCS plant only and the net power output P

EROEI and LCOE for CCS

- *EROEI and EROC* → $EROC = \left[\frac{(1-EROEI)}{(carbon\ emission\ factor)}\right]$

Process	cf	EROEI	EROC
NGCC no CCS	0.40	17.60	16.81
	0.85	21.37	16.99
NGCC + CCS MEA	0.40	7.73	163.1
	0.85	12.36	167.1
NGCC + CCS HPC	0.40	5.21	163.1
	0.85	9.06	167.1

- LCOE

cf	NGCC with MEA	Extra cost due to MEA	NGCC with HPC	Extra cost due to HPC
0.40	[131 – 153]	53	[178 –200]	100
0.85	[102 – 124]	24	[126 – 148]	48

E. Barbera, A. Mio, A. Massi Pavan, A. Bertucco, M. Fermeglia, 2021, Applied Energy, Submitted

Unconventional fossil fuel: Shale oil & Gas

“Fracking”: problems and risks

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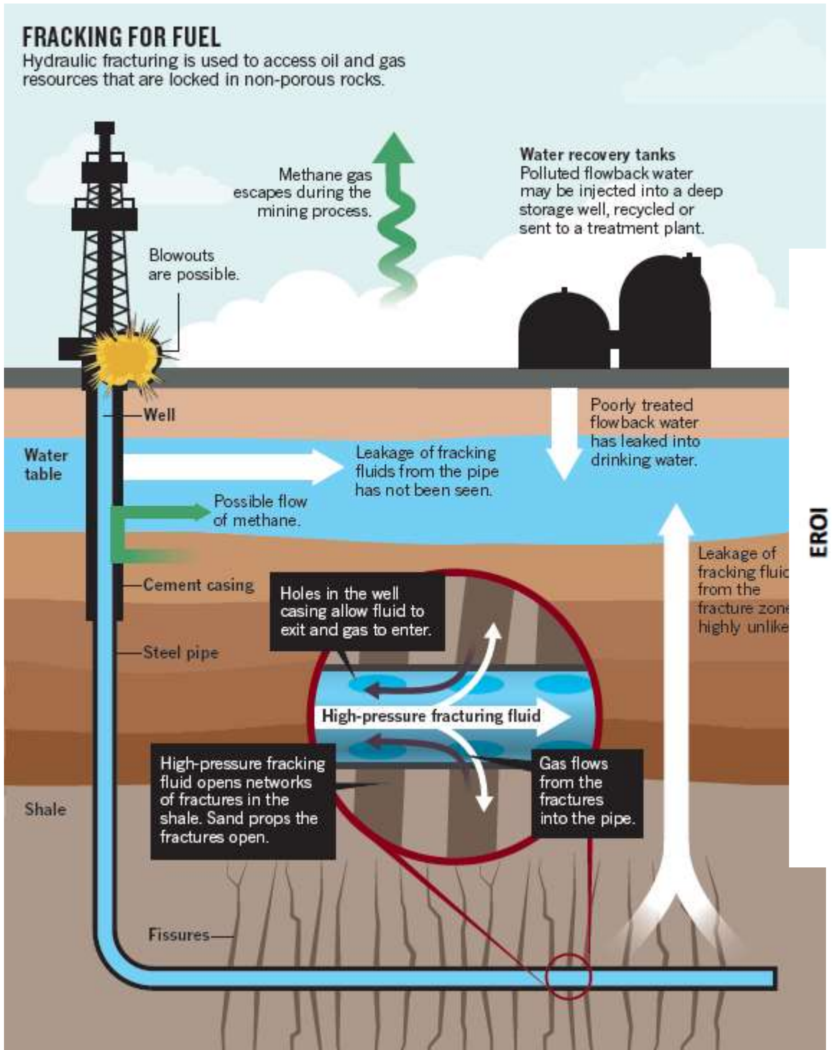
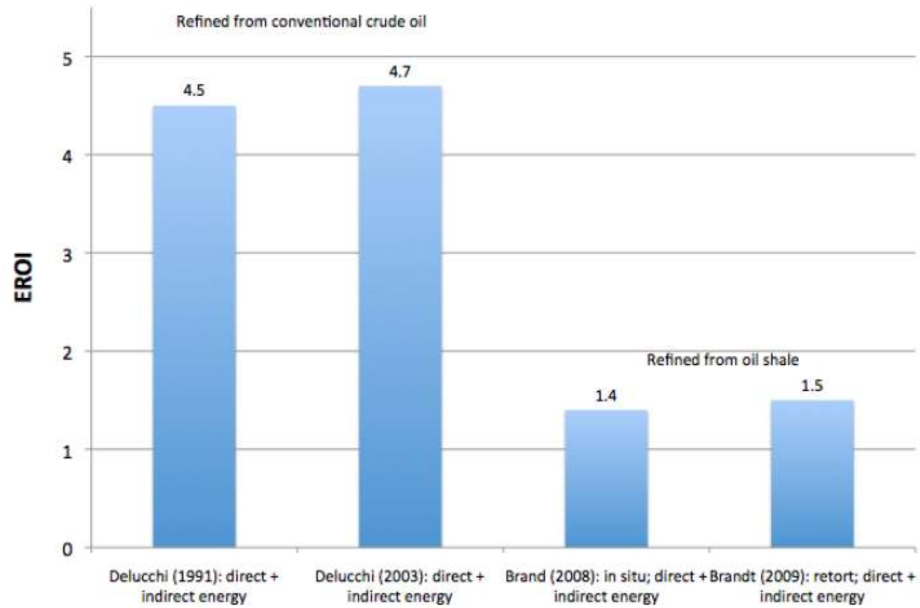


Nature **2011**, *477*, 271

Ground water contamination

Science **2013**, *340*, 826
PNAS **2013**, *110*, 11250
Nature **2013**, *498*, 415



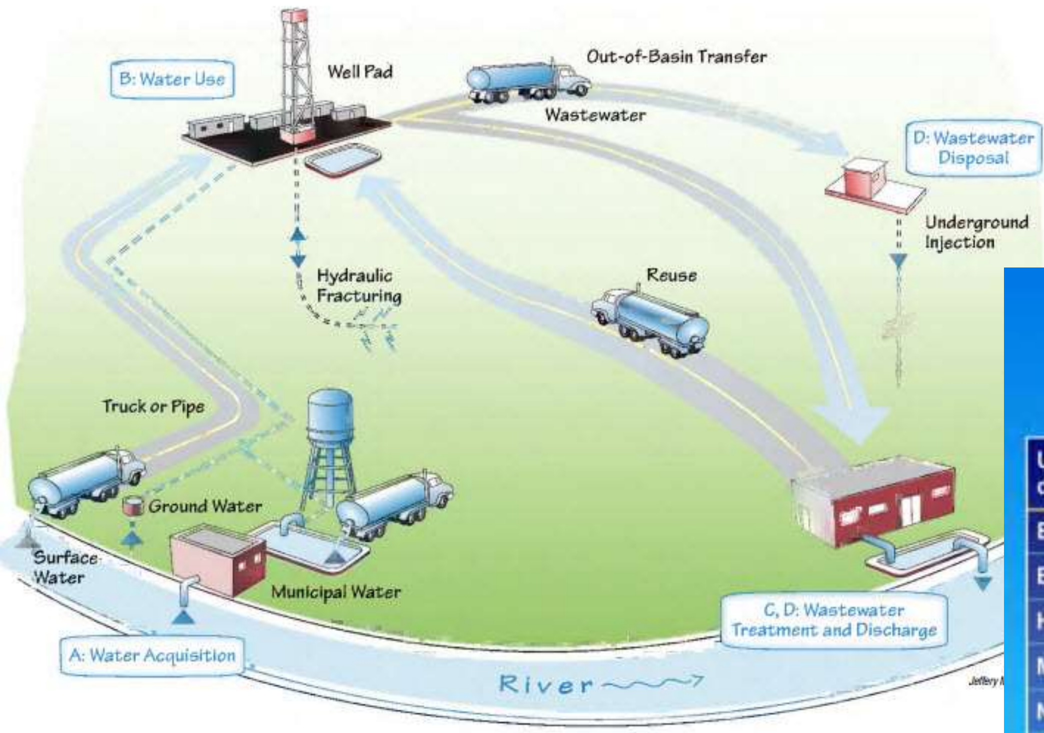
67-3

Low EROEI

Environ. Sci. Tech. **2013**, *47*, 5459

Fracking: water consumption

- Water consumption per frack: average 5 Mil gallons (=20 Mil liters)
  - 400 – 600 incoming trucks
  - 200 – 300 outgoing trucks
  - Water volume equivalent to 15 Olympic water pools



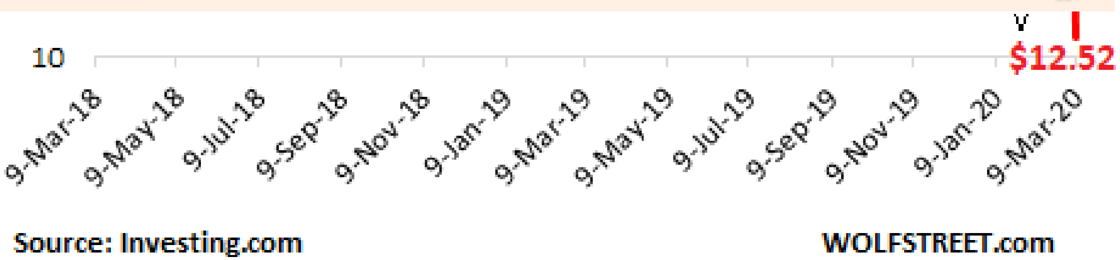
Average Water Volumes for Drilling and Hydraulic Fracturing of Shale Gas Wells

Unconventional development	Average fresh water volume for drilling	Average fresh water volume for fracturing	Average salt water volume for fracturing
Barnett	250,000 gallons	4,600,000 gallons	
Eagle Ford	125,000 gallons	5,000,000 gallons	
Haynesville	600,000 gallons	5,000,000 gallons	
Marcellus	85,000 gallons	5,600,000 gallons	
Niobrara	300,000 gallons	3,000,000 gallons	
Horn River (Apache)	250,000 gallons	negligible	8 to 12,000,000 gallons

From King 2011 (in press)

COVID and oil in 2020…

- Oil price:
  - from 75 to 20 $ barrel
  - < 0 $ on April 20 2020
  - Bounces up at 40 $
- Shale oil industries:
  - Small companies bankrupt
  - 300 billions debts
  - Shale wells down from 800 to 269 (67% less)
    - Nebraska 86% wells closed
    - Texas 83%
    - Montana 80%
- Oil extraction cost in Arabia
  - 5-10 $ barrel
- But is this good?



COVID and oil in 2020…

Commodities Corner

U.S. shale oil production may take years to recover from COVID-19 demand slump

Published: July 24, 2020 at 11:44 a.m. ET

—

By Myra P. Saefong

Domestic shale output won't return to March level before 2023: analyst

L'Espresso

MENU INCHIESTE OPINIONI BLOG

Cerca

Sei in: HOME PLUS ARTICOLI

GEOECONOMIA

È finita l'era dello shale oil degli Stati Uniti. E per Donald Trump è un grosso problema

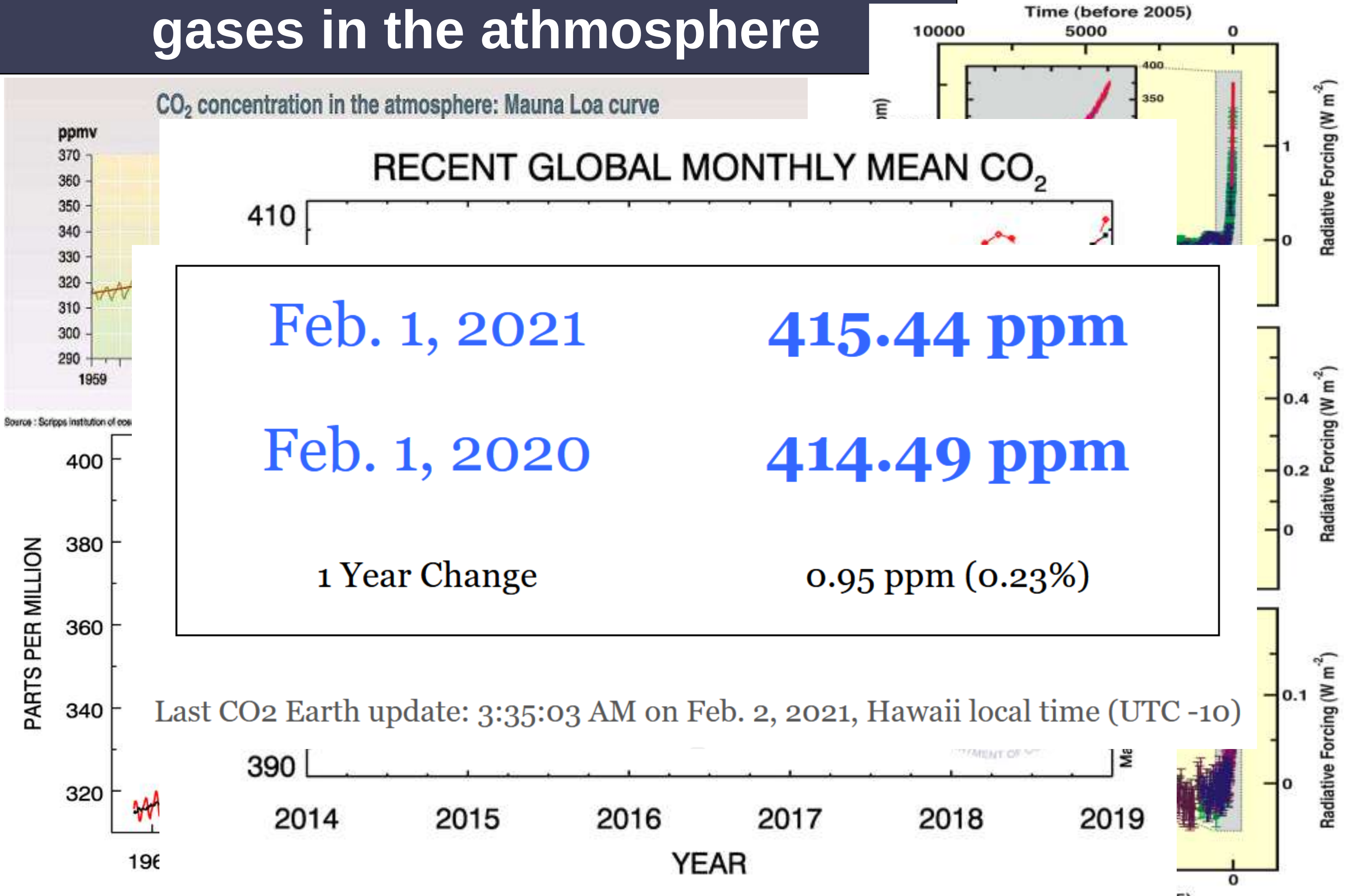
Il crollo del prezzo del greggio rende non più convenienti le estrazioni negli Usa, che devono tornare a rifornirsi in Medio Oriente. Con ricadute politiche importanti

DI EUGENIO OCCORSIO

U.S. shale oil production may take years to recover from COVID-19 demand slump

in Oil & Companies News 27/07/2020

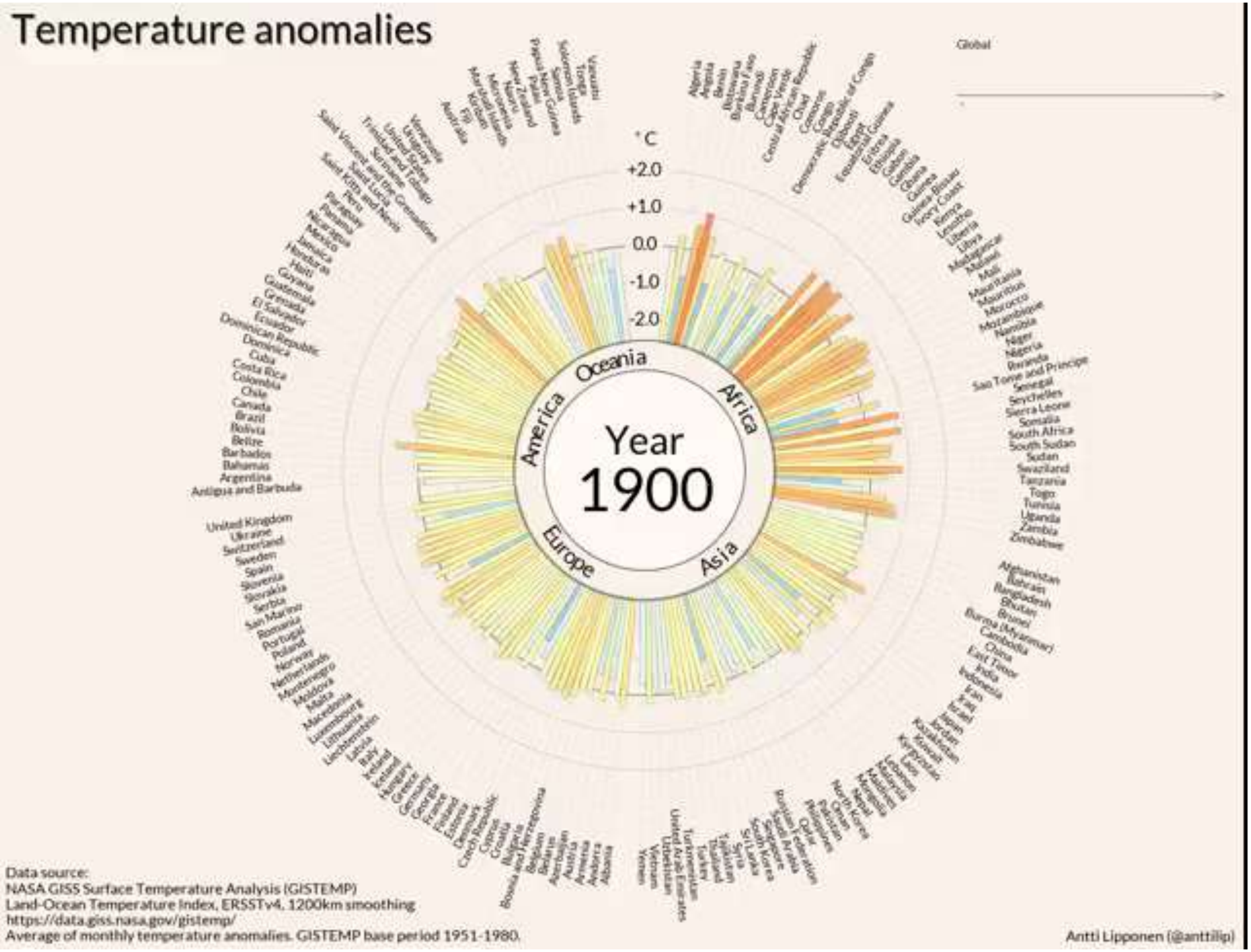
Concentration of greenhouse gases in the athmosphere



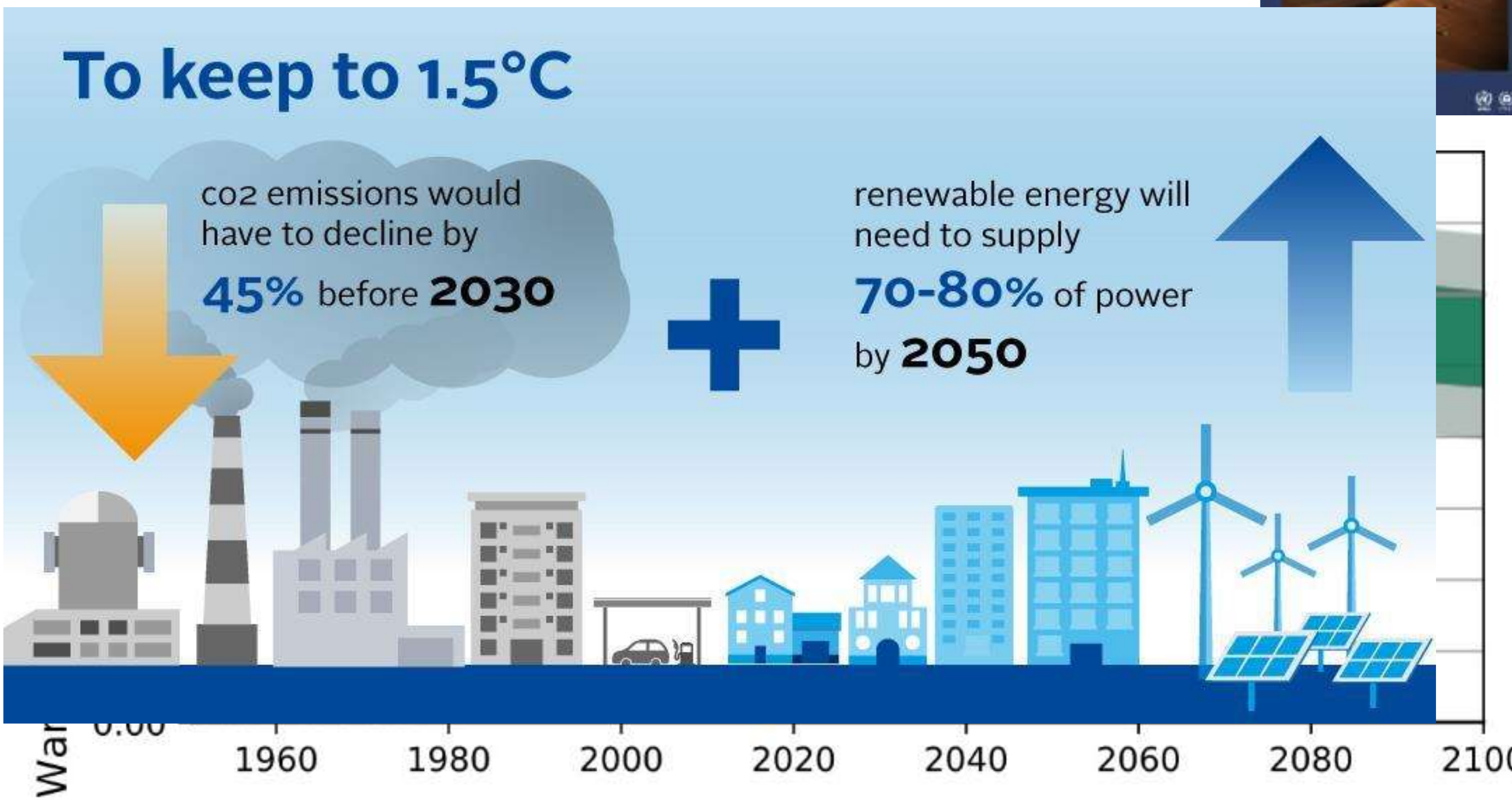
Feb. 1, 2021	**415.44 ppm**
Feb. 1, 2020	**414.49 ppm**
1 Year Change	0.95 ppm (0.23%)

Last CO2 Earth update: 3:35:03 AM on Feb. 2, 2021, Hawaii local time (UTC -10)

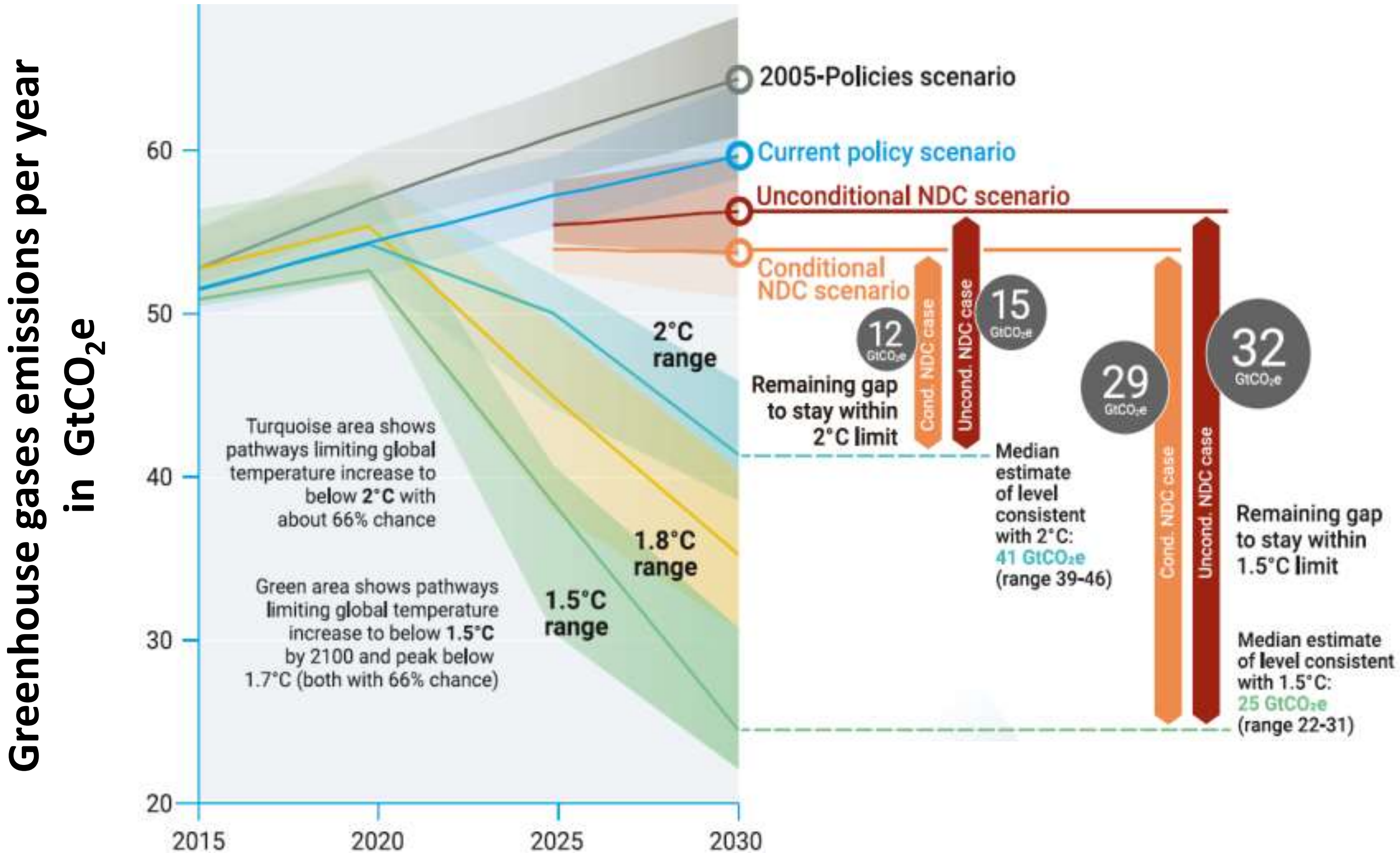
Temperature anomalies



Earth surface temperature has increased by about 0.85 degrees in recent 100 years



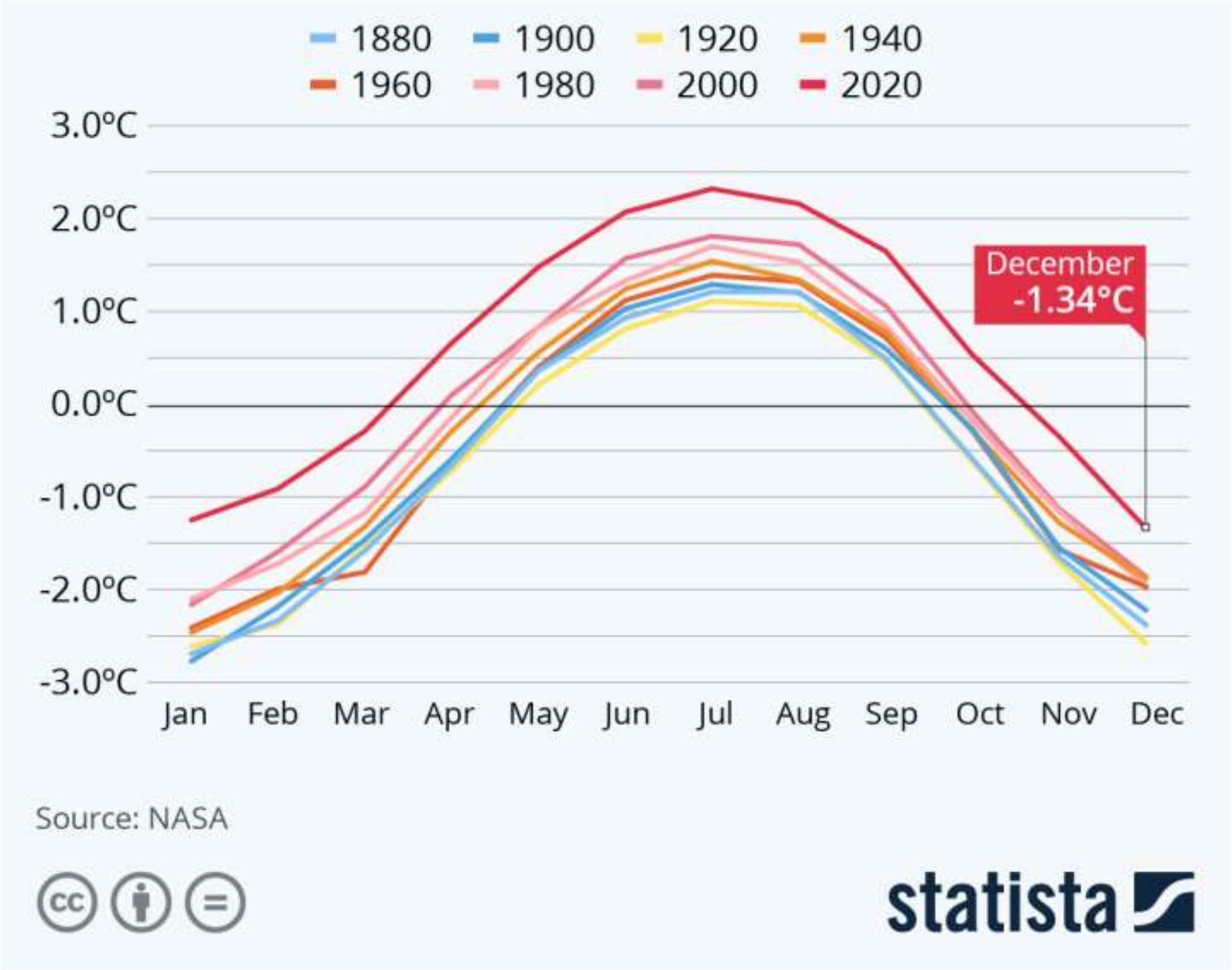
Emission gap



Emission Gap Report 2020 - United Nations Environment Programme

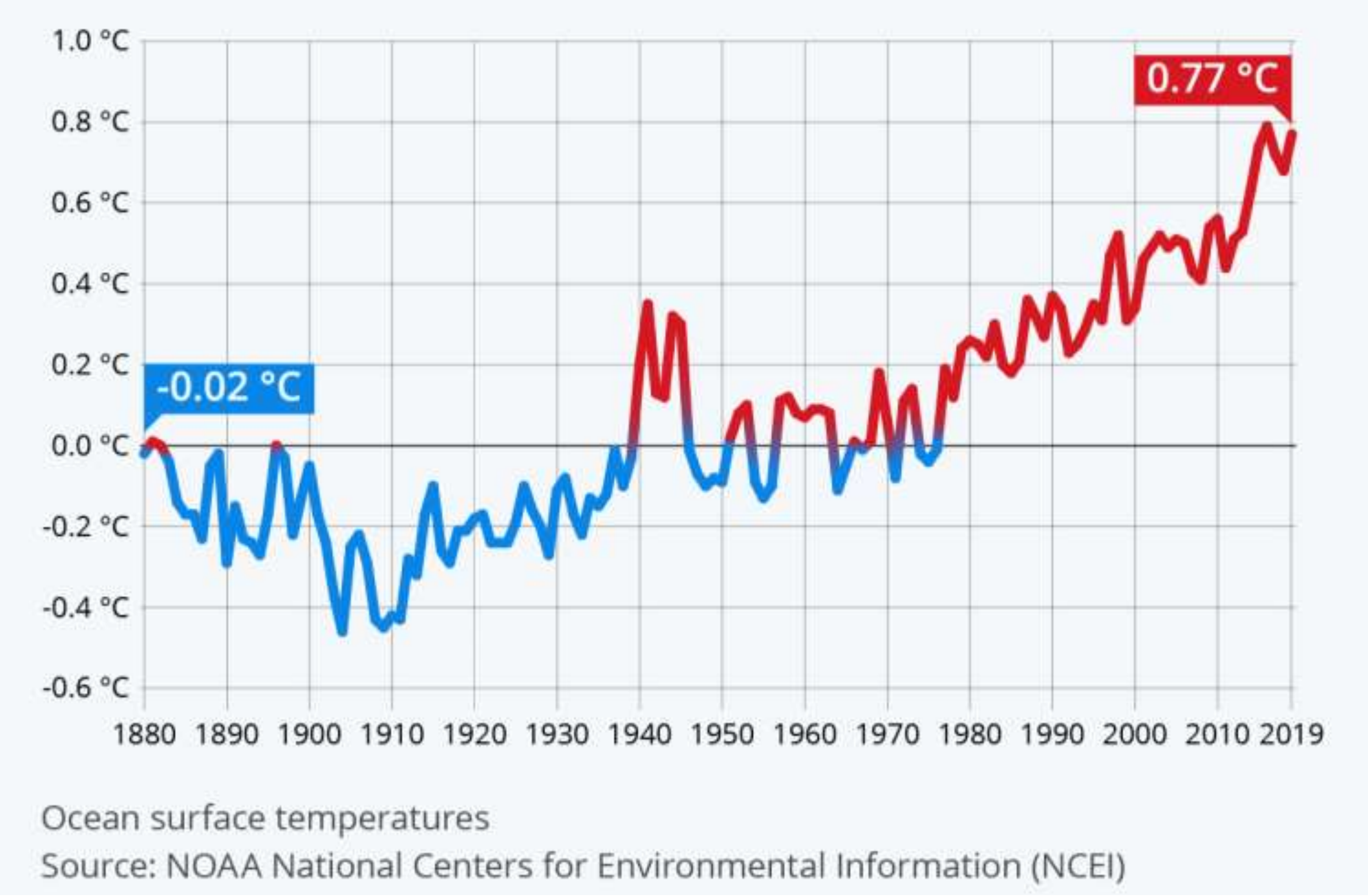
Earth is Heating Up

Monthly divergence from average temperature (calculated for 1880-2015) in selected years

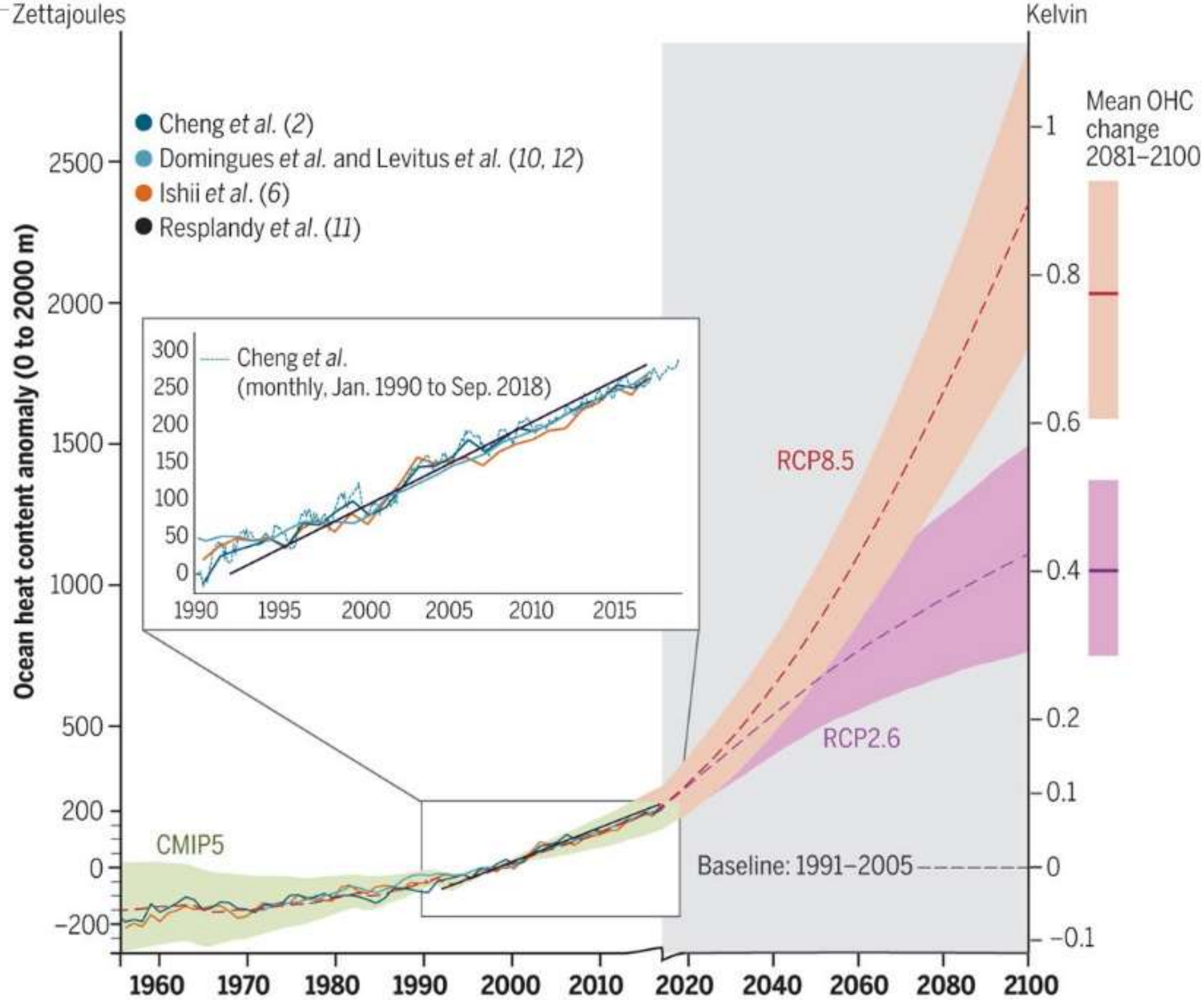


Oceans are heating up

- Annual divergence of global ocean temperature from 20th century average (1880 – 2019)



Ocean temperatures are rising faster than previously thought



What is *really* warming the planet?

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Glaciers melting ….

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

Mont Blanc, Grande Jorasses peak

sciencealert

Trending

CBS NEWS

NEWS SHOWS LIVE

Italy calls fast-melting glacier in Mont Blanc range "an alarm" that can't be ignored

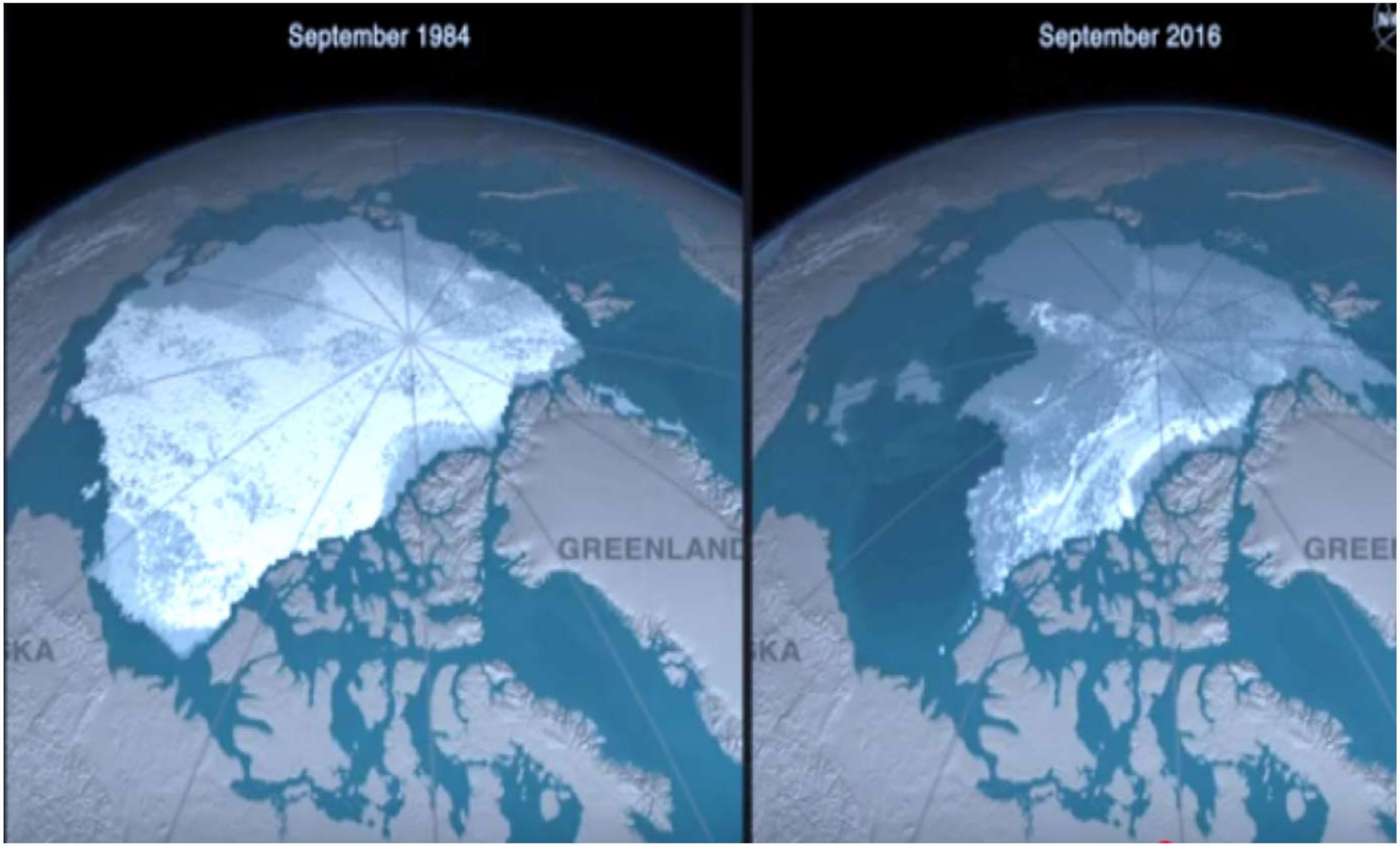
ENVIRONMENT

An Entire Alpine Glacier Might Collapse Any Moment, And People Are Being Evacuated

wp KAYLA EPSTEIN, THE WASHINGTON POST

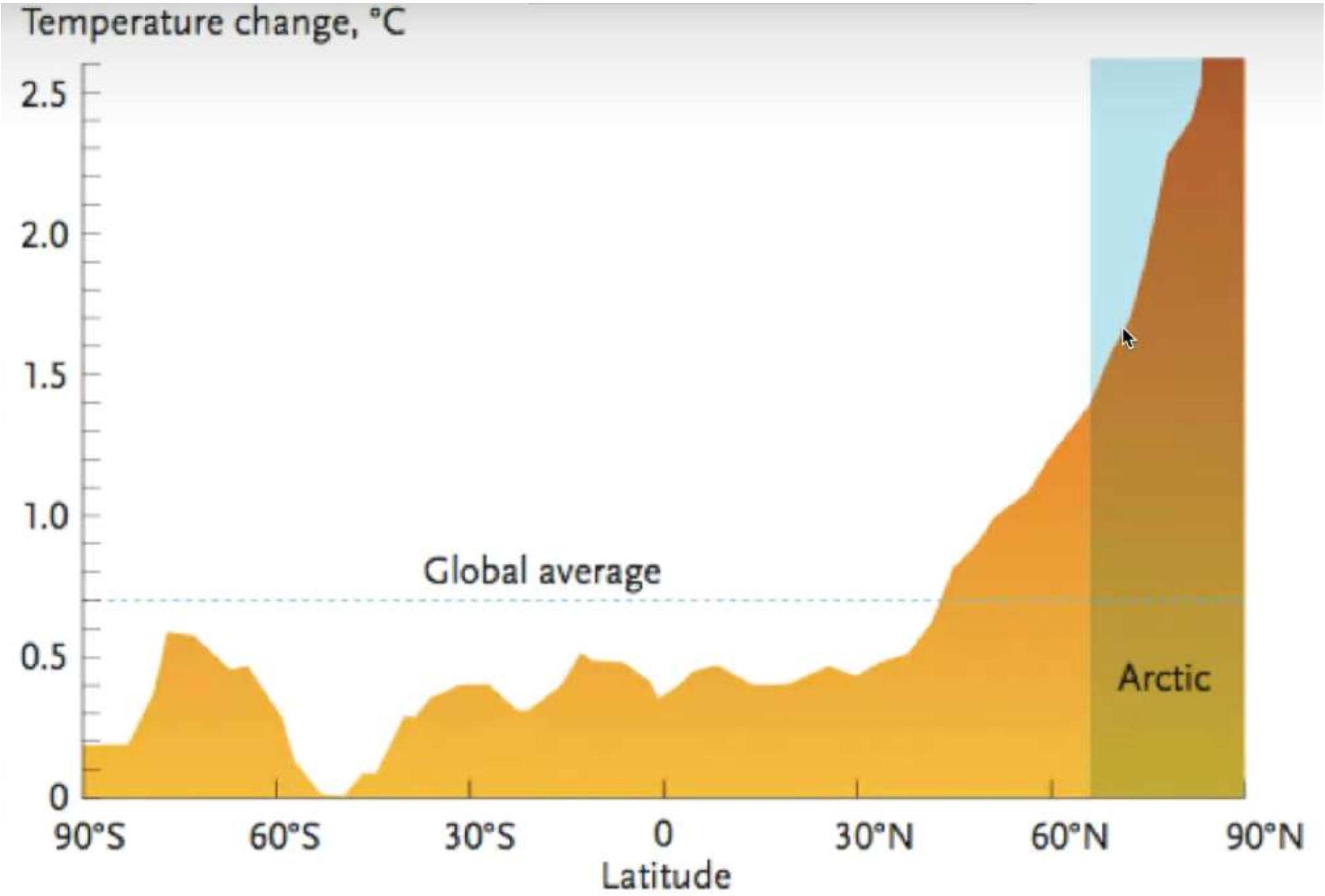
27 SEP 2019

Artic glacier melting



Surface temperature increase in the Arctic

- The average increase in surface temperature since 1951-1980 reference period is greater in the Arctic



Mean sea ice draft

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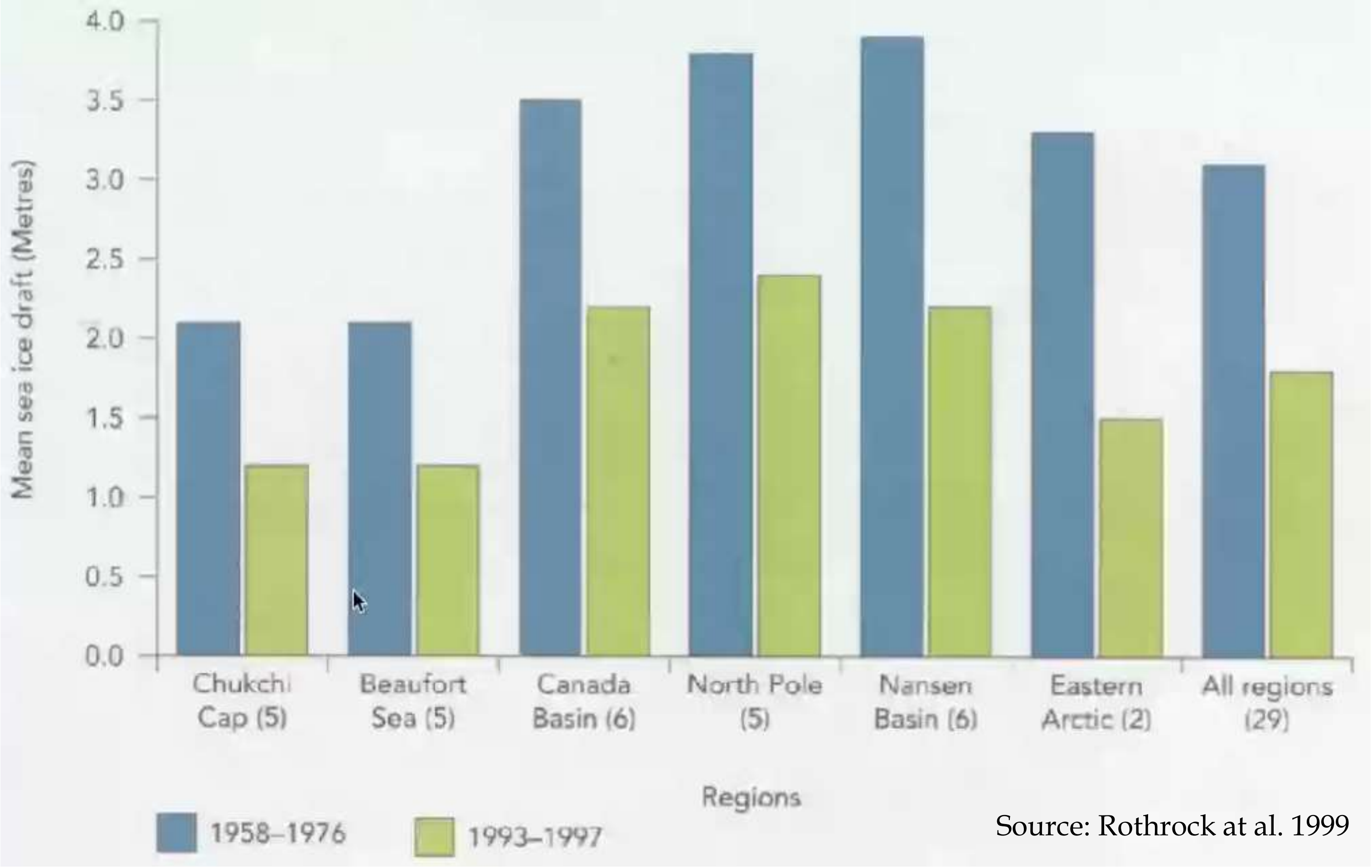
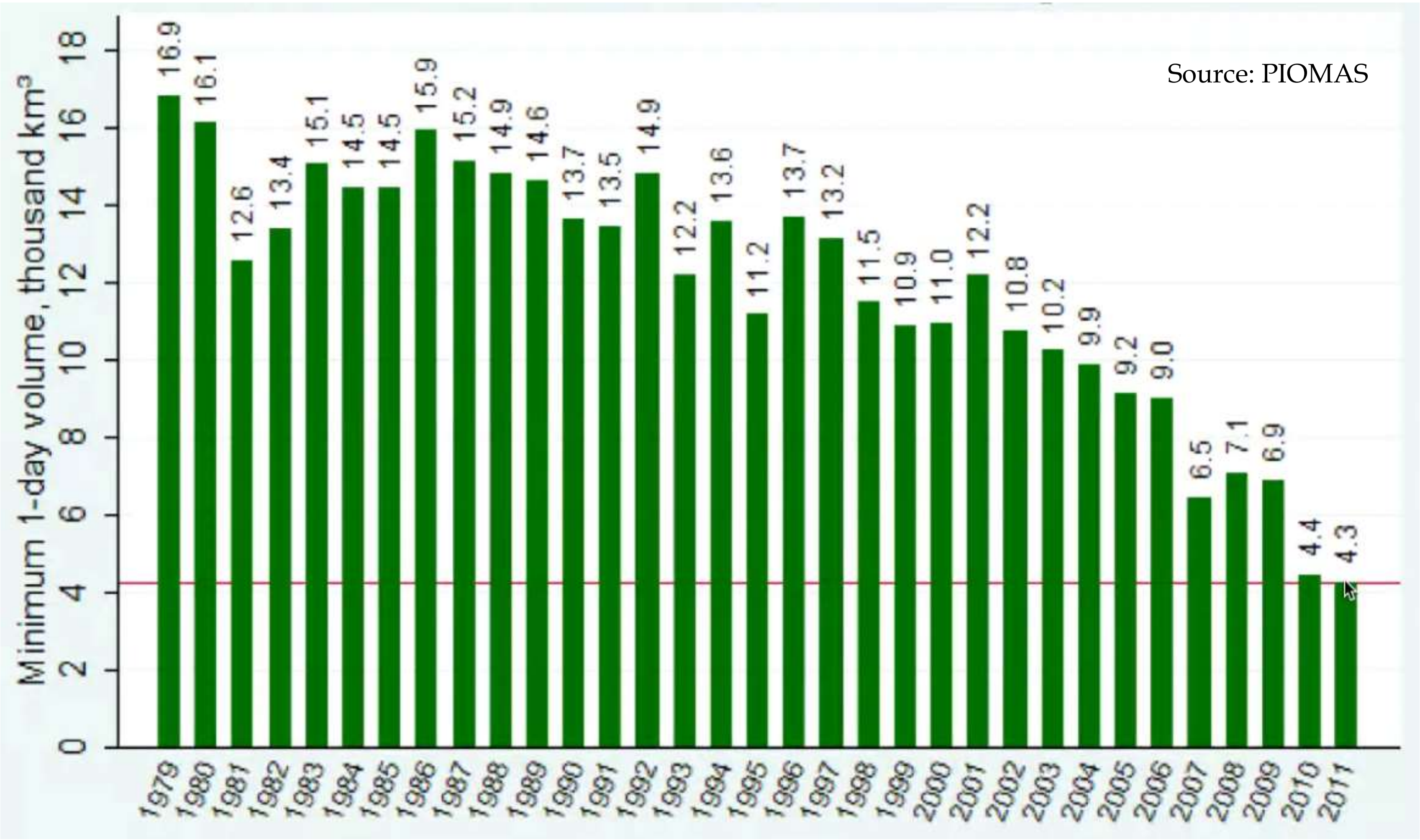
- Sea ice draft is the subsurface fraction of the ice thickness



Source: Rothrock at al. 1999

Minimum sea ice Arctic volume

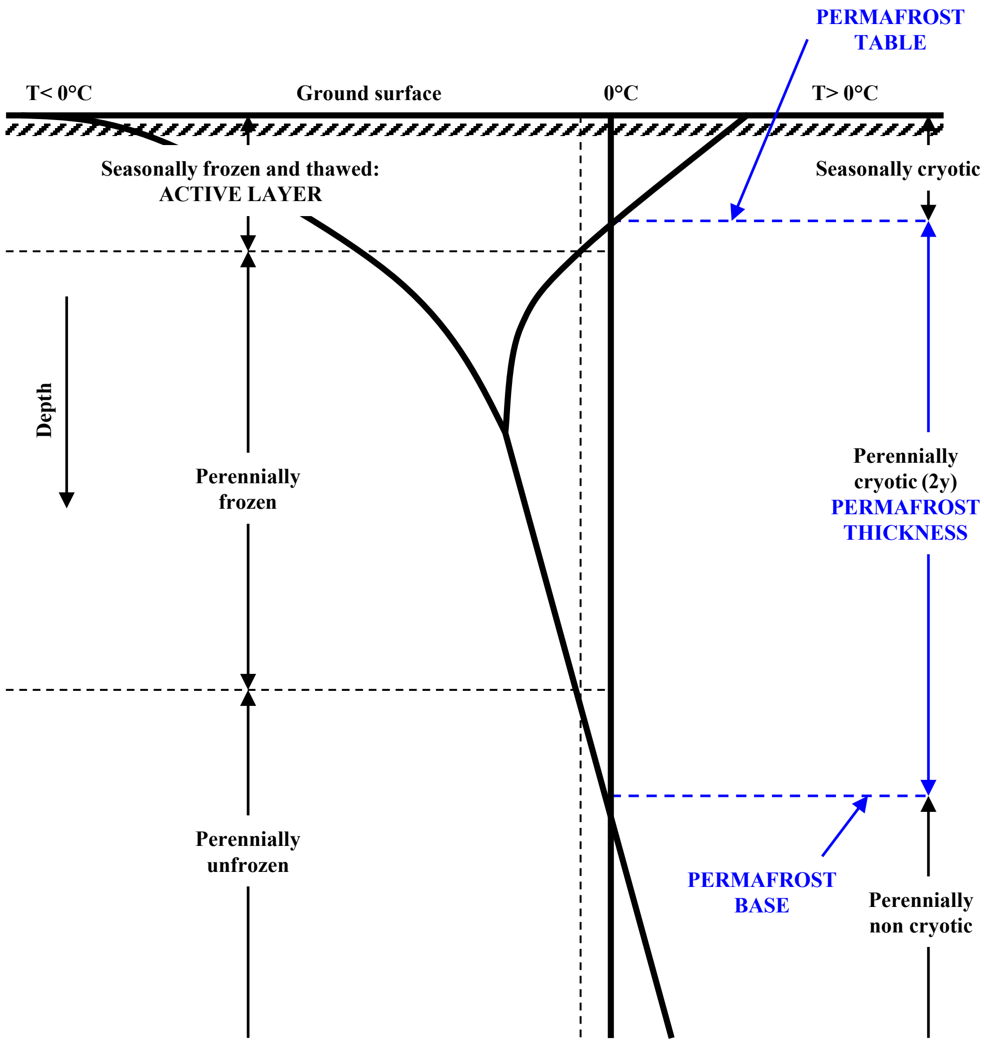
- Min Arctic sea ice volume, 1979 though 2011



Arctic's melting permafrost will cost nearly $70 trillion, study finds

WORLD ECONOMIC FORUM

Permafrost: ground-thermal regime



Permafrost

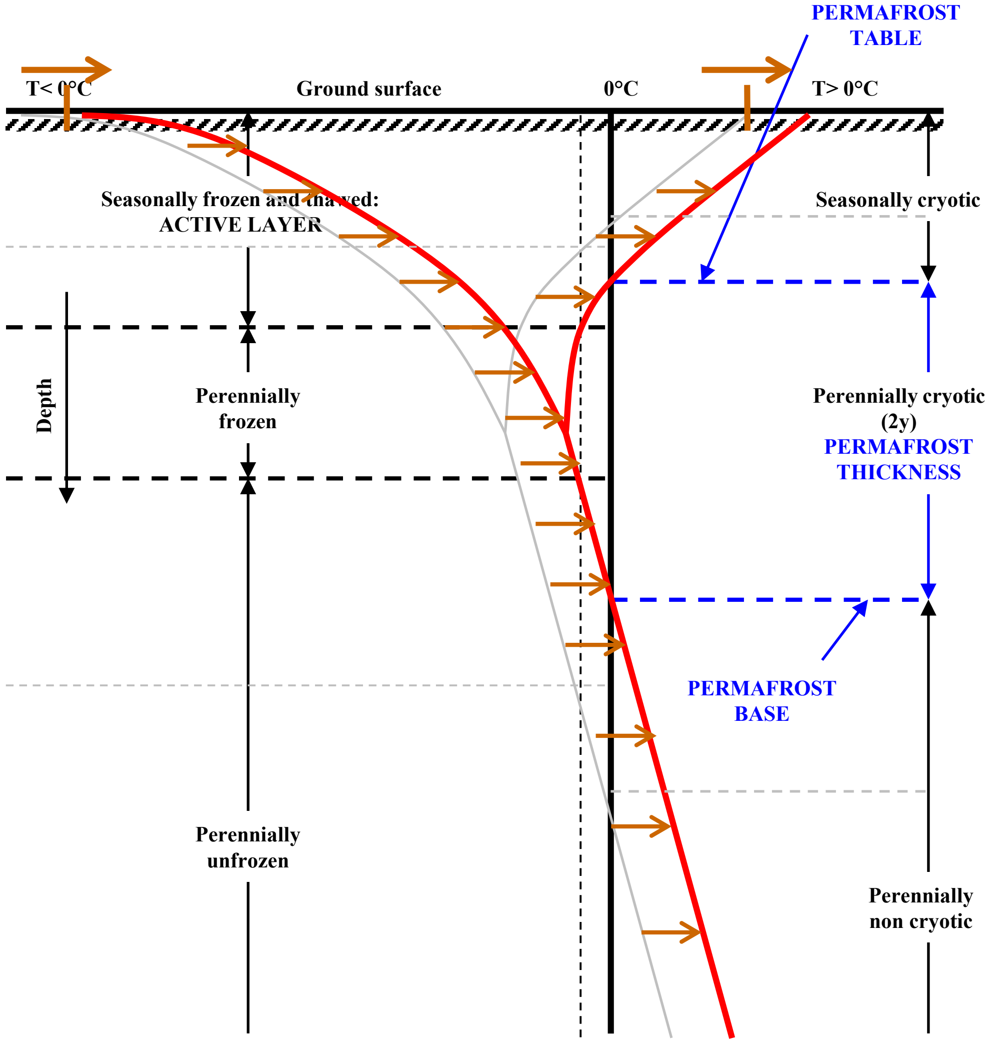
Defined based on **ground temperature**

Defined as ground (sediments, rocks, soil,…) that remains **at or below zero °C** for at least two consecutive years

Humidity, may be present in the permafrost

Permafrost **does not necessarily have to be frozen** since freezing point of water could be lowered by several degrees

Permafrost: ground-thermal regime

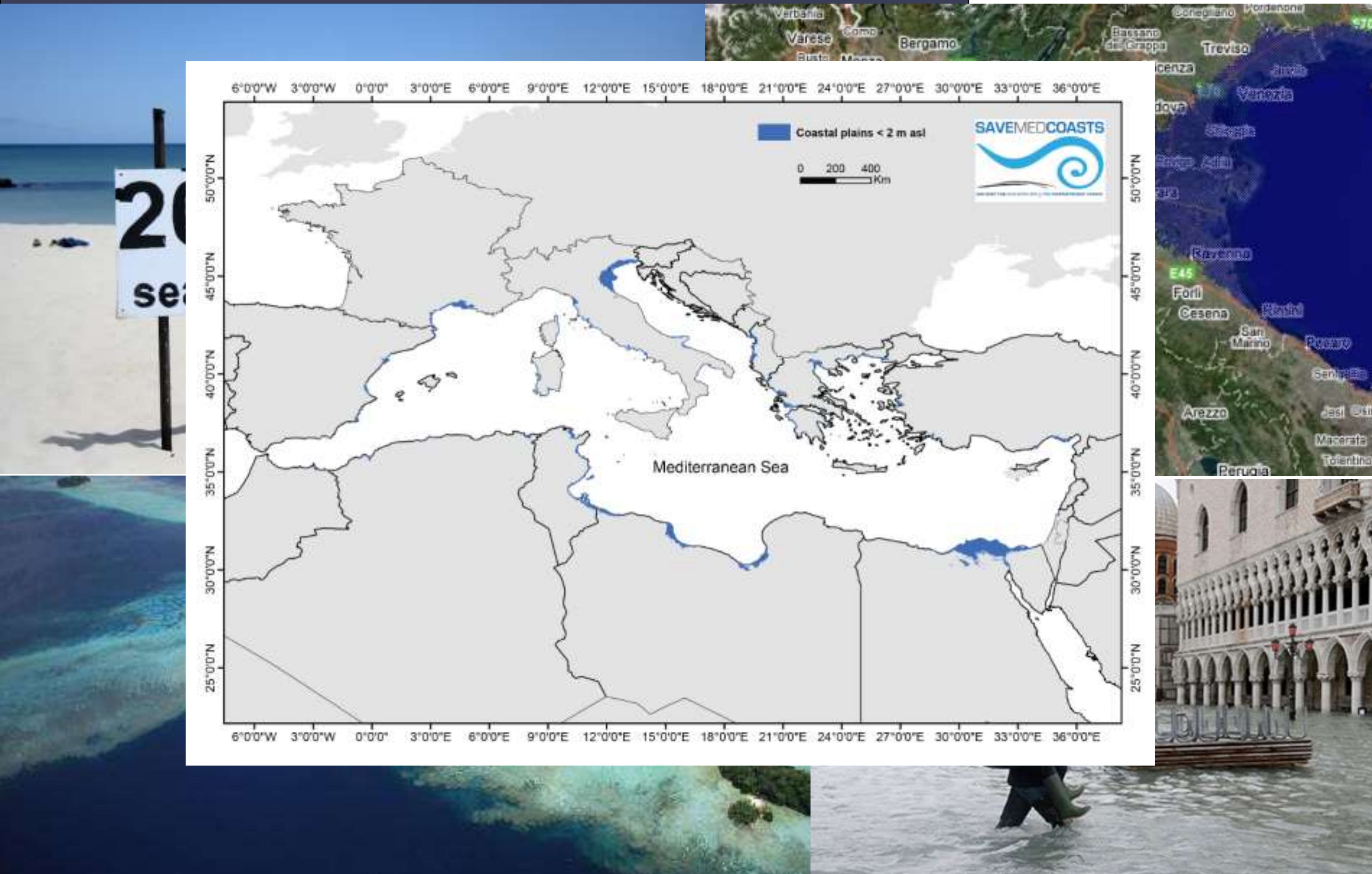


In a warming environment

- Warming of permafrost
- Active layer grows
- Permafrost layer shrinks
- Permafrost base rises up

Permafrost melting in rocks

Raise of the sea level

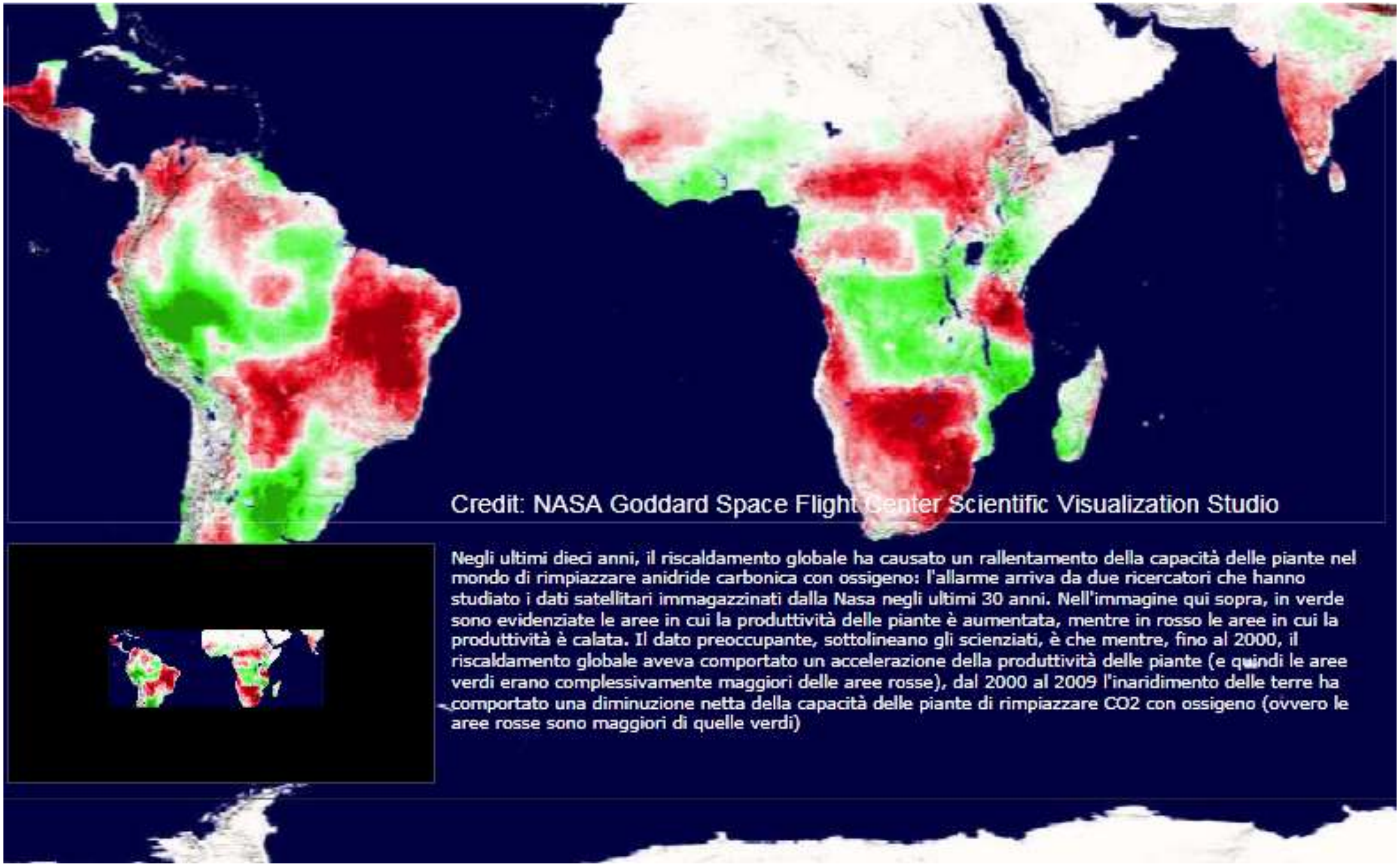


In 2100 large portions of Italian coastline will be underwater

- 5.500 squared km will be flooded due to sea level rising, ENEA scientists said
  - At risk North Adriatic, Gulf of Taranto, Gulf of Oristano and Cagliari.

Plant productivity

– In green increase - In red decrease



… and that's not all about it!!!

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MENU

nature

International journal of science

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NEWS · 15 OCTOBER 2018

Climate change is about to make your beer more expensive

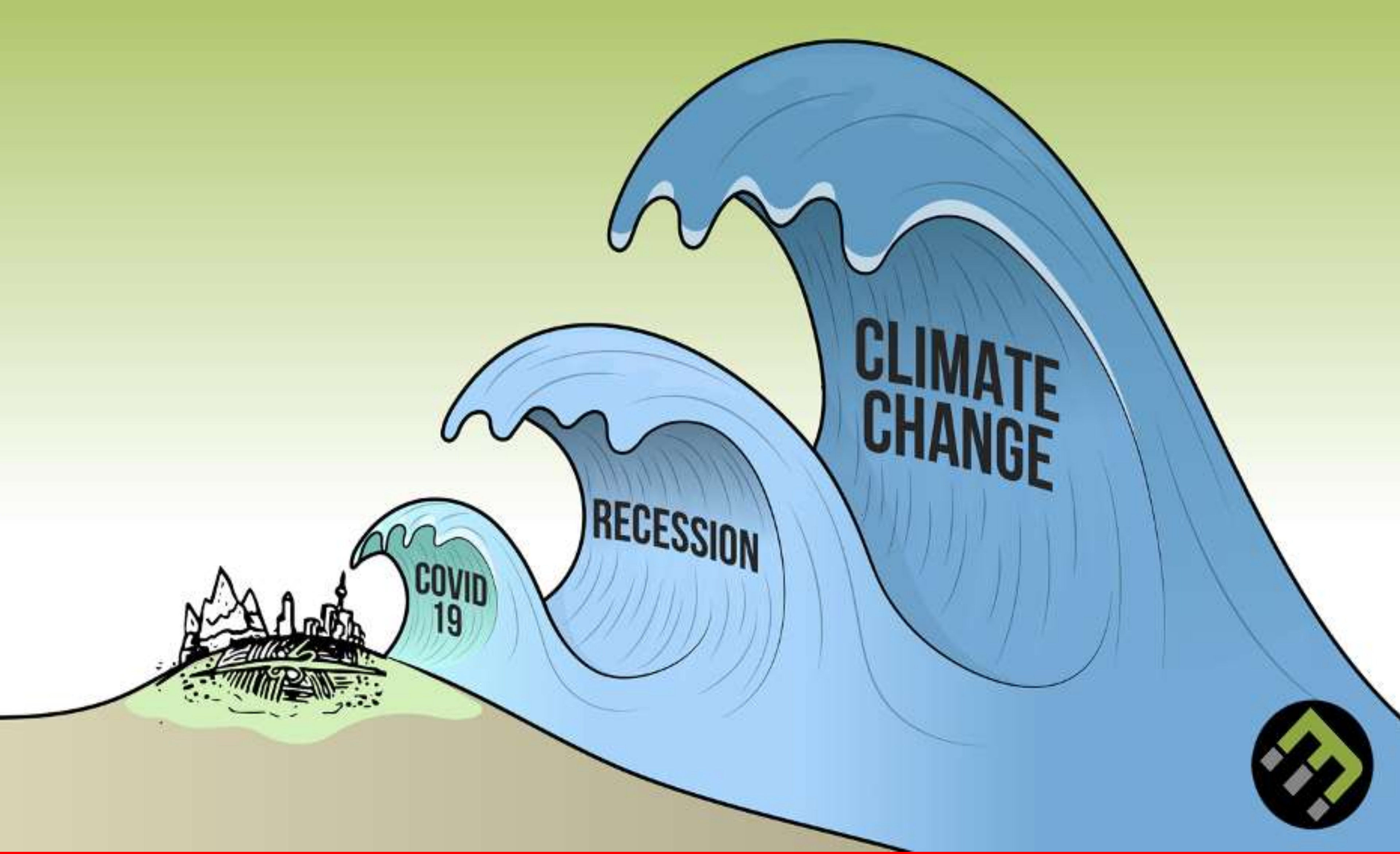
Extreme weather events are expected to reduce global barley production.

The end of stone age

“The Stone Age didn’t end because the world ran out of stone …. And

… The Oil Age will not end because we run out of oil! “

Don Huberts



There is nothing of greater importance!