



UNIVERSITÀ
DEGLI STUDI DI TRIESTE

La transizione energetica del ventunesimo secolo

Alessandro Massi Pavan



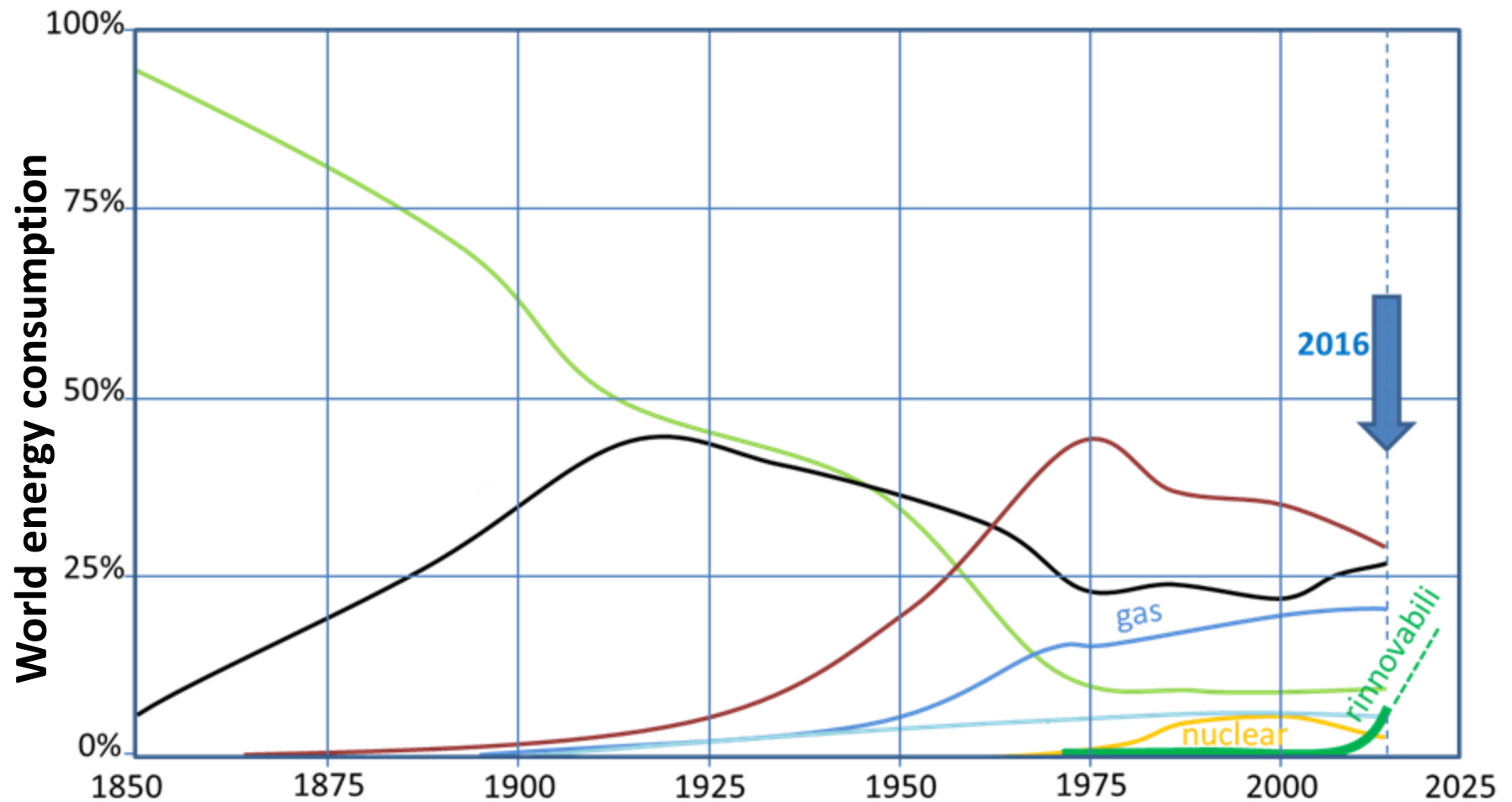
 awareenergy
www.awareenergy.eu

Dipartimento di Ingegneria e Architettura



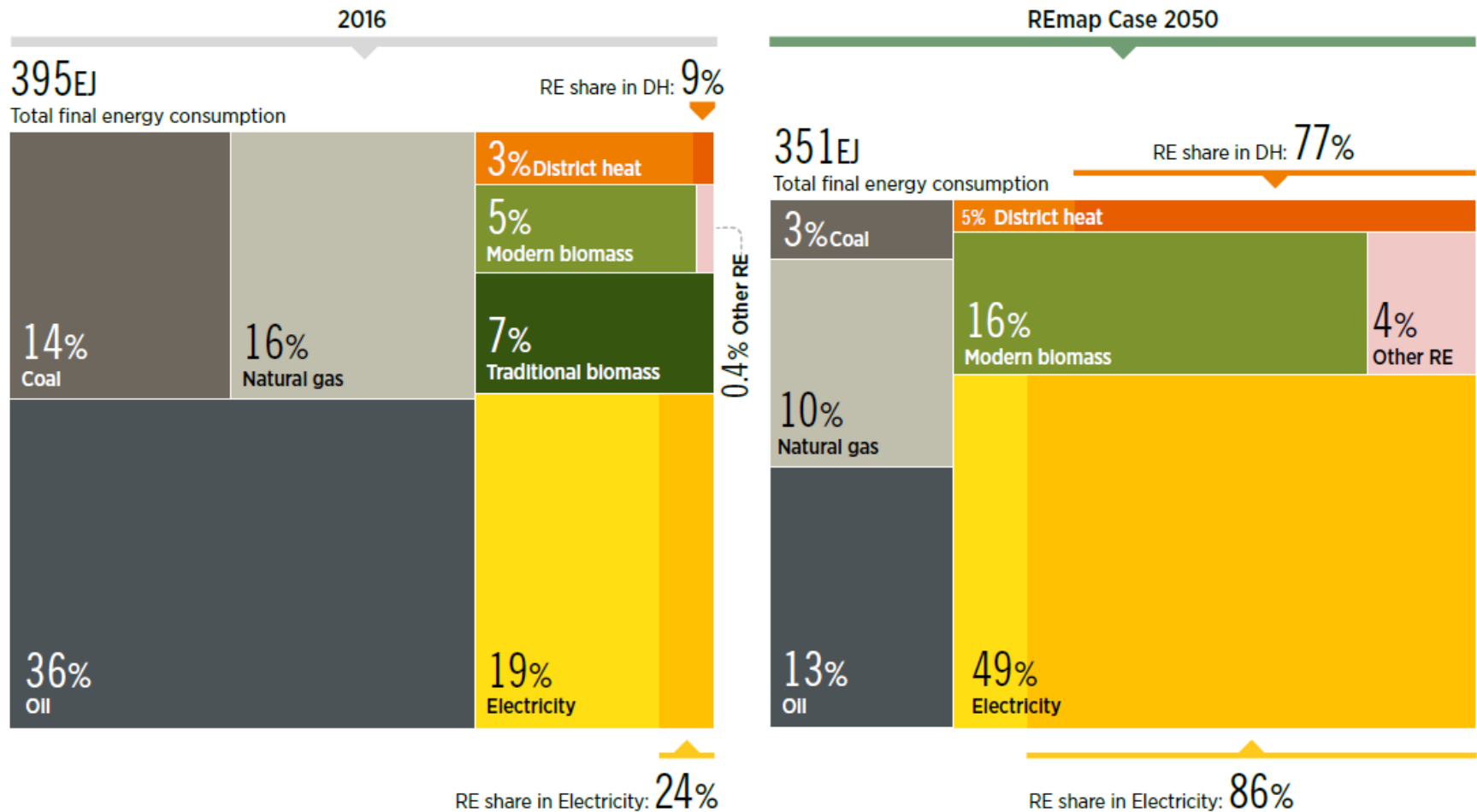
Summer School on Energy
Giacomo Ciamician

TRANSIZIONI ENERGETICHE



ENERGIA ELETTRICA UN'ALTRA TRANSIZIONE

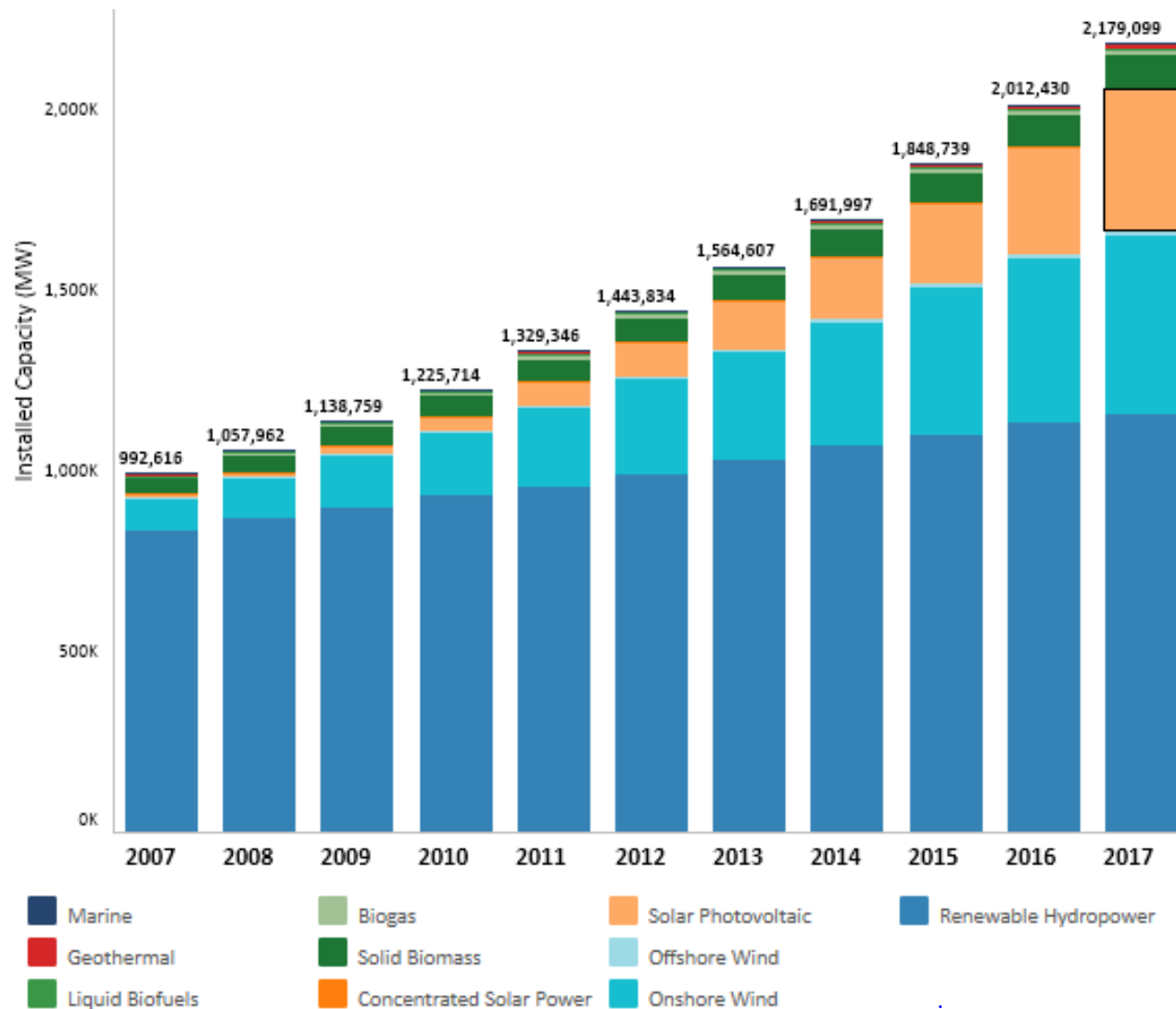
Total final energy consumption breakdown by energy carrier (%)



La transizione energetica 07052020

Alessandro Massi Pavan

BOOM DI RINNOVABILI



www.irena.org

Zero-carbon electricity outstrips fossil fuels in Britain across 2019

Rise in renewables and decline in coal-fired power leads to cleanest year on record for electrical energy



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Germany Just Got Almost All of Its Power From Renewable Energy

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TRENDING > malaria case • growth • Pope Francis • Colombia • dioxins alarm • vaccines

ANSA.it • English • Latest News • **Italy sets record of 87% of electricity via renewables**

Italy sets record of 87% of electricity via renewables

New high reached on May 21 says Terna CEO

Redazione ANSA

ROME

27 July 2017

17:08

NEWS

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(ANSA) - Rome, July 27 - Italy met 87% of its electricity demand via energy produced from renewable sources on May 21, a new record, Luigi Ferraris, the CEO of power-grid company Terna, said on Thursday.

An entire region of China just ran on 100% renewable energy for 7 days

Leanna Garfield  

🕒 Jun. 27, 2017, 5:20 PM 🔥 1,001



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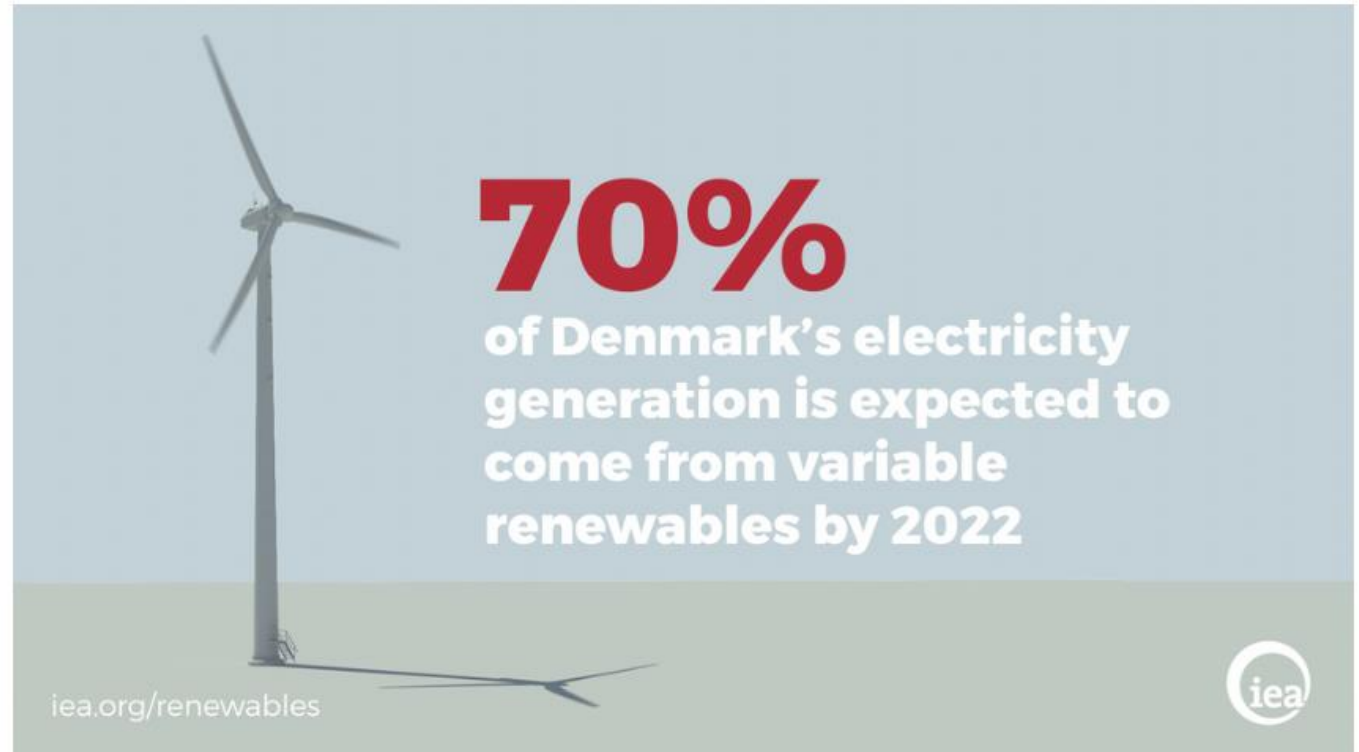
PRINT

9% Governm

Invest In Renewable Ene
securedbonds.co.uk/en

From [Pittsburgh](#) to [Frankfurt](#) cities around the world are pledging to stop burning fossil fuels for electricity by 2030 or sooner.

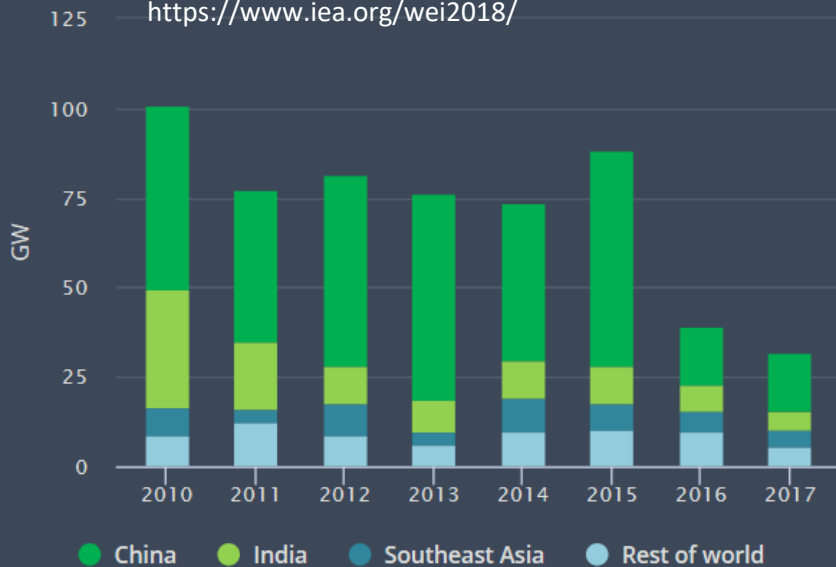
But the Chinese province of Qinghai has already reached that goal, according to ne



E LE TRADIZIONALI ...

Coal-fired generation

<https://www.iea.org/wei2018/>



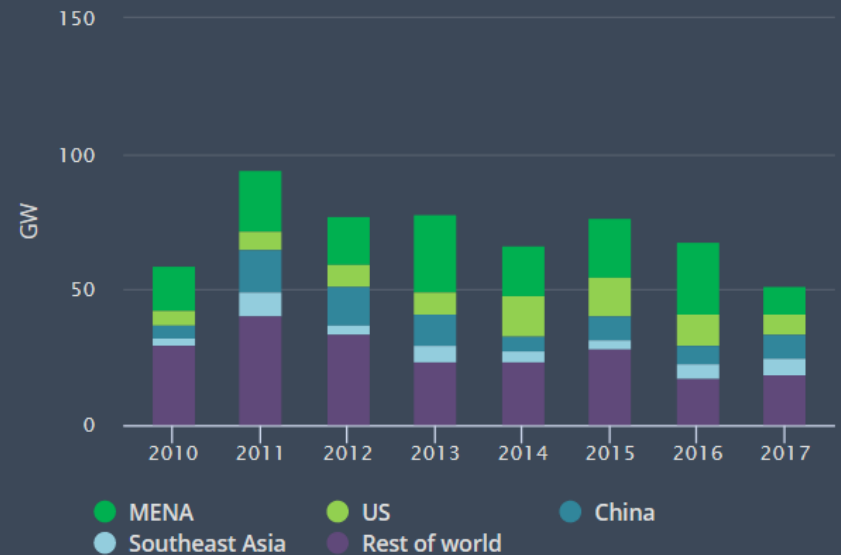
RES $\approx$ 2,2TW

NUCLEARE $\approx$ 0,5TW

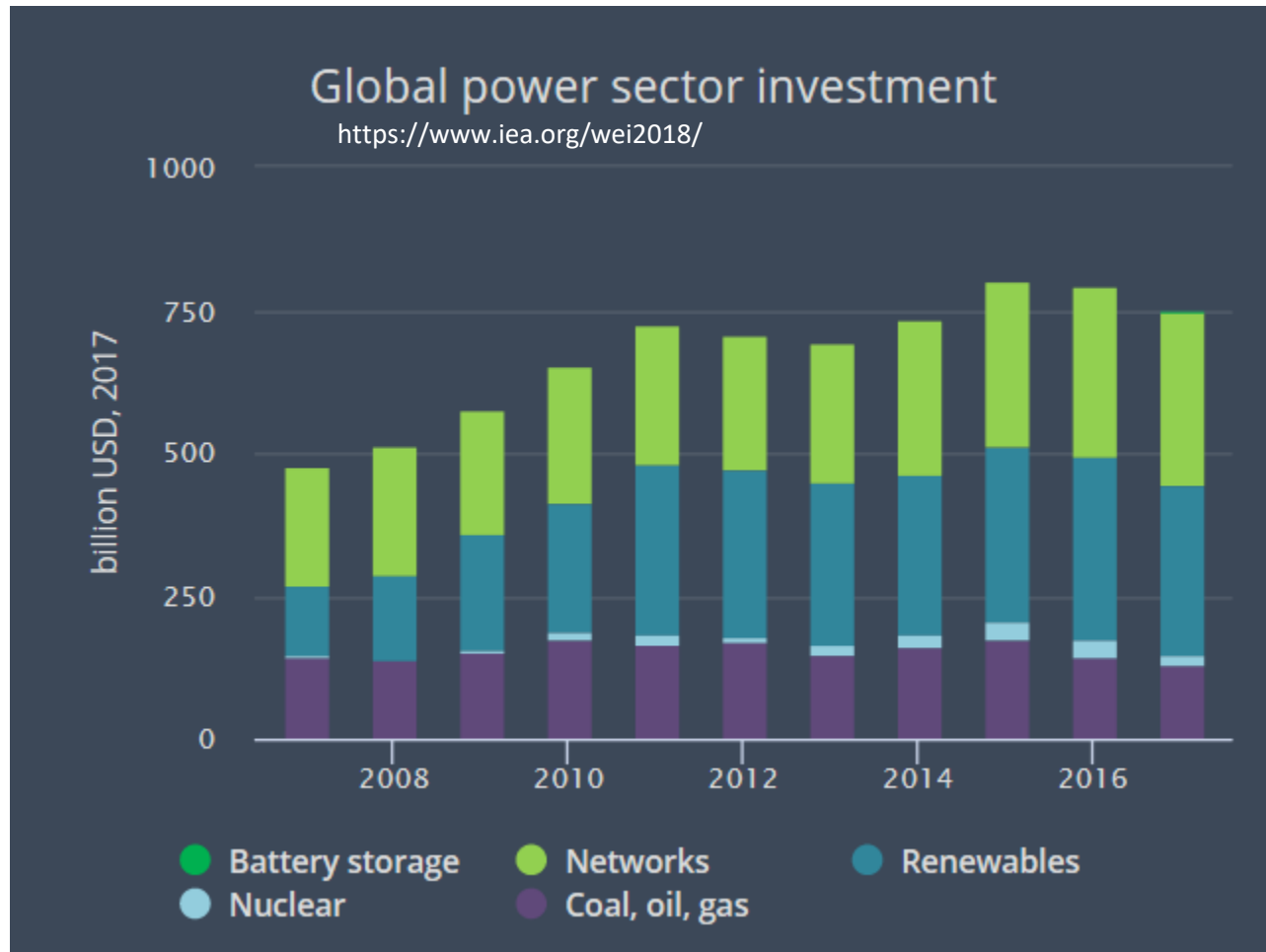
GAS $\approx$ 1,5TW

CARBONE $\approx$ 1,9TW

Gas-fired generation



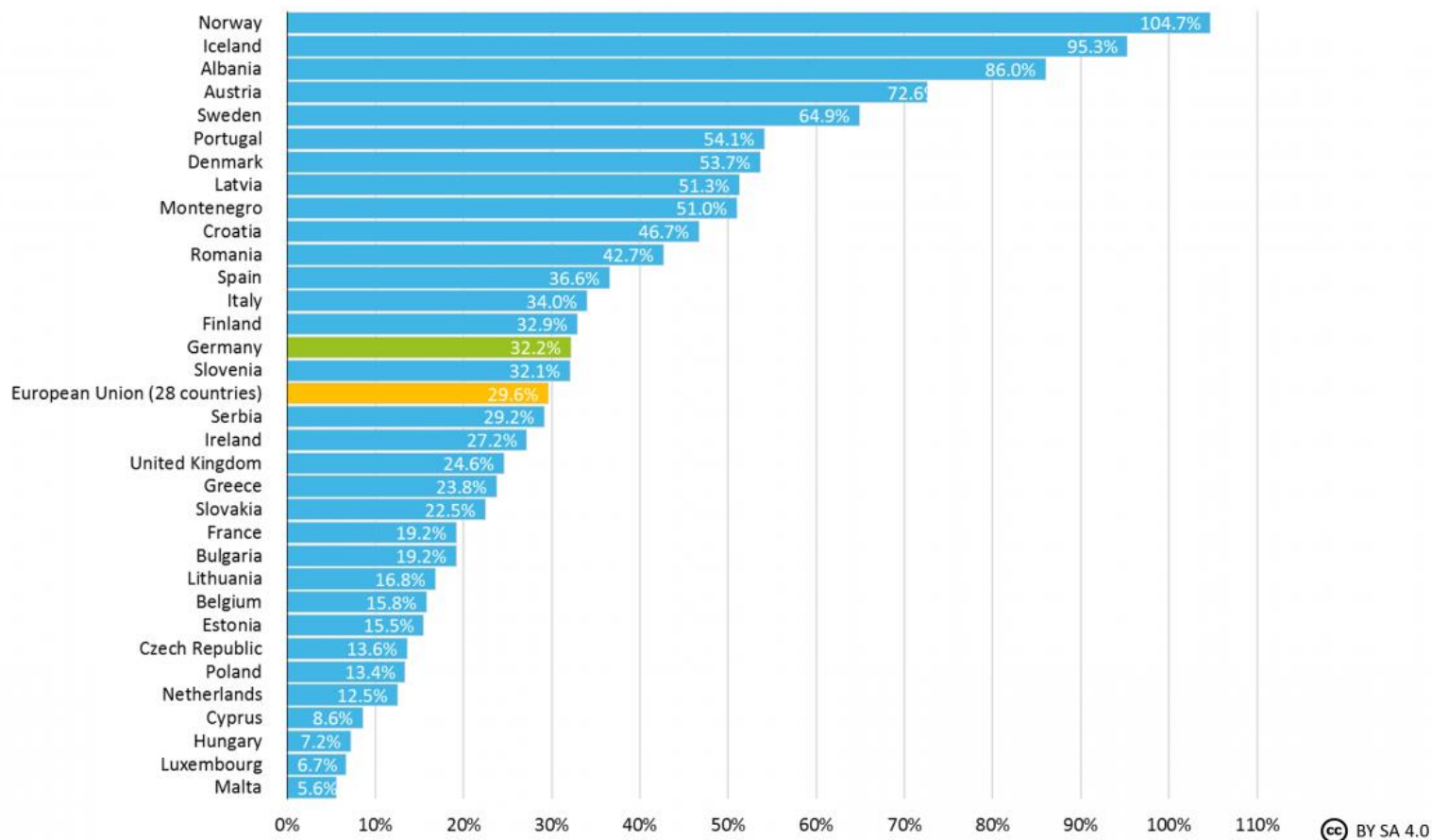
INVESTIMENTI SETTORE ENERGETICO



POWER GENERATION IN EUROPE

Share of electricity from renewable sources in gross electricity consumption in European countries in 2016.

Data: Eurostat 2018.

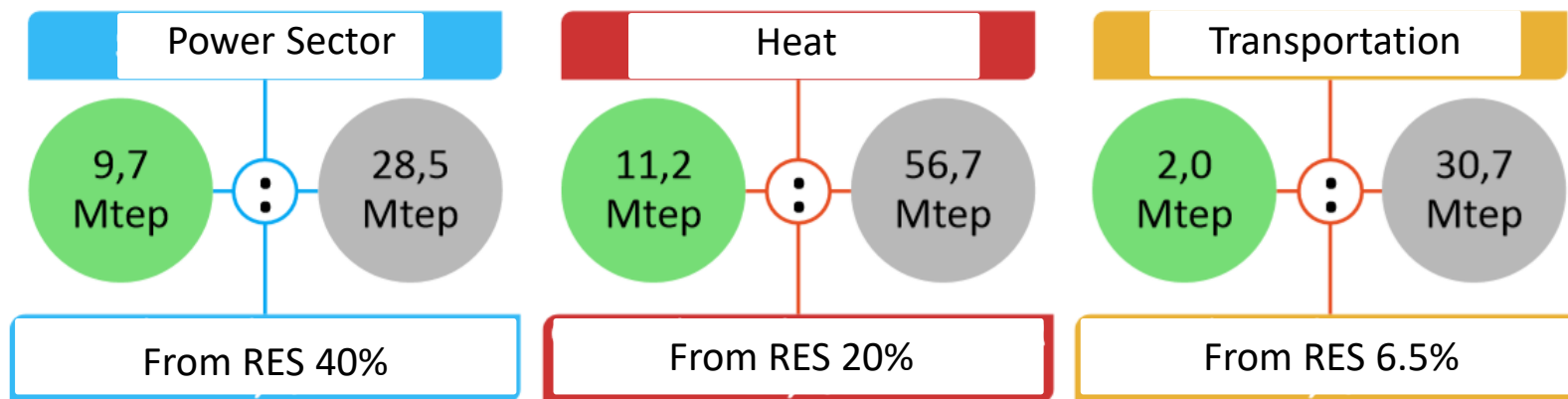


POWER GENERATION – ITALY

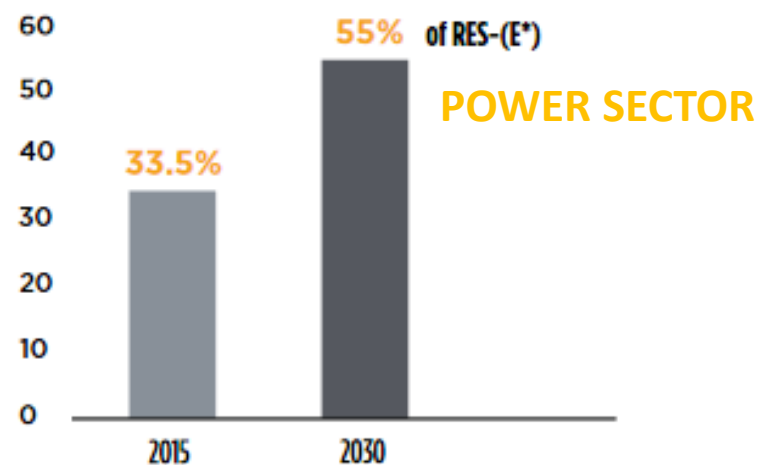
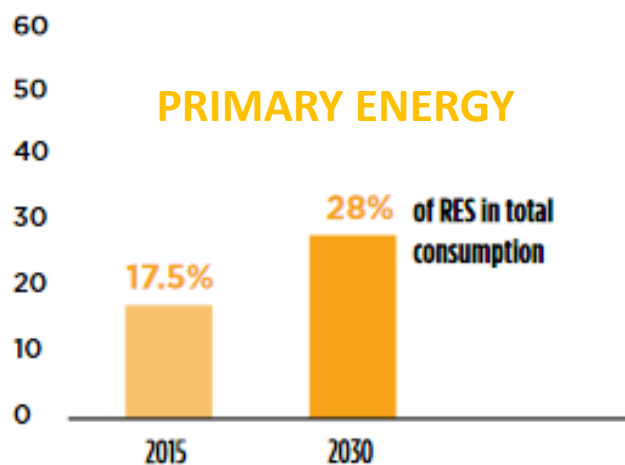
	2018	2005
Thermal power	59%	81%
Hydropower	18%	15%
Photovoltaics	8%	0%
Wind power	6%	1%
Biomass	6%	2%
Geothermal	2%	2%

Total Renewables in 2018 was 40%, whereas in 2005 was 20%!!!

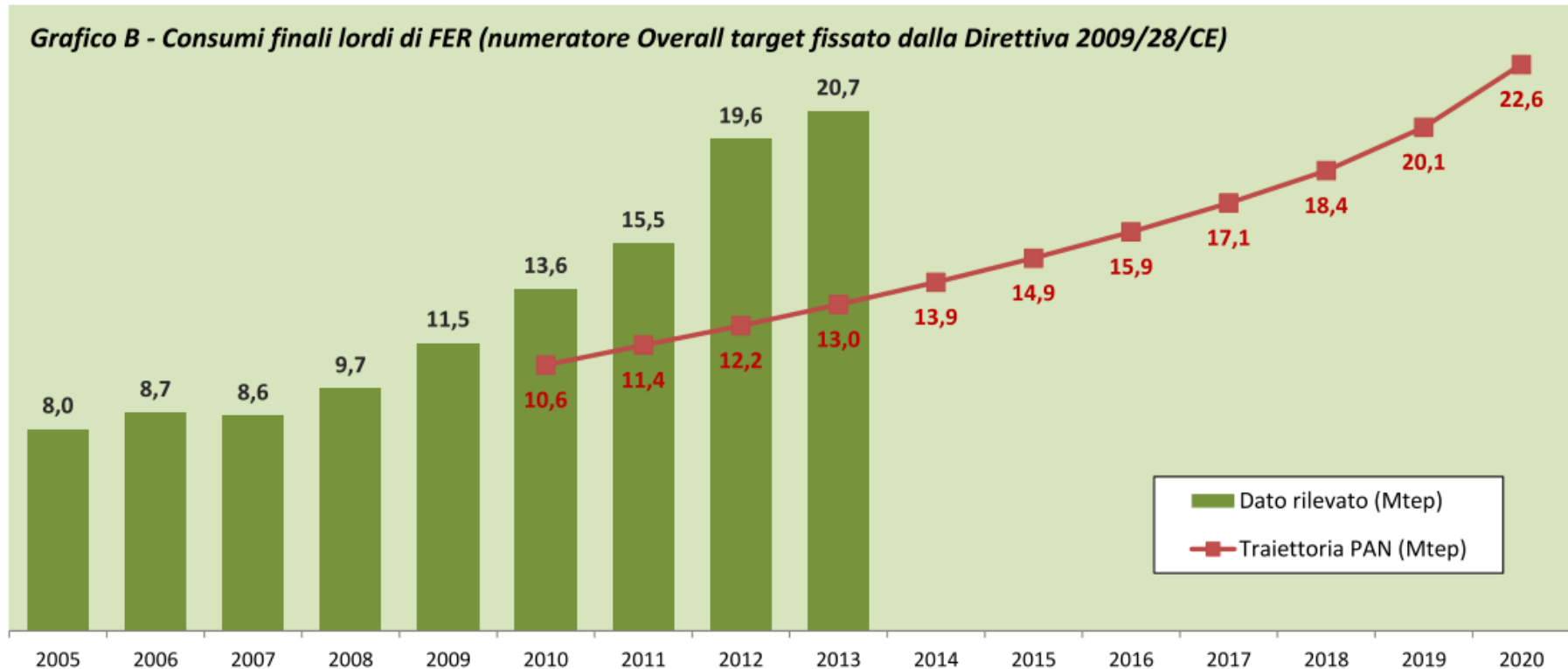
THERE'S NOT ONLY POWER!



ITALY'S NATIONAL ENERGY STRATEGY 2017



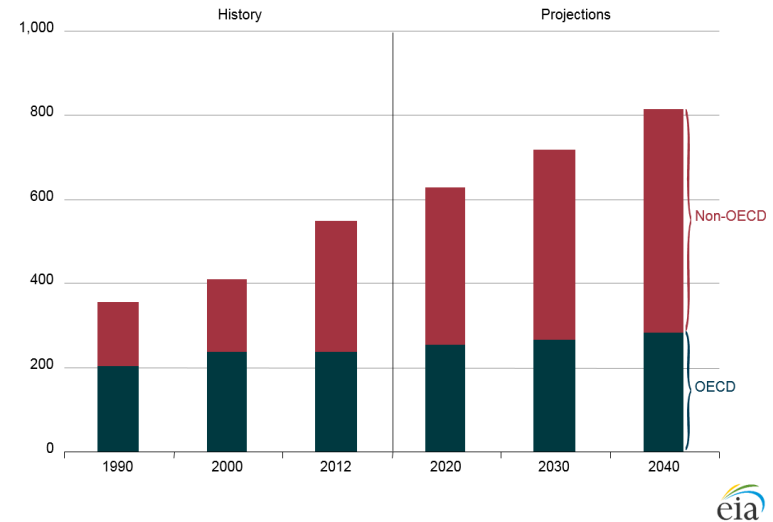
RES – PRIMARY ENERGY



I. LE RISORSE ENERGETICHE SONO LIMITATE



Figure 1-1. World energy consumption, 1990-2040
quadrillion Btu



Estimates of world crude oil and NGLs resources

billion barrels

Average Oil Demand (2013-2035): 100

Cumulative production to 2010 (a)

446

Non-OPEC

695

Total world

1,142

Proved reserves (b)

YEARS TO GO ARE $2,704/100 = 27!!!$

1,467

Reserves to be added ultimately (c)

617

620

1,237

[World Oil Outlook – OPEC 2012](#)

Total reserves: 2,704

TUTTO E' LIMITATO

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Oil, Food, Water: Is Everything Past Its Peak?



Thousands of Chinese people gather at Asia's biggest floating-swimming pool to cool off in southwest China's Sichuan province on July 20, 2010. The temperature had reached 35 degrees Celsius (95 degrees Fahrenheit). STR/AFP/Getty Images

By Eric Roston | Feb 6, 2012 6:11 PM GMT

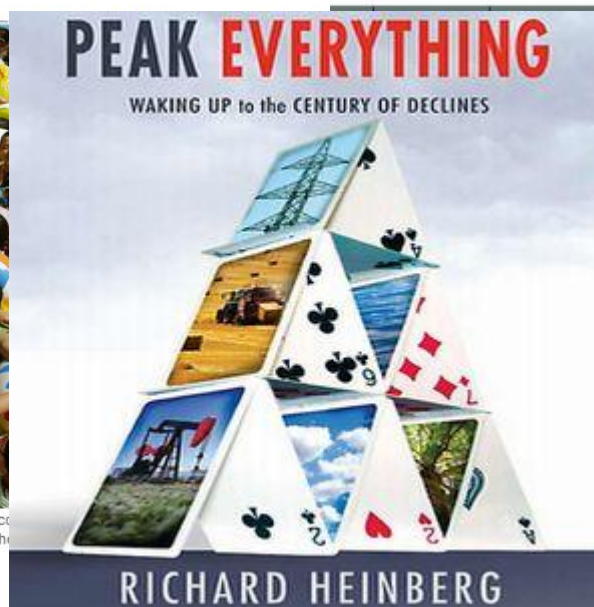


47 COMMENTS

QUEUE



An unprecedented crisis faced America. Oil production was going to peak in just three to five years, resulting in foreign oil addiction and economic calamity. The scientist responsible for slapping the nation into consciousness implored industry and government to act: "The smug

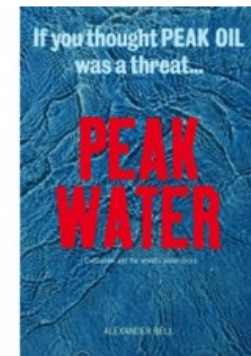


Peak Water offers a light into our changing th water

ilization on water and drained the subject of Alexander Bell's



the





AMBIENTE

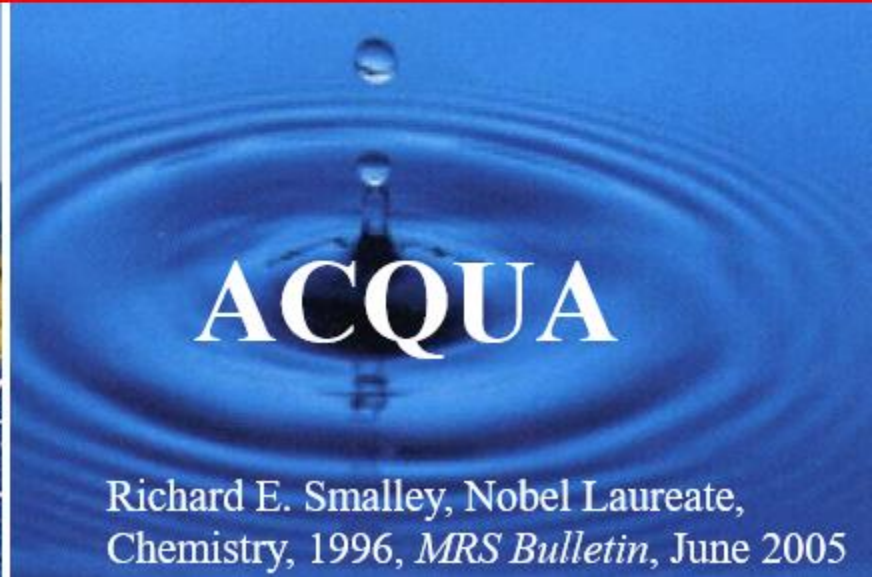


CIBO

4 Emergenze a livello Mondiale



ENERGIA



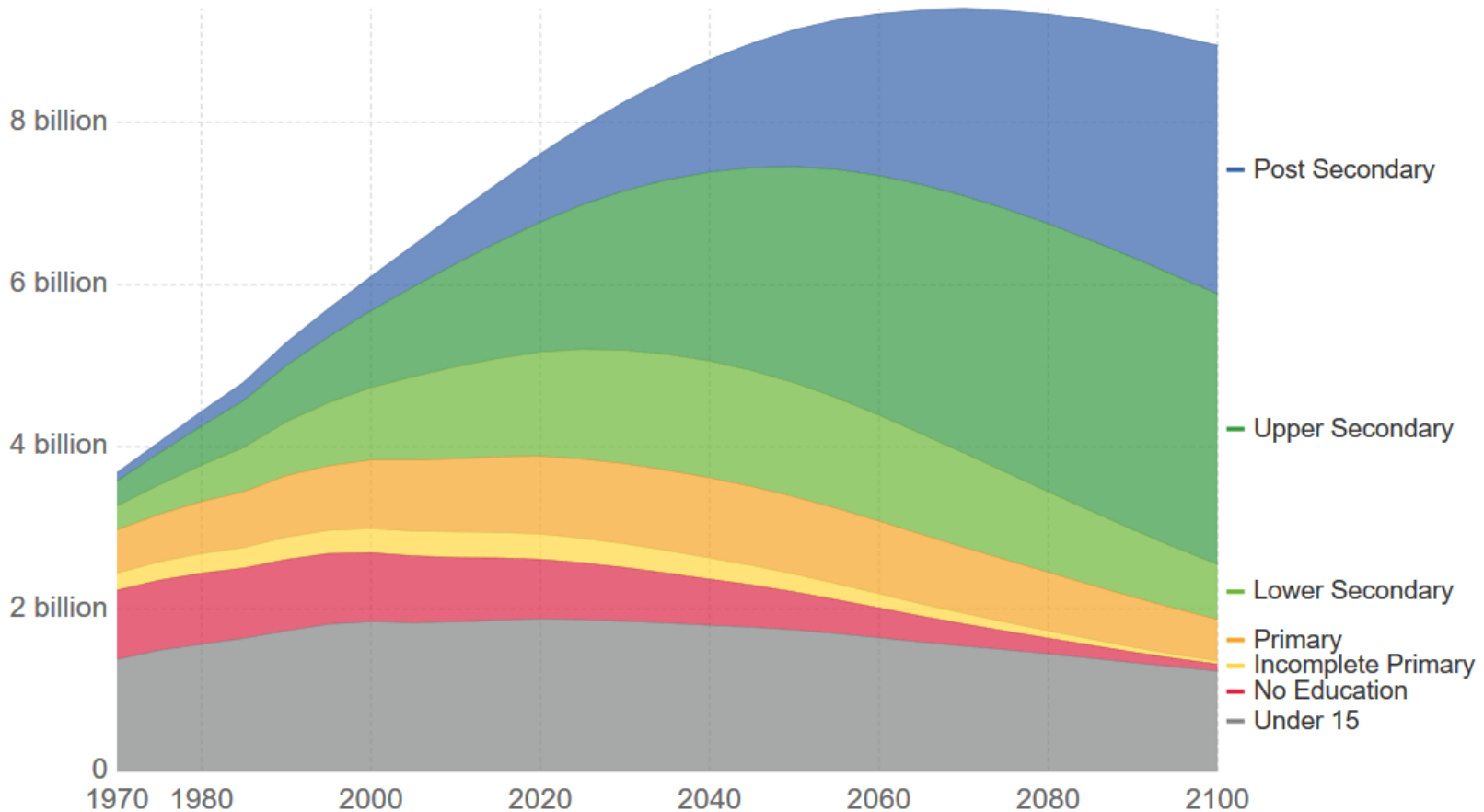
ACQUA

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

TUTTO E' LIMITATO

Projected world population by level of education

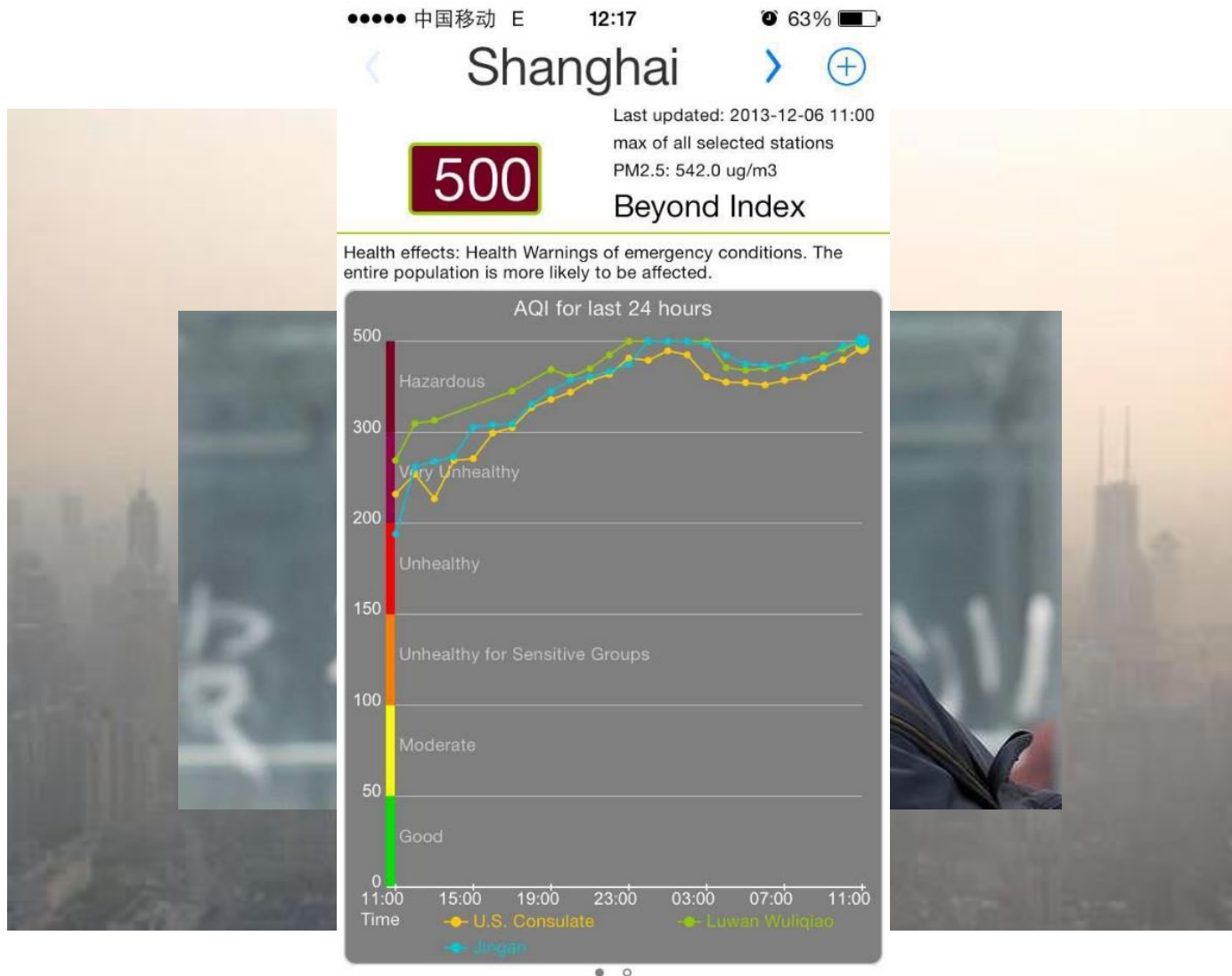
This visualization shows the Medium projection by the International Institute for Applied Systems Analysis (IIASA). The researchers who created this projection describe it as their "middle of the road scenario that can also be seen as the most likely path".



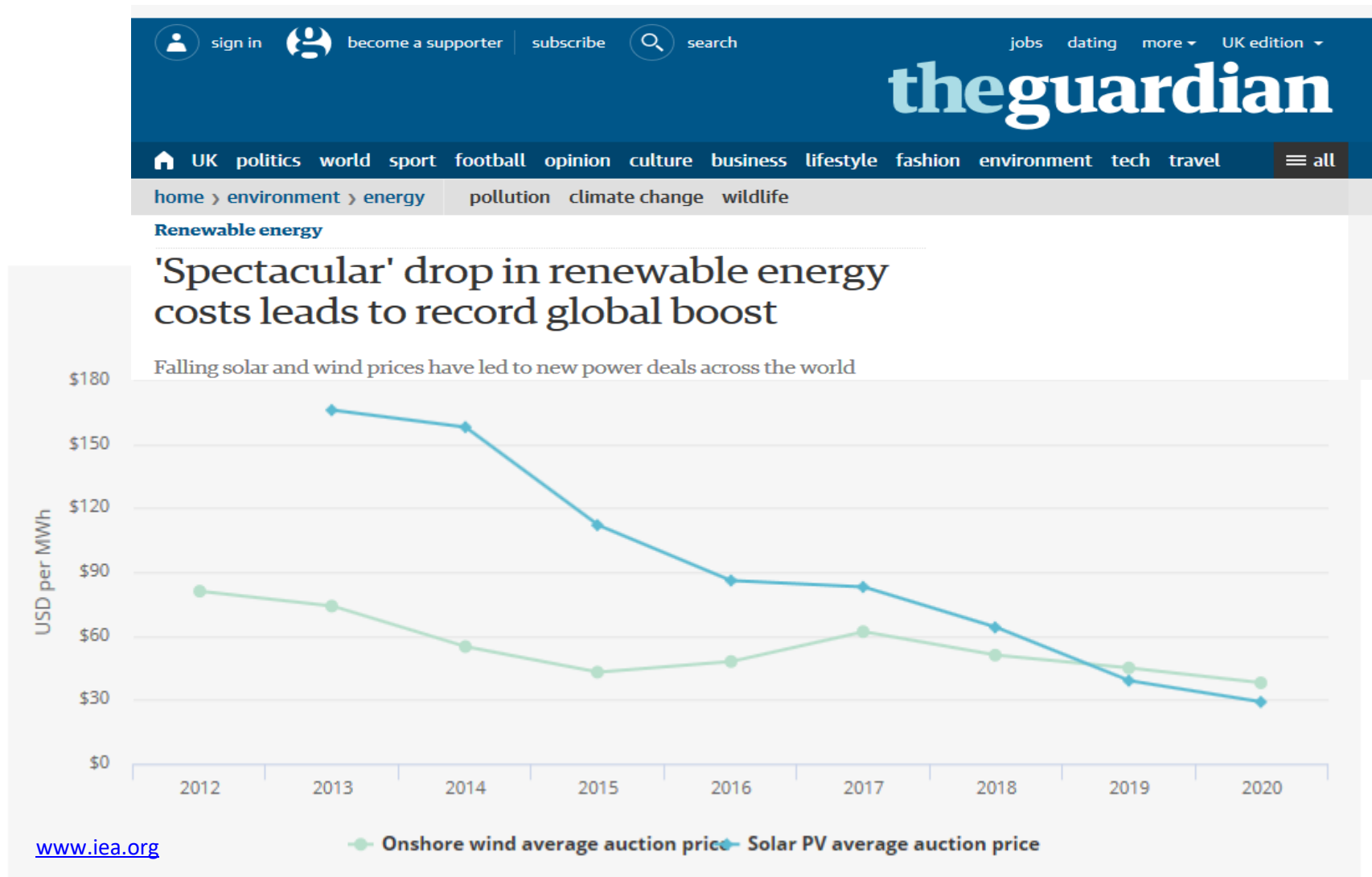
Source: Global Projection, Medium SSP2 - IIASA (2016)

OurWorldInData.org/world-population-growth/ • CC BY-SA

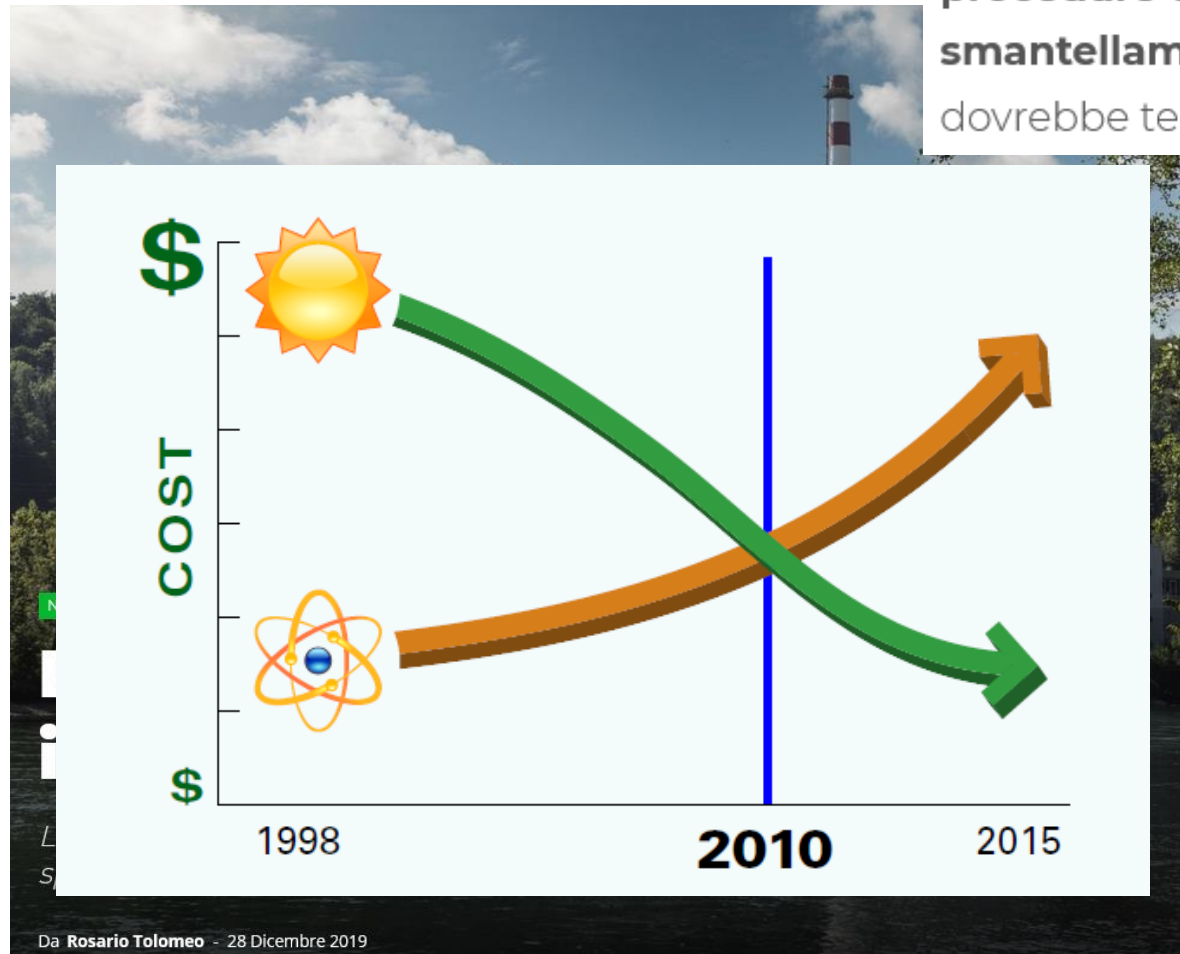
2. QUALITA' DELLA VITA NELLE CITTA'



3. CONVENIENZA ECONOMICA



Per la centrale nucleare di Muehleberg, alle 12:30 del 20 dicembre, sono iniziate le **procedure di spegnimento**. Lo **smantellamento** della centrale dovrebbe terminare nel 2034. È la



4. TEMPI DI INSTALLAZIONE

IRENA – Global Landscape of renewable energy finance 2018

Technology	Number of years
 Solar PV	0.5
 Wind onshore	0.8
 Bioenergy	1.7
 Wind offshore	1.7
 Geothermal	1.9
 Solar thermal	2
 Marine	2.2
 Small hydro	2.3

Nucleare 6 – 12,5!!!

<https://www.oecd-neo.org/ndd/pubs/2015/7195-nn-build-2015.pdf>

5. RISCALDAMENTO GLOBALE



The Telegraph

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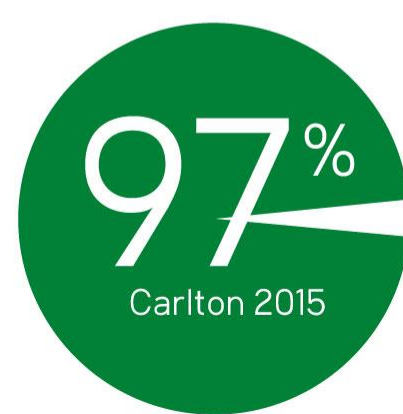
News

Italian composer Ludovico Einaudi solemn gig in the Arctic



5. RISCALDAMENTO GLOBALE

Studies into scientific agreement on human-caused global warming

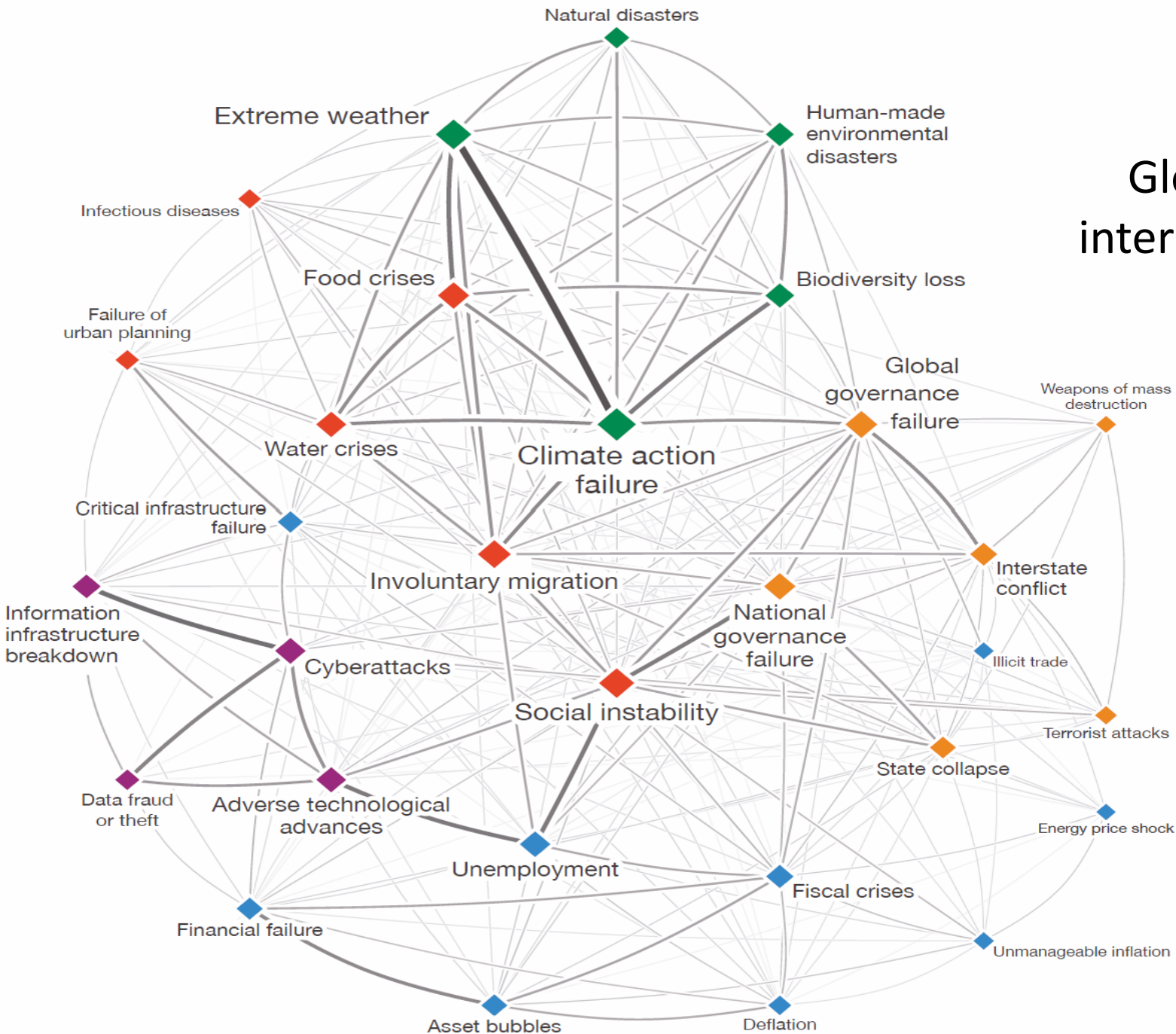


RISCALDAMENTO GLOBALE

L'UNICA VERA PROVA NON E' SCIENTIFICA!



Global Risk interconnection map



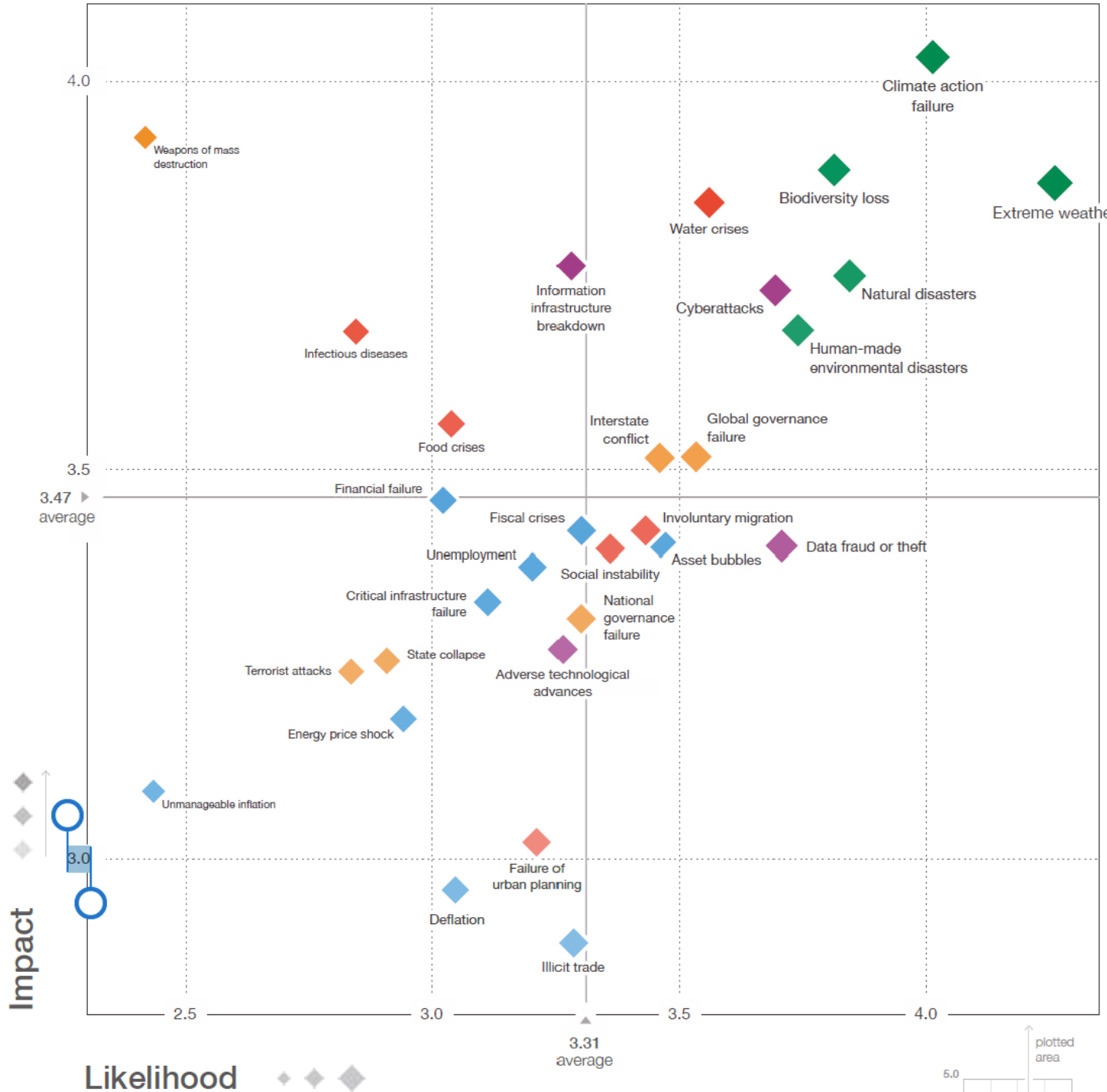
Source: The Global
Risks Report 2020
15th Edition

Top 10 risks in terms of Likelihood

- 1 Extreme weather
- 2 Climate action failure
- 3 Natural disasters
- 4 Biodiversity loss
- 5 Human-made environmental disasters
- 6 Data fraud or theft
- 7 Cyberattacks
- 8 Water crises
- 9 Global governance failure
- 10 Asset bubbles

Top 10 risks in terms of Impact

- 1 Climate action failure
- 2 Weapons of mass destruction
- 3 Biodiversity loss
- 4 Extreme weather
- 5 Water crises
- 6 Information infrastructure breakdown
- 7 Natural disasters
- 8 Cyberattacks
- 9 Human-made environmental disasters
- 10 Infectious diseases



Source: The Global Risks Report 2020 15th Edition

Top 5 Global Risks in Terms of Likelihood

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1st	Infrastructure breakdown	Blow up in asset prices	Asset price collapse	Asset price collapse	Storms and cyclones	Income disparity	Income disparity	Income disparity	Interstate conflict	Involuntary migration	Extreme weather	Extreme weather	Extreme weather	Extreme weather
2nd	Chronic diseases	Middle East instability	China economic slowdown	China economic slowdown	Flooding	Fiscal imbalances	Fiscal imbalances	Extreme weather	Extreme weather	Extreme weather	Involuntary migration	Natural disasters	Climate action failure	Climate action failure
3rd	Oil price shock	Failed and failing states	Chronic diseases	Chronic disease	Corruption	Greenhouse gas emissions	Greenhouse gas emissions	Unemployment	Failure of national governance	Climate action failure	Natural disasters	Cyberattacks	Natural disasters	Natural disasters
4th	China hard landing	Oil price shock	Global governance gaps	Fiscal crises	Biodiversity loss	Cyberattacks	Water crises	Climate action failure	State collapse or crisis	Interstate conflict	Terrorist attacks	Data fraud or theft	Data fraud or theft	Biodiversity loss
5th	Blow up in asset prices	Chronic diseases	Deglobalization (emerging)	Global governance gaps	Climate change	Water crises	Population ageing	Cyberattacks	Unemployment	Natural catastrophes	Data fraud or theft	Climate action failure	Cyberattacks	Human-made environmental disasters

Top 5 Global Risks in Terms of Impact

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1st	Blow up in asset prices	Blow up in asset prices	Asset price collapse	Asset price collapse	Fiscal crises	Financial failure	Financial failure	Fiscal crises	Water crises	Climate action failure	Weapons of mass destruction	Weapons of mass destruction	Weapons of mass destruction	Climate action failure
2nd	Deglobalization	Deglobalization (developed)	Deglobalization (developed)	Deglobalization (developed)	Climate change	Water crises	Water crises	Climate action failure	Infectious diseases	Weapons of mass destruction	Extreme weather	Extreme weather	Climate action failure	Weapons of mass destruction
3rd	Interstate and civil wars	China hard landing	Oil and gas price spike	Oil price spikes	Geopolitical conflict	Food crises	Fiscal imbalances	Water crises	Weapons of mass destruction	Water crises	Water crises	Natural disasters	Extreme weather	Biodiversity loss
4th	Pandemics	Oil price shock	Chronic diseases	Chronic disease	Asset price collapse	Fiscal imbalances	Weapons of mass destruction	Unemployment	Interstate conflict	Involuntary migration	Natural disasters	Climate action failure	Water crises	Extreme weather
5th	Oil price shock	Pandemics	Fiscal crises	Fiscal crises	Energy price volatility	Energy price volatility	Climate action failure	Infrastructure breakdown	Climate action failure	Energy price shock	Climate action failure	Water crises	Natural disasters	Water crises

■ Economic
 ■ Environmental
 ■ Geopolitical
 ■ Societal
 ■ Technological

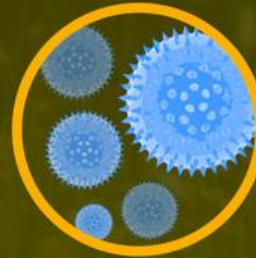
Planet has only until 2030 to stem catastrophic climate change, experts warn



**West Nile.
Dengue Fever.
Zika.
What's the
climate
connection?**

Climate C
makes
me
si

Climate Change & Allergies



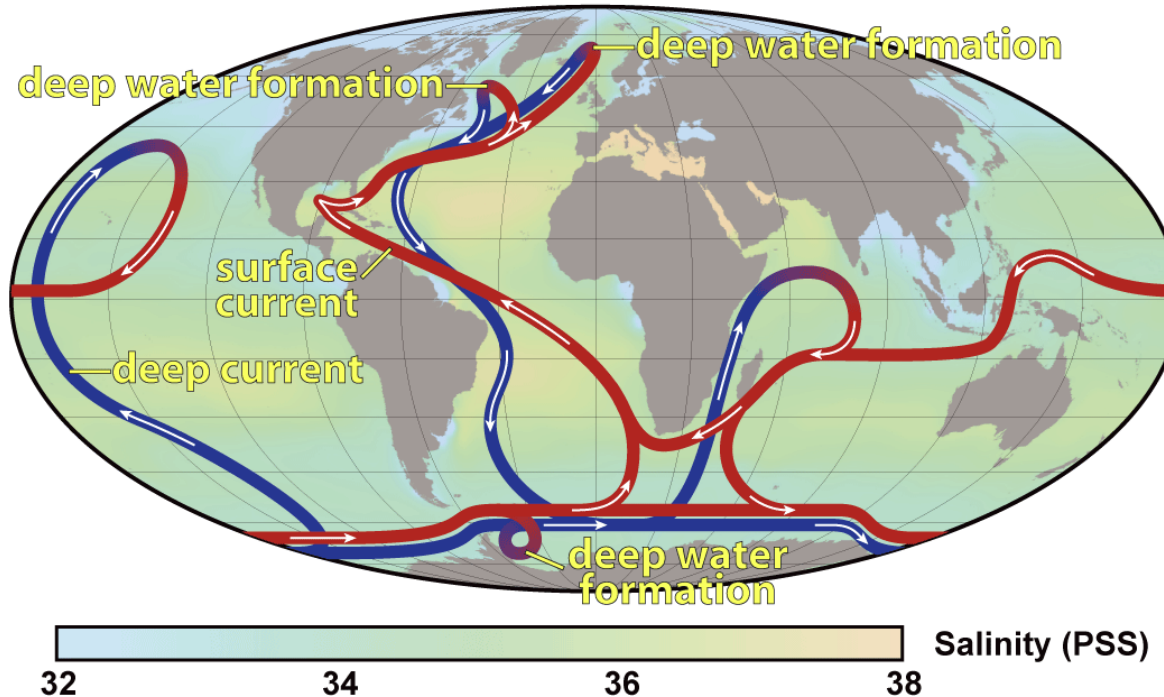
Pollen moving
to new areas

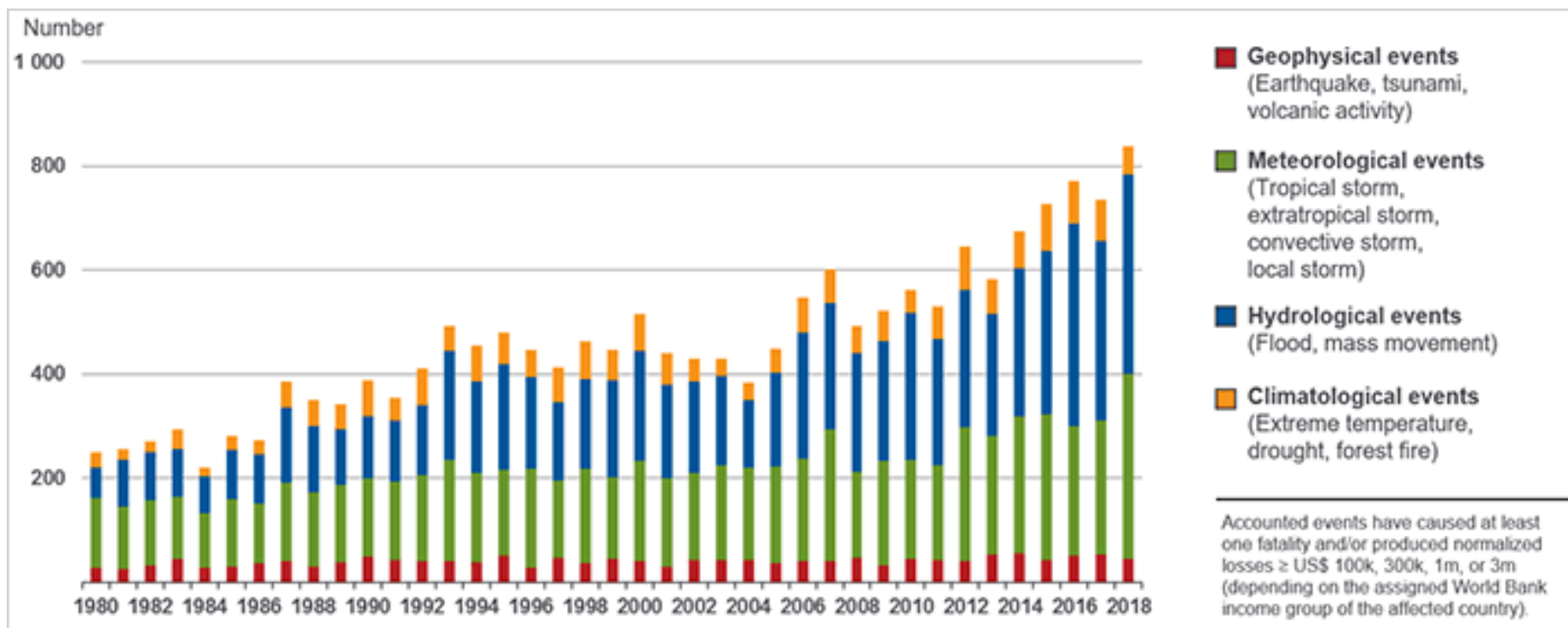


Longer & more
severe season

CLIMATE CO CENTRAL

Thermohaline Circulation





14 gennaio 2020

Ue, approvato il Green Deal: in arrivo mille miliardi di investimenti per l'economia verde

la Repubblica



Il vicepresidente della Commissione europea Valdis Dombrovskis

Il piano di investimenti per i prossimi dieci anni. L'Unione europea prevede di dedicare un quarto del proprio bilancio alla lotta ai cambiamenti climatici.

Netherlands climate change: Court orders bigger cuts in emissions

20 December 2019

f t e Share

Climate change



The Dutch government has struggled to cut carbon emissions since 1990

The highest court in the Netherlands has upheld a ruling requiring the government to slash greenhouse gas emissions by at least 25% of 1990 levels by the end of next year.

e f t

European Investment Bank drops fossil fuel funding

14 November 2019

BBC

f t e Share

Climate change



Study: U.S. Fossil Fuel Subsidies Exceed Pentagon Spending

These subsidies are largely invisible to the public, and don't appear in national budgets. But according to the IMF, the world spent \$4.7 trillion — or 6.3 percent of global GDP — in 2015 to subsidize fossil fuel use, a figure it estimated rose to \$5.2 trillion in 2017. The world would be richer and healthier if the full costs of fossil fuels were paid, according to a new report from the International Monetary Fund



The dome of the U.S. Capitol is seen behind the smoke stacks of the Capitol Power Plant, the only coal-burning power plant in Washington, D.C.

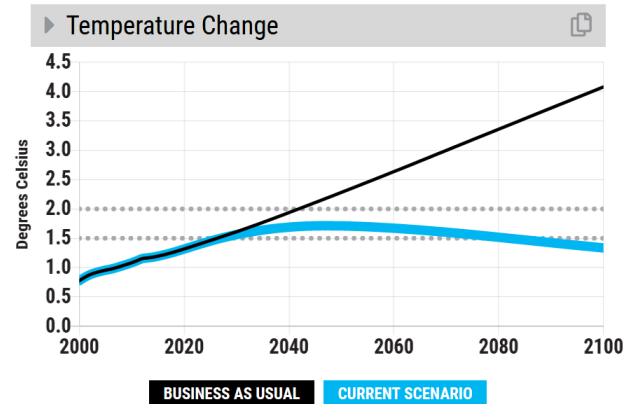
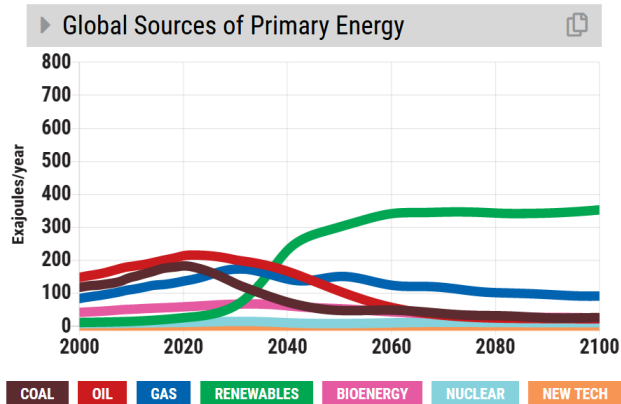
a transizione energetica 07052020
Alessandro Massi Pavan

QUALCOSA STA CAMBIANDO

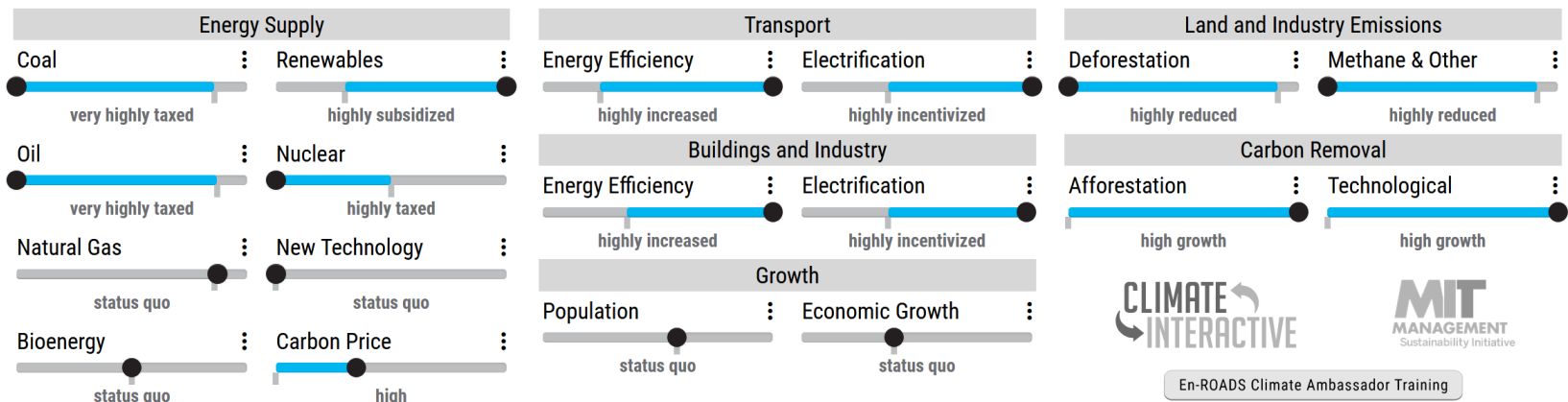


Despite widespread expectations of another increase, global energy-related carbon dioxide emissions stopped growing in 2019, according to IEA data released today.

After two years of growth, global emissions were unchanged at 33 gigatonnes in 2019 even as the world economy expanded by 2.9%. This was primarily due to declining emissions from electricity generation in advanced economies, thanks to the expanding role of renewable sources (mainly wind and solar), fuel switching from coal to natural gas, and higher nuclear power generation. Other factors included milder weather in several countries, and slower economic growth in some emerging markets.

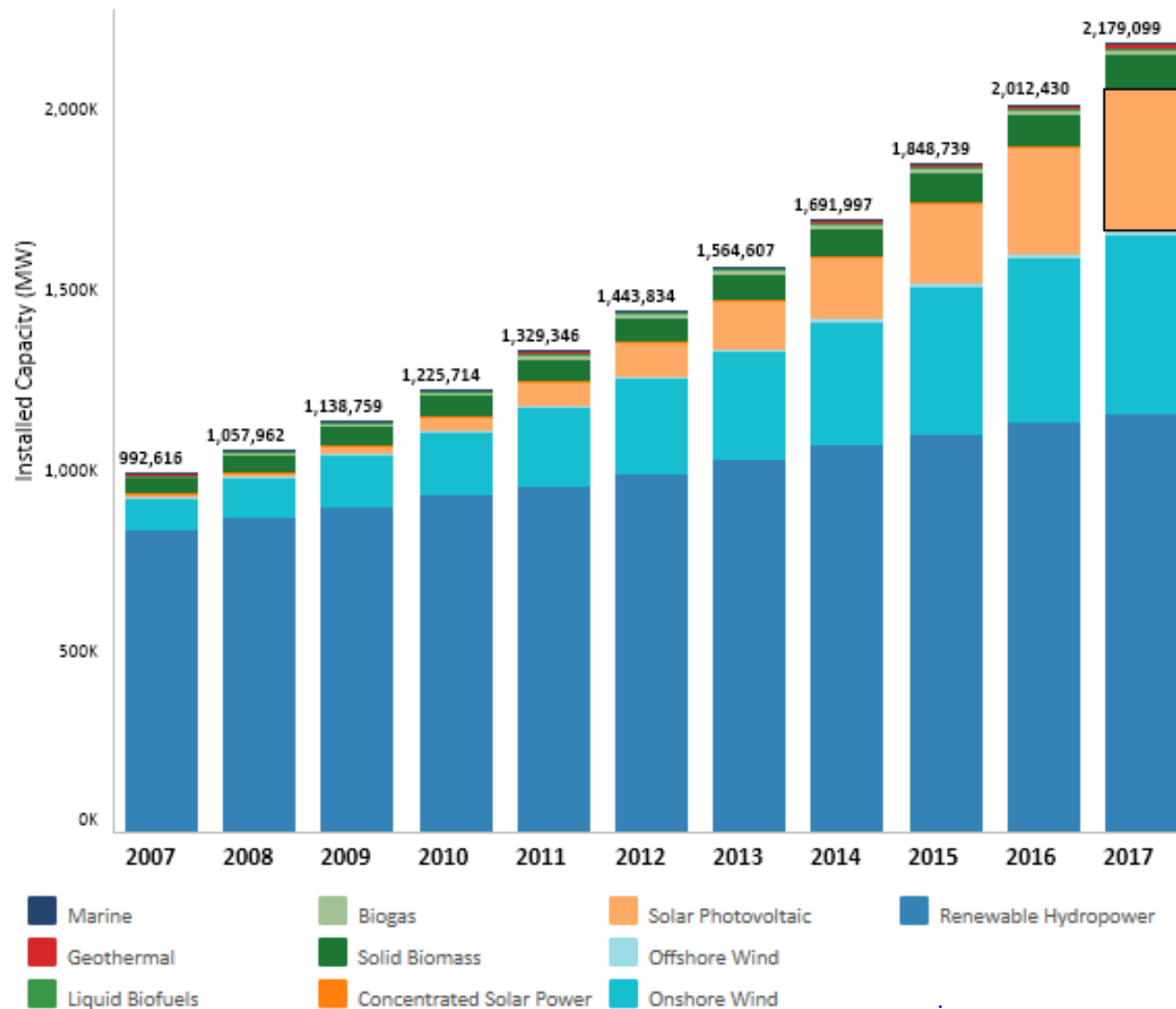


+1.3°C
+2.4°F
Temperature Increase by 2100



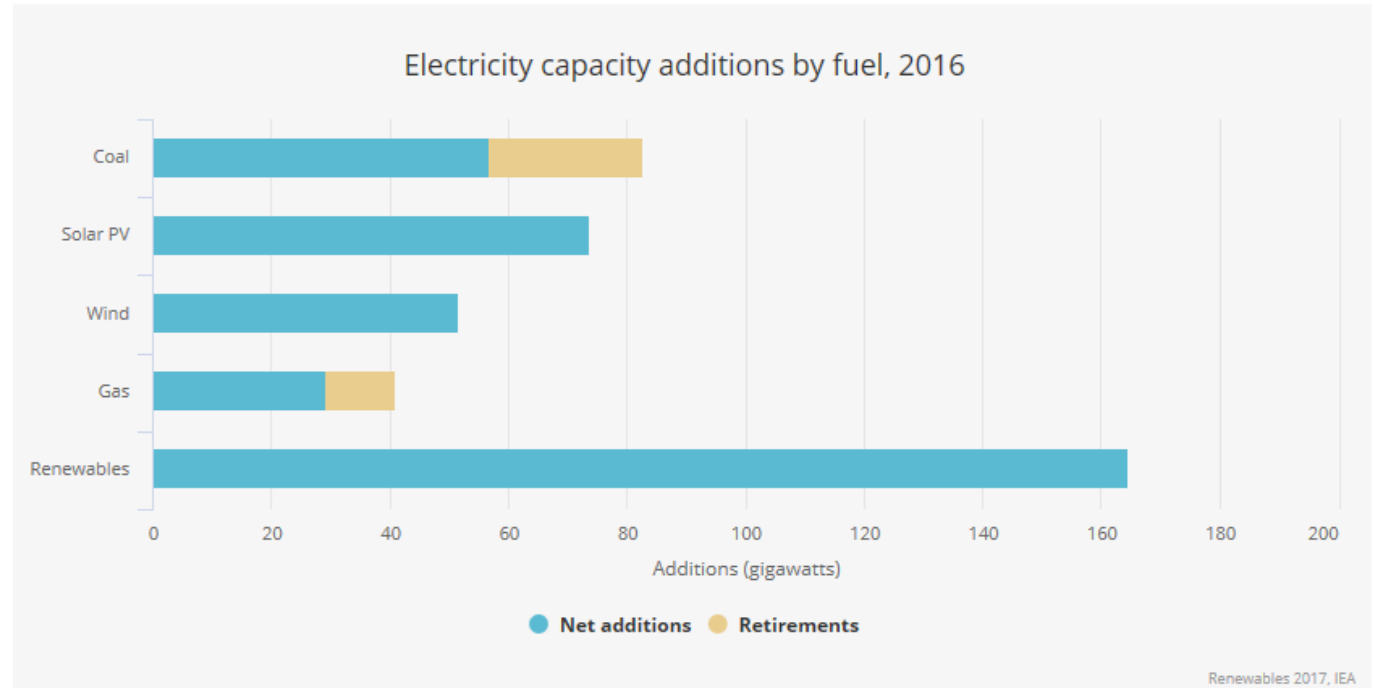
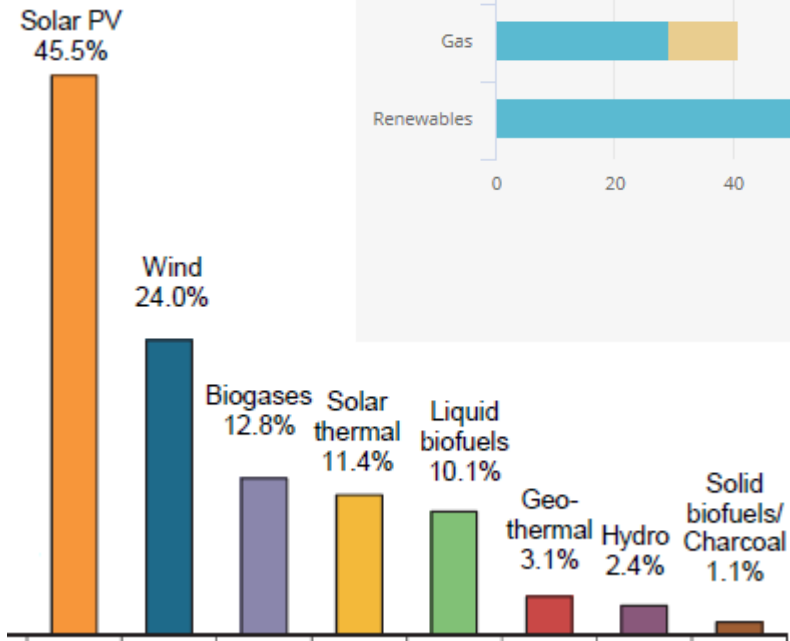
<https://en-roads.climateinteractive.org/scenario.html?p1=120&p7=100&p10=-0.1&p16=-0.07&p30=0.07&p39=87&p47=5&p50=5&p53=5&p55=4.8&p57=-10&p59=-100&p65=100&p67=100&v=2.7.6>

BOOM DI RINNOVABILI



www.irena.org

IL RUOLO DEL FOTOVOLTAICO



Tasso annuo di crescita per le
tecnologie rinnovabili nel periodo

IEA, Renewables information: overview statistics, 2017

MOTIVI DEL PRIMATO SOLARE

😊 Fonte primaria infinita, diffusa e gratuita

😊 Affidabilità e durata

😊 Facilità e velocità d'installazione

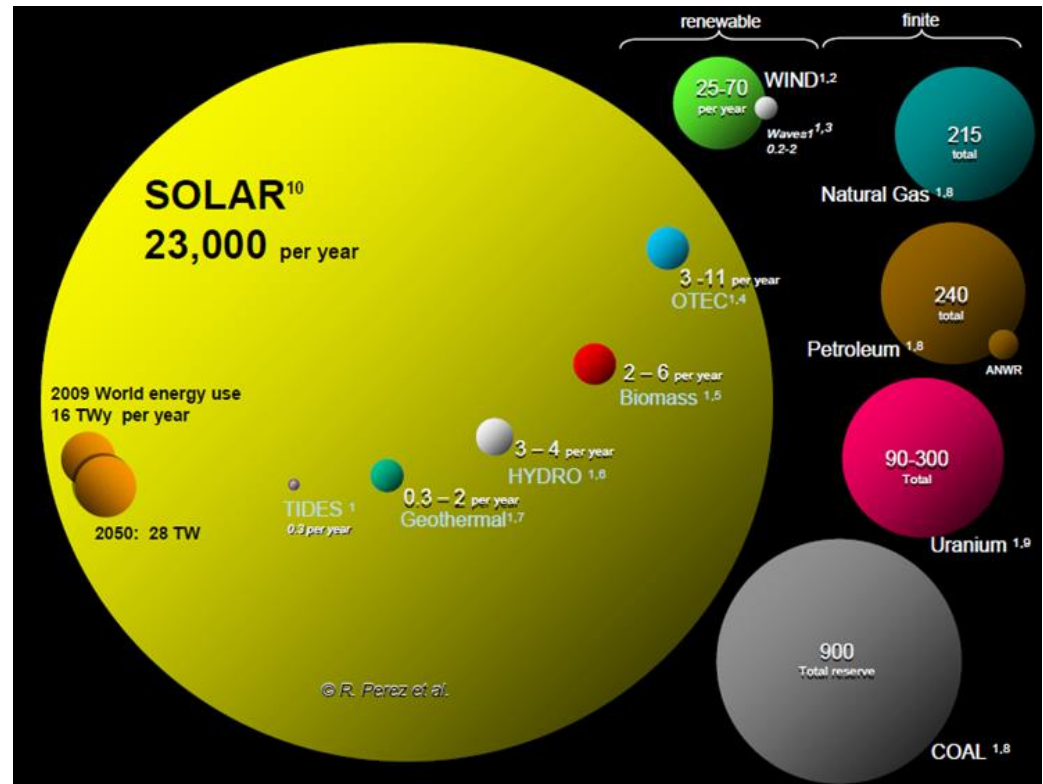
😊 Tecnologia modulare

😊 Assenza di emissioni

😊 Integrazione edilizia

😊 Fonte di lavoro distribuita e non specializzata

😊 Generazione distribuita



UN'IDEA ANTICA

SCIENCE



FRIDAY, SEPTEMBER 27, 1912

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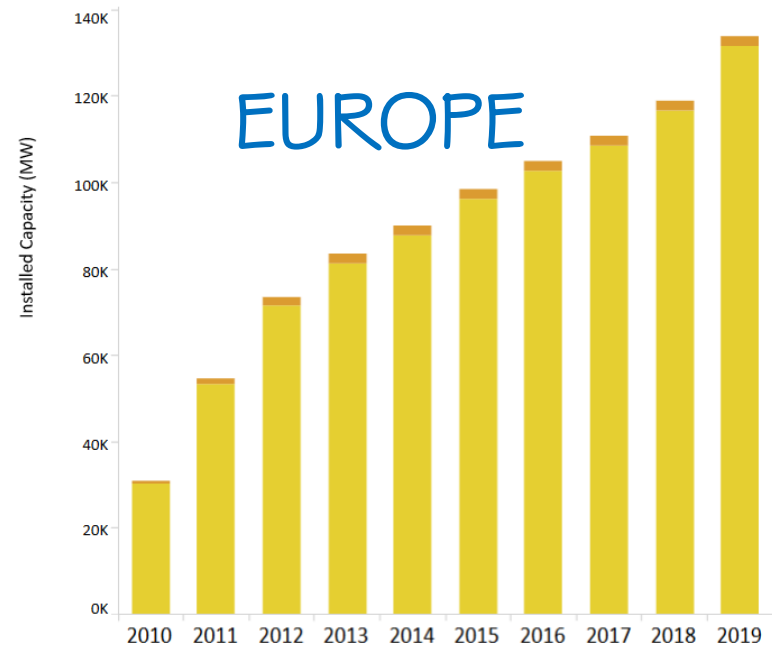
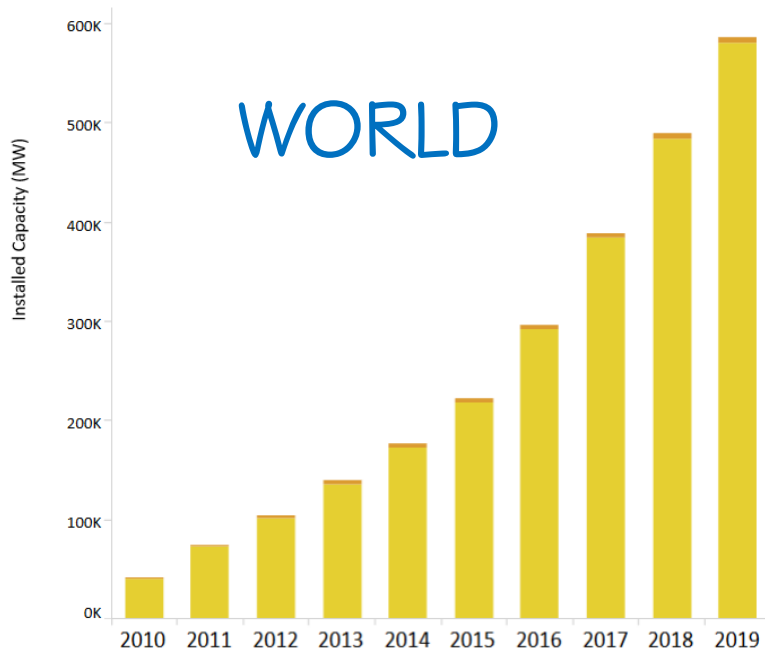
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THE PHOTOCHEMISTRY OF THE FUTURE¹

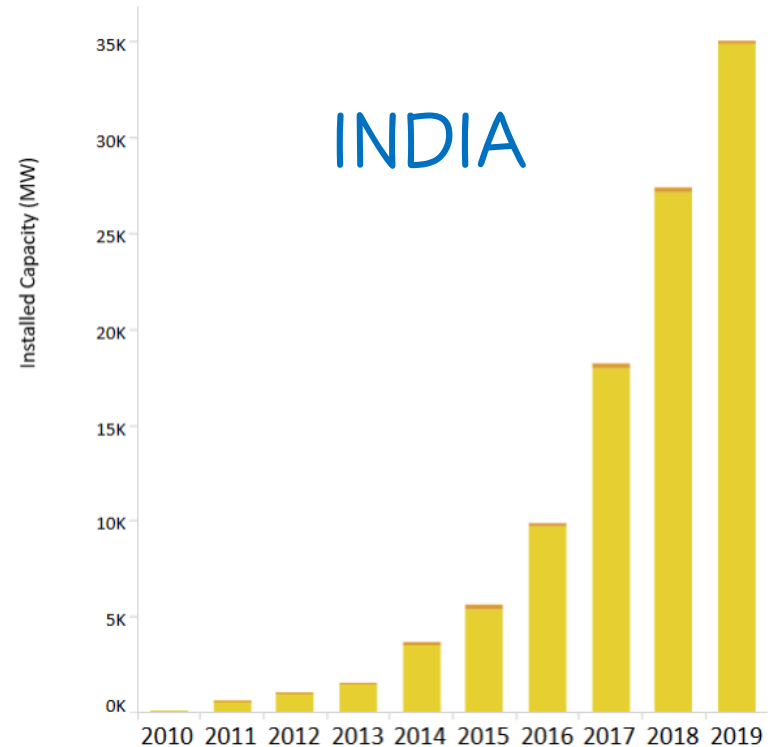
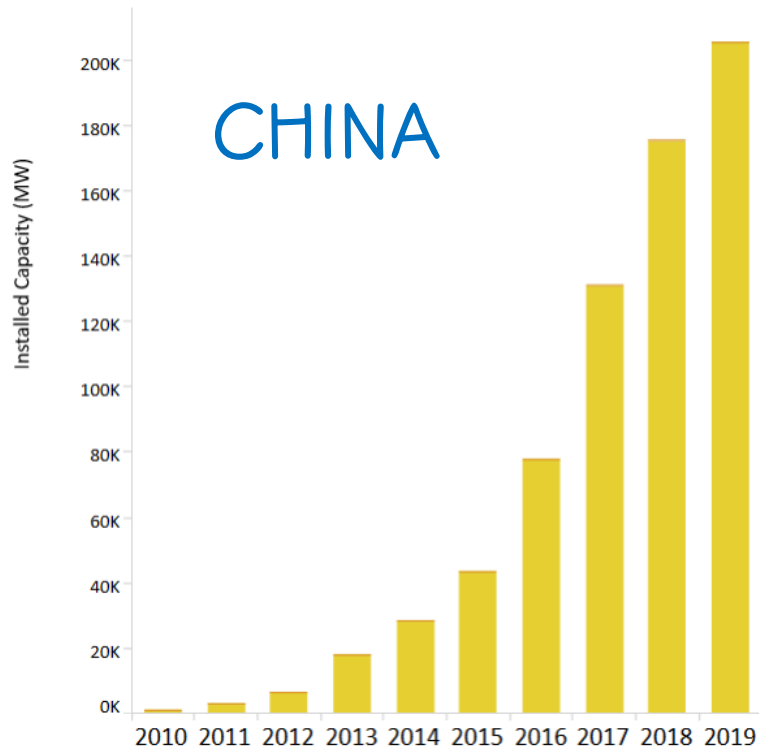
MODERN civilization is the daughter of coal, for this offers to mankind the solar energy in its most concentrated form; that is, in a form in which it has been accumulated in a long series of centuries. Modern man uses it with increasing eagerness and thoughtless prodigality for the conquest of the world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

"...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."

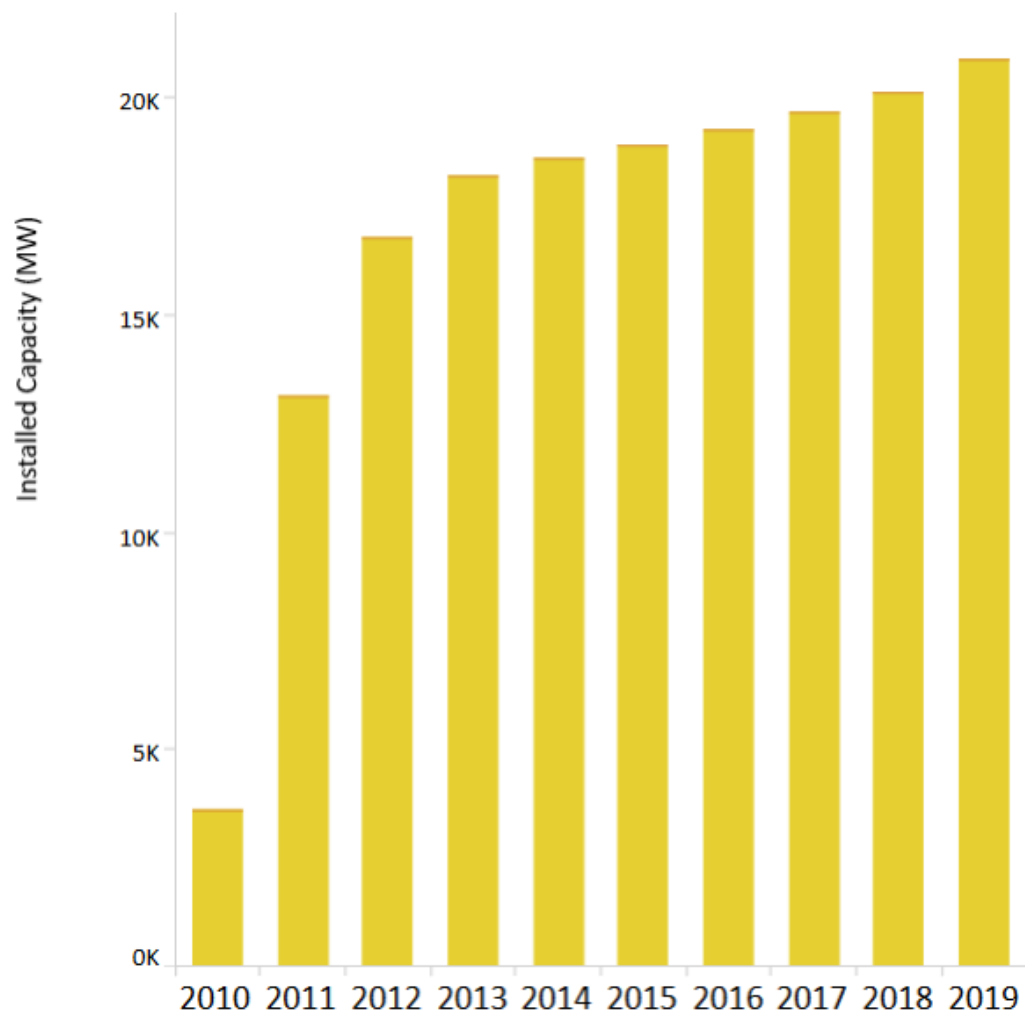
PV CUMULATIVE POWER



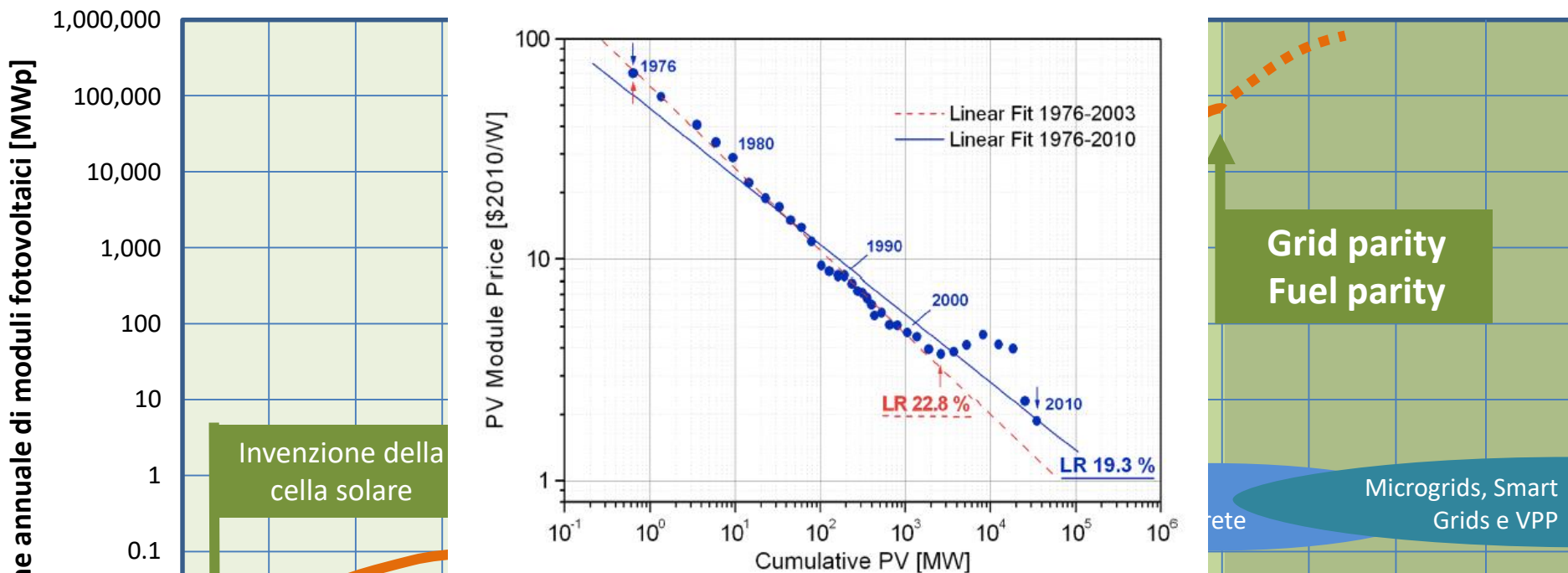
PV CUMULATIVE POWER



PV CUMULATIVE POWER - ITALY



STORIA DEL FOTOVOLTAICO



1955, 1975, 1995, ... il 2015 rappresenta una tappa fondamentale nella storia del fotovoltaico: i primi casi di grid e fuel-parity

POTENZA PRO CAPITE

IL PRIMO INDIZIO

COUNTRY	Installed Power [GW]*	Population [Millions]	Wp/per capita	Growth (%)
Germany	49.0	83.1	590	3.8
Japan	61.8	125.9	491	11.4
Italy	20.9	60.2	334	4.0
Europe	116.1	447	260	14.3
USA	60.5	329.6	184	17.7
China	205.1	1,402.5	142	17.2
India	34.8	1,361.9	26	28.4
-----	-----	-----	---	---

*2019

GRID E FUL-PARITY

IL SECONDO INDIZIO

- Il grid-parity si verifica quando il costo del kWh prodotto dall'impianto fotovoltaico è inferiore a quello pagato in bolletta dall'utente
- Il fuel-parity si verifica quando il costo del kWh fotovoltaico è comparabile con quello prodotto da tecnologie tradizionali per la produzione di energia elettrica

COSTO DI PRODUZIONE

GRID-PARITY – DOMESTICO E COMMERCIALE/INDUSTRIALE

Prezzo dell'energia elettrica (cent/kWh)	10 – 22
Costo dell'energia elettrica fotovoltaica (cent/kWh)	5 – 11

FUEL-PARITY – IMPIANTI DI GENERAZIONE

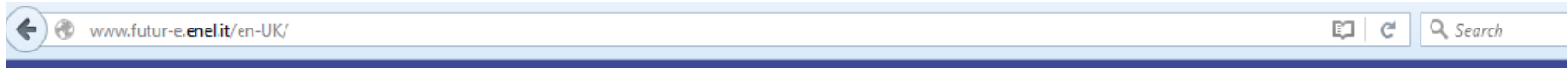
Costo dell'energia elettrica prodotta da diverse fonti tradizionali (cent/kWh)	4,4 – 19
Costo dell'energia elettrica fotovoltaica (cent/kWh)	3,2 – 4.4

RIDUZIONE DEL BOS – ECONOMIE DI SCALA – NUOVE TECNOLOGIE LCOE PREVISTI (2025)

Domestico e C&I (cent/kWh)	4 – 9
Impianti di generazione fotovoltaici – Sicilia (cent/kWh)	2,5 – 3,5

I COLOSSI DELL'ENERGIA

IL TERZO INDIZIO



Futur-E

MANIFESTO INITIATIVES ENERGY SCENARIO POWER PLANTS AND TERRITORY NEWS MEDIA

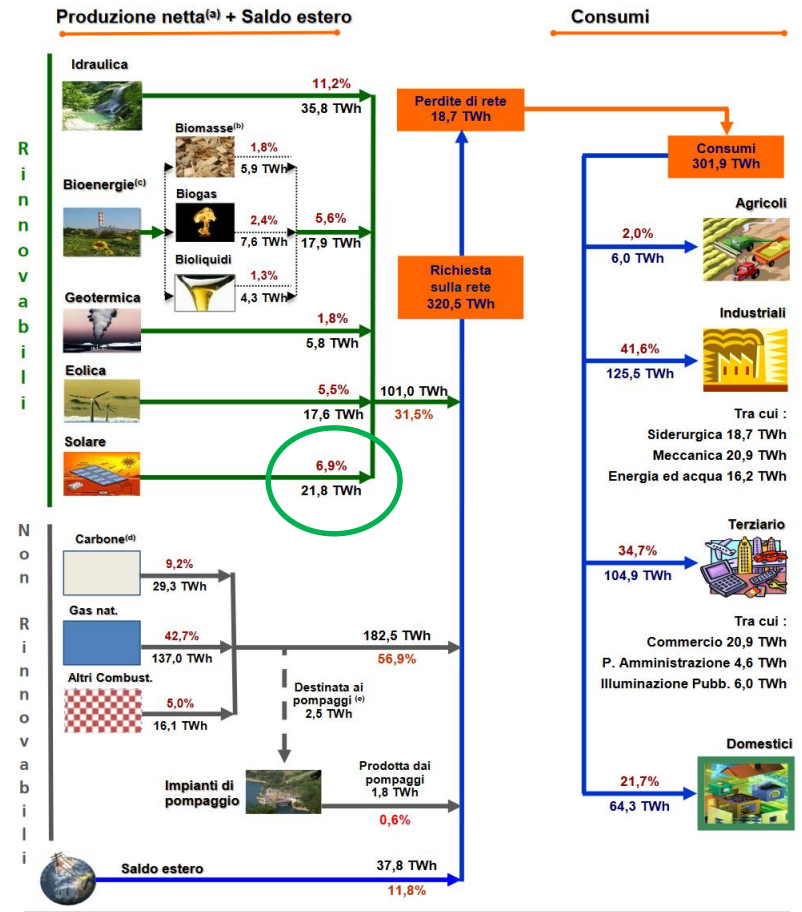
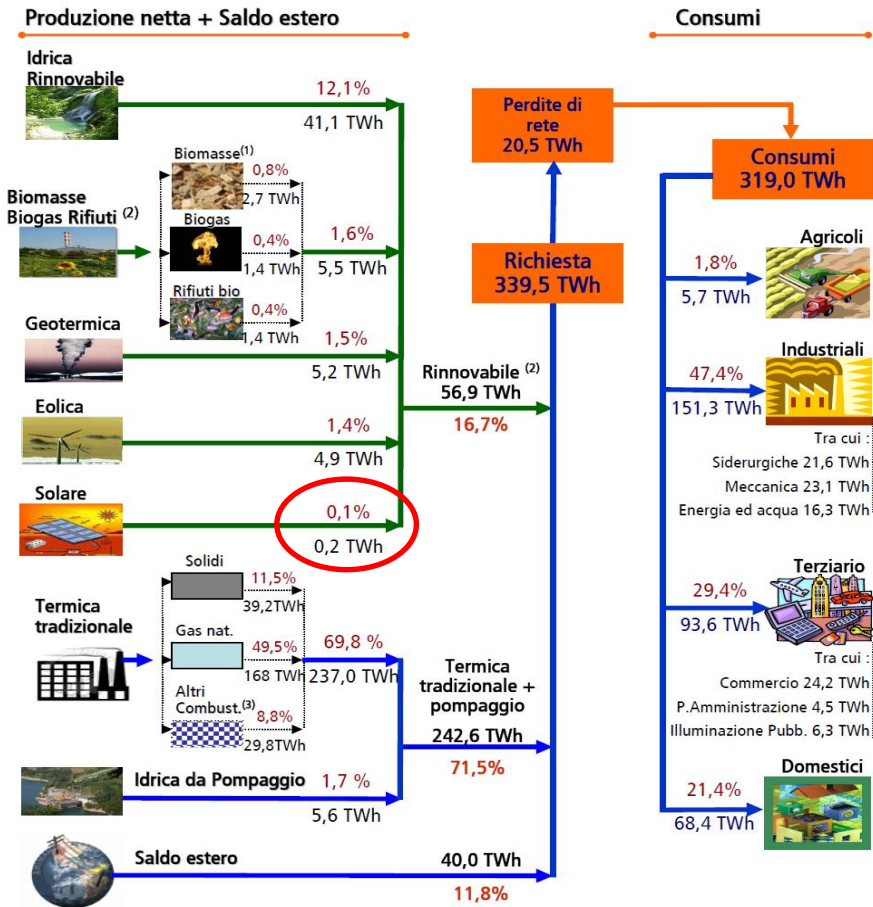
ENEL AND THE ROAD FOR RELAUNCHING

The energy revolution will lead to a strong growth in domestic solar PV and the spread of energy storage devices



POWER SUPPLY CHAIN

ITALY 2003 - 2017



GW

4000

3000

2000

1000

0

2



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- Coal
- Gas
- Oil
- Nuclear
- Wind
- Solar PV
- Other renewables
- Hydro
- Battery storage

The energy transition from fossil fuels to renewables is already ongoing, but it will be a long and difficult process because the energy system is a gigantic and complex machine (with an extraordinary economic inertia)

Today, key renewables data show the remarkable growth of solar electricity ...

Whatever will happen, the age of hydrocarbons and coal entered its final stage. When this century will be concluded, nothing will ever be the same

N. Armaroli, V. Balzani

Solar Electricity and Solar Fuels: Status and Perspectives in the Context of the Energy Transition

Chemistry, vol. 22, page 32-57, 2016

La transizione energetica 07052020

Alessandro Massi Pavan

CONCLUSIONS

- Renewables energy market grows exponentially since 20 years
- Conventional and nuclear power markets are not growing (if not declining)
- Hydropower is currently the most common form of RES and its market is mature
- Wind power and photovoltaics follow and are the fastest growing RES

CONCLUSIONS

- Awareness is the key! Awareness of what is happening and of what we can do
- Individual responsibility
- Pay attention to Business As Usual pattern
- ... and also to the boundary conditions
- Communication is another key!