



UNIVERSITÀ
DEGLI STUDI DI TRIESTE

IL RUOLO DEL FOTOVOLTAICO NELLA TRANSIZIONE ENERGETICA DEL VENTUNESIMO SECOLO

A cura del dott. Alessandro Massi Pavan

Dipartimento di Ingegneria e Architettura UniTs



Dipartimento di Ingegneria e Architettura

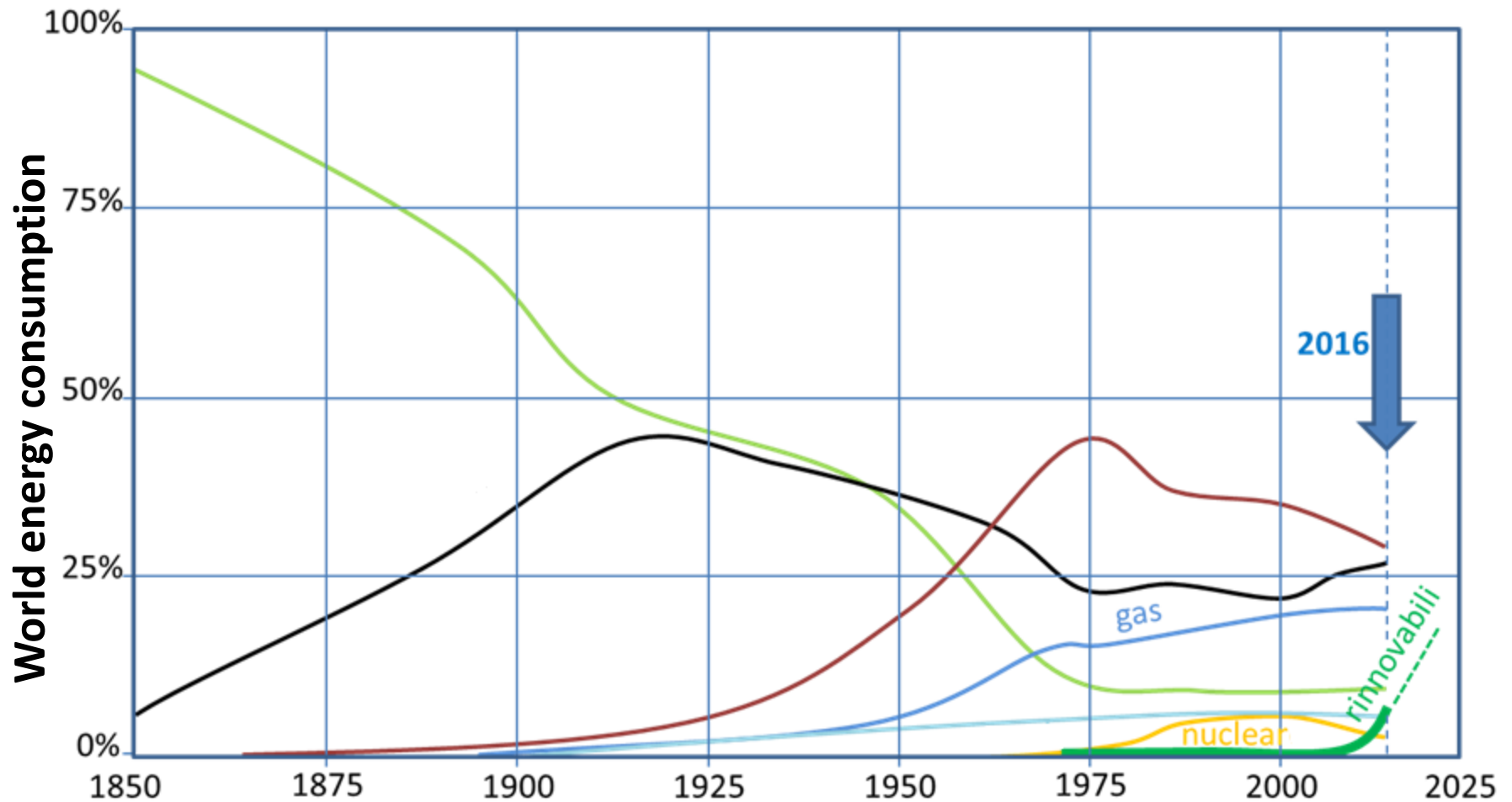


www.awareenergy.eu



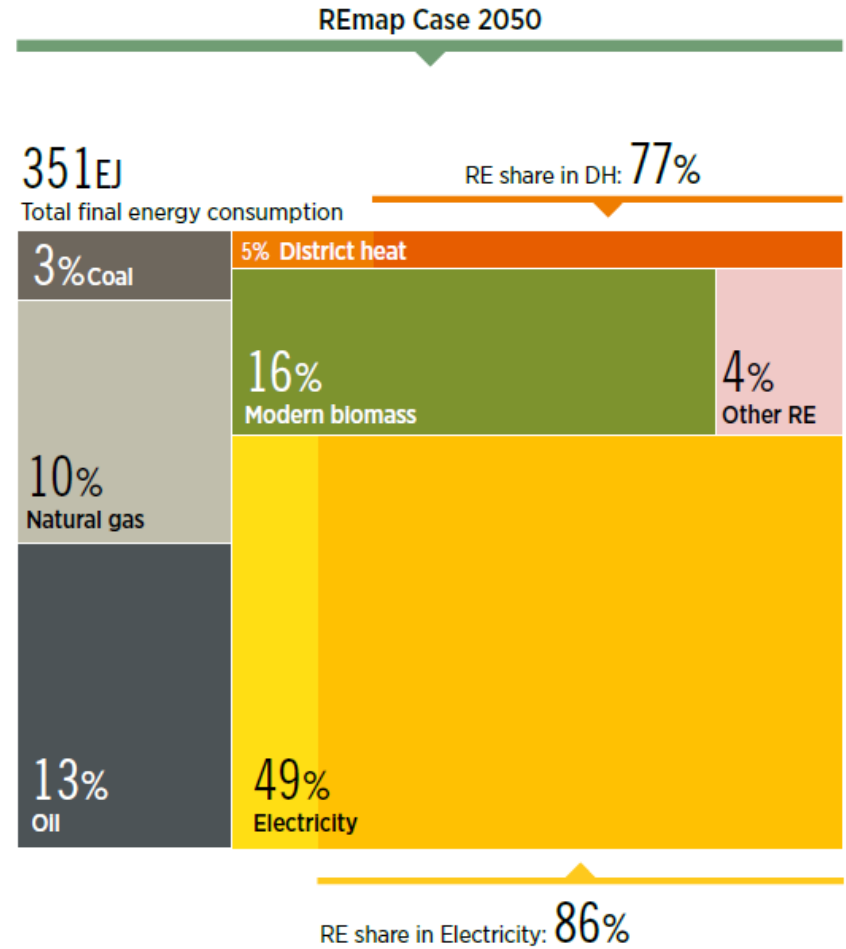
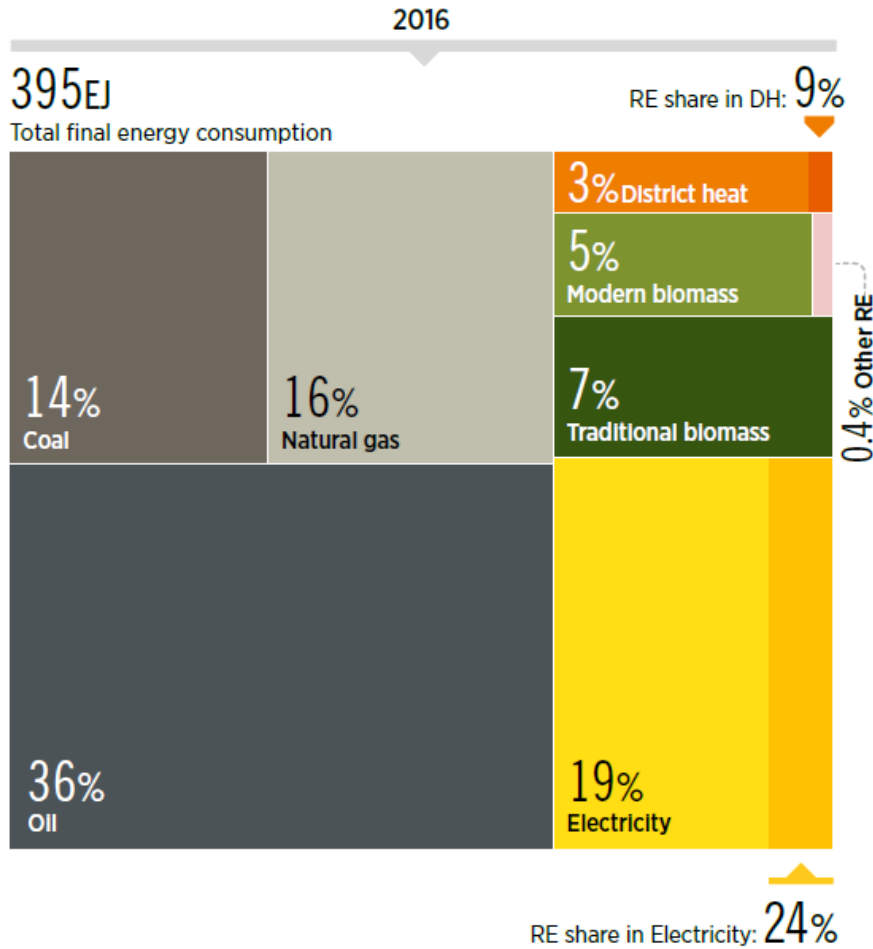
Summer School on Energy
Giacomo Ciamician

TRANSIZIONI ENERGETICHE

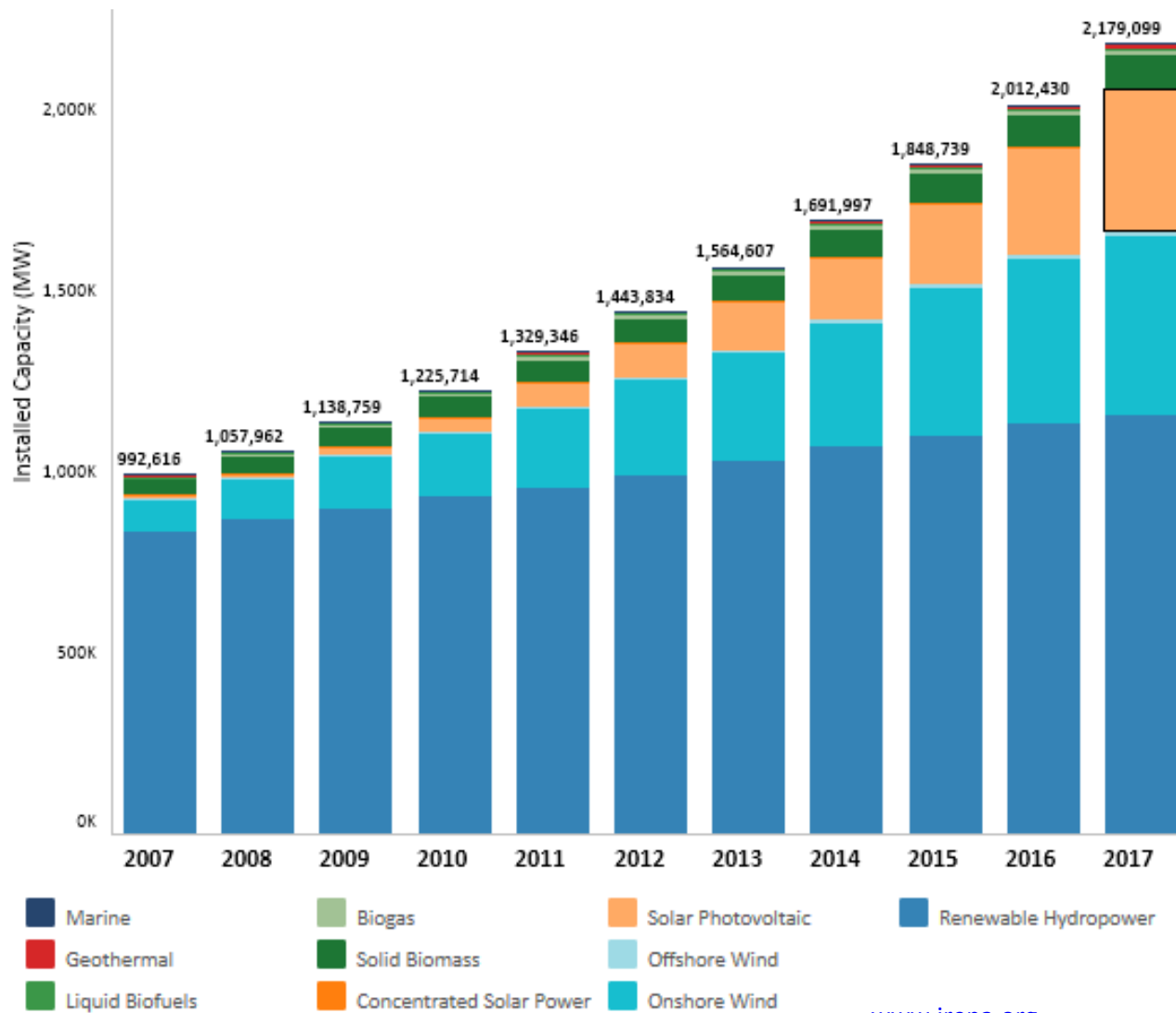


A. Massi Pavan, V. Lughì La forza del Sole Sapere, 2016

Total final energy consumption breakdown by energy carrier (%)

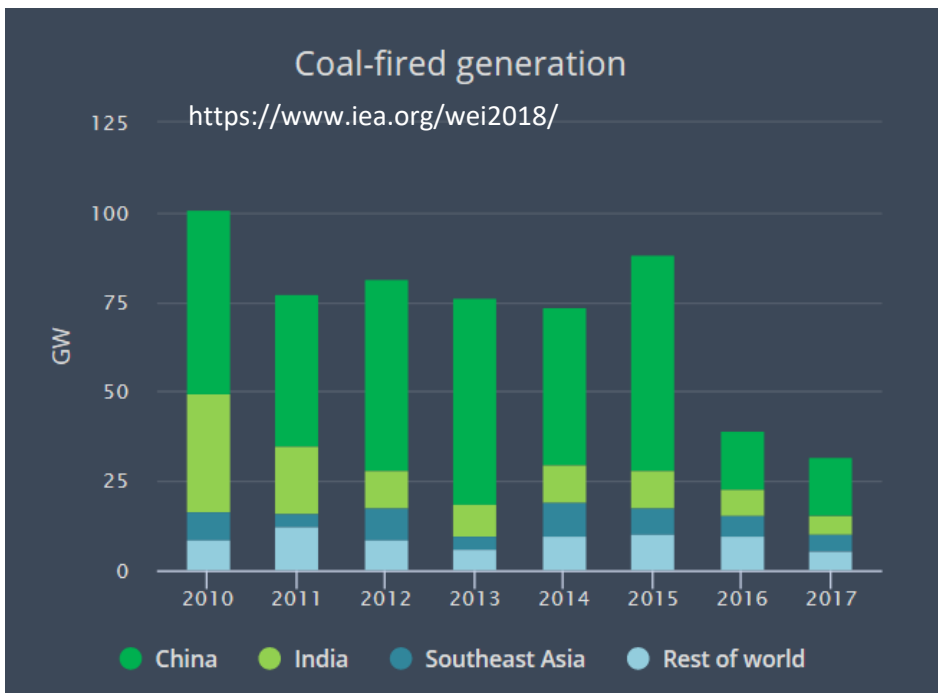


BOOM DI RINNOVABILI

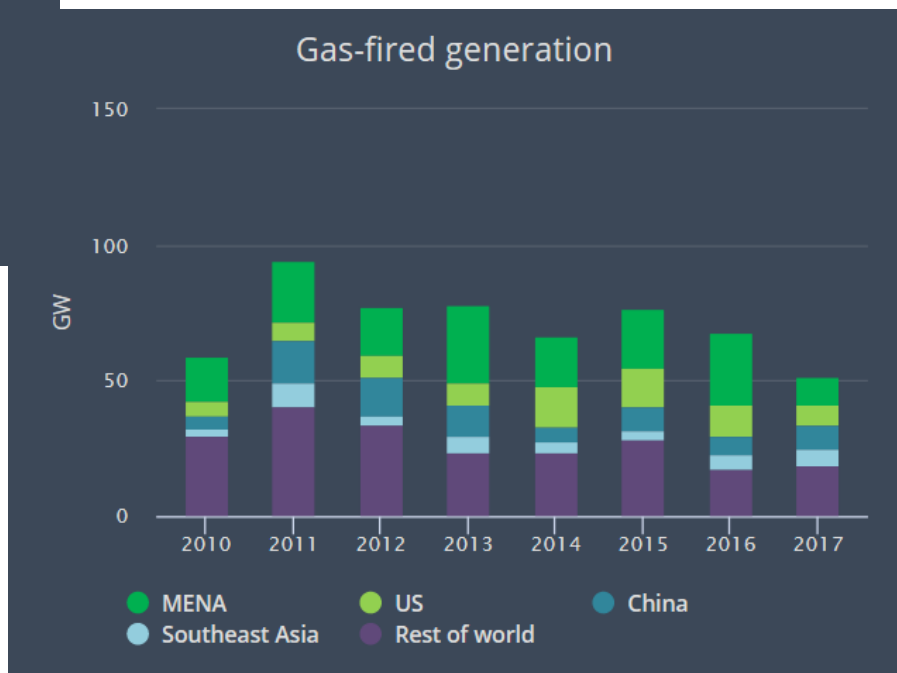


www.irena.org

E LE TRADIZIONALI ...



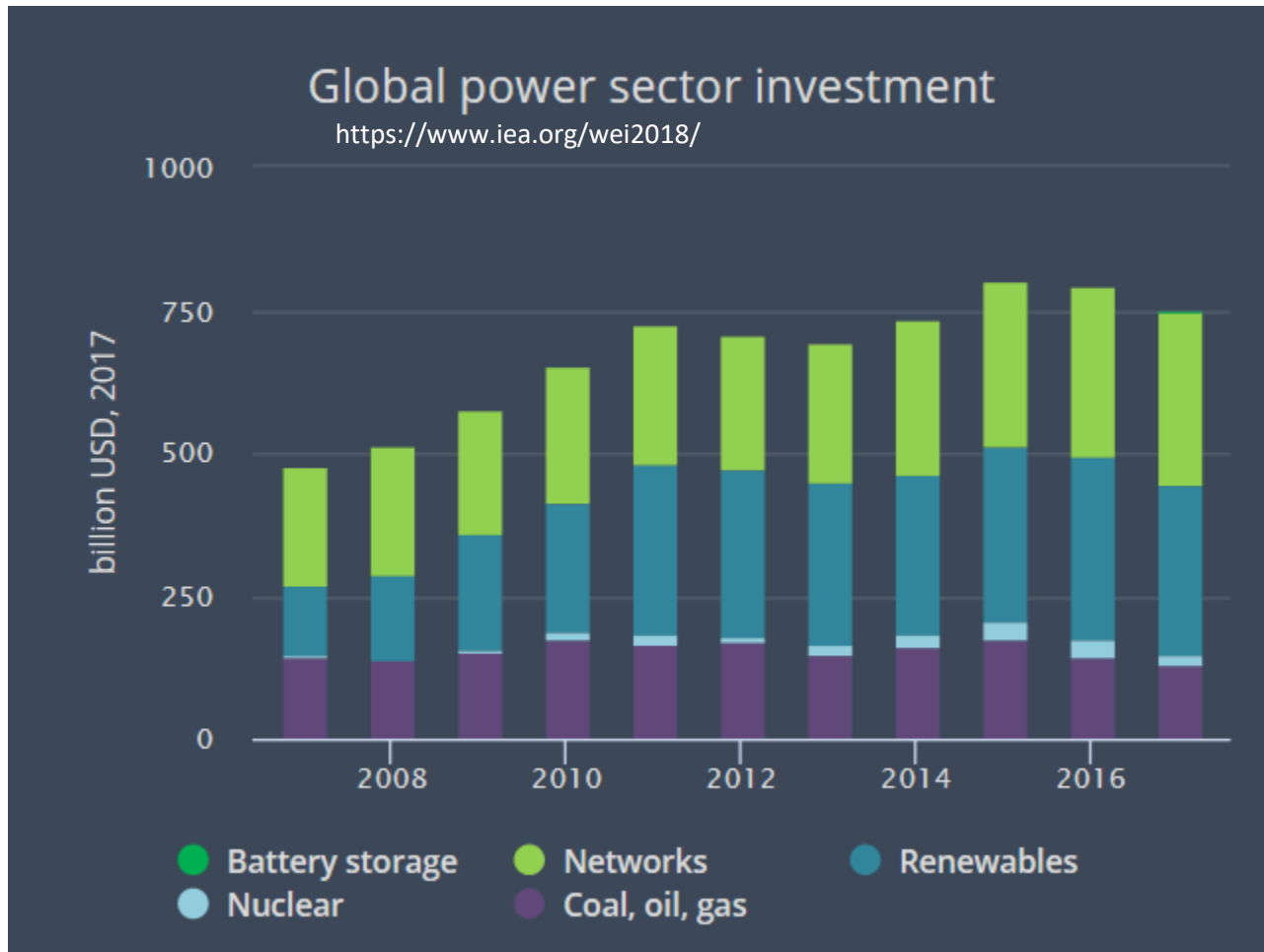
RES \approx 2,2TW
NUCLEARE \approx 0,5TW



GAS \approx 1,5TW

CARBONE \approx 1,9TW

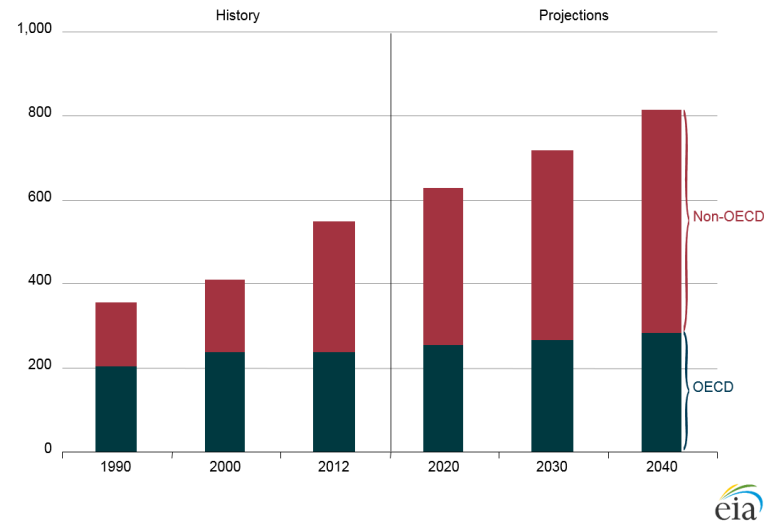
INVESTIMENTI SETTORE ENERGETICO



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

	OPEC	Non-OPEC	Total world
Cumulative production to 2010 (a)	446	695	1,142
Proved reserves (b)			1,467
Reserves to be added ultimately (c)	617	620	1,237

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

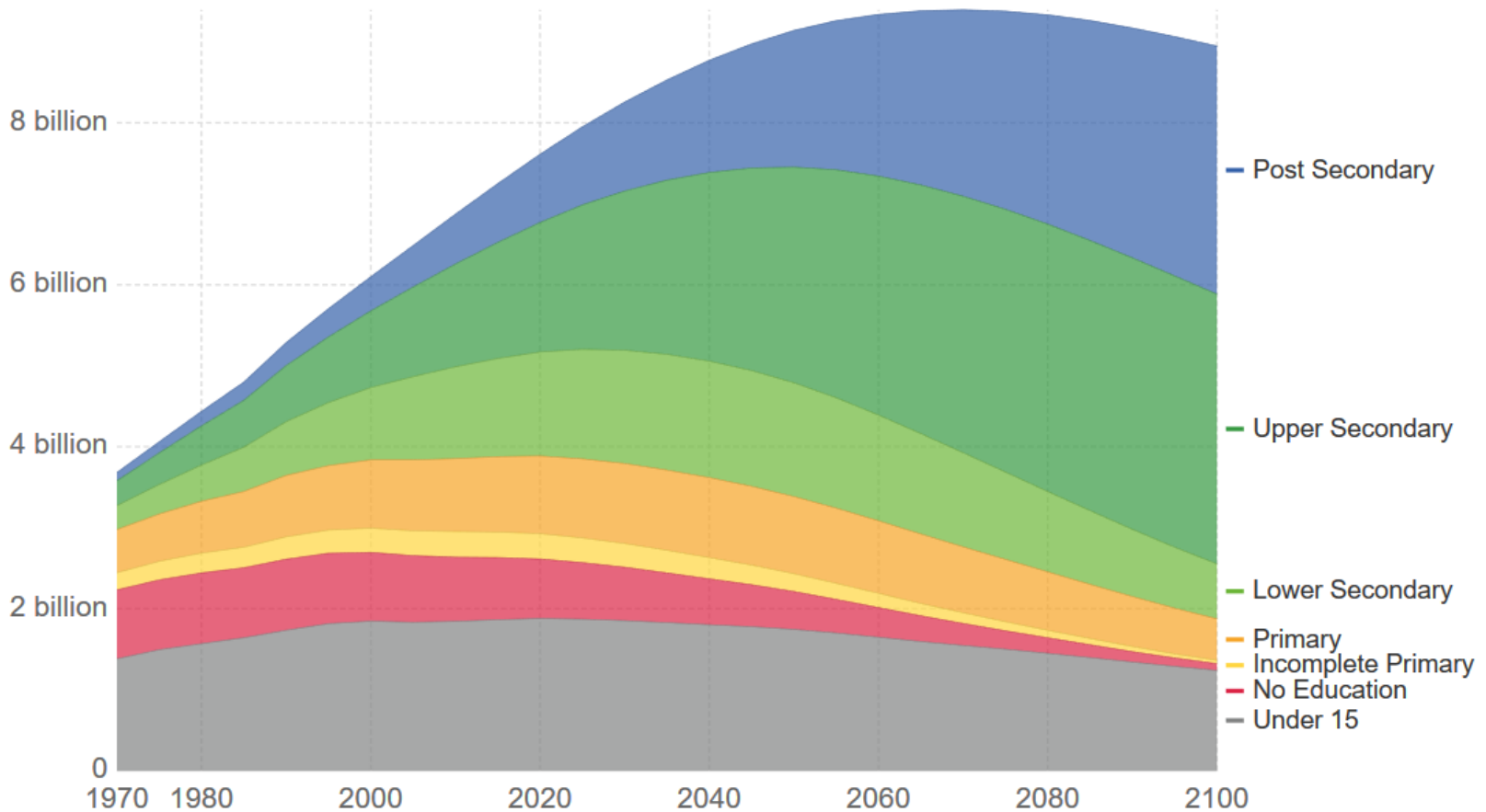
[World Oil Outlook – OPEC 2012](#)

Total reserves: 2,704

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

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Trieste, 16092019

2. RISCALDAMENTO GLOBALE



Climate change
is real.
It's happening
right



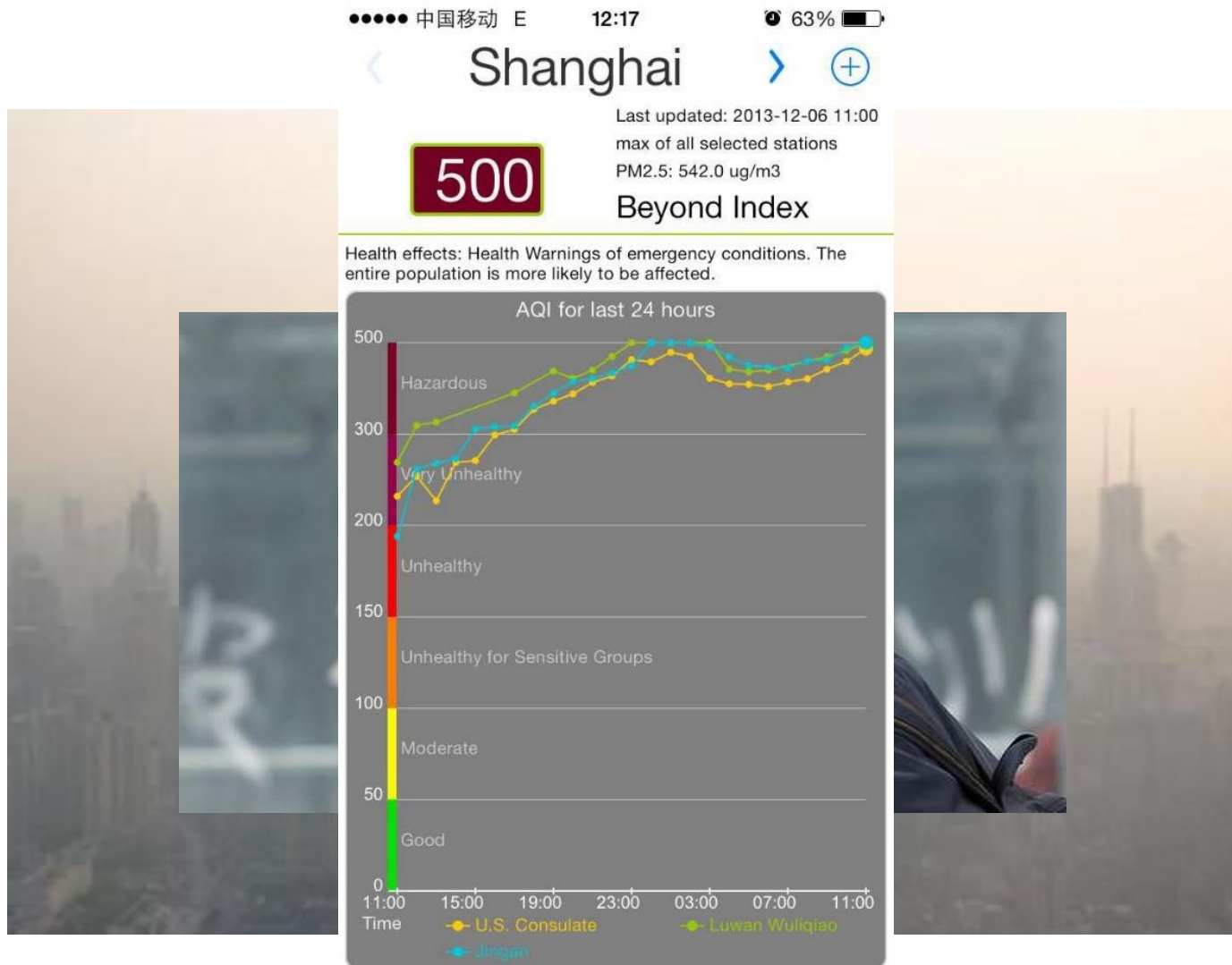
HOME | NEWS | SPC
Pictures | EU referendum

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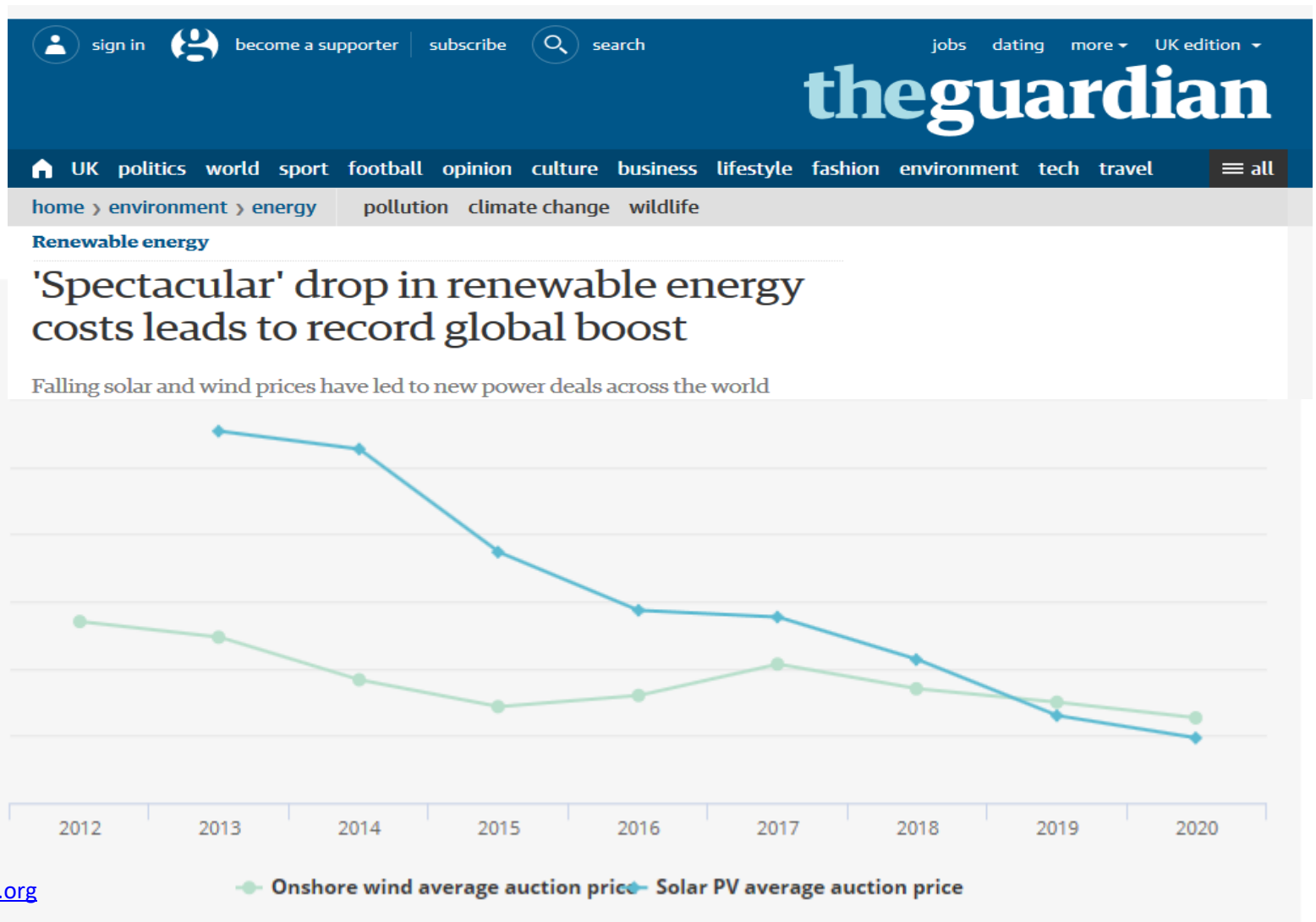


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3. QUALITA' DELLA VITA



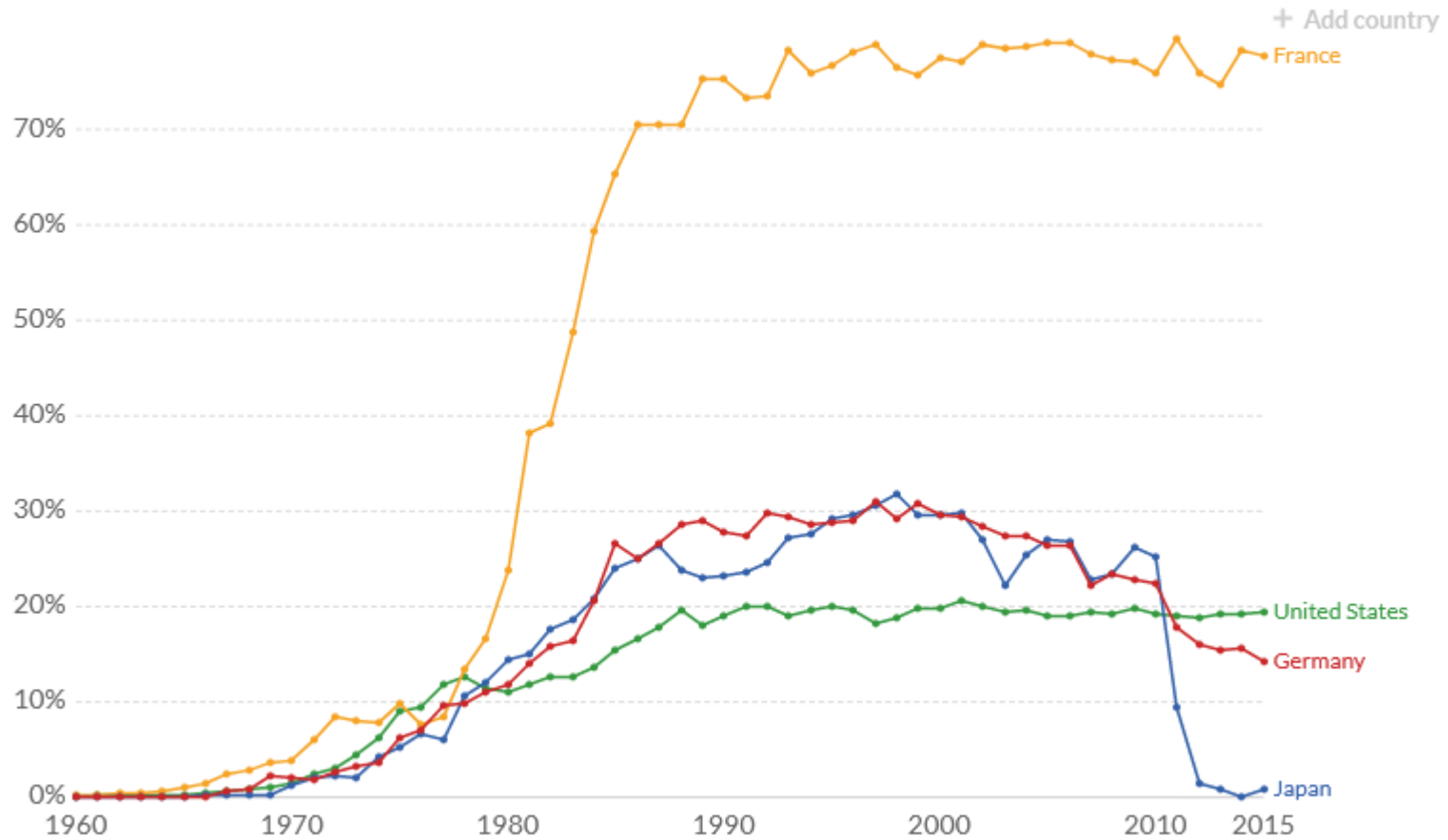
4. CONVENIENZA ECONOMICA



NON PER IL NUCLEARE ...

Nuclear energy, share of electricity production

The share of nuclear energy in the electricity mix, measured as a percentage of total electricity production.











Source: International Energy Agency (IEA) via The World Bank

CC BY

5. TEMPI DI INSTALLAZIONE

IRENA – Global Landscape of renewable energy finance 2018

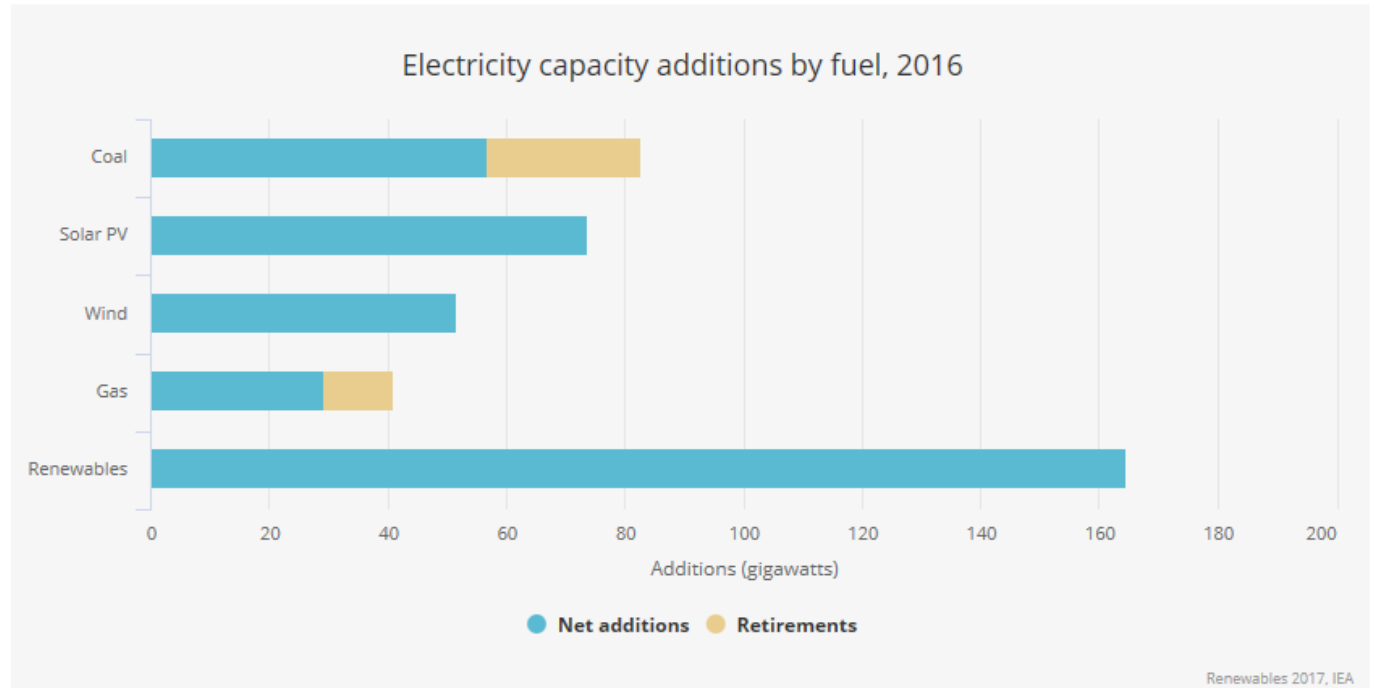
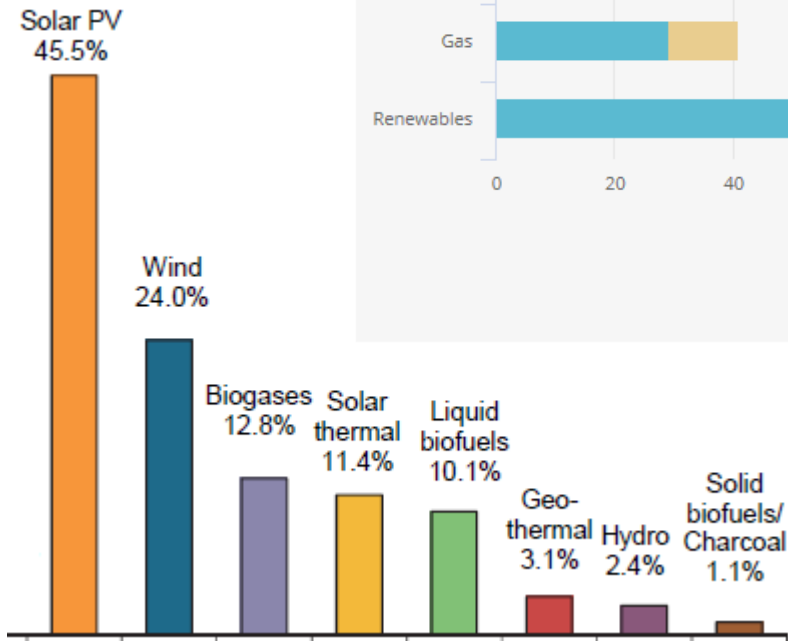
Technology	Number of years
 Solar PV	0.5
 Wind onshore	0.8
 Bioenergy	1.7
 Wind offshore	1.7
 Geothermal	1.9
 Solar thermal	2
 Marine	2.2
 Small hydro	2.3

Nucleare 6 – 12,5!!!

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

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IL RUOLO DEL FOTOVOLTAICO



Tasso annuo di crescita per le tecnologie rinnovabili nel periodo

1990-2015

MOTIVI DEL PRIMATO SOLARE

😊 Fonte primaria infinita, diffusa e gratuita

😊 Affidabilità e durata

😊 Facilità e velocità d'installazione

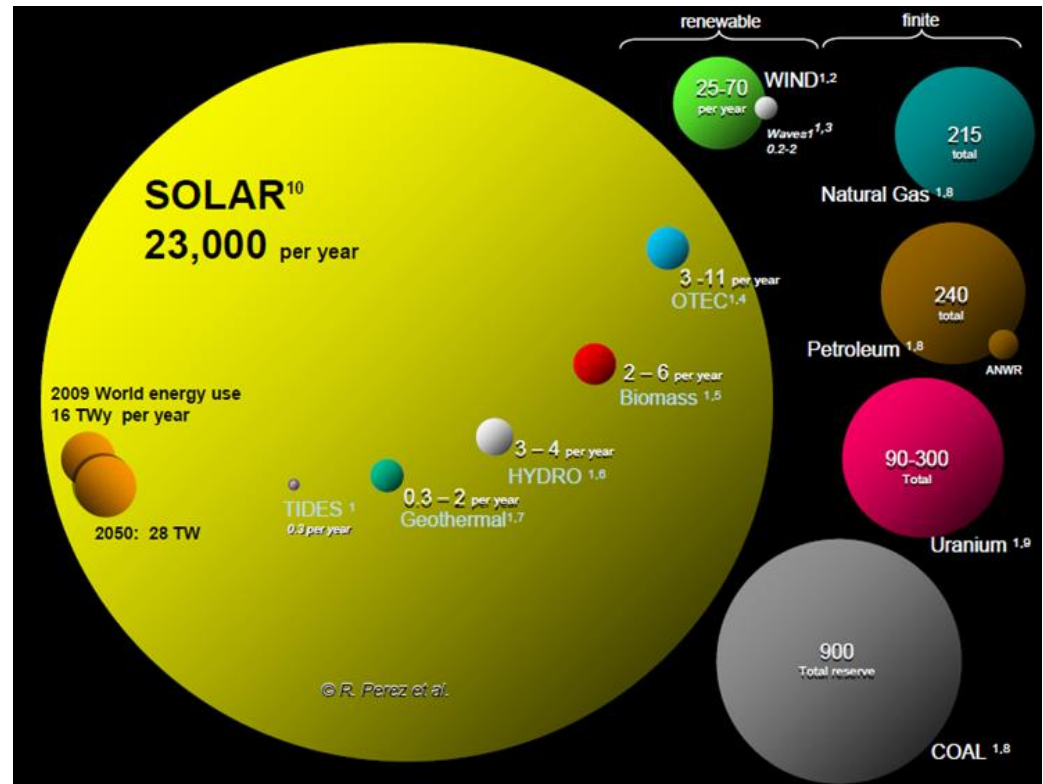
😊 Tecnologia modulare

😊 Assenza di emissioni

😊 Integrazione edilizia

😊 Fonte di lavoro distribuita e non specializzata

😊 Generazione distribuita



UN'IDEA ANTICA

SCIENCE



FRIDAY, SEPTEMBER 27, 1912

CONTENTS

<i>The Photochemistry of the Future:</i> PROFESSOR GIACOMO CIAMICIAN	385
<i>The First International Eugenics Congress:</i> PROFESSOR RAYMOND PEARL	395
<i>Industrial Education in the Philippines</i>	396
<i>Graduates from American Colleges and Uni- versities</i>	397

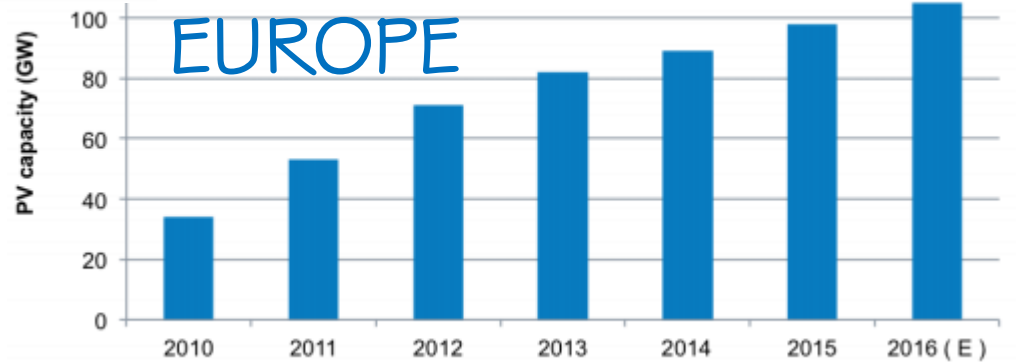
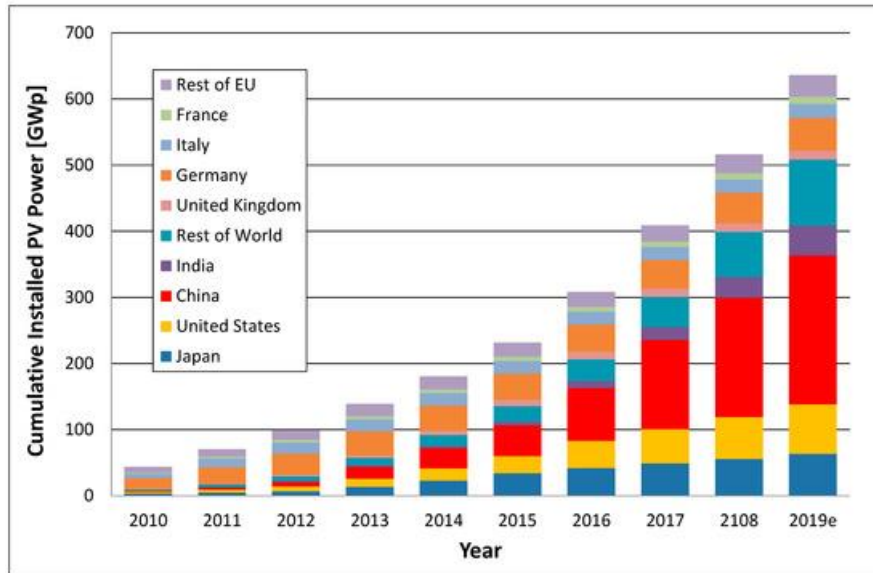
*THE PHOTOCHEMISTRY OF THE FUTURE*¹

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.

"...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."

POTENZA INSTALLATA

WORLD

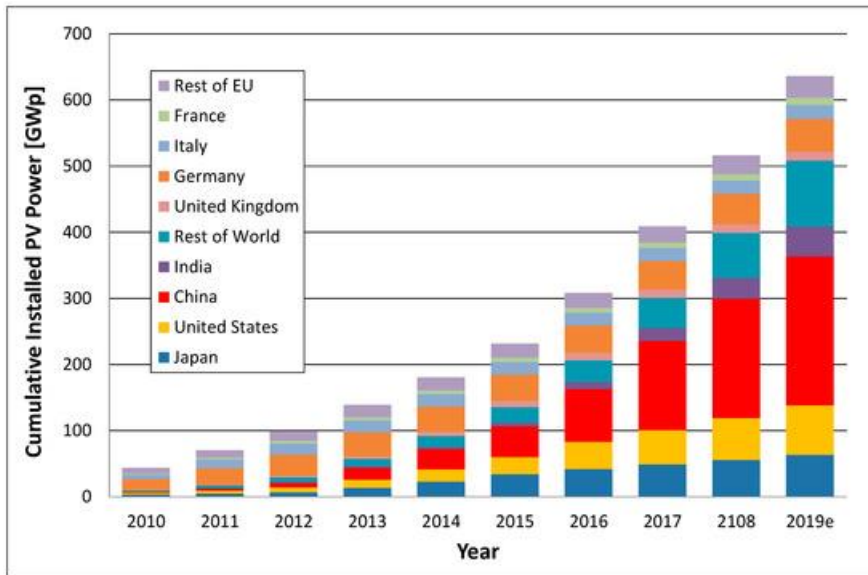


Source: IHS

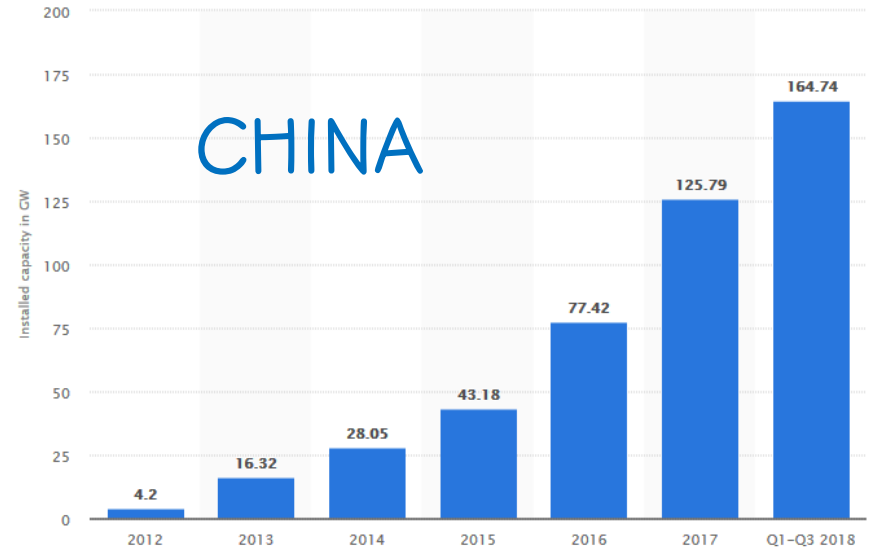
© 2016 IHS

POTENZA INSTALLATA

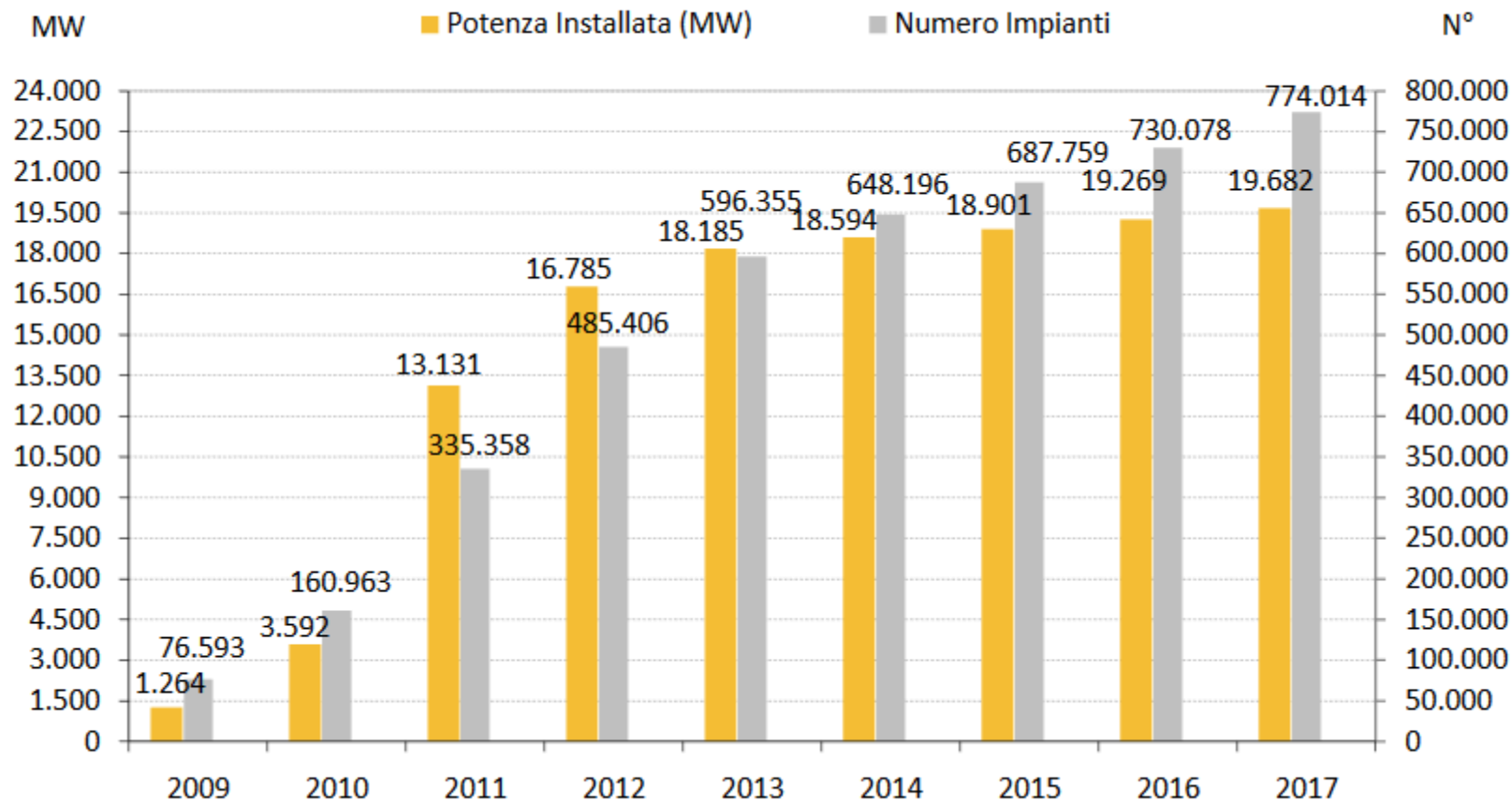
WORLD



A. Jager-Waldau. Snapshot of Photovoltaics, Energies 2019

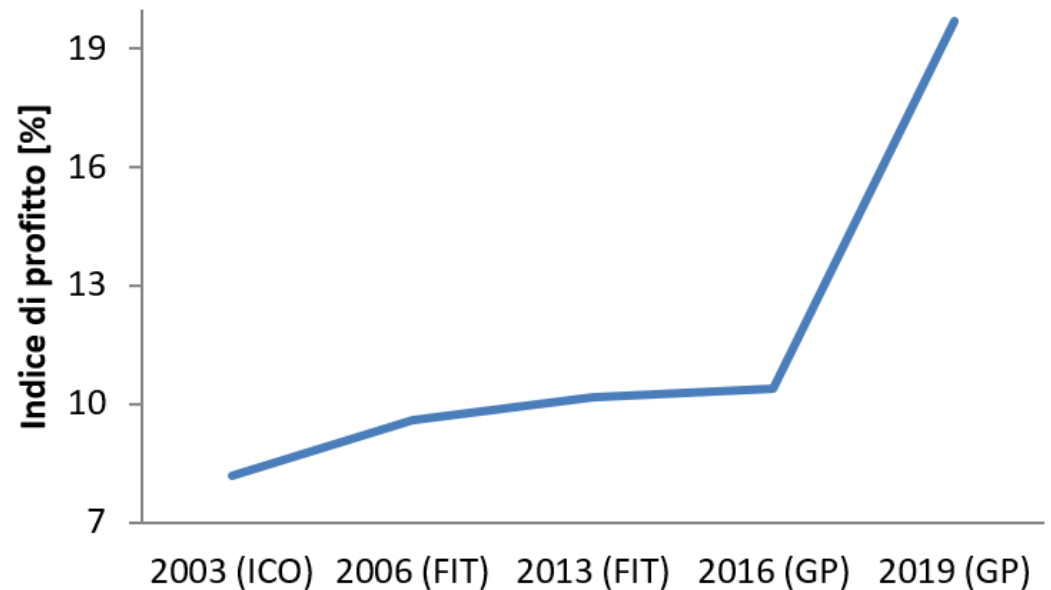
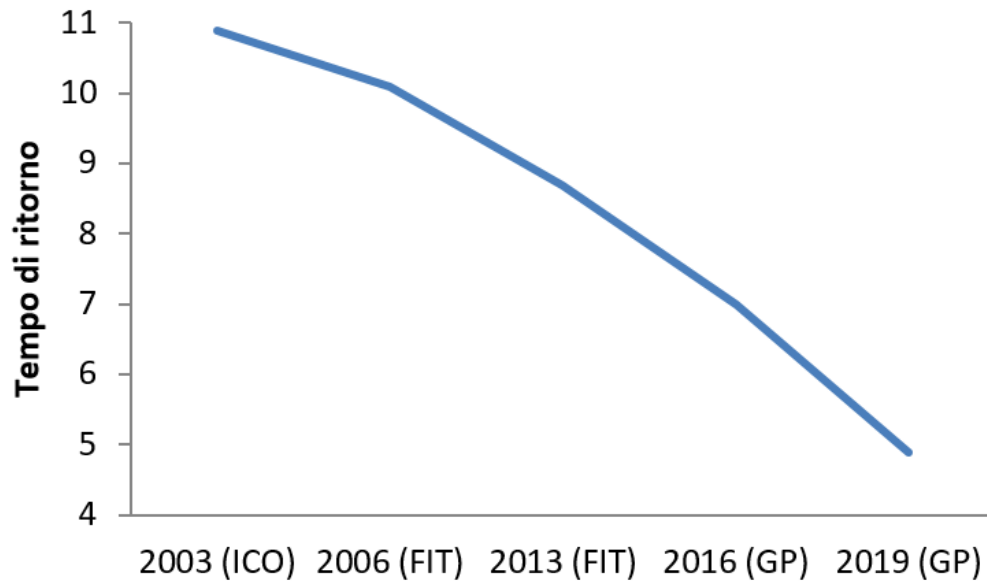


PV CUMULATIVE POWER - ITALY



<http://enerweb.casaccia.enea.it/enearegioni/UserFiles/Solare%20Fotovoltaico%20-%20Rapporto%20Statistico%202017.pdf>

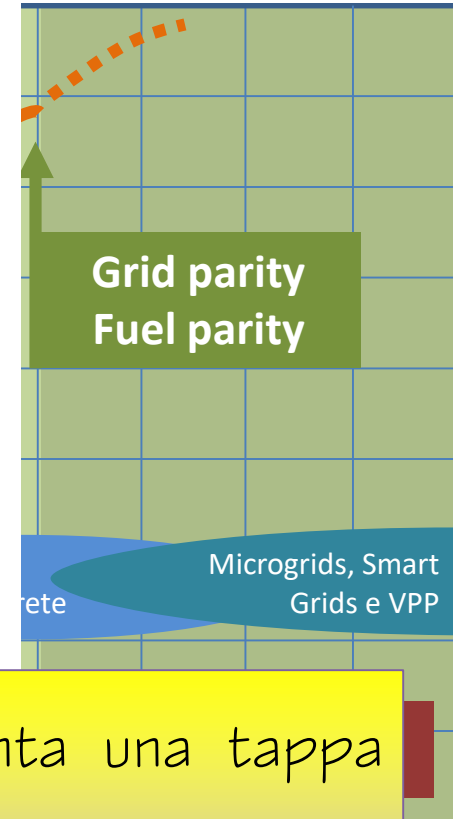
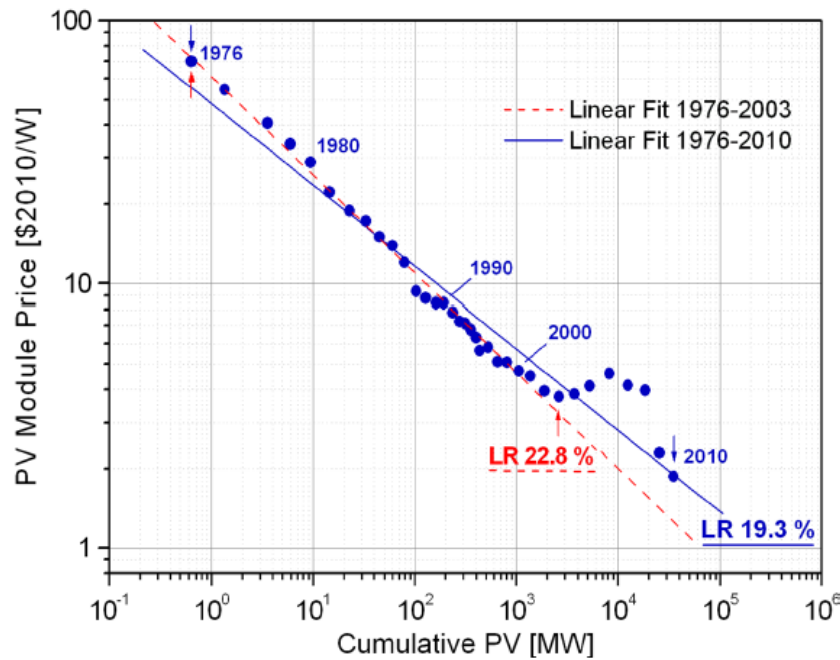
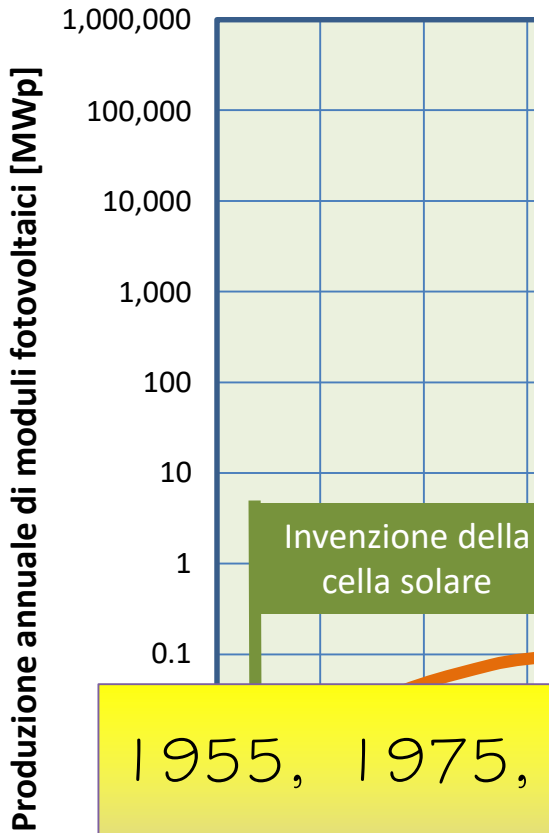
ITALIA ... UN PAESE «CURIOSO»



POTENZA FOTOVOLTAICA PRO CAPITE 2016

COUNTRY	Installed Power [GW]	Population [Millions]	Wp/per capita	Growth (%)
Germany	42	81	518	4
Italy	19	60	317	2
Japan	28	127	220	25
Europe	149	742	200	5
UK	13	66	197	20
USA	40	319	125	58
China	78	1360	57	79
India	9	1250	7	79
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World	302	7571	40	32

STORIA DEL FOTOVOLTAICO



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

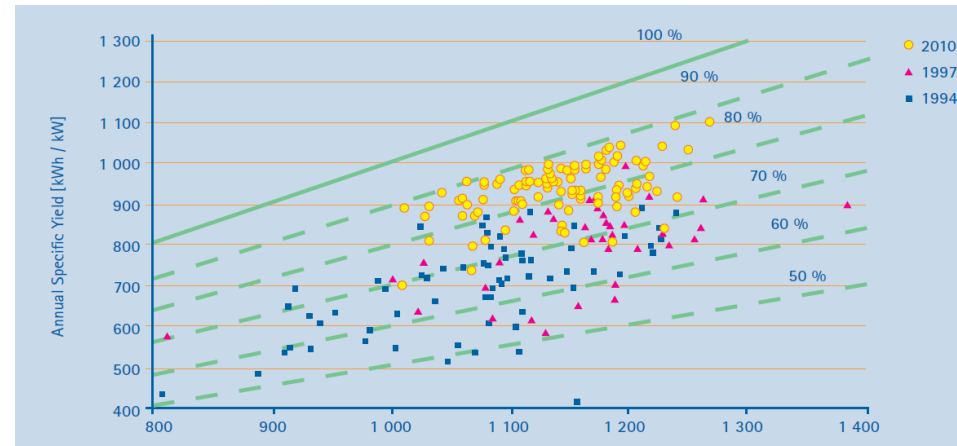
GRID AND FUEL PARITY

- 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

VERSO GRID E FUEL PARITY GLOBALI

$$LCOE = \frac{OCS \times CRF + FO\&MC}{\frac{E_0}{N} \times \sum_{k=1}^N \left(1 - \frac{d_r \times (k-1)}{100}\right)}$$

IERI/OGGI
PERFORMANCE



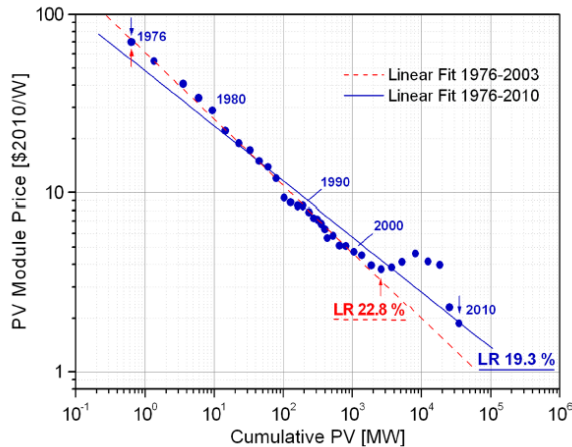
IEA PVPS Annual report 2012

OGGI/DOMANI - BOS

	Moduli [€/Wp]	BOS [€/Wp]	Impianto [€/Wp]	BOS/ impianto [%]
1990	10	2,5	12,5	20
2000	5,5	1,5	7	21
2011	1,1	1,3	2,4	54
2017	0,6	1,2	1,8	67
Riduzione[%]	94	52	86	/

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IERI - MODULI



Il BOS (Balance Of the System) è l'insieme dei costi associati alla costruzione dell'impianto. Eccetto quello dei moduli.

COSTO DI PRODUZIONE

GRID-PARITY – DOMESTICO E COMMERCIALE/INDUSTRIALE

(Italian) Electricity Price (€/kWh)	0.193 – 0.283
Photovoltaic LCOE (€/kWh)	0.05 – 0.11

FUEL-PARITY – IMPIANTI DI GENERAZIONE

Cost of electricity by different sources (€/kWh)	0.045 – 0.150
Cost of electricity from a PV Utility Scale (€/kWh)	0.035 – 0.05

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

Residential and C&I (€/kWh)	0.04 – 0.09
Utility Scale – Sicily (€/kWh)	0.025 – 0.035

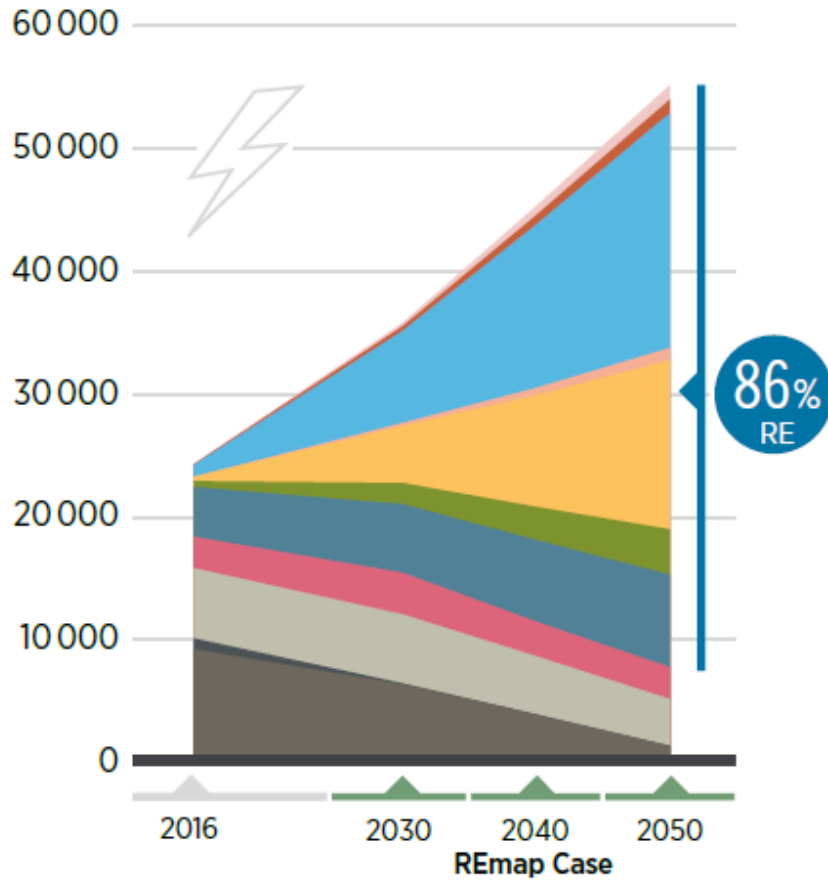
THE ROLE OF DSOs

ENEL AND THE ROAD FOR RELAUNCHING

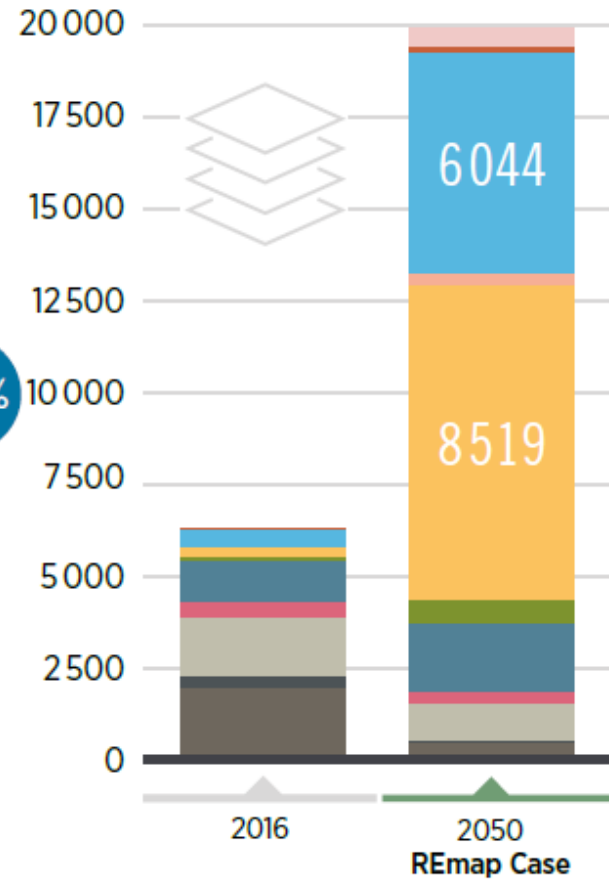
The energy revolution will lead to a strong growth in domestic solar PV and the spread of energy storage devices



Electricity generation (TWh/yr)



Total installed power capacity (GW)



- Coal
- Nuclear
- Solar PV
- Geothermal
- Oil
- Hydro (excl. pumped)
- CSP
- Others (incl. marine)
- Natural gas
- Bioenergy
- Wind (onshore and offshore)

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2010	TODAY (2017/2018)	2030	REMAP CASE		ON/OFF TRACK	IMPLICATIONS
			2040	2050		

ELECTRIFICATION WITH RENEWABLES

Share of electricity in final energy consumption (TFEC)	18%	20%	29%	38%	49%	Off track	Focus on electric mobility and electrifying heat in buildings and industry, and on synthetic fuels and feedstocks – see further recommendations below.
Renewable energy share in power generation	20%	25%	57%	75%	86%	Progress	Emphasise solar and wind deployment, but also maximise solid biomass and biogas in the niche applications where they make sense.
Annual solar PV additions	17 GW/yr	109 GW/yr	300 GW/yr	355 GW/yr	360 GW/yr	Progress	Accelerate solar deployment by reinforcing existing policy and market support.
Annual wind additions	31 GW/yr	54 GW/yr	200 GW/yr	210 GW/yr	240 GW/yr	Off track	Plan for wind industry and required logistics to enable accelerated deployment. Consider the large potential of offshore deployment.
Passenger electric cars on the road	<0.5 mln	6 mln	157 mln	745 mln	1166 mln	Progress	Enact measures to support getting electric cars purchasing price down and invest heavily in charging infrastructure.
Heat pumps		20 mln	155 mln	259 mln	334 mln	Off track	Promote public awareness about the advantages of heat pumps and create special lines of finance to project developers that can disseminate the technology.
Hydrogen production with renewable electricity			3 EJ	8 EJ	19 EJ	Emerging	Find the niches where this makes sense today and support commercial-scale pilot projects.