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

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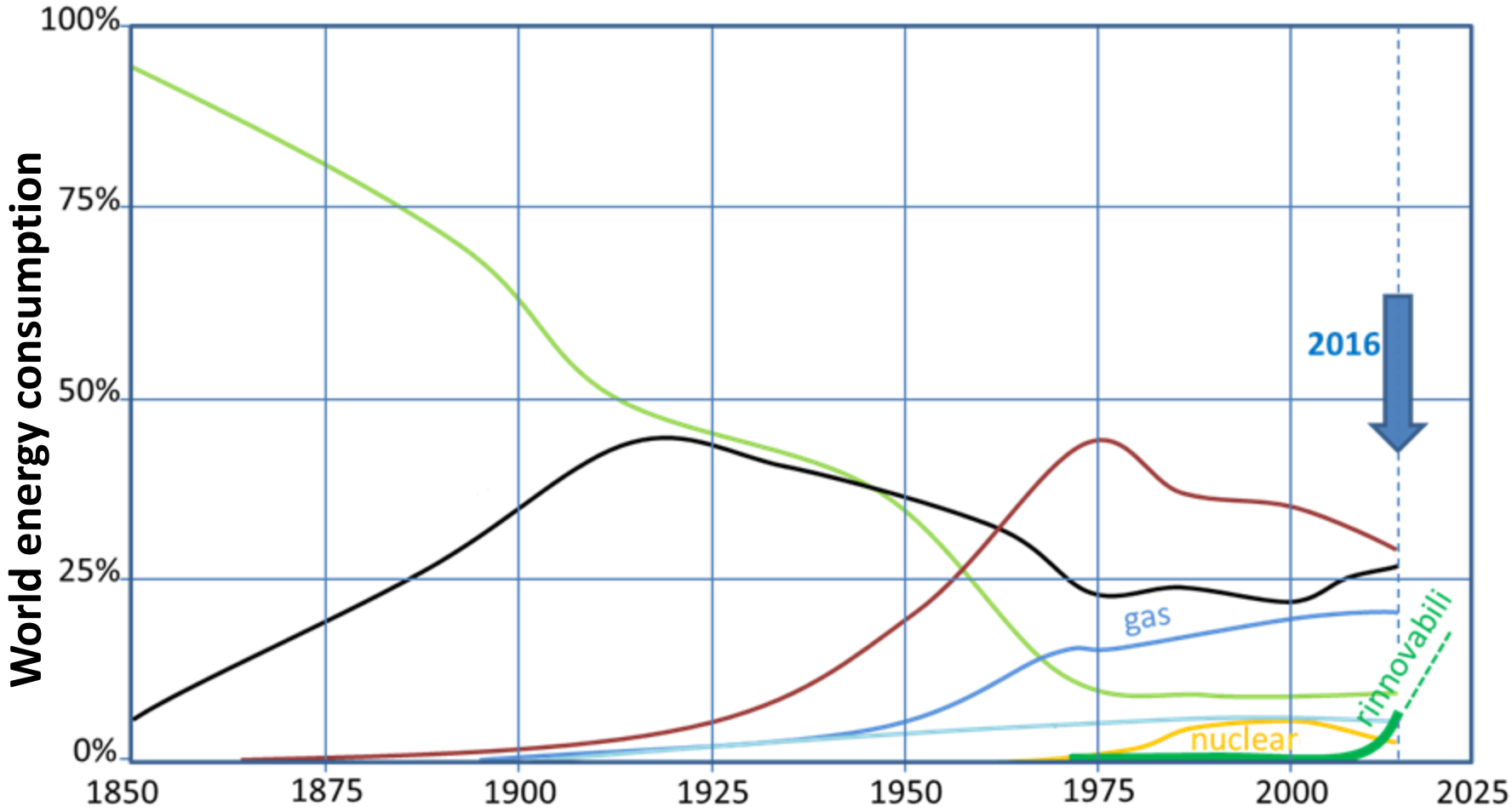
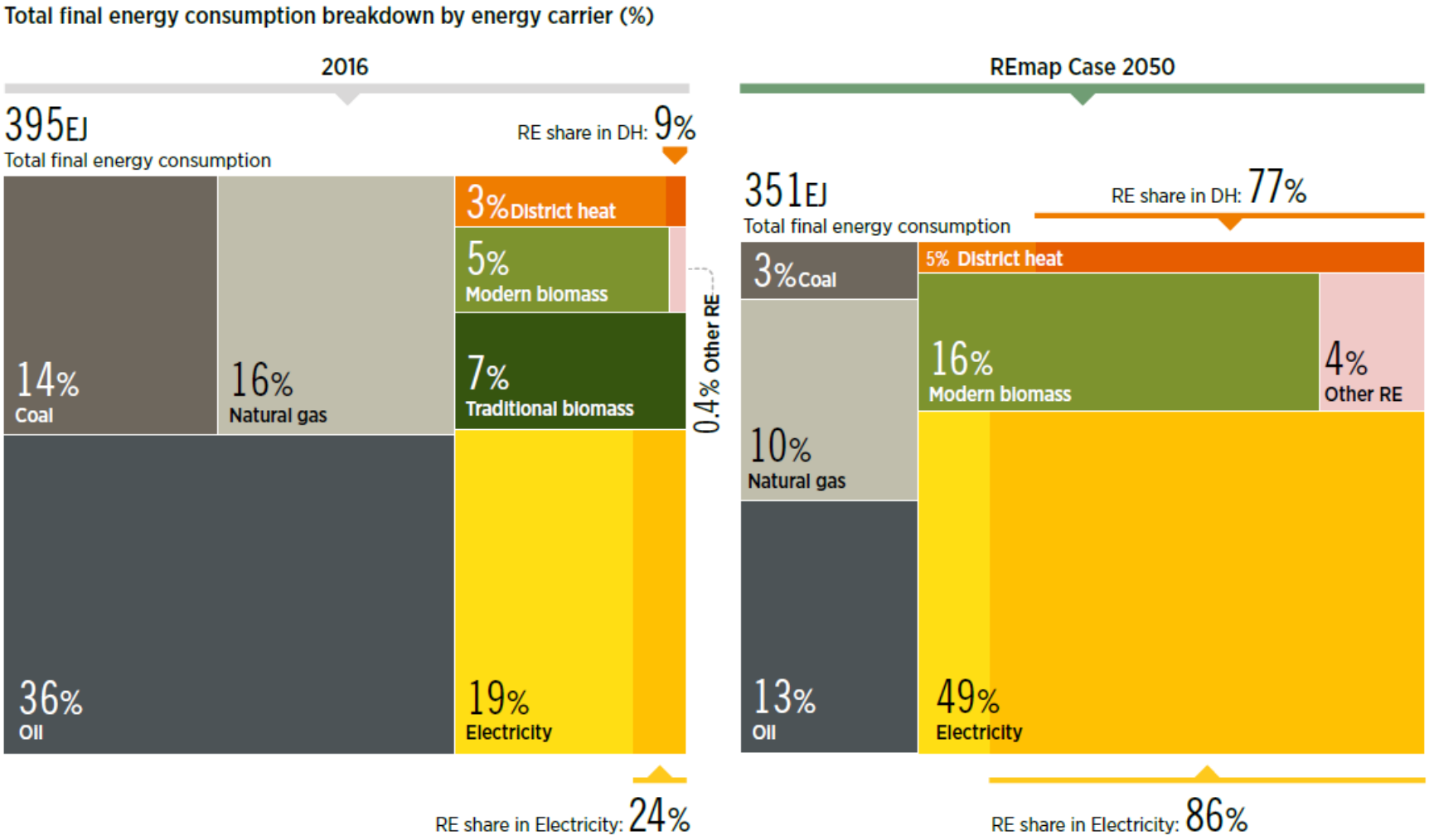
Summer School on Energy
Giacomo Ciamician

TRANSIZIONI ENERGETICHE

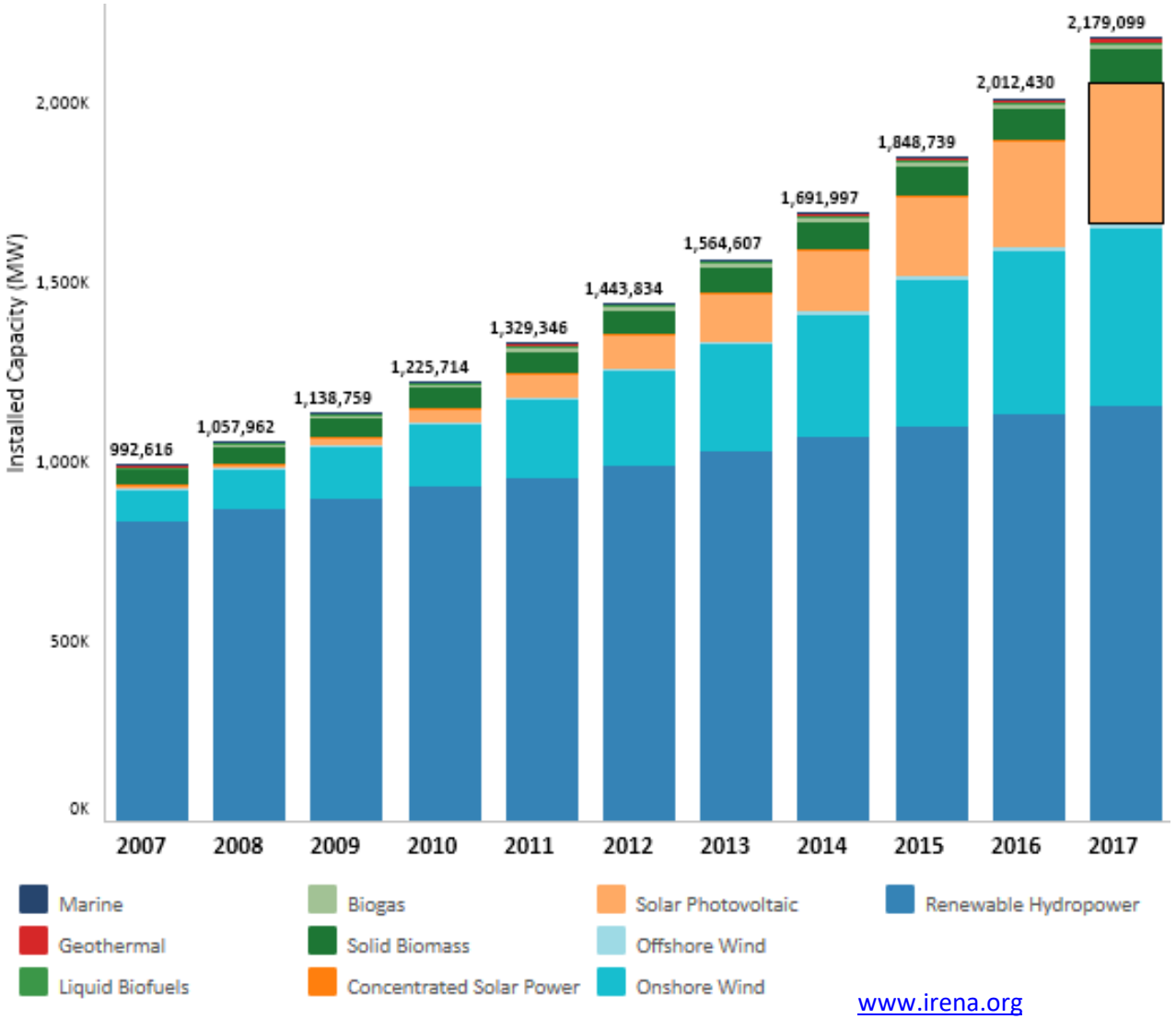


A. Massi Pavan, V. Lughi La forza del Sole Sapere, 2016



Global energy transformation, IRENA 2019

BOOM DI RINNOVABILI

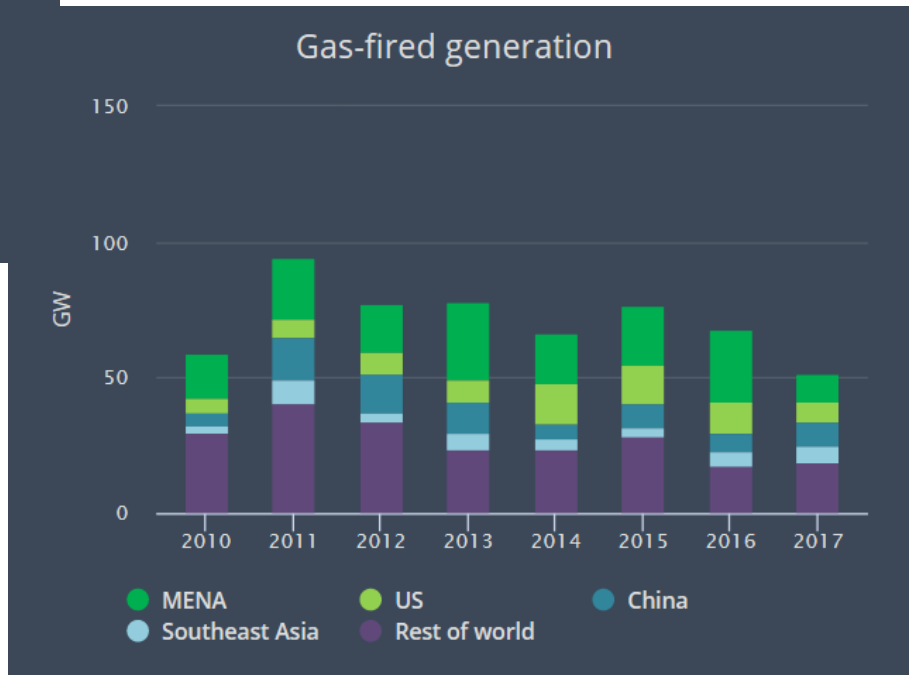


www.irena.org

E LE TRADIZIONALI …

RES ≈ 2,2TW

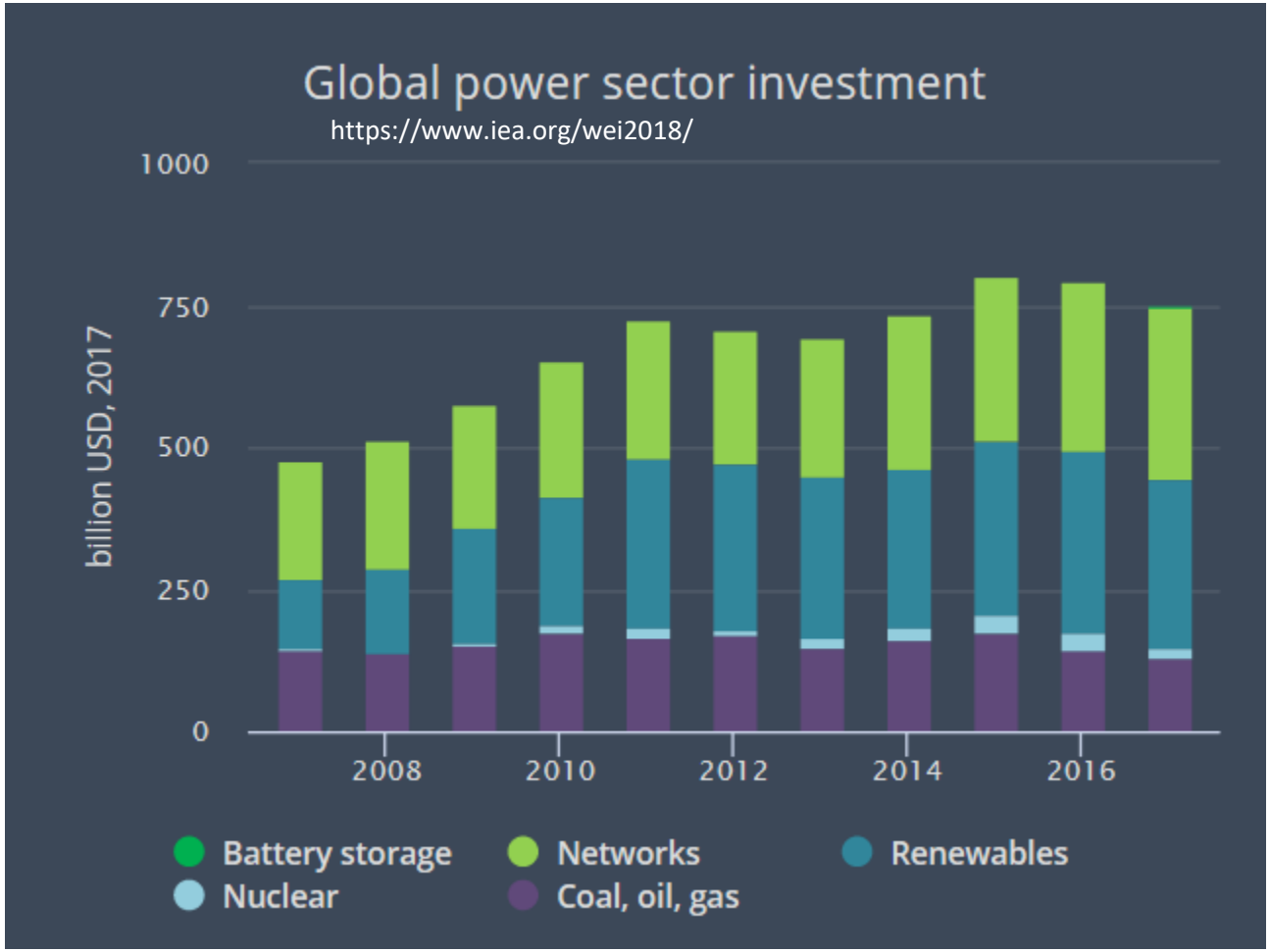
NUCLEARE ≈ 0,5TW



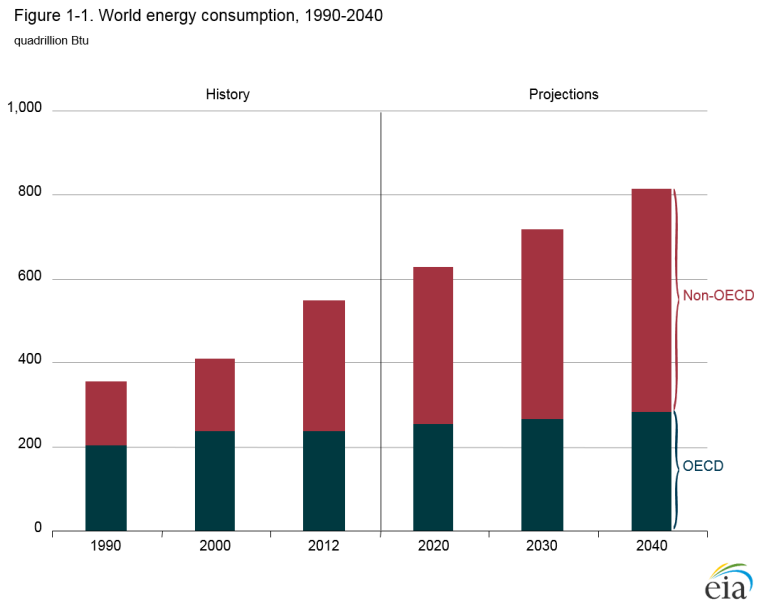
GAS ≈ 1,5TW

CARBONE ≈ 1,9TW

INVESTIMENTI SETTORE ENERGETICO



1. LE RISORSE ENERGETICHE SONO LIMITATE



Estimates of world crude oil and NGLs resources *billion barrels*

Average Oil Demand (2013-2035): 100

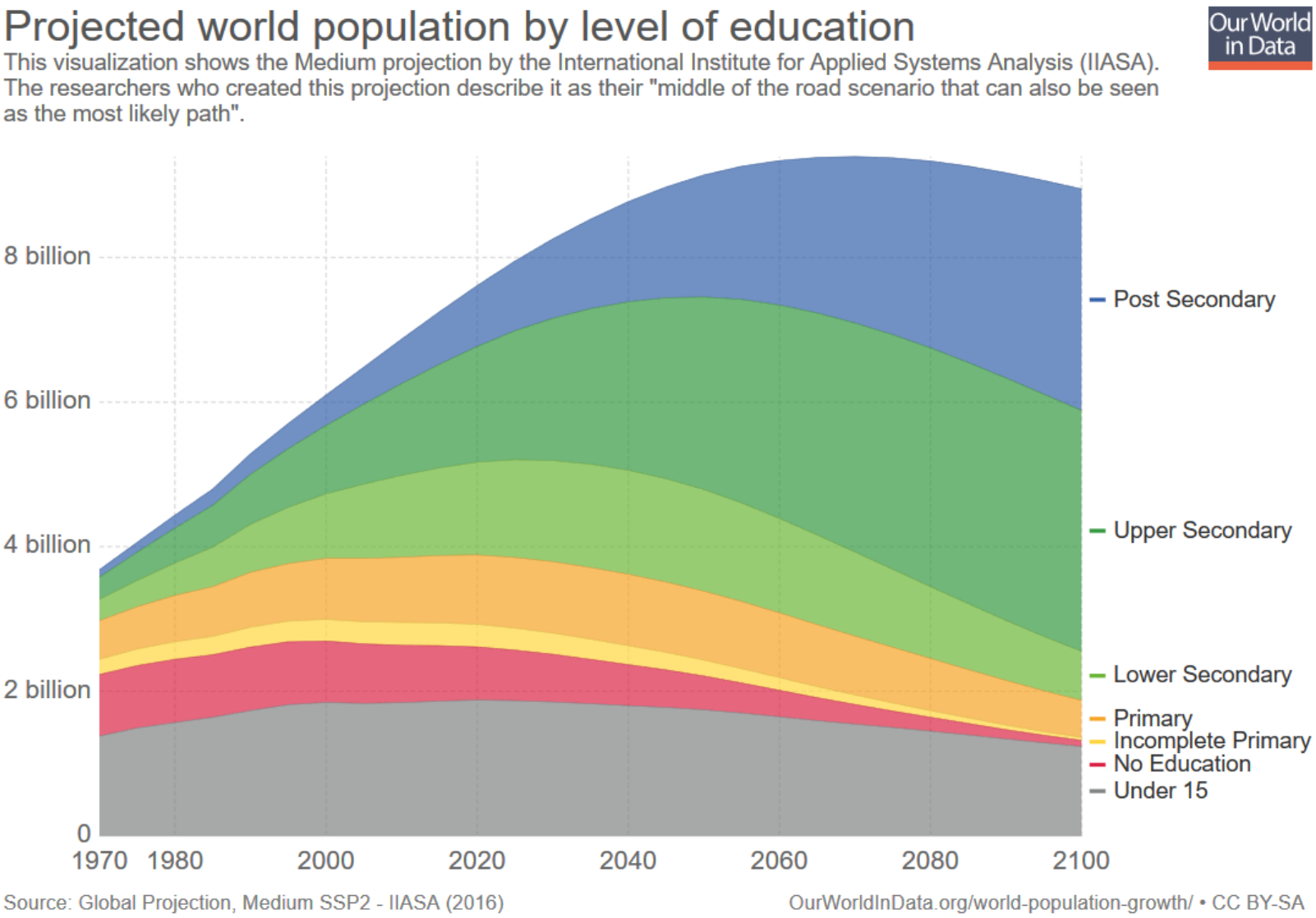
		Non-OPEC	Total world
Cumulative production to 2010 (a)	446	695	1,142
Proved reserves (b)			1,467
Reserves to be added ultimately (c)	**617**	**620**	**1,237**

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

World Oil Outlook – OPEC 2012

Total reserves: 2,704

TUTTO E' LIMITATO



2. RISCALDAMENTO GLOBALE

HOME | NEWS | SPO

Pictures | EU referendum

r Ludovico
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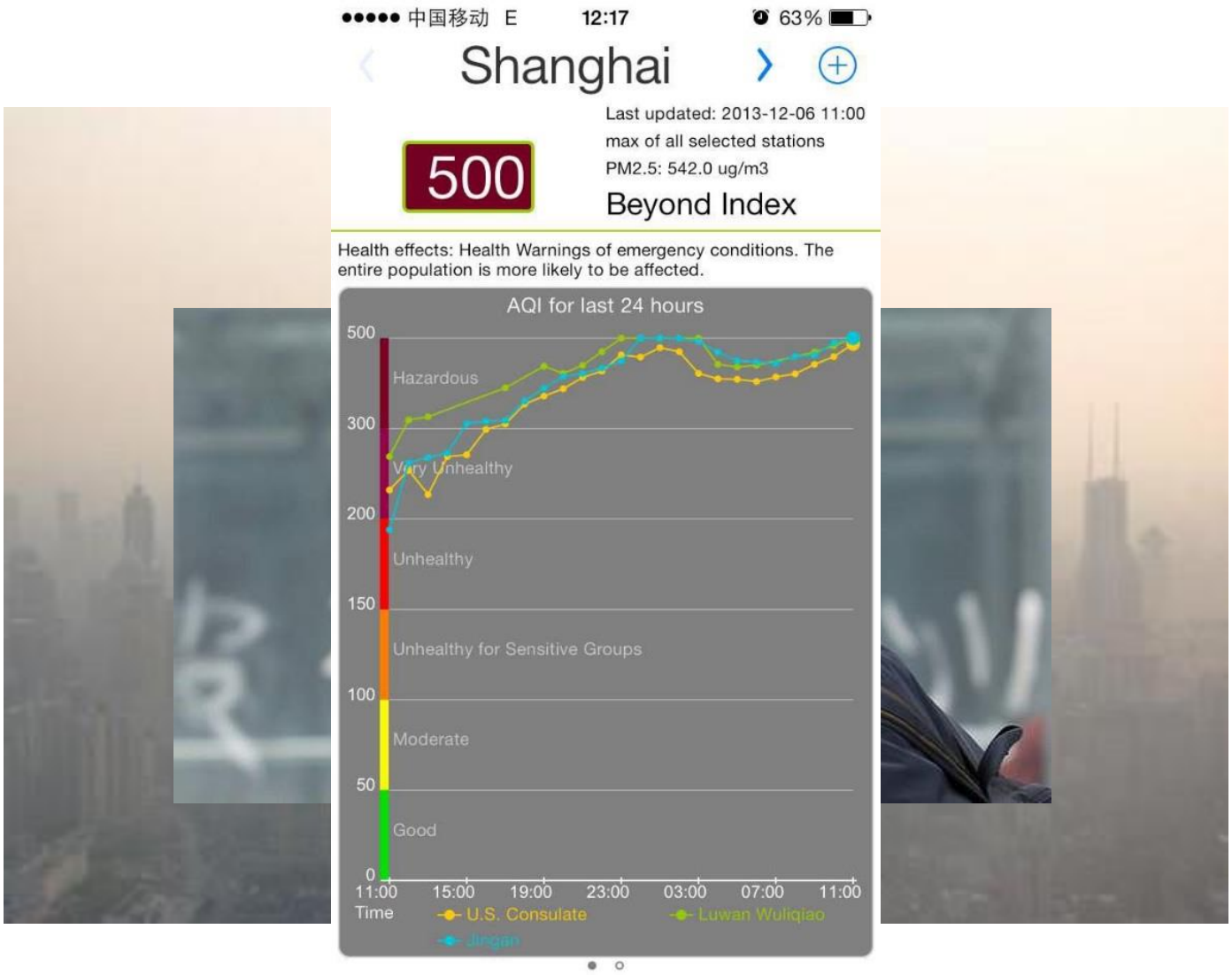
3. QUALITA' DELLA VITA



4. CONVENIENZA ECONOMICA

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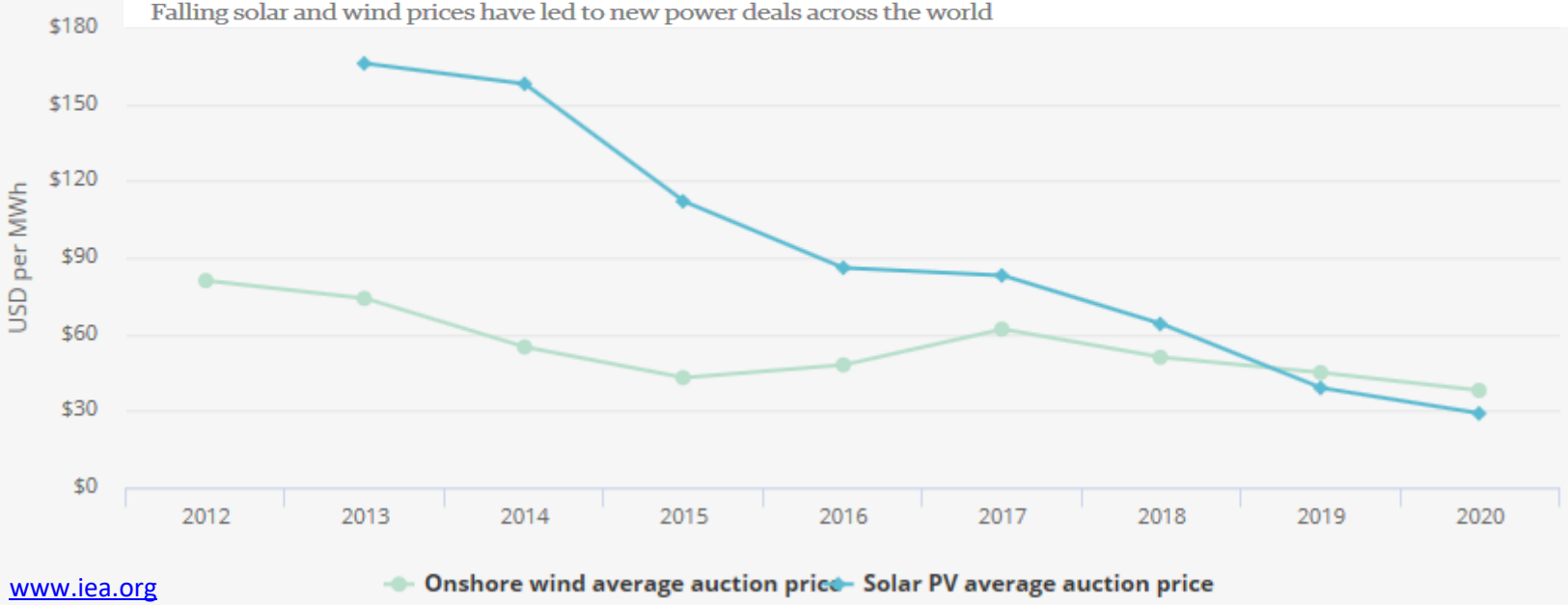
Renewable energy

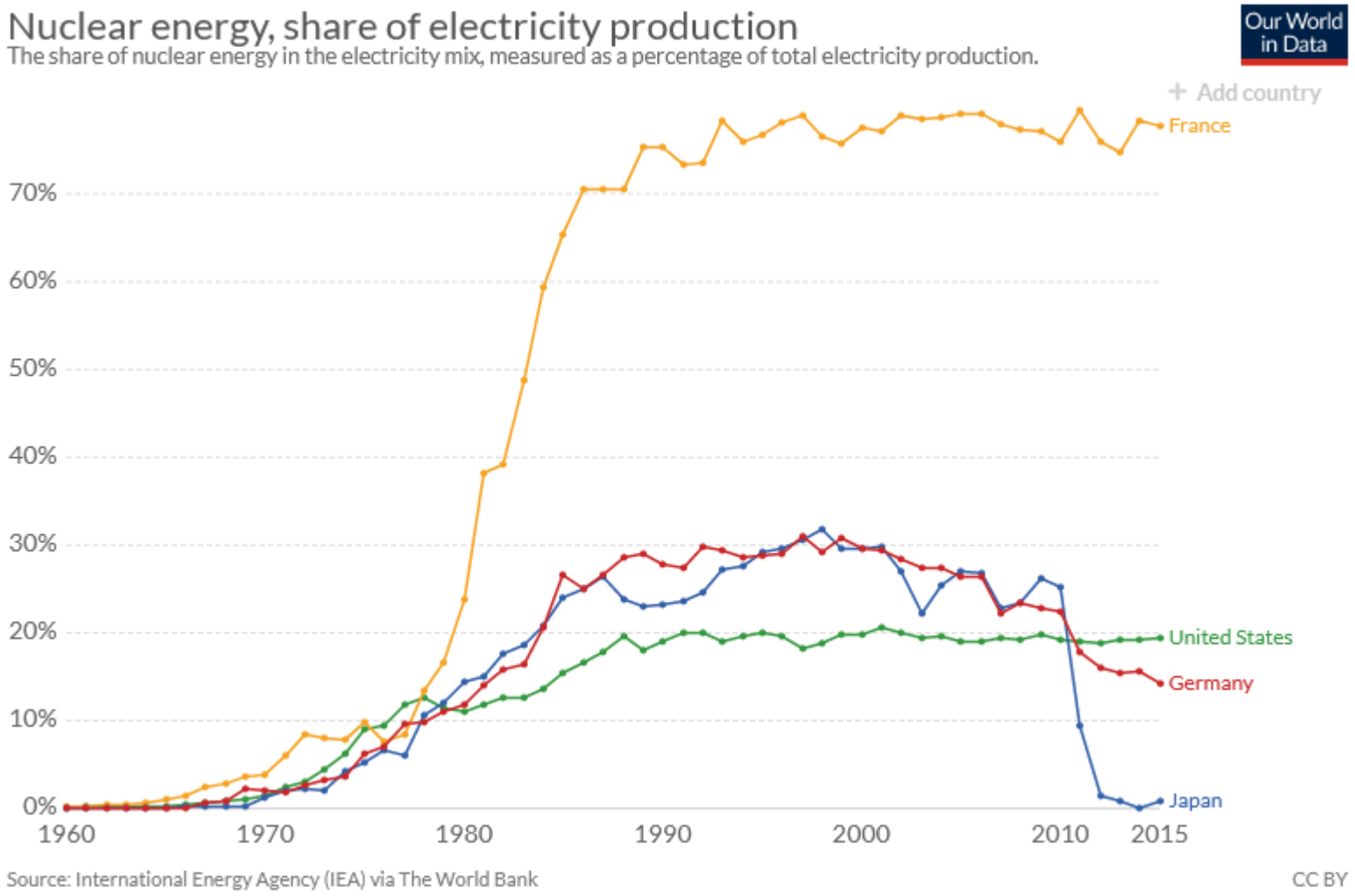
'Spectacular' drop in renewable energy costs leads to record global boost

Falling solar and wind prices have led to new power deals across the world



www.iea.org

NON PER IL NUCLEARE …



Alessandro Massi Pavan
Trieste, 16092019

5. TEMPI DI INSTALLAZIONE

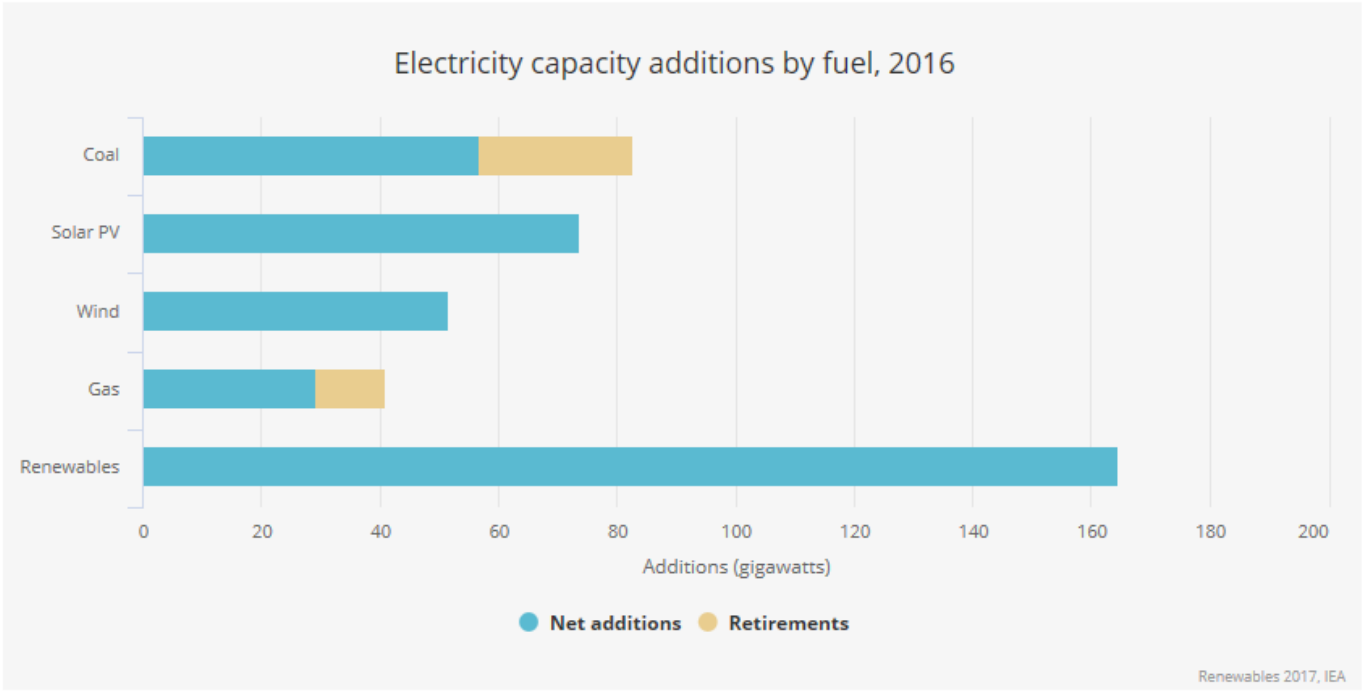
IRENA – *Global Landscape of renewable energy finance 2018*

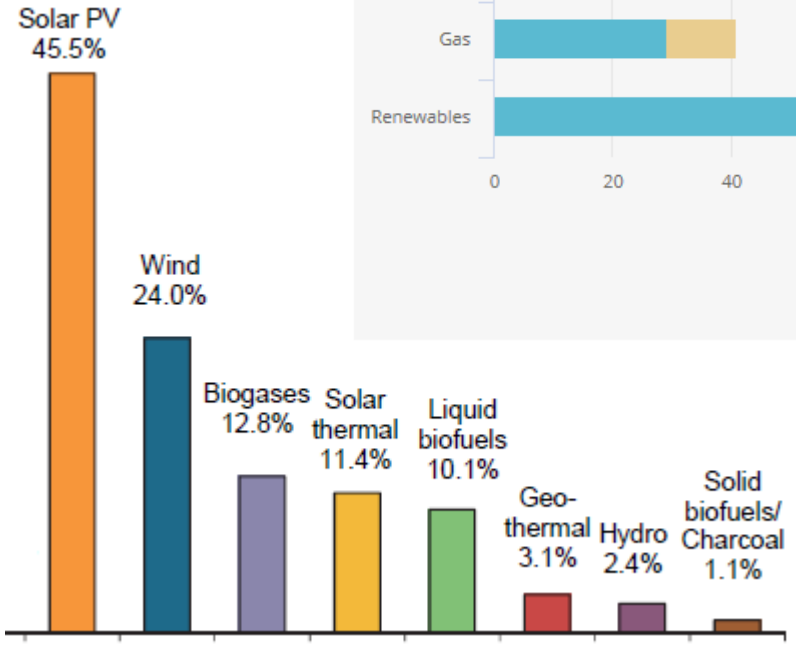
Technology	Number of years
Solar PV	**0.5**
Wind onshore	**0.8**
Bioenergy	**1.7**
Wind offshore	**1.7**
Geothermal	**1.9**
Solar thermal	**2**
Marine	**2.2**
Small hydro	**2.3**

Nucleare 6 – 12,5!!!

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

IL RUOLO DEL FOTOVOLTAICO



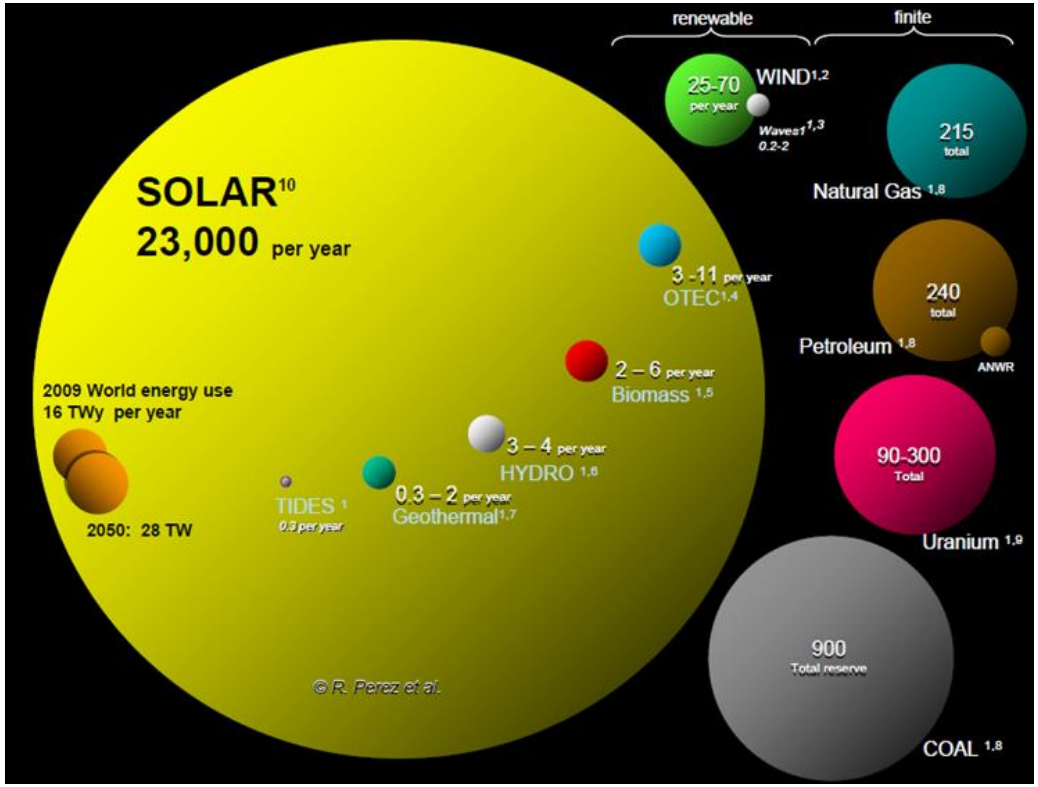


IEA, Renewables information: overview statistics, 2017

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

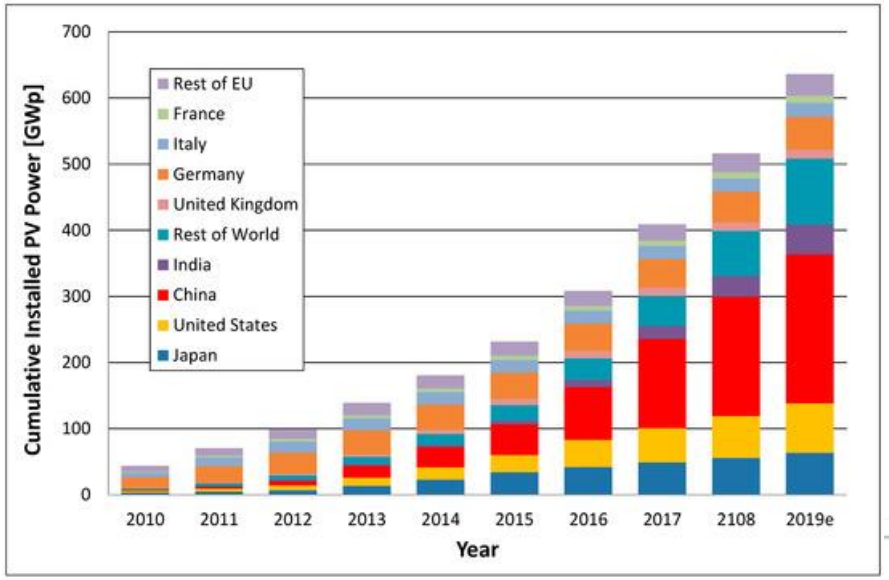
THE PHOTOCHEMISTRY OF THE FUTURE[1]

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.

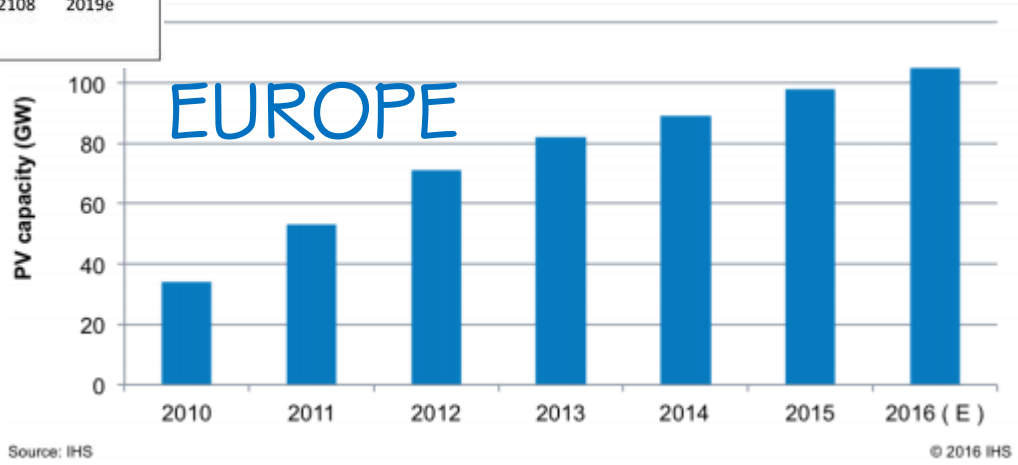
"...if our black and nervous civilization, based on coal, shall be followed by a quieter civilization based on the utilization of solar energy, that will not be harmful to progress and to human happiness."

POTENZA INSTALLATA

WORLD

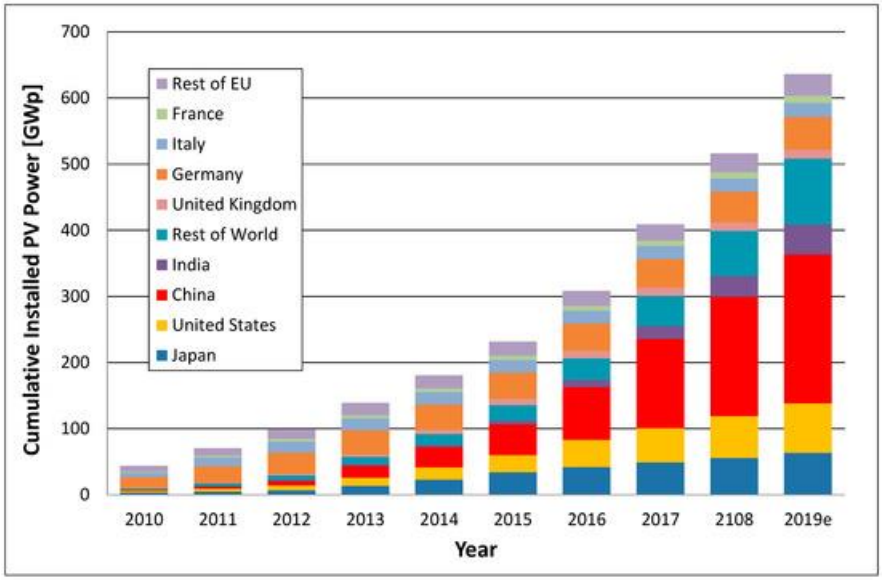


EUROPE



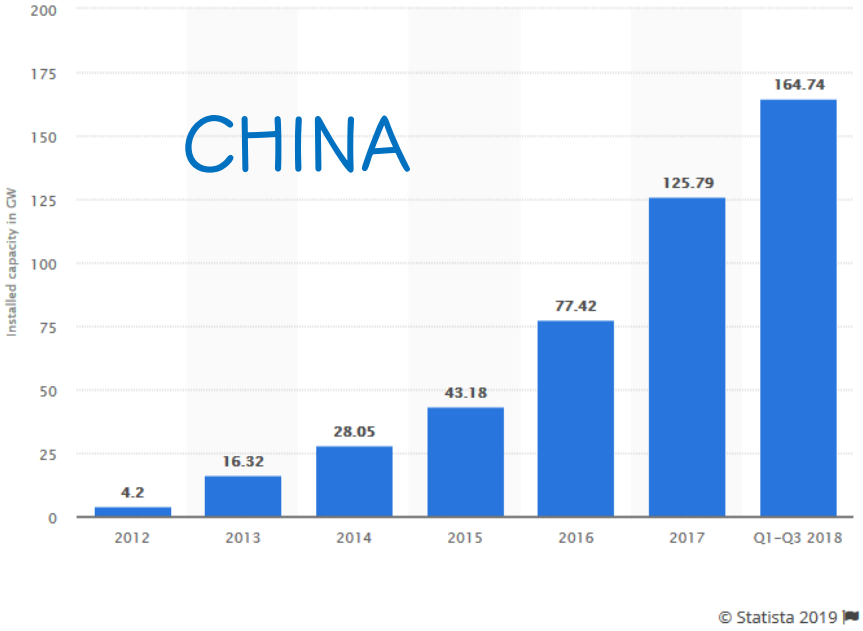
POTENZA INSTALLATA

WORLD

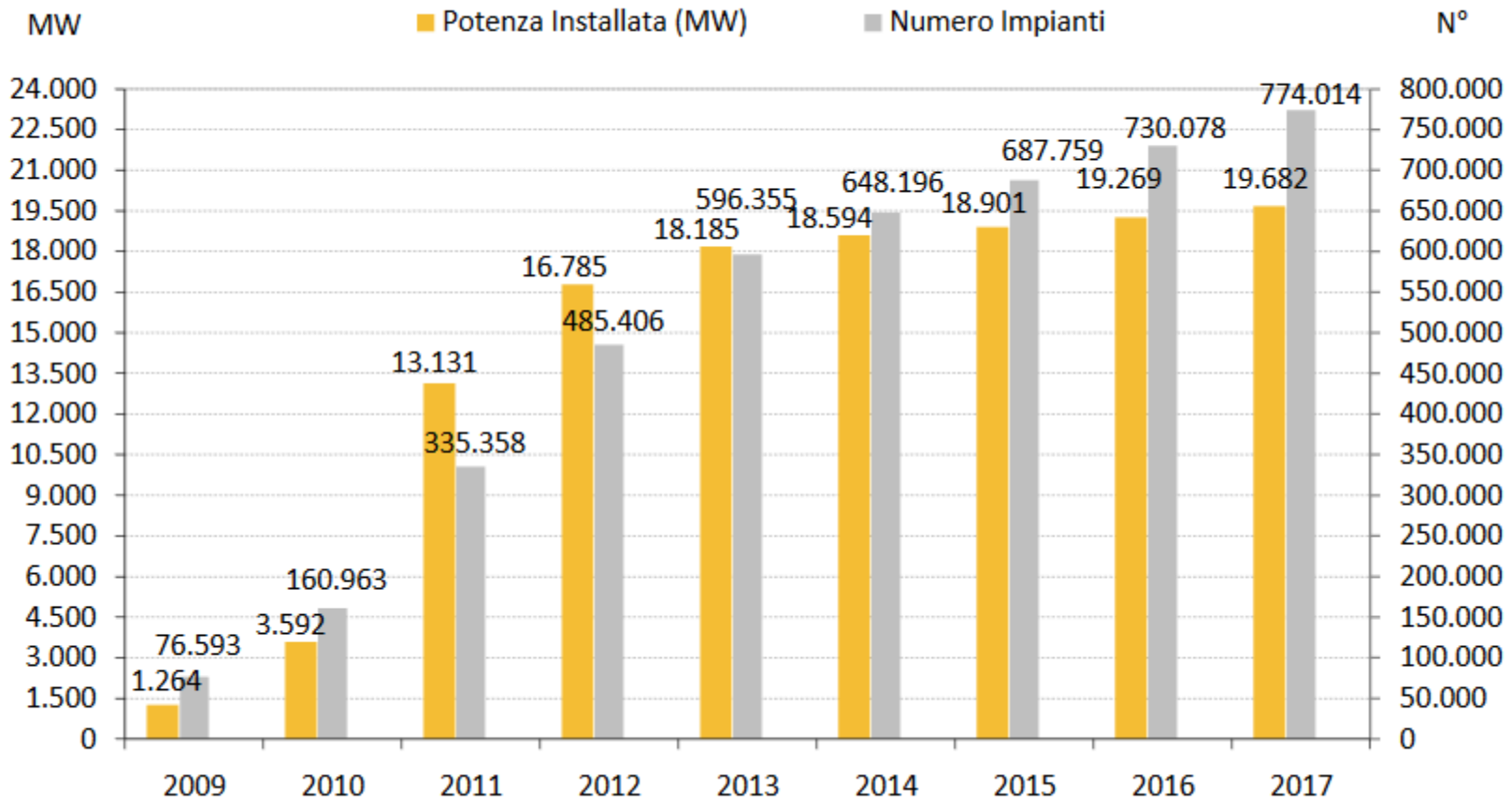


A. Jager-Waldau. Snapshot of Photovoltaics, Energies 2019

CHINA

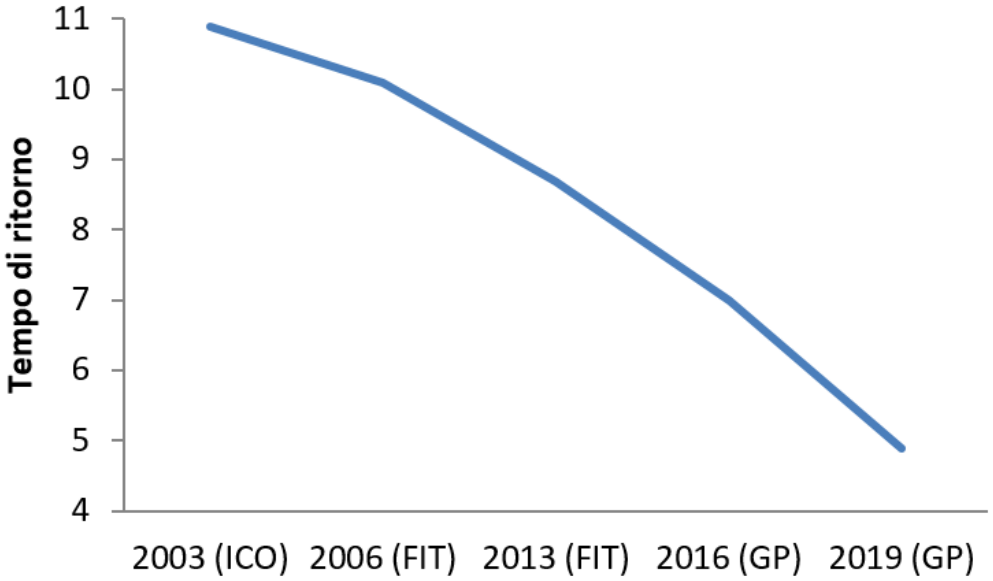


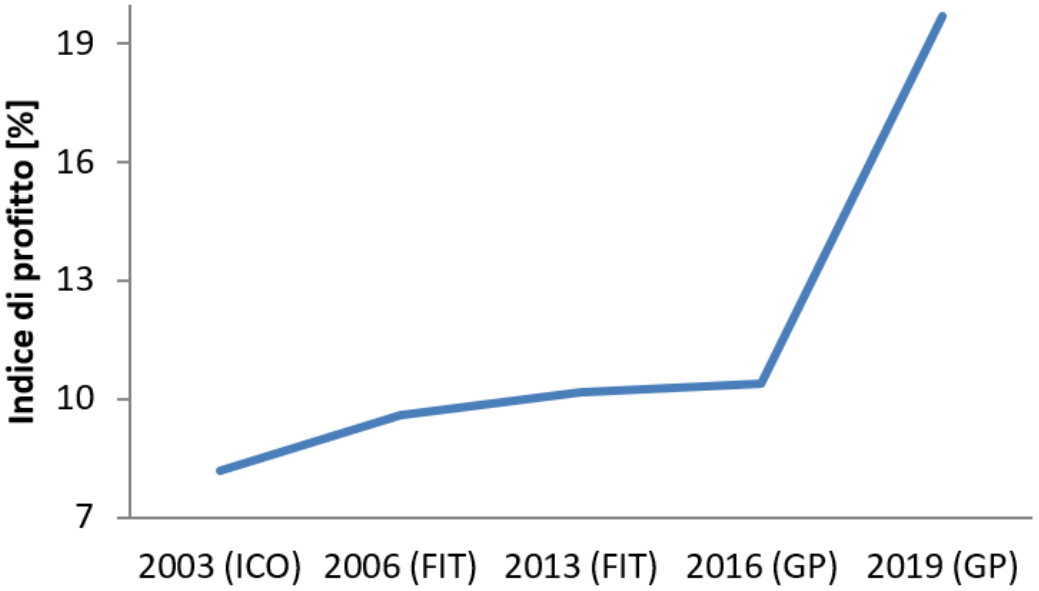
PV CUMULATIVE POWER - ITALY



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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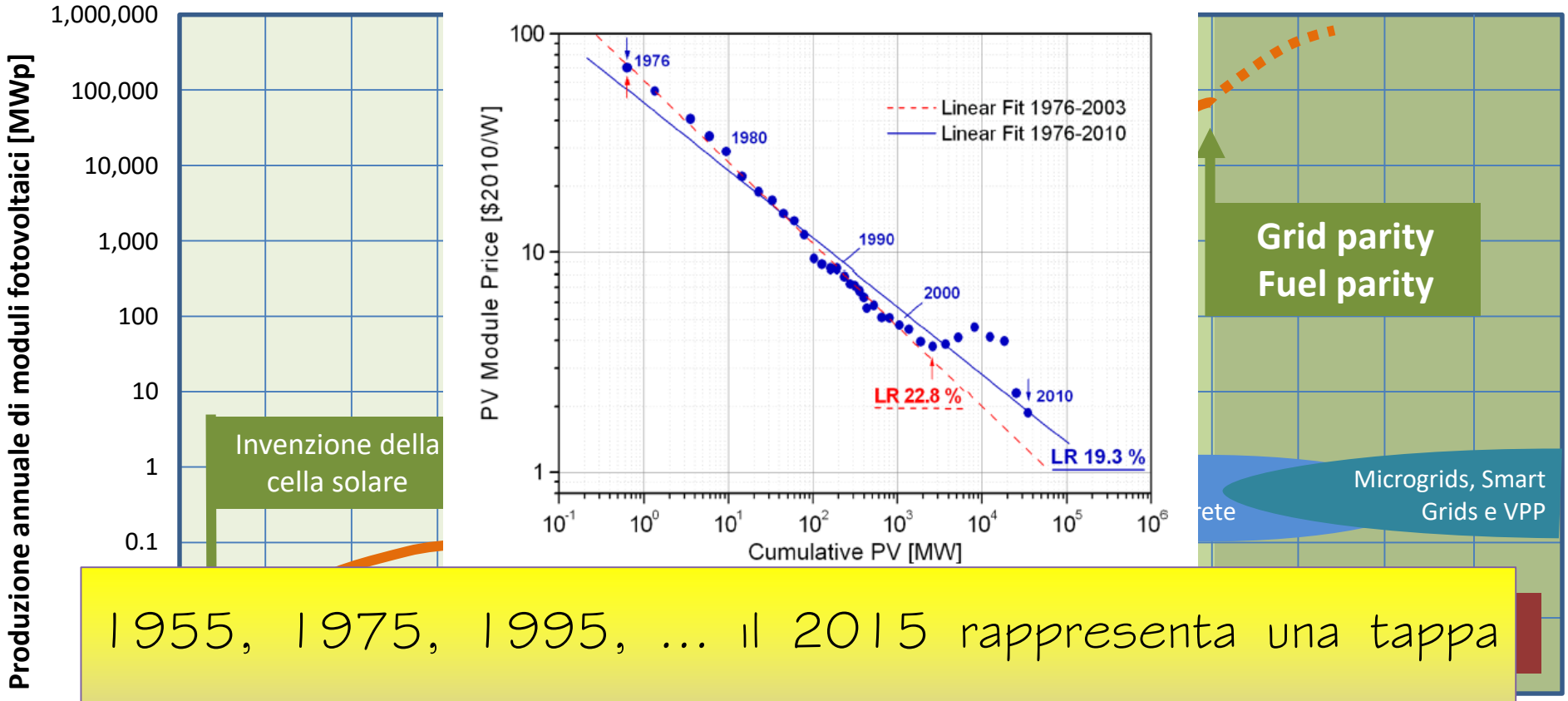
World	**302**	**7571**	**40**	**32**

STORIA DEL FOTOVOLTAICO



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

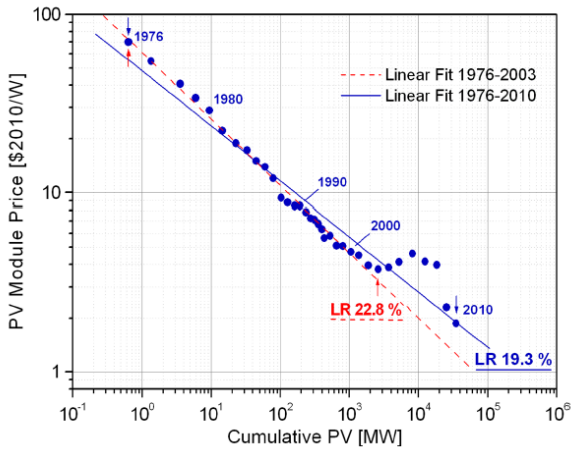
GRID AND FUEL PARITY

- 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

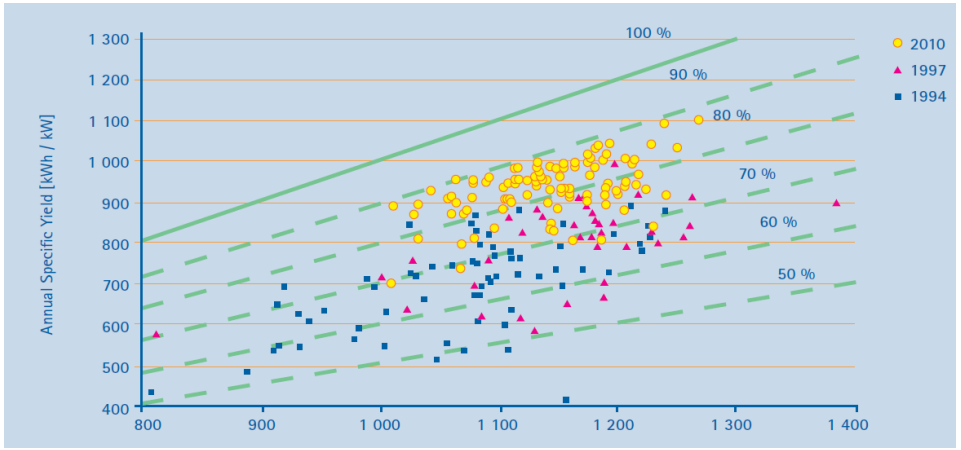
VERSO GRID E FUEL PARITY GLOBALI

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

IERI - MODULI



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	/

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

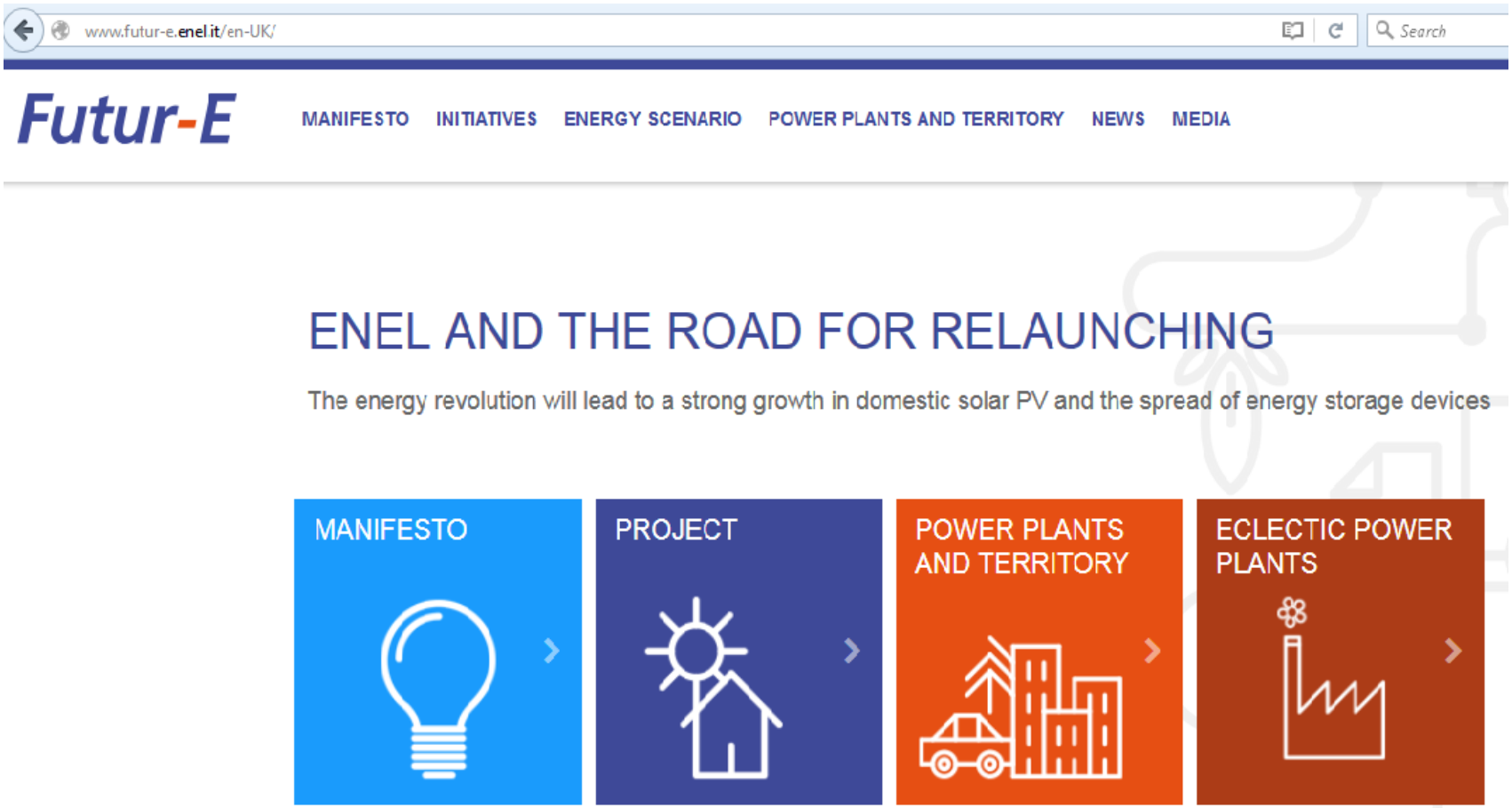
COSTO DI PRODUZIONE

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



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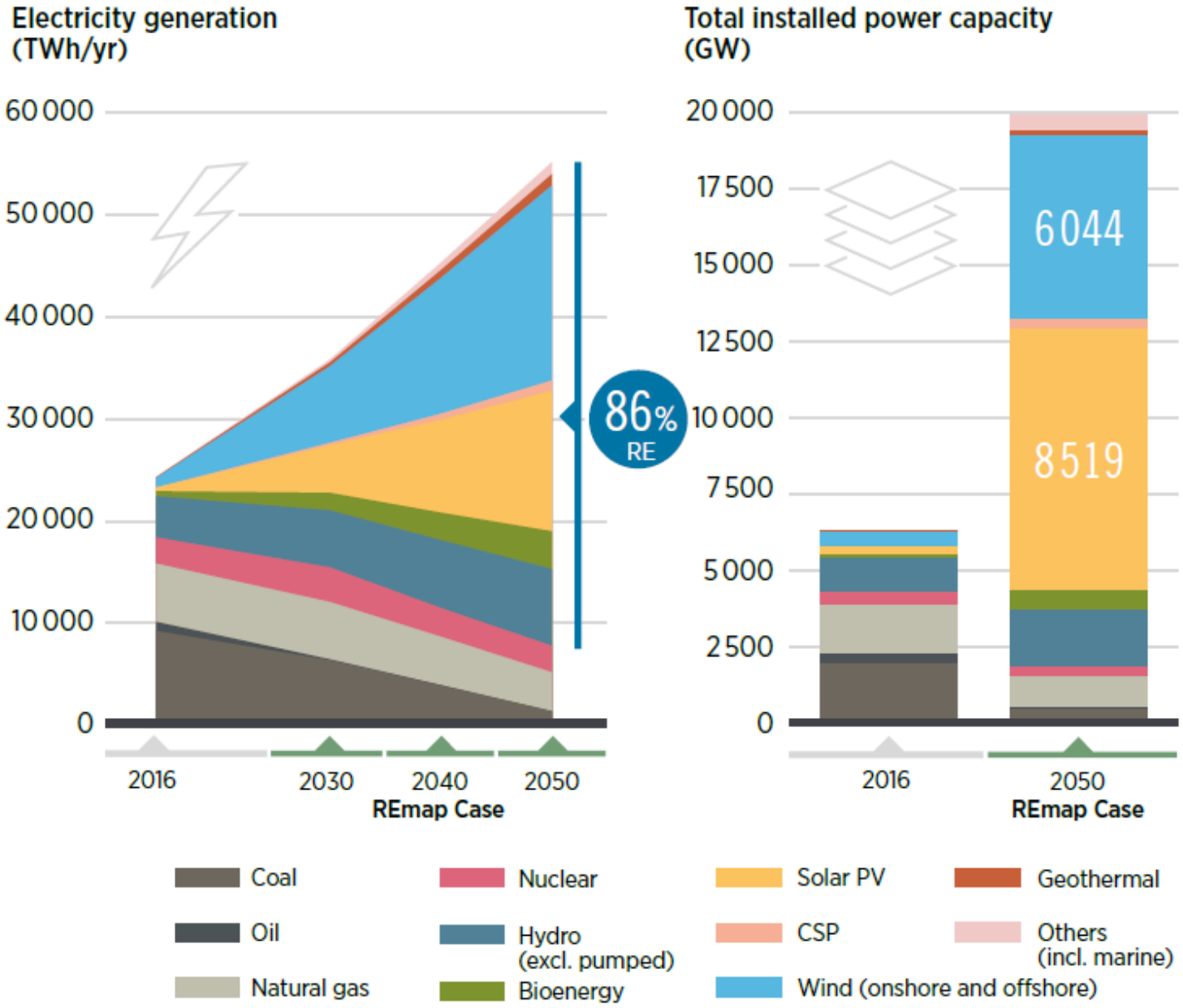
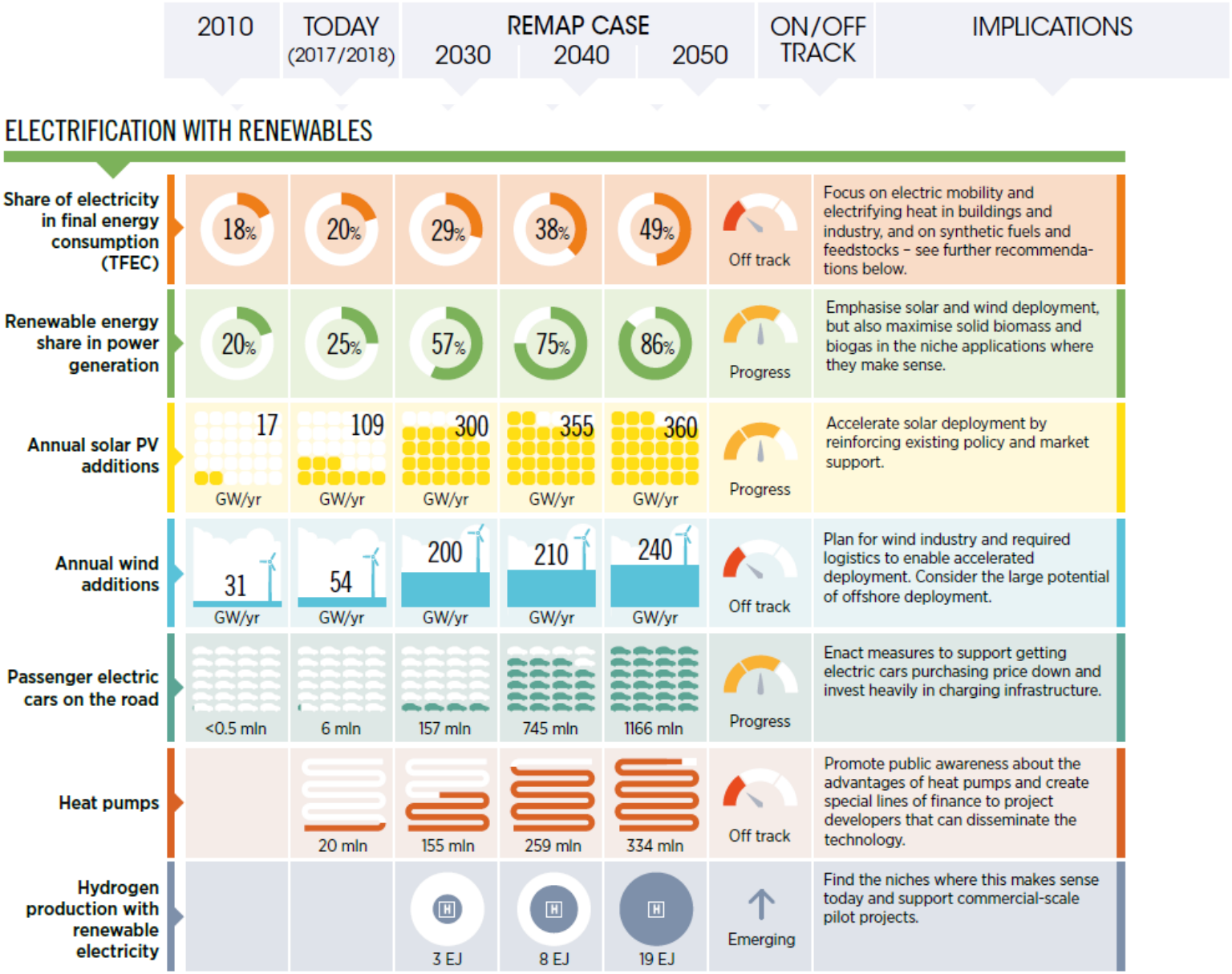


Global energy transformation, IRENA 2019



Global energy transformation, IRENA 2019