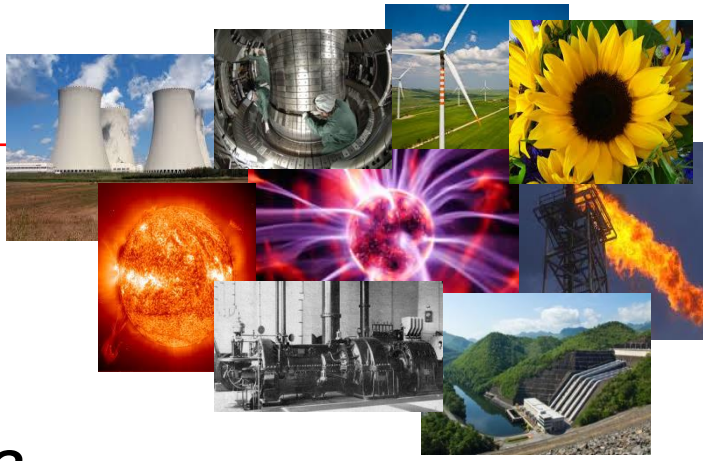


Engineering School
University of Florence

Can RENEWABLE ENERGY make it on ITS OWN?

Prof. Carlo Carcasci

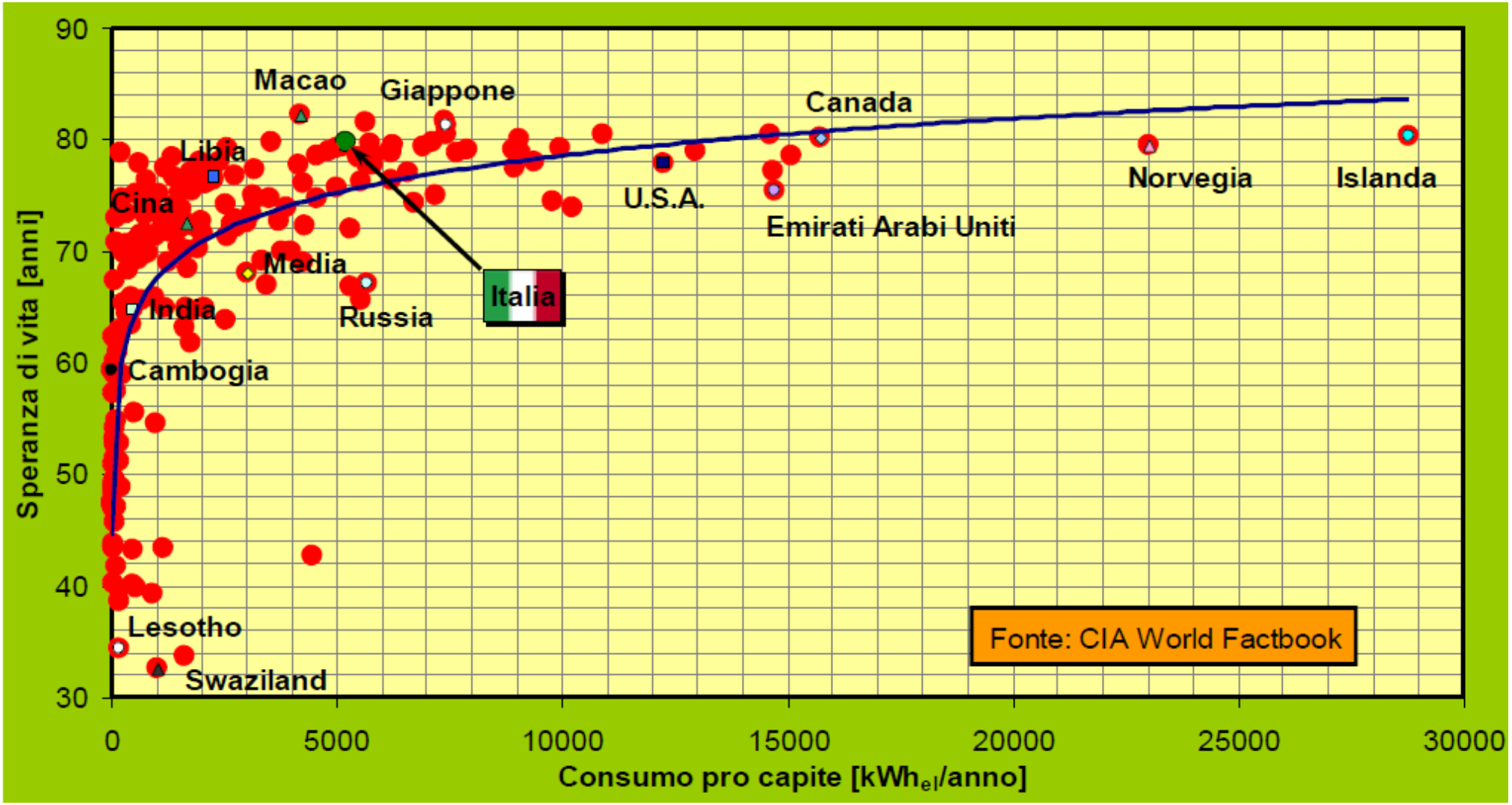
Lezione di divulgativa scientifica
Course of "Energy, Environment and European security"

aa 2020/2021

How much is important the Energy Today??

- The influence of energy in our life is high!
  - ⇨ Direct-Mode
    - ➔ Transport
      - – Car
      - – Airplane
      - – …
    - ➔ Heater
      - – Domestic
      - – Industrial
    - ➔ Elettricity
      - – Light
      - – Household appliences
      - – ….

Life Expectancy VS Energy



How much energy…

- To sustain the quality of life you need (much) energy:
  - ⇨ A school student 400 kWh/year [1]
  - ⇨ A university student 1700 kWh/ year[1]
  - ⇨ A hospital bed 3000 kWh/ year[2]
  - ⇨ A prisoner 7000 kWh/ year[3]

- How much electricity energy can a person produce in a year?

Kahoot #5

  - ⇨ **200. kWh/y** =0.20 MWh = 200.kWh/y
    - ➔ 100 W ·40h/week ·50 week/year
    - ➔ A school student consumes **twice** as much energy as he himself can produce
      - 200kWh/y produced against 400.kWh/y consumed

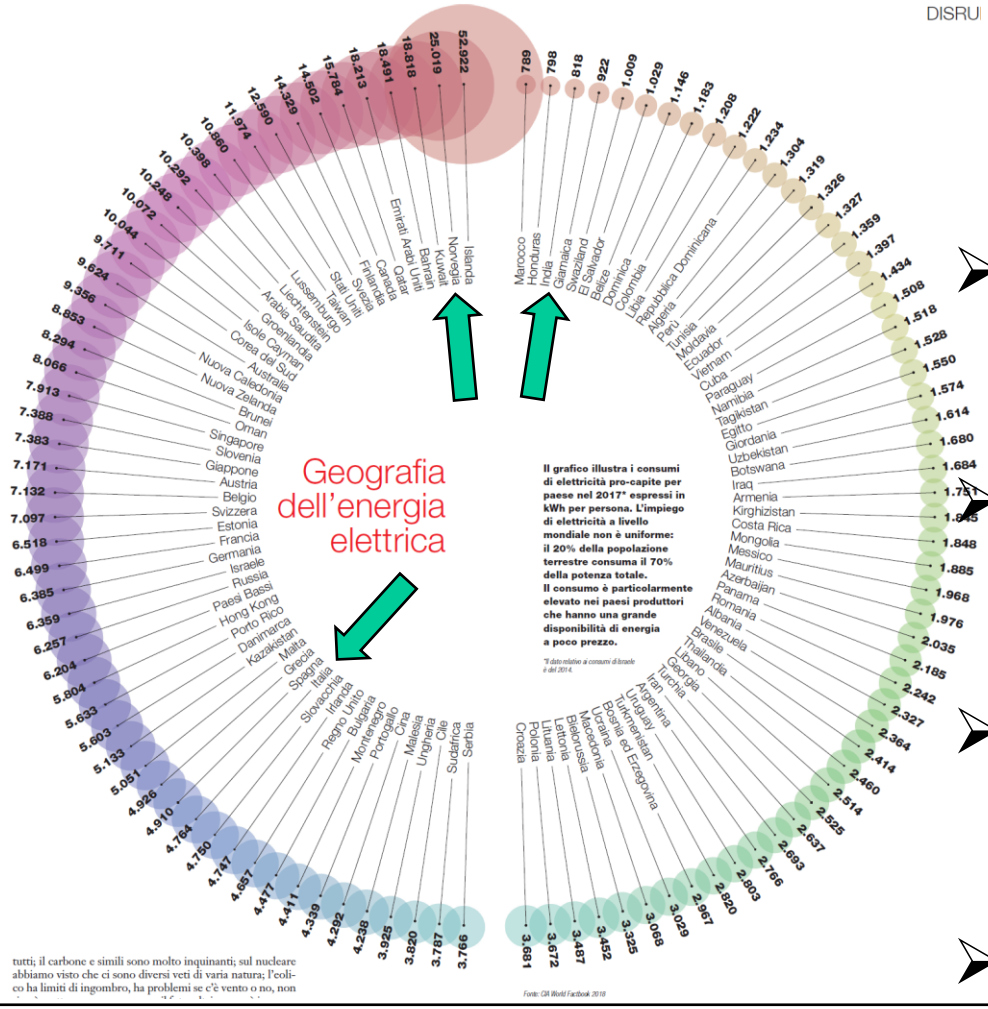
[1] AA.VV., 2003, "The UK Potential for Community Heating with Combined Heat and Power", Building Research Establishment Ltd.
[2] Piacentino, A., 2004, Applicazioni della cogenerazione e della trigenerazione in edifici residenziali e del terziario civile: analisi energetica, exergetica ed economica delle diverse soluzioni impiantistiche utilizzabili, Università degli Studi di Palermo.
[3] AA.VV., 2004, Energy Consumption Guide ECG084 – Energy Use in Prisons, Action Energy.

How much energy…

- In ITALY, we consume about 5.00 MWh/Year per capita of electricity
  - ⇨ We emit the corresponding pollution.
  - ⇨ **25 times** the energy that a person can produce
- In **Angola**, they consume (and corresponding pollution) for 0.16 MWh
  - ⇨ About the same energy produced by a person
  - ⇨ But…
    - ➔ 20% of children die by the first year of age
    - ➔ Life expectancy is 39 years
      - – As in Italy 150 years ago!

[1] AA.VV., 2003, "The UK Potential for Community Heating with Combined Heat and Power", Building Research Establishment Ltd.
[2] Piacentino, A., 2004, Applicazioni della cogenerazione e della trigenerazione in edifici residenziali e del terziario civile: analisi energetica, exergetica ed economica delle diverse soluzioni impiantistiche utilizzabili, Università degli Studi di Palermo.
[3] AA.VV., 2004, Energy Consumption Guide ECG084 – Energy Use in Prisons, Action Energy.

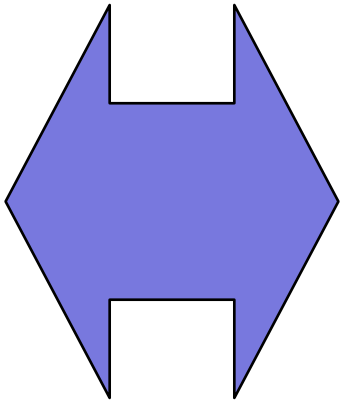
Electricity consumption per capita of electricity 2017

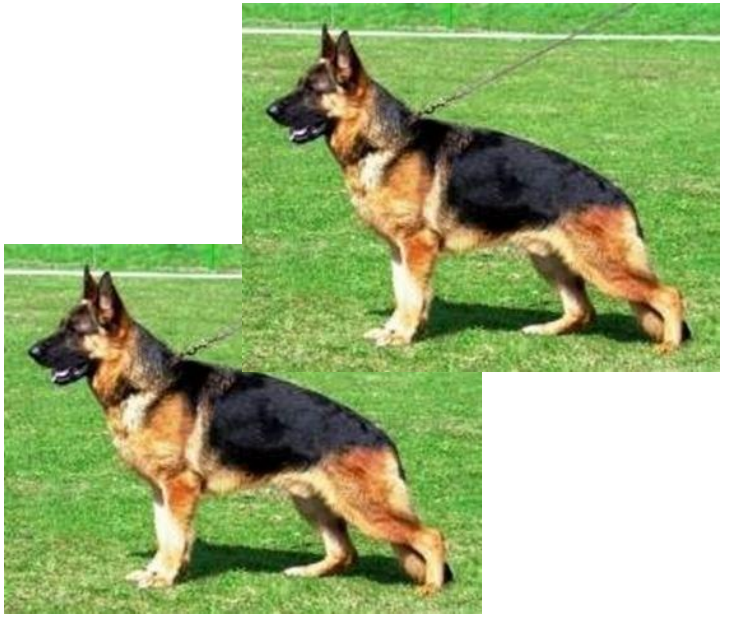


- **Italian** electricity consumption: 4764. kWh/person *Kahoot #6*
  - ⇨ Each of us has about 24 "slave-equivalents" *Kahoot #7*
- **Norway**: 25019 kWh/person
  - ➔ 5 times as much Italy
  - ➔ Is Norway a susteinable country???
- **India** 818. kWh/person
  - ➔ 1/6 of Italy
  - ➔ They are over 1 billion citizens
- **China**: 4292 kWh/person
  - ➔ A little less than Italy
  - ➔ Most populous country
- 20% of the population consumes 70% of the total power

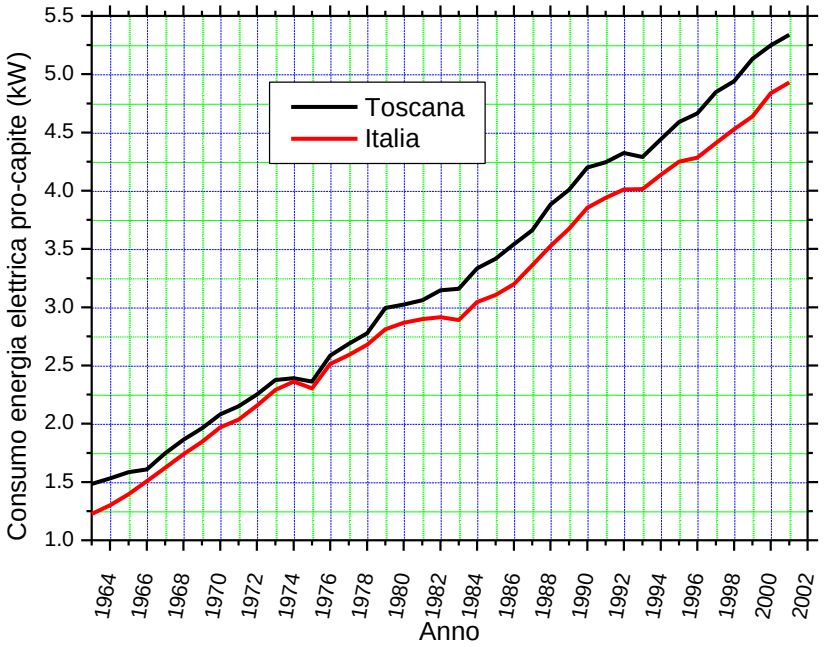
How much energy…

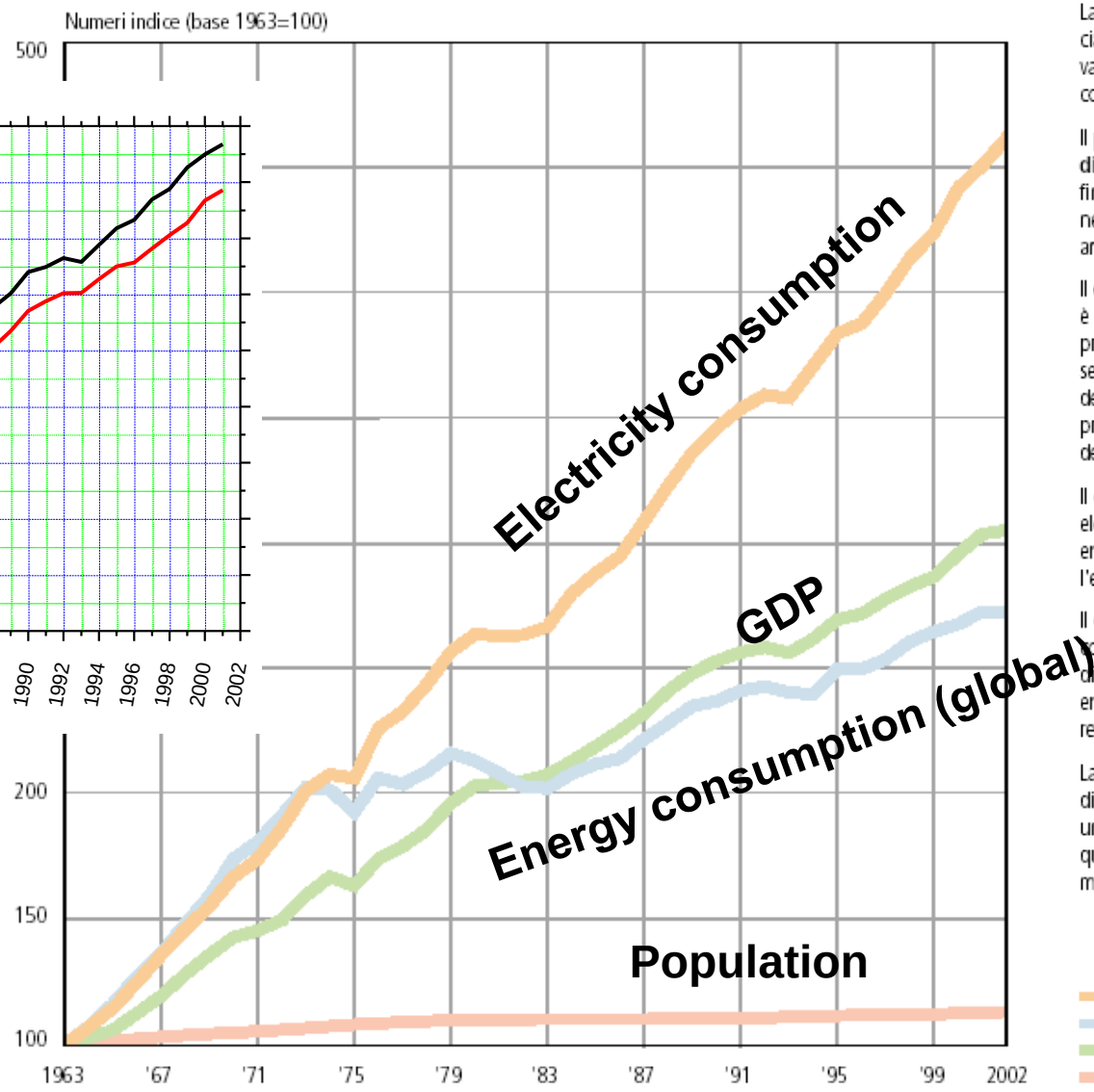
- Attitudes of good practices
  - ⇨ We (Italians) can easily reduce our consumption "without" affecting the quality of our lives.
  - ⇨ Two german shepherd dogs consume more resources than an average bangladeshi





Population, profits and energy consumption in Italy





La **popolazione residente** a metà di ciascun anno è calcolata come media dei valori relativi al 31 dicembre dell'anno considerato e di quello precedente.

Il **prodotto interno lordo ai prezzi di mercato** è il valore dei beni e servizi finali prodotti dal sistema economico nell'anno di riferimento, al lordo degli ammortamenti e delle imposte indirette.

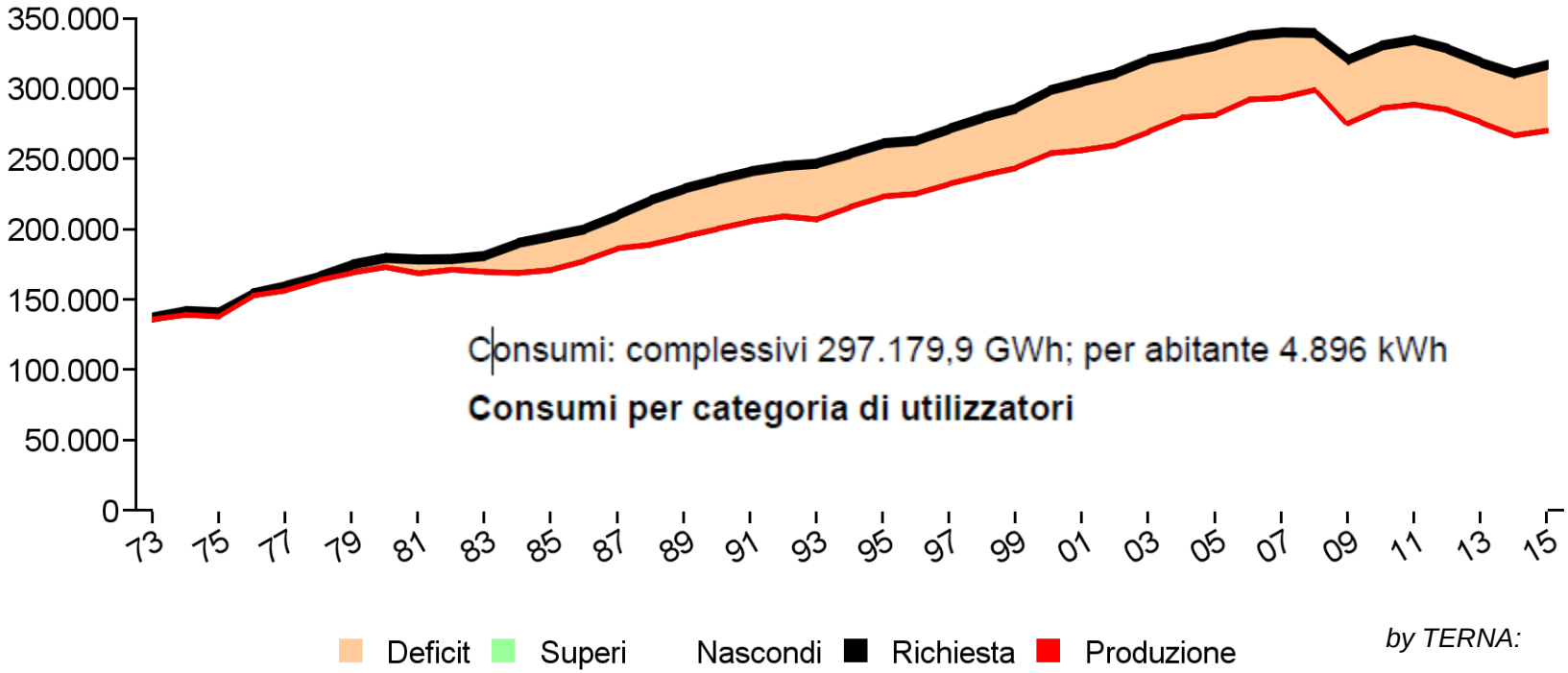
Il **consumo interno lordo di energia** è dato dalla somma dei quantitativi di fonti primarie prodotte, di fonti primarie e secondarie importate e della variazione delle scorte di fonti primarie e secondarie presso produttori e importatori, diminuita delle fonti primarie e secondarie esportate.

Il **consumo interno lordo** di energia elettrica è uguale alla produzione lorda di energia elettrica più il saldo scambi con l'estero.

Il **consumo finale di energia** è dato dal consumo interno lordo di energia diminuito del consumo del settore energetico; quest'ultimo include le relative variazioni delle scorte.

La **produzione lorda** di energia elettrica di un insieme di impianti di generazione, in un determinato periodo, è la somma delle quantità di energia elettrica prodotte, misurate ai morsetti dei generatori elettrici.

Electricity required and produced in Italy



by TERNA:

- Consumption is about the twice in about 25 years.
- The energy produced is less than energy requirement
  - ⇨ The difference is filled bying energy from others countries
- Note 2008 crisis

The cost of energy

- Question:
  - ⇨ Is a liter of gasoline cheap or expensive??
    - ➔ 1.600 €/L^{Ago2021}
  - ⇨ **CHEAP!!**
  - ⇨ How much are you willing to pay 0.5 liters of water??
    - ➔ 1.0€
    - ➔ 2.0€/L
      - – More than gasoline!!!

How much energy…

- An example of the "illogicali[illegible] our habits
-

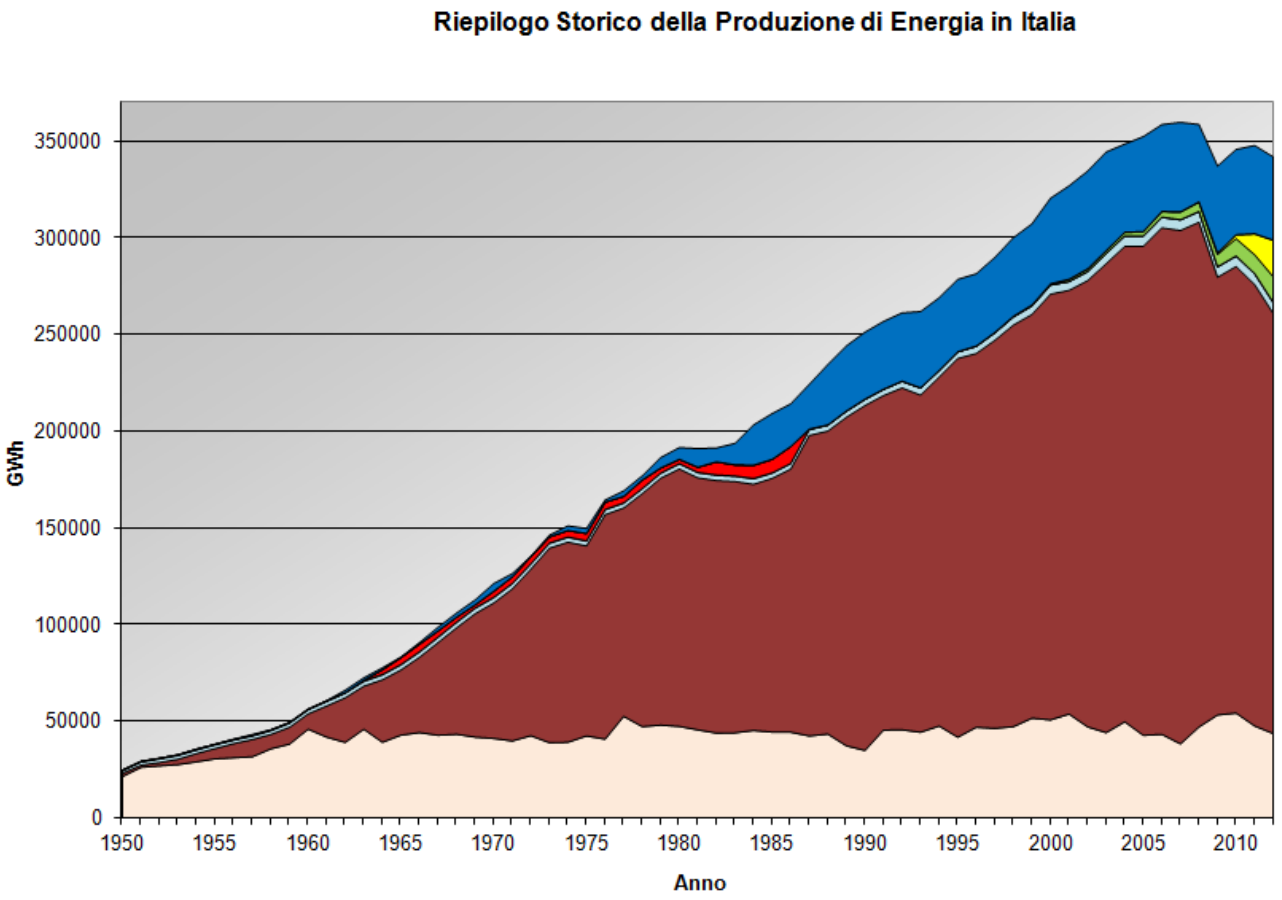
How much energy…

- But it is NOT EASY to **GIVE UP** certain **RIGHT-BENEFITS**!
  - ⇨ Are we willing to let our **infants** die??
  - ⇨ Are we willing to die at **50 years** old??
  - ⇨ Are we willing to not get our **kids in school**?
  - ⇨ Are we willing to not have **efficient hospitals**?
  - ⇨ Are we willing to not have **mobilephone**?
  - ⇨ Are we willing to not have **vacations**?
  - ⇨ Are we willing to suffer **cold** in our homes?
    - ➔ But hot, too?

- **Energy IS NEEDED!!!**
  - ⇨ Unless we are willing to go back in time 150 years!

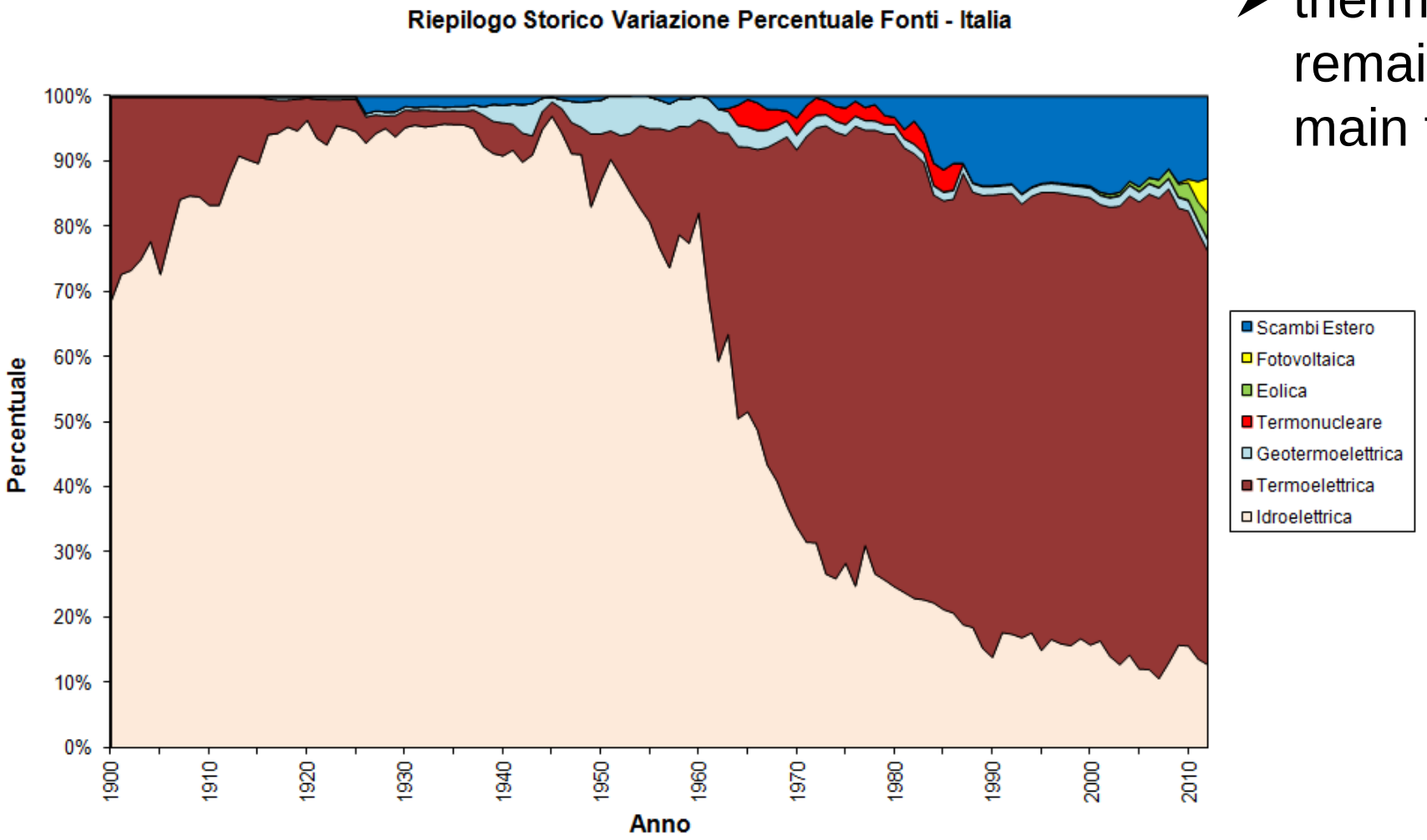
What energy source do <u>we</u> use?

Gross electricity production (Italy)



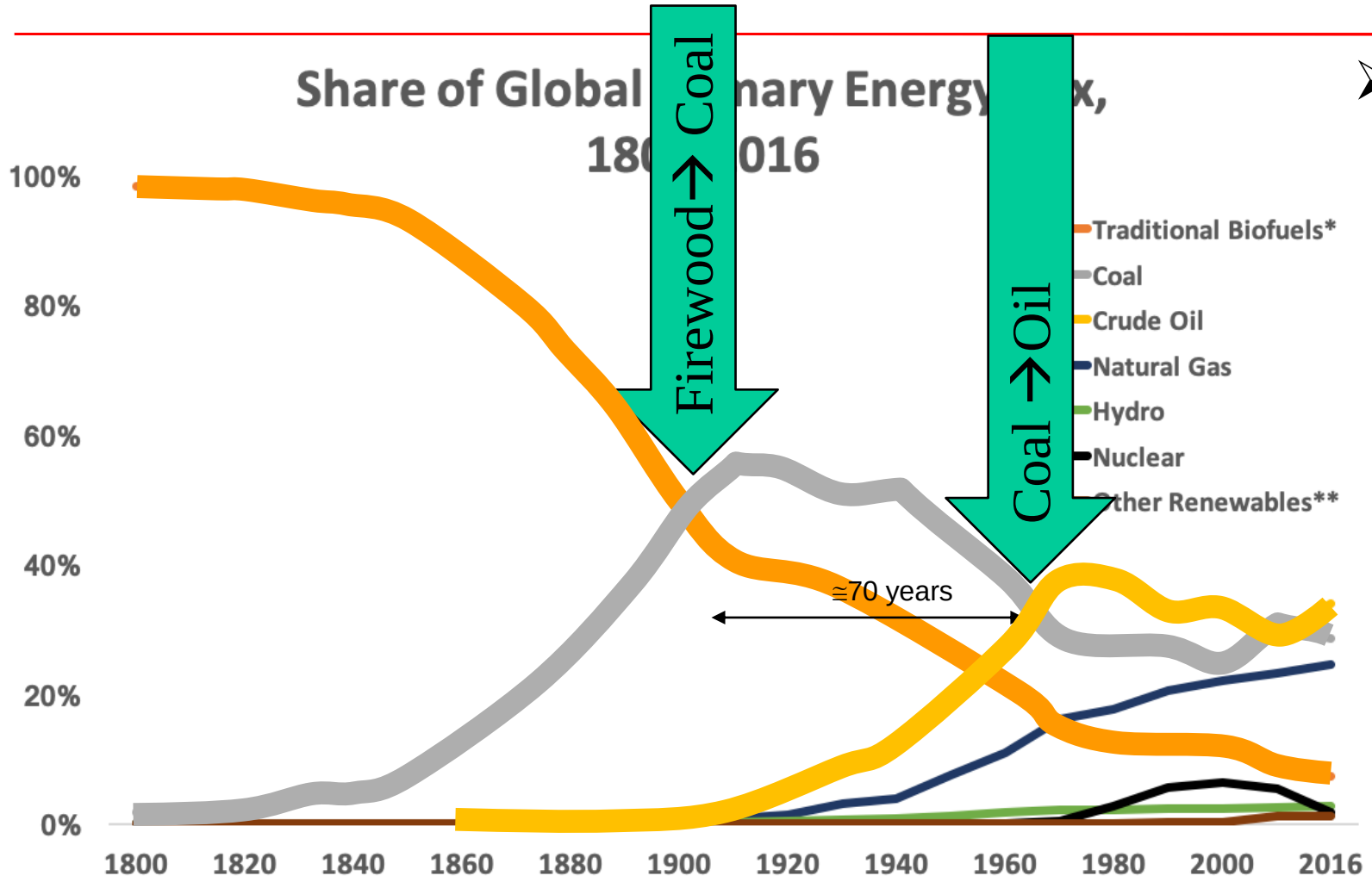
- Growing foreign exchange
- Hydropower is stable since 1960
- Thermoelectric power is growed
- Photovoltaic is relevant only from 2010

History of electricity production in Italy



- thermo-electric remains the main fraction

Fuel in history…

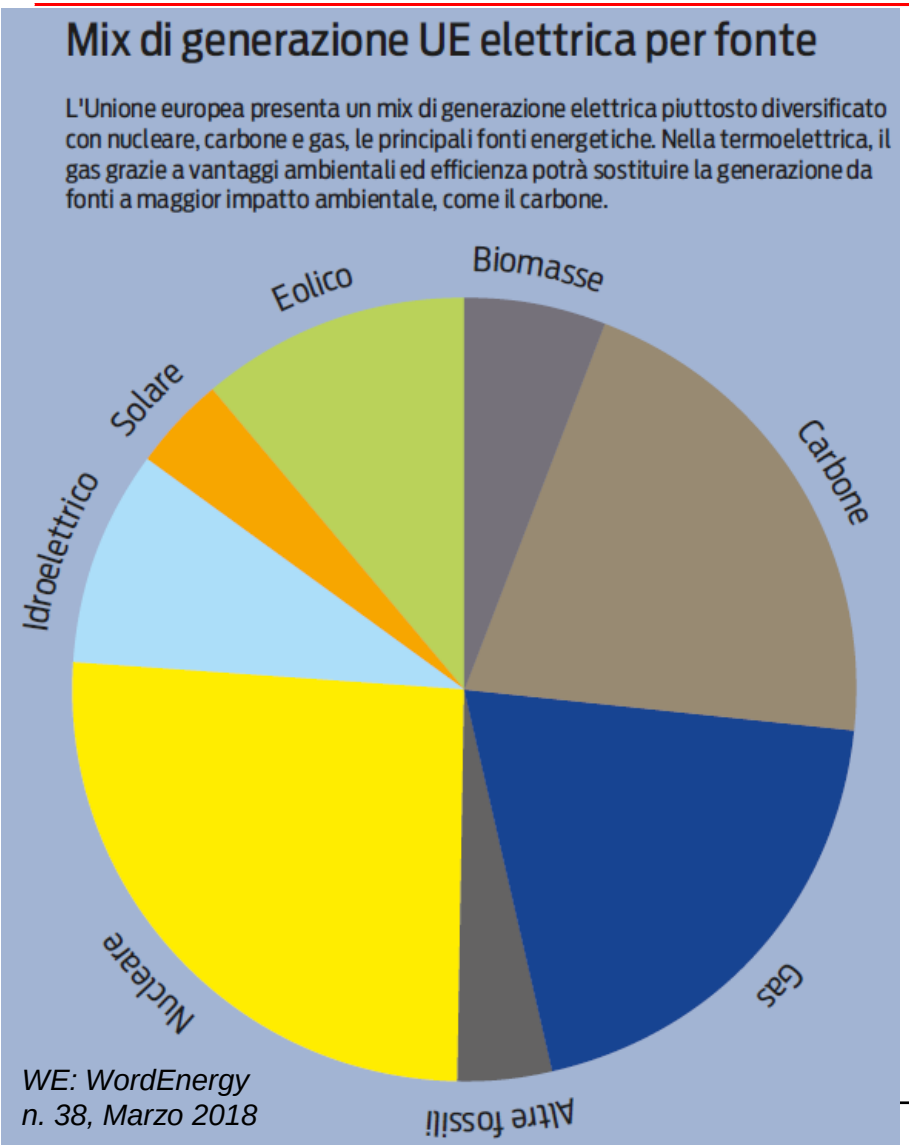


Data Source: Vaclav Smil (2017), Energy Transitions: Global and National Perspectives
*Notes: *Burning wood and other organic matter*
***Wind, solar and modern biofuels*

- 2 energy transitions
  - ⇨ from Wood to coal
    - ➔ ≈'900
  - ⇨ From coal to Oil
    - ➔ ≈1970
  - ⇨ ≈70 years

Crystol

EU: Electricity mix production by fuel (2017)



WE: WordEnergy
n. 38, Marzo 2018

- The electricity is produced mainly using
  - ⇨ Nuclear
  - ⇨ Coal
  - ⇨ Natural Gas
    - ➔ In the future, It will substitute the carbon

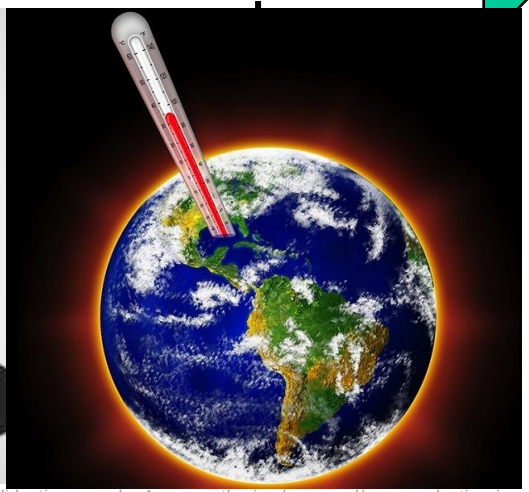
Problems in history…

≈1973 Oil Crisis

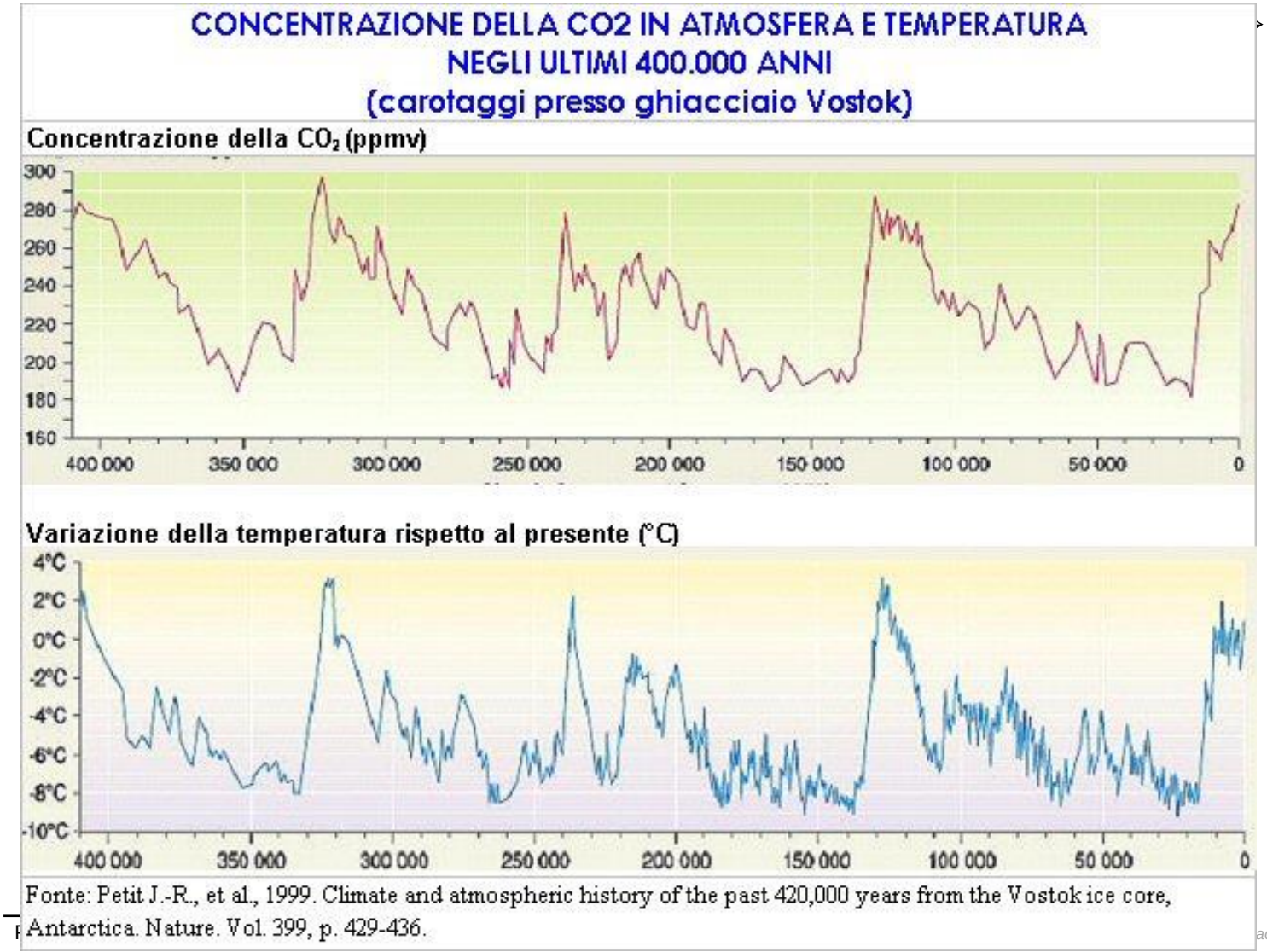
≈1990 Pollutants NOx, CO

2000/05 Depletion

2015/20 Greenhouse effect



Greenhouse effect and trend of terrestrial temperatures



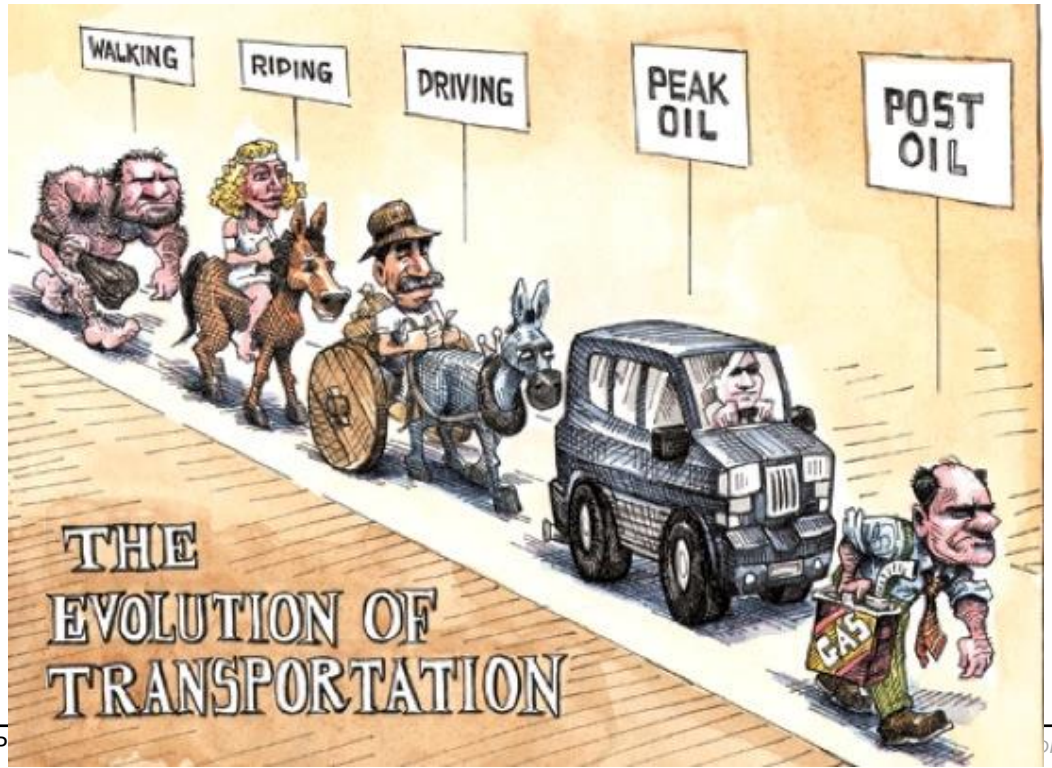
Fonte: Petit J.-R., et al., 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Nature. Vol. 399, p. 429-436.

To reduce CO_2 emissions is equivalent to reduce fossil fuels!!

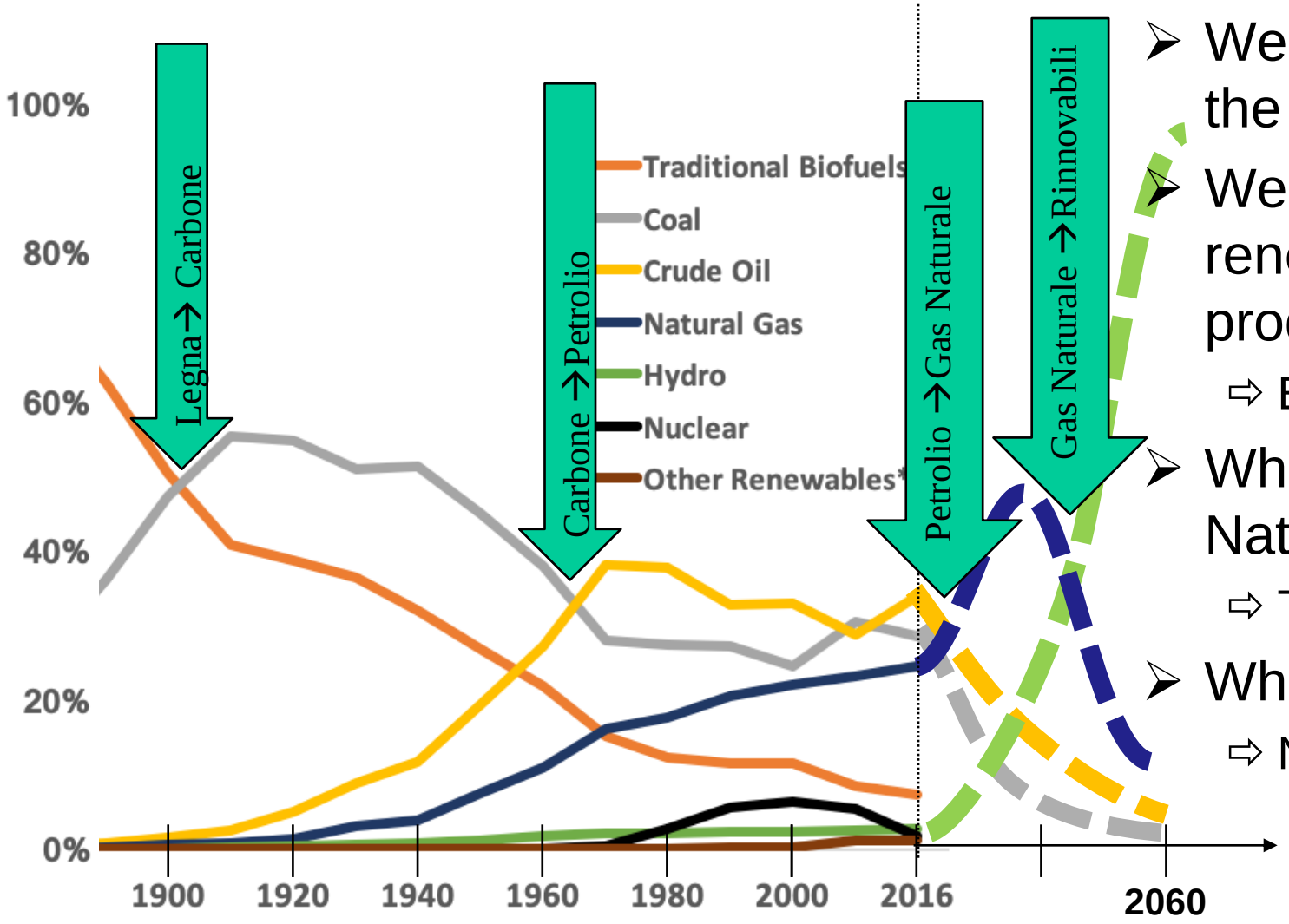
- ⇨ Coal (C)
- ⇨ Oil (C_nH_m)
- ⇨ Natural Gas (CH_4)

The age of Oil…

- We are living in **the "age of oil"**
  - ⇨ How there was the Copper, Bronze and Iron Ages
  - ⇨ When it ends, we will pass (forcibly) to another "age"
- "Unconventional" energies will have the upper hand

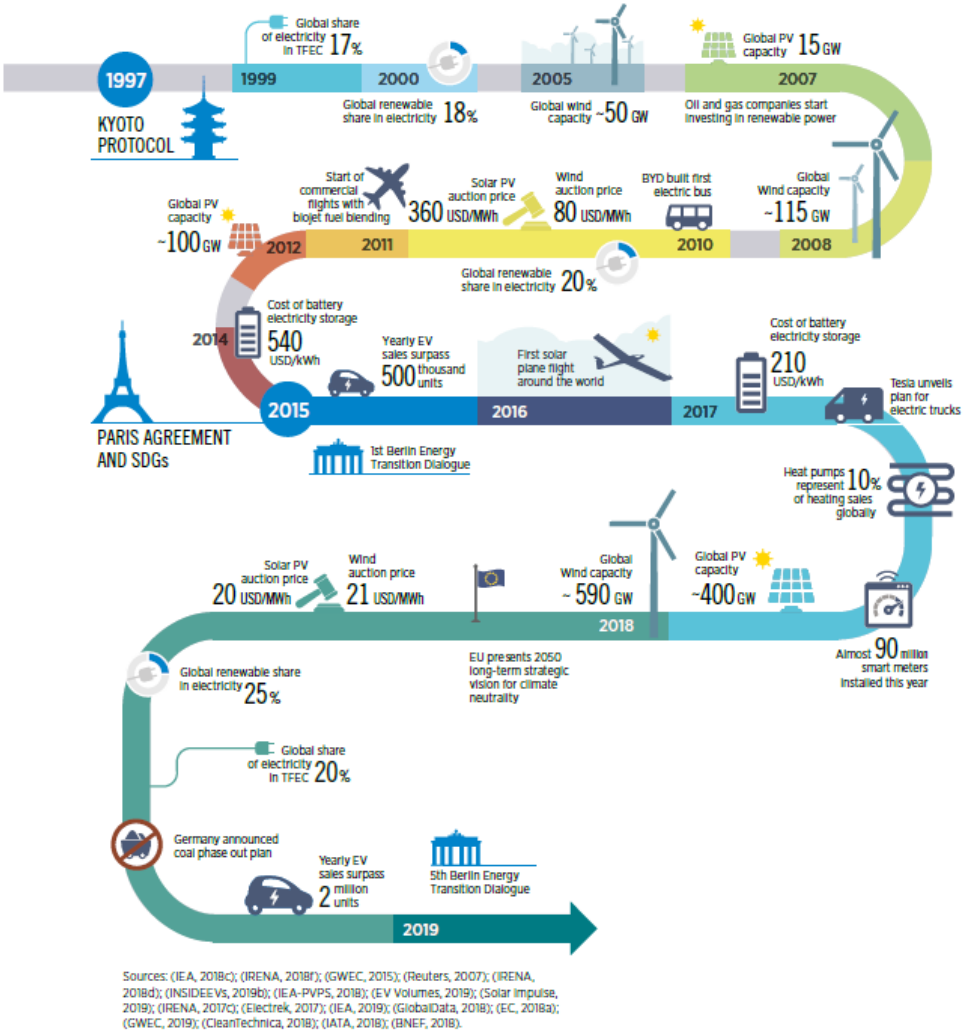


Fuel in history and … in the FUTURE!



- We Must Decrease the Oil and Coal use
- We need to increase renewable energy production
  - ⇨ Electric
- While... use of Natural Gas
  - ⇨ Transition
- When???
  - ⇨ Now!!!
    - ➔ In the next 15 years

Where are we today?



Sources: (IEA, 2018c); (IRENA, 2018f); (GWEC, 2015); (Reuters, 2007); (IRENA, 2018d); (INSIDEEVs, 2019b); (IEA-PVPS, 2018); (EV Volumes, 2019); (Solar Impulse, 2019); (IRENA, 2017c); (Electrek, 2017); (IEA, 2019); (GlobalData, 2018); (EC, 2018a); (GWEC, 2019); (CleanTechnica, 2018); (IATA, 2018); (BNEF, 2018).

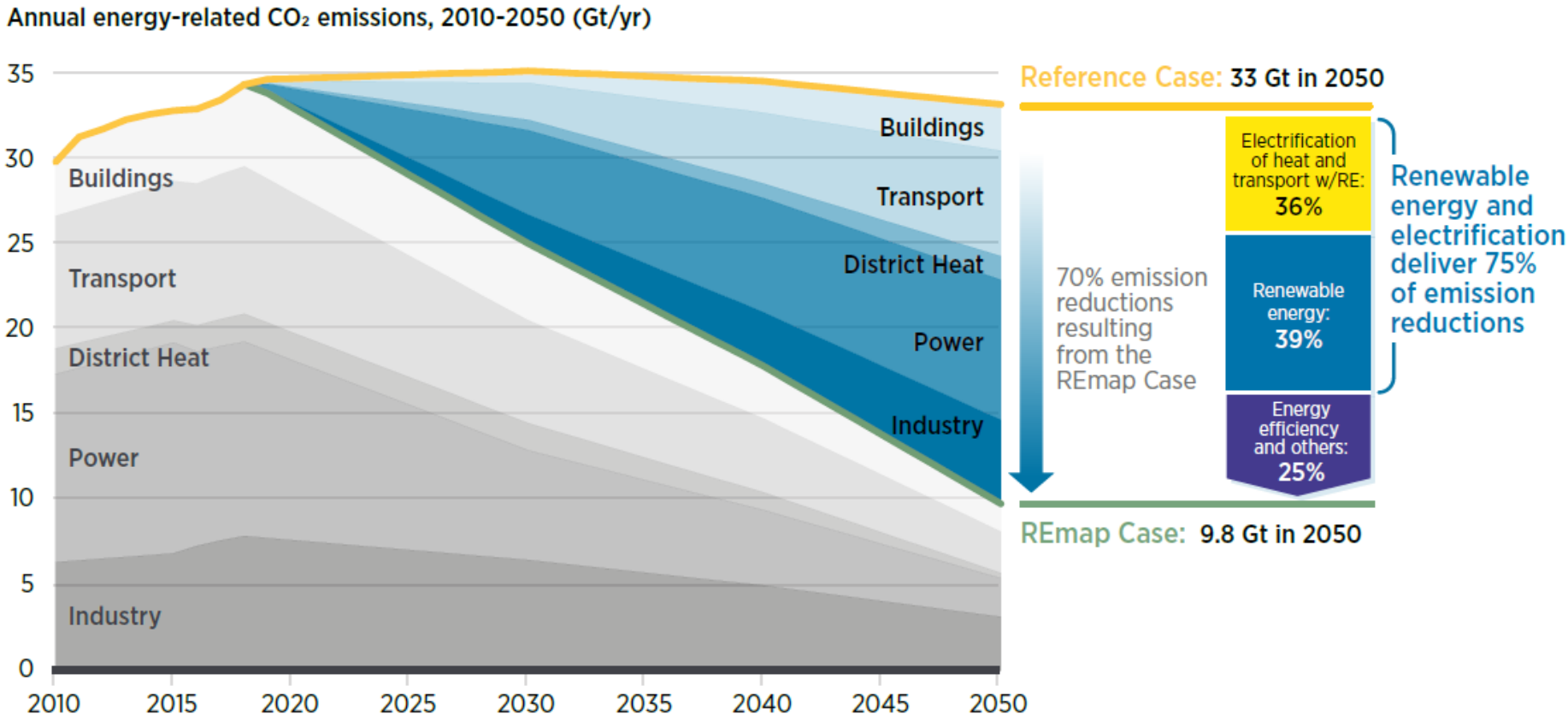
- The energy transition path has already begun
- Started with the Kyoto Protocol
  - ➔ 1997
  - ⇨ And... the benefits can already be observed
    - ➔ but they are not sufficient

KEY BENEFITS OF THE ENERGY TRANSFORMATION

- Lower renewable power costs
- Increase energy access
- CO_2 Reduce emissions and air pollution
- Increase welfare and growth

Where are we going?

- The path taken is only at the beginning
  - ⇨ The actions taken so far are not enough...☹

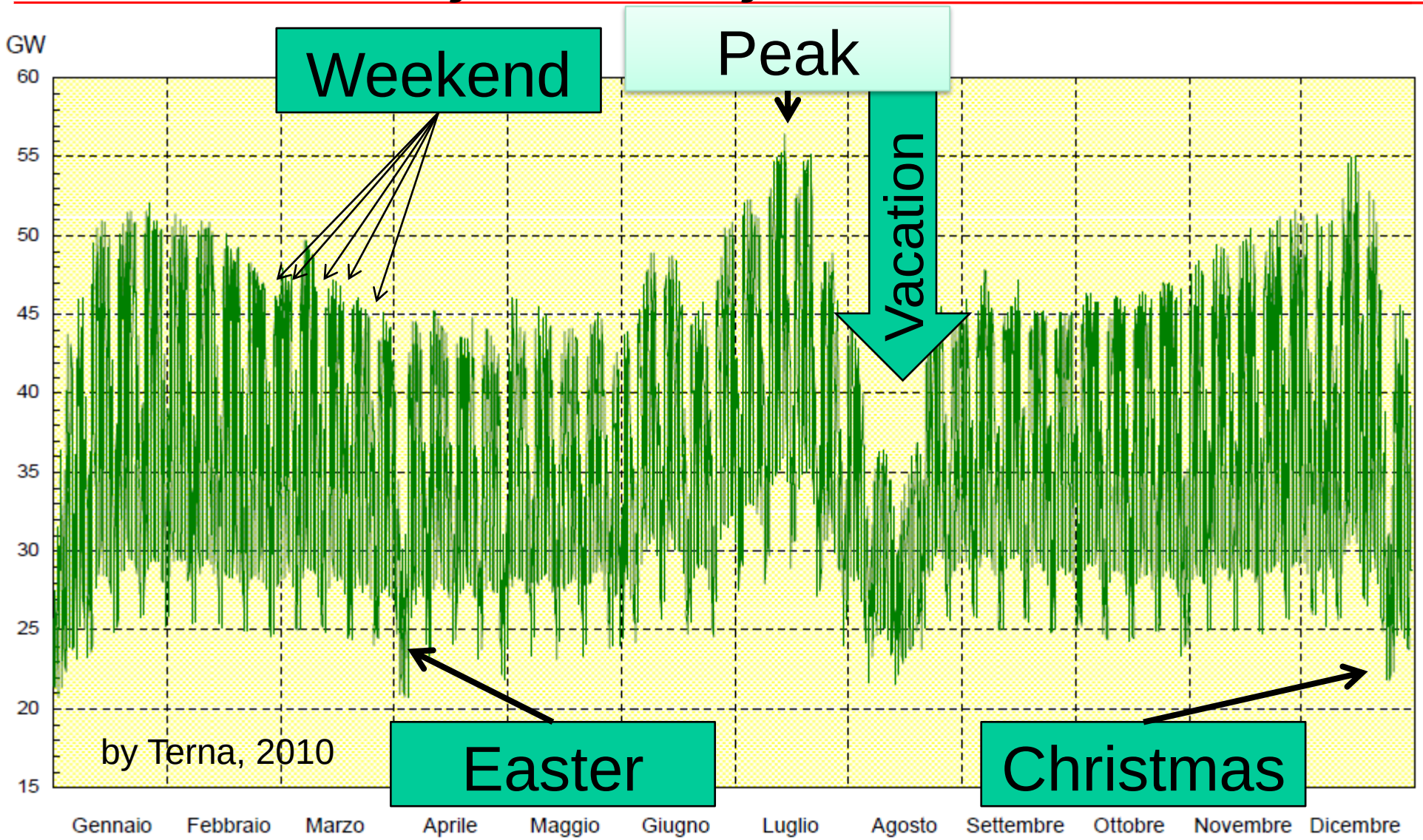


Which energy sources are CO_2-free?

- Types of energy
  - ⇨ Solar
  - ⇨ Wind
  - ⇨ Geothermic
  - ⇨ (Nuclear!)
- **<u>Technologies Mature!</u>**

Kahoot #9

Chronological curve of hourly powers in the hourly year in the year 2010



Supply-demand match

- Electricity Supply and Demand MUST be BALANCED
  - ⇨ Difficult to store electricity!

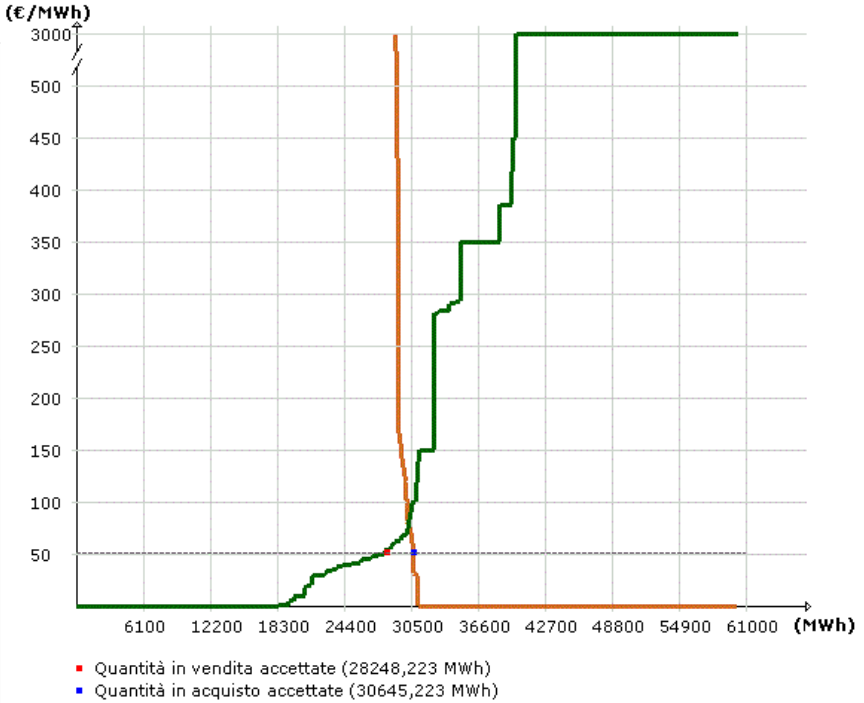
Main feature of the electrical system

- Electricity **cannot be stored** (on large scale)
  - ⇨ At <u>all times</u>, a perfect balance must be maintained between:
    - ➔ Production (Generators, "Cyclists")
    - ➔ Consumption/demand (Loads, "slope of the road")
- The **demand** is left **free** to vary "like-it-want"
  - ⇨ Generators must react instantly to adapt to load variation
    - ➔ Sliding-Production

Demand-Supply curve

Zona di mercato: CNOR; NORD; AUST; CORS; FRAN; MFTV; SLOV; SVIZ; XFRA

Data: 05/07/2017 **Ora:** 12



Mercato del Giorno Prima

Giorno:	Mese:	Anno:	Ora:
05	Luglio	2017	12

Prezzi Zona: **nord**

prezzo di vendita (€/MWh)	acquisti (MWh)	vendite (MWh)
51,94	25.484,36	22.355,05

Transiti zonali

da	limite (MWh)	transito (MWh)
AUST	10.000,00	00,00
CNOR	1.100,00	779,09
FRAN	10.000,00	00,00
MFTV	10.000,00	00,00
SLOV	10.000,00	00,00
SVIZ	10.000,00	00,00

Zona: **nord**

a	limite (MWh)	transito (MWh)
AUST	10.000,00	-237,00
CNOR	3.600,00	00,00
FRAN	10.000,00	-289,22
MFTV	10.000,00	00,00
SLOV	10.000,00	620,00
SVIZ	10.000,00	-2.444,00

Torna alla cartina

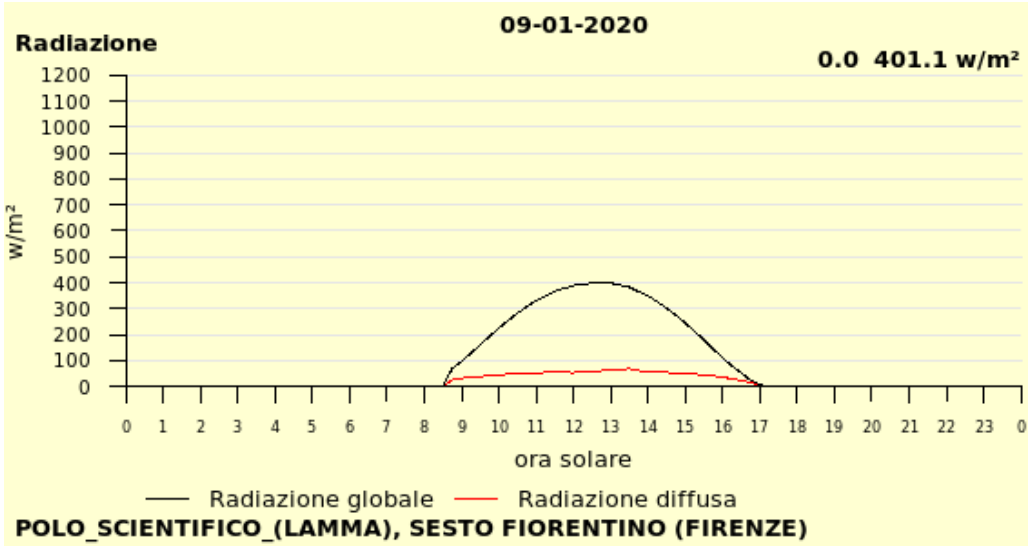
LEGENDA

AUST	BRNN	CNOR	COAC	CORS	CSUD	FOGN	FRAN	GREC	MALT	XFRA
Austria	Brindisi	Centro Nord	Corsica Ac	Corsica	Centro Sud	Foggia	Francia	Grecia	Malta	Francia coupling*
MFTV	**NORD**	**PRGP**	**ROSN**	**SARD**	**SICI**	**SLOV**	**SUD**	**SVIZ**	**BSP**	**XAUS**
Monfalcone	Nord	Priolo G.	Rossano	Sardegna	Sicilia	Slovenia	Sud	Svizzera	Slovenia coupling*	Austria coupling*

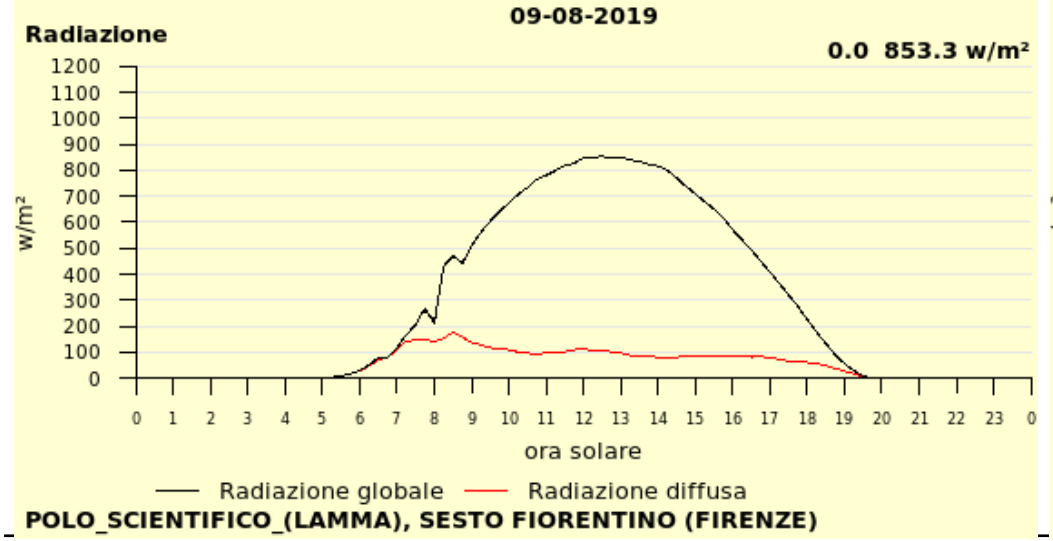
* Zona rappresentativa dell'interconnessione dedicata al market coupling tra Italia e Slovenia/Francia/Austria

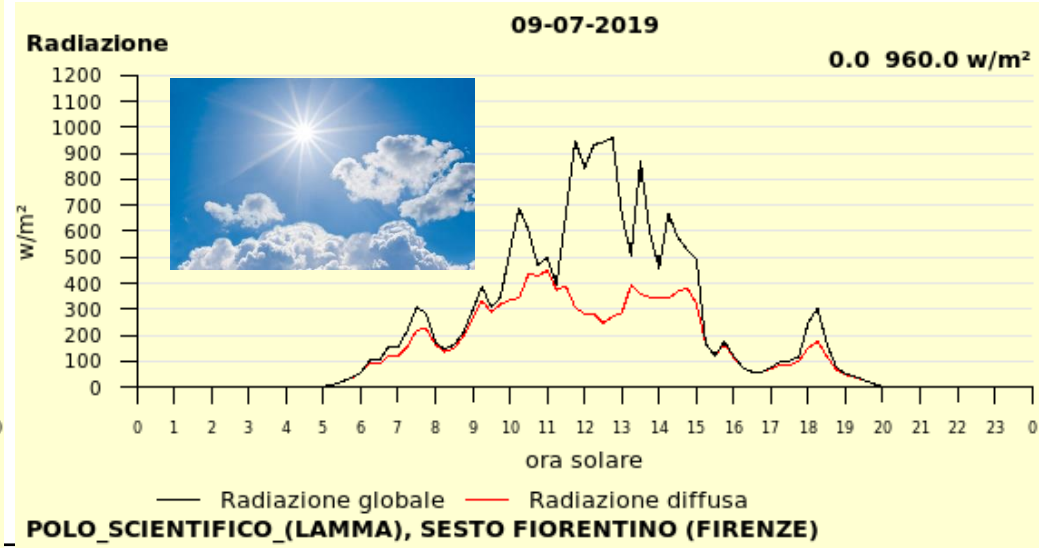
- Price is formed by the meeting of the supply and demand curve
- The demand curve is fixed
  - ⇨ It's almost vertical

The "gasoline" of the solar panels is not predictable!!



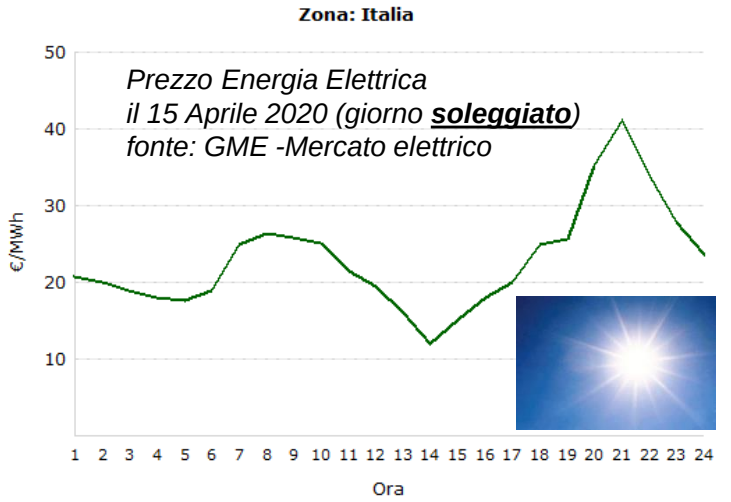
- Winter-Day
  - ⇨ Only 6-7 h, peak: 400.W/m^2
    - ➔ *What's happen if we want a pizza for dinner??!!*
- Summer-Day
  - ⇨ 11 h, peak 900 W/m^2
  - ⇨ But… a couple of coulds that…



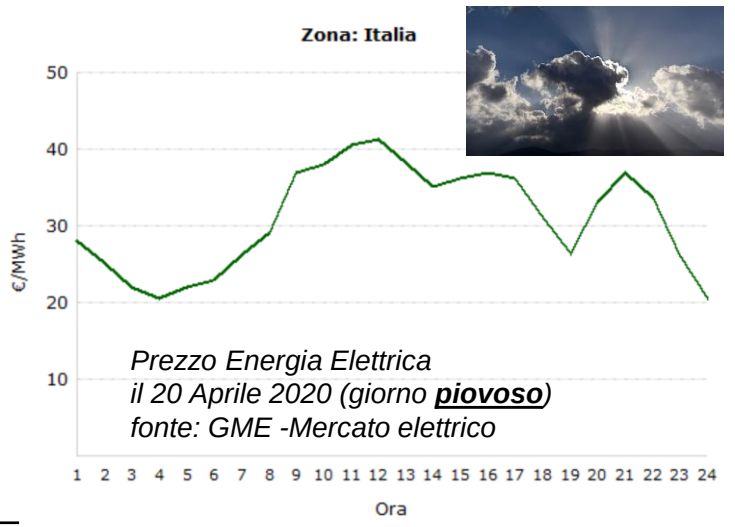


If we install many and many solar panels…

- **<u>Needless</u>** to install a lot of solar panels
  - ⇨ None of these produce energy for me at night

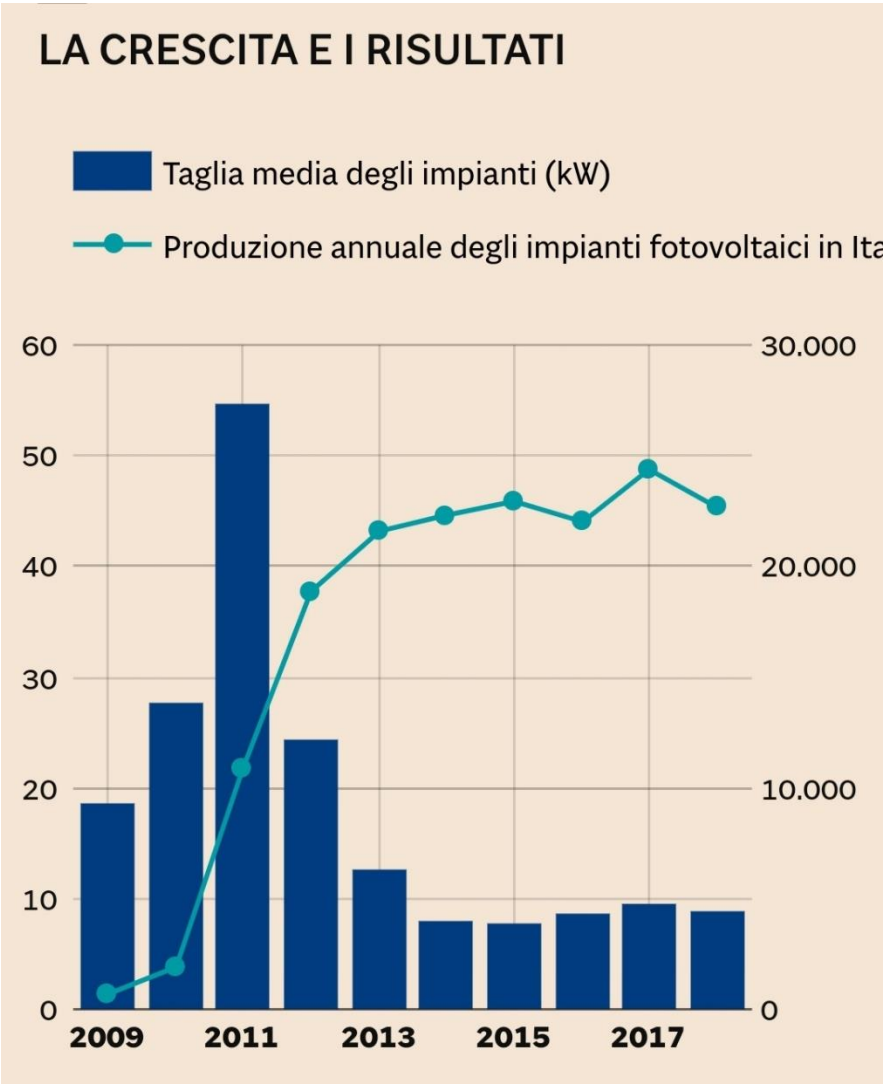


del giorno: **20/04/2020**



- The price is already low during the day
  - ⇨ Sunny-Day: problem between 20:00-22:00
  - ⇨ Cloudy-Day: problem between 10:00-13:00

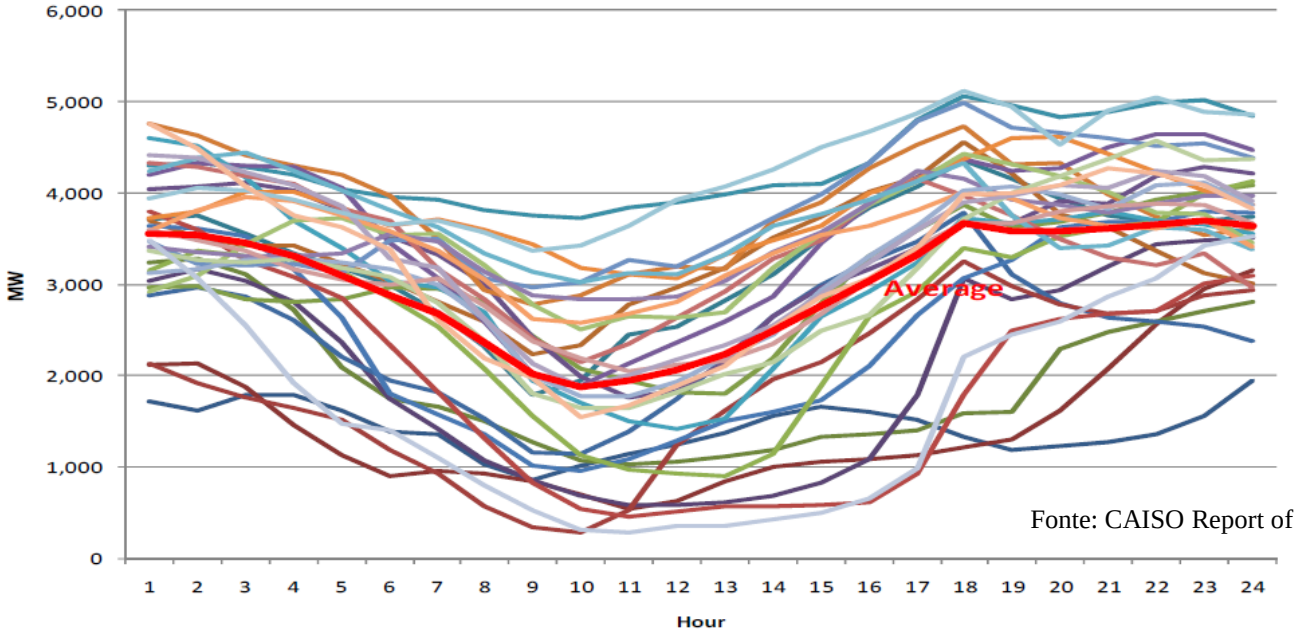
Growth of photovoltaic systems and their effects



- After 2011, the average size of the plants decreased
  - ⇨ Around 8-9 kW
    - ➔ Domestic plants
- Since 2014, despite new plants, the annual production does NOT increase!
  - ⇨ <u>In this configuration</u>, **NO to incentivize** solar panel!

Wind Energy - Non-programmability!

- Wind production is not programmable
  - ⇨ Great variation during the day and between different days.



Fonte: CAISO Report of Integration of Renewable Resources 2010

  - ➔ Wind power from 2005 to 2012 for many days in California.
    - – Each color represents a different day, while the thick line is the monthly average
  - ⇨ for example: Fixing at 10:00 am, one day the power is 100.MW and another day it is 3'800. MW
    - ➔ 38 times larger

Current limitations

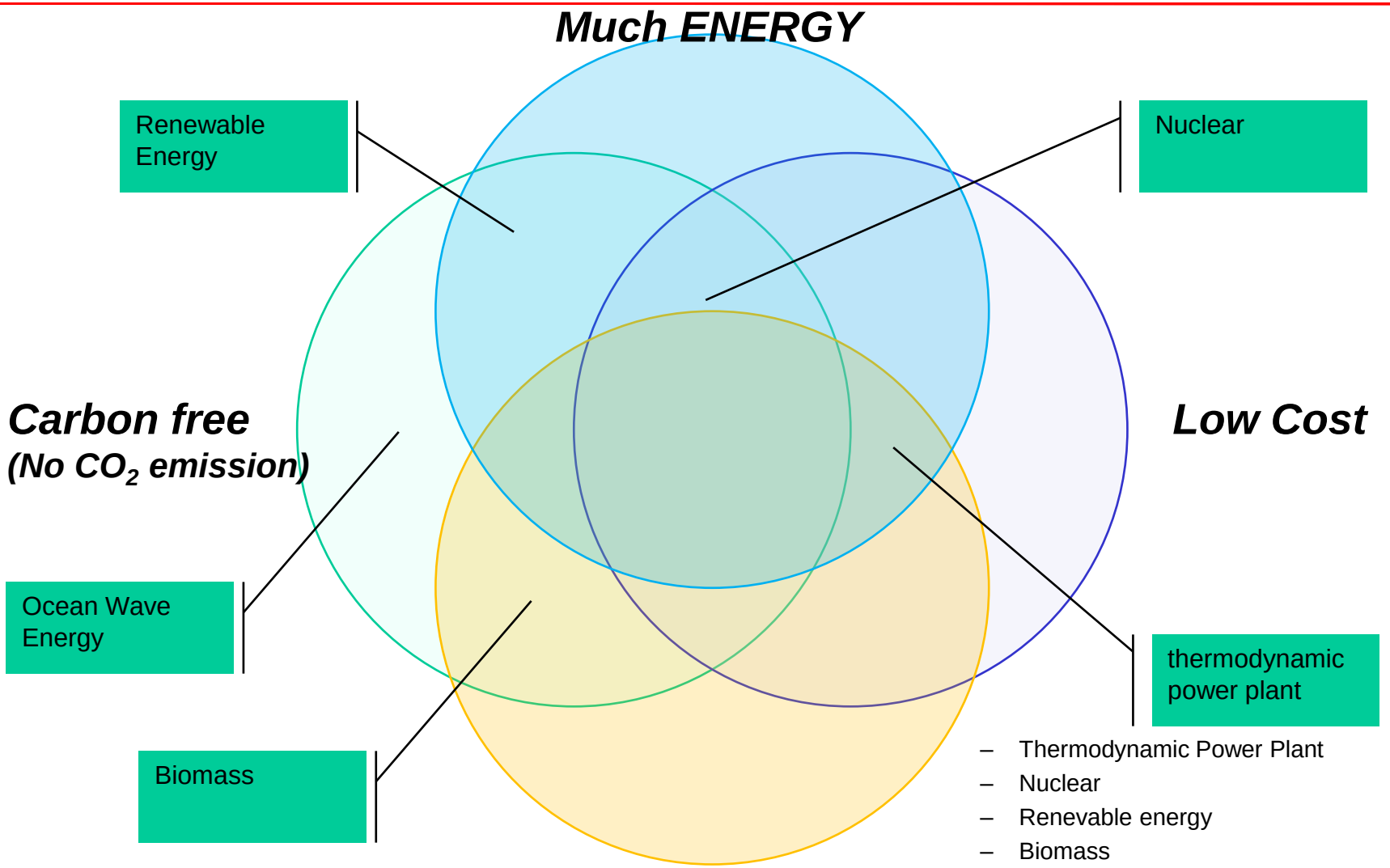
- The demand is fixed
  - ⇨ Power generation MUST follow the demand

- Limits of renewable energy
  - ⇨ They are "**Non-programmable**" energies
    - ➔ Solar panels work **ONLY** with daylight (and sunny)
    - ➔ 'Wind turbines' work **ONLY** in the presence of wind
  - ⇨ Without particular climatic conditions, the power systems stop!
    - ➔ Electricity is not produced!

But then?

- I need a lot of (low-cost) energy
- I cannot emit CO_2
  - Fossil fuels cannot be used
- I have to follow the electrical load
  - Programmable power plants are necessary
  - Thermodynamic power plant are perfect
    - But they use Fossil fuel ☹

Requirement needs

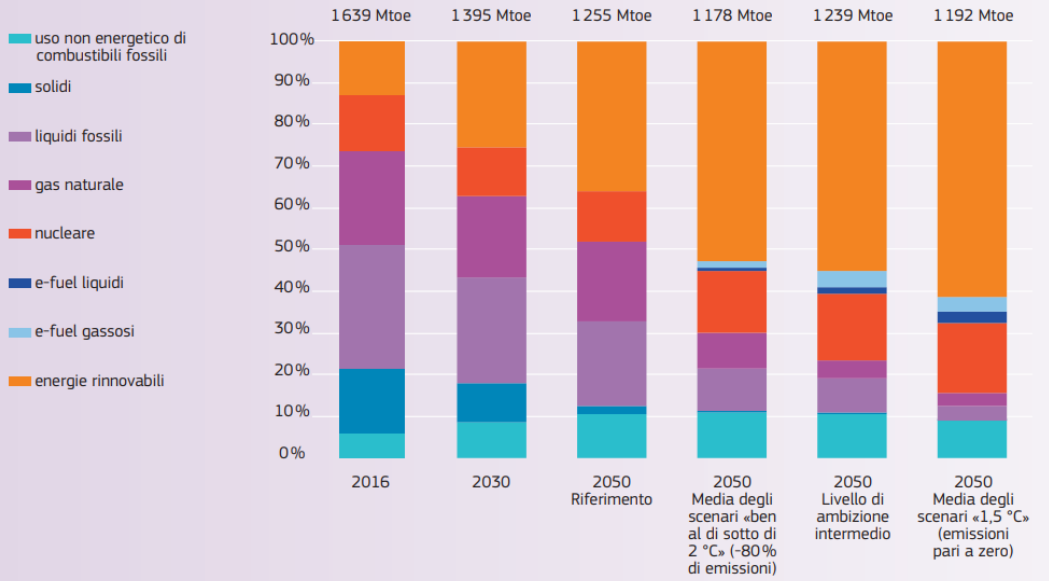


- Thermodynamic Power Plant
- Nuclear
- Renevable energy
- Biomass
- Ocen Energy

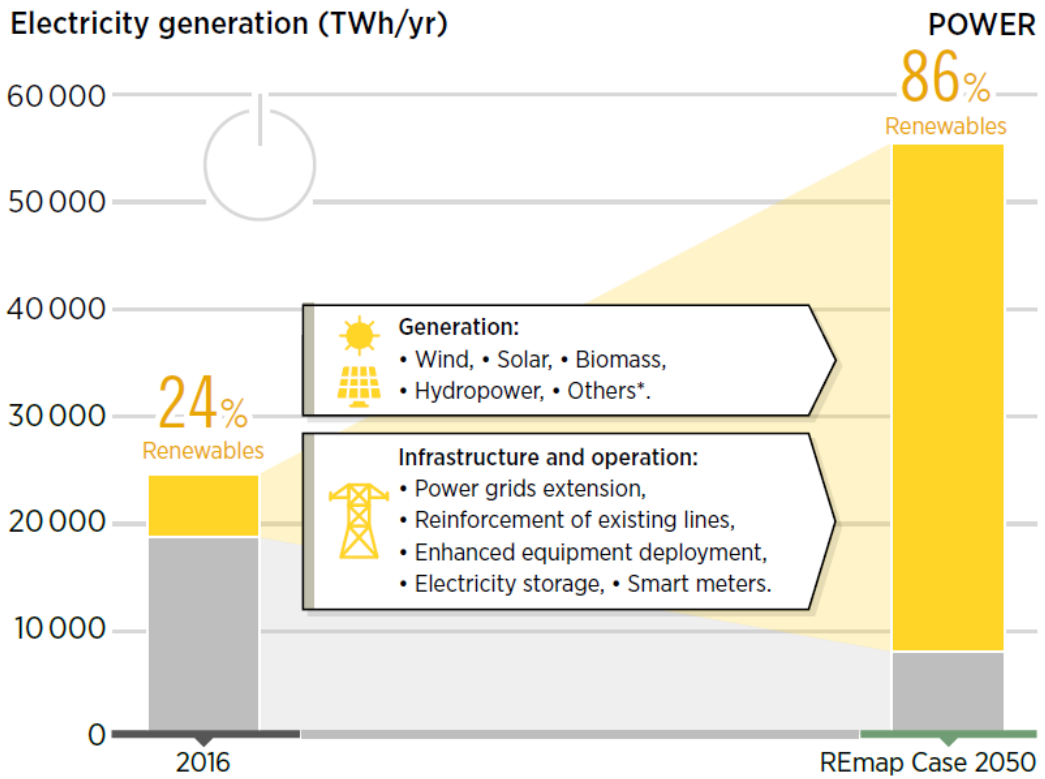
Declaration of intents for 2030 and for 2050

- In 2050, **80%** of energy should be carbon-free
- In 2030, **30%** of energy should be carbon-free
  - ⇨ Energy Transition!
    - ➔ The "*Oil Age*" is finishing!

Figura 1. Consumo interno lordo di energia



Electricity production



- How to increase the percentage of electricity produced from renewable sources?
  - ⇨ Increasing renewable energy plants
    - ➔ But… it is not sufficient!
  - ⇨ But also it needs:
    - ➔ Develop transmission networks
    - ➔ Manage Energy demand
    - ➔ Take advantage sources that allow flexibility
    - ➔ Energy Storage

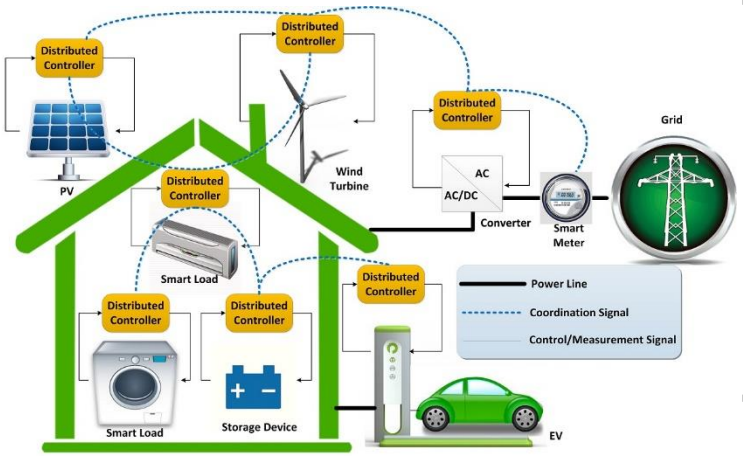
Problems and solutions

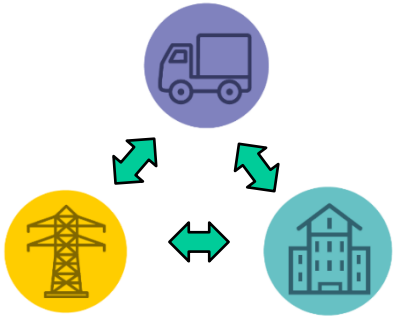
Problems	Solution
➢ Too much energy consumed	➢ Energy saving ⇨ To decrese energy loss ⇨ To Increase efficiency conversion
➢ Time shifting between Demand and Production	➢ Energy Storage ⇨ Hydraulic pumping plant ⇨ Battery ⇨ Hydrogen
➢ Fixed energy demand	➢ Demand management ⇨ Smart city - Smart Energy
➢ «Oneway» energy flow	➢ Sector coupling ⇨ End user and energy system

Smart City

Demand managment

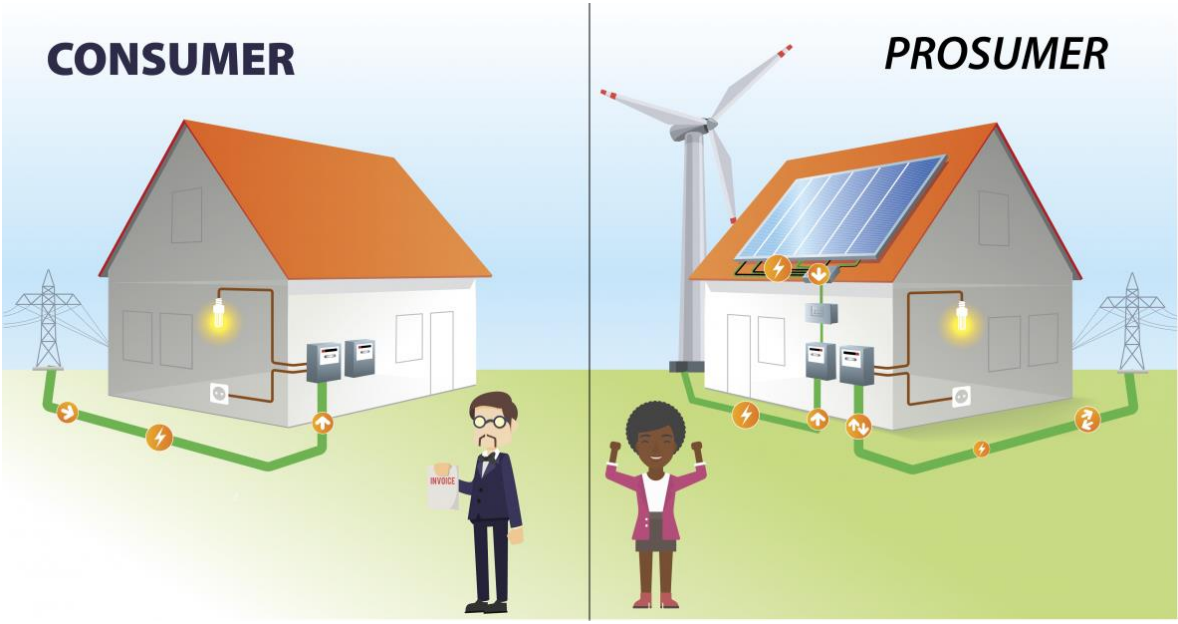
- Residential
  - ⇨ Demand (Loads) can be managed "intelligently" (smart)
    - ➔ **Smart meters** that decide when to start appliances
      - The user imposes a time range to start or finish the operation
        - » i.e. washing machine can start from 22:00 to 8:00
          - » because at 8:00 I want dry them
        - » A computer matches demand with supply (AI)
          - » The wheater forecast is fundamental!
    - ➔ **Storage systems** in homes
      - Electric cars can supply energy overnight
        - » They recharge power when you arrive in the office!
        - » Application of **sector coupling**
  - ⇨ **Domotic!**
    - ➔ Home automation
  - ⇨ **Load shifting!**





Who are PRO-SUMER?

- Consumers (us) become an active part of the system
  - ⇨ we are not more only CONSUMER
  - ⇨ We produce energy, too!
    - ➔ Thus, we consume, produce, store and sell energy!
  - ⇨ A new figure **PROSUMER**
    - ➔ **PRO**ducer + con**SUMER**

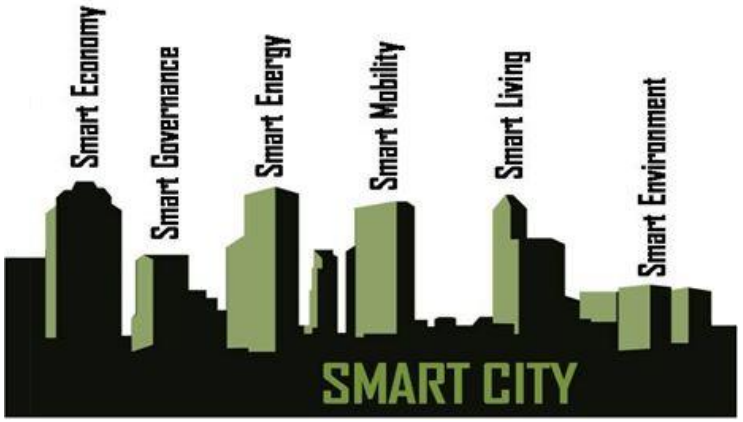


SMART CITY CONCEPT

- The concept of Smart City was born in 2009, in Rio de Janeiro
  - ⇨ Plan aimed at improving the **quality of life** of citizens
  - ⇨ To optimize **waste management**
  - ⇨ Limit **energy waste**
  - ⇨ Use of **technological innovation**
- It is defined “intelligente”, “smart”, the city that would emulate the proposed project in Rio de Janeiro.

"Smart" introduced in the European Union as part of the "Horizon 2020" program

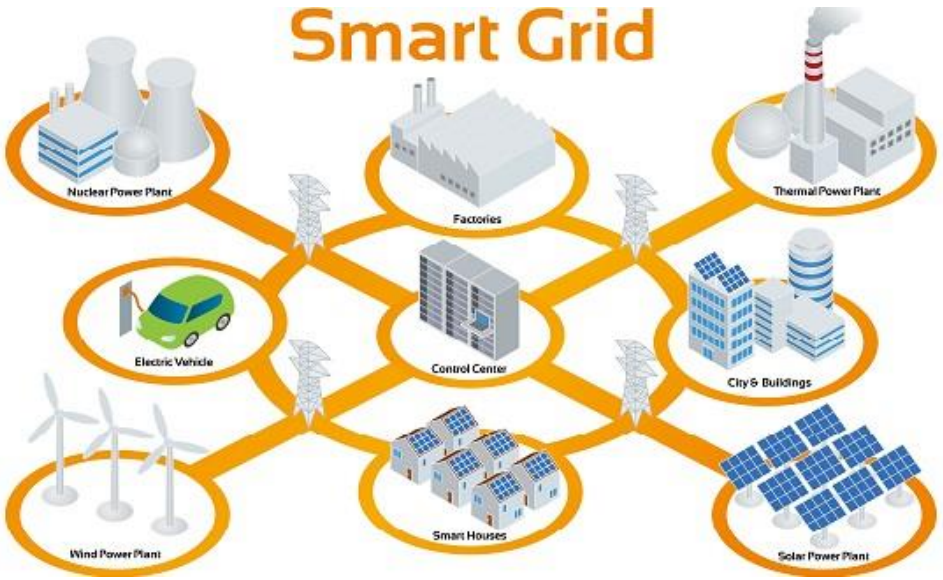
- Smart city as a place having the following 6 dimensions:
  1. Smart mobility,
  2. Smart economy,
  3. Smart life,
  4. Smart citizens,
  5. Smart intelligent,
  6. Smart environment.



Five major sectors in smart cities

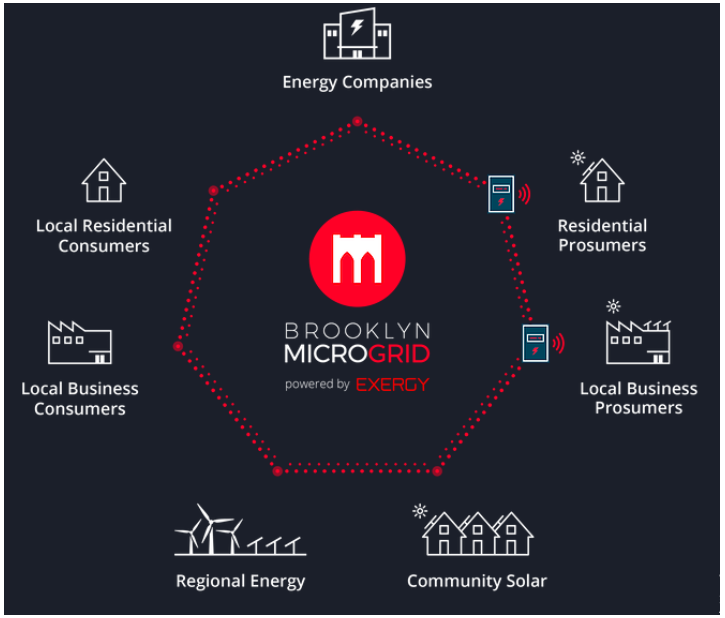
Smart-Grid

- A "smart-grid" electricity grid connects producers and consumers
  - ⇨ It use a network of information
- What do it DO?…
  - ⇨ Retrieve information from Smart-meters, vehicles and all products and tools connected to users
    - ➔ Smart-meter not only for prosumer
    - ➔ In real time
    - ➔ Using 5G
  - ⇨ Rationalizes energy consumption and generation
    - ➔ demand-supply match!
  - ⇨ Efficient distribution energy
    - ➔ Avoiding overloads and voltage variations.



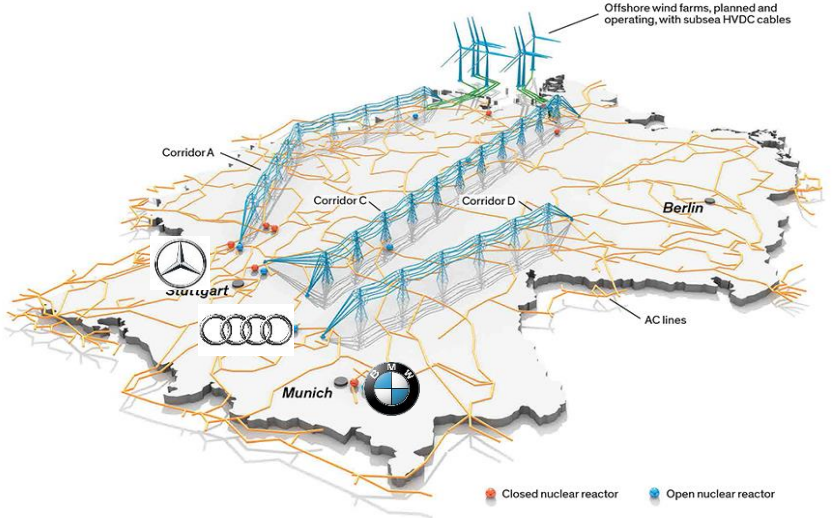
Oltre il 2050

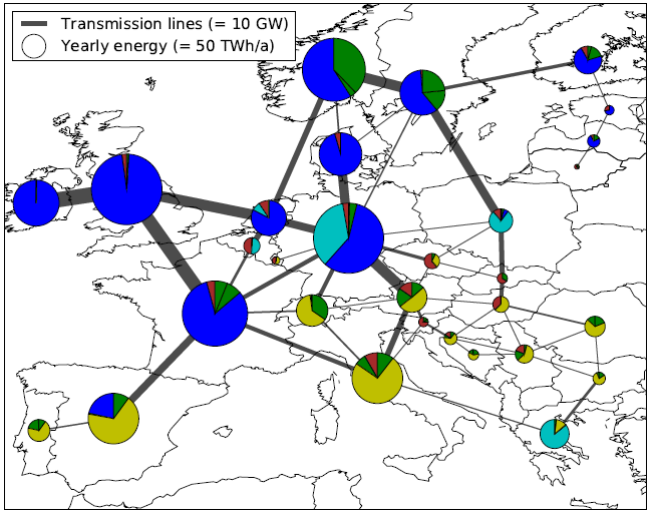
- Production from distributed energy sources introduce **blockchain transactions** between ProSumer
  - ⇨ Peer-to-Peer (P2P) energy trading
    - ➔ There are not more intermediary
    - ➔ It permits the transition to a real decentralized system
  - ⇨ This system already exists
    - ➔ "Brooklyn MicroGrid"

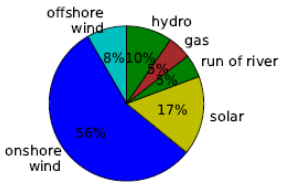


Strengthening transmission networks

- Link between production and consuming
- Keyword: **INFRASTRUCTURE**!
  - ⇨ Example: Germany
    - ➔ Offshore wind power generation in the North Sea
    - ➔ Energy consumption in factories in the south
- To permite between neighbouring countries

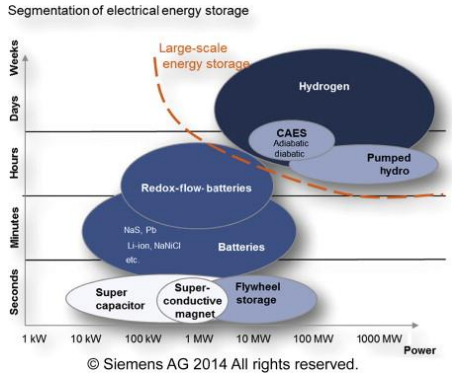


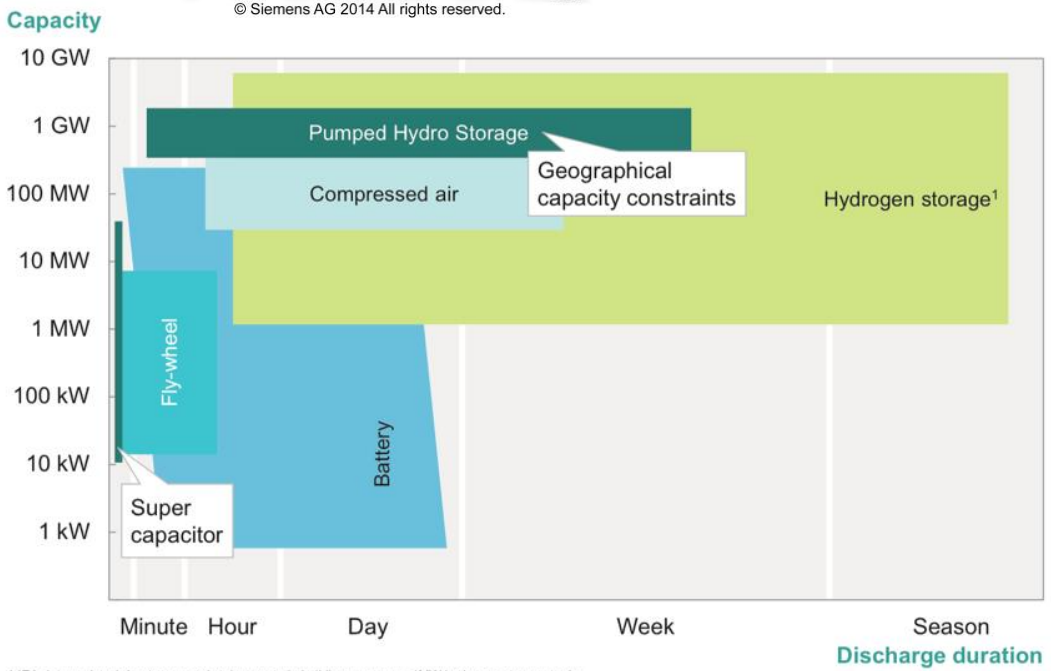




Energy STORAGE and Hydrogen

Energy Storage Technologies





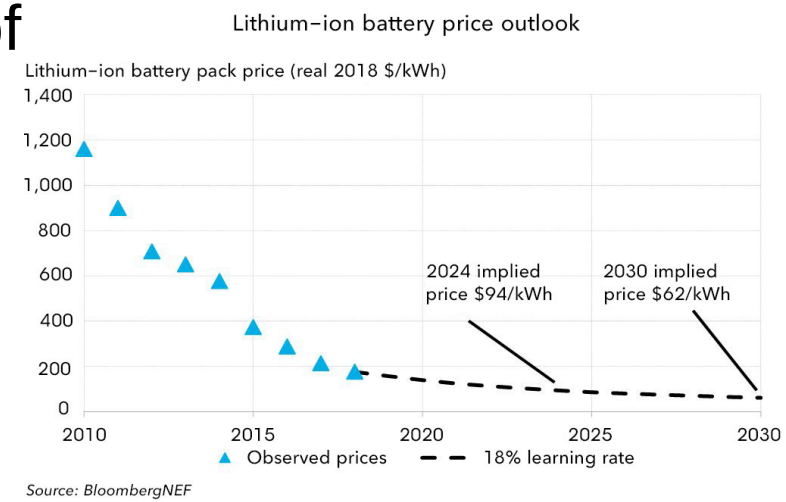
1 IEA data updated due to recent developments in building numerous 1MW hydrogen storage tanks

Source: IEA Energy Technology Roadmap Hydrogen and Fuel Cells, JRC Scientific and Policy Report 2013

- Energy criteria
  - ⇨ Specific Energy
    - ➔ kJ/kg or kJ/m^3
  - ⇨ Peak Power
    - ➔ kW/kg
  - ⇨ Cost
  - ⇨ Size
    - ➔ kW
  - ⇨ Discharge time at rated power
    - ➔ hours

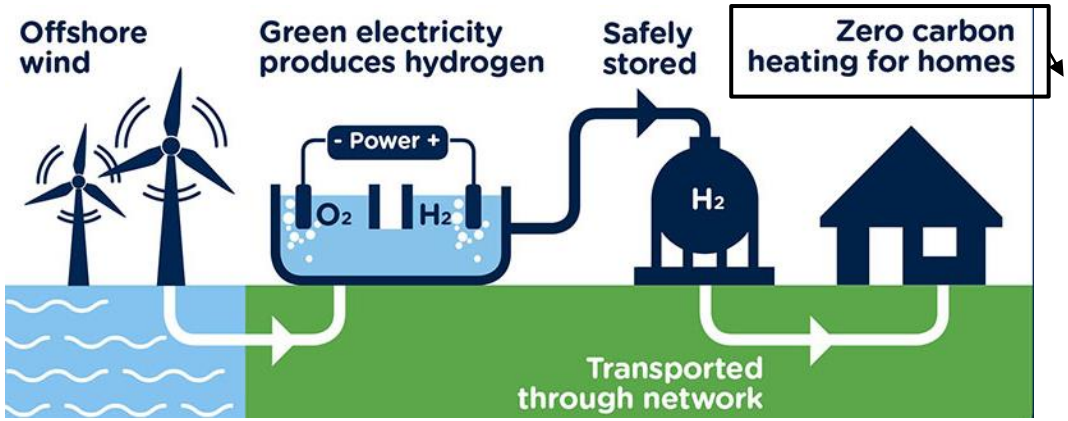
Energy storage

- The progressive decrease in the costs of storage systems is making electricity storage costs competitive
- For storage in homes
  - ⇨ For the construction of real storage plants



Energy Storage: Power-to-X

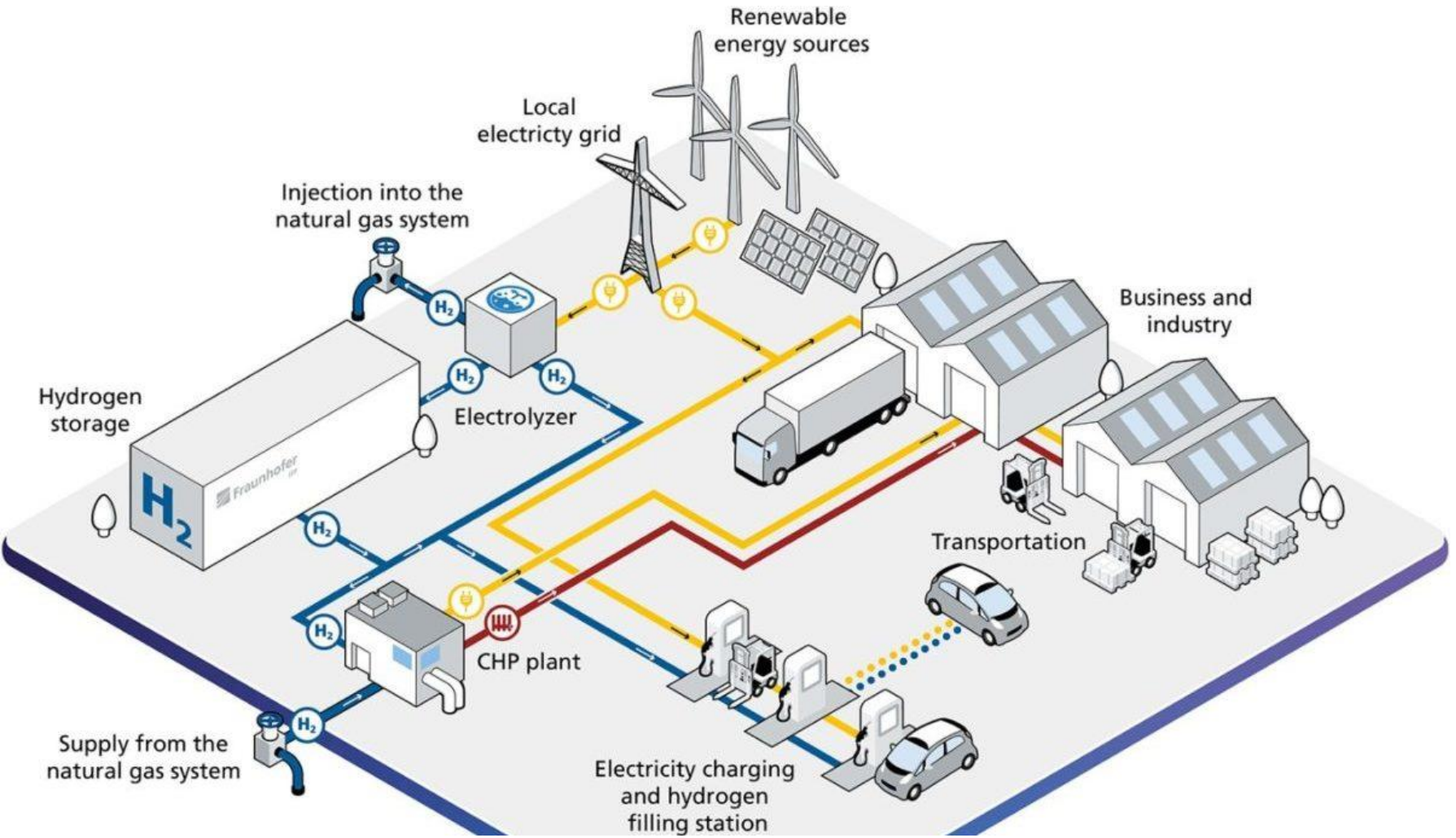
- Power-to-X
  - ⇨ Excess energy produced from renewable sources at peak times of production is converted to ***X***
  - ⇨ For example: **hydrogen: P2H2**
    - ➔ Hydrogen (in molecular form, from water) can then be:
      - Stored
      - Introduced into the gas distribution grid



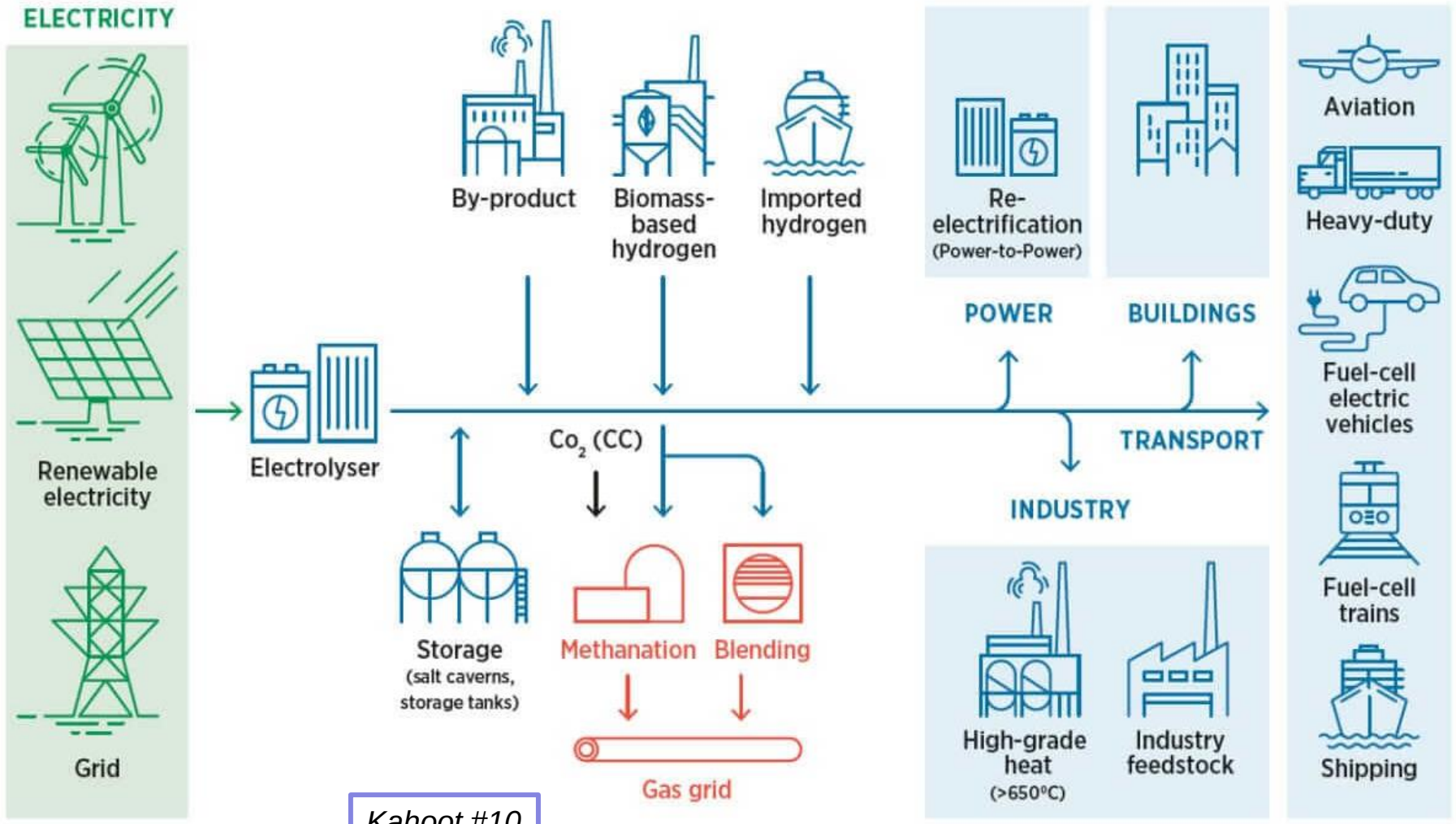
Burning hydrogen does not produce CO_2!

$$2H_2 + O_2 \rightarrow H_2O$$

Hydrogen e Sector-Coupling



The hydrogen supply chain



Kahoot #10

Italy and Hydrogen

SNAM: PER LA PRIMA VOLTA IN EUROPA FORNITURA DI IDROGENO MISTO A GAS NATURALE SU RETE DI TRASMISSIONE A UTENTI INDUSTRIALI

01 APR

01 aprile 2019 - 14:20 CEST

TAGS idrogeno, gas naturale, rete di trasmissione, utenti industriali

Al via sperimentazione in Campania: l'idrogeno è una tecnologia chiave per la decarbonizzazione e lo stoccaggio delle fonti rinnovabili

Contursi Terme (Salerno), 1 aprile 2019 – Snam ha avviato ufficialmente oggi la sperimentazione dell'immissione di una miscela di idrogeno al 5% in volume e gas naturale nella rete di trasporto gas italiana. La sperimentazione, prima di questo genere in Europa, ha luogo a Contursi Terme, in provincia di Salerno, e prevede la fornitura di H2NG (miscela di idrogeno e gas) a due imprese industriali della zona, un pastificio e un'azienda di imbottigliamento di acque minerali.

All'inizio della sperimentazione era presente, insieme all'amministratore delegato di Snam Marco Alverà, il sottosegretario al Ministero per lo Sviluppo economico Andrea Cioffi.

L'idrogeno avrà un ruolo cruciale nel garantire il raggiungimento degli obiettivi europei e globali di decarbonizzazione al 2050. La combustione dell'idrogeno, infatti, non genera emissioni di anidride carbonica. In prospettiva, inoltre, l'idrogeno "green" prodotto

- In April 2019, SNAM injected a Natural Gas-hydrogen mixture into its grid
  - ⇨ 5% in volume
  - ⇨ First time in Europe
  - ⇨ "*Blending*"

https://youtu.be/Fp3-ZYZu9Ws

IDROGENO IN RETE

01 APR

01 aprile 2019 - 11:00 CEST

TAGS idrogeno, cambiamento climatico

fonte: snam.it

Snam ha avviato la sperimentazione dell'immissione di una miscela di idrogeno al 5% in volume e gas naturale nella rete di trasporto gas italiana. La sperimentazione, prima di questo genere in Europa, ha luogo a Contursi Terme e prevede la fornitura di H2NG (miscela di idrogeno e gas) a due imprese industriali della zona.

" *La prima iniezione di idrogeno in Europa in una rete di trasporto con fornitura diretta a clienti industriali* – ha dichiarato l'AD Snam Marco Alverà – *proietta Snam e il nostro Paese nel futuro dell'energia pulita. I gas rinnovabili come l'idrogeno green e il biometano, infatti, avranno un ruolo centrale nel mix energetico decarbonizzato oltre il 2050 insieme alle fonti rinnovabili tradizionali*".

The prospects of hydrogen in Germany (May 2020)

Initial H2 2030 grid in blue; later additions of "visionary grid" in green

14 May 2020, 14:03 Sören Amelang

Germany's gas grid operators present concept for 2030 green hydrogen grid

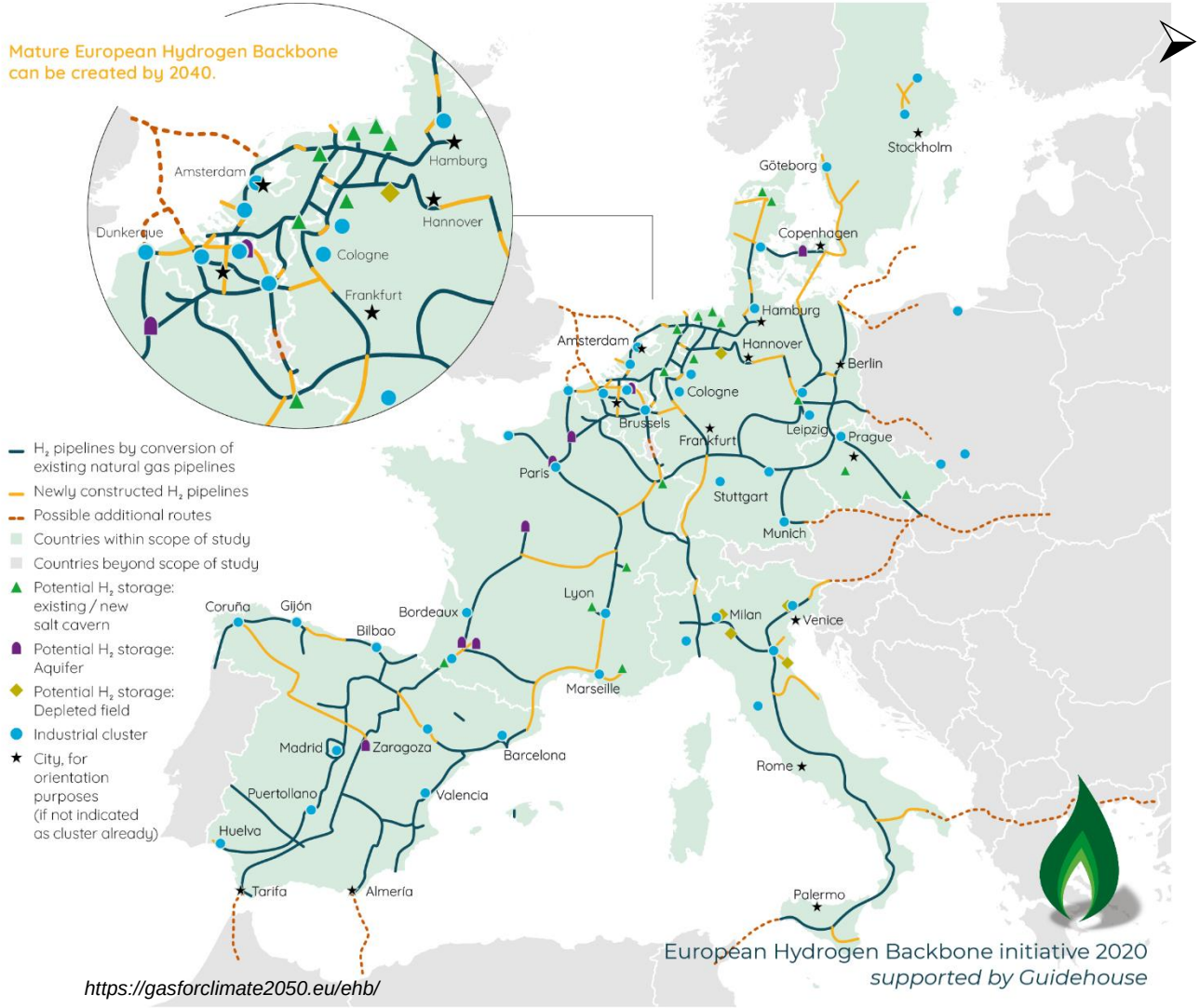
#Gas

Clean Energy Wire

- For 2030, hydrogen grid
  - ⇨ 1200 km
  - ⇨ Using the existing natural gas grid
  - ⇨ Group's director says:
    - "*This would create a completely new energy network in Germany on the basis of the existing natural gas network, giving industries such as steel or chemicals the opportunity to become climate neutral*"

https://youtu.be/ztStKmRx4ZE

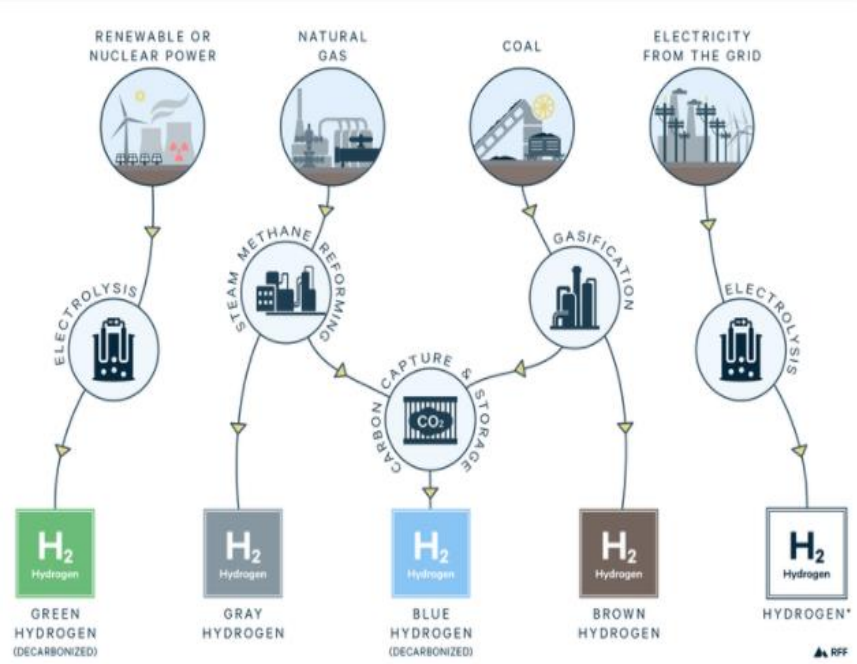
New infrastructure



https://gasforclimate2050.eu/ehb/

- Pipeline
  - ⇨ 6800 km for 2030
  - ⇨ 23000 km for 2040
  - ⇨ Investment:
    - ➔ €27-64 billion, for the 2040 infrastructure
  - ⇨ Cost of transport:
    - ➔ €0.09-0.17 per kg of hydrogen, per 1,000 km

The colors of hydrogen



Research for Future,Jay Bartlett and Alan Krupnick, 2020

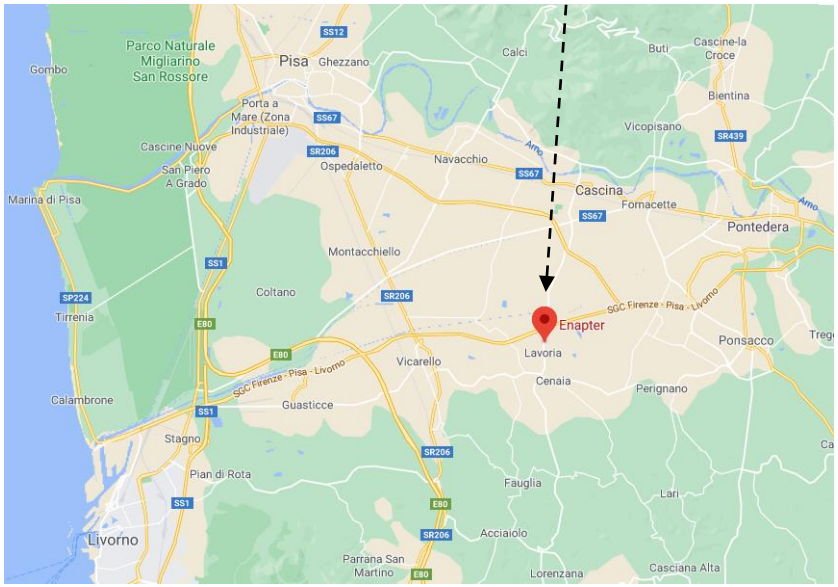
- A color can be associate in base of production
  - ⇨ **GREY hydrogen**
    - ➔ From **fossil fuel**
      - with CO2 emissions
  - ⇨ **BLUE hydrogen**
    - ➔ From **fossil fuel**
      - Without CO2 emissions
        - » CO2 capture (and… stored!!)
  - ⇨ **VIOLET hydrogen**
    - ➔ Elettrolizers use electric electrolyzers use electricity from **nuclear Plant**
  - ⇨ **GREEN hydrogen**
    - ➔ Electrolyzers use electricity **renewable Energy**
      - Solare ed eolica ad esempio
- Traceability!

Hydrogen in your home…

- Enapter
  - ⇨ Close to Lavoria (PI)
  - ⇨ Electrolyzer to produce Hydrogen at home
  - ⇨ Integration with home solar panels!

Electrolyser
EL 2.1

Enapter



Hydrogen costs by color

- Hydrogen costs by color
  - ⇨ **GREY hydrogen**
    - ➔ the cheapest
    - ➔ depends on the price of methane
    - ➔ about 1.0 €/kg
  - ⇨ **Blue hydrogen**
    - ➔ add costs for carbon capture.
    - ➔ about 1.5 €/kg_{H2}
      - – +0,5 €/kg_{H2} more than gray hydrogen
  - ⇨ **GREEN hydrogen**
    - ➔ It depends on the cost of the electrolysers and the cost of the renewable electricity that powers them
    - ➔ In Italy, it cost from 6,0 to 8,7 €/kg_{H2}
      - – In 2030 it will cost from 3,7 to 5,9 €/kg_{H2}
        - » With 1.kg_{H2}, a **car** can traver 100 km
          - » TODAY, the cost is about twice as much as a diesel car.
    - ➔ A study of Bloomberg esteem for 2050 a Hydrogen cost about 1 $/kg

the future costs of the various 'types' of hydrogen

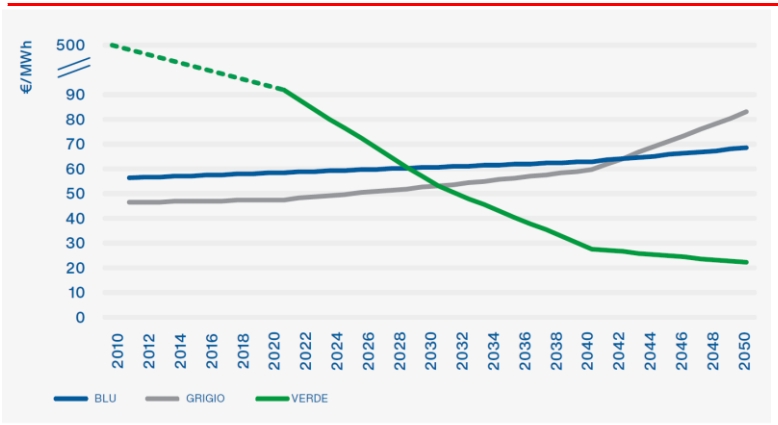
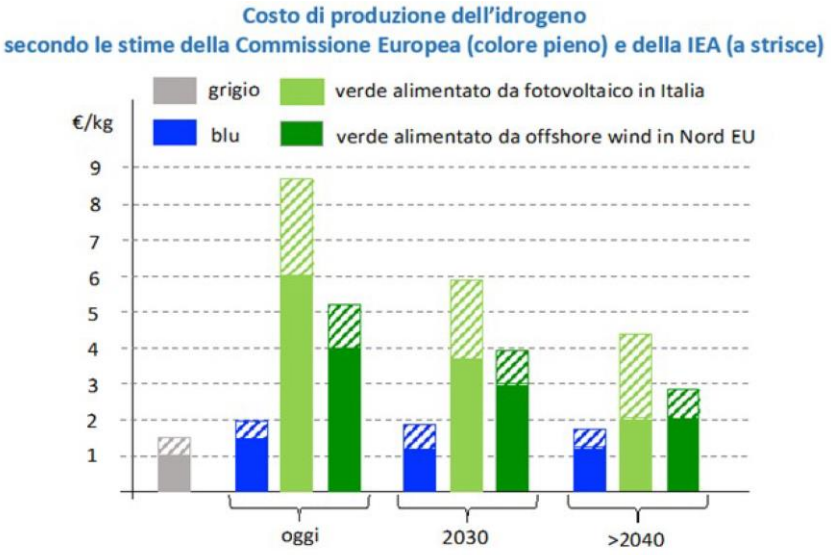


Figura 44 – Costi di produzione dell'idrogeno per tipologia (€/MWh), 2010-2050.
Fonte: elaborazione di The European House – Ambrosetti su dati Snam, 2020.

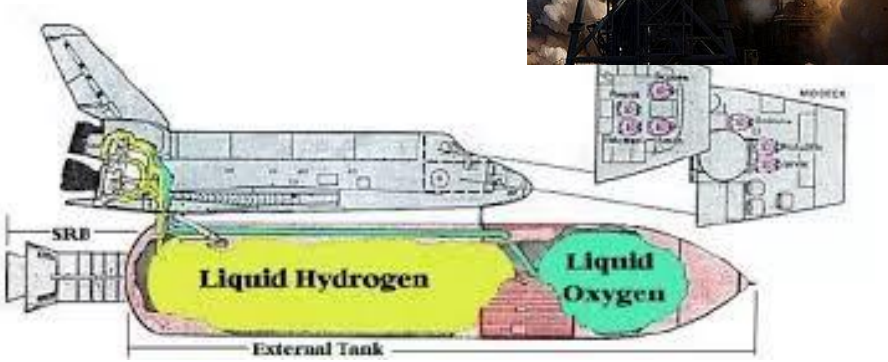


...anche se alimentato da rete al 100% rinnovabile

- In the transition phase, it is important not to discourage the production of **blue** hydrogen (by H2IT)
  - ⇨ Blue hydrogen is cheaper than green hydrogen
    - ➔ Green hydrogen incentives would be premature and very expensive today
    - ➔ To promote the diffusion of hydrogen, it is better to start from the blue one
    - ➔

Main storage technologies

- Liquefied hydrogen
  - Liquid hydrogen (*LH2*)
  - *LH2* has a higher energy density than gaseous hydrogen
  - It requires liquefaction at **–253°C**!
    - ➔ A complex technical plant and an extra economic cost
  - The tanks and storage facilities have to be <u>insulated</u>
  - Today primarily in **space** travel
  - The energy input for **liquefaction** (cooling) is around 30% of the final energy



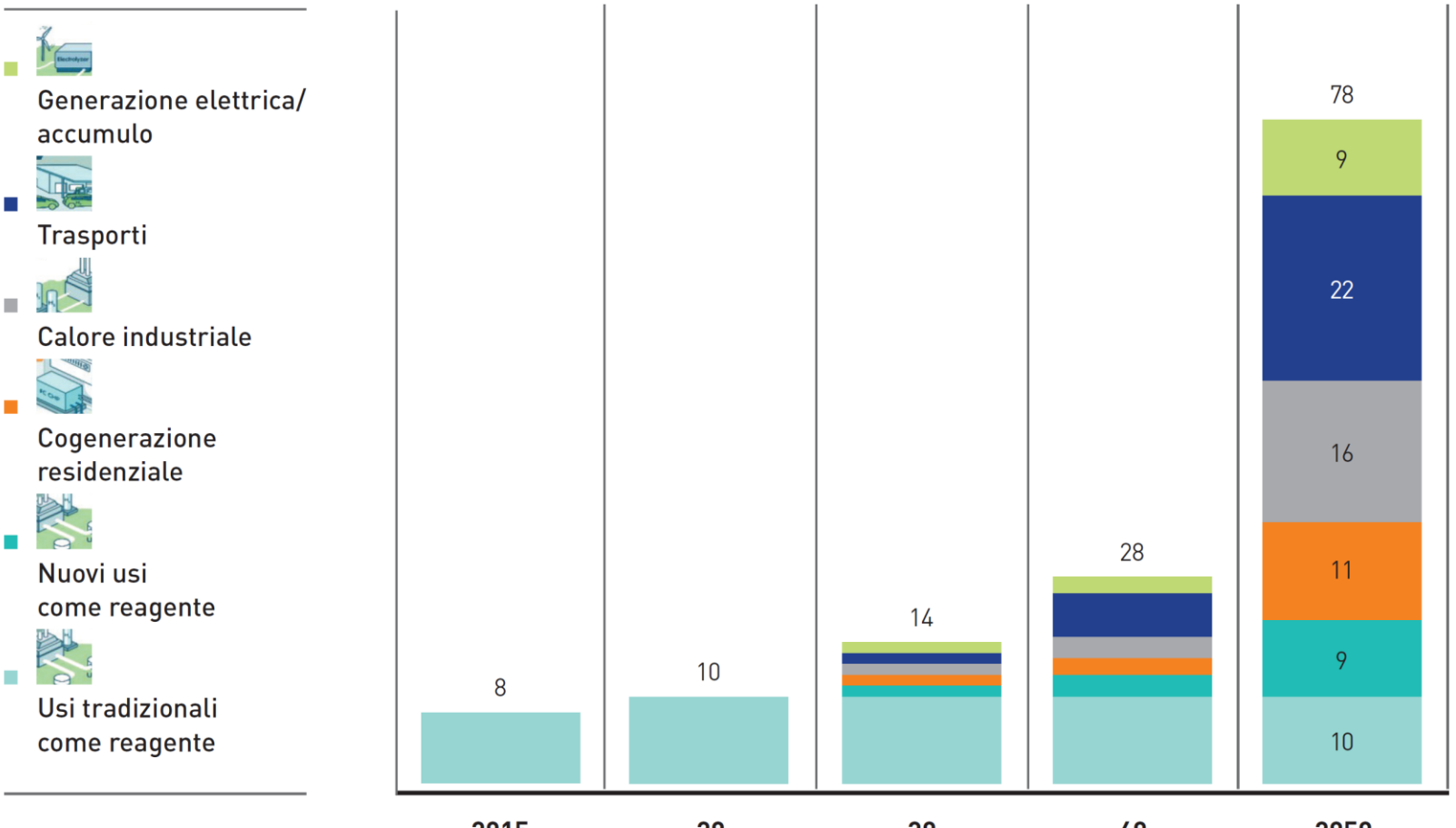
Prospects for the future of hydrogen use

FIGURA 2

Previsioni sull'utilizzo dell'idrogeno fino al 2050

(fonte: [50])

Fonte: RSEview
«Idrogeno Un vettore energetico per la decarbonizzazione»
Gennaio 2021



Hydrogen demand and production

- If all current dedicated hydrogen production were produced through water electrolysis, this would result in:
  - ⇨ An annual electricity demand of 3 600 TWh
    - ➔ More than the annual electricity generation of the European Union.
  - ⇨ Water requirements would be 617 million m^3
    - ➔ 1.3% of the water consumption of the global energy sector today
      - – This is roughly twice the current water consumption for hydrogen from natural gas
        - » IEA, 2019

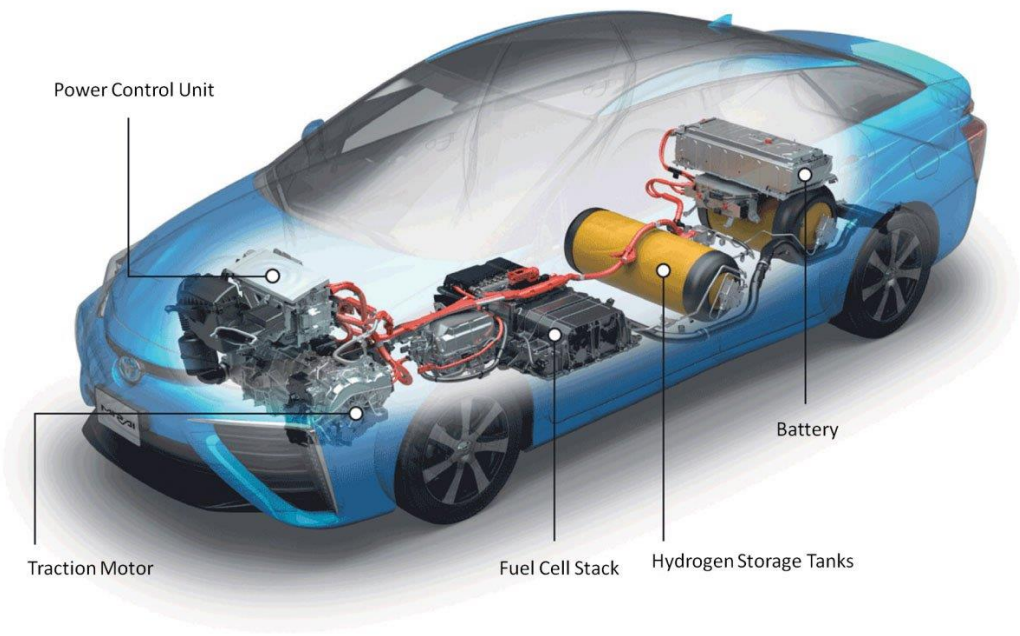
Hydrogen applied to car. Are we sure??

ALTRO MONDO C'È

IL FUTURO È DELL'IDROGENO: LE AUTO ELETTRICHE SCOMPARIRANNO GIÀ NEL 2030?

Elettrico o idrogeno? La VW: vincerà l'elettrico

di **Redazione** - 18 Settembre 2019 9



Hydrogen train… We CAN!

- Hydrogen trains in Valcamonica
  - ⇨ "Hydrogen Valley"
  - ⇨ In 2023, Hydrogen trains
    - ➔ Six new trains
    - ➔ By **Alstom**

Conclusioni

- Complex problem!
- There is no single solution
  - ⇨ Depends on the national and international context
    - ➔ European/World Energy Policy
- Global effort of ALL sectors
  - ⇨ Together!
- It can lead to numerous benefits
  - ⇨ Environment
  - ⇨ Growth
  - ⇨ Occupation
  - ⇨ …

NON possiamo PERDERE TEMPO!!

Conclusions

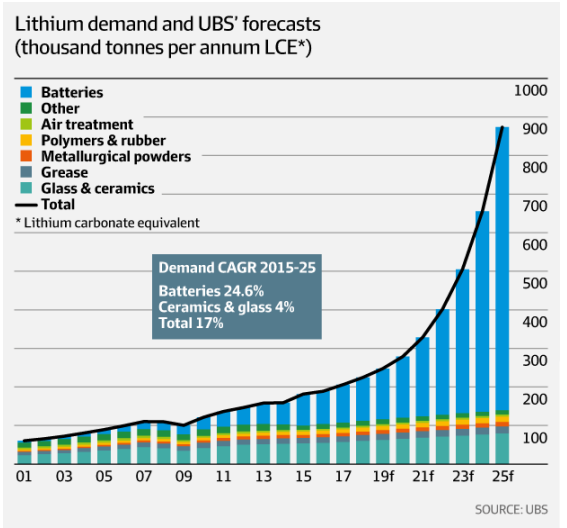
- But… some problems can be glimbsed
  - Energy poverty
    - ➔ An electric cable is not more sufficient to give power
    - ➔ A house with domotic is necessary
  - Rare-Earth problem

Scenari

Nel 2030 il mondo andrà a batterie. Ecco quanto costerà produrle per tutti

Sole 24 Ore 19/08/2021

Si stimano investimenti per quasi 600 miliardi di dollari. Le vendite passeranno da 80 a 160 miliardi di dollari. Preoccupano le scorte di litio, potrebbero scarseggiare dal 2026



  - Biofuel
    - ➔ in a farm, it is more profitable business…
      - Produce a wheat, or…
        - » cheap bread for **poor people**
      - Produce tree
        - » to produce energy for **rich people**
          - » i.e.: *Vattenfall company import trees from Africa so produce "green energy" in Germany*.

Dept. of Industrial Enginerring
University of Florence

Can RENEWABLE ENERGY make it on ITS OWN?

Kahoot #11,12

Prof. Carlo Carcasci