Energia per l'Astronave Terra

Solar Energy

$$2\ H_2O \rightarrow O_2 + 2\ \text{“}H_2\text{”}$$

$$2\ \text{“}H_2\text{”} + 2\ CO_2 \rightarrow [CH_2O]$$

Fuel

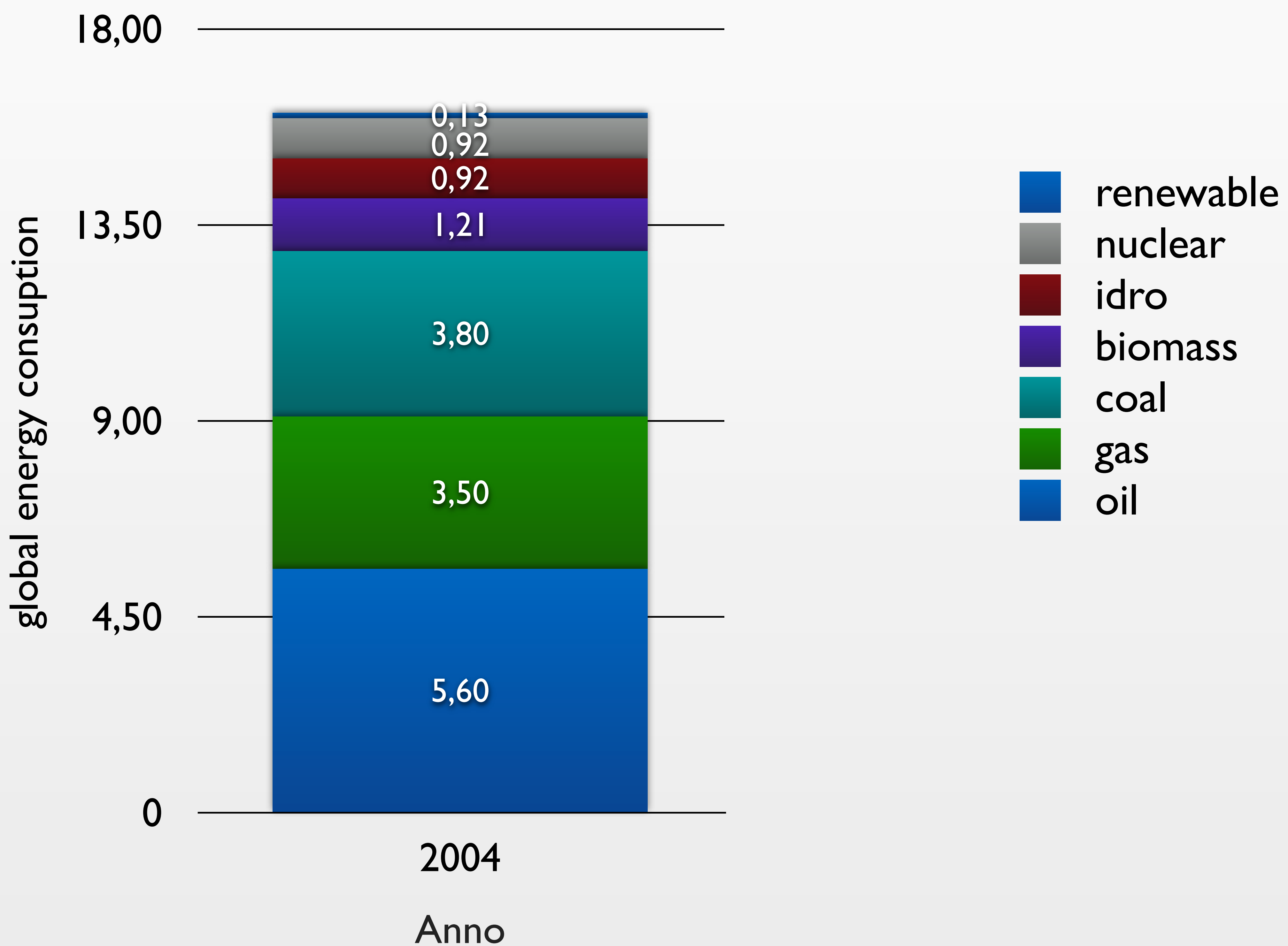
Le sfide della scienza nel 21th Secolo

- "...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... "
- "...For our purposes the fundamental problem from the technical point of view is how to fix the solar energy through suitable photochemical reactions. To do this it would be sufficient to be able to imitate the assimilating processes of plants..."

  - Giacomo Ciamician in "The Photochemistry of the Future," **Science (1912), 36(926)**

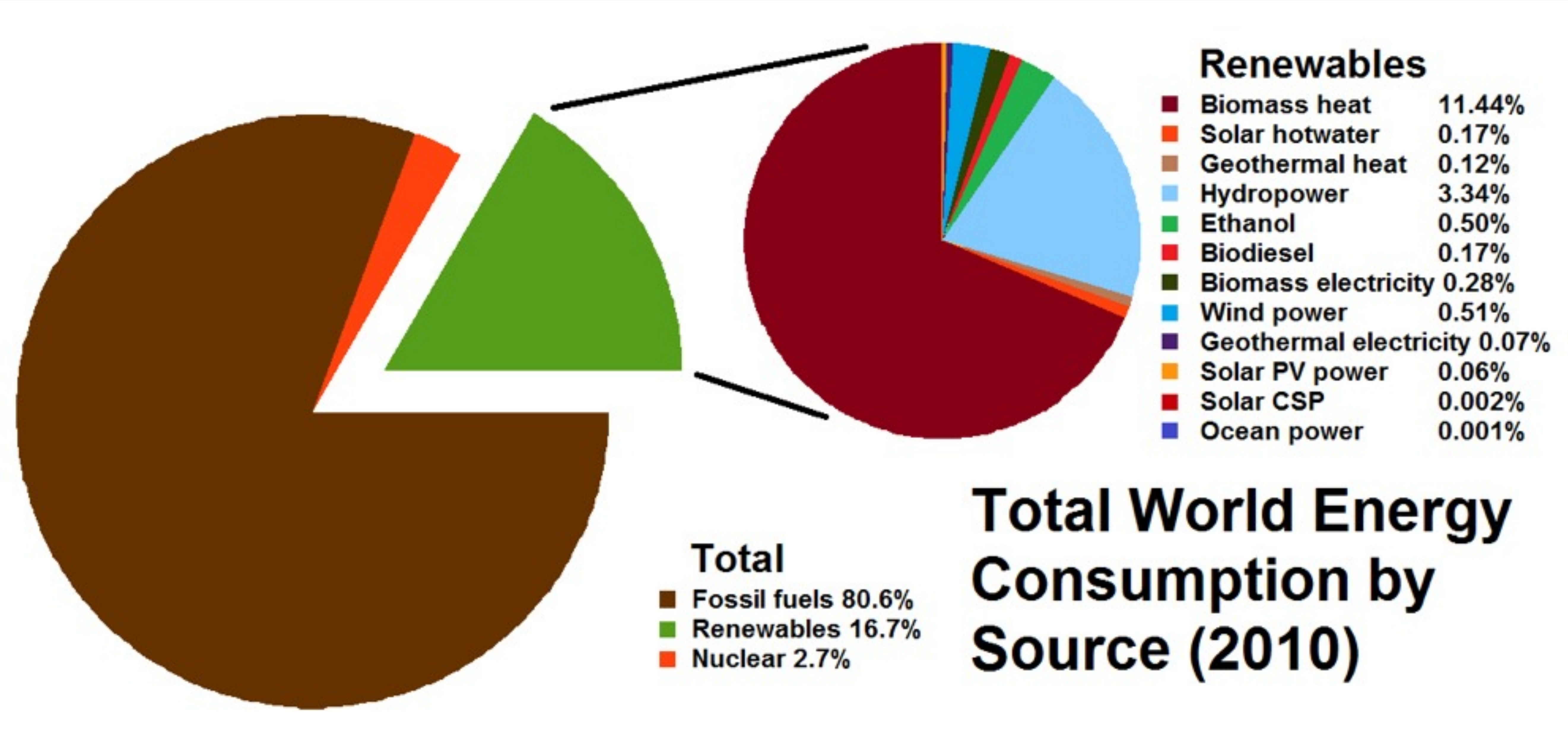
Consumo globale energia

- Punto di partenza



Consumo globale energia

- 80% combustibili fossili
- Rinnovabili 16%



Consumo globale energia

- Domanda energetica per gruppi di paesi

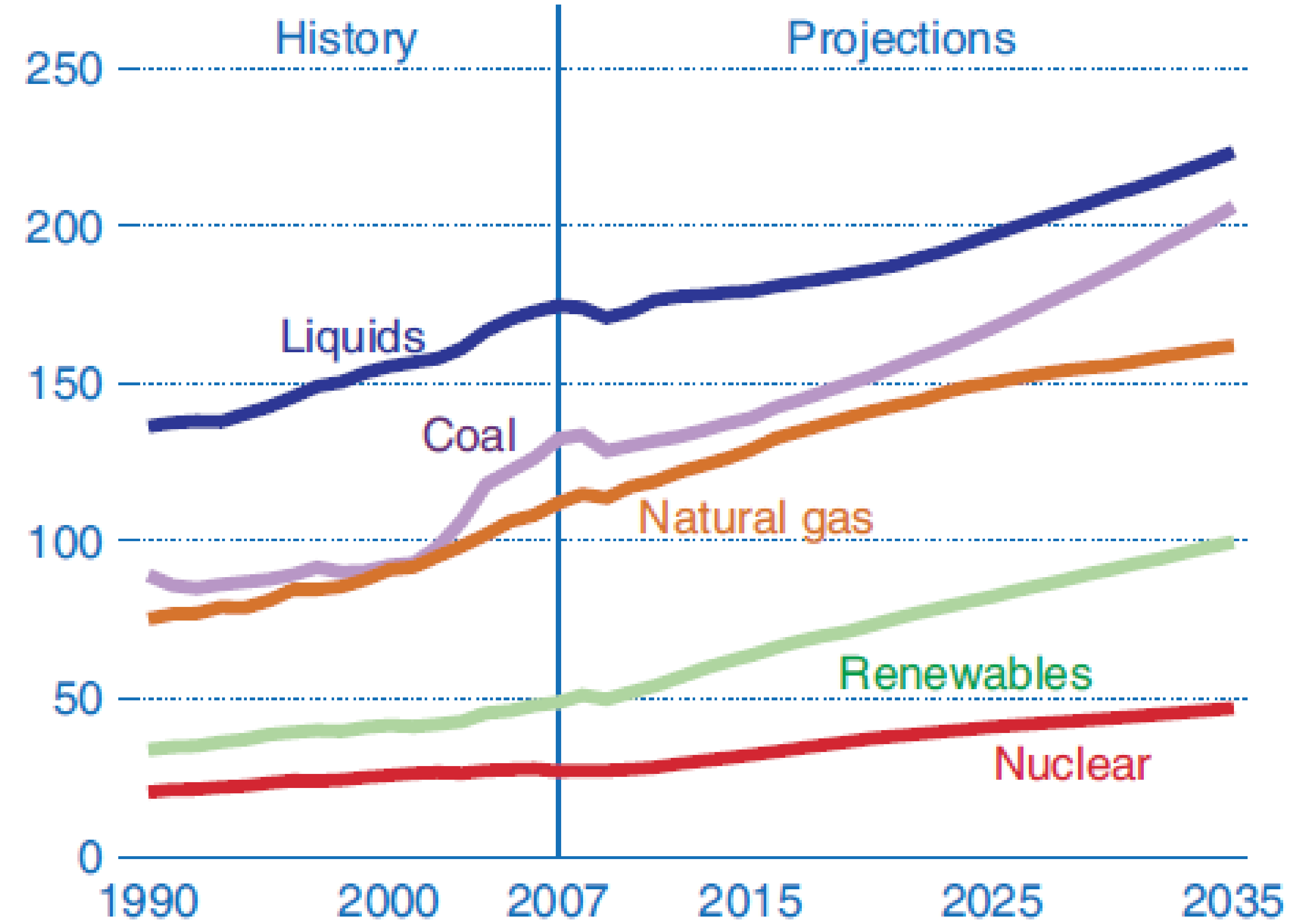
Table 1. World marketed energy consumption by country grouping, 2007-2035 (quadrillion Btu)

Region	2007	2015	2020	2025	2030	2035	Average annu[al] percent chang[e] 2007-2035
OECD	**245.7**	**246.0**	**254.2**	**263.2**	**271.4**	**280.7**	**0.5**
North America	123.7	124.3	129.4	134.9	140.2	146.3	0.6
Europe	82.3	82.0	83.0	85.0	86.5	88.2	0.2
Asia	39.7	39.7	41.8	43.3	44.8	46.3	0.5
Non-OECD	**249.5**	**297.5**	**336.3**	**375.5**	**415.2**	**458.0**	**2.2**
Europe and Eurasia	51.5	52.4	54.2	56.2	57.8	60.2	0.6
Asia	127.1	159.3	187.8	217.0	246.9	277.3	2.8
Middle East	25.1	32.9	36.5	39.1	41.8	45.7	2.2
Africa	17.8	20.8	22.5	24.6	26.5	29.0	1.8
Central and South America	28.0	32.1	35.5	38.7	42.2	45.7	1.8
Total World	**495.2**	**543.5**	**590.5**	**638.7**	**686.5**	**738.7**	**1.4**

Consumo globale energia

- Domanda energetica per tipo di combustibile

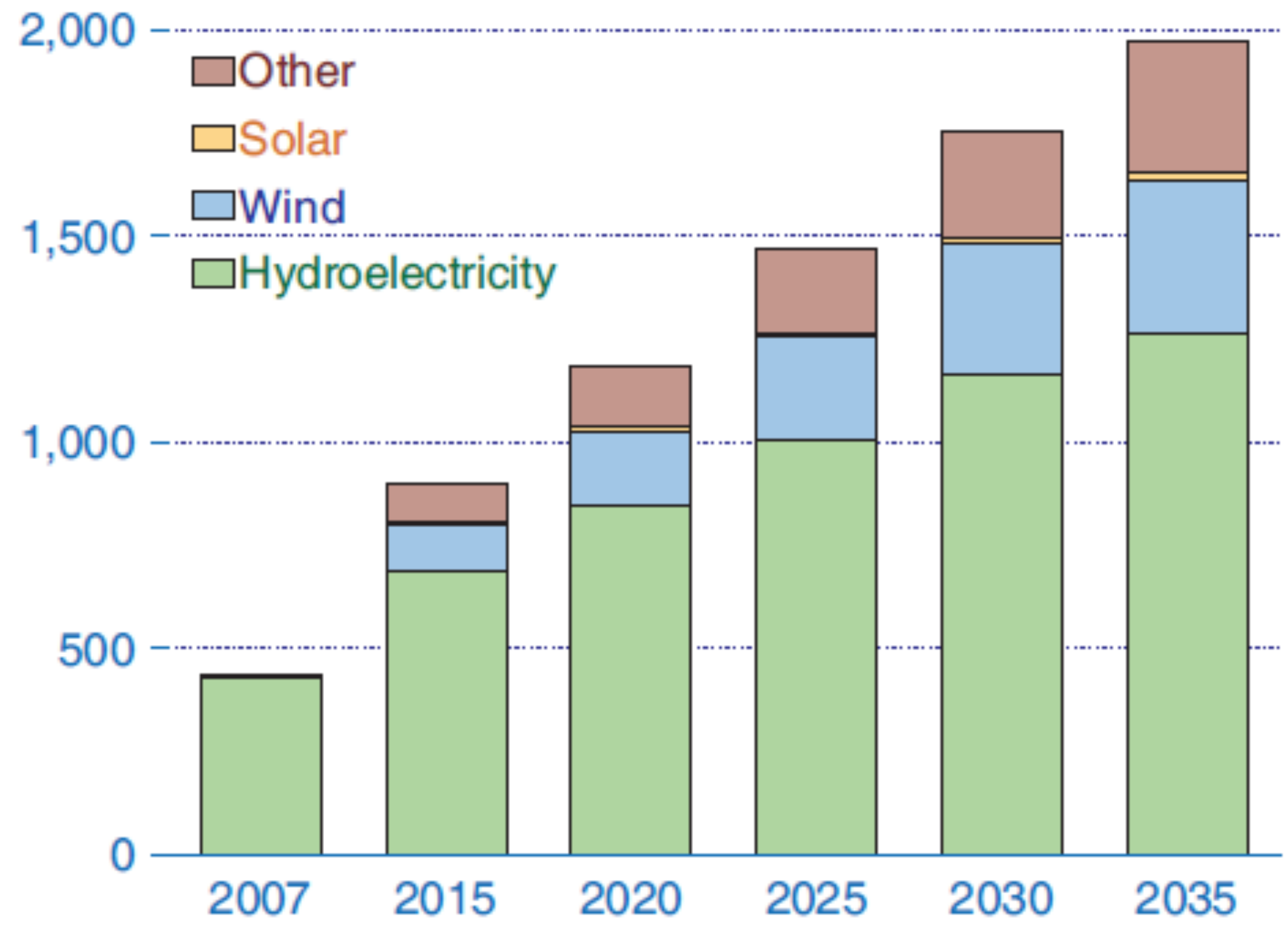
Figure 16. World marketed energy use by fuel type, 1990-2035 (quadrillion Btu)



Consumo globale energia

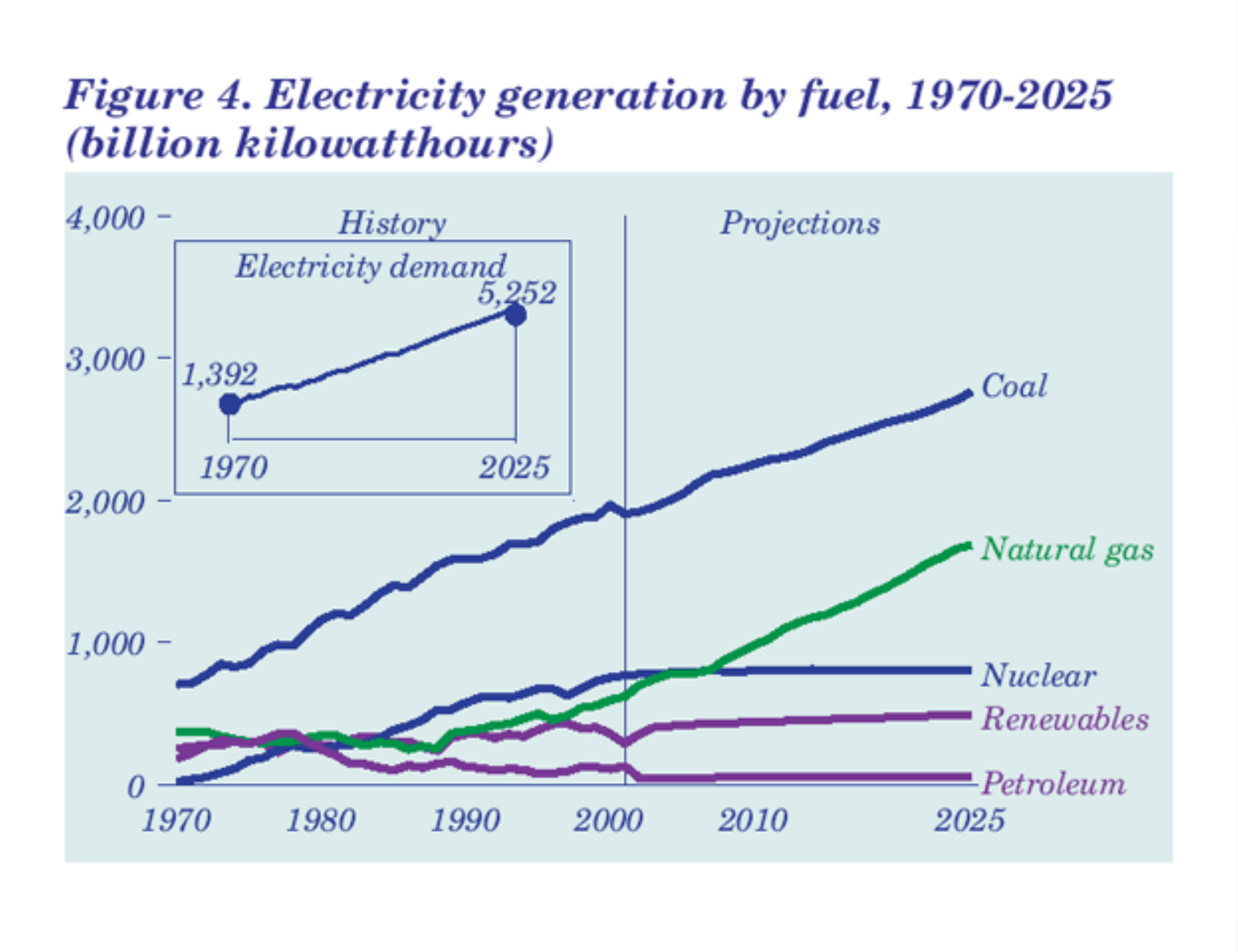
- Energia rinnovabile per generare elettricità in Cina

Figure 19. Renewable electricity generation in China by energy source, 2007-2035 (billion kilowatthours)



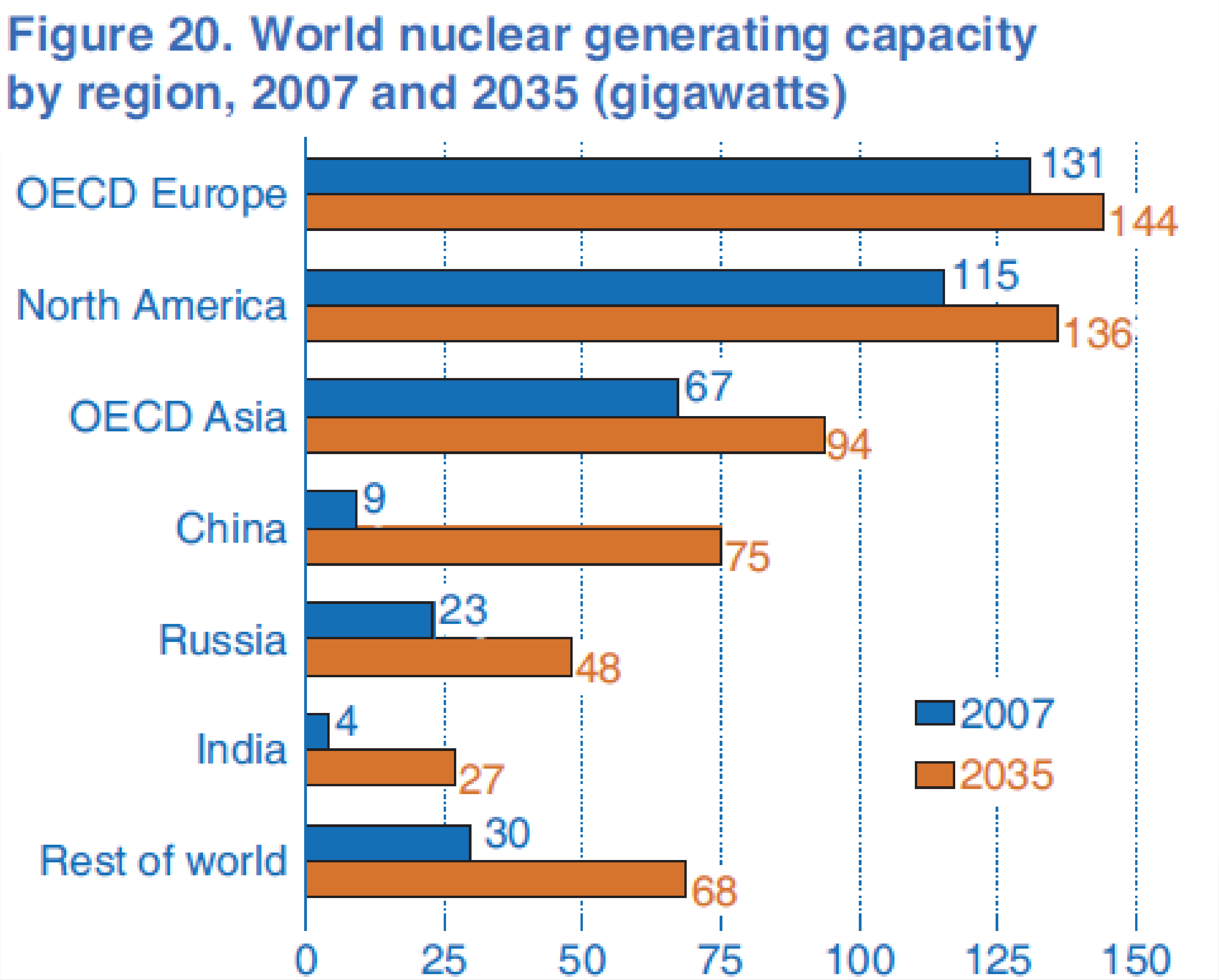
Consumo globale energia

- Energia elettrica generata da combustibili



Consumo globale energia

- Capacità in energia nucleare



Consumo globale energia

- Consumo carbone

Figure 63. Non-OECD coal consumption by region, 1980, 2007, 2020, and 2035 (quadrillion Btu)

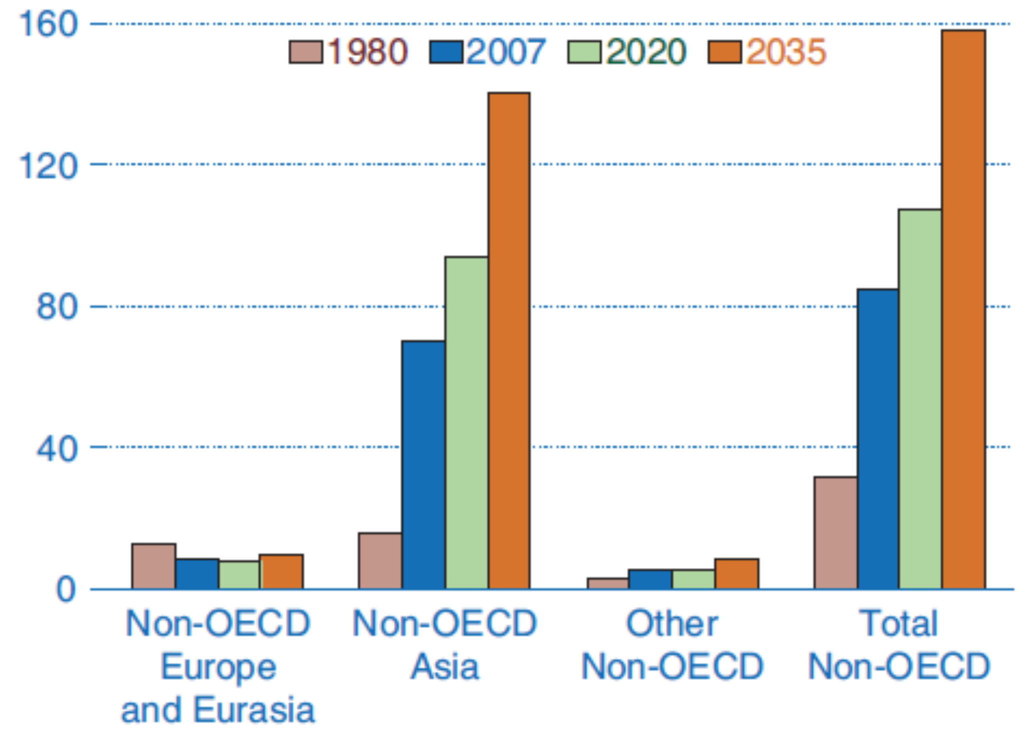
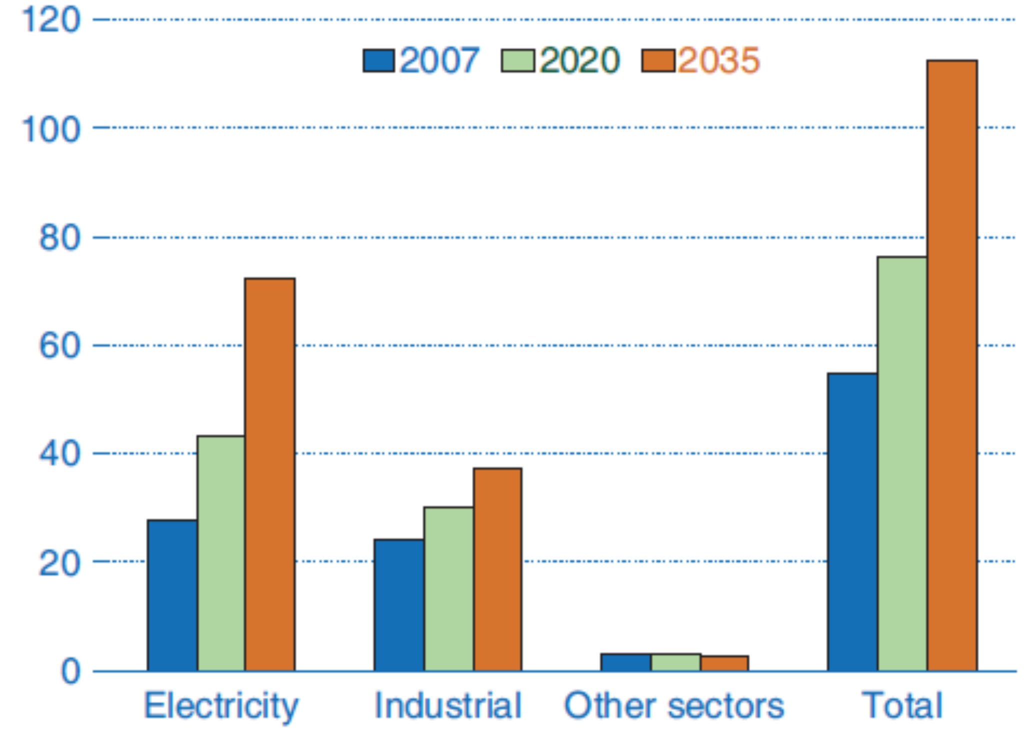


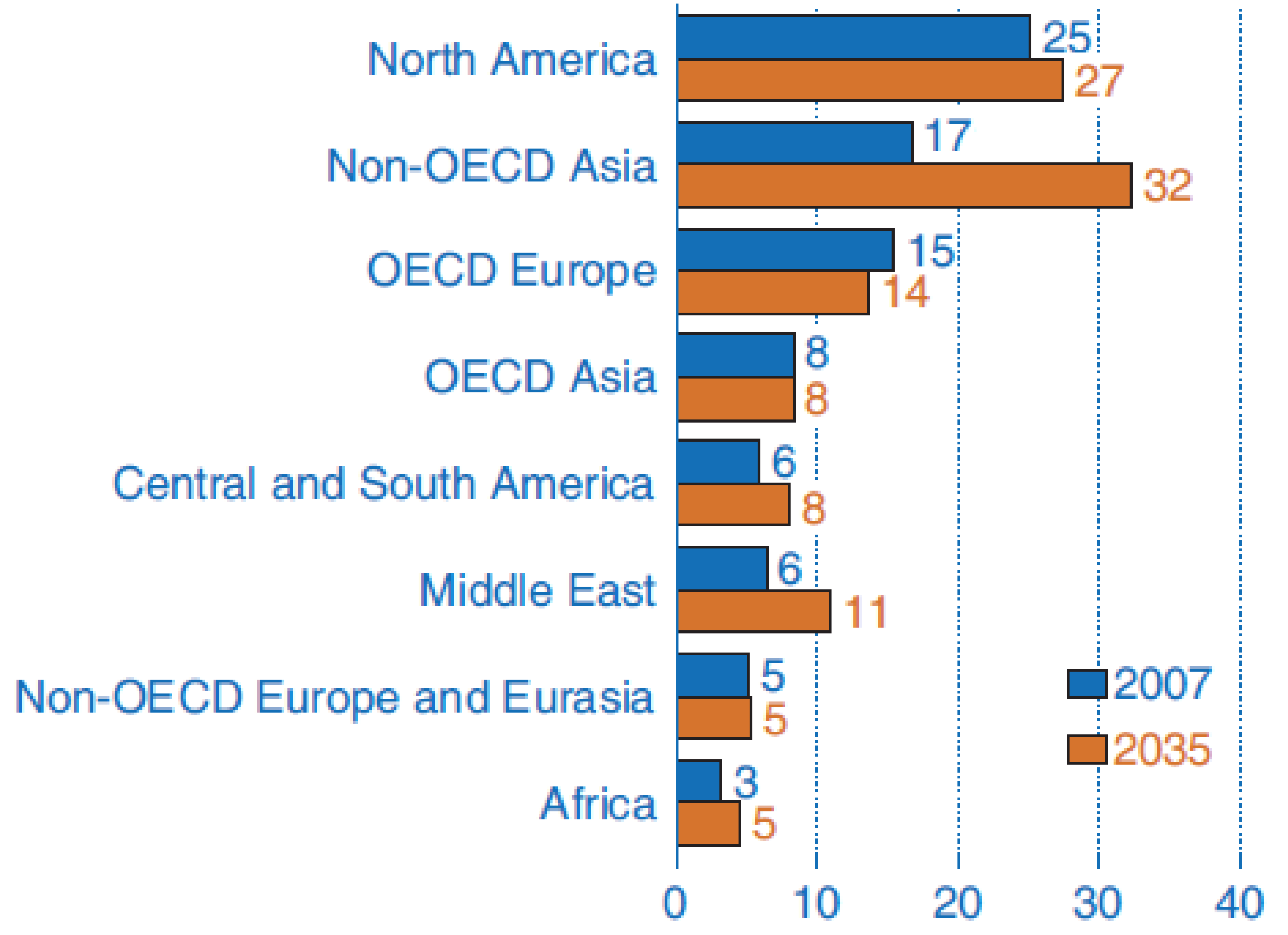
Figure 64. Coal consumption in China by sector, 2007, 2020, and 2035 (quadrillion Btu)



Consumo globale energia

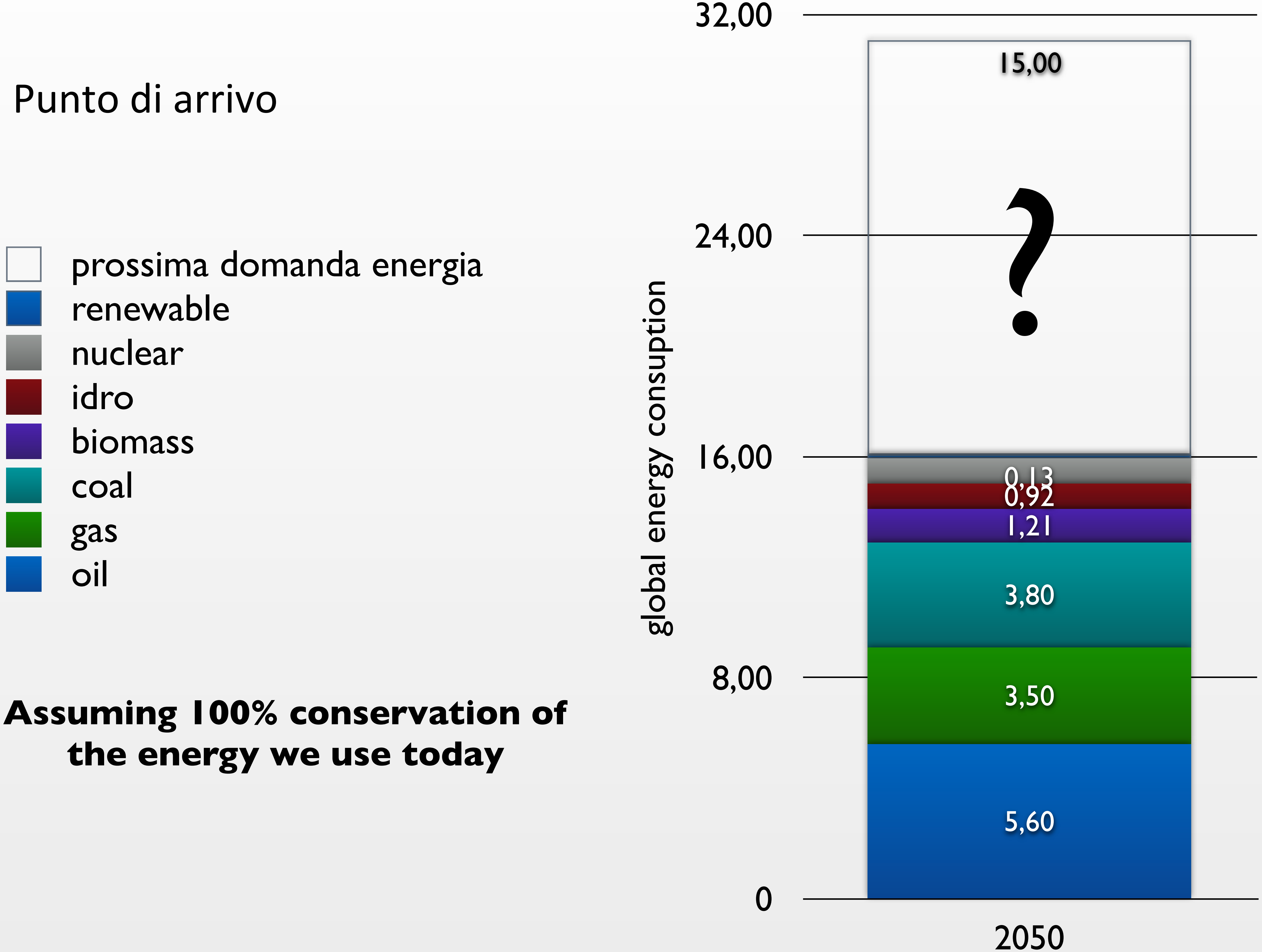
- Consumi di Petrolio

Figure 27. World liquids consumption by region and country group, 2007 and 2035 (million barrels per day)



Consumo globale energia

- Punto di arrivo



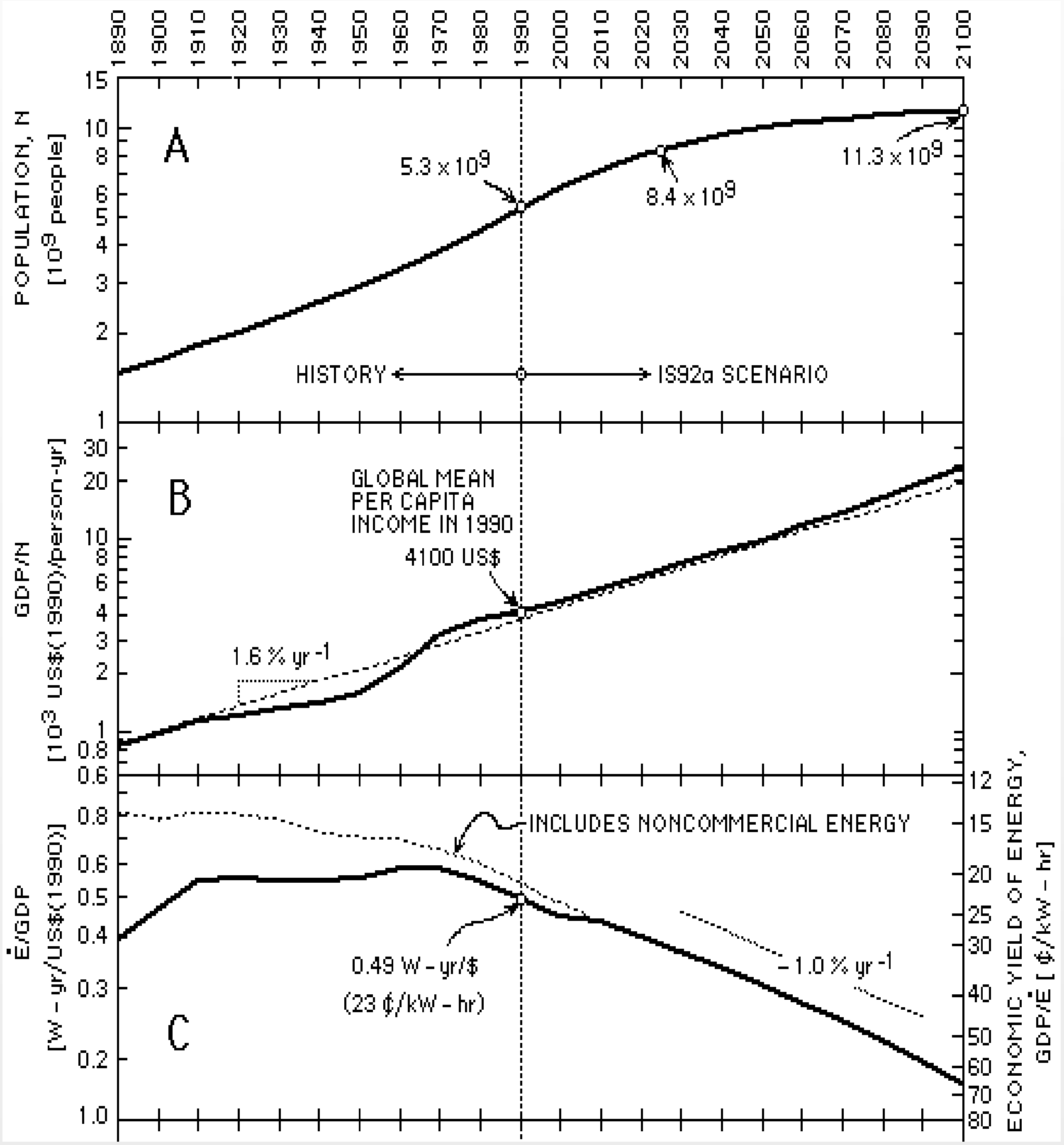
Assuming 100% conservation of the energy we use today

Consumo globale energia

- Formulazione consumo globale energia
- **E= N x (GDP/N) x (E/GDP)**
- E = consumo globale energia (TW)
- N = popolazione mondiale
  - N growth = +0.9%/yr (i.e. from 6 to 9.4 billion GDP/N is per capita GDP)
- GDP = prodotto interno lordo
- GDP/N = prodotto interno lordo pro-capite
  - GDP/N growth = +1.4%/yr (i.e. from $7500 to $15000)
- E/GDP = energy intensity (energy consumed per unit of GDP)

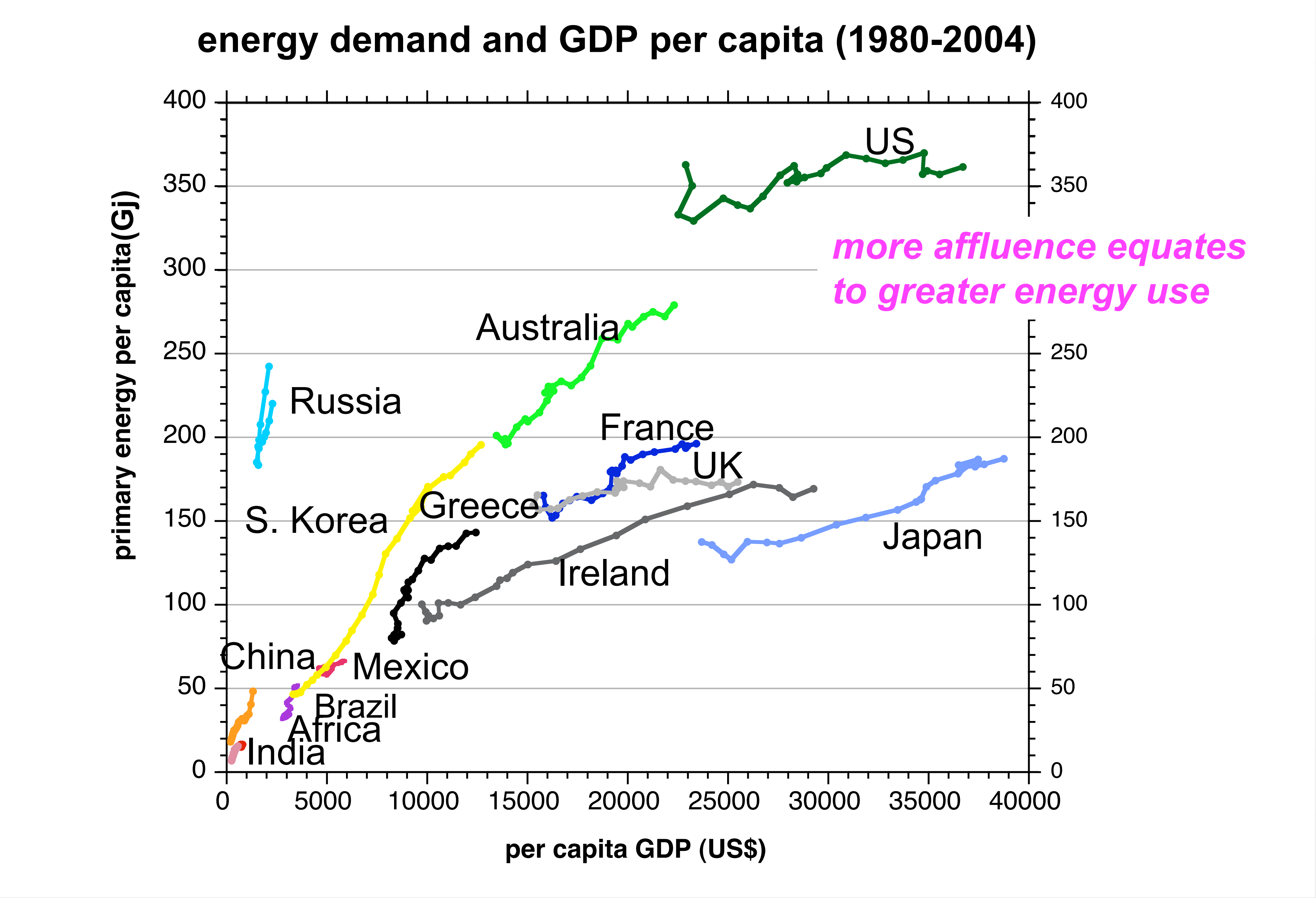
Consumo globale energia

- Population Growth to 10 - 11 Billion People in 2050
- Per Capita GDP Growth at 1.6% yr^{-1}
- Energy consumption per Unit of GDP declines at 1.0% yr^{-1}



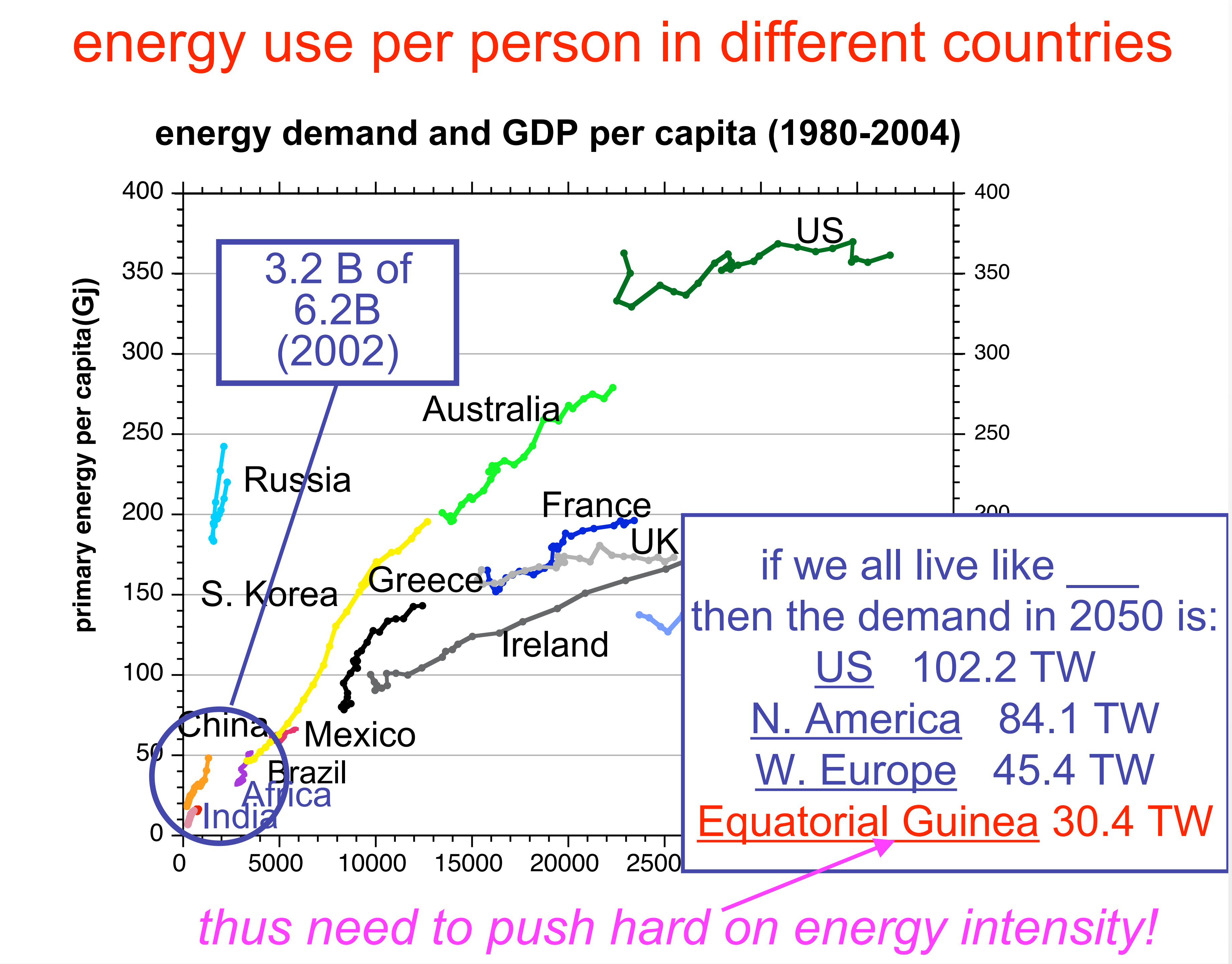
Richiesta energia pro-capite

- Valori per alcuni paesi



Richiesta energia procapite

- Alcune considerazioni per il 2050



Consumo globale energia

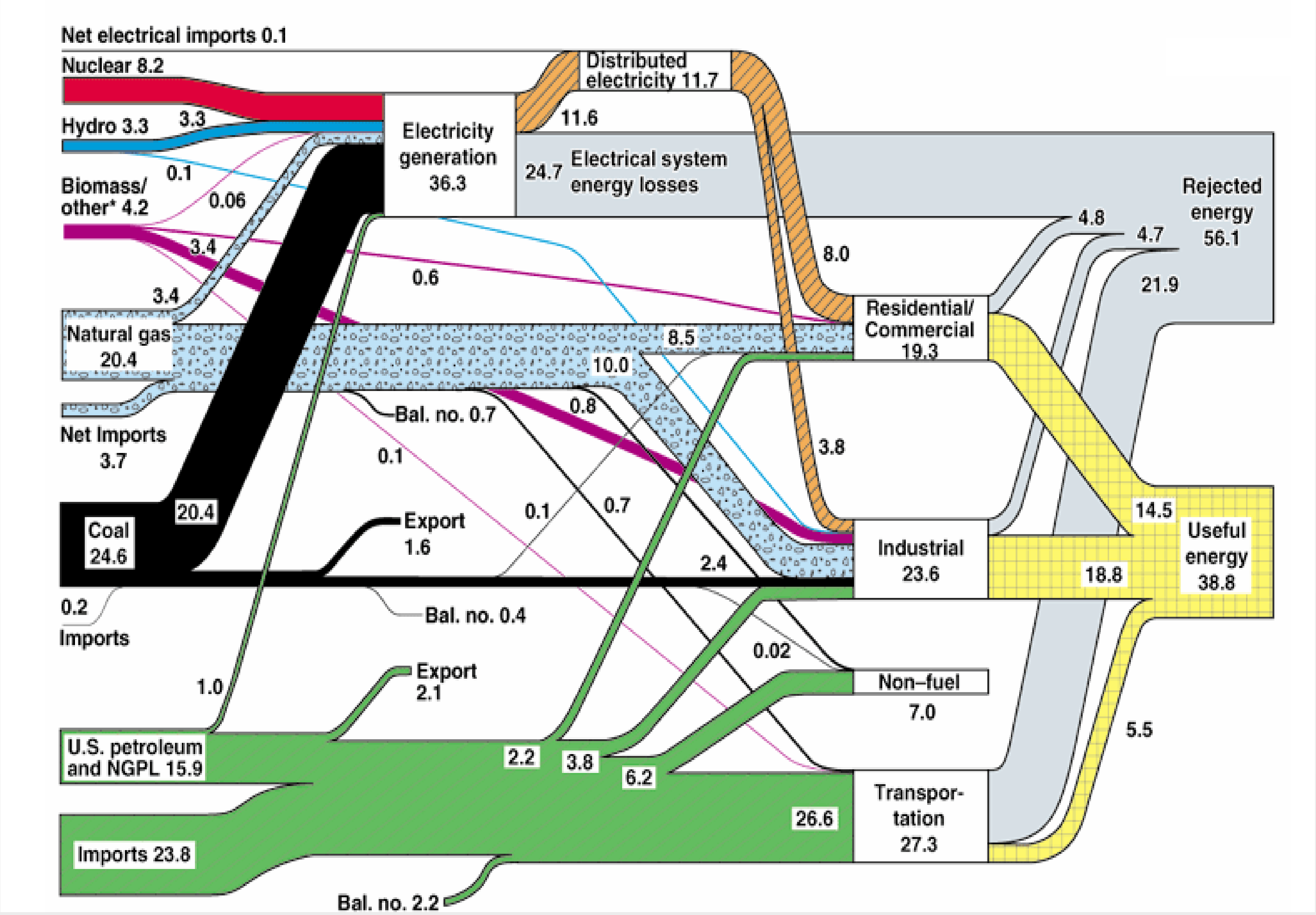
- Formulazione consumo globale energia
- $$E = N \times (GDP/N) \times (E/GDP)$$
- **1 Opzione**
- Diminuire N
  - Educazione femminile

Consumo globale energia

- Formulazione consumo globale energia
- $$E = N \times (GDP/N) \times (E/GDP)$$
- **<u>2 Opzione</u>**
  - fonte di energia rinnovabile e accessibile per tutti
  - Daniel Nocera: *“distributed (personalizez) energy is the key for non-legacy world. Do not downsize current energy system, owing to balance of system cost - start with a black piece of paper and create and invent!”*
  - *“the solution to the energy challege, in my opinion, rest in providing the non-legacy world a carbon-neutral, sustainable energy supply”.*
  - IMPO: Il problema principale riguardante l’energia nei paesi in via di sviluppo è il **costo** e non l’efficienza! Anche perchè più alta è l’efficienza più alti sono i costi.

Consumo globale energia

- Globale vs Locale
  - 1/3 energia proviene dal petrolio. Se eliminassimo il problema del petrolio rimarrebbe cmq il problema dei 16 TW.



Consumo globale energia

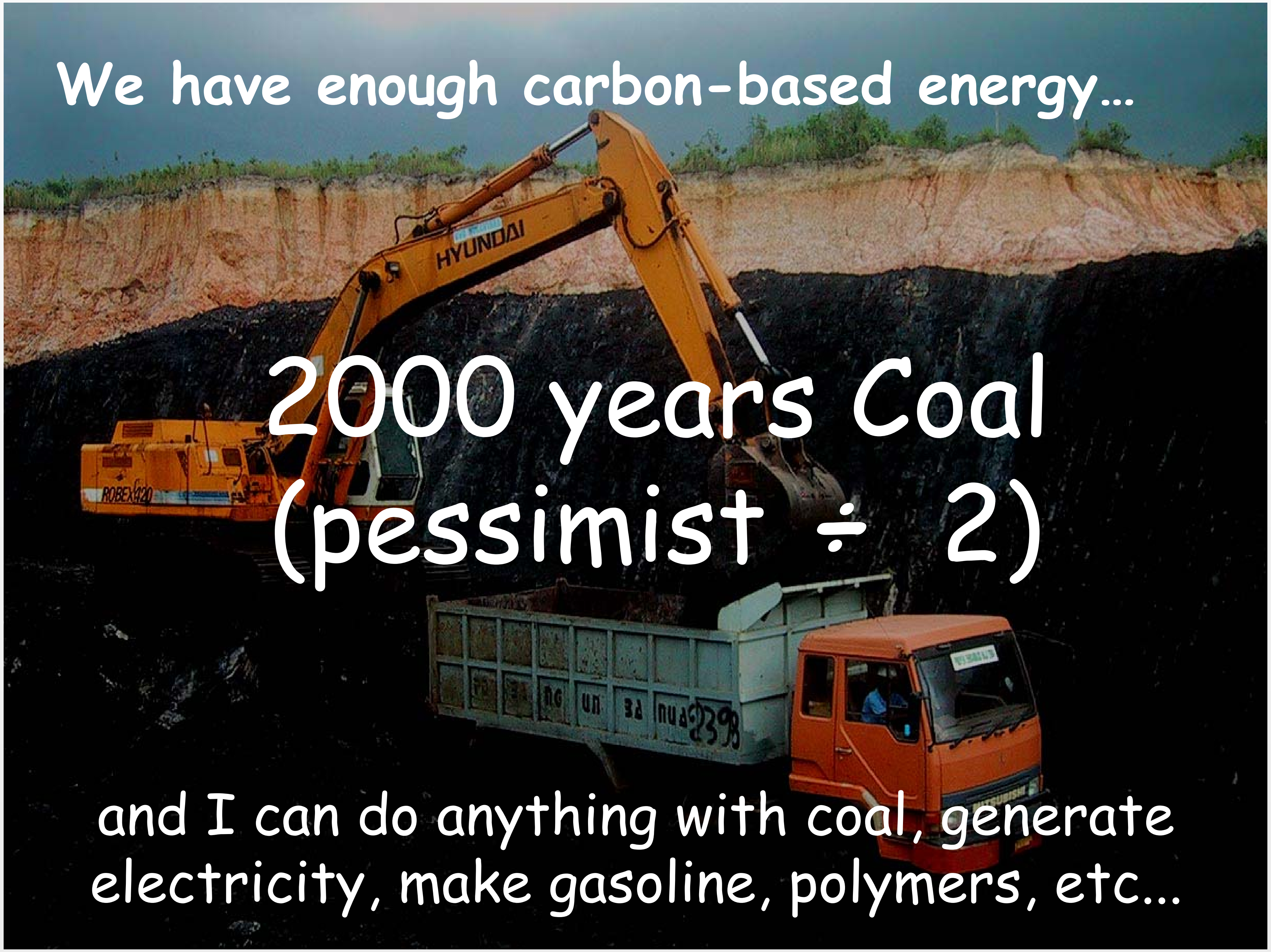
- Quanto petrolio abbiamo ancora in stiva...

Consumo globale energia

- Quanto gas abbiamo ancora in stiva...

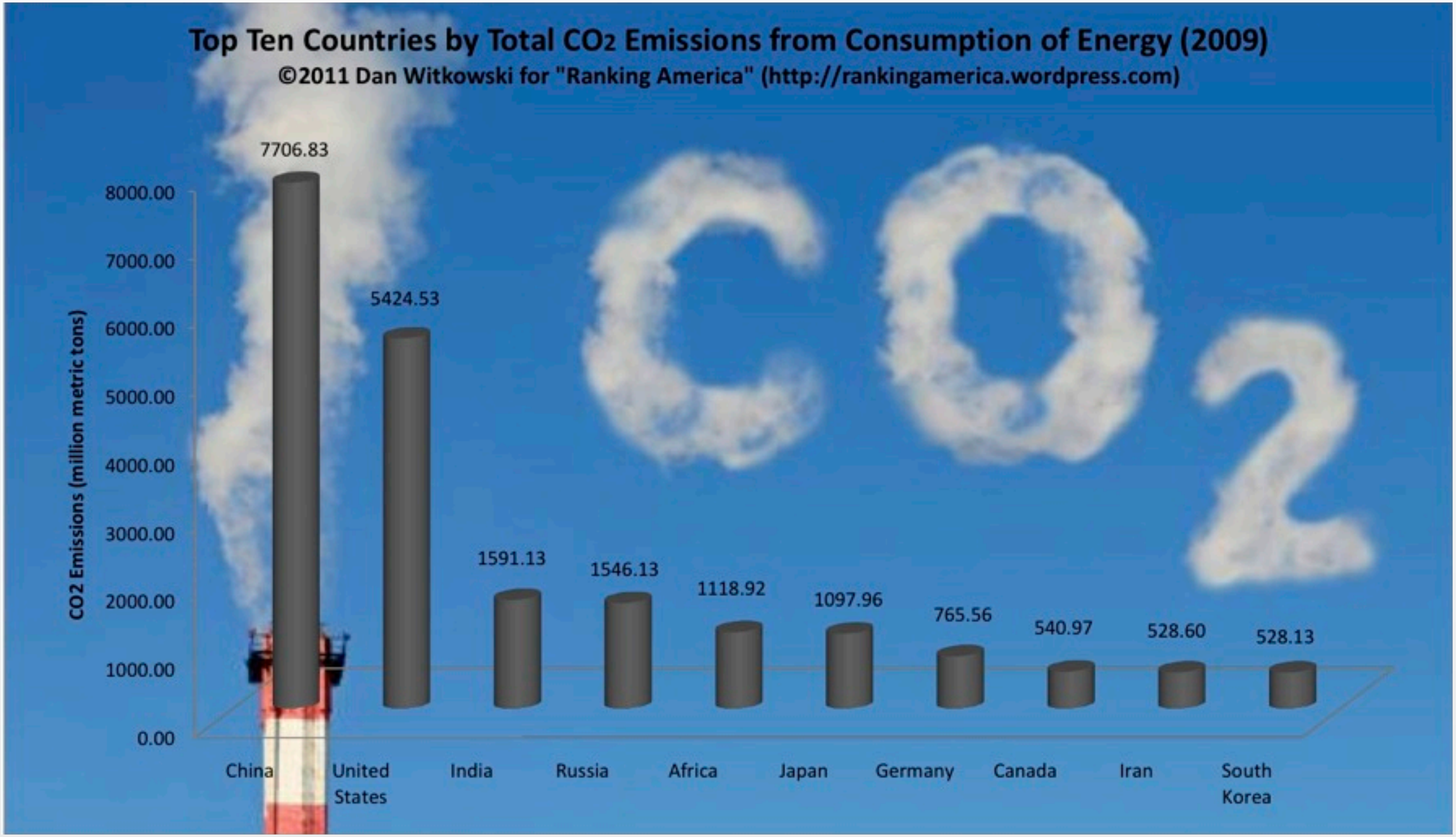
Consumo globale energia

- Quanto carbone abbiamo ancora in stiva...



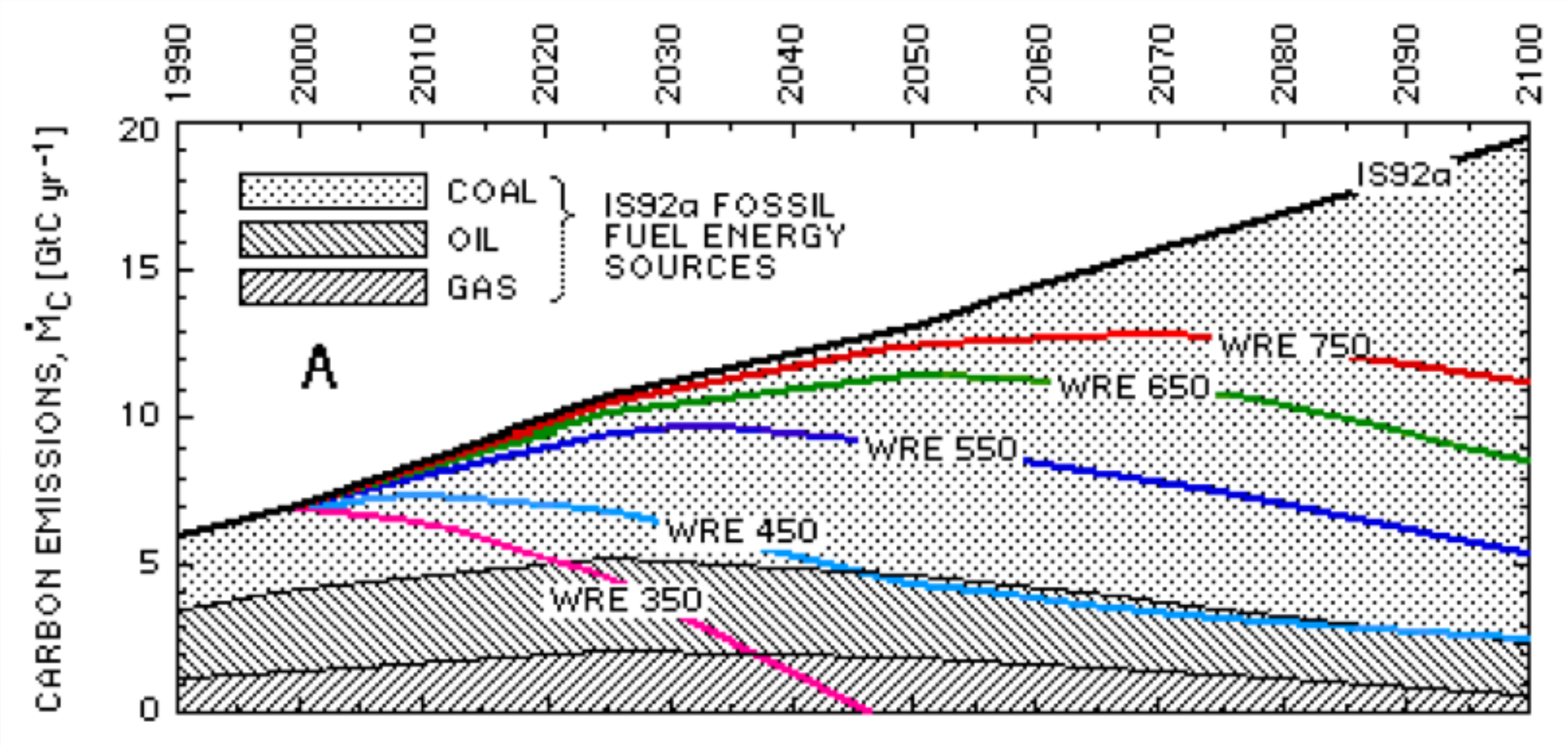
Emissioni globali CO_2

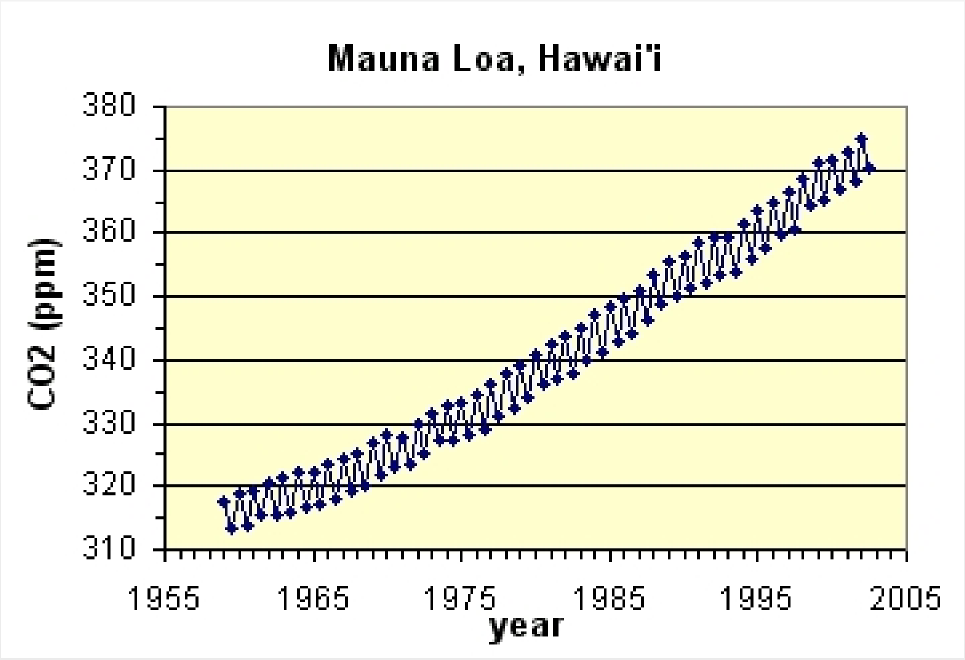
- Top Ten? Worse ten!

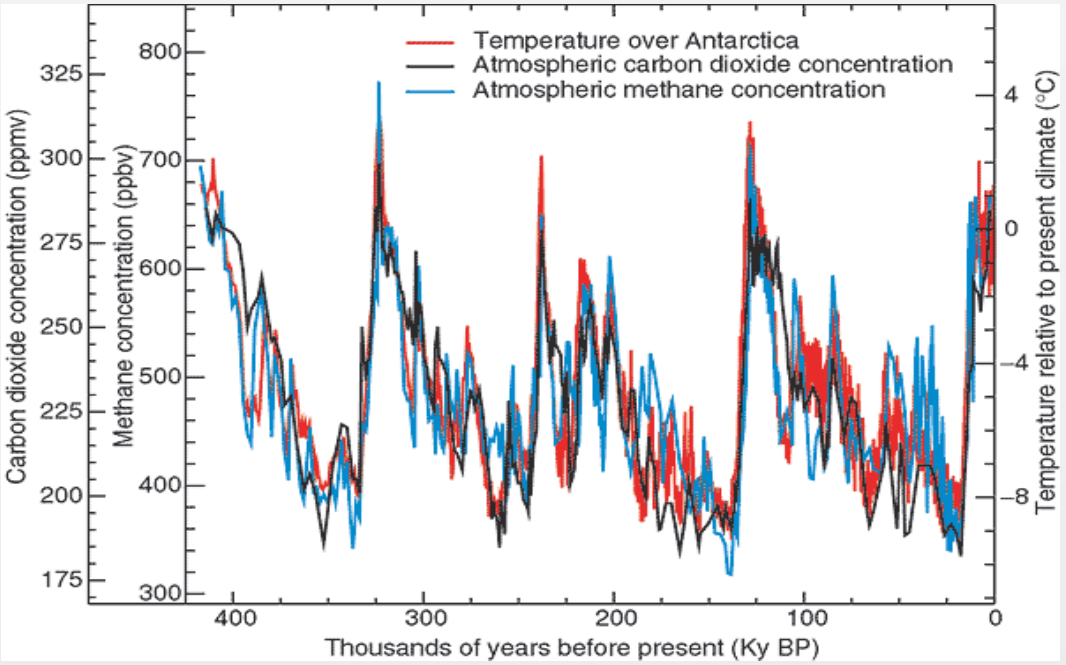


Emissioni globali CO_2

- Problema complesso che affronteremo in seguito...
- attenzione però ad affrontare bene il problema!







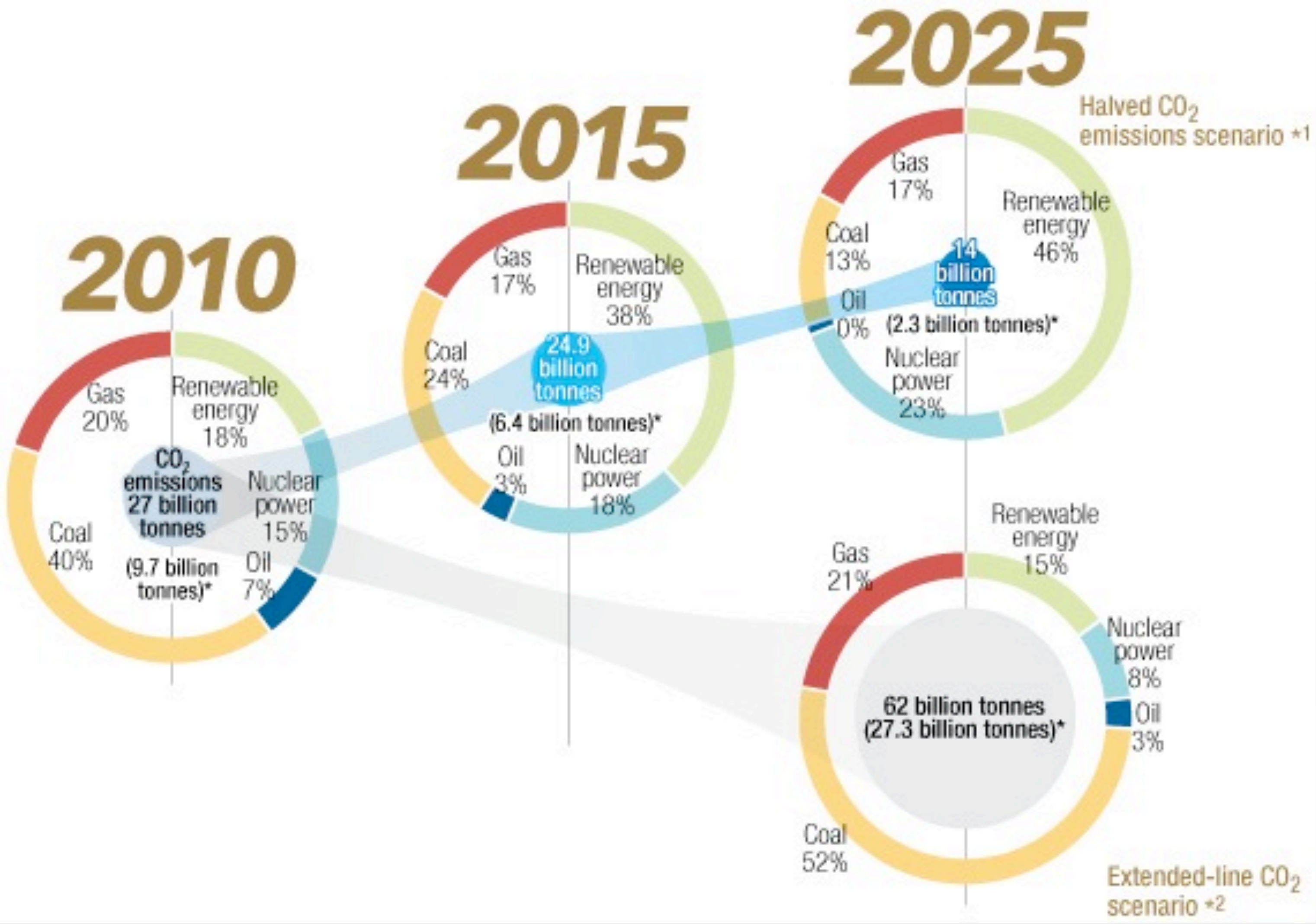
Emissioni globali CO_2

- **Halved CO_2 emissions scenario**

  Forecasts of electric power supply mix and CO2 emission volumes under a scenario in which CO2 emissions are halved

- **Extended-line CO_2 scenario**

  Forecasts of electric power supply mix and CO2 emission volumes under a scenario in which current reduction policies remain unchanged



Emissioni globali CO_2

- Attenti alle estrapolazioni...

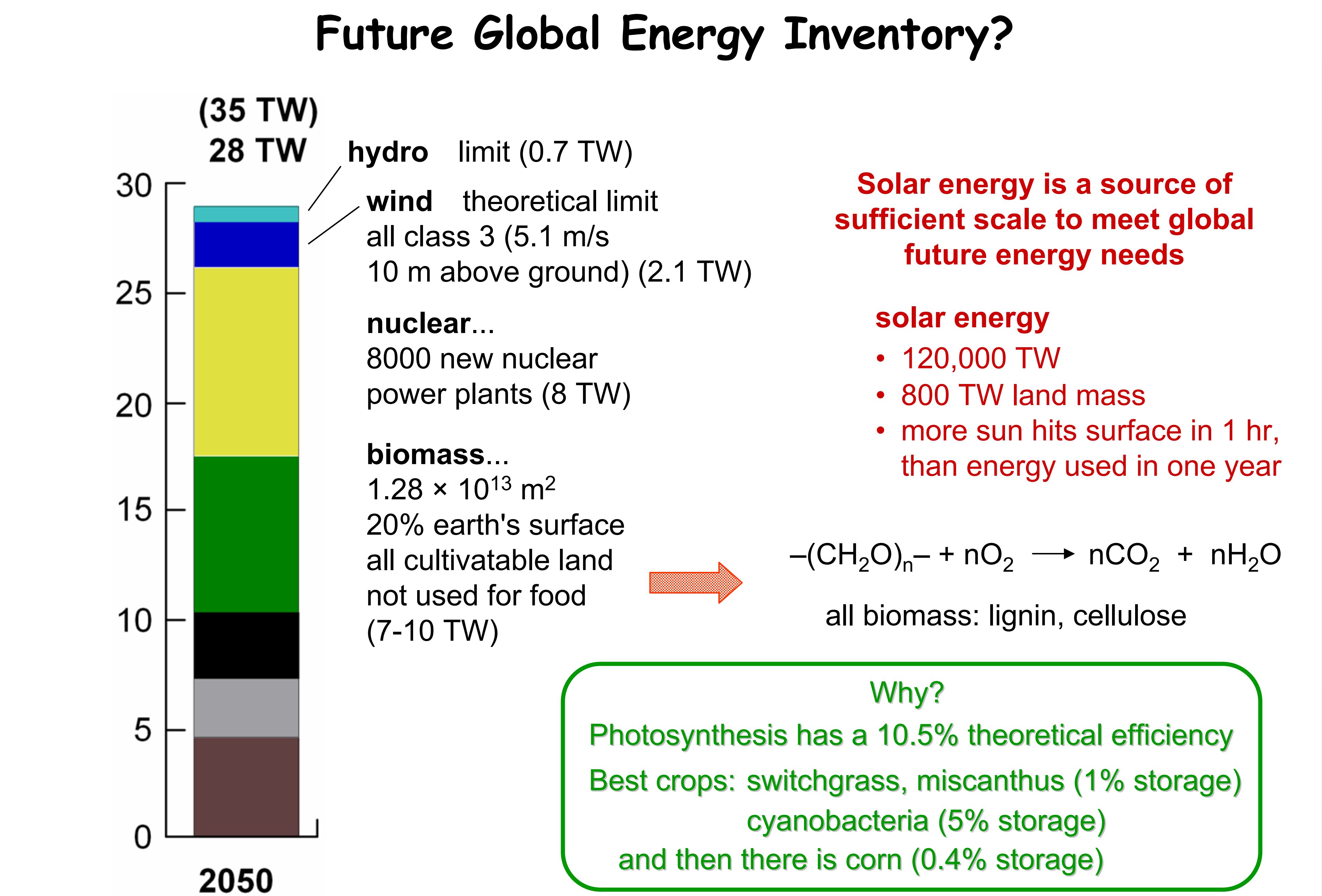
  Nineteenth-century cities depended on thousands of horses for their daily functioning. All transport, whether of goods or people, was drawn by horses. London in 1900 had 11,000 cabs, all horse-powered. There were also several thousand buses, each of which required 12 horses per day, a total of more than 50,000 horses. In addition, there were countless carts, drays, and wains, all working constantly to deliver the goods needed by the rapidly growing population of what was then the largest city in the world. Similar figures could be produced for any great city of the time. The problem of course was that all these horses produced huge amounts of manure. A horse will on average produce between 15 and 35 pounds of manure per day. Consequently, the streets of nineteenth-century cities were covered by horse manure.

Emissioni globali CO_2

- In 1898 the first international urban-planning conference convened in New York. It was abandoned after three days, instead of the scheduled ten, because none of the delegates could see any solution to the growing crisis posed by urban horses and their output. The problem did indeed seem intractable. The larger and richer that cities became, the more horses they needed to function. The more horses, the more manure. Writing in the Times of London in 1894, one writer estimated that in 50 years every street in London would be buried under nine feet of manure.

Proiezioni energetiche 2050

- Nocera, Daedalus 2006 *"Cerchiamo disperatamente di raggiungere 35TW)"*



Nocera, *Daedalus*, 2006

Proiezioni energetiche 2050

- Ottenere Energia dal Sole è certamente una delle vie più green
  - Solare Fotovoltaico
  - Solare termico...

- **Theoretical: $1.2x10^5$ TW solar energy potential** (1.76 x105 TW striking Earth; 0.30 Global mean albedo)
- Energy in 1 hr of sunlight 14 TW for a year
-
- **Practical: > 600 TW solar energy potential**
  (50 TW - 1500 TW depending on land fraction etc.; WEA 2000)
  Onshore electricity generation potential of ≈60 TW (10% conversion efficiency):

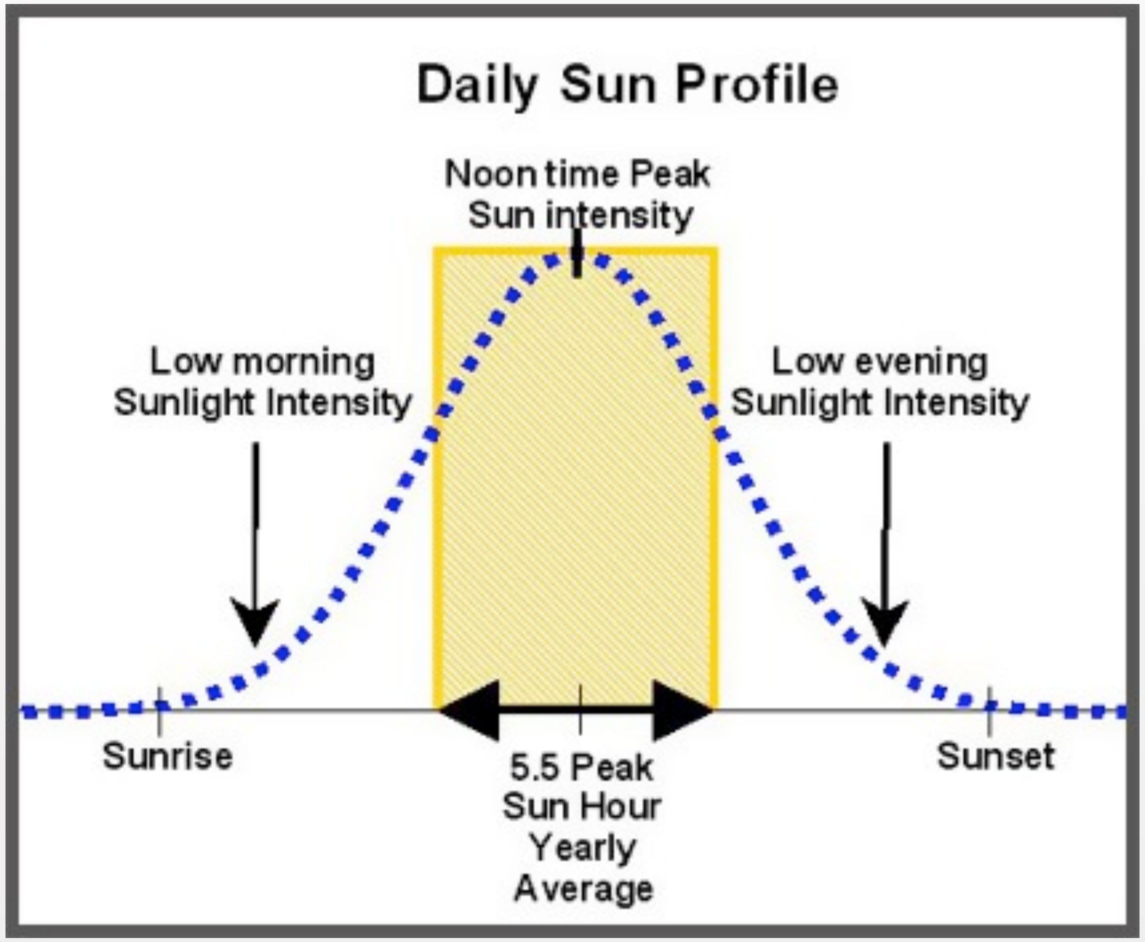
Proiezioni energetiche 2050

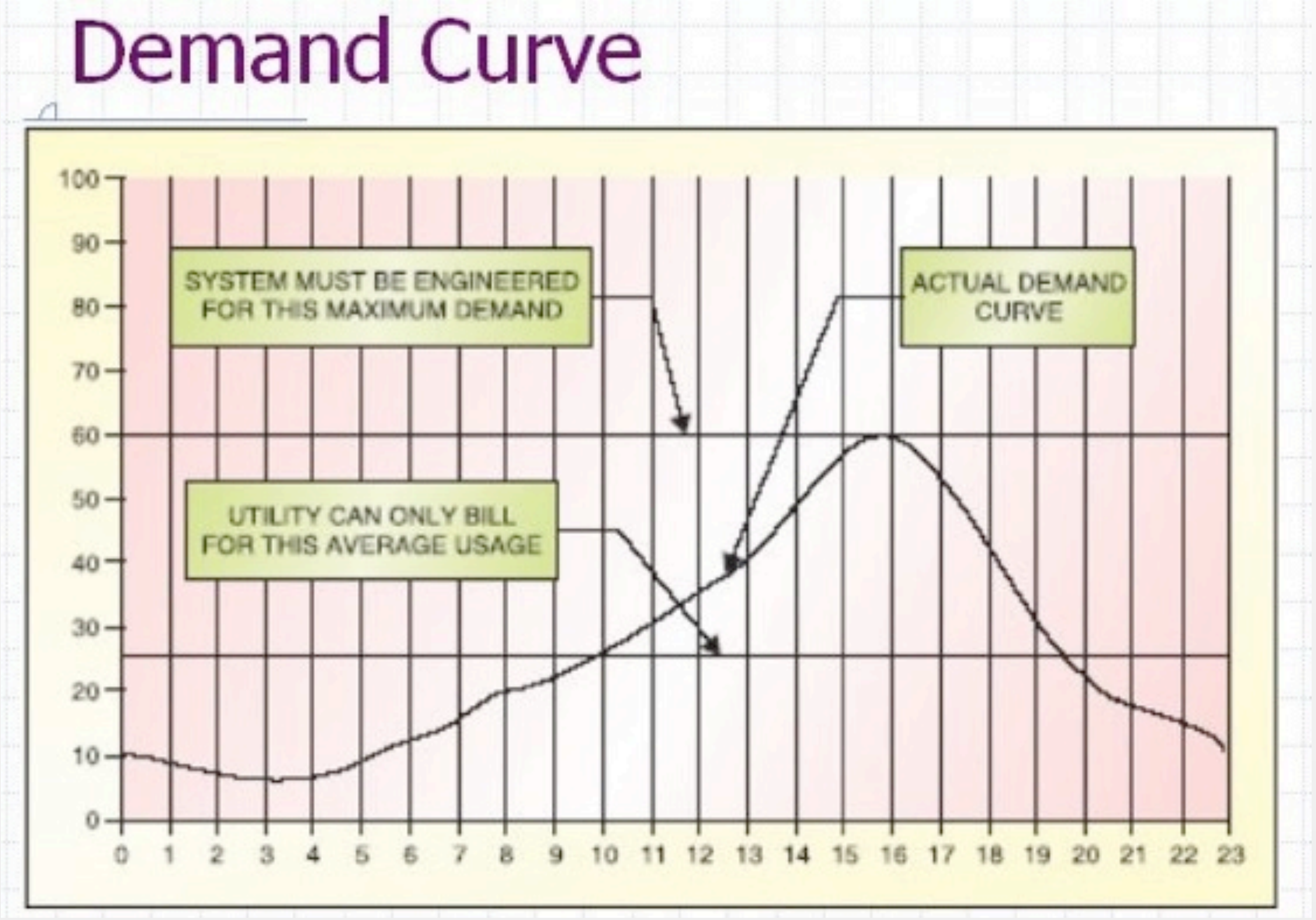
- Potenzialità dell'idrogeno

Proiezioni energetiche 2050

Proiezioni energetiche 2050

- Demand-Solar energy generation
- Immagazzinamento Energia solare

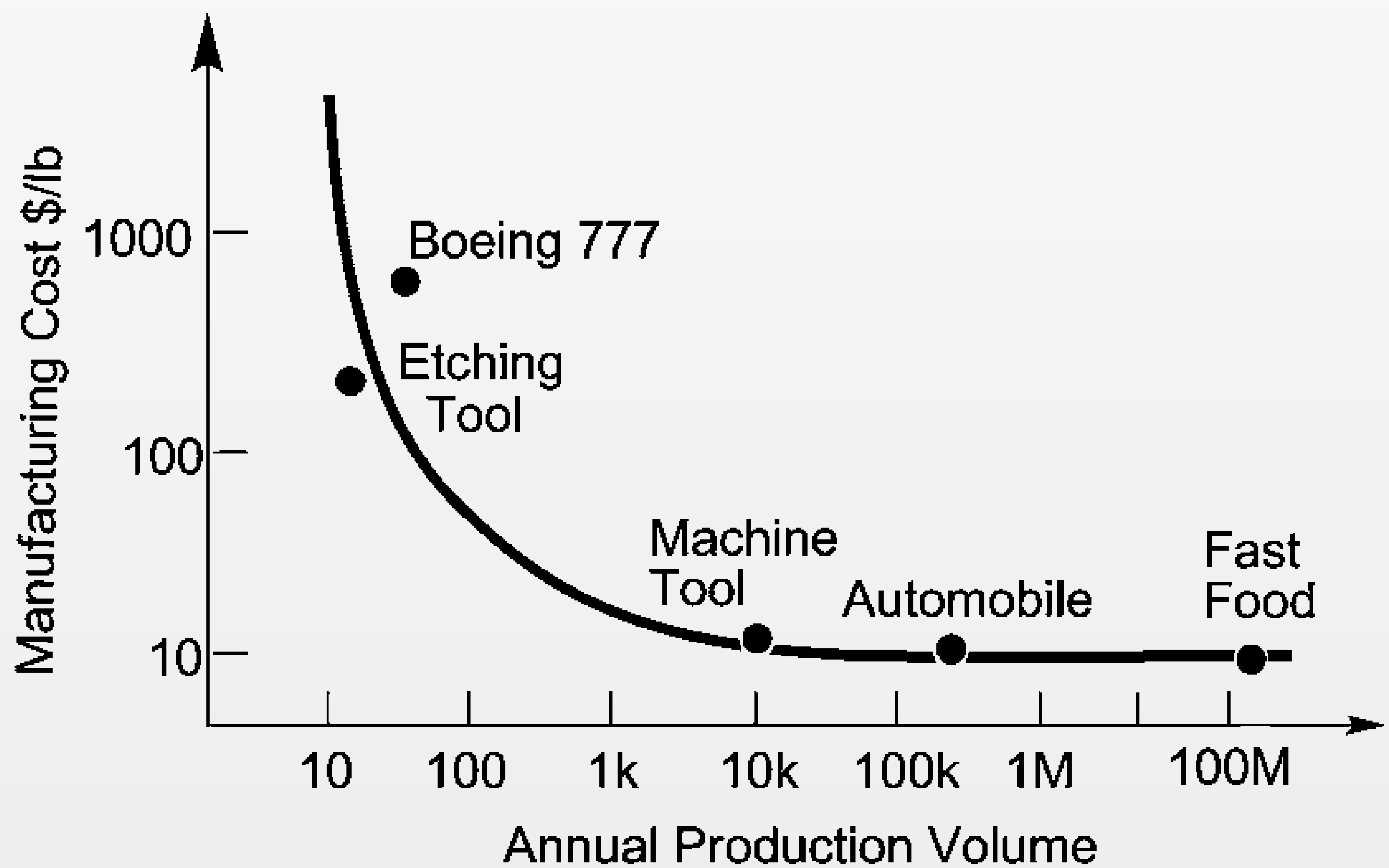




Proiezioni energetiche 2050

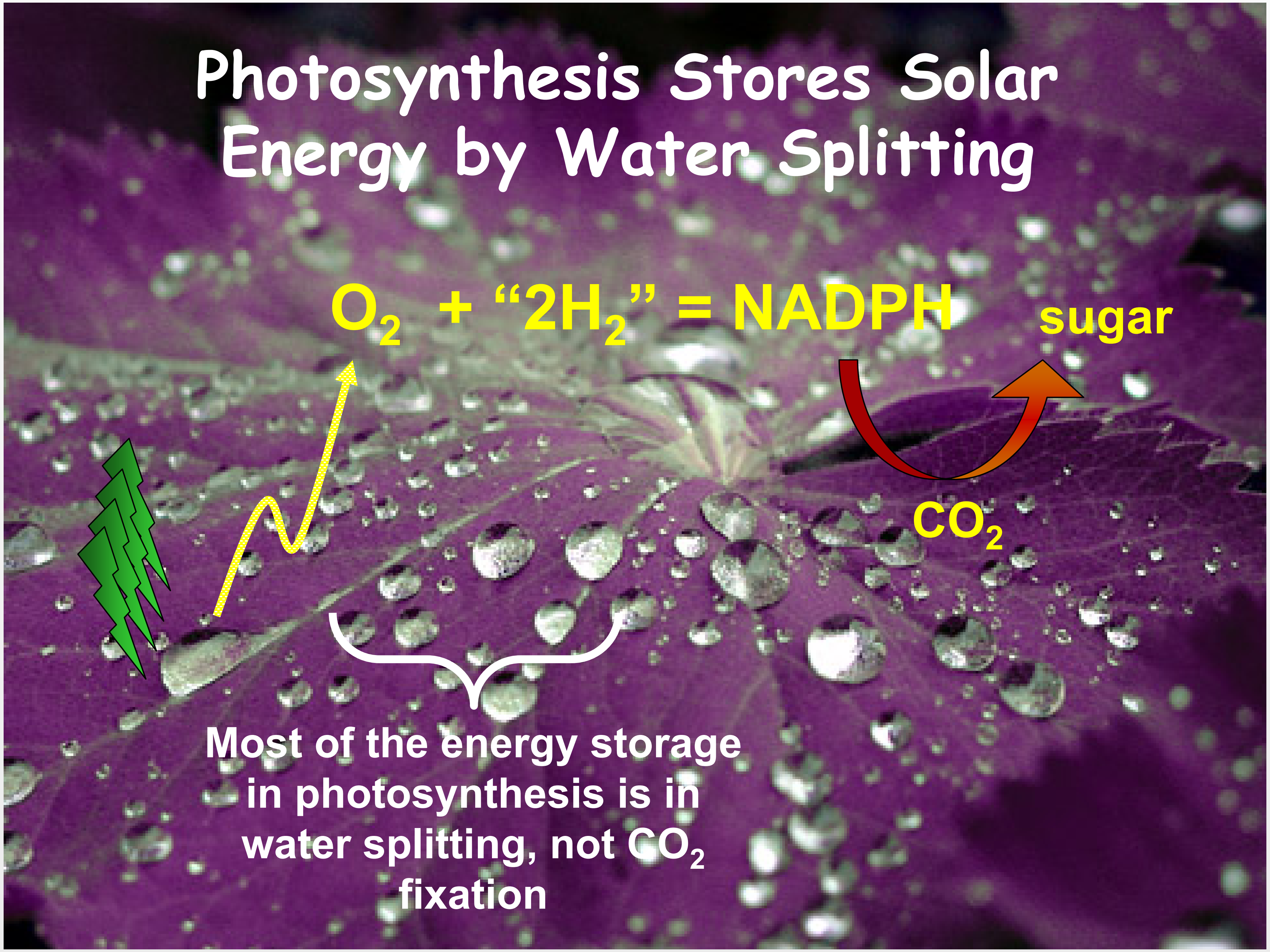
- Costo prodotti vs produzione

Energy system for legal world



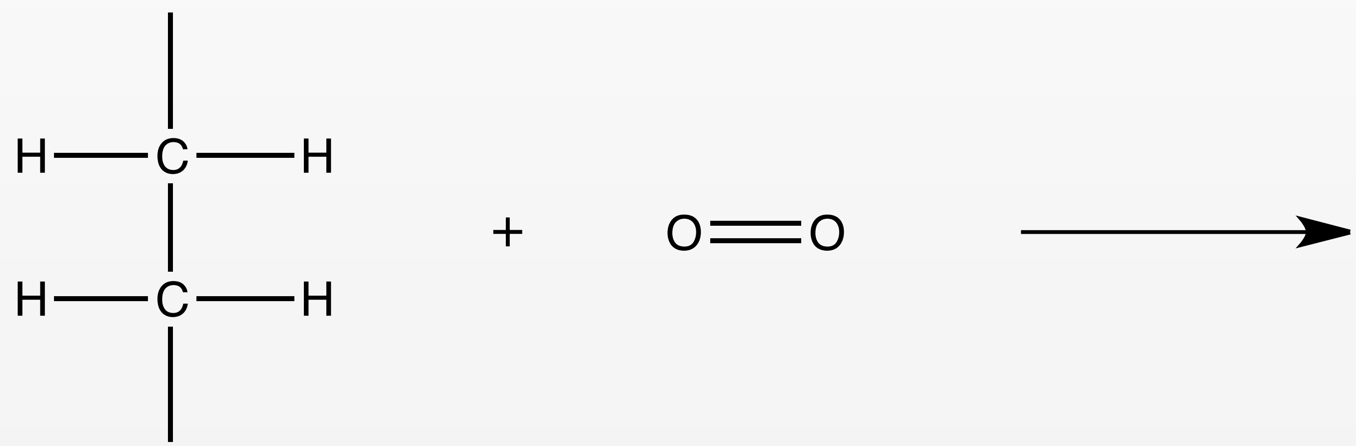
Una possibile via di fuga

- Cerchiamo di “imitare la natura” - **Water splitting**

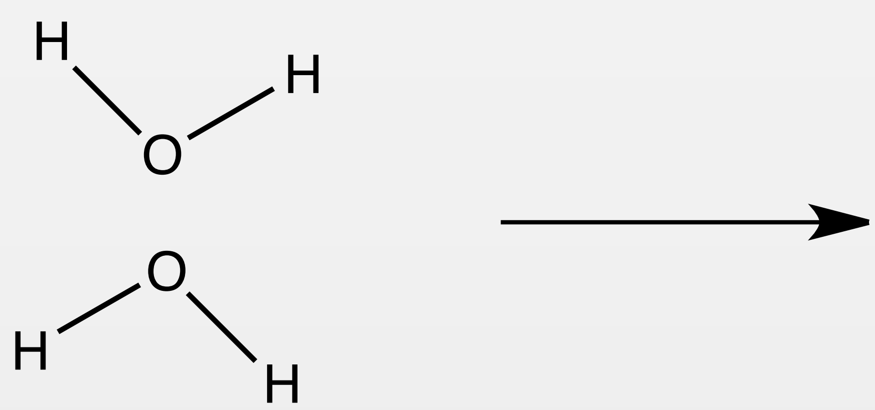


Una possibile via di fuga

- Ottenere energia dall'acqua



$H_2O + CO_2 +$ ENERGIA



$2H_2 + O_2 +$ ENERGIA

but you need an energy input to rearrange the low energy bonds to make high energy ones

Una possibile via di fuga

- La reazione di decomposizione dell'H_2O procede secondo lo schema:
- **$H_2O \rightarrow H_2O + 1/2\ O_2$**
- è un <u>processo non spontaneo</u> a T e P ambiente (dG_0 = 237.2 kJ/mol)
- è un <u>processo fortemente endotermico</u> (dH_0 = 258 kJ/mol)

- Per ottenere H_2 e O_2 occorre lavorare intorno ai 3000 K

Una possibile via di fuga

- La reazione di water splitting presenta però diversi svantaggi quali:

- 3000 k è una temperatura proibitiva per tutte le tecnologie e i materiali attualmente a disposizione
- bisogna evitare la ricombinazione di H_2 e O_2
- La miscela H_2/O_2 è altamente esplosiva

- Per rendere il processo attraente bisogna quindi:
- lavorare a temperature basse
- evitare la formazione di miscele H_2/O_2

Una possibile via di fuga

- Quanta energia nel water splitting

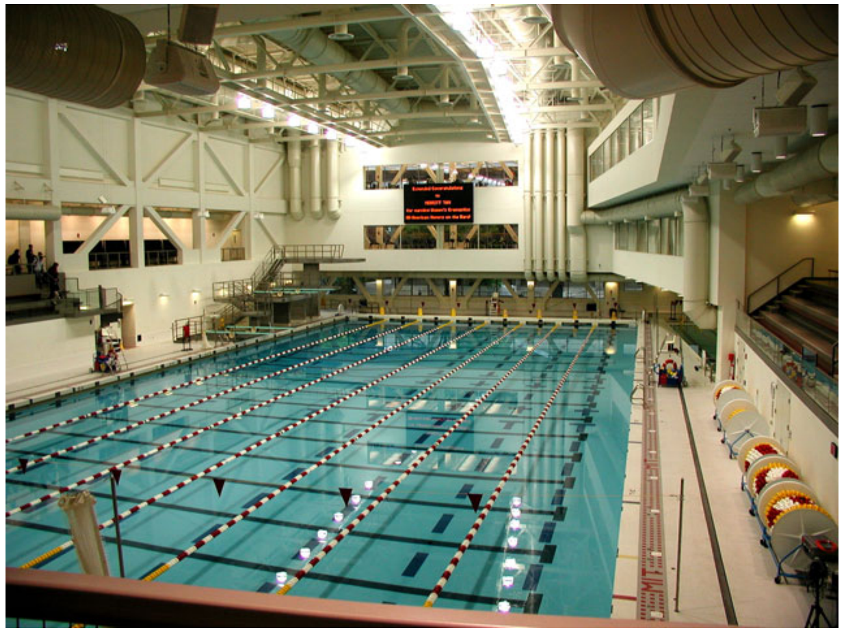
How Much Energy in Water Splitting?

$2H_2O \longrightarrow 2H_2 + O_2$ energy = 237 kJ/mol

energy = 13 million J/liter

MIT pool

3.2 million liter of H_2O



volume of MIT pool to H_2 and O_2 per sec = 42.7 TW

so Water + Light does indeed = Oil (and Coal)

Una possibile via di fuga

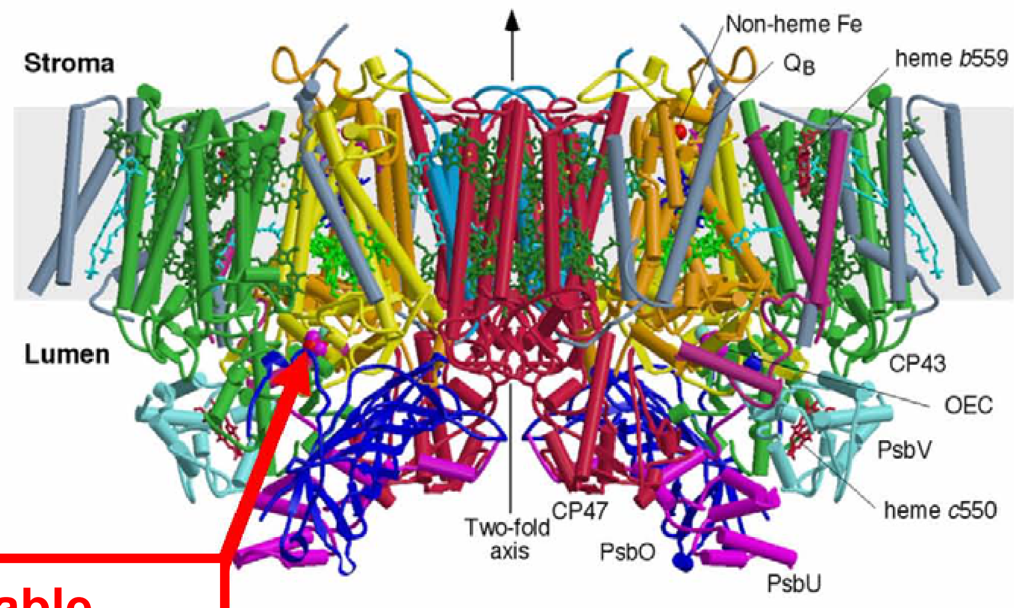
- Condizioni necessarie per rendere il water splitting attraente

facile ed economico da produrre

Semplici condizioni di reazione

Una possibile via di fuga

- Cerchiamo di imitare la natura



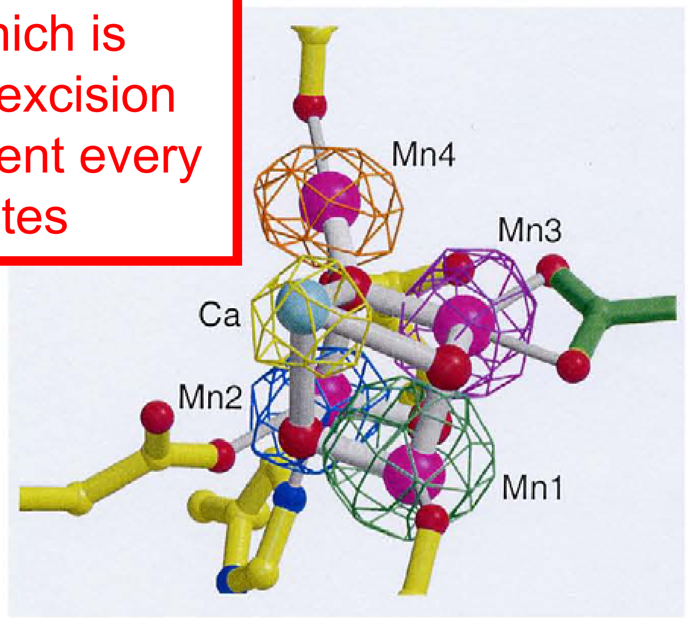
O_2 Generation:

(3) from neutral water at 1 atm and RT

(4) at low overpotential

(5) with proton carriers
since water is a poor base, need alternative base for proton transport e.g., quinones

(2) Not stable
OEC resides in D1 protein, which is ***repaired*** by excision and replacement every 30 minutes

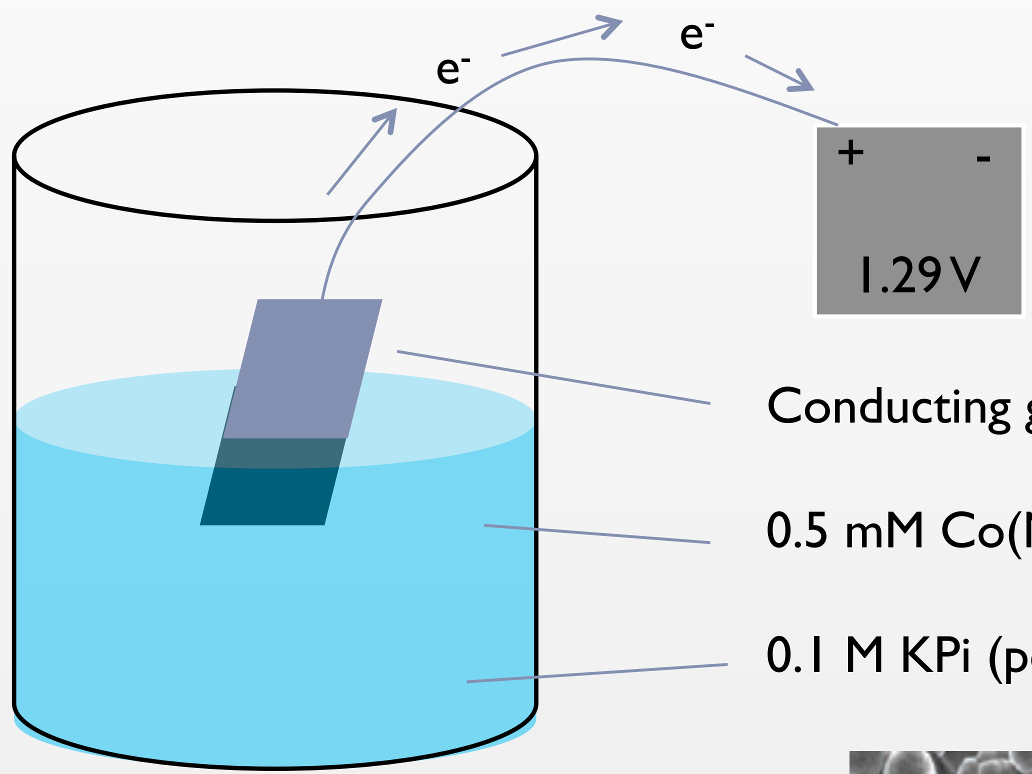


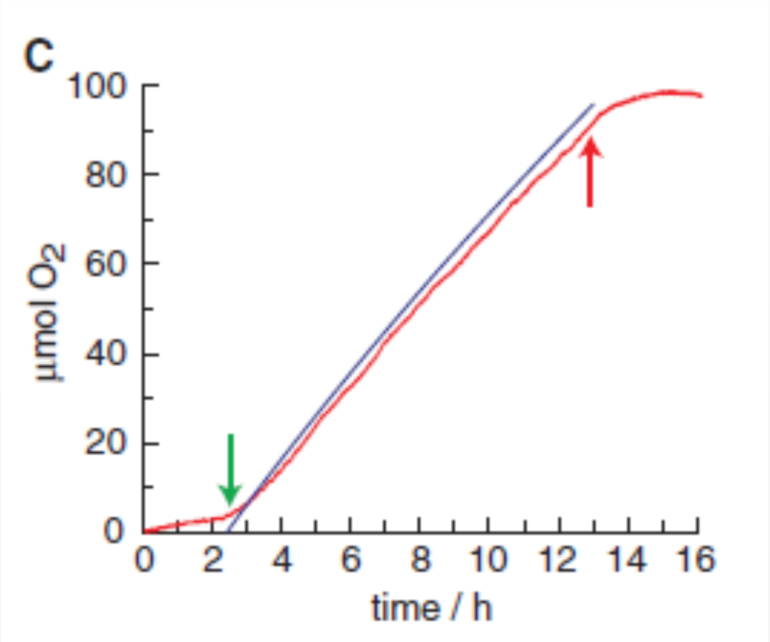
(1) Simple, all-inorganic redox core
a Mn-oxo core
self-assembled from water
only oxygen ligands

Una possibile via di fuga

- D. Nocera, Science 2008

Recent breakthrough



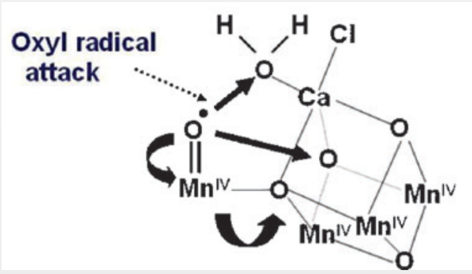


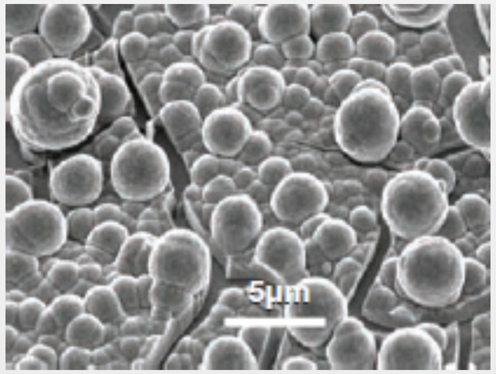
Conducting glass, such as indium tin oxide

0.5 mM $Co(NO_3)_2$

0.1 M KPi (potassium phosphate)

Alternative:





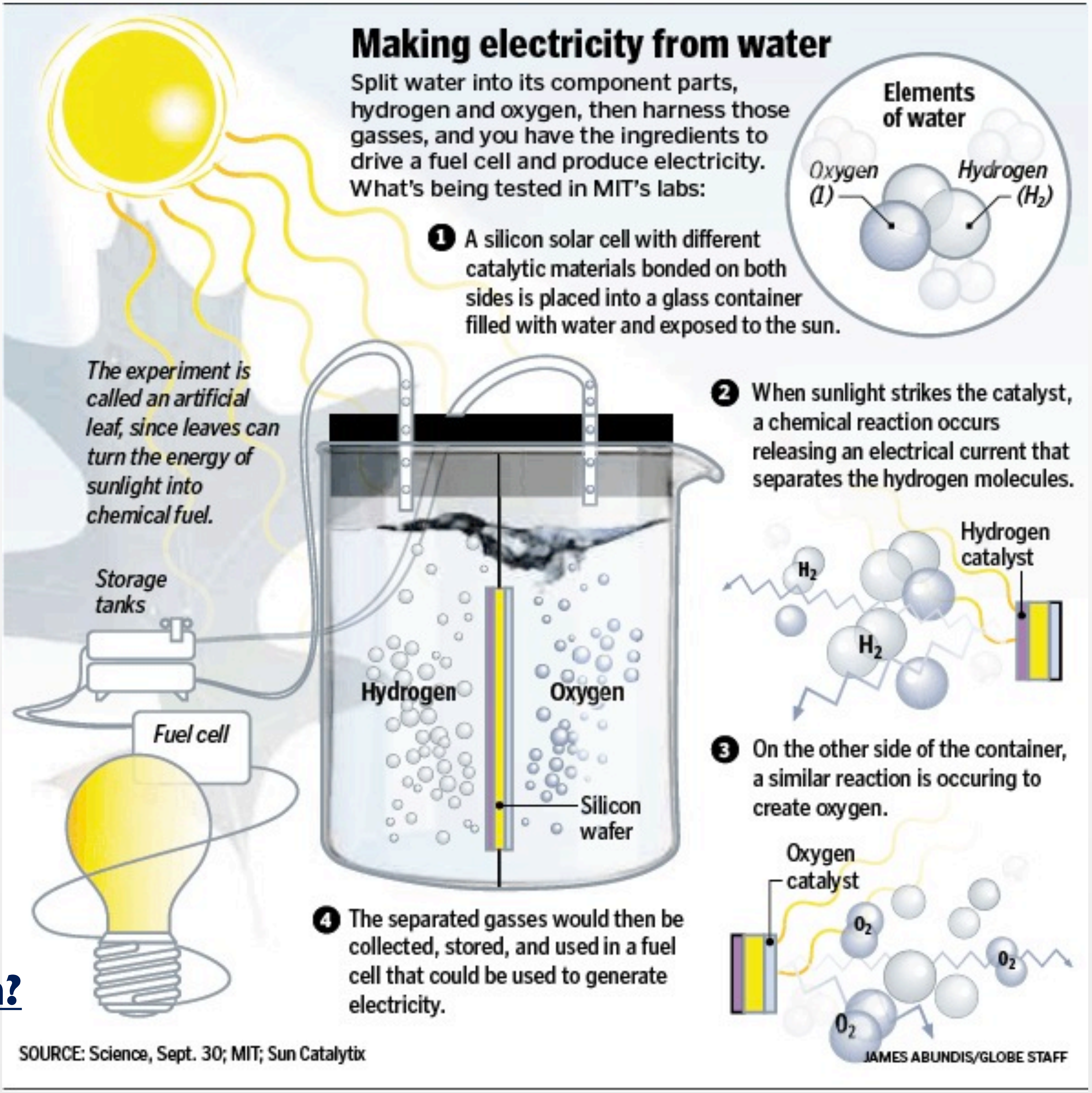
SEM image

Film is 2:1 as Co:Pi

Kanan, M. W. & Nocera, D. G. *Science* **321**, 1072–1075 (2008).

Una possibile via di fuga

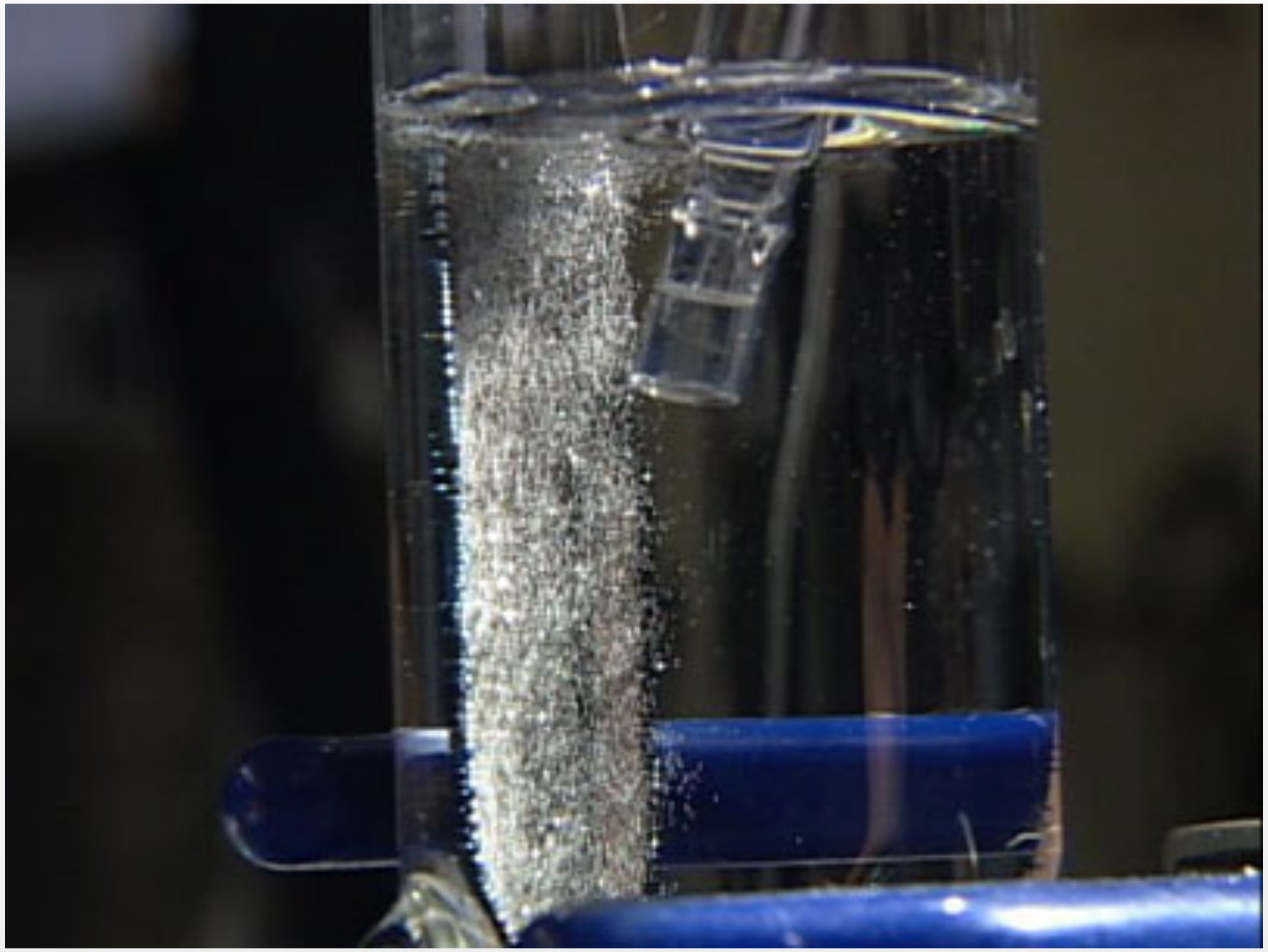
- **Foglia Artificiale**
- Scientific Challenges
- Cheap materials that are robust in water
- Catalysts for the redox reactions at each electrode
- Nanoscale architecture for electron excitation transfer reaction



http://www.youtube.com/watch?v=ZAkM_dV6CFs

Una possibile via di fuga

- Foglia artificiale



http://www.youtube.com/watch?v=sSo005x9hCc

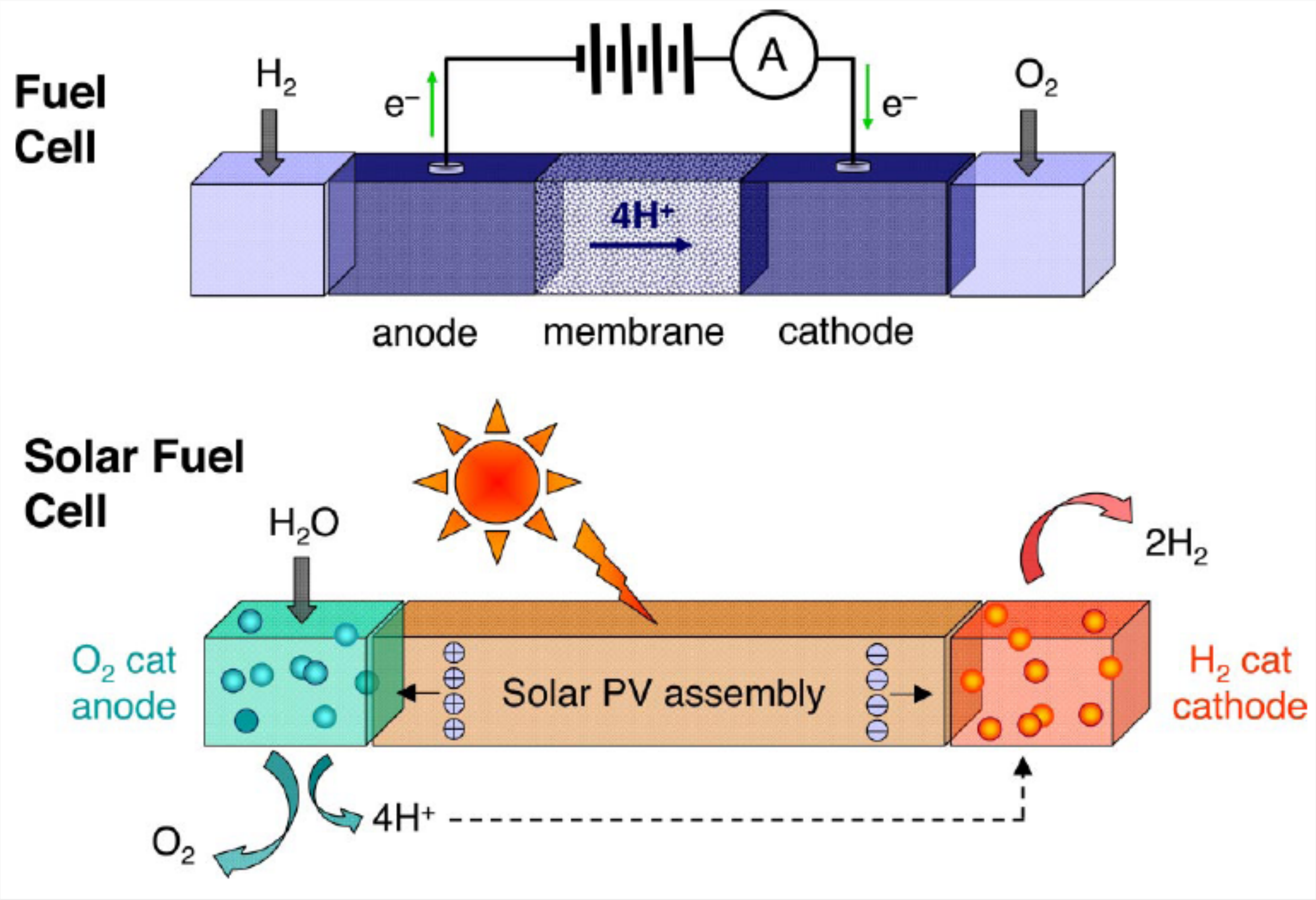
Una possibile via di fuga

- **Foglia artificiale**
- Self-repair mechanism, in situ formation
- Co^{2+}, Co^{3+}, Co^{4+} species likely responsible for balancing different oxidation steps
- Co^{2+}-HPO_4^{2-} (aq) $\rightleftharpoons$ Co^{3+}-HPO_4^{2-} (on electrode surface)
- Composed of earth-abundant materials
- Long lasting O_2 production at low overpotential, neutral pH, room temperature/pressure

- Drawbacks: large initial overpotential, not effective at high current

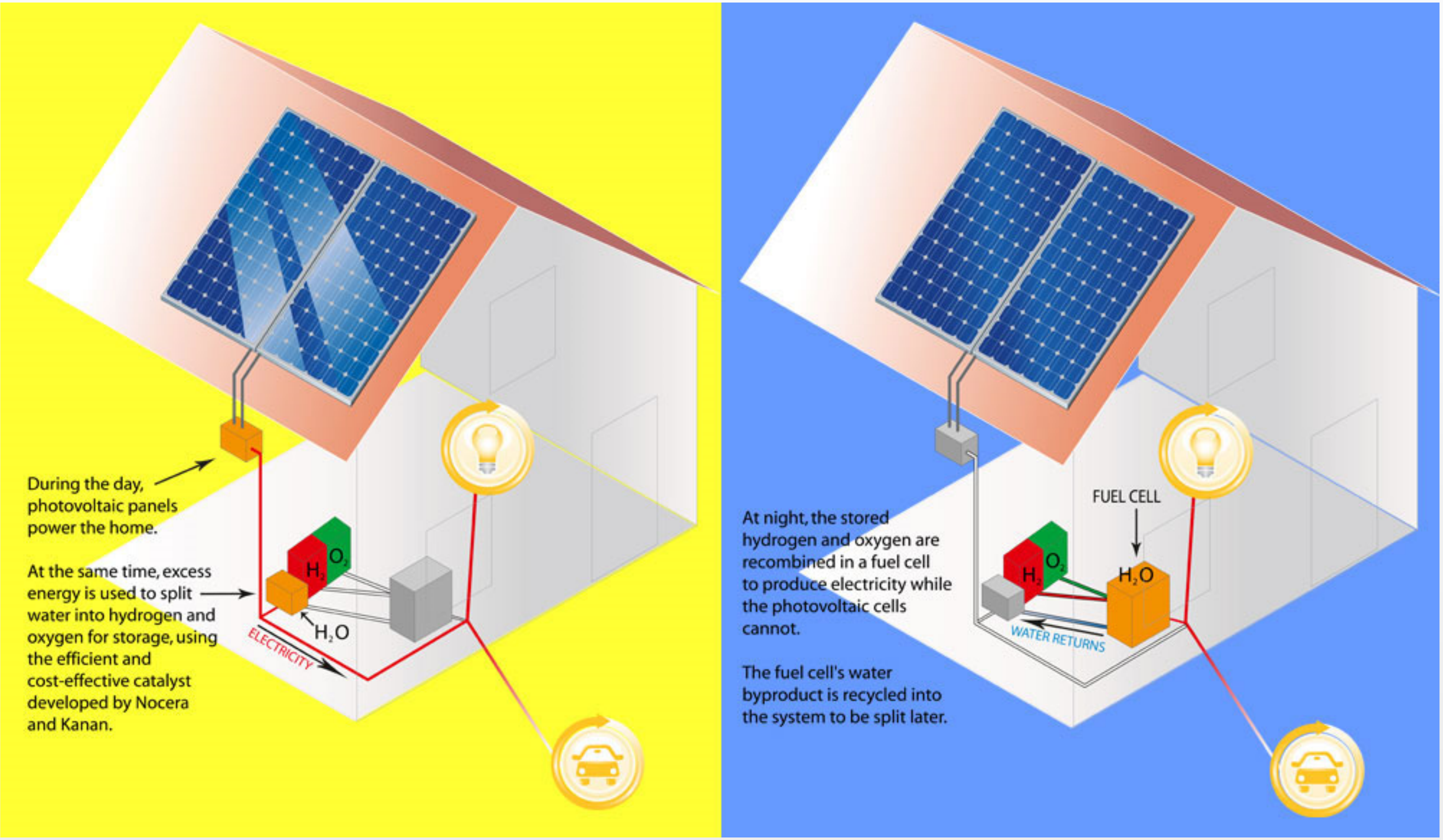
Una possibile via di fuga

- Fuel Cell e Solar Fuel Cell



Una possibile via di fuga

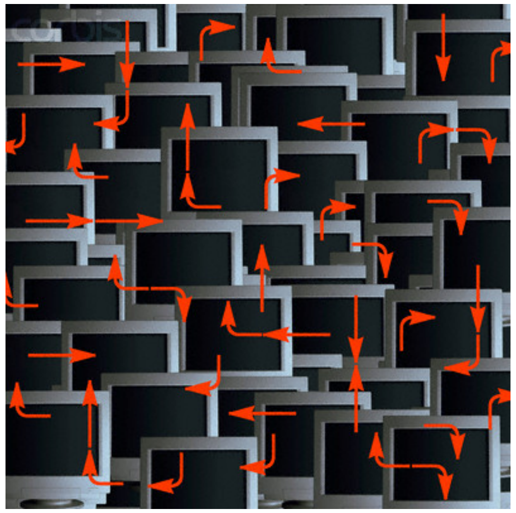
- La nostra nuova casa??



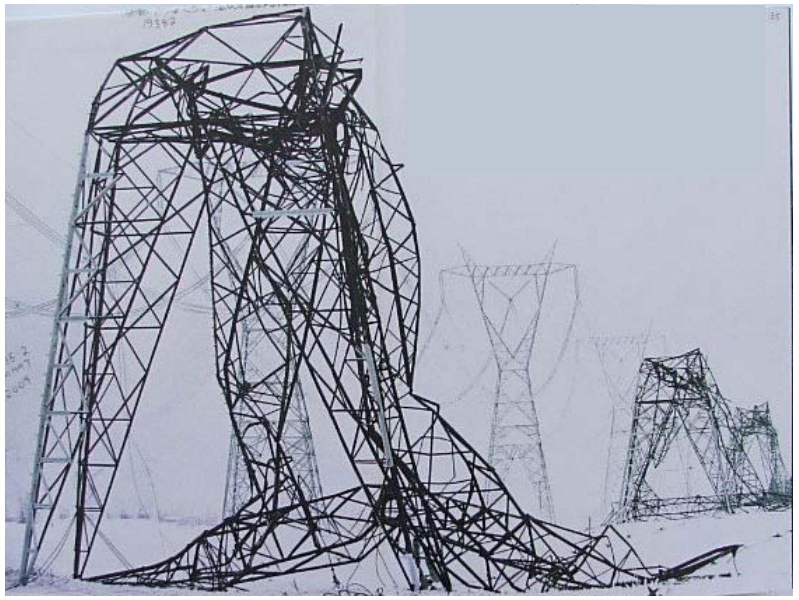
Una possibile via di fuga

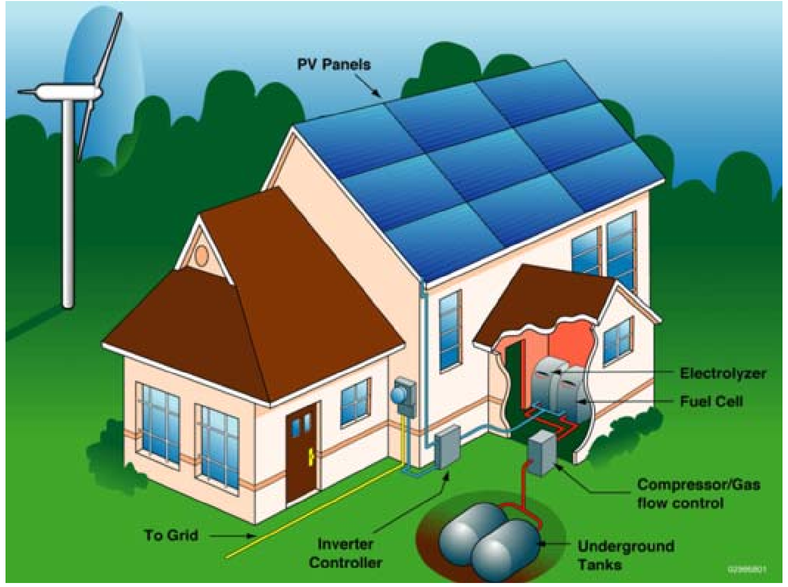
- Cosa abbiamo fatto...cosa faremo??

mainframe → **personal computers** → **network**



grid → **personal energy**





an easier problem

no need to network

Una possibile via di fuga

- Energia personalizzata!