ACADEMIA BRASILEIRA DE CIÊNCIAS
1916 2016

COPPE UFRJ
Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia

Energia: Programando o Futuro do País

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“UM PROJETO DE CIÊNCIA PARA O BRASIL”

“A Project of Science for Brazil”

We have to prepare a text showing the way for research in Brazil. This is the objective.

What should be this way?

My Sets of Knowledge

Before advancing it is important to define my
Sets of Knowledge
(They are only four)

My Set of Knowledge Number 1

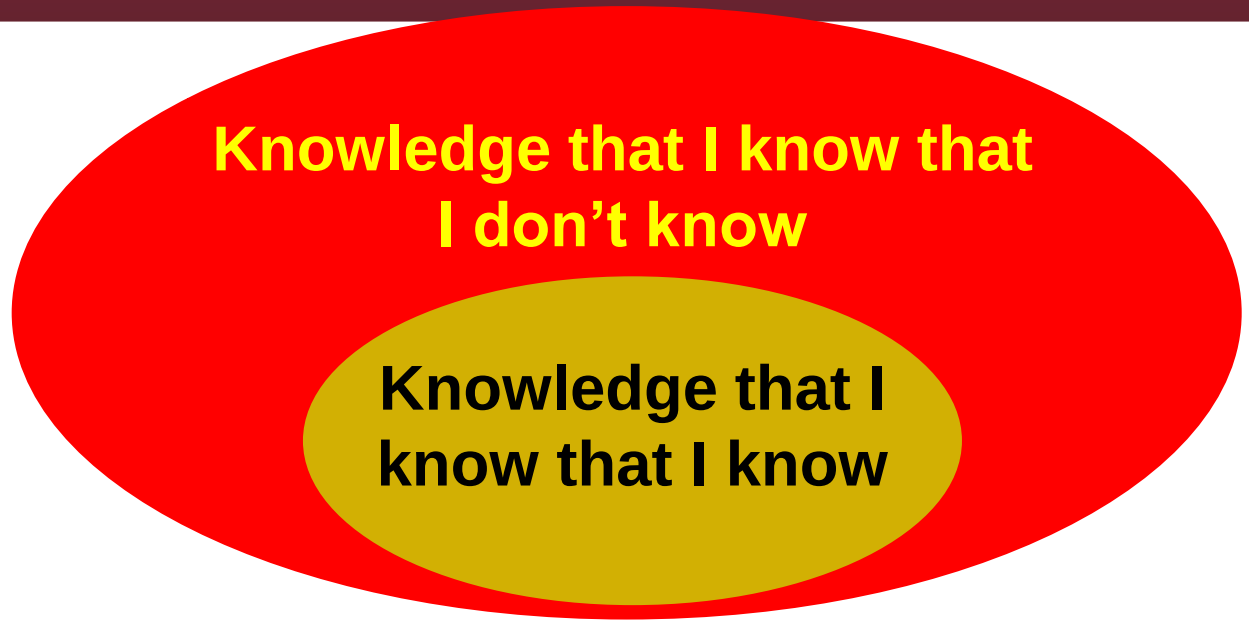
Knowledge that I know that I know

My Set of Knowledge Number 2

Knowledge that I know that I know

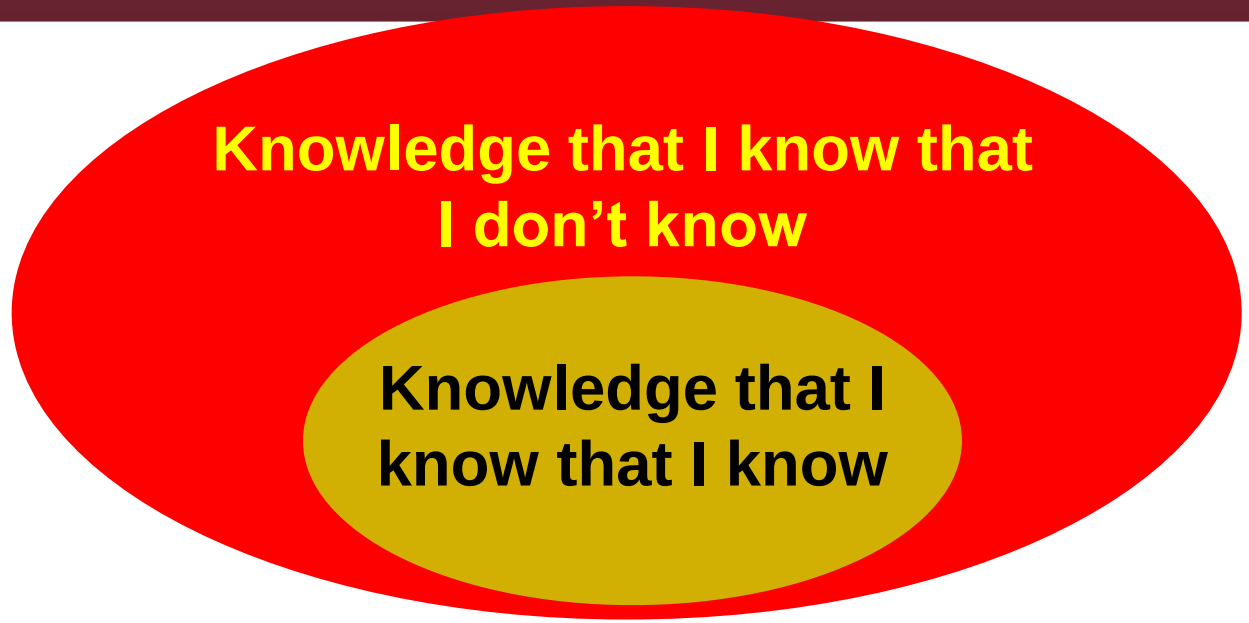
Knowledge that I don't know that I know

My Set of Knowledge Number 3



Knowledge that I know that I don't know

My Set of Knowledge Number 4



Knowledge that I know that I don't know

Knowledge that I don't know that I don't know

Community Sets of Knowledge

Knowledge that we know that we know. (Finite) They are on the books, papers, internet, etc.

Knowledge that we know that we don't know. (Finite) They are the problems.

My dilemma: we only know how to write about things that are in this set.

However, the ideal would be to find something new here.

Knowledge that we don't know that we don't know. (Infinite)

Bicycle Technology

Scientific American published, in march 1973, an interesting paper on how a bicycle improves man's efficiency when moving.

Bicycle Technology

Salmon is the most efficient animal.

But, **man on bicycle**

is much more efficient!

Adapted from Scientific American, 1973.

How Much Energy Do We Need?

- **When we buy potato, tomatoes…: we pay per kg.**
- **When we buy orange, banana...: we pay per dozen.**
- **When we buy electric energy: we pay per kWh (kilo Watt-hour).**

However, do you know what is 1 kWh?

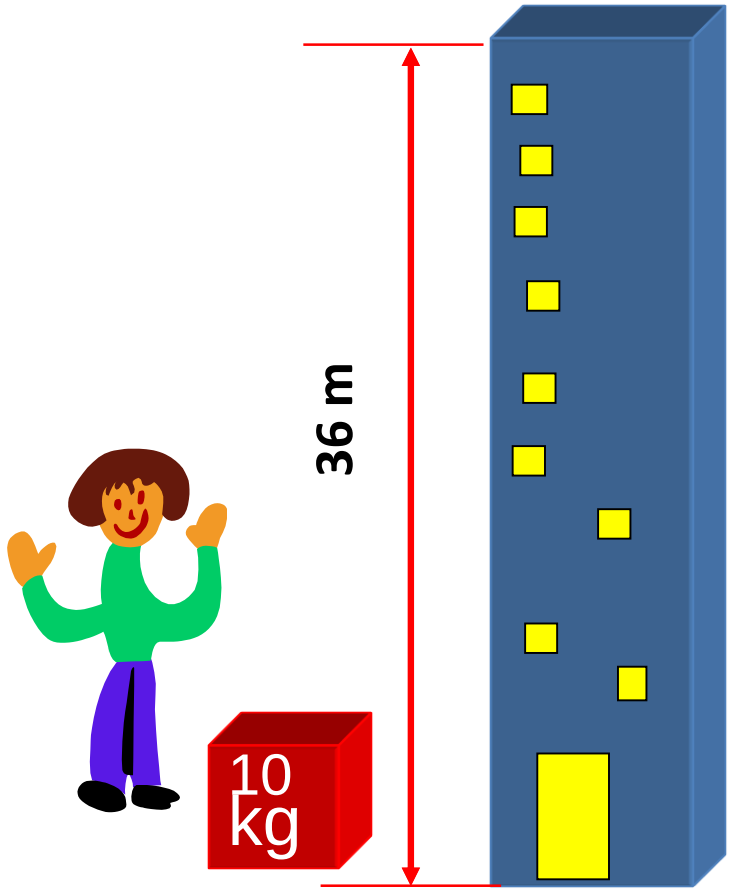
Recipe to Produce 1 kWh

1 kWh is an energy unit corresponding to 3600 J.

But, what is it?
Recipe to produce 1 Wh (Watt-hour):

- Carry 10 kg up to the the 12th (36 m):

10 kg x 10 m/s^2 = 100 N
Energy = 100 N x 36 m
= 3600 J = 1 Wh



To generate 1 kWh: just repeat this 1000 times!

My Energy Consumption per Month

Electric energy: 200 to 500 kWh
Cooking: 250 kWh
Heating: 60 kWh
Transportation: 1000 kWh

- **It is impossible get all this energy from beef, rice and beans only.**

We need to get extra energy from other sources.

Getting Extra Energy

Man discovered that with some tools like wheels he could multiply his capacity of doing things.

He also learned:

- **to use energy from others: horse, cow...**
- **to use renewable energy: sun, wind, water.**

Getting Extra Energy

In the last 100 – 200 years, he learned to use energy from other sources:

- **Oil and coal**
- **Hydro**
- **Nuclear**
- **Biofuel (ethanol, biodiesel, bagasse…)**
- **Geothermal**
- **Wind**
- **Solar**

How Much Electric Energy Do We Need?

Installed capacity: 152 GW

If the economy grows at 5% per year, it is normal that electric energy consumption grows at 7% per year.

This means that we have to double the generation capacity in 10 years!

Where to get all this energy?

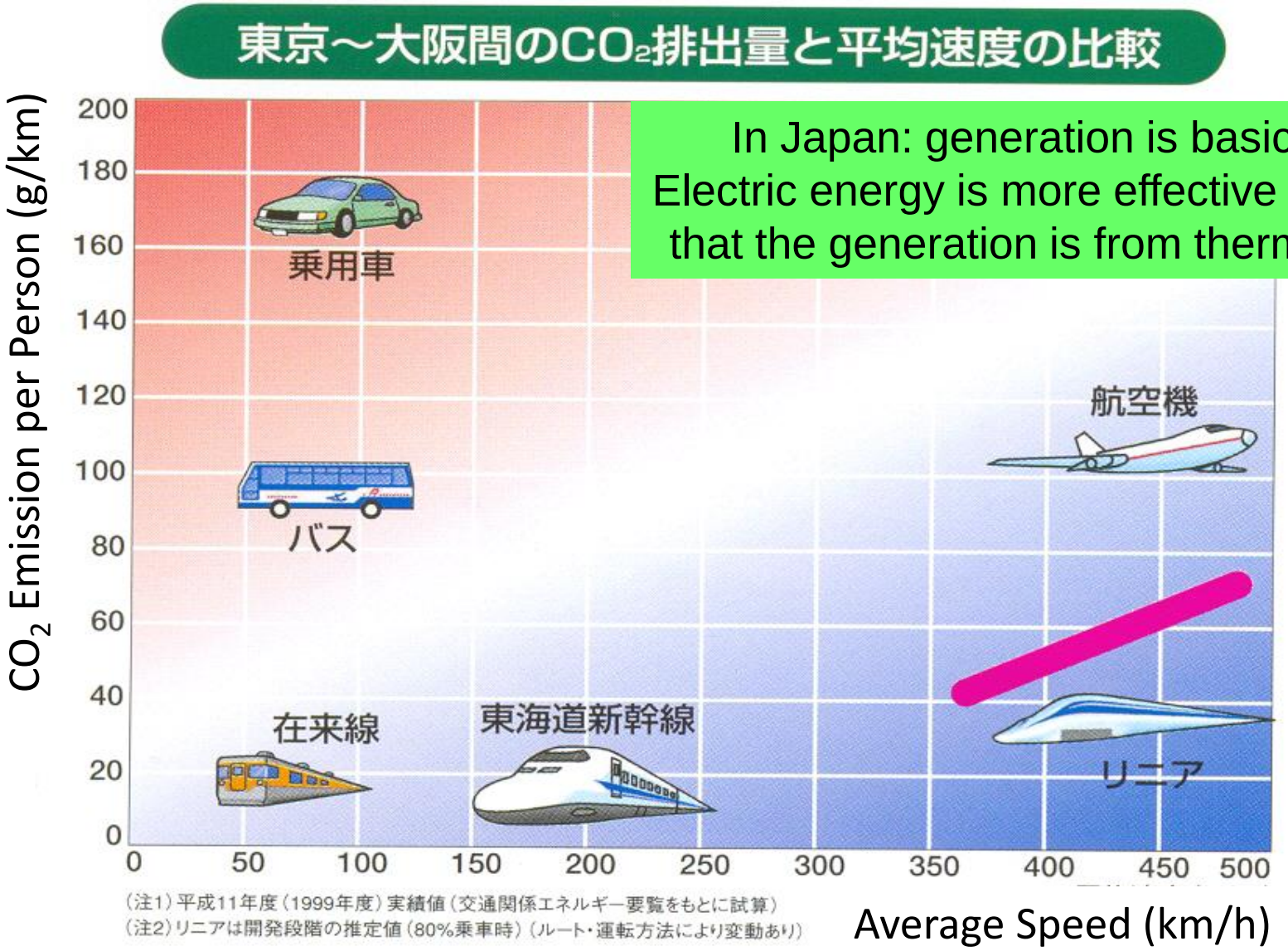
Oil

Is the most important energy source, but non-renewable.

Challenges:

- **Produce more oil from the Pre-Salt;**
- **Carbon capture and storage (CCS);**
- **Production at lower costs;**
- **Automation, robotizing, new materials for risers (pipes);**
- **Decommissioning of old fields;**
- **Study the ecosystem.**

How is the CO_2 Emission Due to Oli?



In Japan: generation is basically thermal. Electric energy is more effective even in the case that the generation is from thermal power plant!

How much CO_2 do I generate (with my car)?

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- **In 2005, I made a quick calculation and found that I was generating with my car about 8 tons of CO_2 per year!**
- **I tried many solutions, but finally choose to stop using gasoline. Since then I use only ethanol (a little more expensive).**
- **The electric car may be a solution form me, but still expensive and autonomy is low.**
- **For a while I will use ethanol.**

How much CO_2 do I generate myself?

- **In 2006, I found out that I was "emitting" about 250 kg of CO_2 per year breathing! I found it too much.**
- **Trivial solution: stop breathing, but it is uncomfortable.**
- **Solution 2: All the CO_2 I "emit" comes from rice, beans, bread, …, therefore it is sustainable like ethanol. Someone collect the carbon from the air. I am only returning it.**
- **We should not use the carbon that is stored under the ground (oil and coal). If we burn it, it goes to the air and there is no return.**

Pollution

The background of this picture looks, for some people, romantic or just beautiful. But, this is pollution: NO_x!

Advertisement of my talk at “Casa da Ciência” – UFRJ.

Coal

- It is non-renewable;
- Small installed power capacity (<5%);
- High generation of CO_2;
- EPE 2030 plan: 10 GW;
- Is it possible to use coal with less pollution?

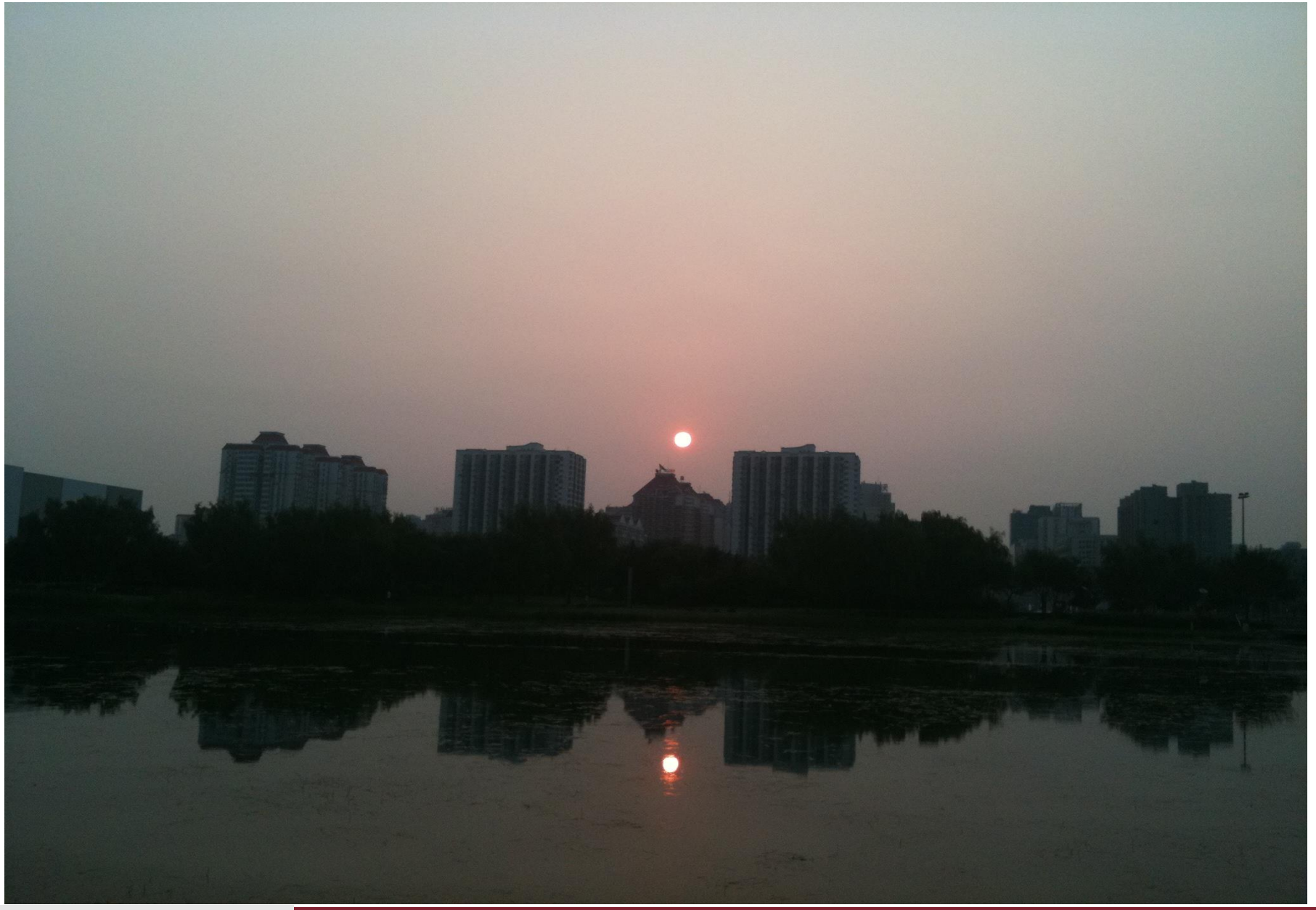
The Case of China

In 2011, the electric system in China was growing at the rate of "one Brazil" per year! (About 100 GW/year).

Essentially, burning **coal**!

I visited China in 2011 and did not see a blue sky there!

Beijing – 6:30 in the morning – No cloud and no blue sky



Beijing – 6:32 in the morning – No cloud and no blue sky

The Great Wall – No cloud and no blue sky

The Great Wall – No cloud and no blue sky

Pollution Cost in China

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O Globo

January 5, 2017

Economia

Poluição já custa à China US$ 1 bilhão por dia

País tem o dilema de continuar crescendo e melhorar qualidade do ar em economia movida a carvão

Com boa parte das cidades ao norte — a capital incluíve — sob alerta máximo de poluição, a China começa 2017 com o dilema de como continu-

res de carros foram impedidos de circular nas ruas, e as escolas suspenderam as aulas. A poluição já é a causa de um terço das mortes na China, segundo estudo da Universidade de Nanquim.

O grande problema é que a China ainda é uma economia

Clima pesado. Poluição atmosférica em Pequim é tão intensa que população tem de usar máscaras nas ruas. País começa o ano em alerta vermelho

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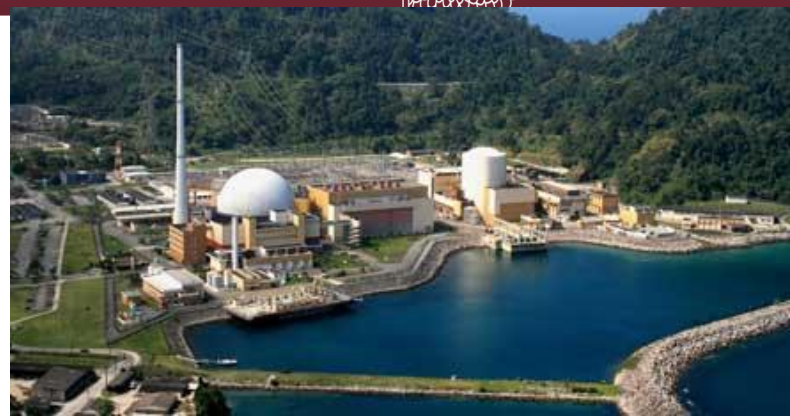
Hydro

- It is renewable and about 75% of our electric energy comes from this source;
- Excellent energy and water storage, except in the Amazon;
- High speed response for load variations;
- Normally, far from consuming center. Therefore, needs long transmission lines;
- Long construction time and high costs;
- But the fuel is free, if we have rain;
- How to store more water (and energy)?

Nuclear



- Non-renewable, but generates no green house gas;
- Generates at constant power;
- "Dispatchable", "on" or "off";
- Good for the "base generation" to free hydropower plant and other thermal plants to regulate intermittent generation by solar or wind;

Some worries:

- How to deal with the nuclear waste?
- Although it is almost as safe as hydro power plant, people have concerns about safety.

Biofuel

Electric Generation:

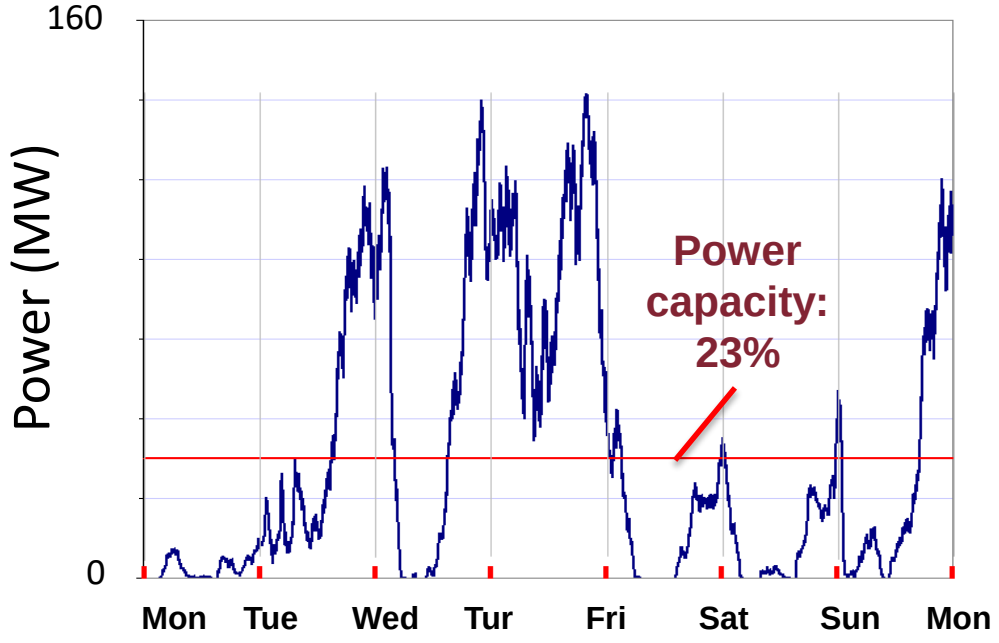
- **It is renewable and about 9 % of our electric energy comes from sugar cane bagasse;**
- **“Dispatchable”;**
- **Fuel could be other plants like rice shell, wood...**
- **Low speed response;**

Fuel for transportation:

- **Ethanol;**
- **Biodiesel.**

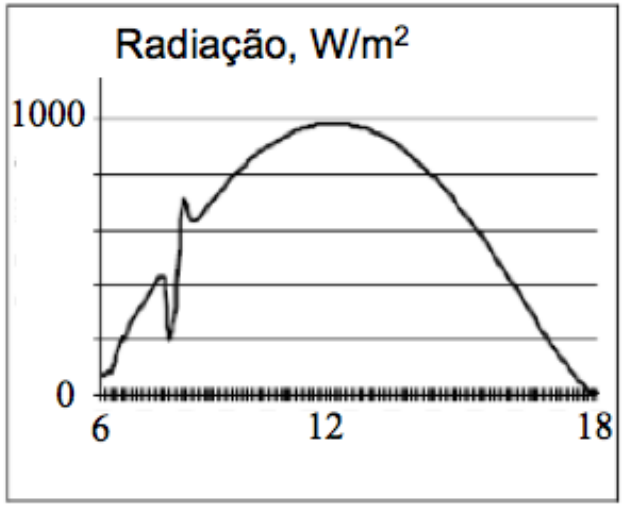
Wind

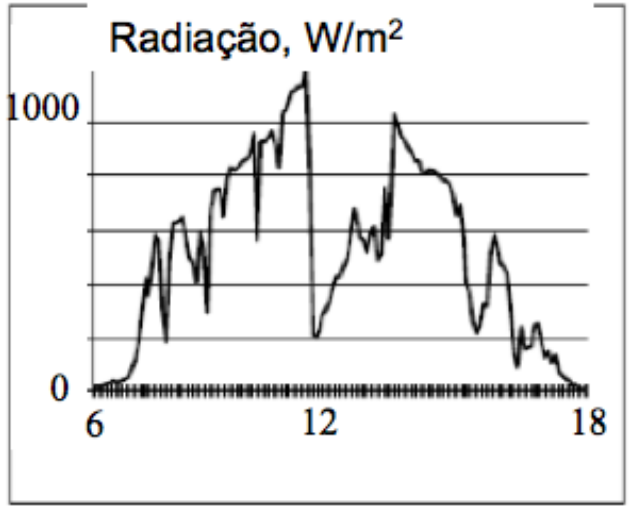
- It is renewable and about 7 % of our electric energy comes from wind;
- Non "Dispatchable";
- Low cost (close to hydro);
- Highly intermittent;
- Highest power capacity in the world: 50%;
- Needs some other complementar source;
- Wind prediction.



Solar

- It is renewable, still insignificant in Brazil (around 0.02%);
- High cost (falling): about 3 times the cost of hydro;
- Highly intermittent (non “Dispatchable”);
- Photovoltaic panel production needs lots of energy and some people say it is polluting.





Source: C. A. S. Querino et al., Revista Brasileira de Meteorologia, v.26, n.2, 204 - 294, 2011

Energy Storage

Due to the intermittent energy sources energy storage is know a big problem to be solved. Some possibilities are:

- **Pumped hydro power plant (PHPP): large capacity (GWh)**
  - Develop PHPP or use surplus energy to pump back water from hydro power plant.

- **Batteries (MWh)**
  - New batteries with higher energy density is the main problem

Energy Storage

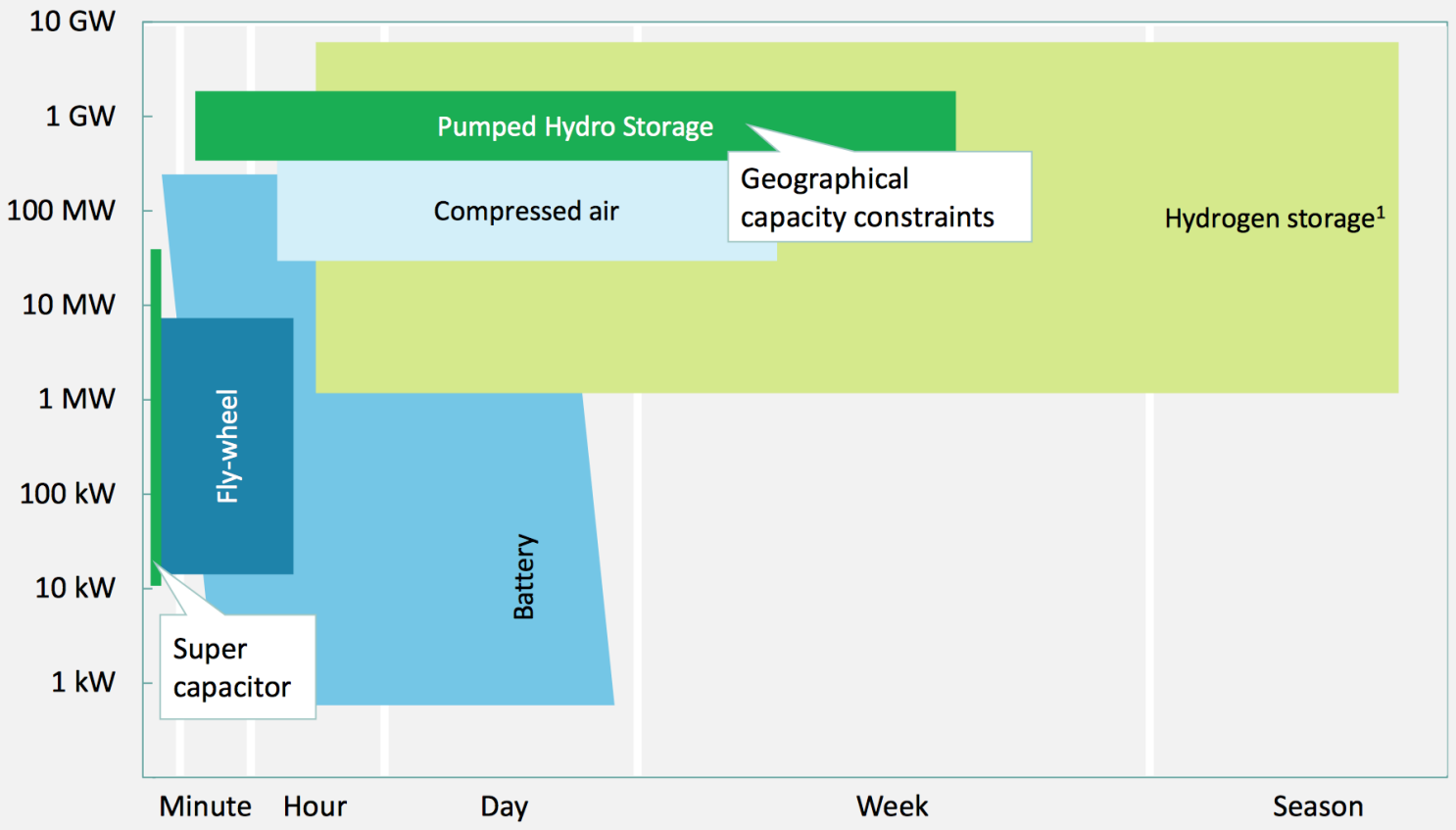
- **Flywheel (kWh)**
- **Compressed air (GWh)**
- **Hydrogen (GWh)**
  - **Develop safe and high density H_2 storage: high pressure or hydrates**
  - **Produce H_2 using surplus renewable energy**
  - **Develop high power fuel cells**
  - **Possibly future automobiles will run on H_2 and the waste will be only water!**

Energy Storage

PROVIDE SEASONAL STORAGE AND IMPROVE SYSTEM EFFICIENCY

1. Hydrogen for long-term carbon-free energy storage

Technology overview of carbon-free energy storage technologies



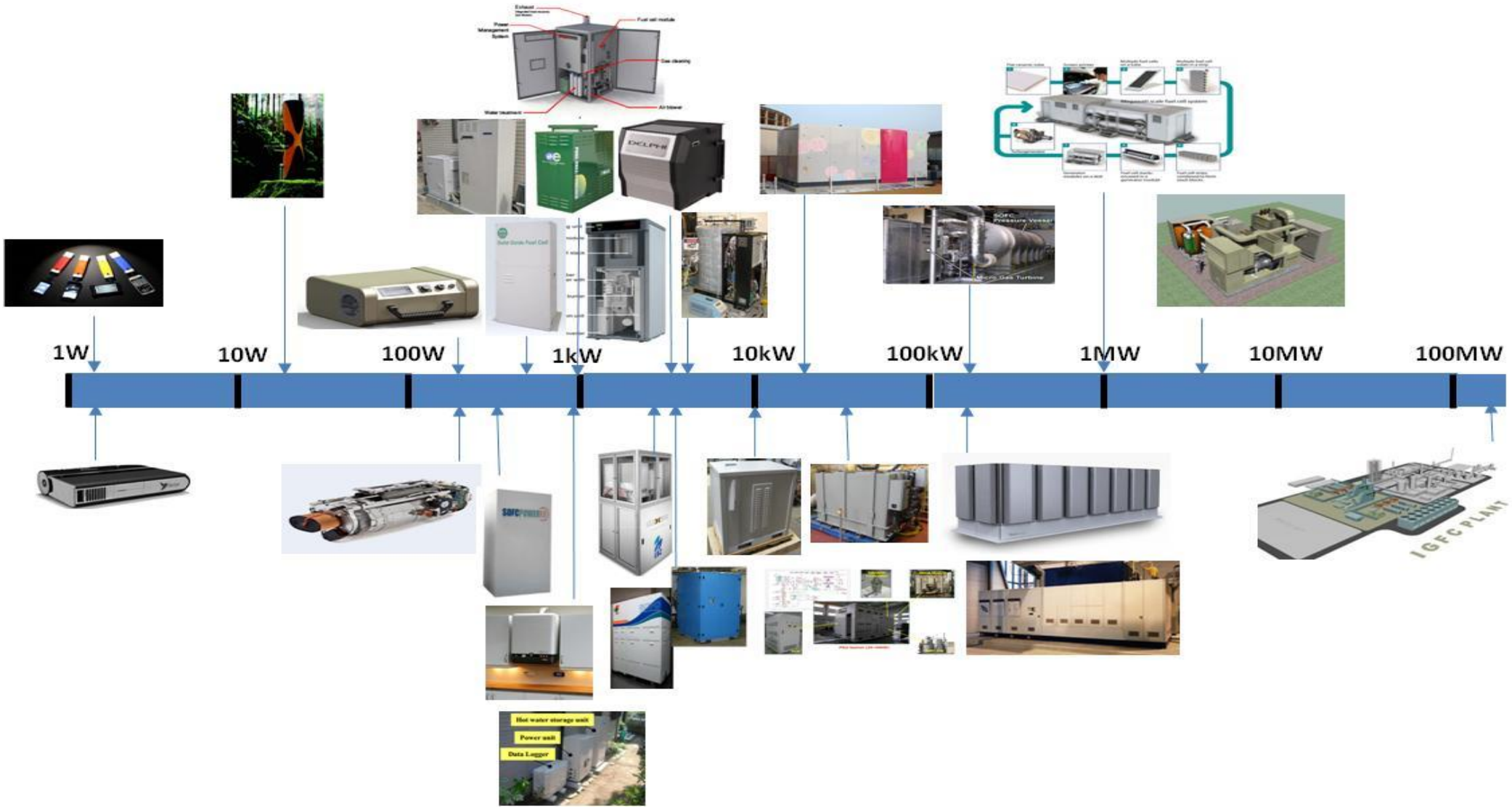
1 IEA data updated due to recent developments in building numerous 1MW hydrogen storage tanks

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

Air Liquide ALSTOM AngloAmerican BMW GROUP DAIMLER ENGIE HONDA HYUNDAI Kawasaki THE LINDE GROUP TOTAL TOYOTA

Solid Oxide Fuel Cells

Power Spectrum



Smart Grid

The grid today:

- Generation follows the demand, no control on consumers

Smart Grid:

- Distributed generation (on consumer side) – prosumers (production + consumer)
- **Demand control**
- High use of **communication, measurements, control**,…

Human Behavior

Japanese law:

- During summer it is allowed to cool down to **28º C** and in winter it is allowed to warm up to **19º C**.
- **No suit and neck-tie** (as they give a thermal sensation of 3º to 4º C above ambient temperature).

In Rio:

- When the temperature rises from **28º to 30º the energy consumption rises about 1 GW**!
- Challenge: Design man's clothes light and inspiring respect!

Serious Shirt

My proposal 1

Who would believe in this?
In Brazil?

Serious Shirt

My proposal 2

41

Serious Shirt

My proposal 3

42

Bureaucracy and Human Behavior

Important conclusion:

Bureaucracy and human behavior also impact the environment!

43

In 1968, we discovered that
Earth is a small blue dot
in the Universe and fragile!

Picture taken from Apollo 8.

Death per 100 GW/Year

Scientific American, September, 2011

Hydro 0,27

2,7 x — **Nuclear 0,73**

26 x — **Natural gas 7,19**

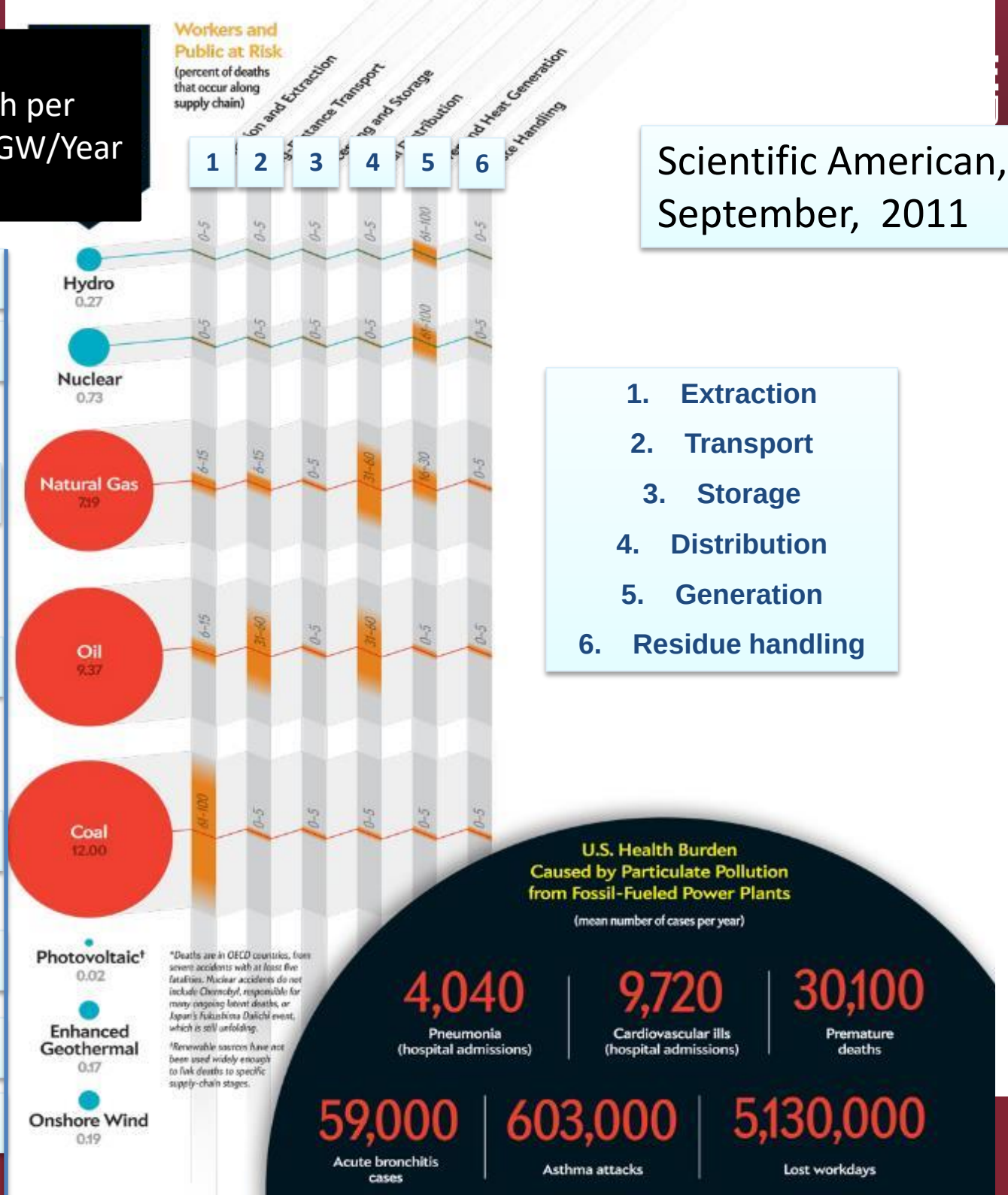
34 x — **Oil 9,37**

44 x — **Coal 12**

Photovoltaic 0.02

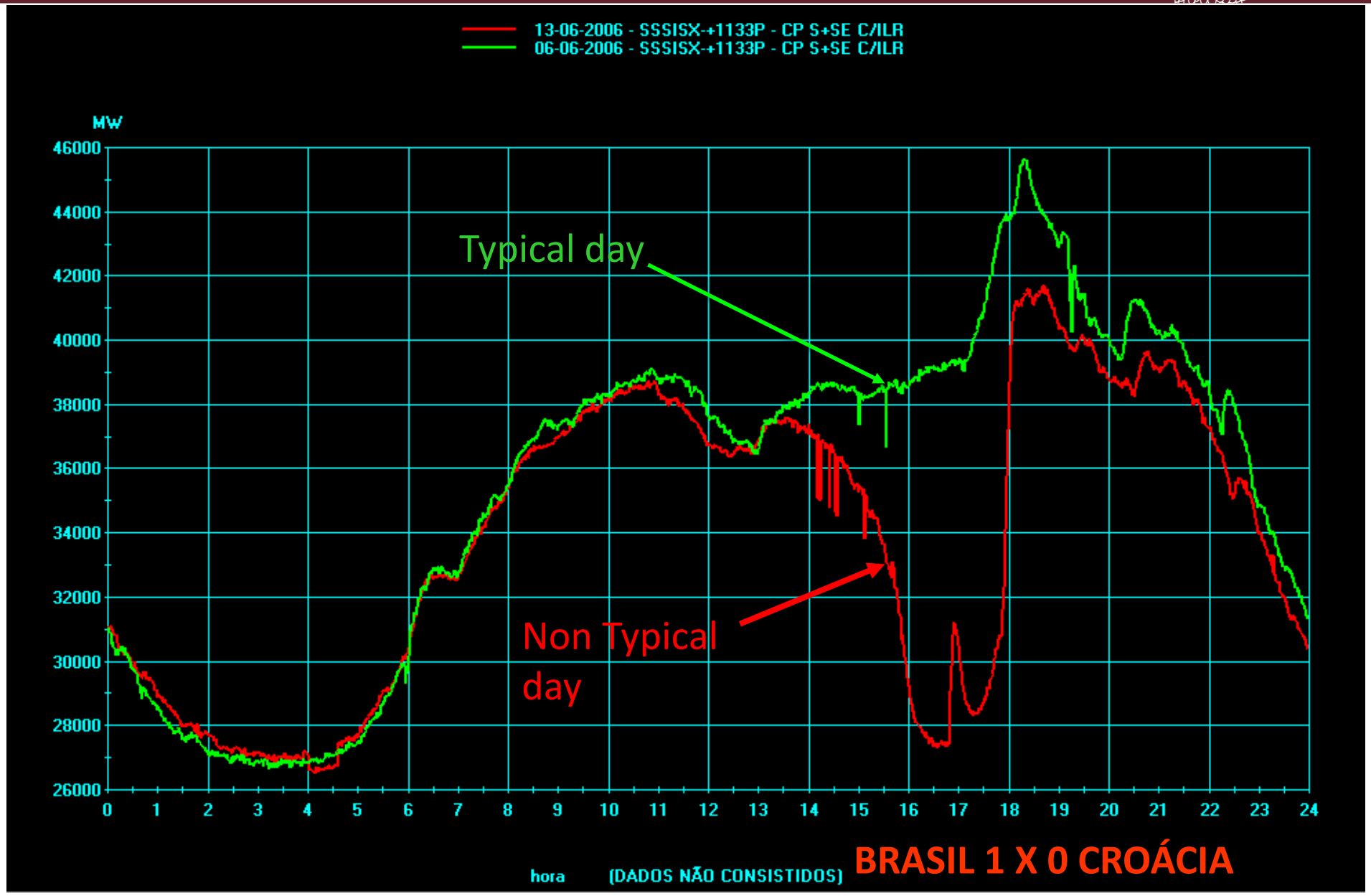
Geothermal 0.17

On-shore wind 0.19



1. Extraction
2. Transport
3. Storage
4. Distribution
5. Generation
6. Residue handling

Electric Energy – Non Typical Day



46