Faculdade de Ciências da Universidade de Lisboa

Energy Sustainability:
can we achieve it?
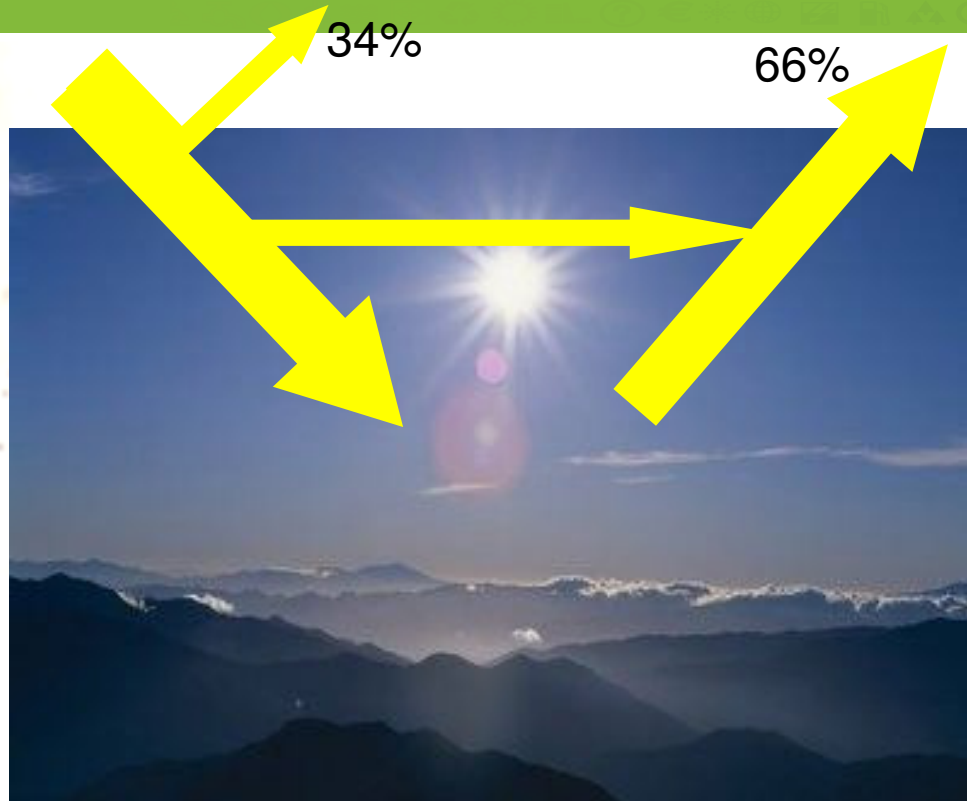
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DE CIÊNCIAS
UNIVERSIDADE DE LISBOA

Energy Sustainability: what does it mean?

let's think about a bank account….

- **cash input (deposit)**

- **cash output (withdraw)**

34%

66%

How much energy coming from the Sun "is deposited" in our planet by unit time?

In the top of the atmosphere the planet receives about 1.4kWm^{-2} !

34% is reflected back to space.

The remaining 66% "is deposited" in the system Hearth / Atmosphere and somehow is reemitted to space.

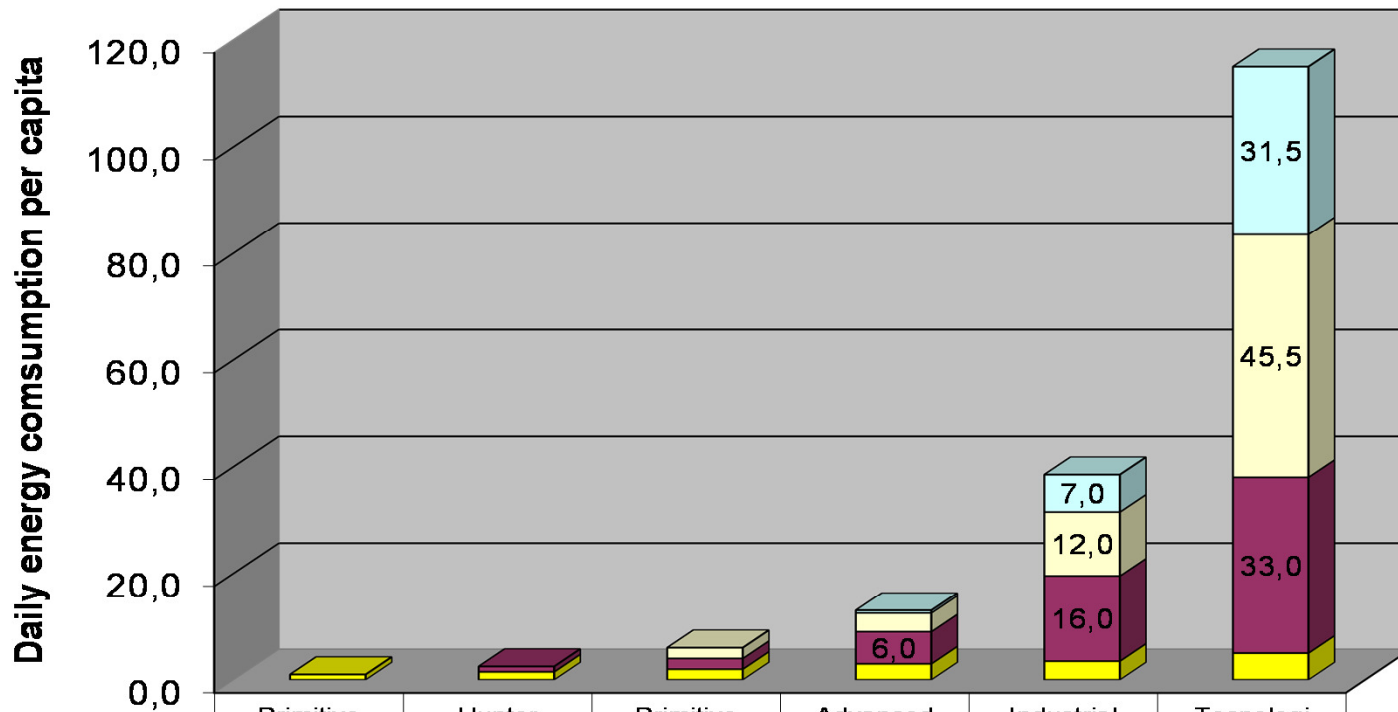**Renewable energy flux: 10^{24}J ano^{-1} (1000000000000000000000000 J ano^{-1} !)**

This is our global "energy salary"…

This energy was used by the planet to support all life forms in the past

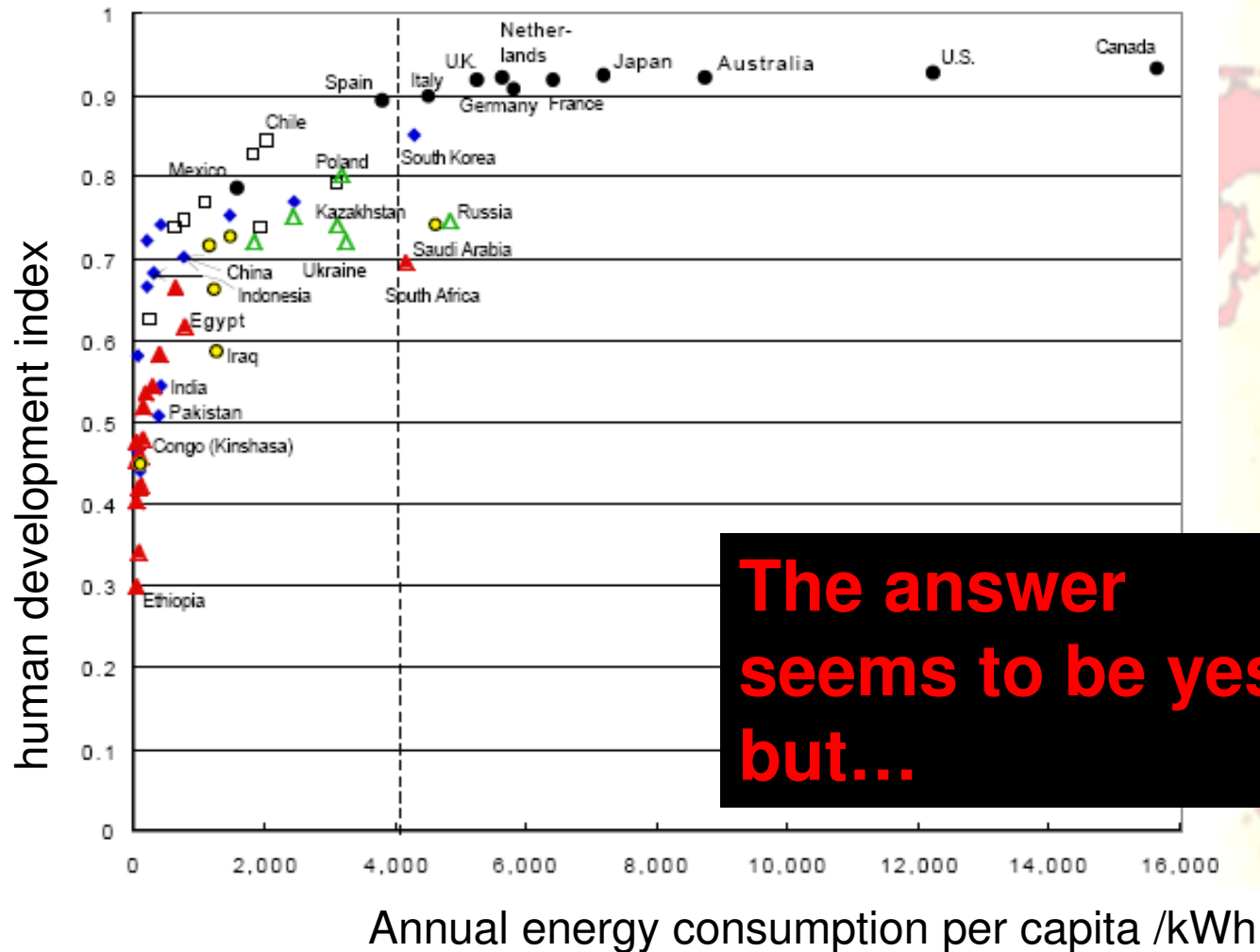**In fact, the planet used this energy to do something like a "savings account"…**

… that we call fossil fuels!

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And what about our "expenses"?

	Primitive	Hunter	Primitive agricultor	Advanced agricultor	Industrial	Tecnologic
☐ Transportation				0,5	7,0	31,5
☐ Industry & Agriculture			2,0	3,5	12,0	45,5
☐ Home & Comerce		1,0	2,0	6,0	16,0	33,0
☐ Food	1,0	1,5	2,0	3,0	3,5	5,0

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Do we really need to use all this energy?

human development index

Annual energy consumption per capita /kWh

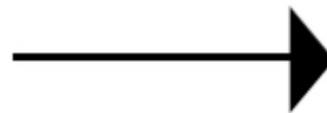**The answer seems to be yes, but...**

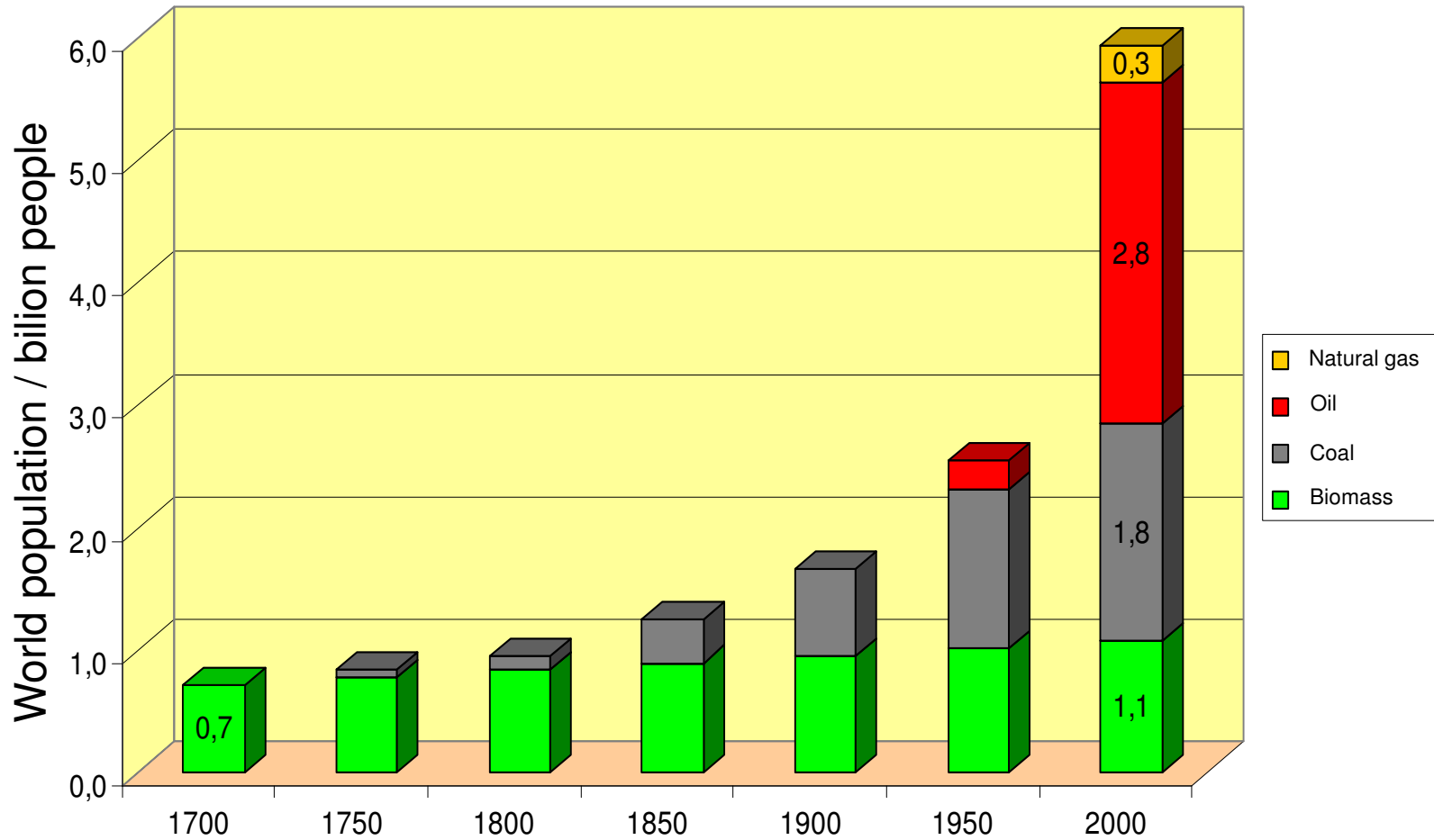**maybe it was not difficult to make less rubbish…**

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maybe it was not difficult to make less rubbish…
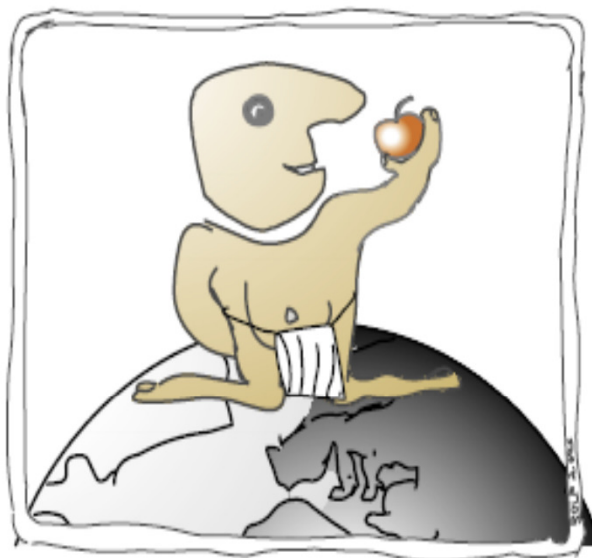
'Homo gastronomicus'

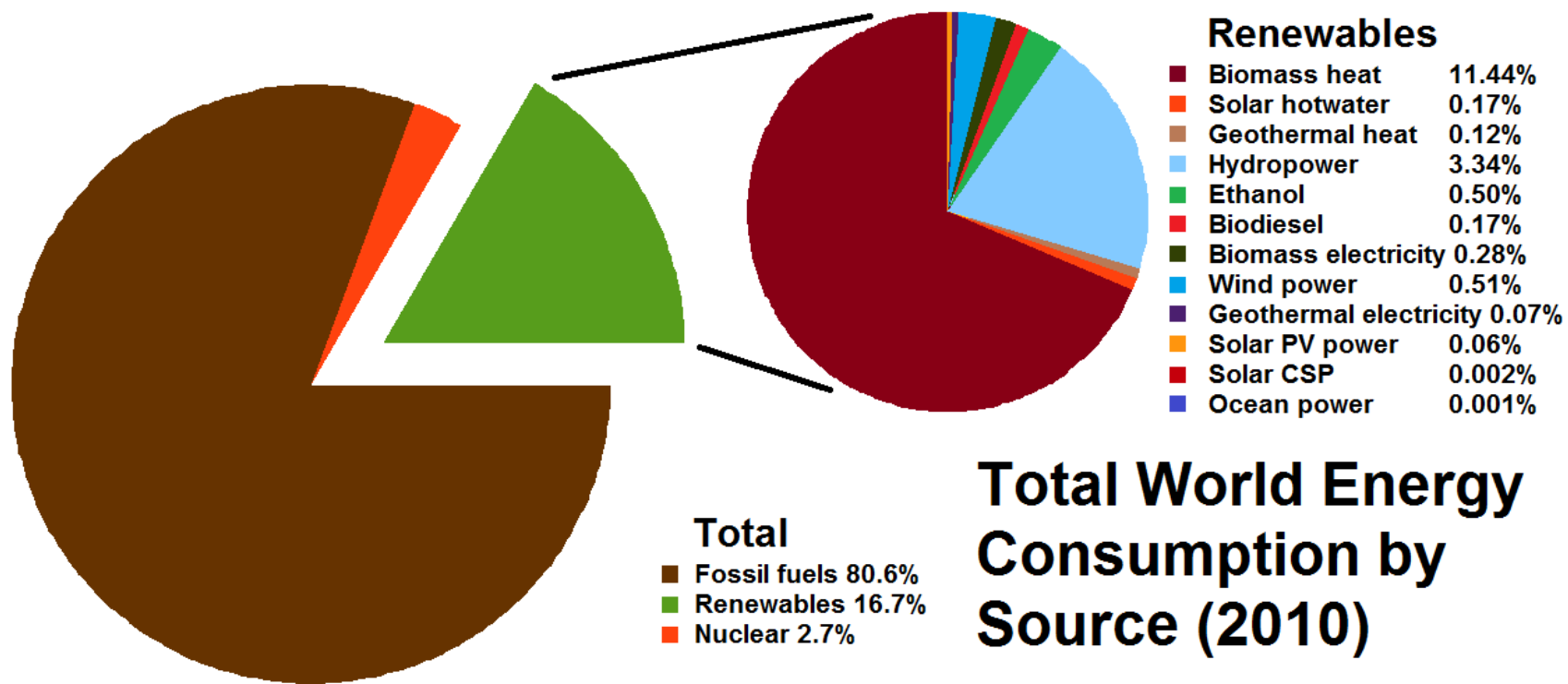**And were did we get all this energy from?**

...from the planet "savings account" that we inherit!

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And were did we get all this energy from?

Renewables

■	Biomass heat	11.44%
■	Solar hotwater	0.17%
■	Geothermal heat	0.12%
■	Hydropower	3.34%
■	Ethanol	0.50%
■	Biodiesel	0.17%
■	Biomass electricity	0.28%
■	Wind power	0.51%
■	Geothermal electricity	0.07%
■	Solar PV power	0.06%
■	Solar CSP	0.002%
■	Ocean power	0.001%

Total World Energy Consumption by Source (2010)

Total
- ■ Fossil fuels 80.6%
- ■ Renewables 16.7%
- ■ Nuclear 2.7%

Source: Renewables 2012 Global Status Report.

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And what about the future?

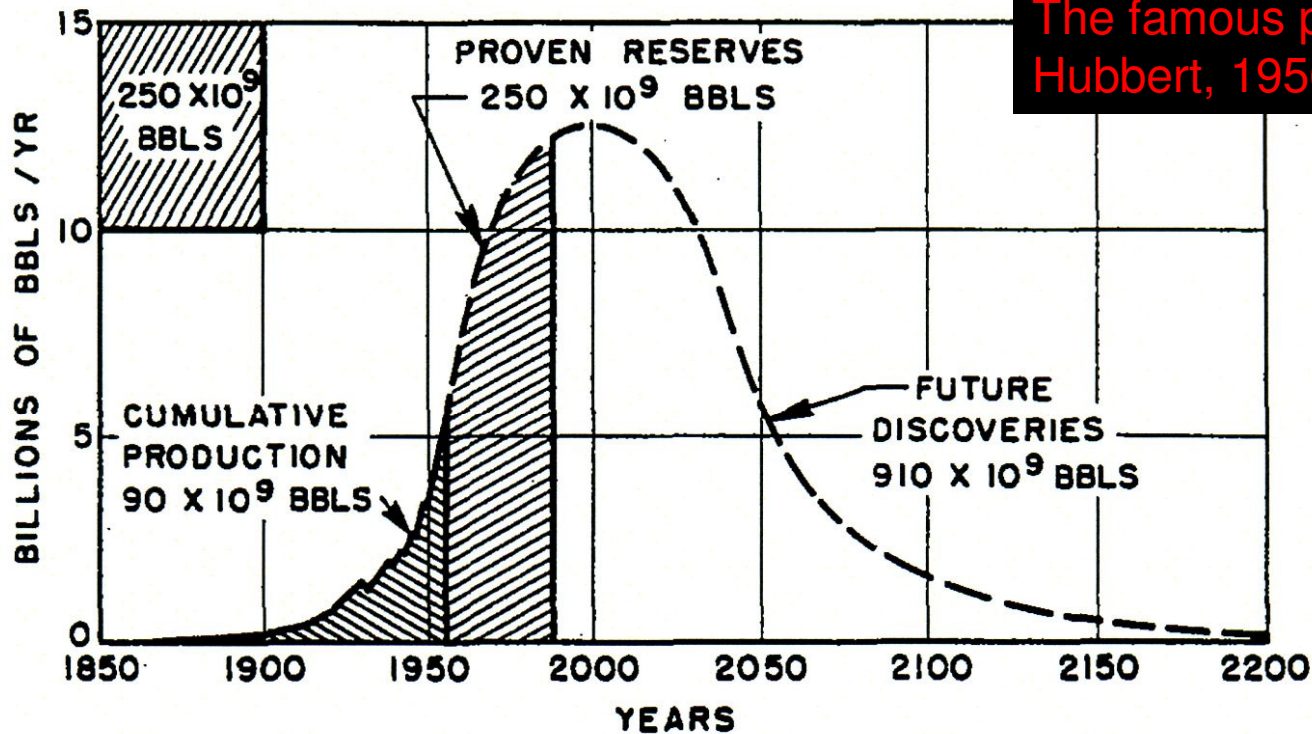The famous peak oil: Hubbert, 1956

Figure 20 – Ultimate world crude-oil production based upon initial reserves of 1250 billion barrels.

Oil production will reach a maximum some day, and then will come down to zero, although we do not know exactly when…

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What will happen to the world population if the energy available does not continue to increase?

It is clear that, at best, it will have to stabilize…

Does this mean that we have become "energy eating" machines that are doomed to extinction?!

It depends on our behaviour!
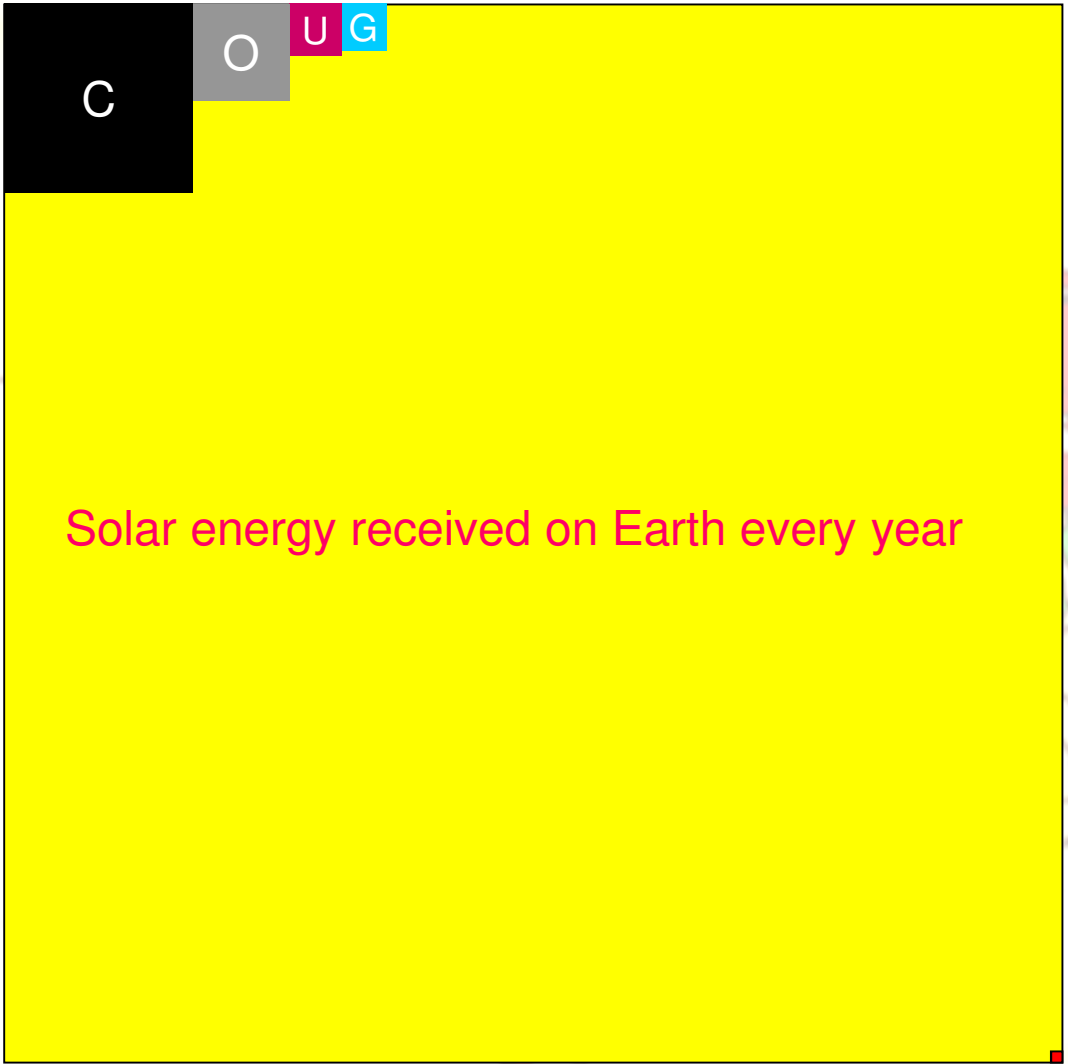
C O U G

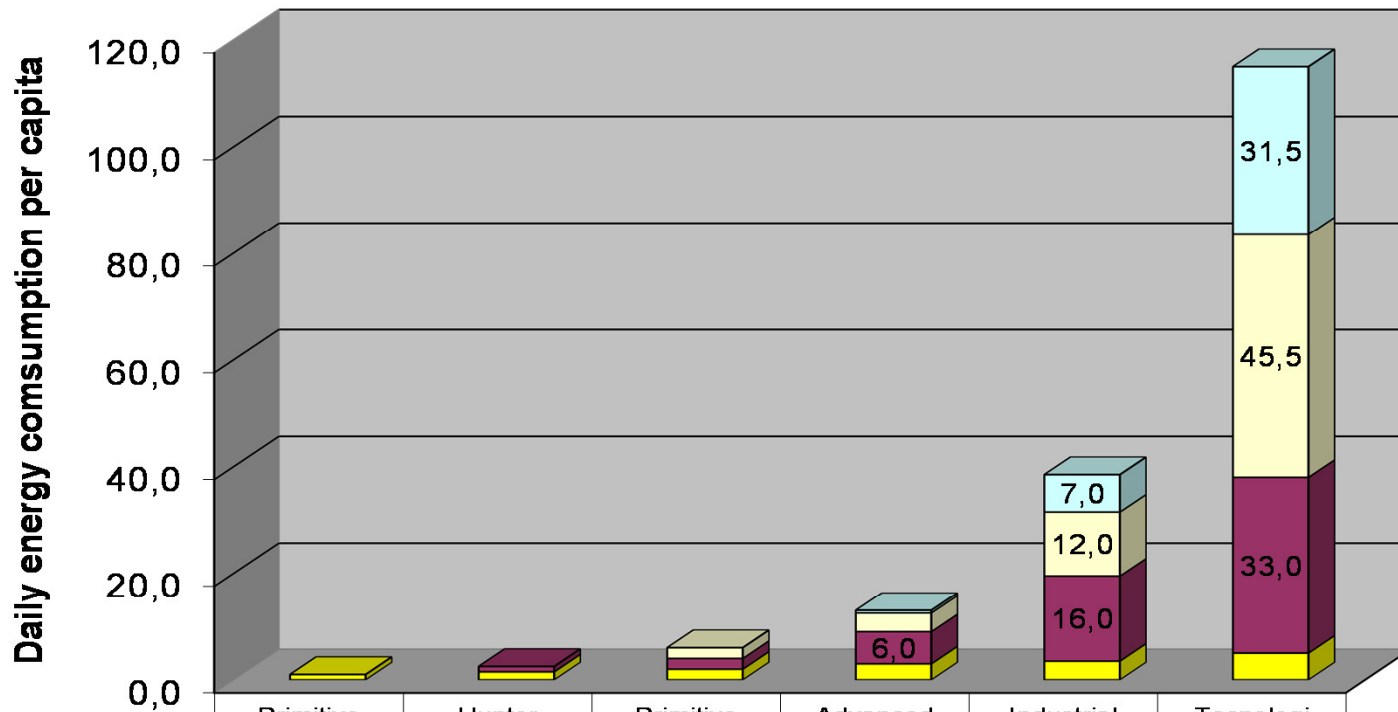Solar energy received on Earth every year

We could be happy today simply using less then 0,1% of the clean energy that we receive from the sun every day!

photosynthesis– 0,023%

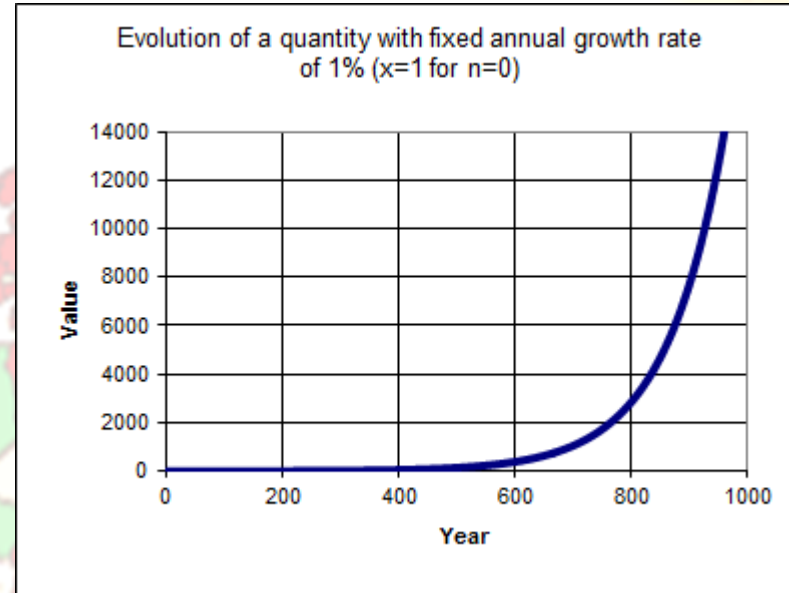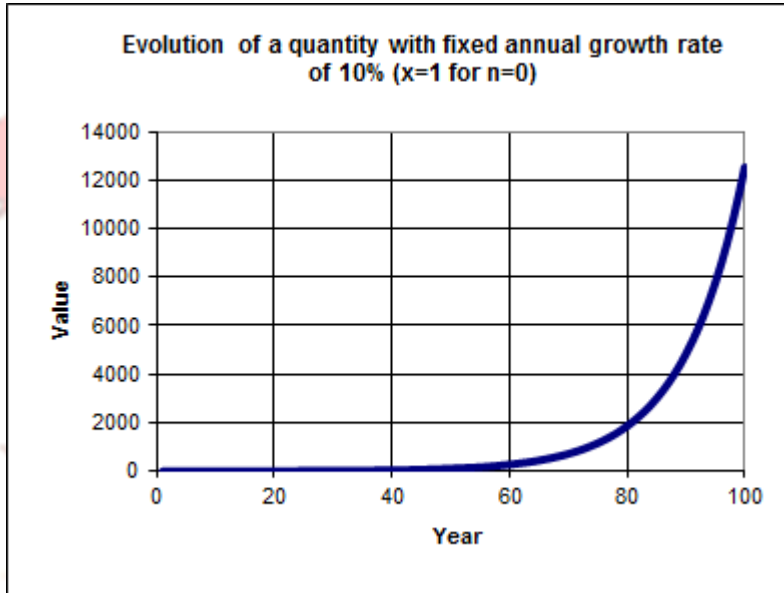In fact we already know how to do it!

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But be careful: this latter slide may be misleading…

	Primitive	Hunter	Primitive agricultor	Advanced agricultor	Industrial	Tecnologic
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How does one get this type of curve?

Two examples:

Evolution of a quantity with fixed annual growth rate of 10% (x=1 for n=0)

Evolution of a quantity with fixed annual growth rate of 1% (x=1 for n=0)

The shape is the same whatever annual growth rate we are considering:

in the beginning it looks like nothing is happening…

… and then, it seems impossible to control!

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Question: if a quantity increases at a fixed annual rate t, how long does it take to double its initial value?

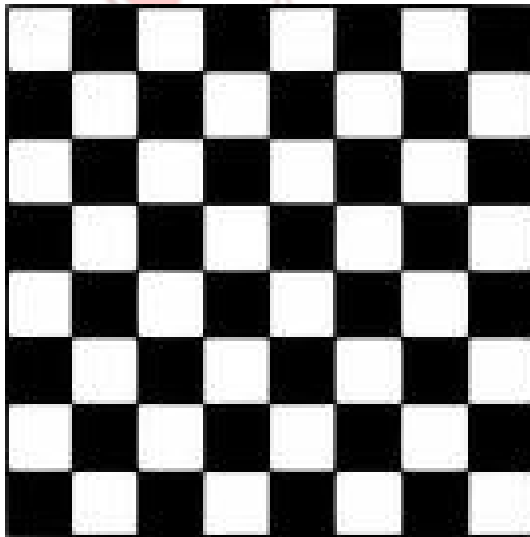| Growth rate	Duplication time / years
1	69.7
2	35.0
3	23.4
4	17.7
5	14.2
6	11.9
7	10.2
8	9.0
9	8.0
10	7.3

Answer:

$$\sim \frac{70}{t}$$

**even with a 1% rate the doubling time is less than the current human average life expectancy …**

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And what does it mean "doubling"?

Doubling does not mean having always the same increase in absolute terms: it means a very significant increase!

it is interesting to recall the legend of wheat grains associated with the creation of the chess game …

And what does it mean "doubling"?
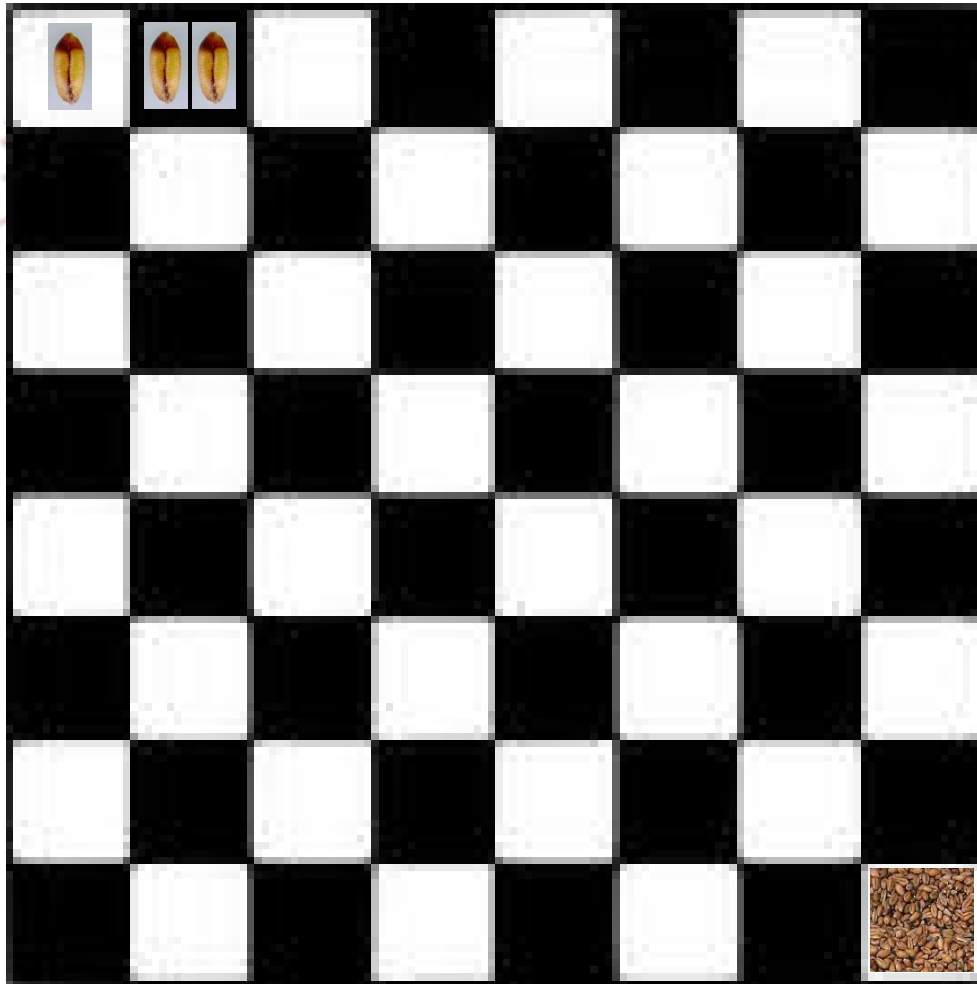
one wheat grain on the first square, two on the second, and so on…

The grains in the last square will be my reward…

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And what does it mean "doubling"?

Square	Number of grains
1	$1=2^0$
2	$2=2^1$
3	$4=2^2$
4	$8=2^3$
(…)	(…)
64	2^{63}

how much wheat is 2^{63} grains?

One grain weights on average about 30mg, so we are talking about:

$2^{63} \times 3 \times 10^{-8}$ ton = 2,8×10^{11} ton

This represents about 460 times the world wheat production in 2007/08 (~ 604 million ton)

And what does it mean "doubling"?

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(…)	(…)
64	2^{63}

every time we double the consumption of any good we consume more then we had ever consumed before!

Another interesting example:

(Albert Bartlett, Arithmetic, Population and Energy)

Bacteria reproduce themselves by duplication: a bacterium divides into two, these will divide into four…

Suppose we put a bacterium inside an empty bottle at 11:00 am, that they reproduce once per minute…

Another interesting example:

(Albert Bartlett, Arithmetic, Population and Energy)

Bacteria reproduce themselves by duplication: a bacterium divides into two, these will divide into four…

… and that after 1h, at 12:00, bacteria had reproduced to occupy the entire volume of the bottle…

Another interesting example:

(Albert Bartlett, Arithmetic, Population and Energy)

Bacteria reproduce themselves by duplication: a bacterium divides into two, these will divide into four…

What time was half the volume of the bottle occupied?

… at 11:59!

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Another interesting example:

(Albert Bartlett, Arithmetic, Population and Energy)

Bacteria reproduce themselves by duplication: a bacterium divides into two, these will divide into four…

If I were a bacterium inside the bottle, when would I get suspicious that I could have a space problem in the bottle?

at 11:55 only 3% of space inside the bottle is occupied!

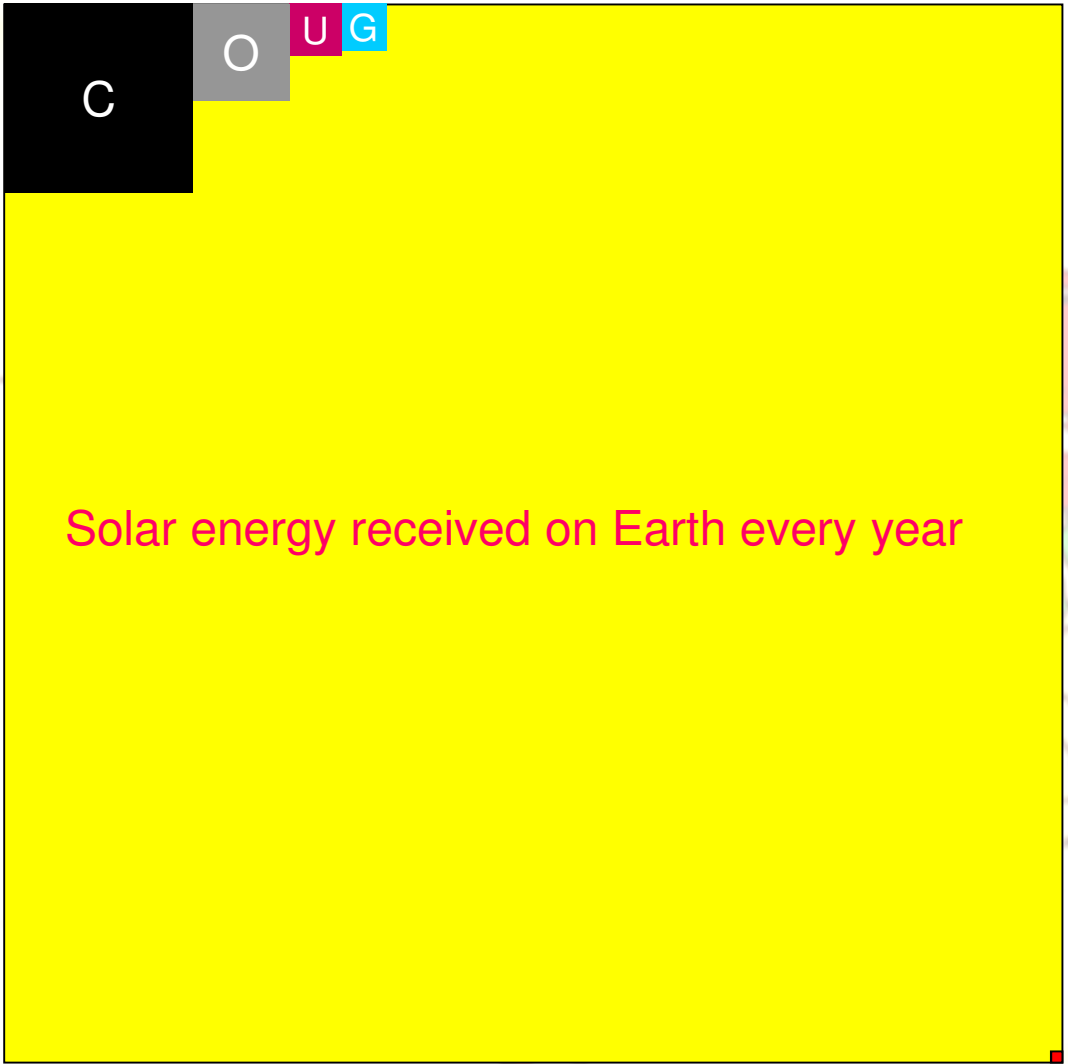25

Another interesting example:

(Albert Bartlett, Arithmetic, Population and Energy)

Bacteria reproduce themselves by duplication: a bacterium divides into two, these will divide into four…

Suppose now that two minutes before 12:00, a group of brave bacteria locate 3 new bottles outside!
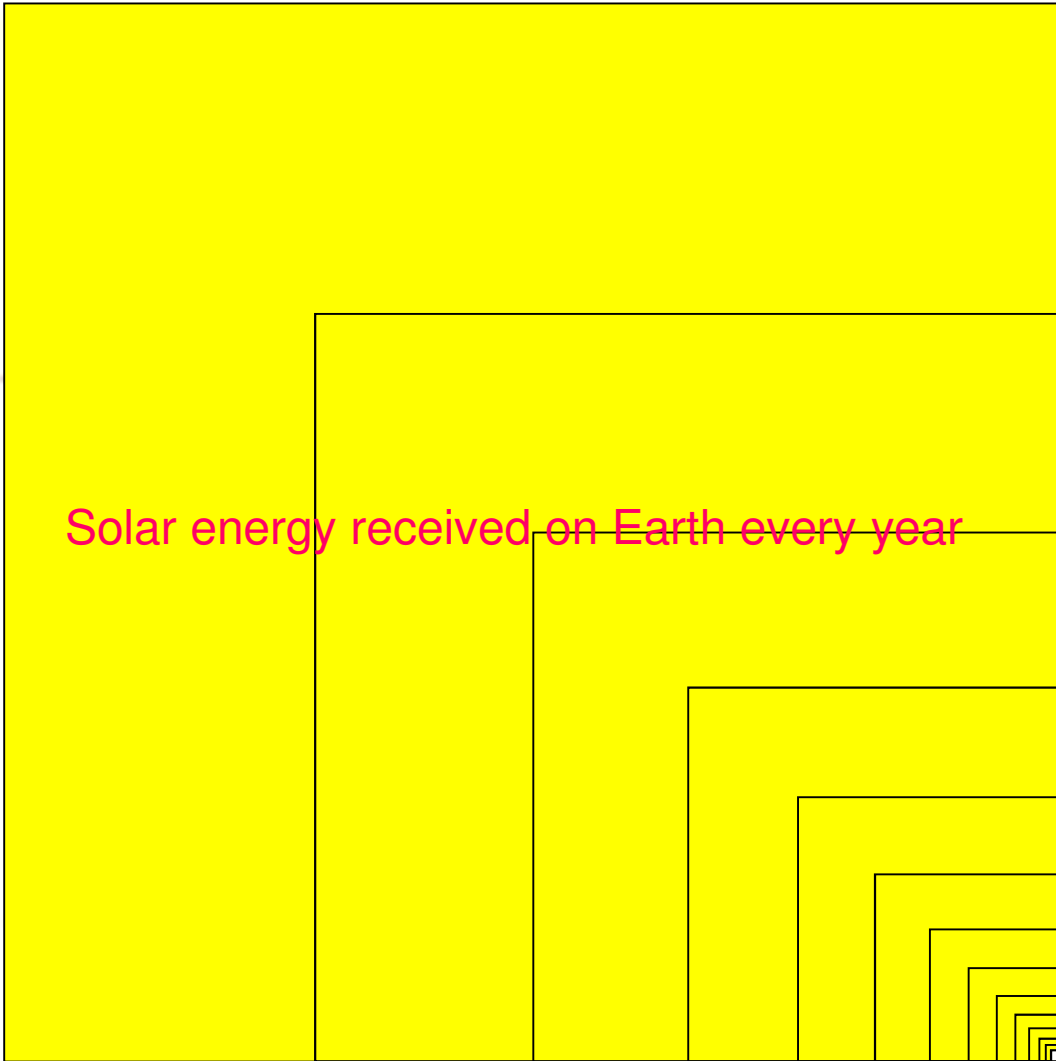
the colony gained two more minutes of life!

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C O U G

Solar energy received on Earth every year

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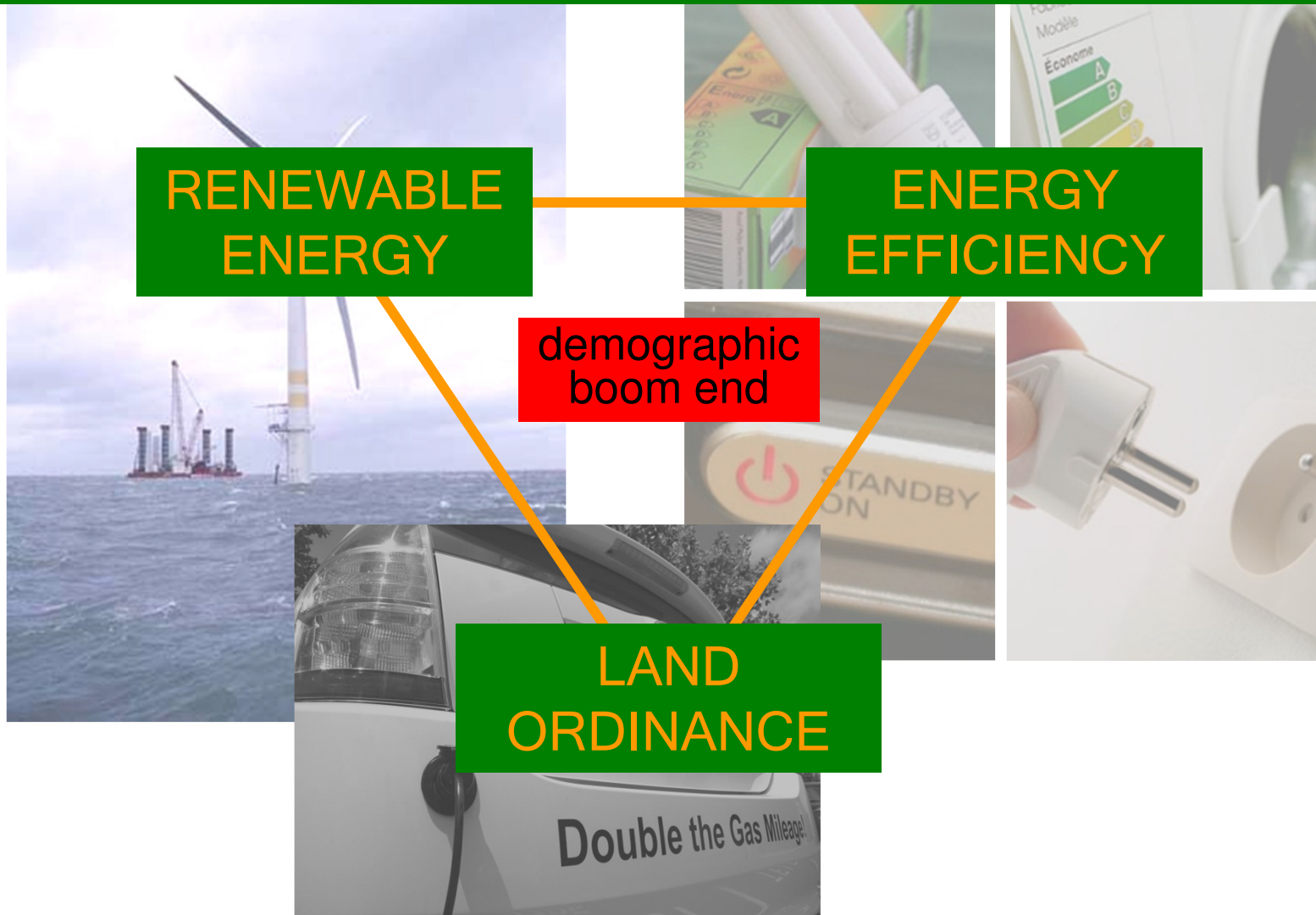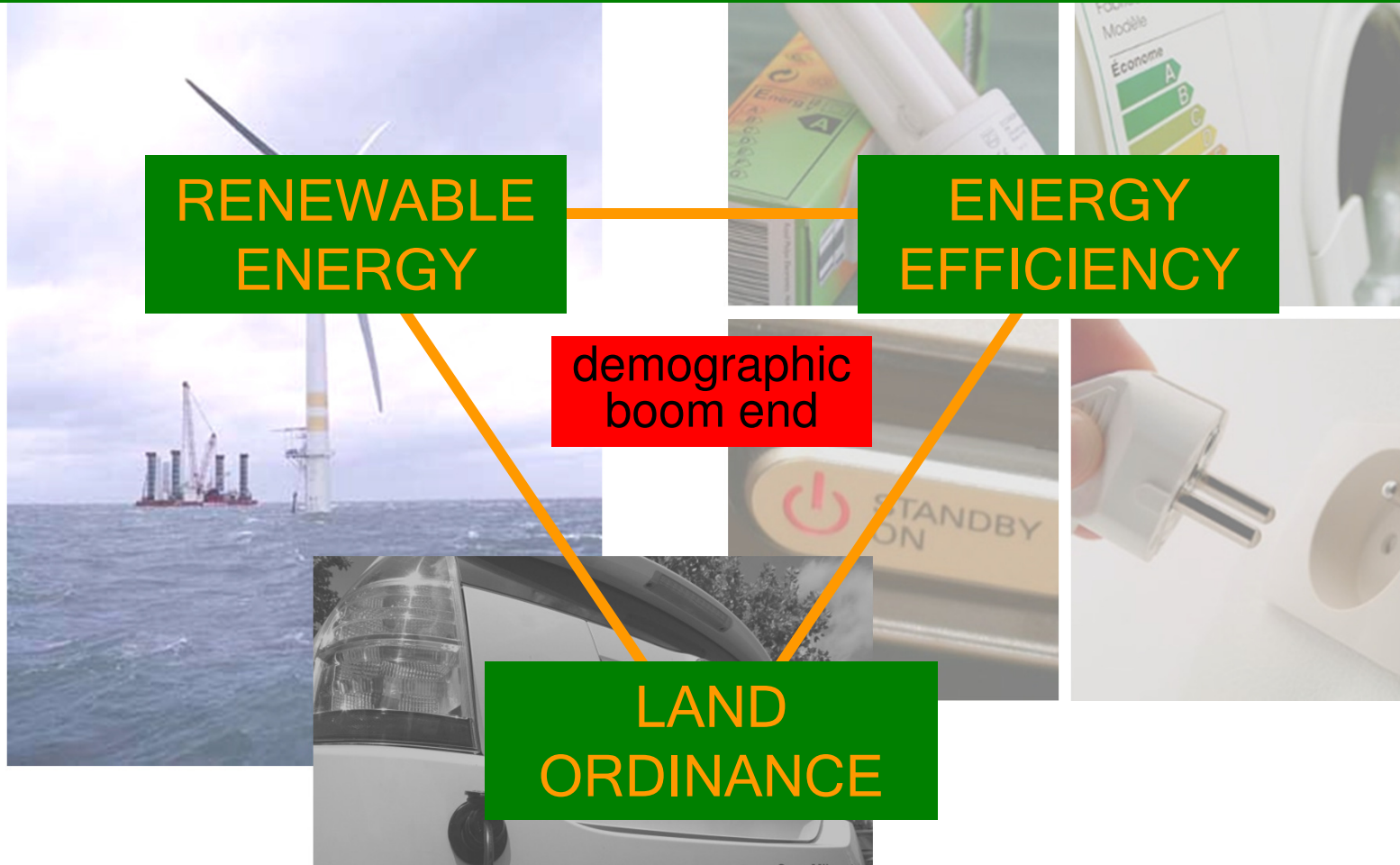In fact we already know how to do it!

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Solar energy received on Earth every year

What time is it know?

11:47

How can we achieve energy sustainability?

RENEWABLE ENERGY

ENERGY EFFICIENCY

demographic boom end

LAND ORDINANCE

How can we achieve energy sustainability?

RENEWABLE ENERGY

ENERGY EFFICIENCY

demographic boom end

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Thank you for your attention!