

Energy Sustainability: can we achieve it?

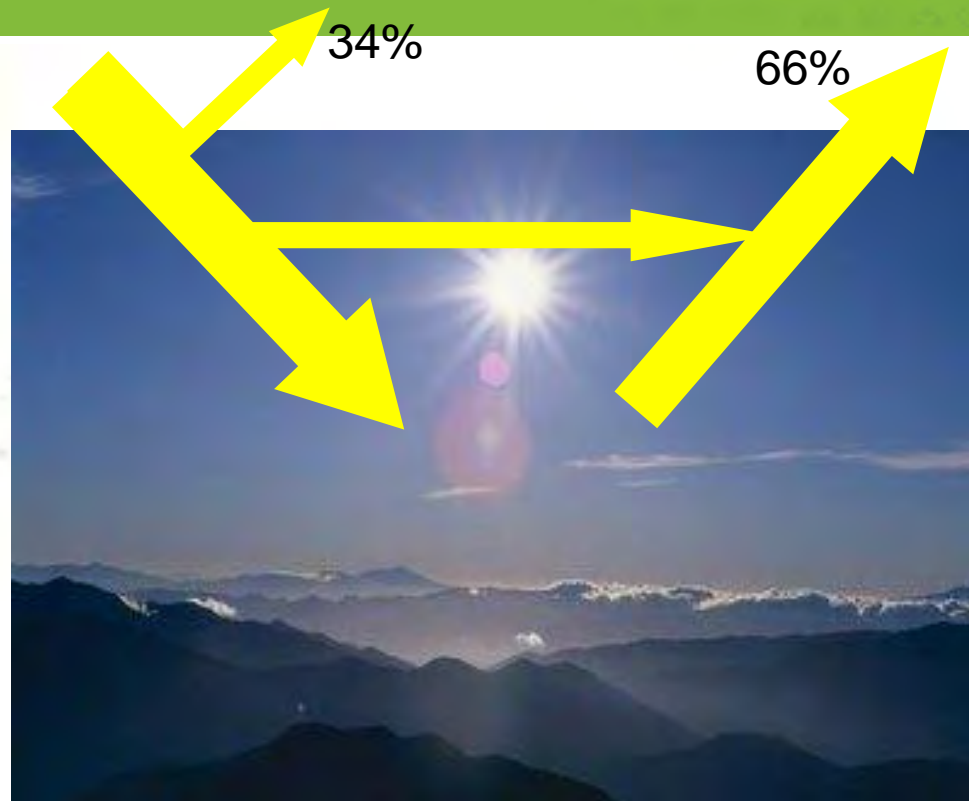


Jorge Maia Alves

Energy Sustainability: what does it mean?

let's think about a bank account....

- **cash input (deposit)**
- **cash output (withdraw)**



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 Earth / Atmosphere and somehow is reemitted to space.

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



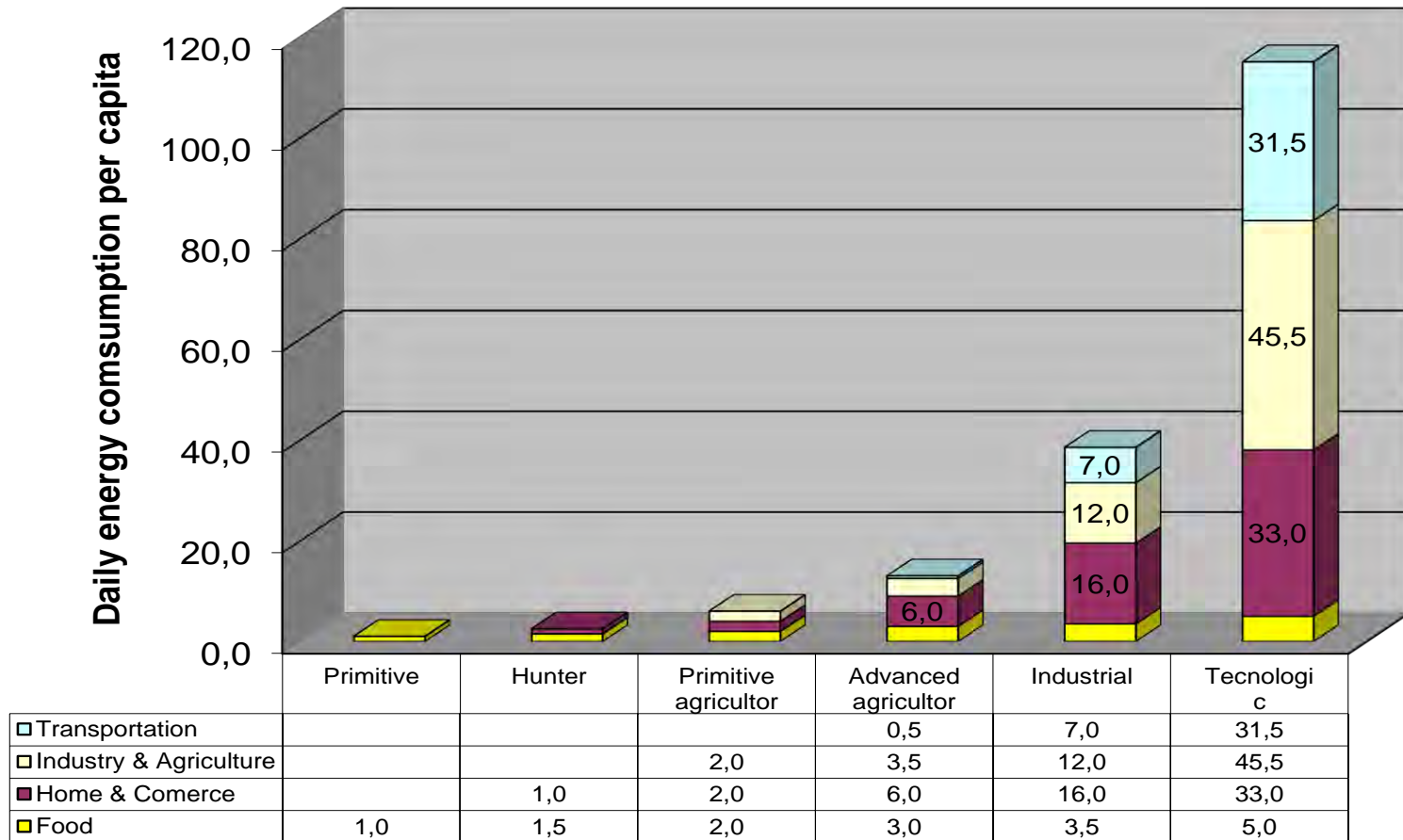
**This is our global
“energy salary”...**

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

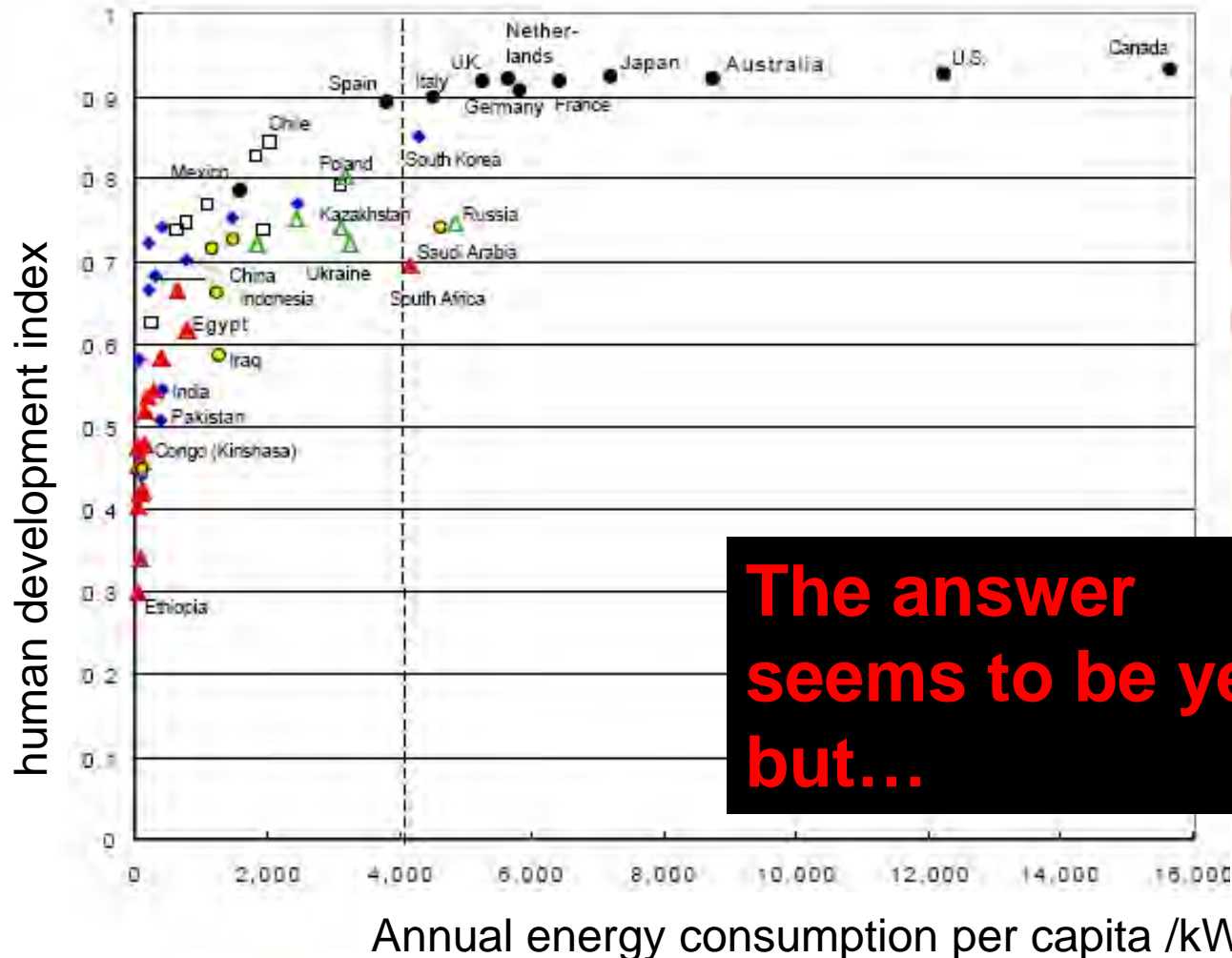
**In fact, the planet used this energy to do something like a
“savings account”...**

... that we call fossil fuels!

And what about our “expenses”?



Do we really need to use all this energy?



maybe it was not difficult to make less rubbish...



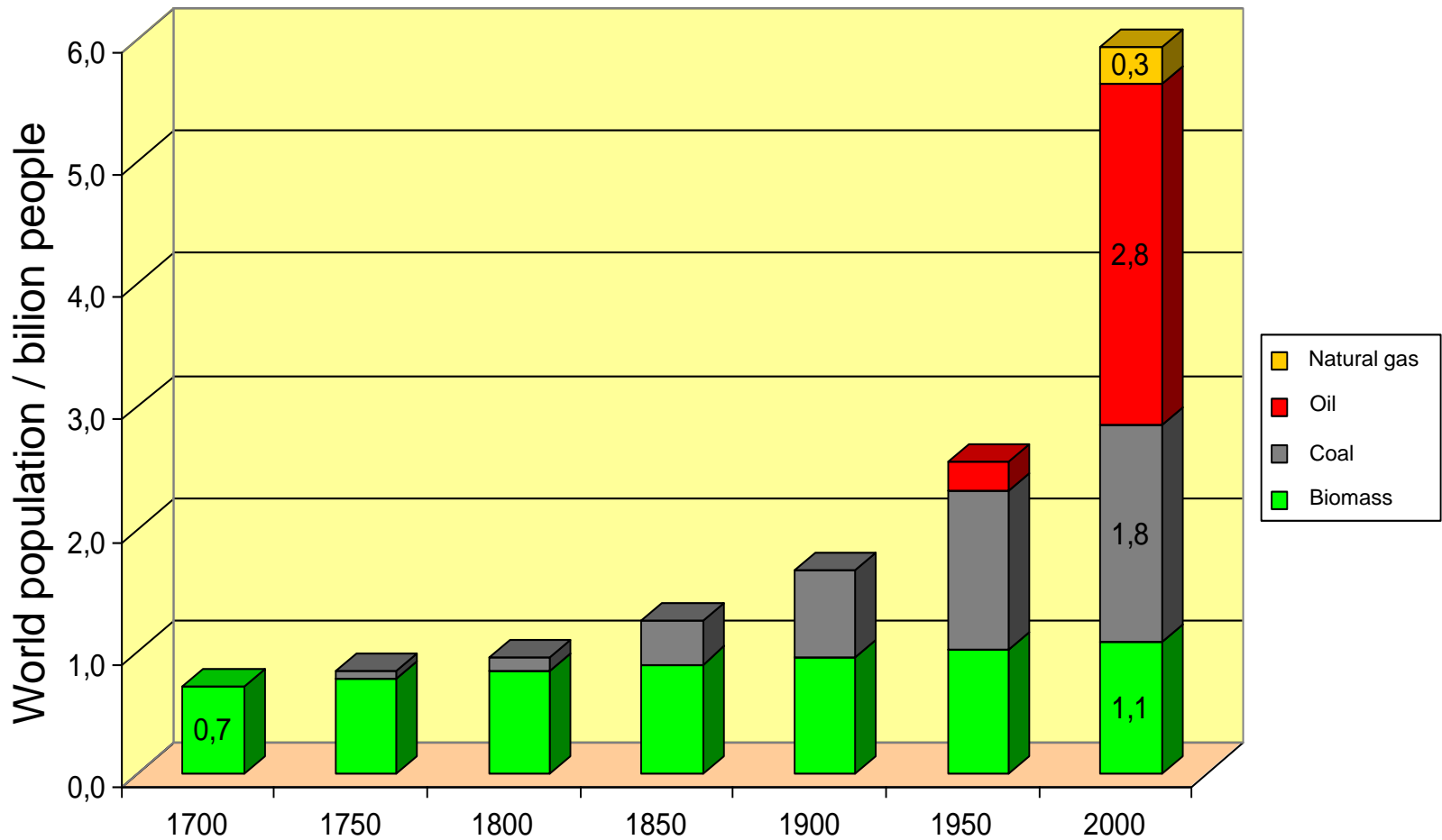
maybe it was not difficult to make less rubbish...



'Homo gastronomicus'

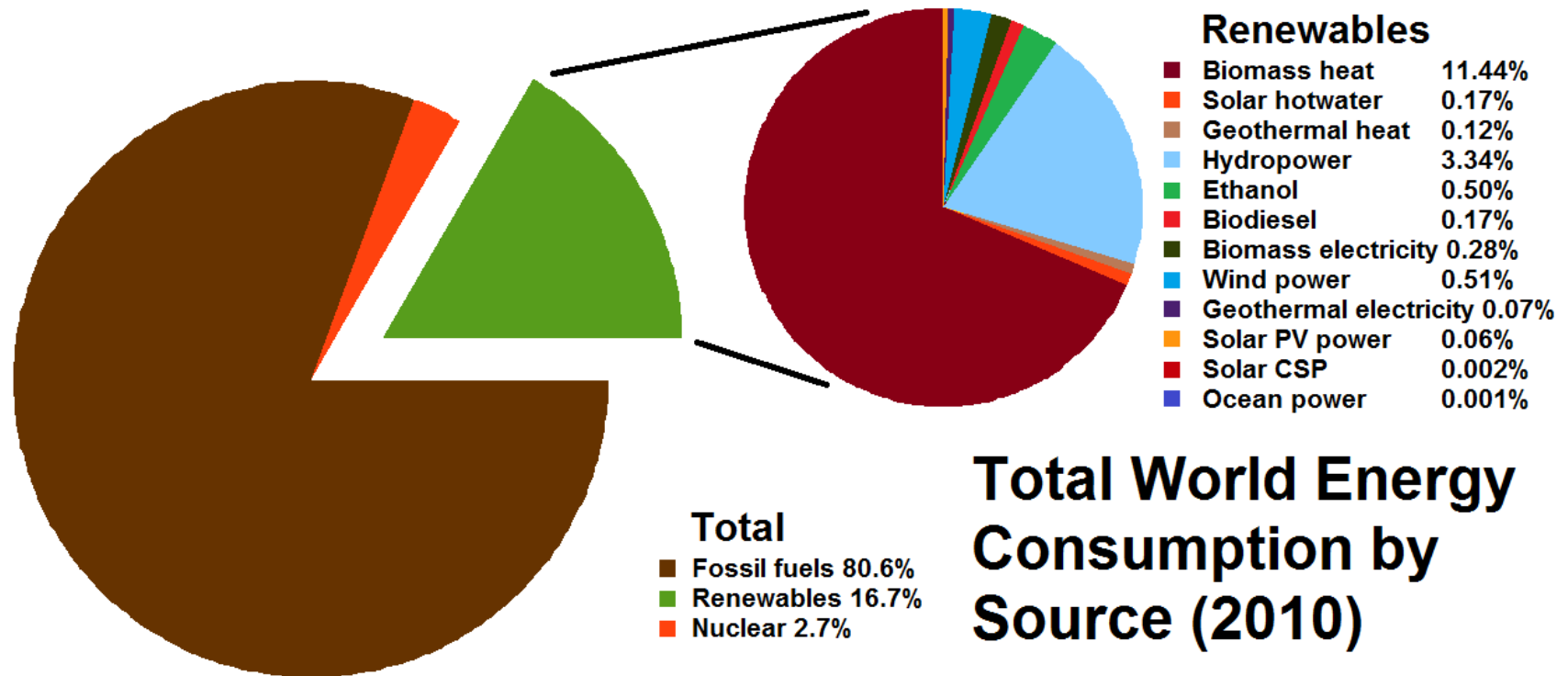


And where did we get all this energy from?



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

And where did we get all this energy from?



Source: [Renewables 2012 Global Status Report](#).

And what about the future?

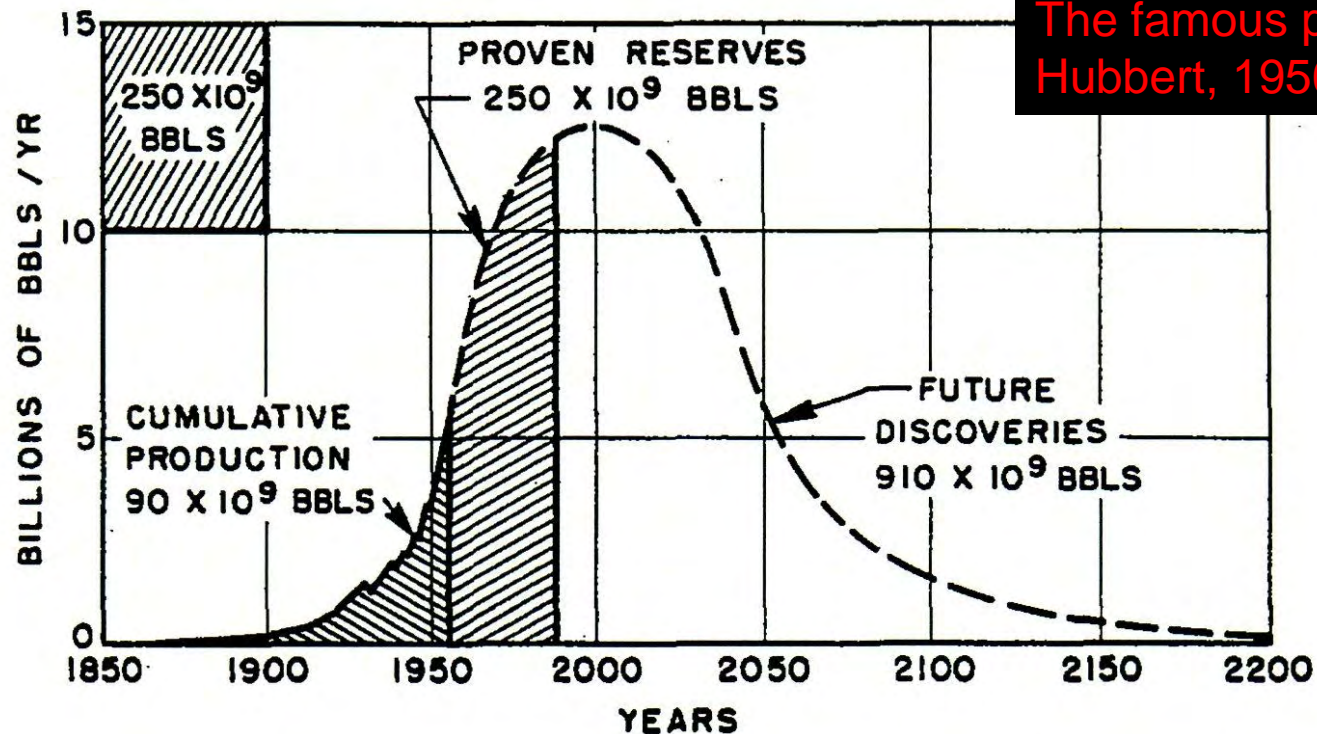


Figure 20 – Ultimate world crude-oil production based upon initial reserves of 1250 billion barrels.

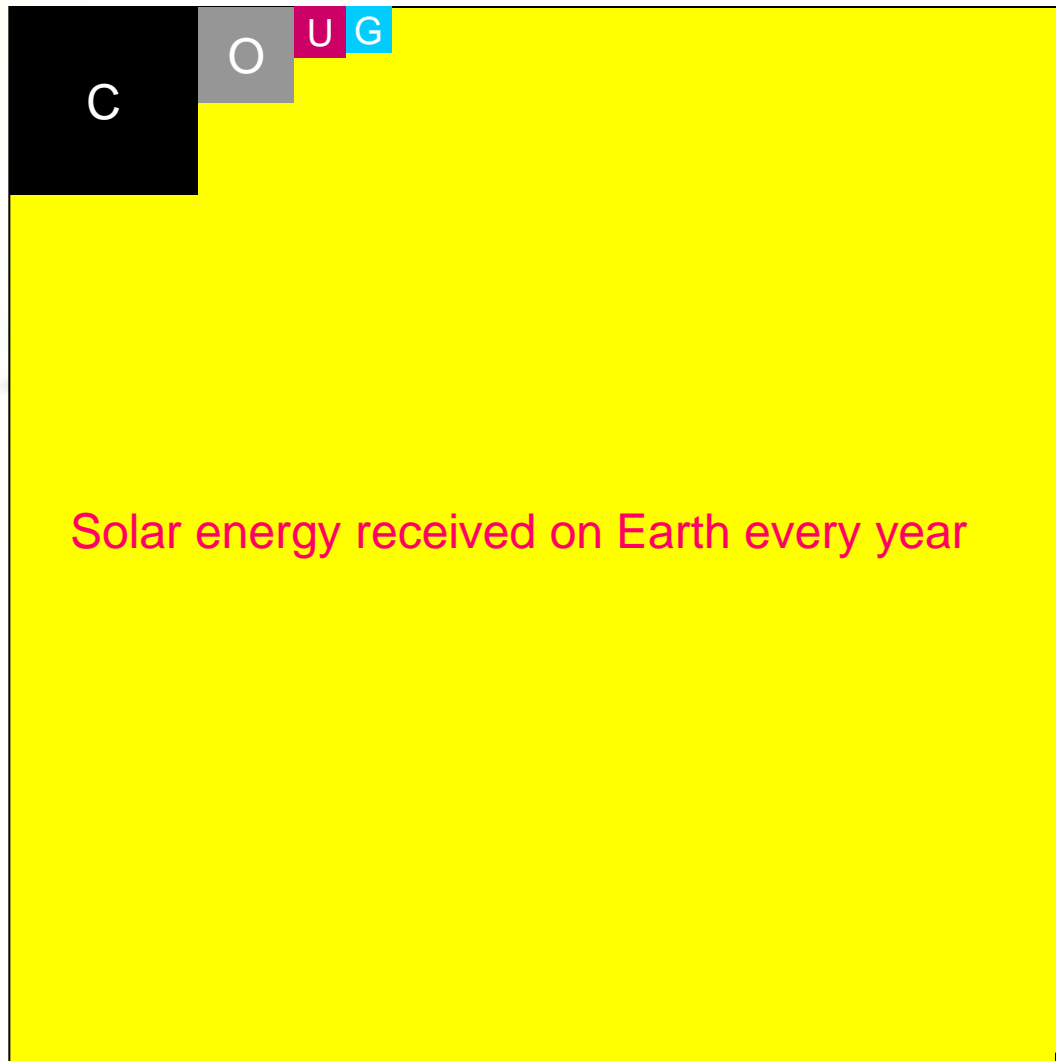
Oil production will reach a maximum some day, and then will come down to zero, although we do not know exactly when...

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!

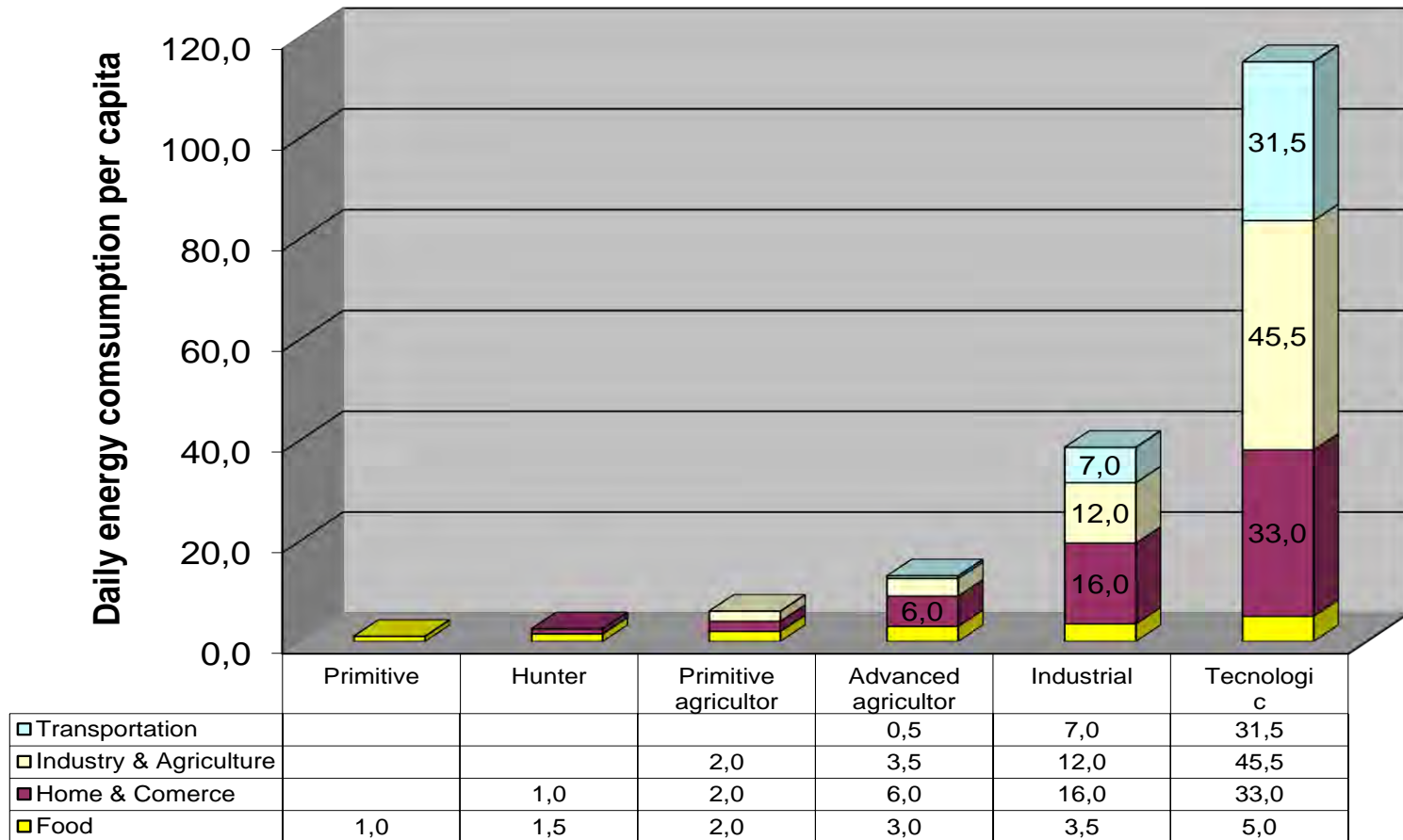


We could be happy today simply using less than 0,1% of the clean energy that we receive from the sun every day!

photosynthesis— 0,023%

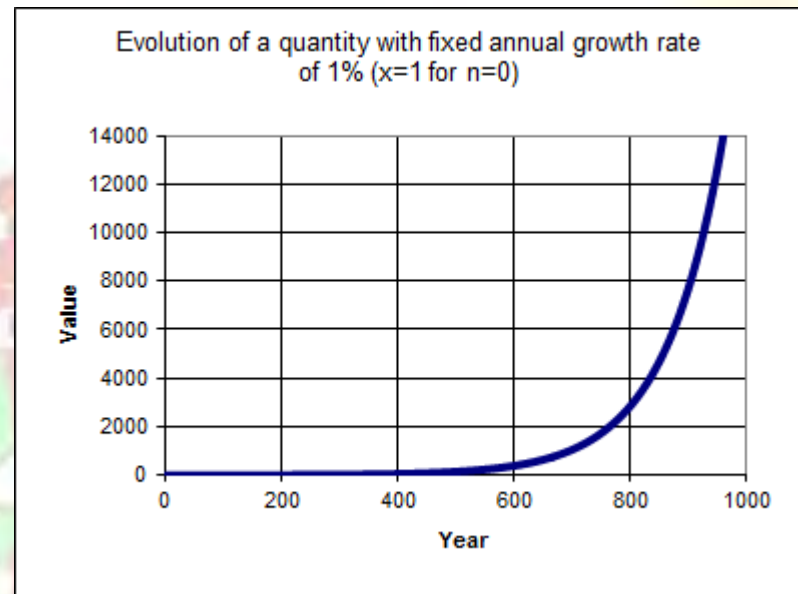
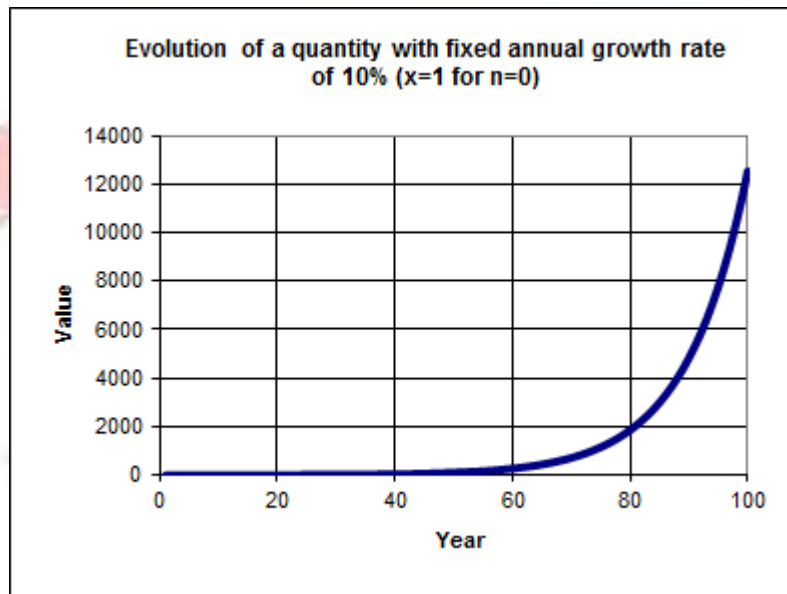
In fact we already know how to do it!

But be careful: this latter slide may be misleading...



How does one get this type of curve?

Two examples:



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!

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

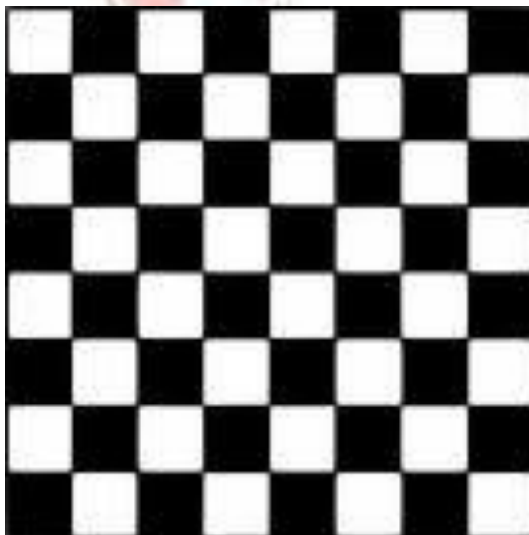
Answer:

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

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

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...**

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:**

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

**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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1	$1=2^0$
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(...)	(...)
64	2^{63}

**every time we
double the
consumption of
any good we
consume more
than 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!

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!

Another interesting example:

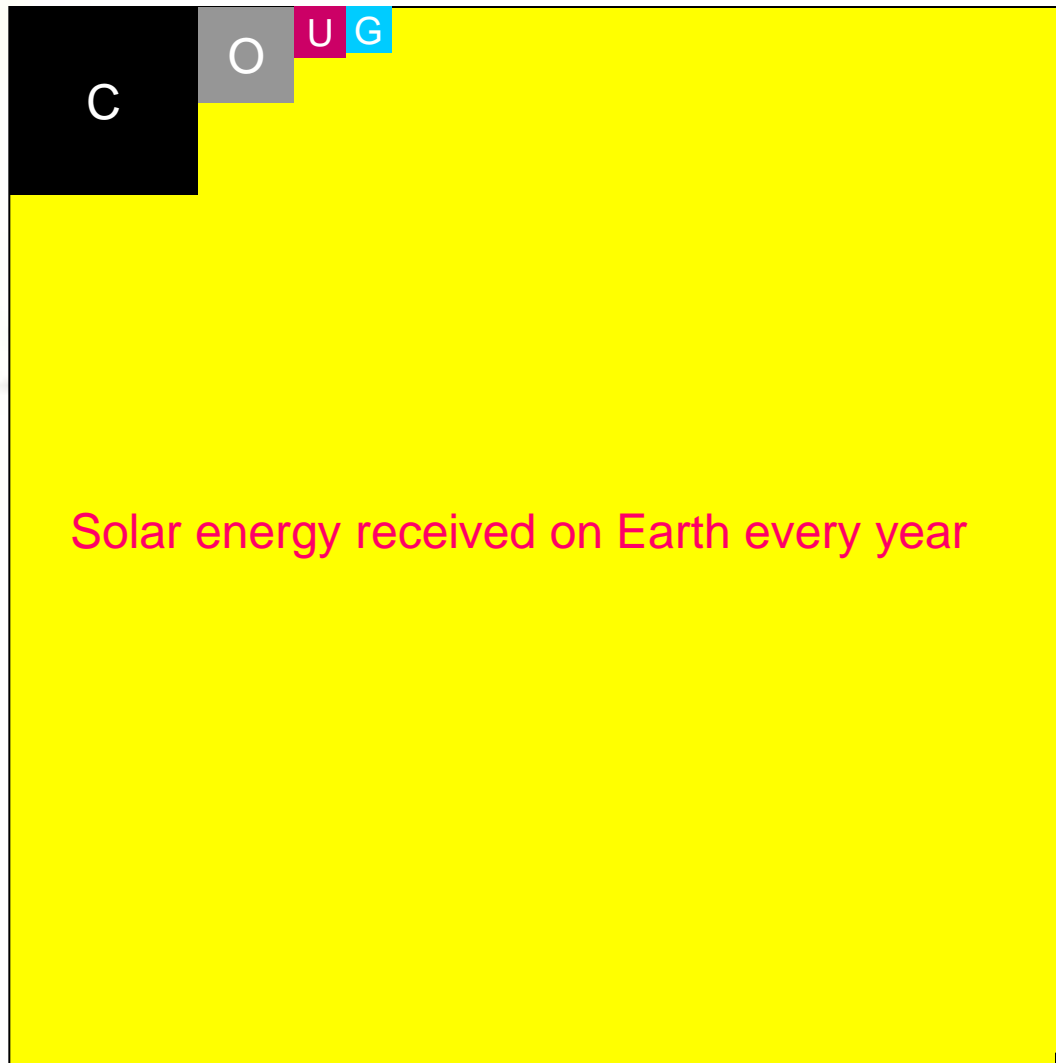
(Albert Bartlett, Arithmetic, Population and Energy)

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!

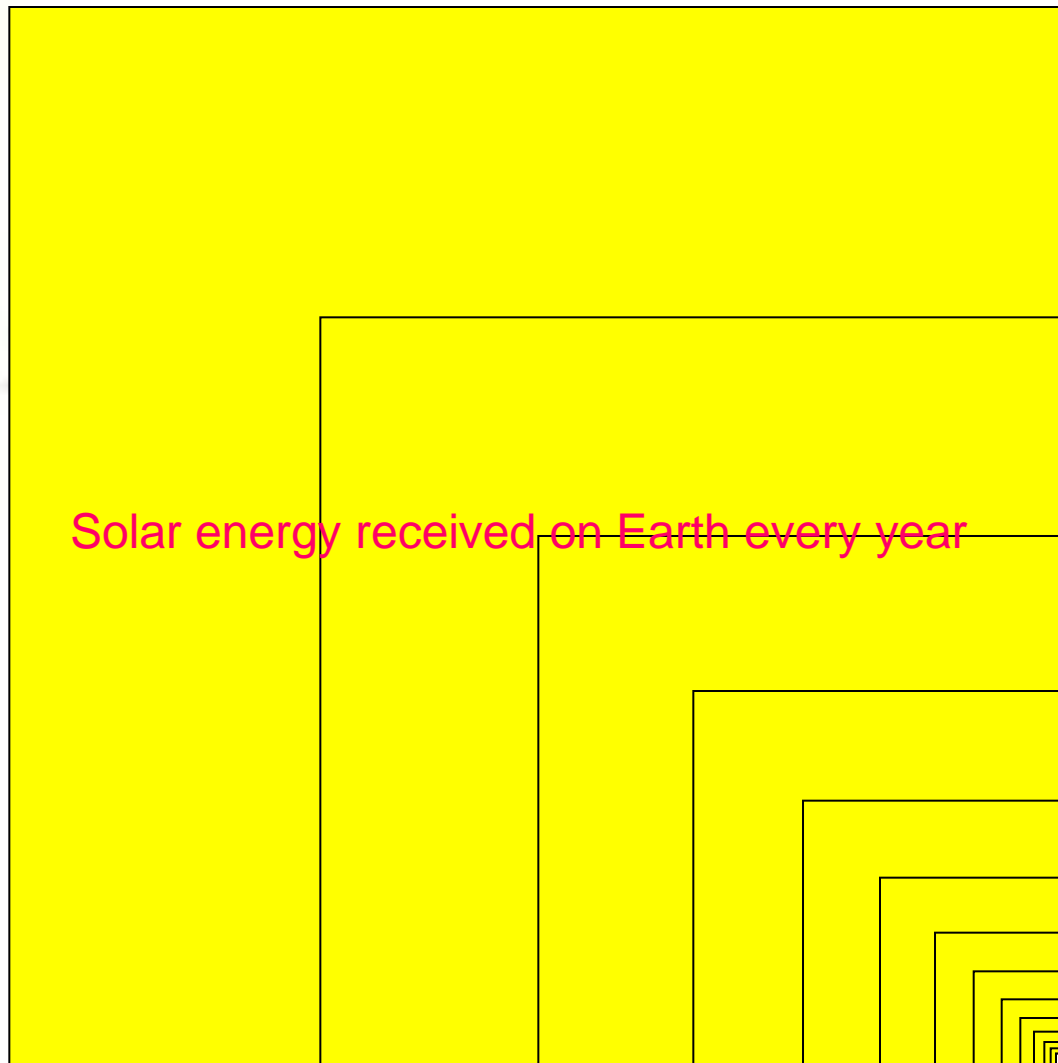
the colony gained two more minutes of life!



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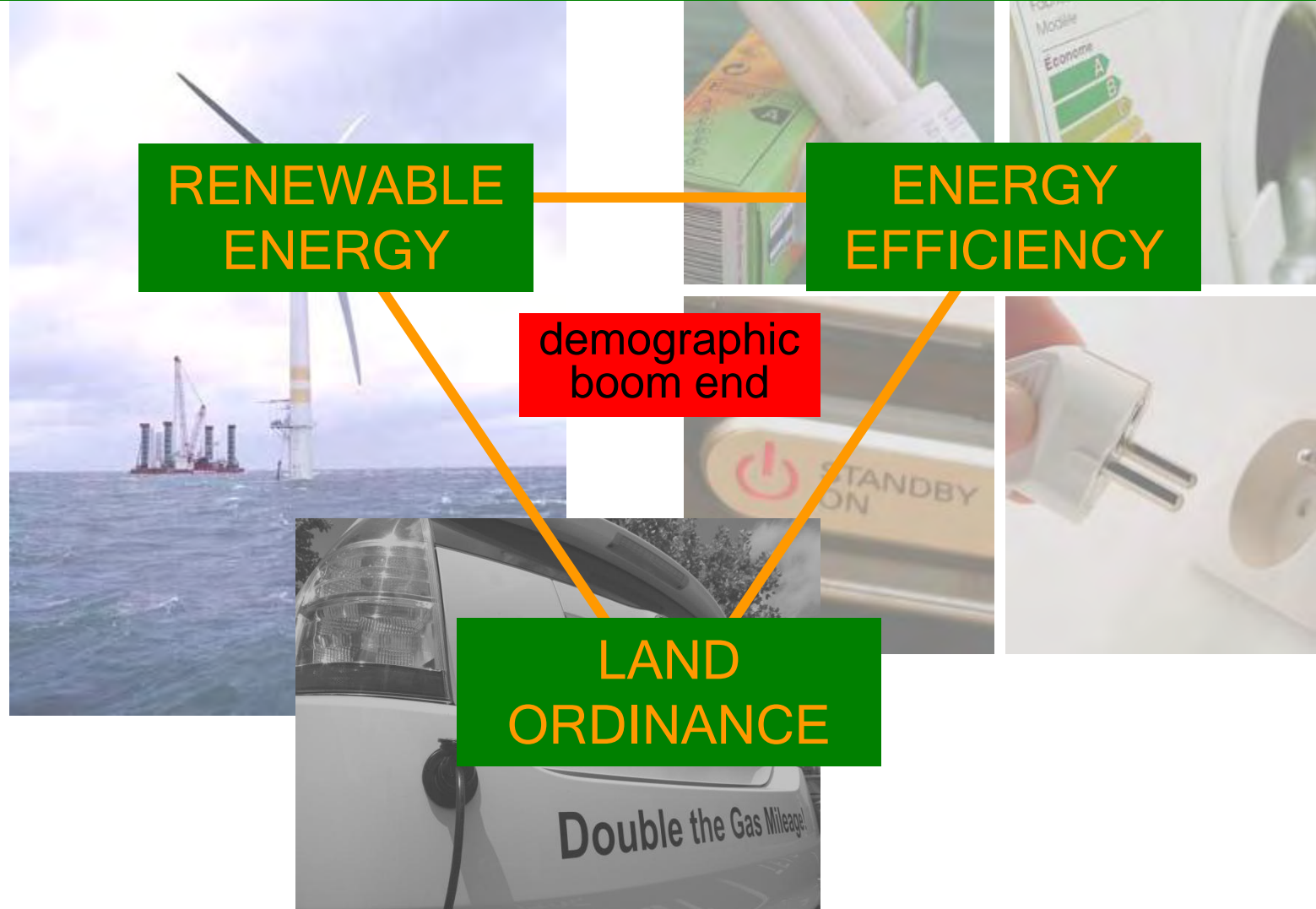
In fact we already know how to do it!



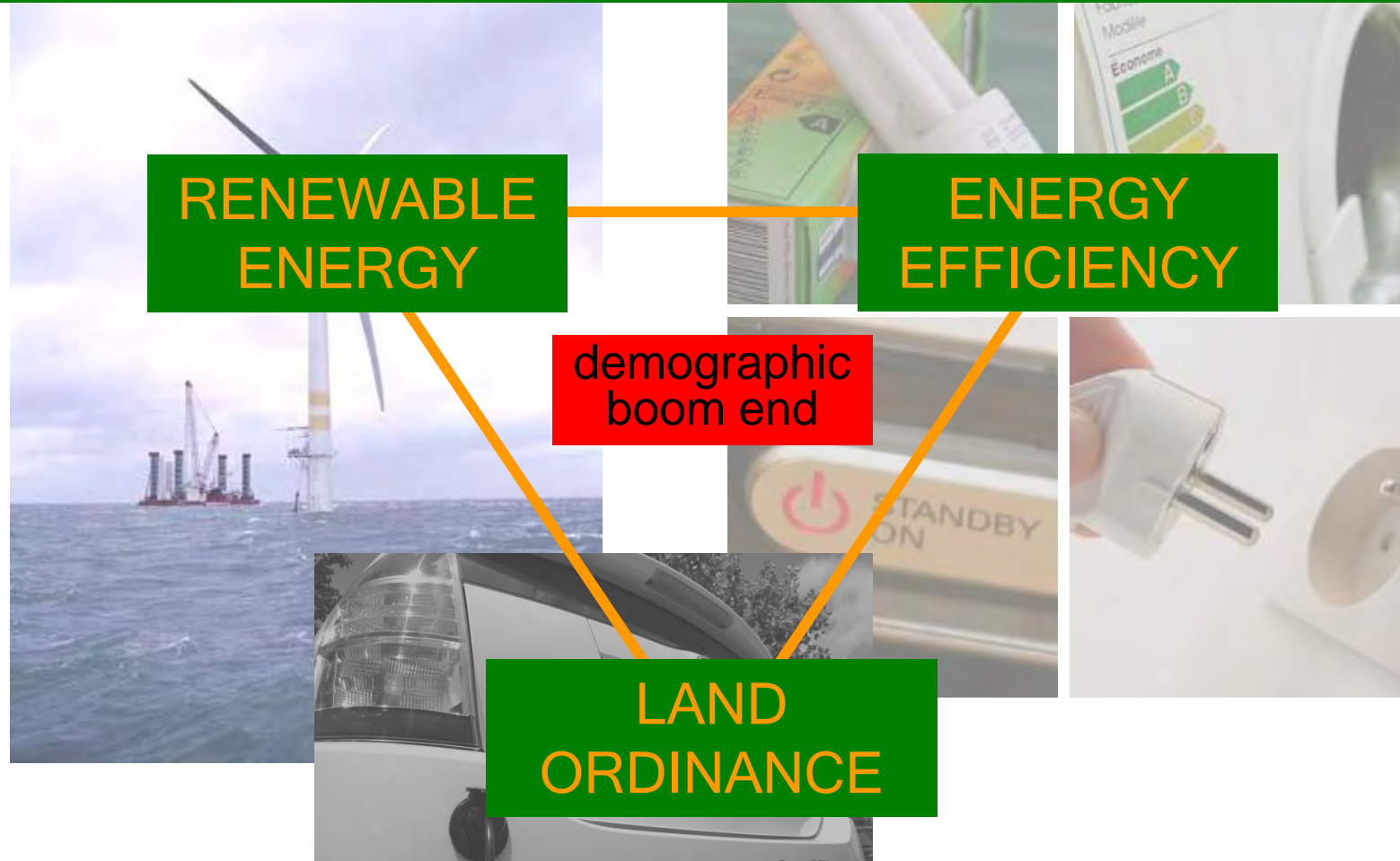
What
time is it
know?

11:47

How can we achieve energy sustainability?



How can we achieve energy sustainability?



Thank you for your attention!