



We are living in exponential times...
...but what does it really mean?

Pablo Garcia Tello
CERN IdeaSquare

Why a physicist at CERN would want to lecture business people about this topic?

Exponential ~ hugely accelerated



At our LHC we accelerate “stuff” pretty fast and study what happens when this “stuff” collides.

Why would you be interested in “exponential”?

Because you maybe interested in “sustainability”



Let's briefly explore together.

I will not use equations...because

Editors always warn that for every equation in a book, the readership is halved. So I don't want to end up this presentation talking to myself.

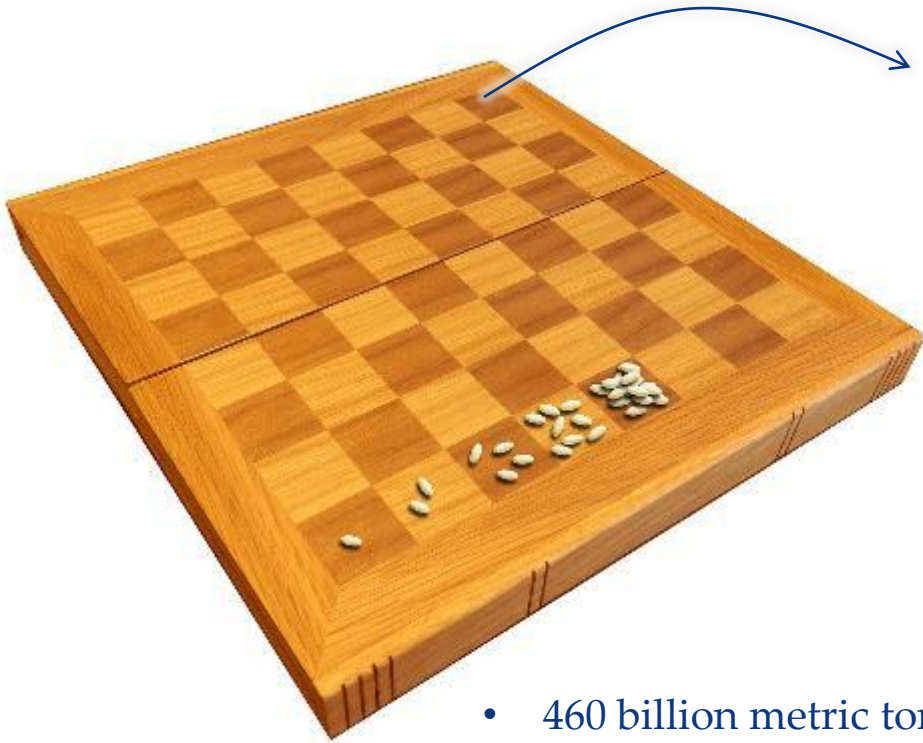
I am not the kind of physicist that likes equations too much except when they really tell something (..I say it here at CERN only to very good friends).

**Let's understand
“exponential”...
two stories and a
quiz for you**

First story: The legend of the invention of Chess.



The legend of the invention of Chess.



Please, 2^{63} rice grains here!!

- 460 billion metric tons (rice grain weight ~ 25 mg);
- 630 years of worldwide rice production;
- 10 light years of rice laid end to end (rice grain size ~ 5 mm long);
- A tower of rice 40 x 40 m² base rising all the way to the Moon.

Second story: What is the cheapest way to get to the Moon?



What is the cheapest way to get to the Moon?



1. Take a piece of paper.

2. Start folding it in half each time.

What is the cheapest way to get to the Moon?

45 folds ~ Congratulations, you have reached the Moon!

40 folds
~ GPS satellite orbit



30 folds
~ Altitude of planes



25 folds
~ Empire State Building



Folding increases thickness exponentially

And now the quiz...

I am an evil physicist.



Disguised in a business suit I kidnap you.

I tie you to the highest seat in the Yankee stadium (NY).

At 15:00 h I set up a device that releases a first drop.


I set up my device so water accumulates doubling in size every minute...

... How much time do you have for escaping before you drown?

(assume the stadium is water tight)



Any guesses????



You are here

My device is here

**You have until
15:50 h.**

**...ok that's bad news...
Can things get worse?**

When will the stadium be 93%
filled up so it gets you really nervous?
Again, any guesses?



At 15:45 h...

**...yes, things can get
worse...**

Two lessons...

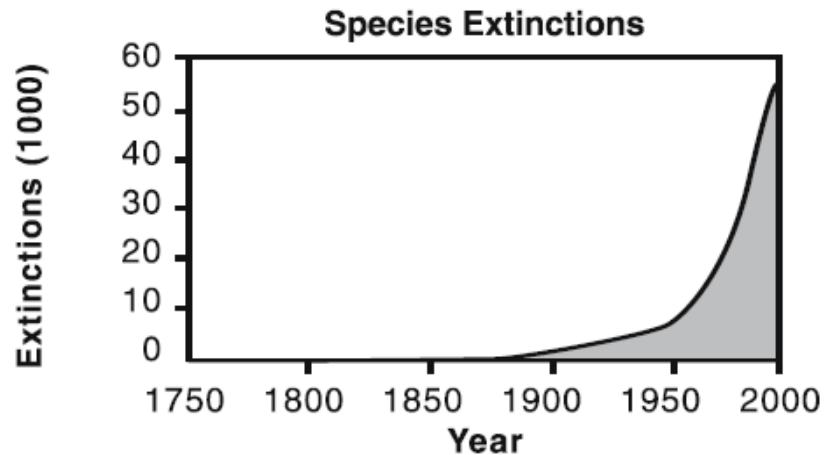
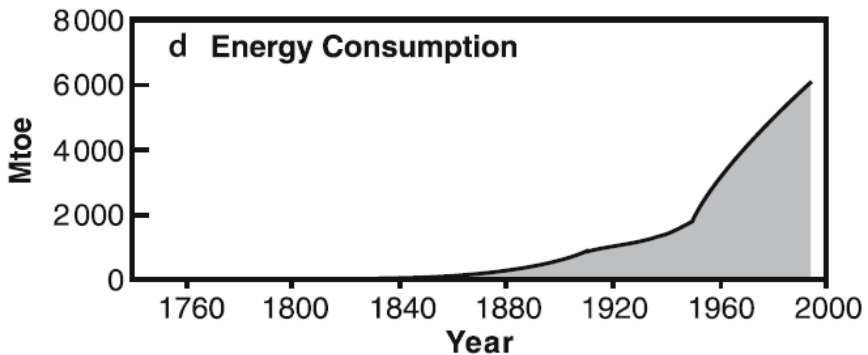
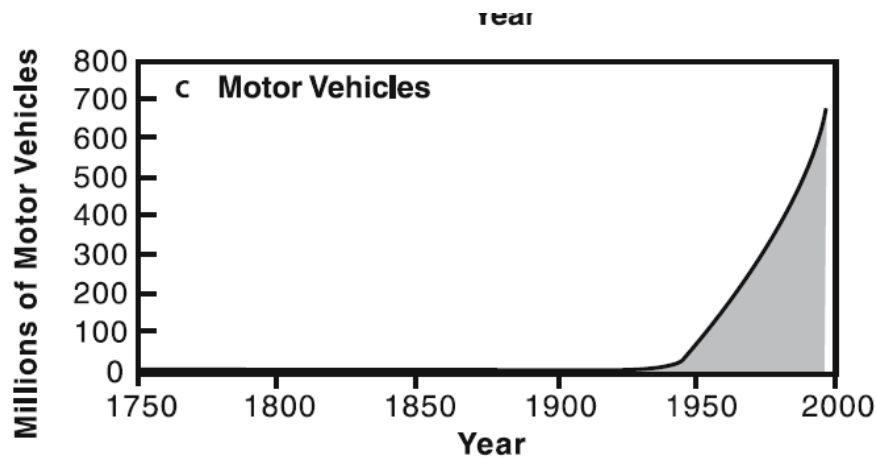
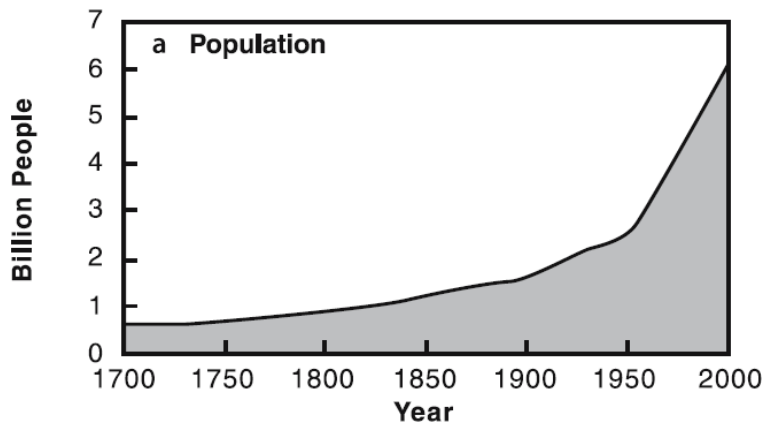
**If something grows exponentially it means
really, really fast.**

**Whatever happens as a consequence it hits up
really, really hard in the last moment.**

How does exponential growth looks like?

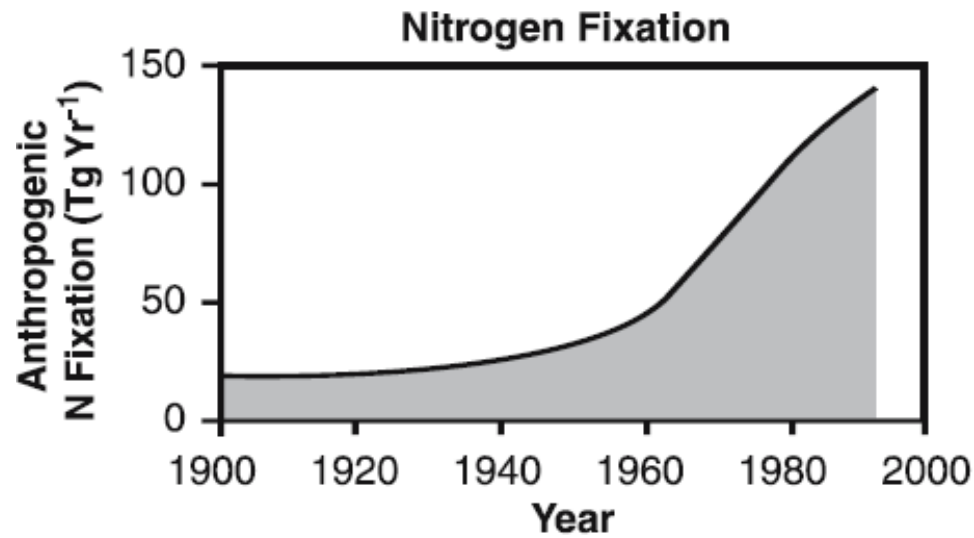
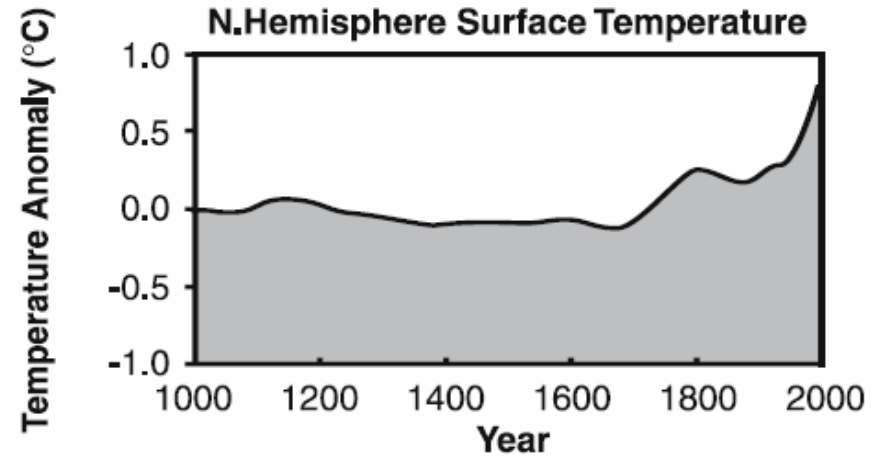
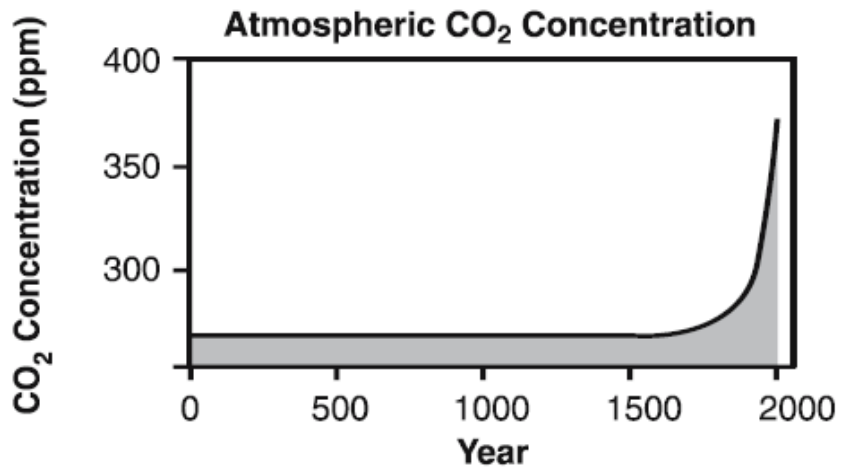


**Let me show you some examples
of “stuff” that seems to grow
exponentially in this planet.**



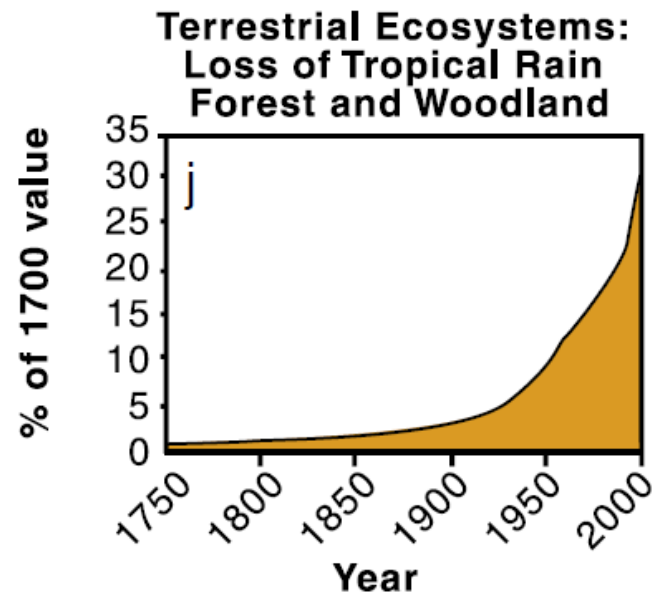
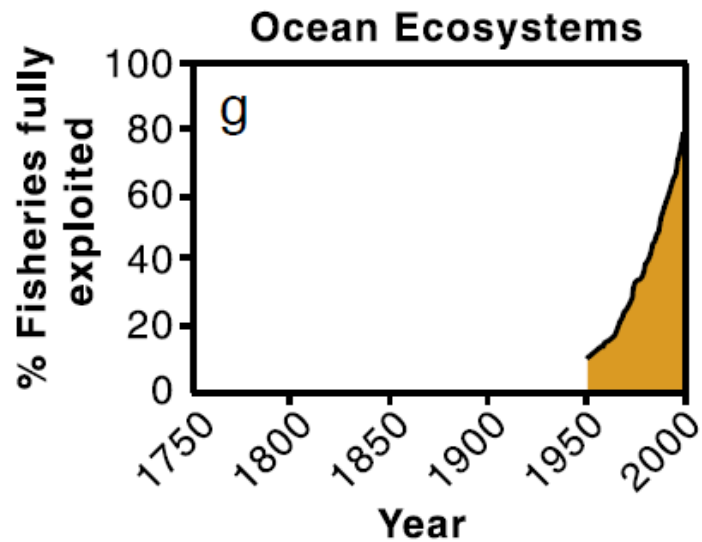
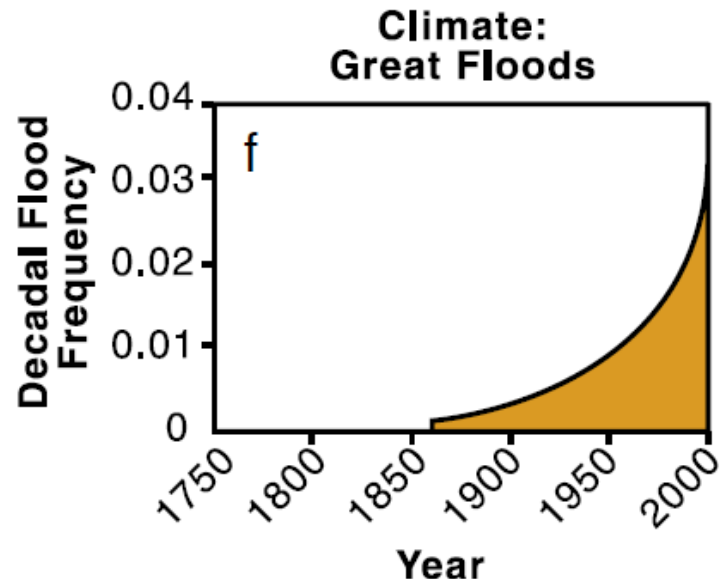
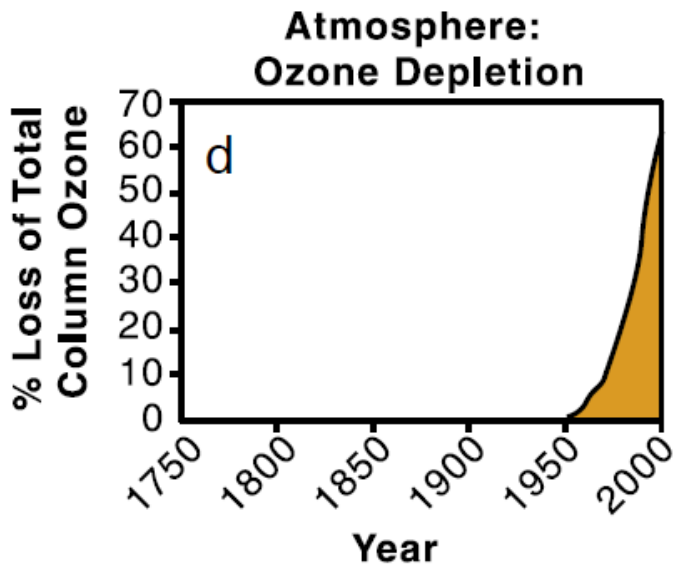
Source:
 “Global Change and the Earth System: A Planet Under Pressure” (2004), W. Steffen, et al., Springer-Verlag Berlin Heidelberg New York.





Source:

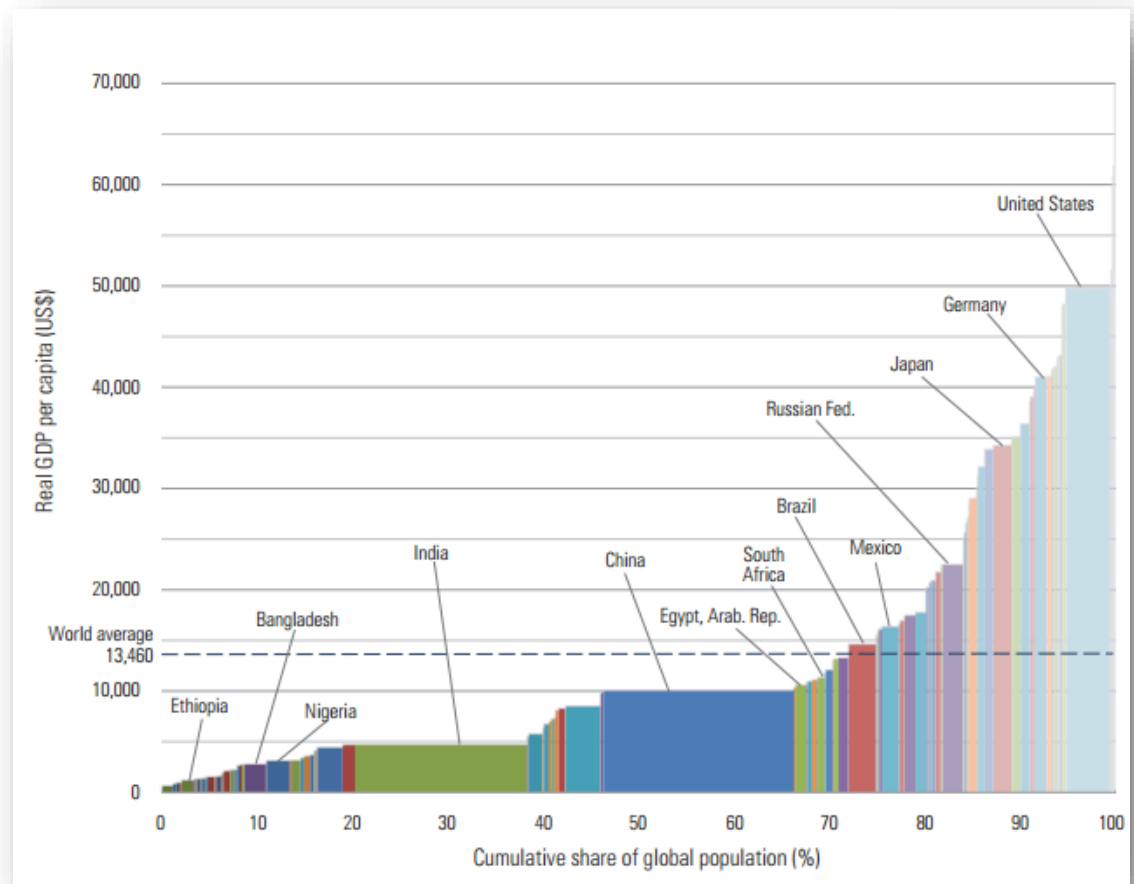
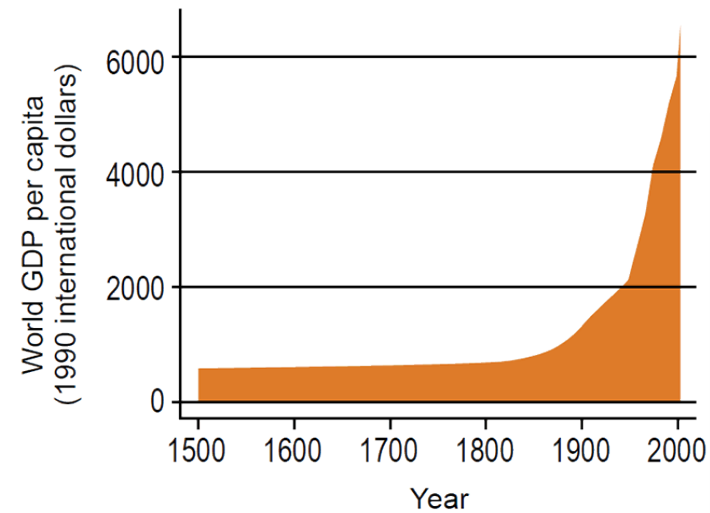
“Global Change and the Earth System: A Planet Under Pressure” (2004), W. Steffen, et al., Springer-Verlag Berlin Heidelberg New York.



Source: "Global Change and the Earth System: A Planet Under Pressure" (2004), W. Steffen, et al., Springer-Verlag Berlin Heidelberg New York.

BE AWARE!!

Sometimes (global) exponentials hide inequality in wealth distribution.



Source: Purchasing Power Parities and Real Expenditures of World Economies, 2014 International Bank for Reconstruction and Development / The World Bank.



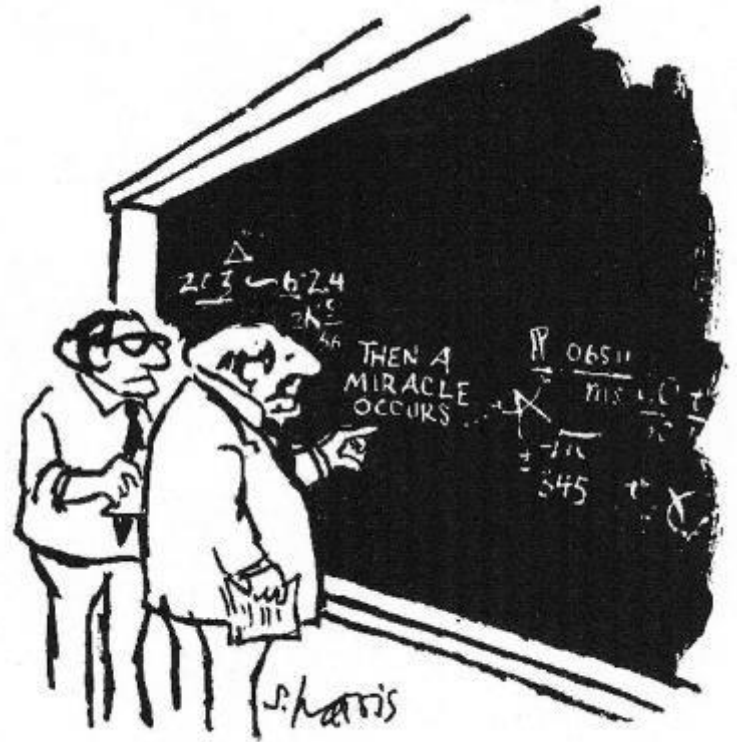
Now that we have a feeling about “exponential” allow me to offer you some food for thought (3 cases).

Case 1

Will science and technology
alone save the day?

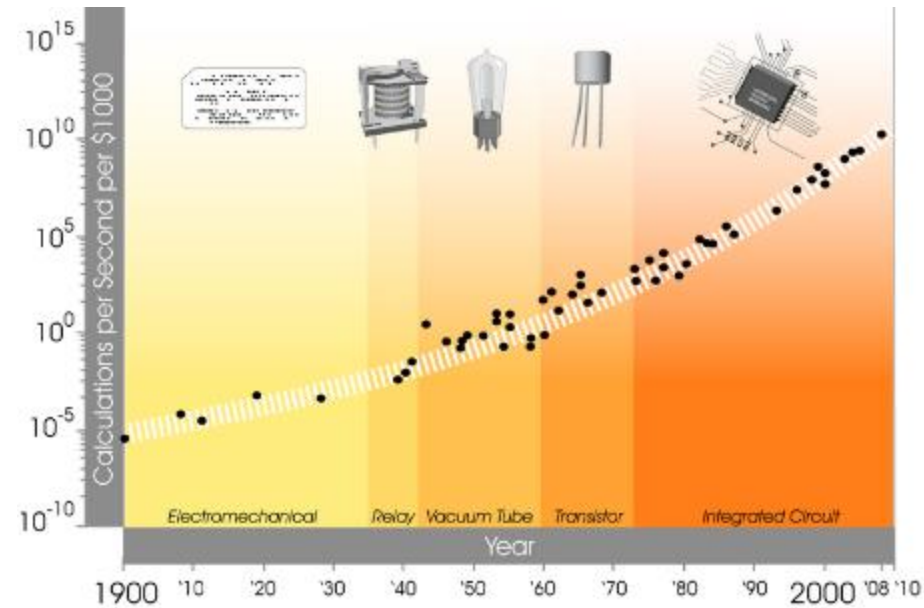
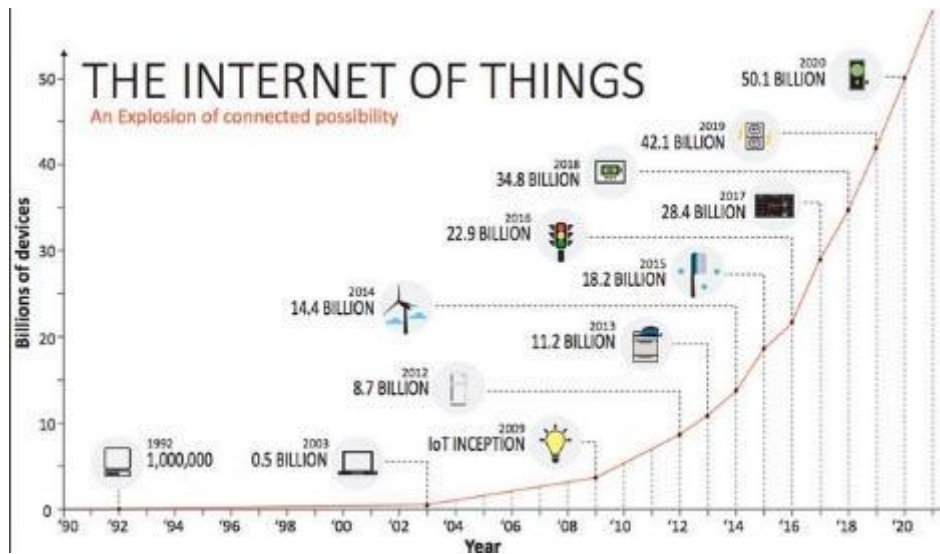
My answer: I don't know...

I am just a physicist.



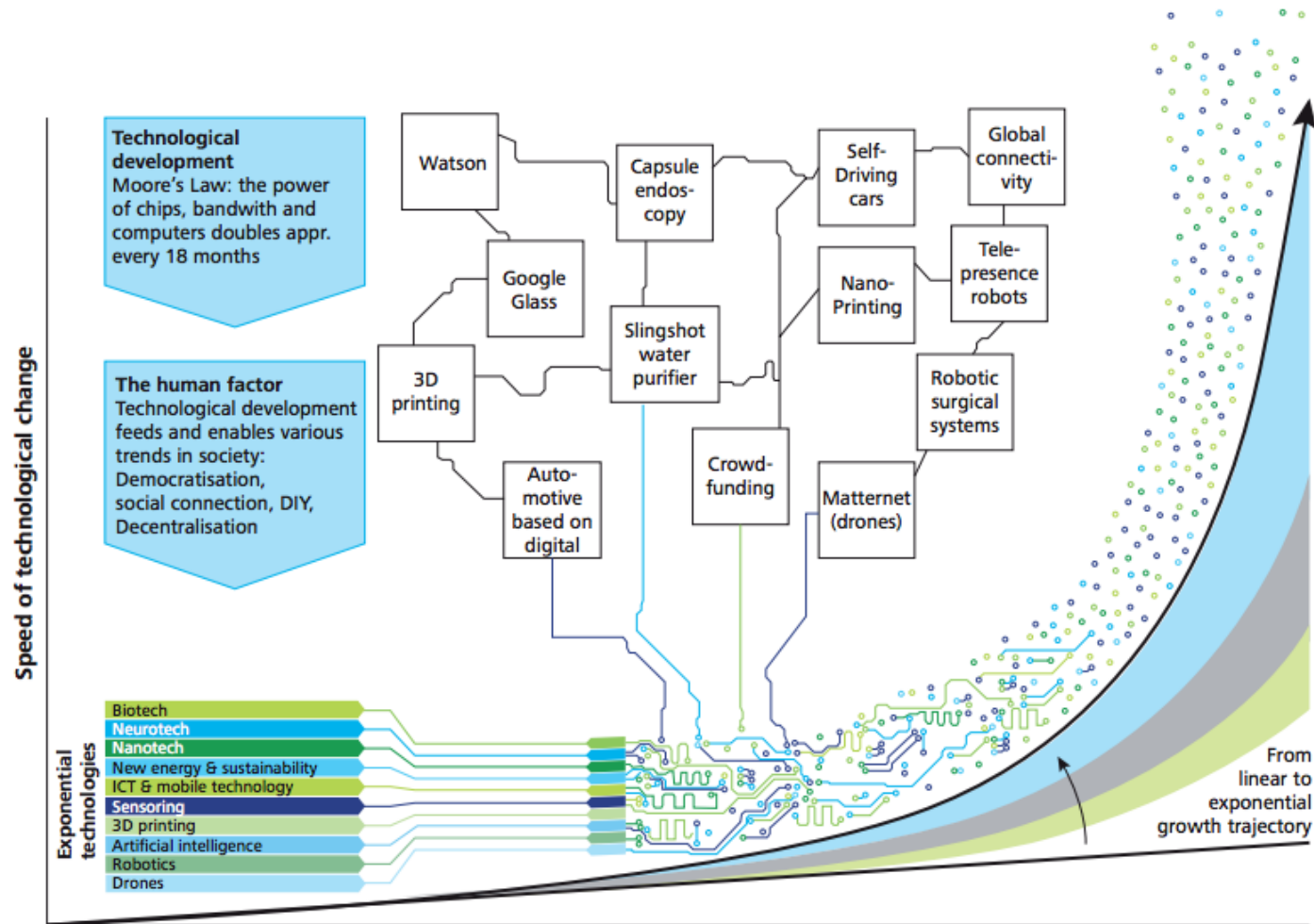
"I think you should be more explicit here in step two."

Technology seems to grow exponentially...



Internet of Things: online guide to the Internet of Things, <http://www.i-scoop.eu/internet-of-things/> and <https://exponential.singularityu.org/>

As well as the way several technologies are converging, adopted and the possibilities they may bring...

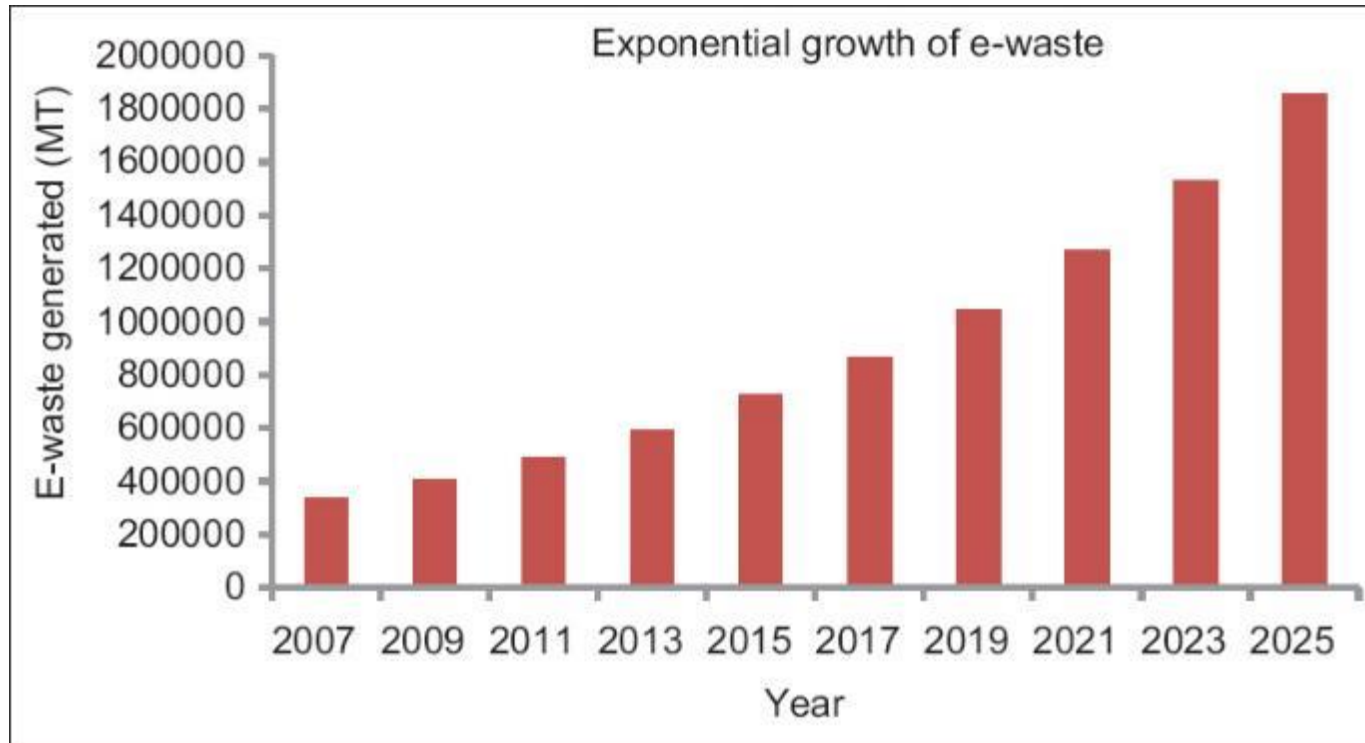


Source: Deloitte 4.0 report 2015

<https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-4-0-24102014.pdf>

Pablo Garcia Tello, CERN, IdeaSquare

...but this doesn't come for free...

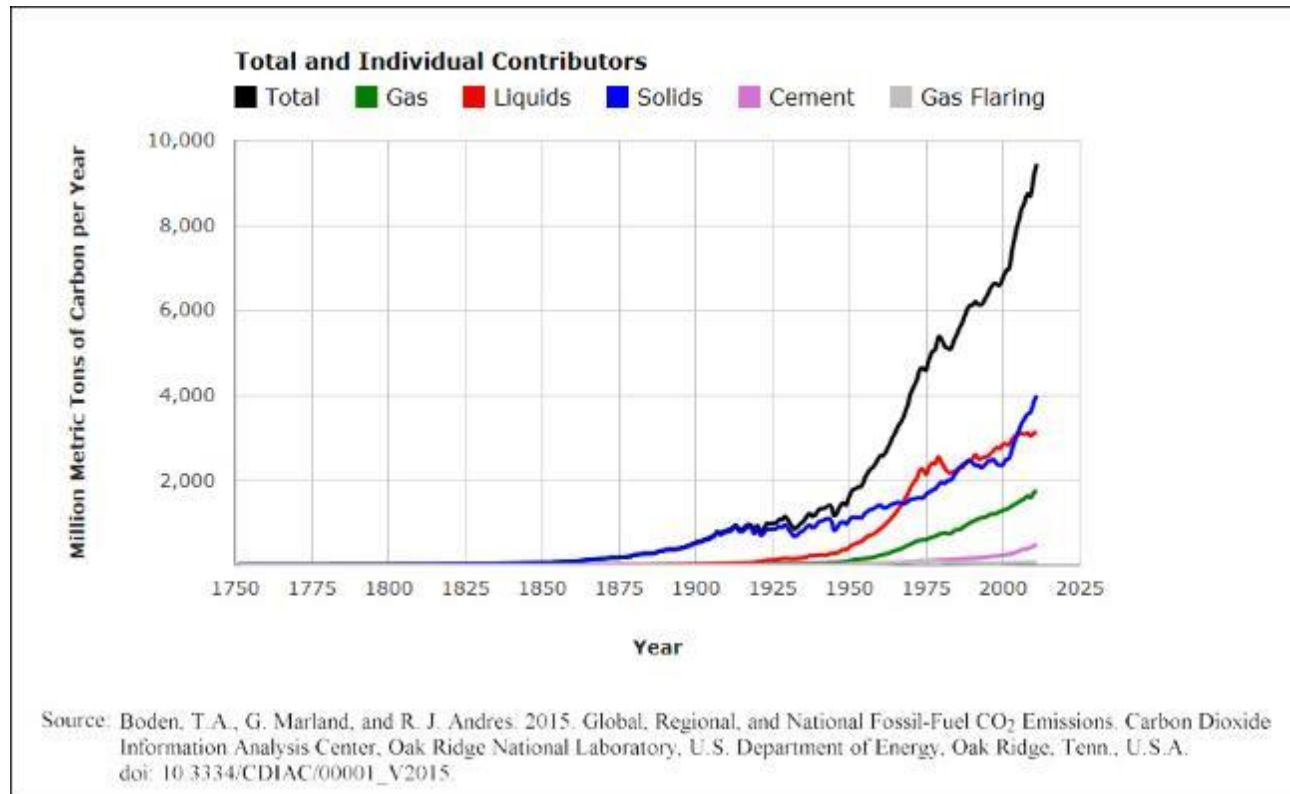


(India figures)

J. Annamalai, *Occupational health hazards related to informal recycling of E-waste in India: An overview*, *Indian Journal of Occupational and Environmental Medicine*, Vol. 19, No. 1, January-April, 2015, pp. 61-65.



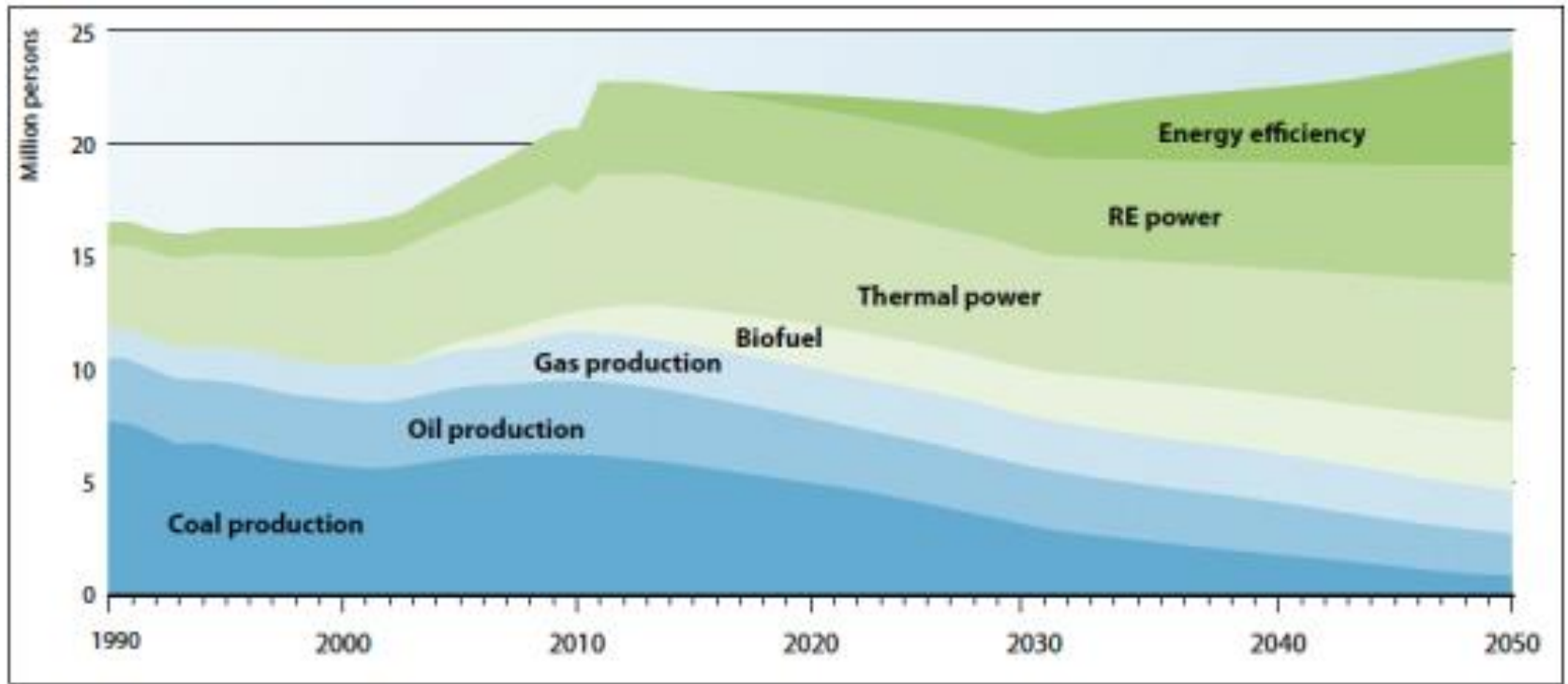
Case 2: A provocative question....



The graph above shows that our environmental problems are growing exponentially...should we advance exponentially towards a “green economy”?

Any answers?

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Source: Green Economy, UNEP Report 2011 <http://web.unep.org/greeneconomy/resources/green-economy-report>

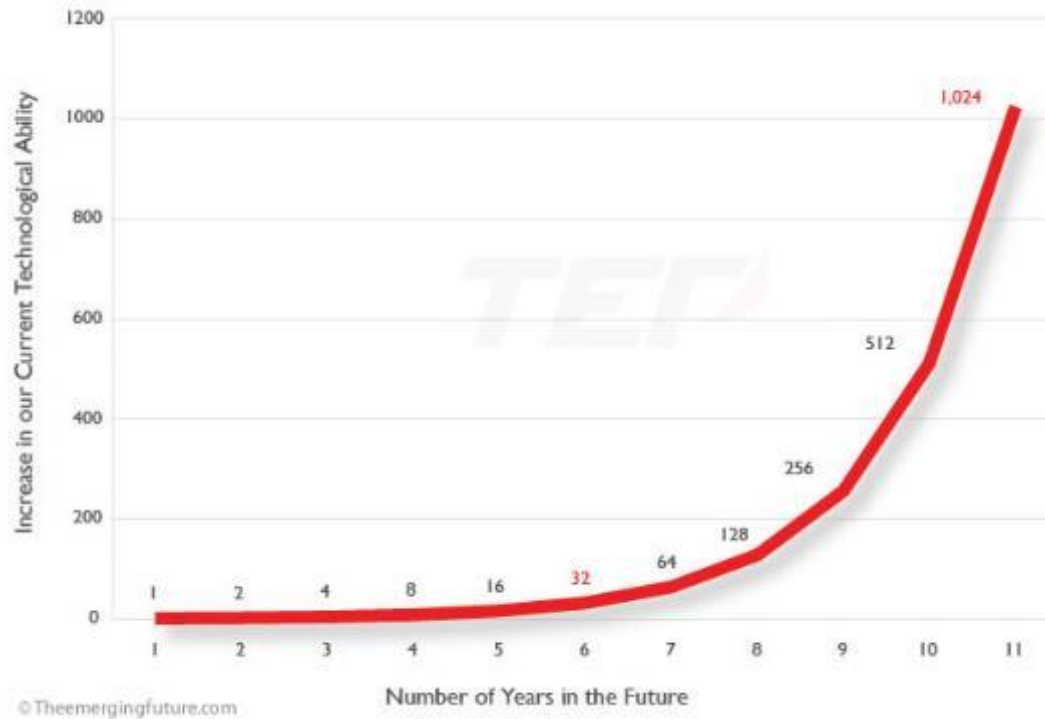
What do we do with the people that will loose their jobs in nowadays polluting energy generation sectors?

My answer: Hell I know!

Case 3: Another provocative question....

Human Intuitive Perspective of Technological Advancement in Ten Years

A Thousand Times More Advanced

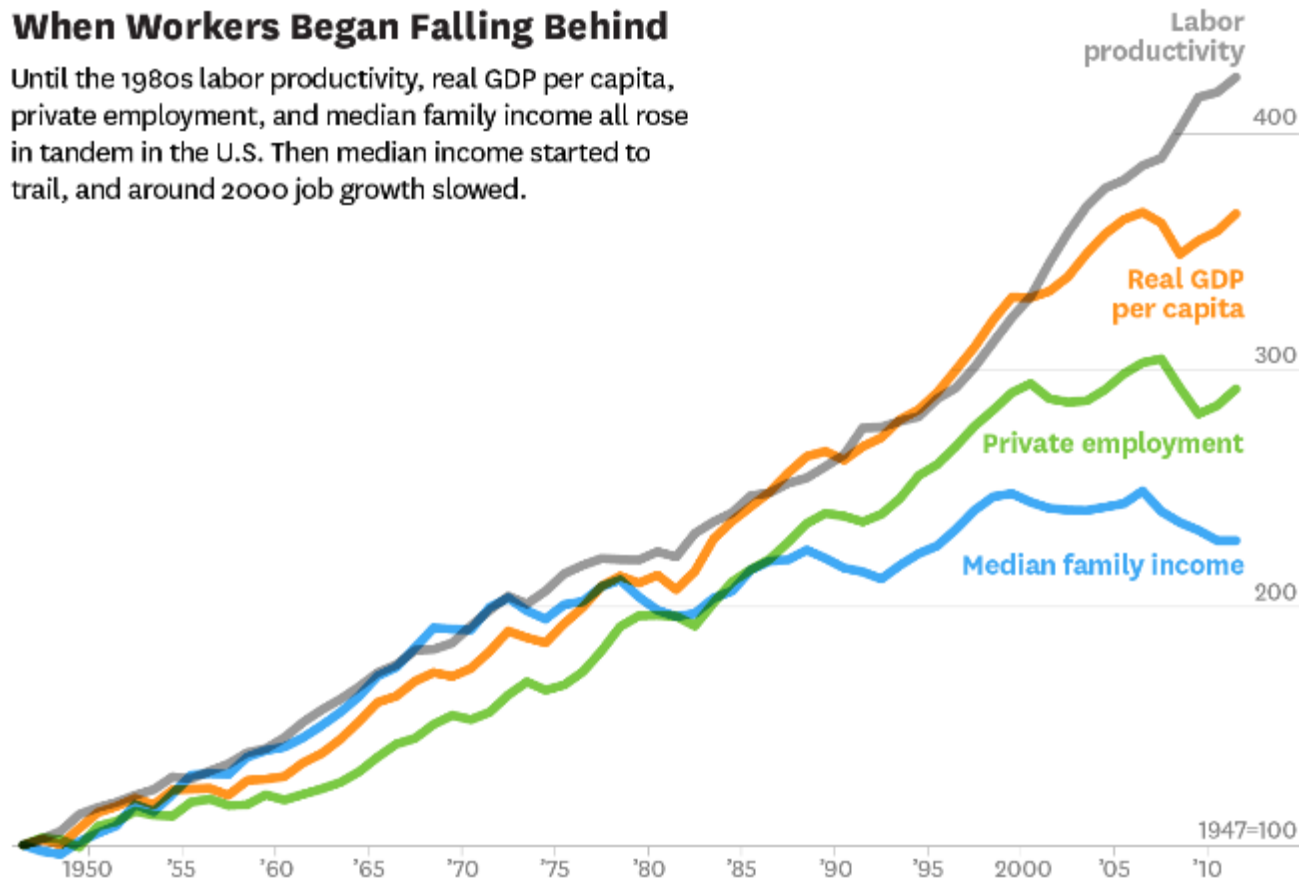


Source: Estimating the Speed of exponential technological advancement, <http://www.theemergingfuture.com/>

An exponential growth of the capability of our
technology will be good or bad?

When Workers Began Falling Behind

Until the 1980s labor productivity, real GDP per capita, private employment, and median family income all rose in tandem in the U.S. Then median income started to trail, and around 2000 job growth slowed.



SOURCE FEDERAL RESERVE BANK OF ST. LOUIS; ERIK BRYNJOLFSSON AND ANDREW MCAFEE
FROM "THE GREAT DECOUPLING," JUNE 2015

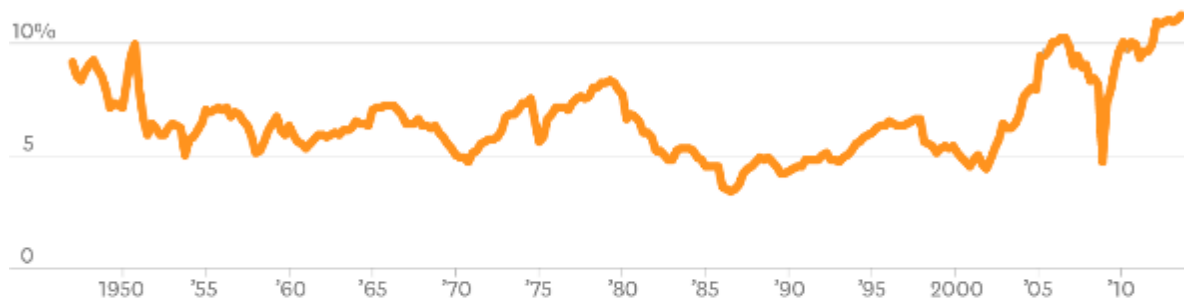
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Quite some wise voices are starting to talk about “The Great Decoupling”:
productivity is rising, but employment may not.

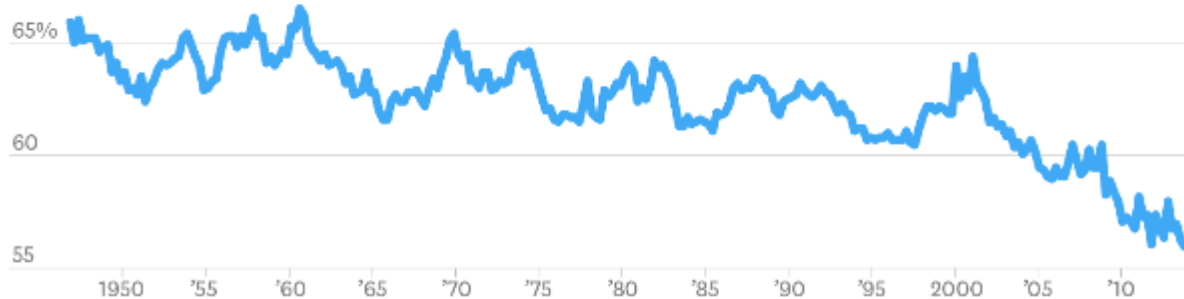
As Profits Climb, Wages Plummet

In the U.S., corporate profits were rising before the 2008 recession and quickly recovered from it. In contrast, labor's share of GDP, which was healthy for many decades, has fallen sharply since 2000.

CORPORATE PROFITS AS A PERCENTAGE OF GDP



WAGES AS A PERCENTAGE OF GDP



SOURCE: FEDERAL RESERVE BANK OF ST. LOUIS; ERIK BRYNJOLFSSON AND ANDREW MCAFEE
FROM "THE GREAT DECOUPLING," JUNE 2015

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“The Great Decoupling”: Breaking most sacred economic dogmas

Rise in productivity = rise in employment = rise in wealth.



For ending my talk let me show you some quick math useful for getting a fast feeling for “exponential”.

I know I promised no formulas ...but you remained with me... so now I take my chances.

The rule of 70

If something grows exponentially at a constant rate it is interesting to get a feeling about how much time it takes for this something to double (= doubling time).

Doubling time is the amount of time it takes for a given quantity to double in size.

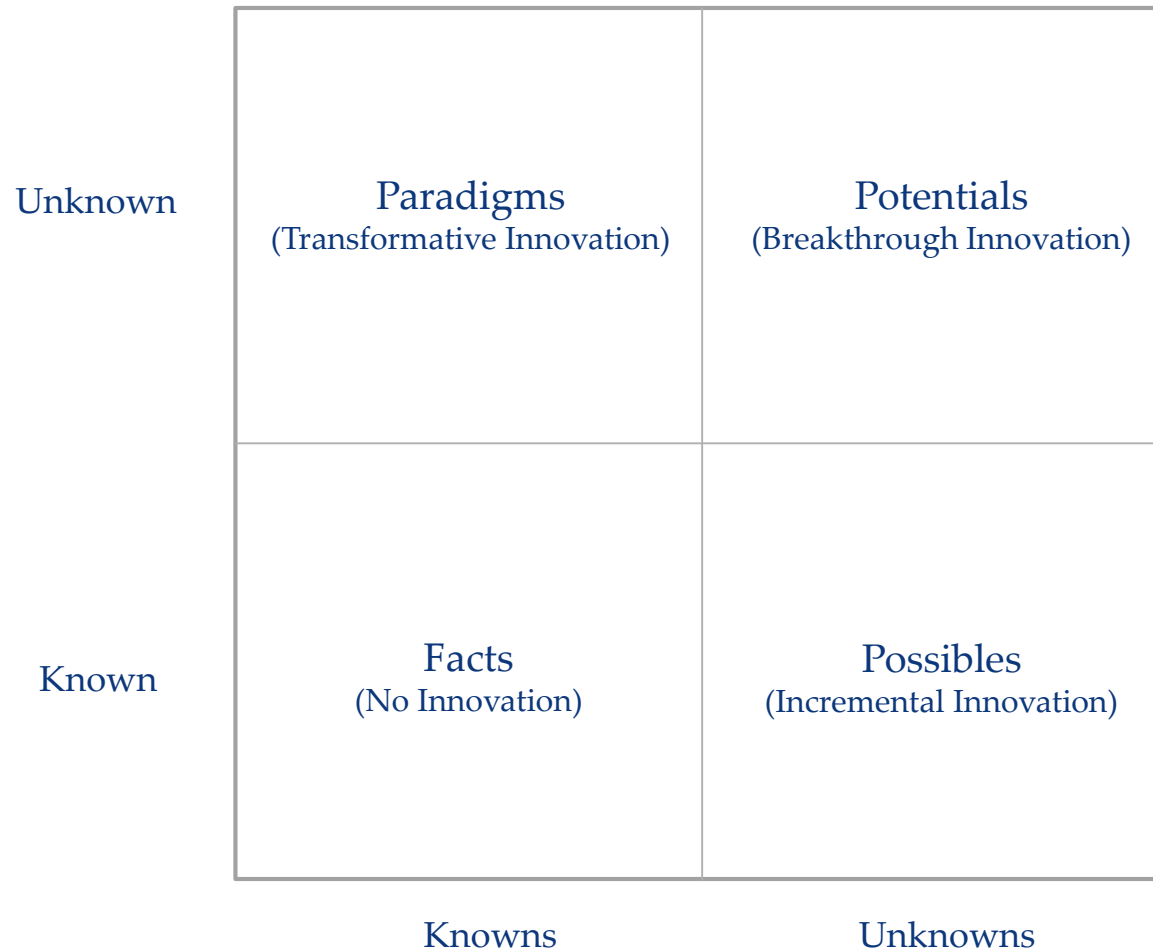
The rule of 70

Quick math trick

$$\text{Doubling time} = \frac{70}{\% \text{ growth rate}}$$

For example, if somebody tells you that unemployment in your region has 2% annual growth it will double in just 35 years.

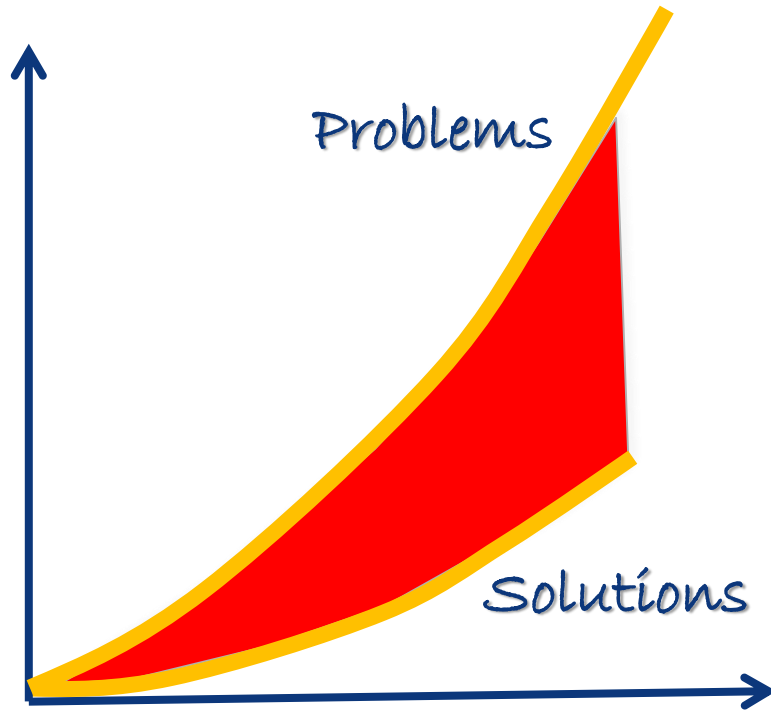
Transformation wanted!



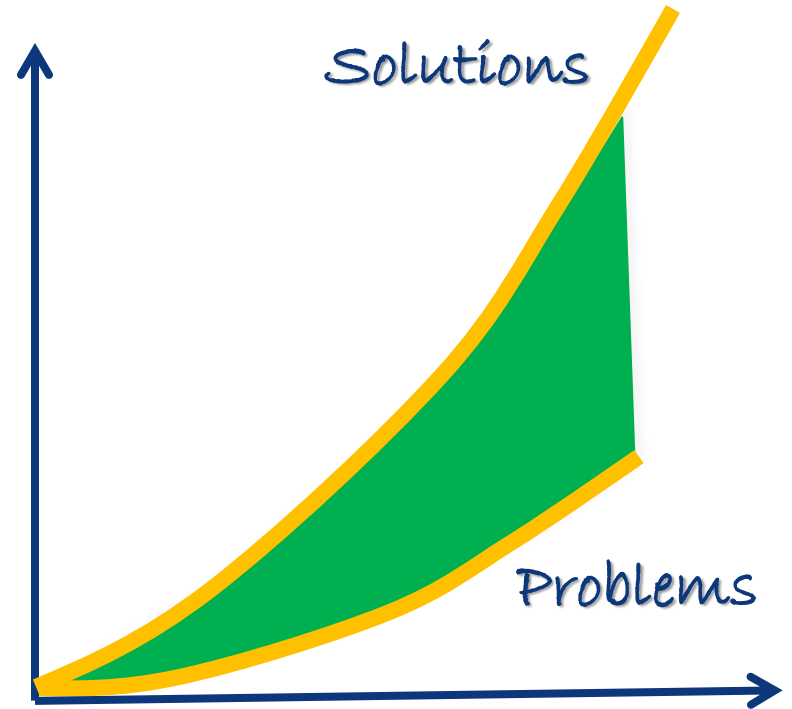
If we meet again my talk will be about

Super-exponential...
...when things get really scary

Conclusion: I hope humankind will follow the right law...



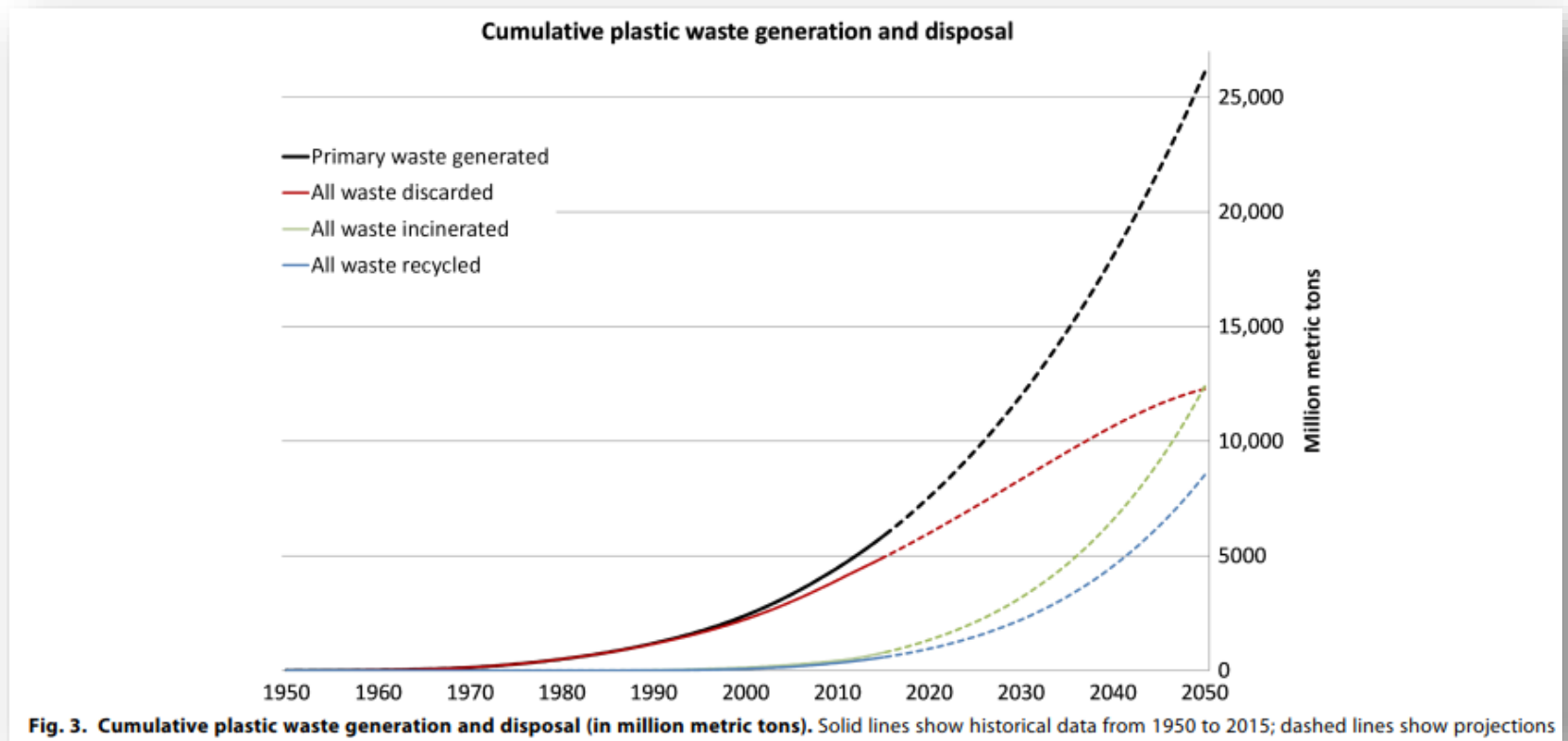
Law of increasing ignorance



Law of increasing wisdom

But it is just hope...after all, I am a physicist working at CERN...

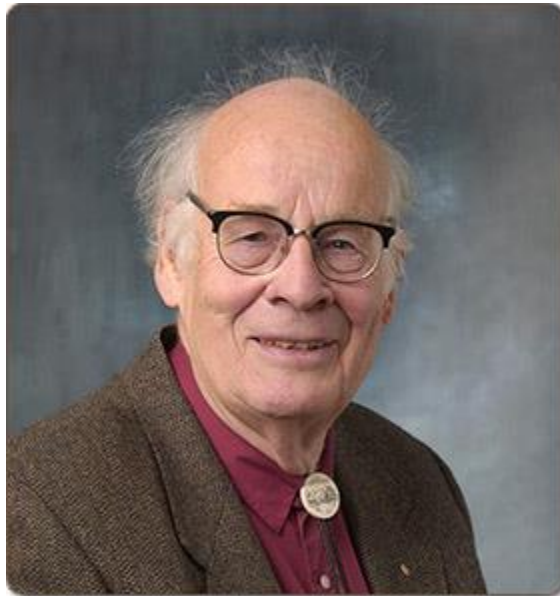
Example: Plastic waste



Problems grow at a higher exponential rate than solutions → **NEW PARADIGM CHANGE THINKING IS NEEDED**

Geyer, Jambeck, Law Sci. Adv. 2017; 3, DOI: 10.1126/sciadv.1700782

Thanks for your attention questions...



*The greatest shortcoming of the human race is our inability
to understand the exponential function.*

Albert A. Bartlett (1923-2013), Physicist