

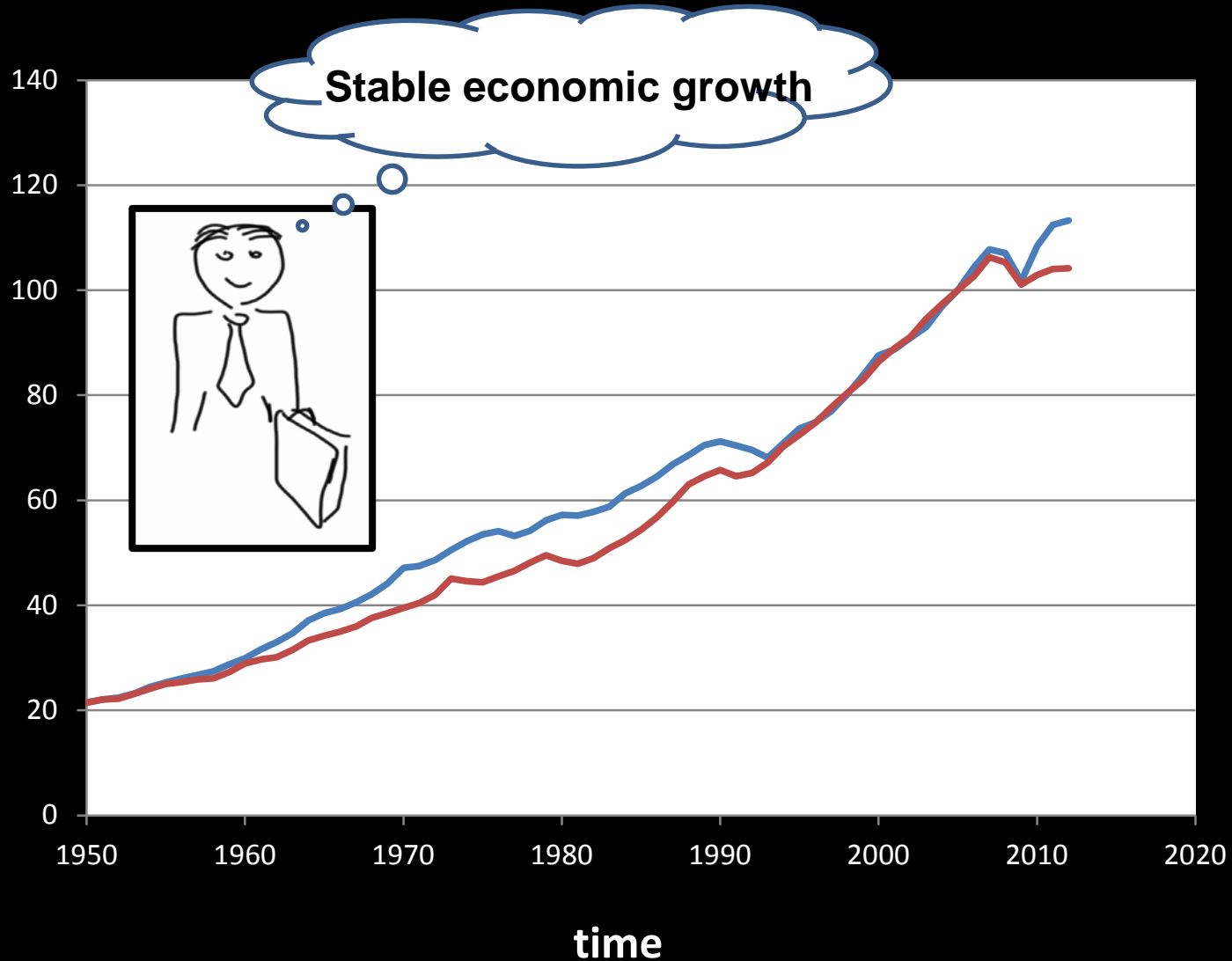
Elsystem: inför en betydelsefull, men oviss framtid
Electricity: more important, less certain



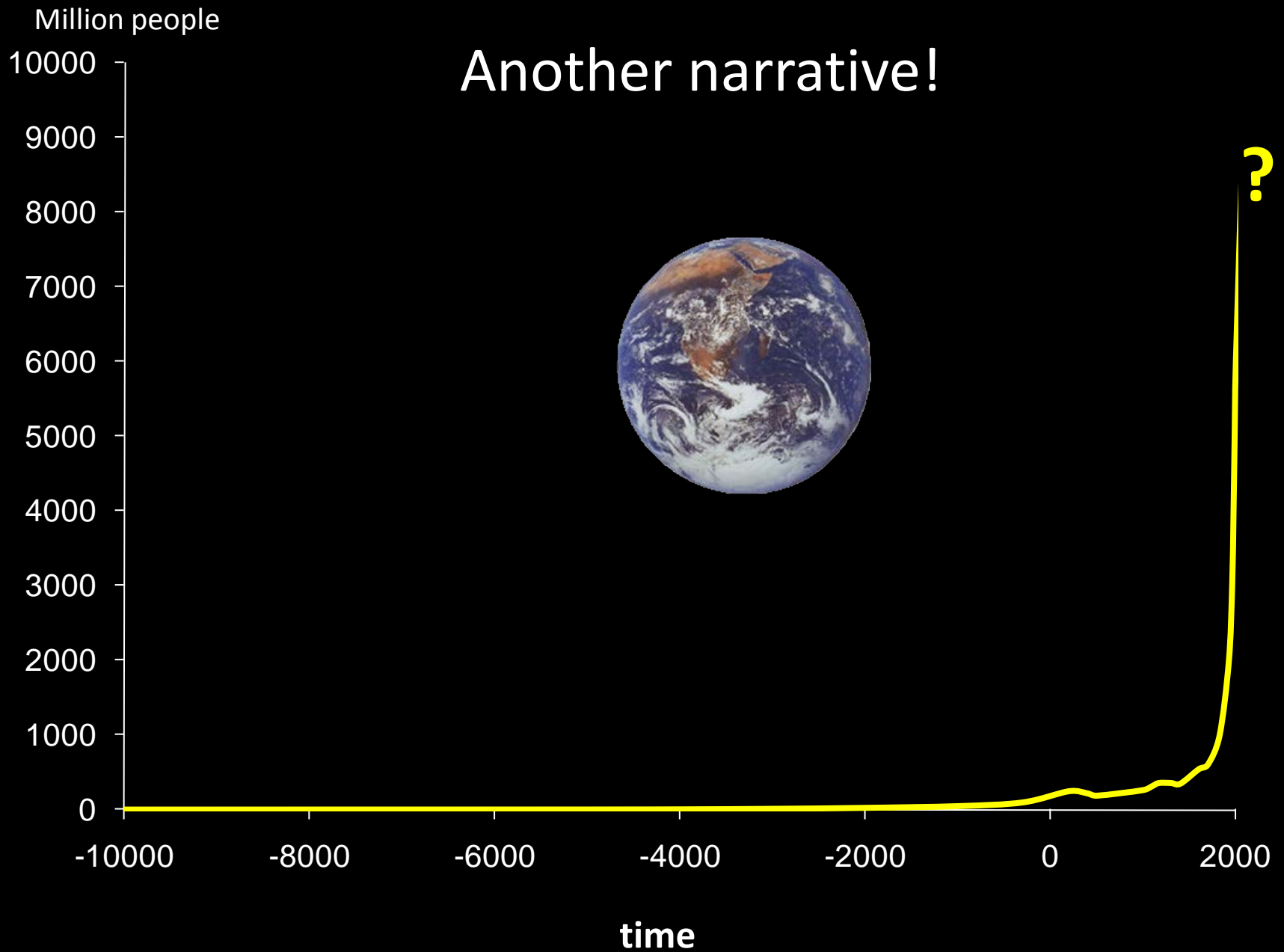
Björn Sandén
Professor of innovation and sustainability

CHALMERS

A dominant narrative...



Another narrative!

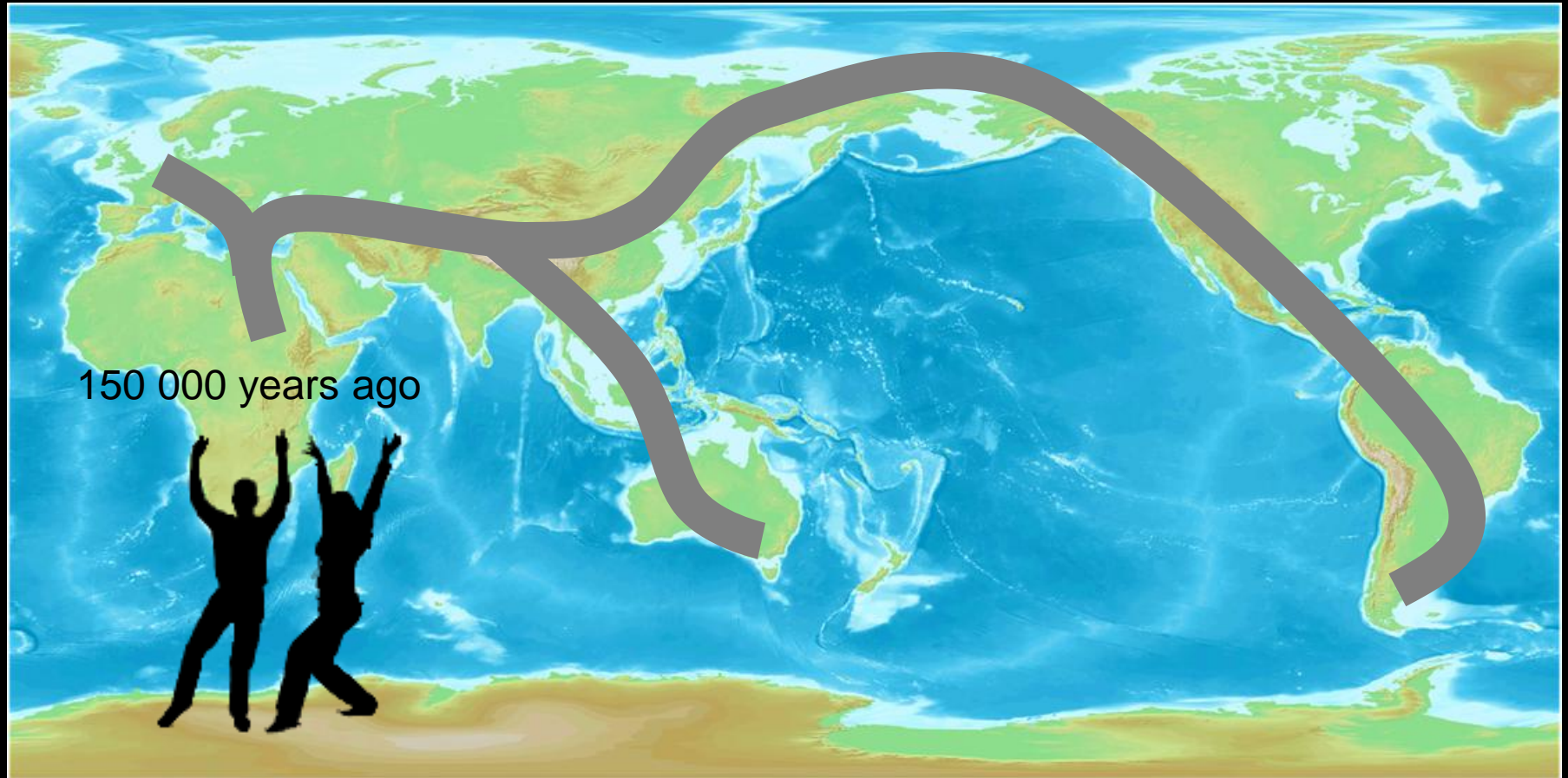






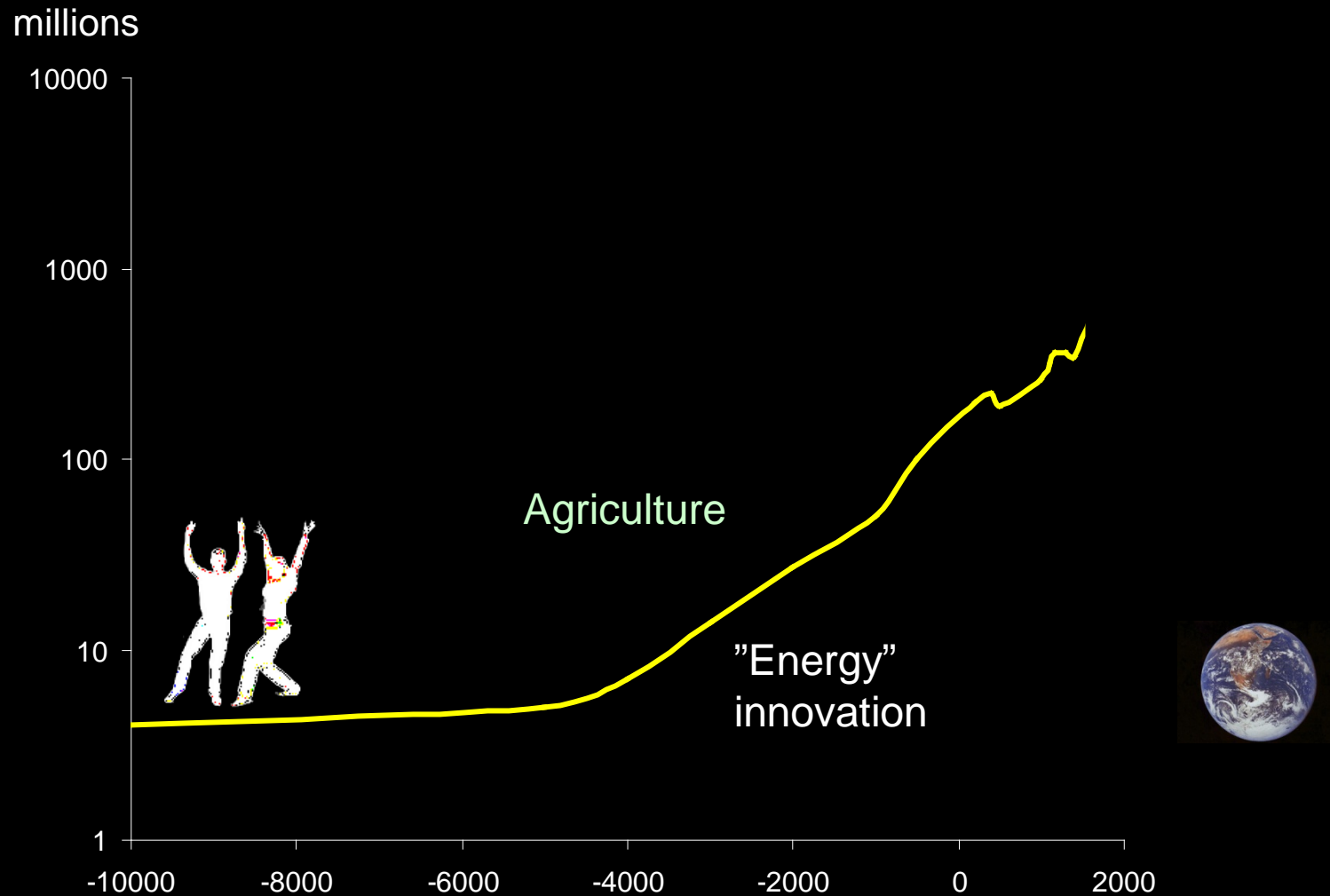
Nanotechnology 1.0

The spread of human settlement



10 000 years ago all the continents were inhabited

More energy – more people



The agricultural transition

Intensified land use and settled societies

Agriculture and forestry
Medium efficiency solar energy
($<1 \text{ kWh/m}^2\text{yr}$)



Traditional materials
designed by nature

Hunters and gatherers
Low efficiency solar energy
($<0.01 \text{ kWh/m}^2\text{yr}$)

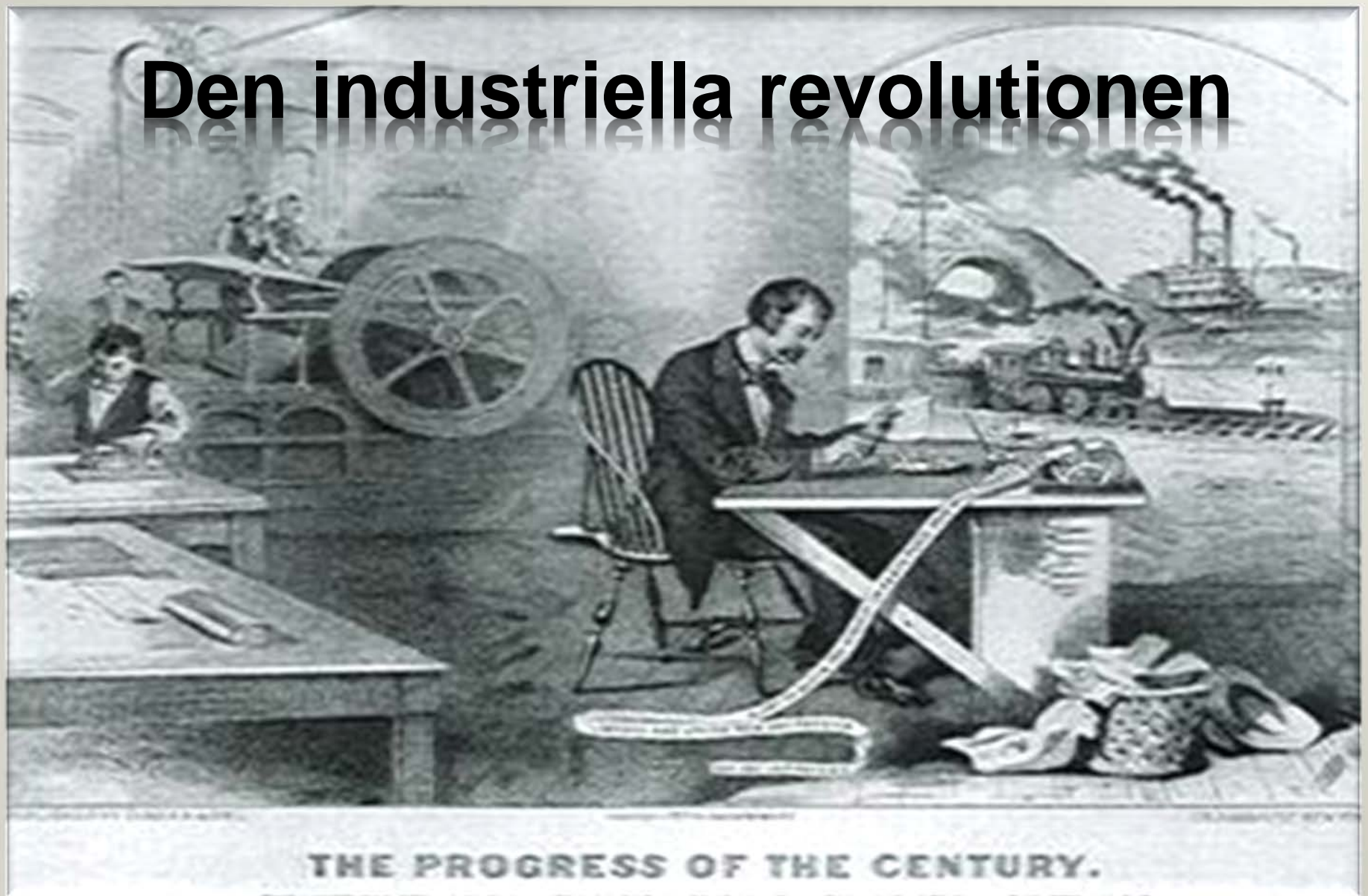


A few tools

**17th century England
Energy crisis!
Lack of wood**

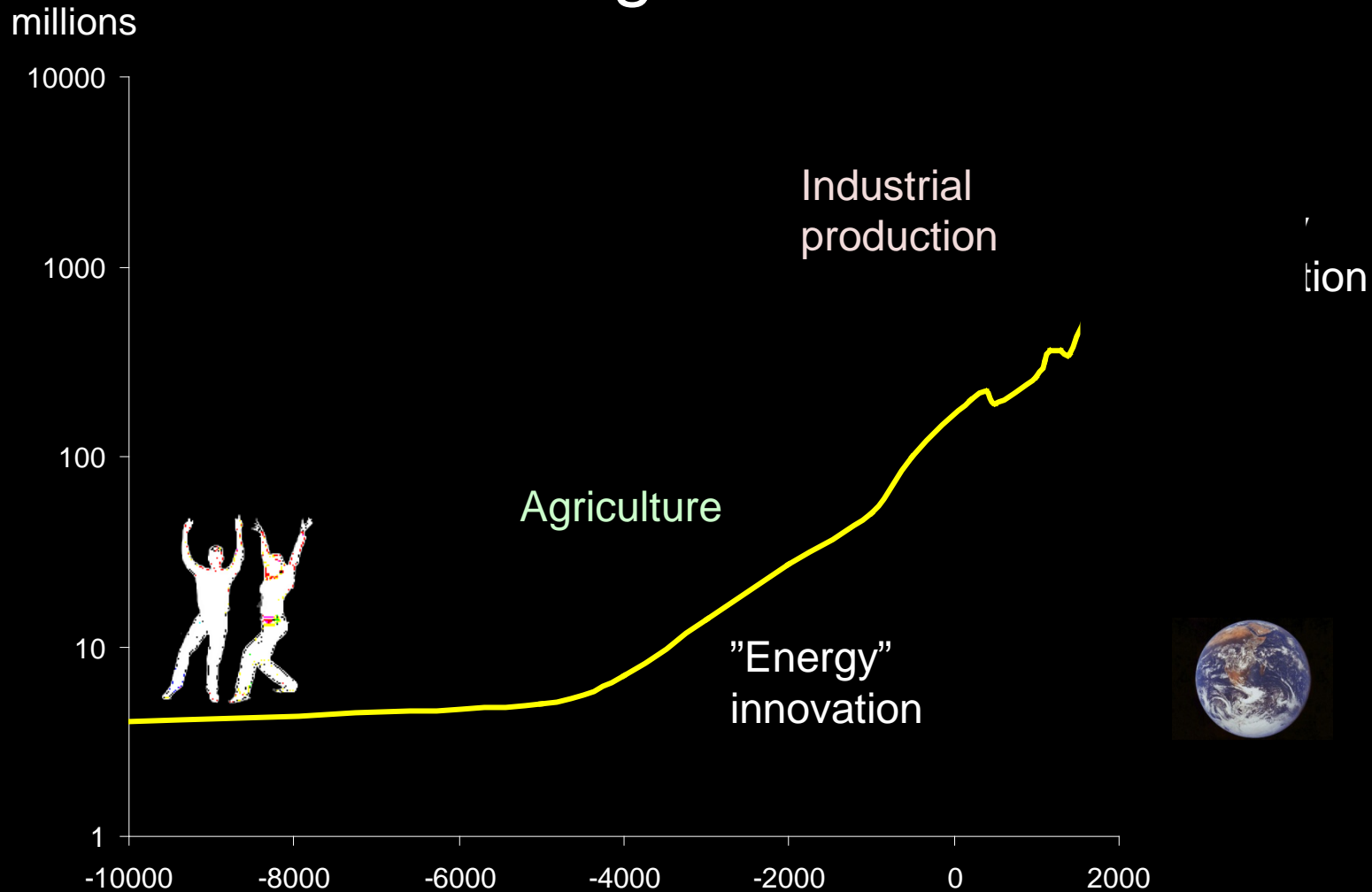


Den industriella revolutionen

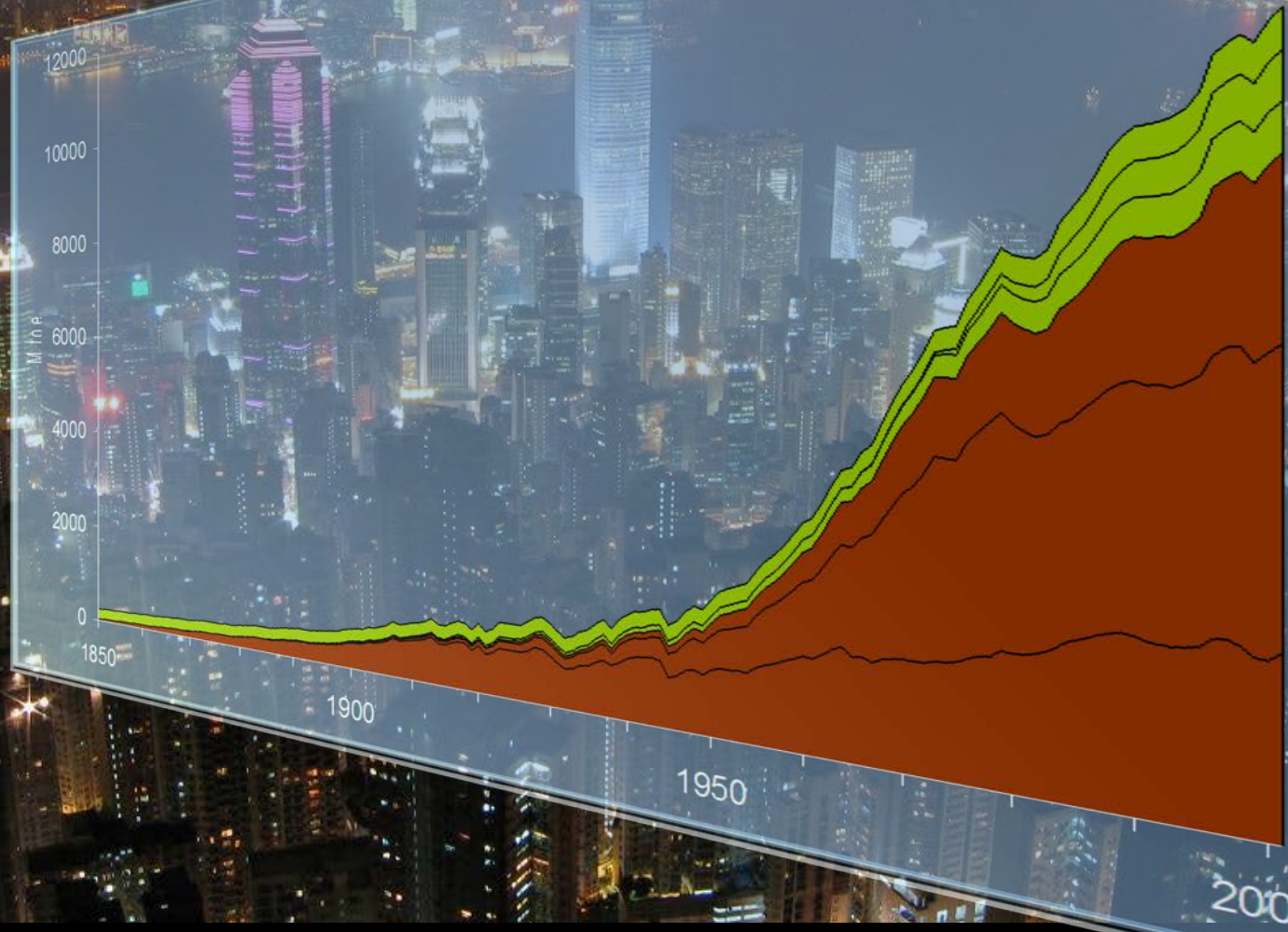


Coal, iron and steam

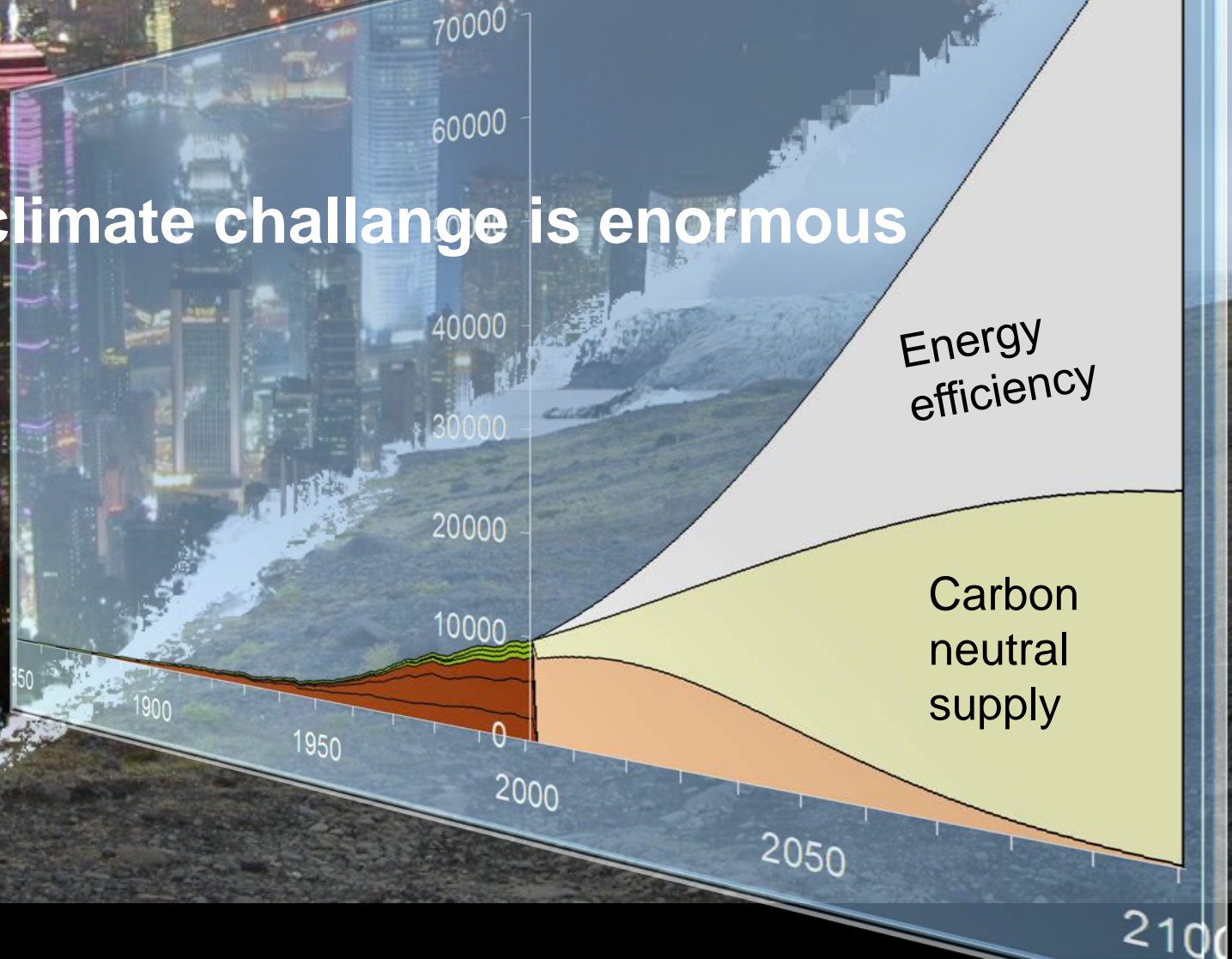
Two grand transitions



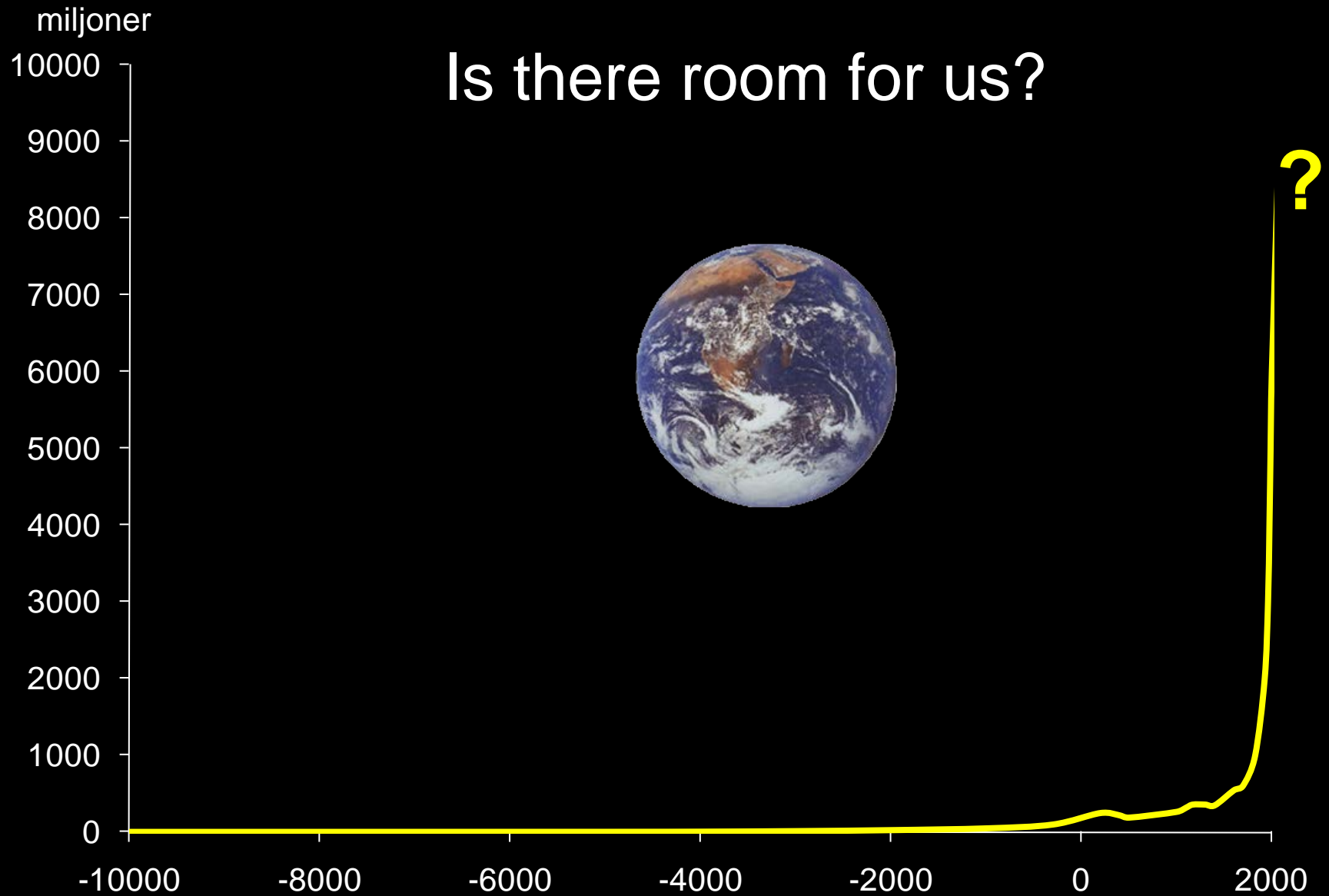
The industrial society is powered by fossil fuels



The climate challenge is enormous



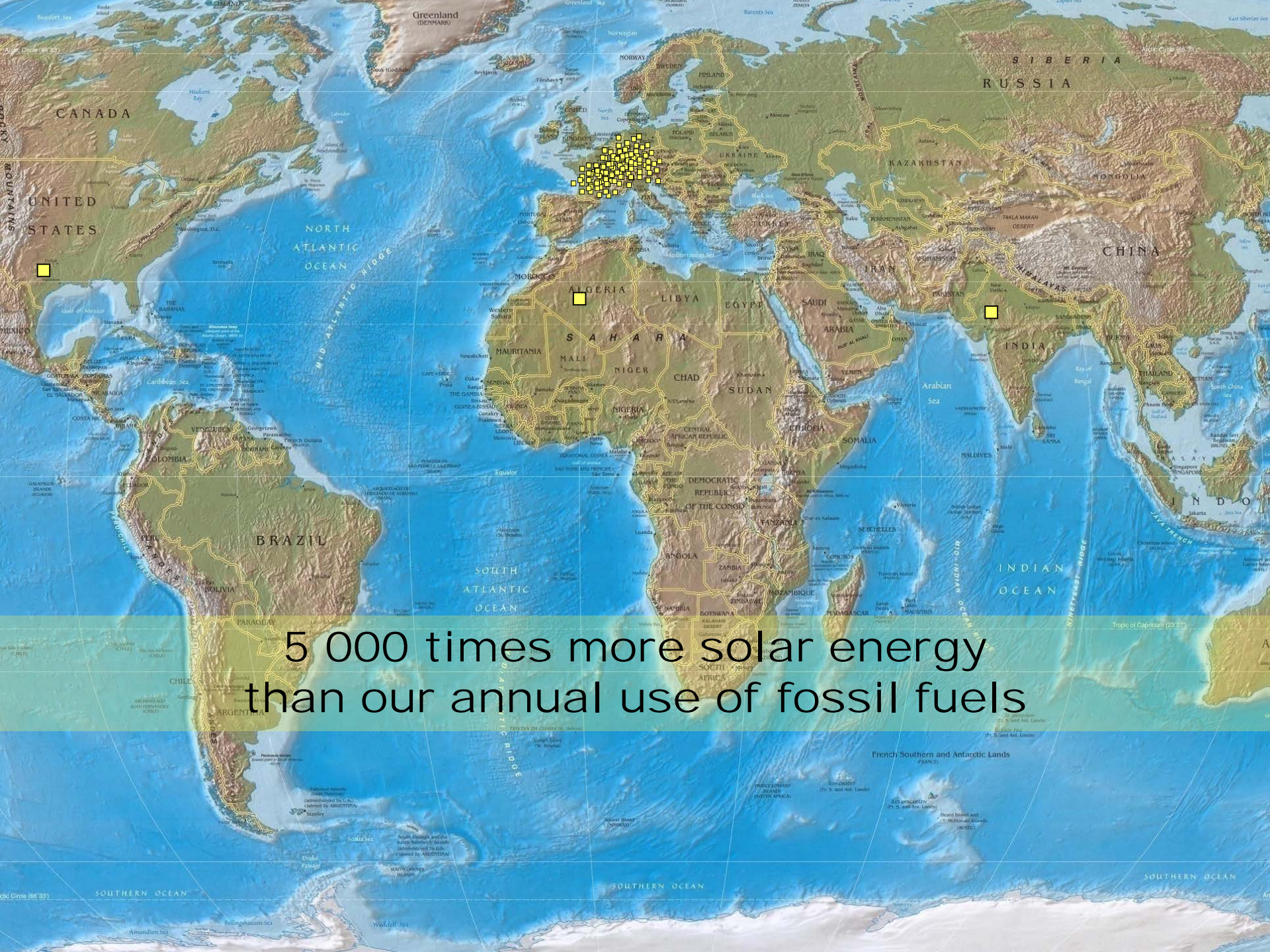
Is there room for us?





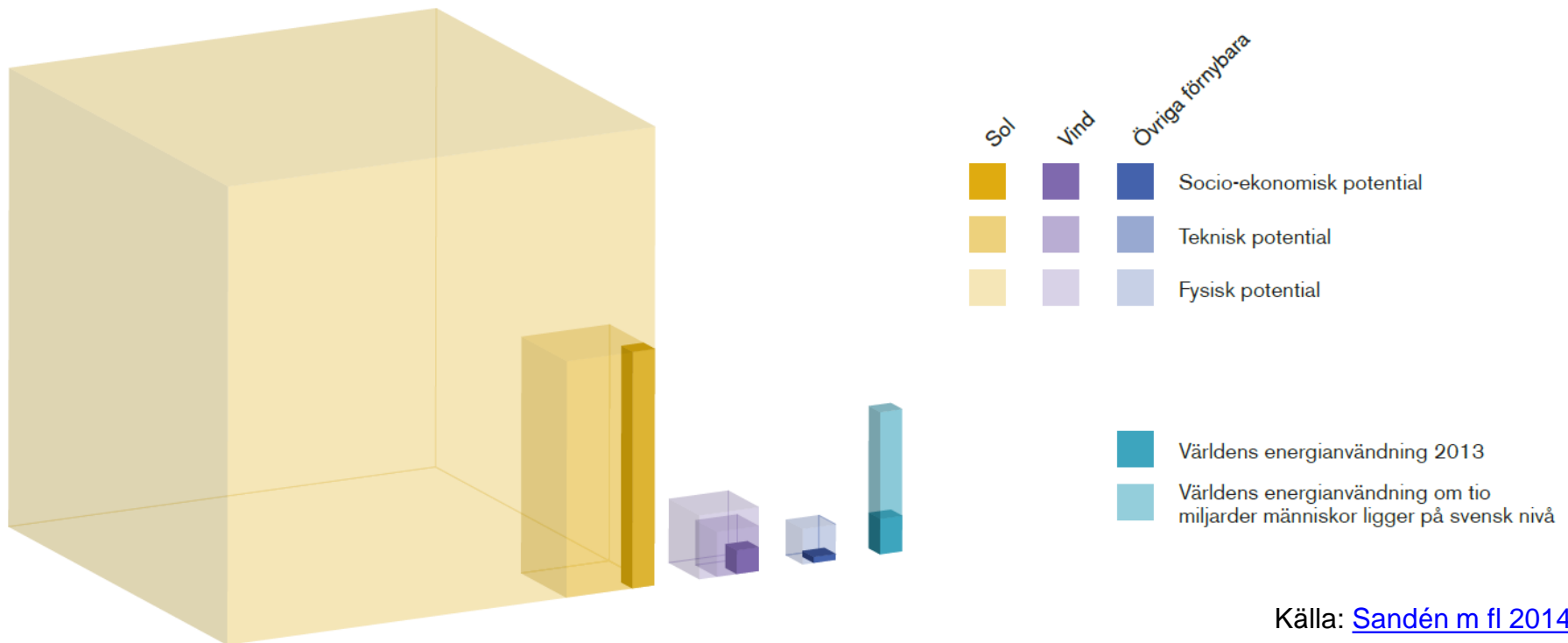
Are there any happy endings?





5 000 times more solar energy
than our annual use of fossil fuels

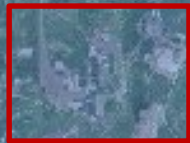
The socioeconomic potential might be ten times the current global energy use

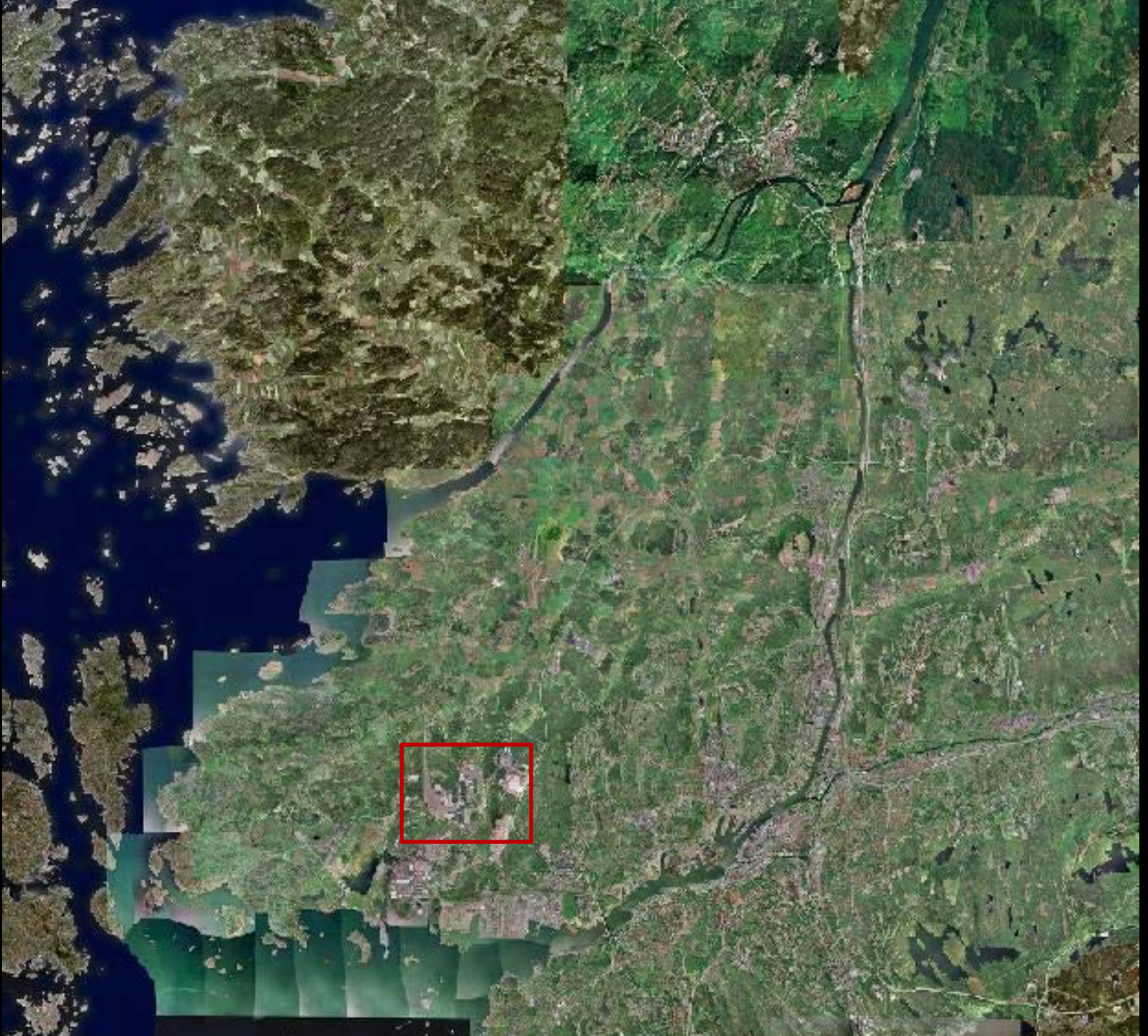


Area requirements for 60,000 cars

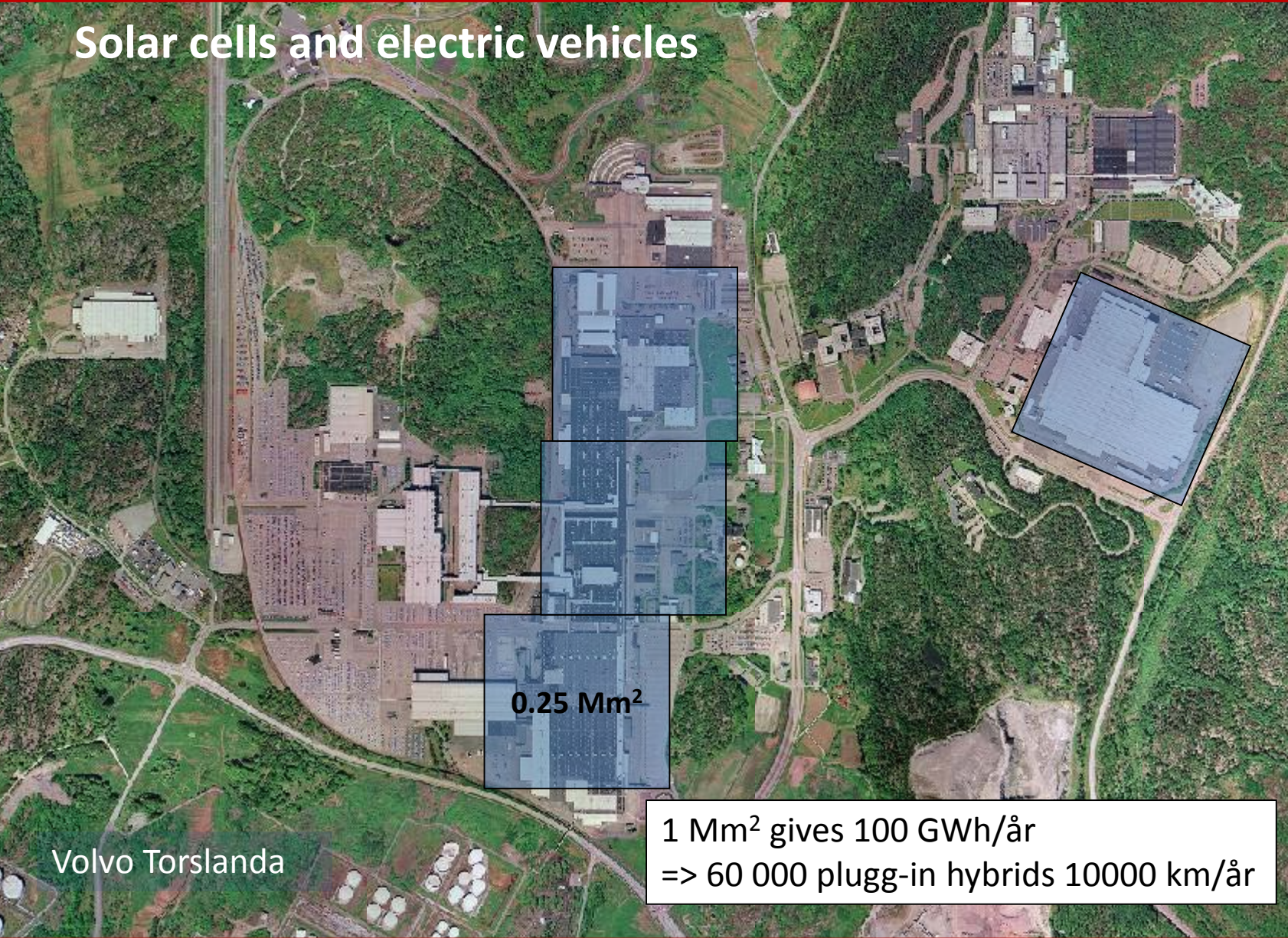
1:a generation biofuel

2:a generation biofuel





Solar cells and electric vehicles



0.25 Mm²

Volvo Torslanda

1 Mm² gives 100 GWh/år
=> 60 000 plugg-in hybrids 10000 km/år

The agricultural transition

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Traditional materials
designed by nature

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($<0.01 \text{ kWh/m}^2\text{yr}$)



A few tools

Two acts of the industrial revolution

Energy, materials and knowledge

Fossil fuels



Mass produced
materials

Direct solar energy
High efficiency
($>100 \text{ kWh/m}^2\text{yr}$)



Materials designed
by science

Agriculture and forestry
Medium efficiency solar energy
($<1 \text{ kWh/m}^2\text{yr}$)



Traditional materials
designed by nature

Is the happy ending inevitable?



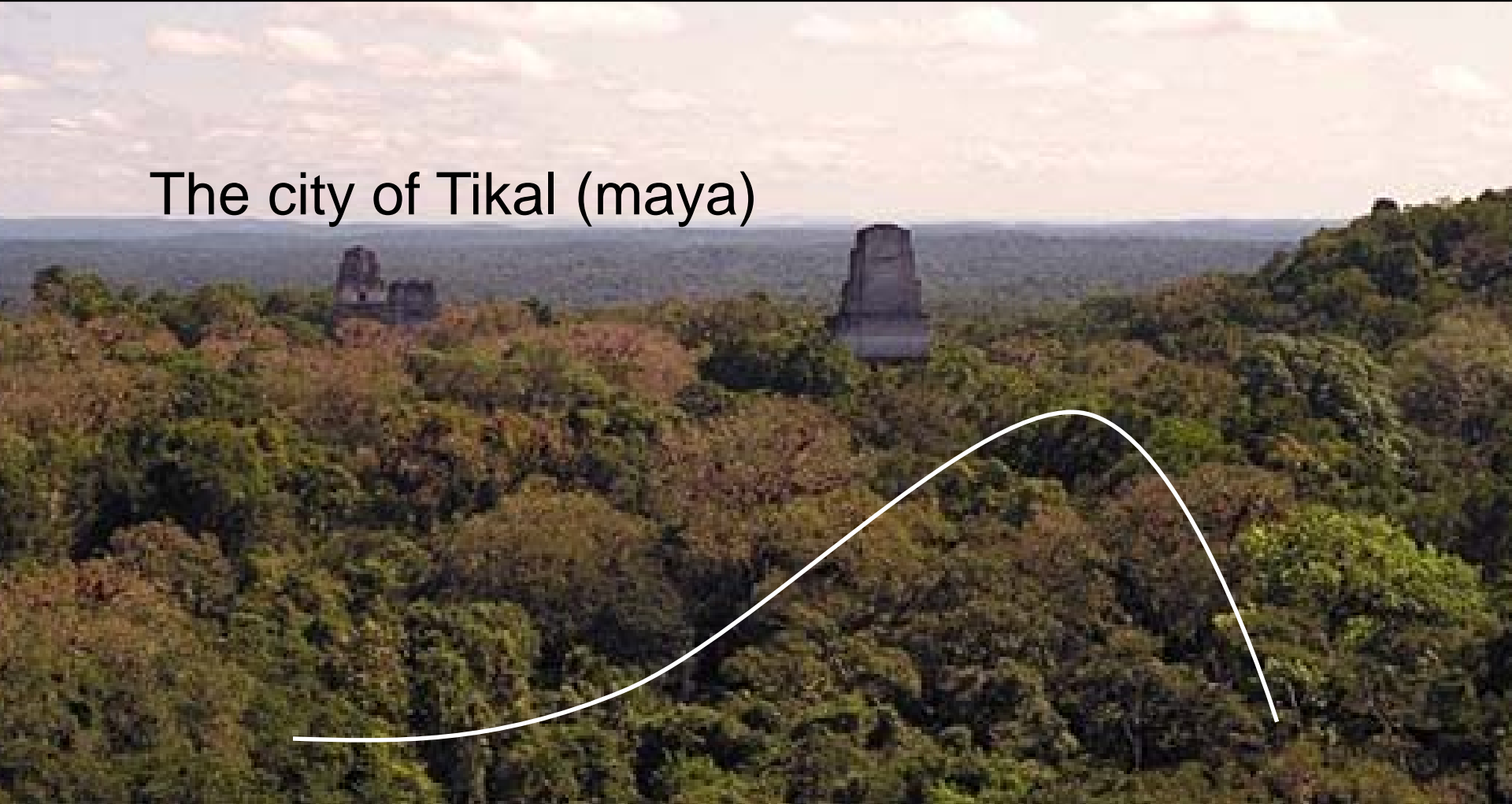
The collapse of great civilizations

The city of Ur

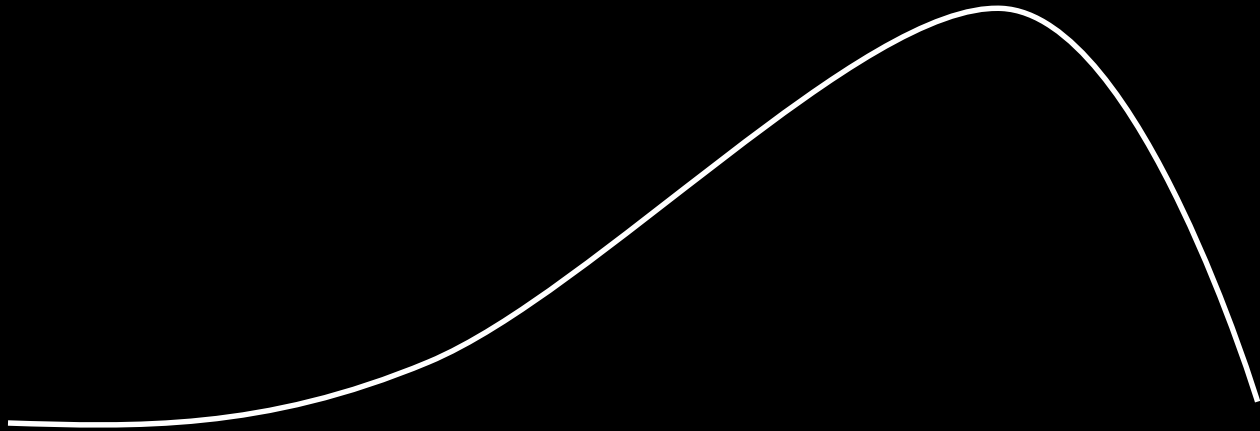


The collapse of great civilizations

The city of Tikal (maya)



Are we smarter than yeast?

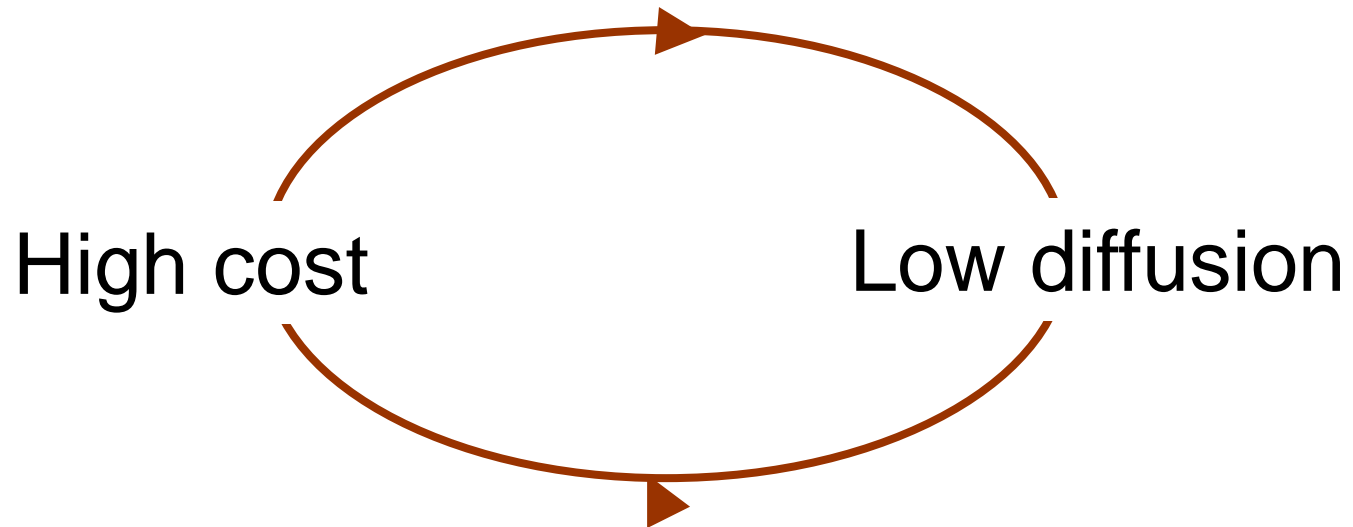


What's the key problem then?



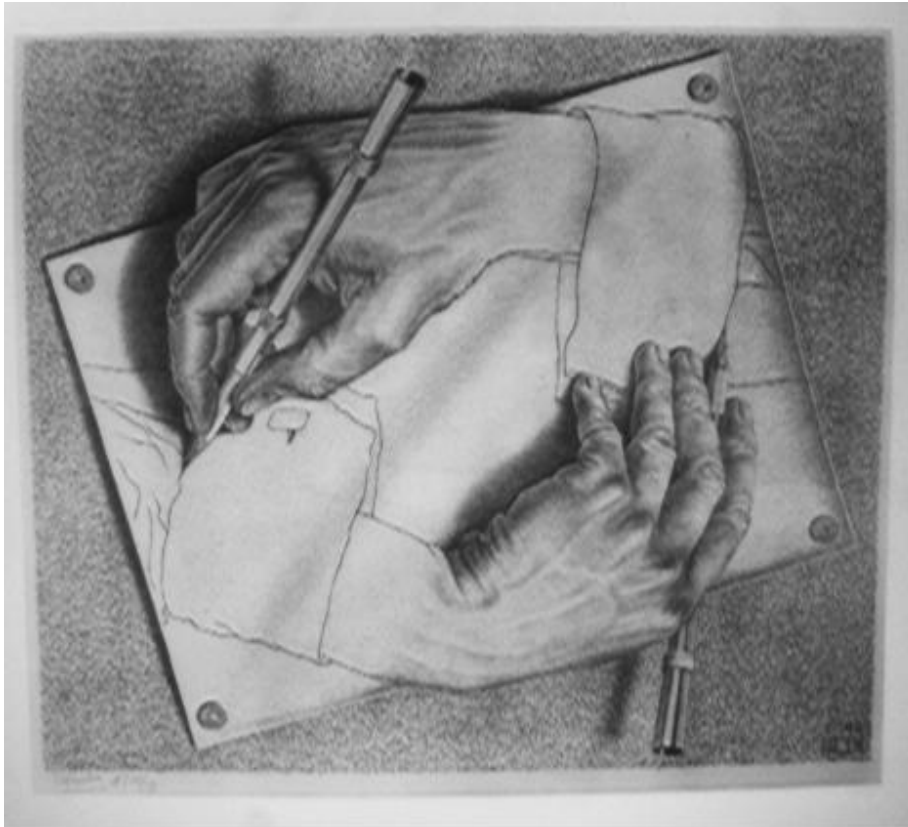
Change

The Catch 22 of technical change



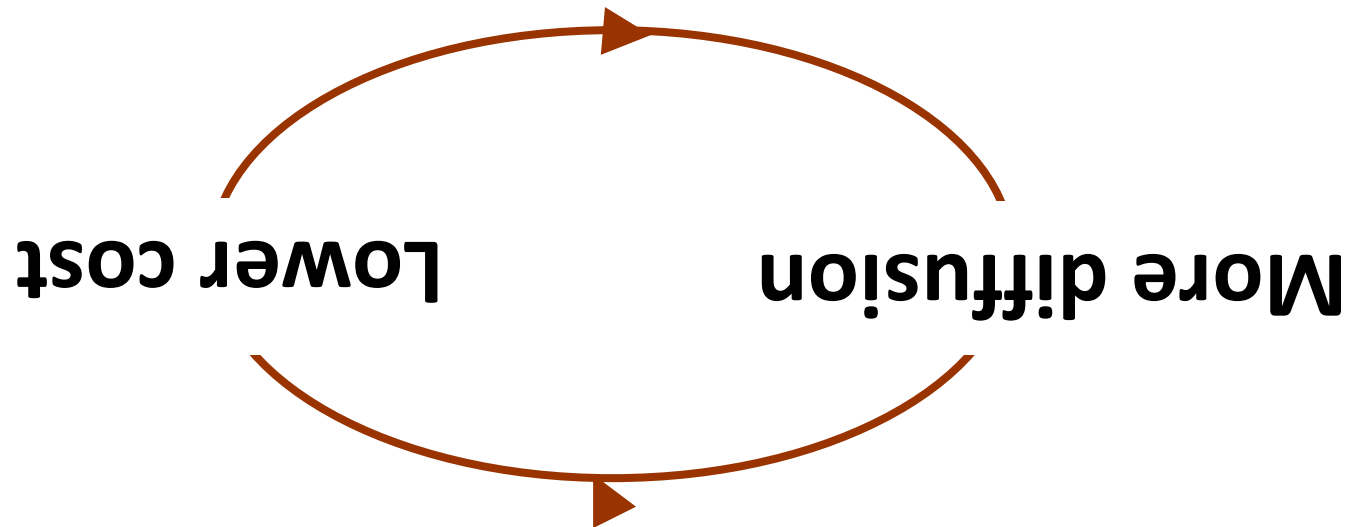
Technology lock-in

The Catch 22 of technical change



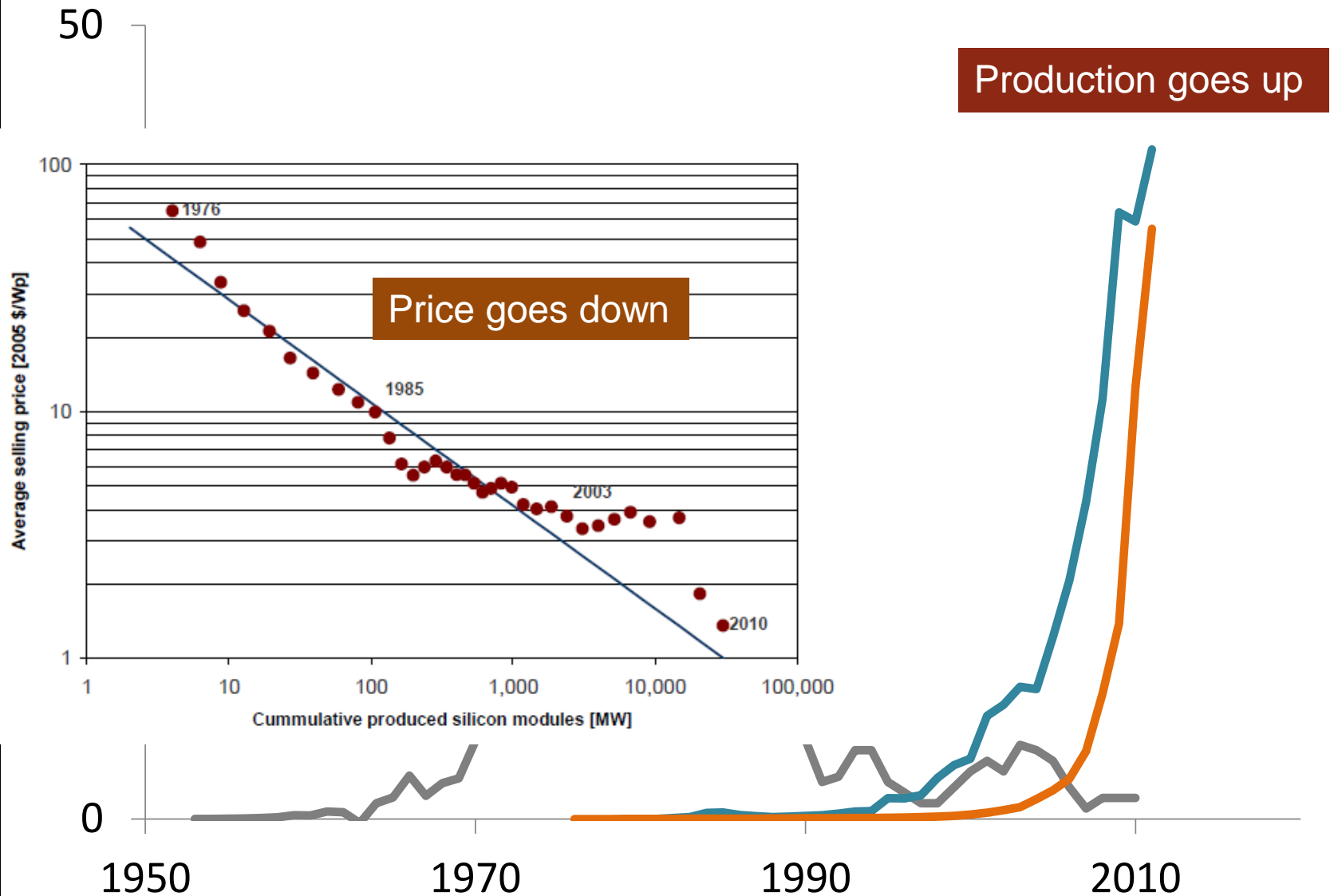
Can we escape from technology lock-in?

The **ENGINE** of technical change



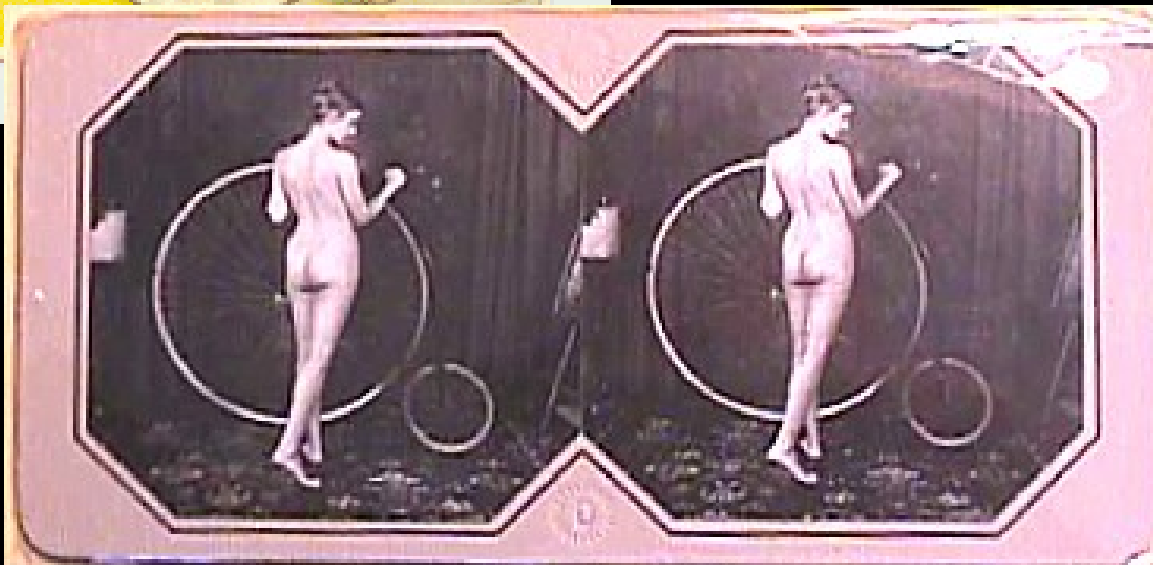
Can we escape from technology lock-in?

There is hope



**What does a normal
bicycle look like?**

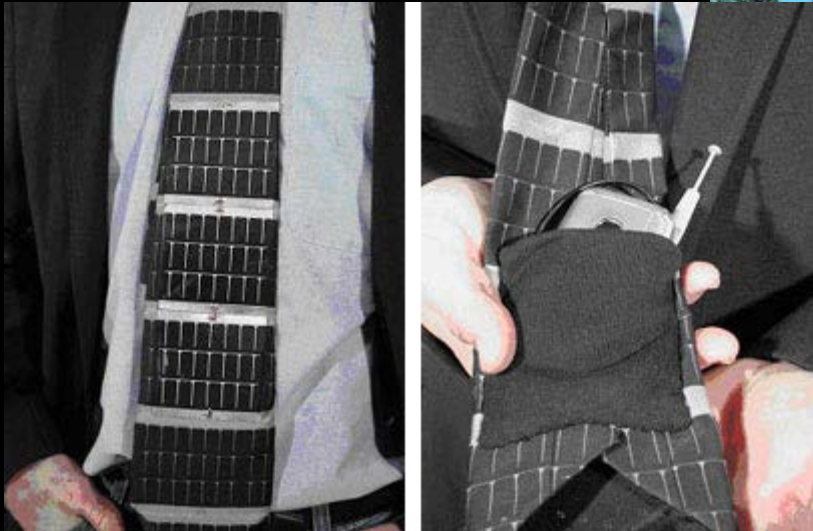






"The safety bicycle"

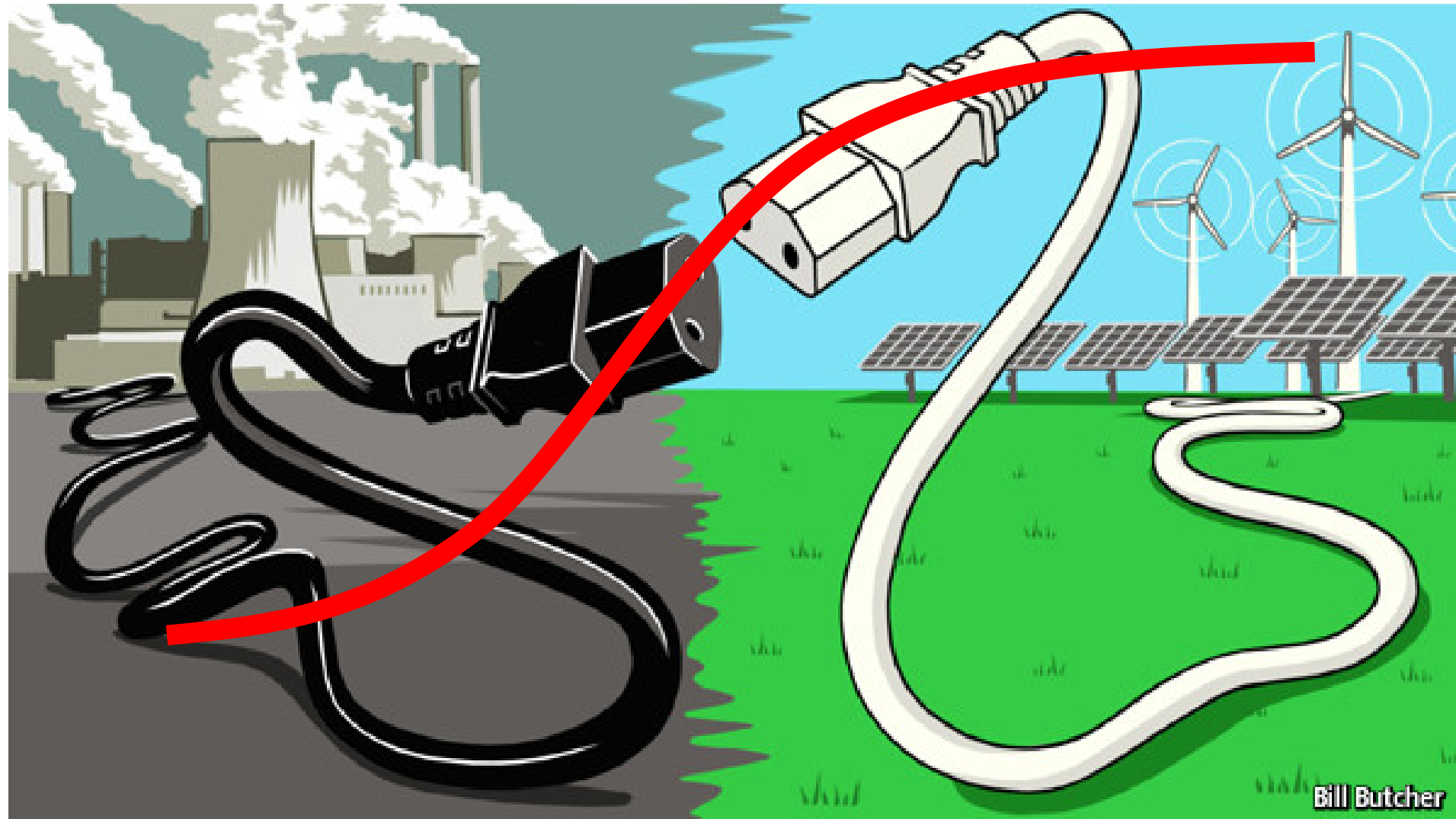
**What does a normal
powerplant look like?**



"There is not reason for any individual to have a computer in their home."

Ken Olson, President Digital Equipment Corp. 1977

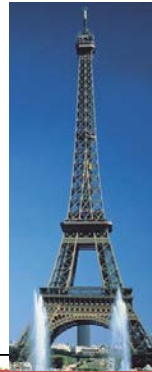
How to lose half a trillion euros



Waves of change



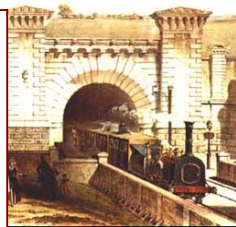
Steam-powered
mechanisation of
industry and trans-
port (iron, coal)



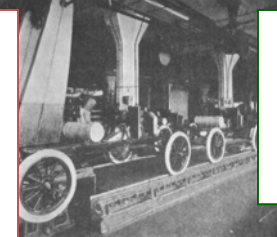
Motorization of
transport civil
economy and war
(oil, gas, plastics)



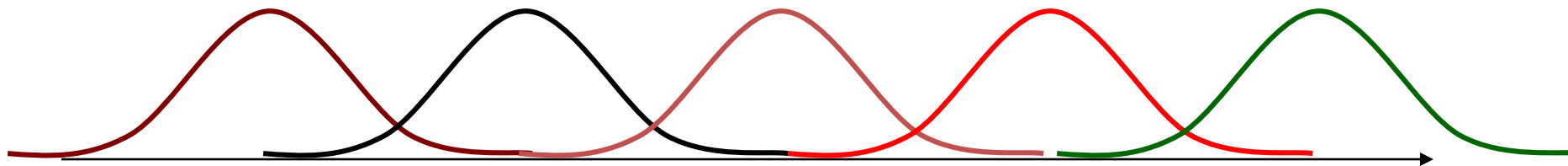
Water-powered
mechanisation of
industry (iron,
cotton, coal)



Electrification of
industry, transport
and the home
(steel, copper)



Computerization
of entire economy
(chips)



1780 1815 1848 1873 1895 1918 1941 1973

The energy transition

Nanotechnology 2.0, IT and
modular energy technology
enables a new industrial revolution



Innovation systems

Technology

Knowledge
Artefacts

Actors

Entrepreneurs
Large firms
Governmental agencies
Universities

Institutions

Attitudes and expectations
Laws and regulations
Standards and routines

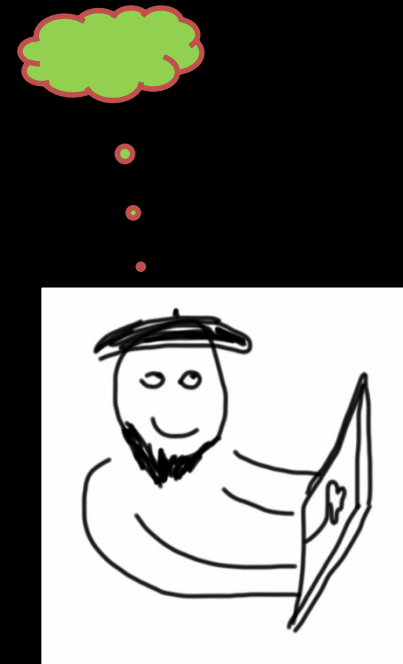
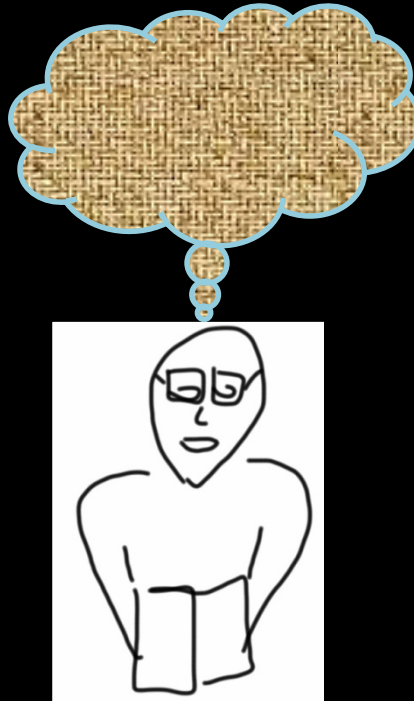
Resources

Skilled labour
Natural resources
Financial capital

Where are the bottlenecks?

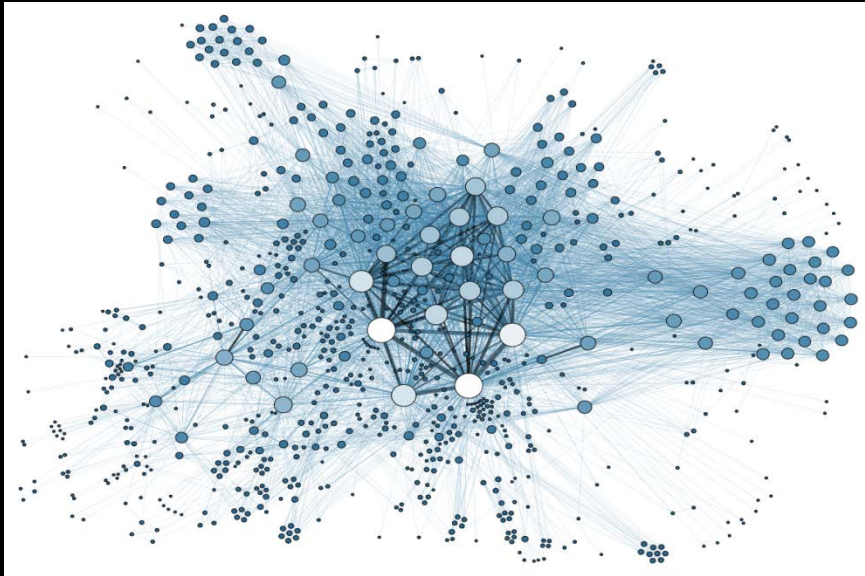
Uncertainty: different development paths

Different worldviews, hopes and expectations



DIFFERENT SYSTEM SOLUTIONS

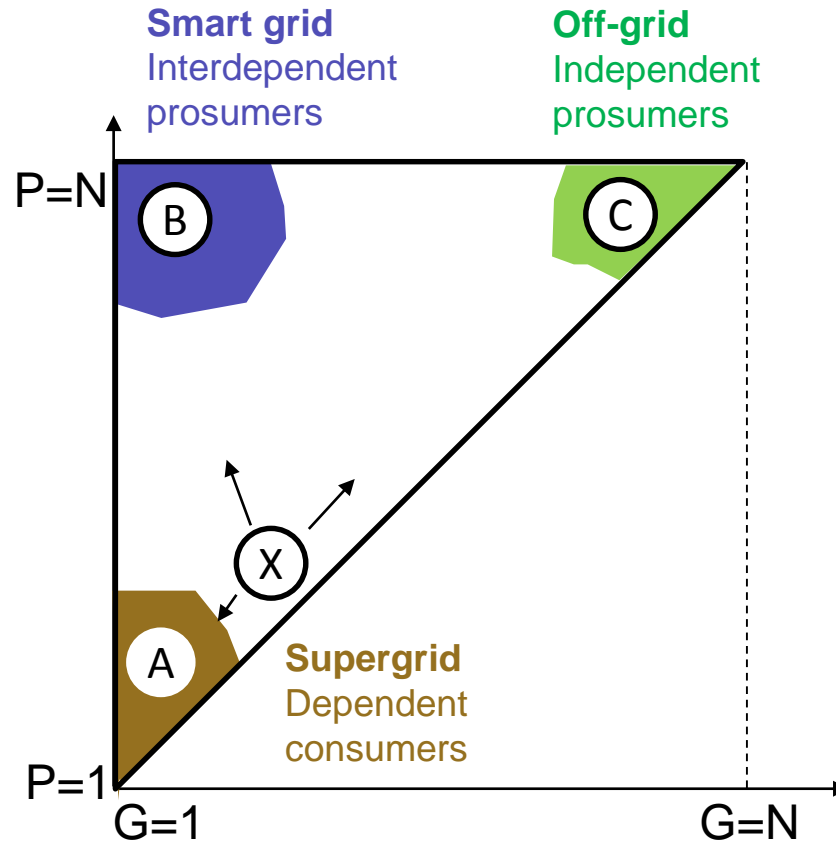
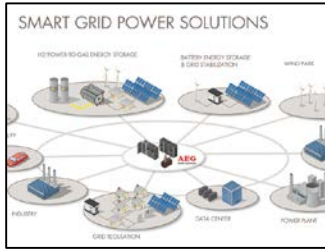
World Wide Watt Web



Monk model



Three alternative electricity futures





Nanotechnology 1.0

Nanotechnology 2.0

A new industrial ecology within reach

Electricity is key!



Thank You!

