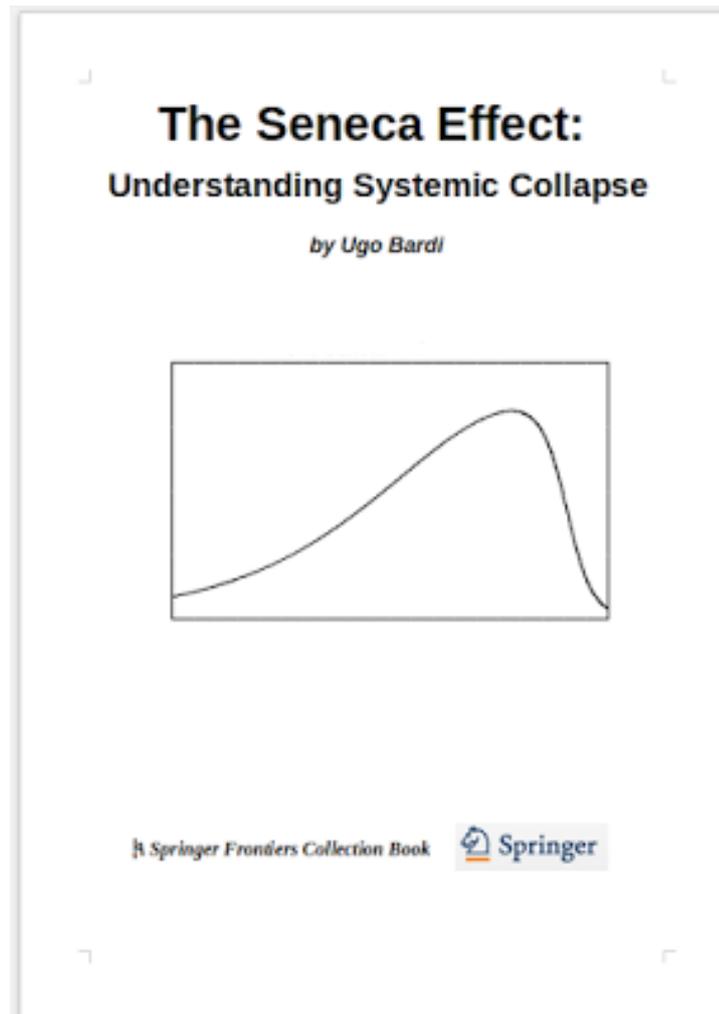
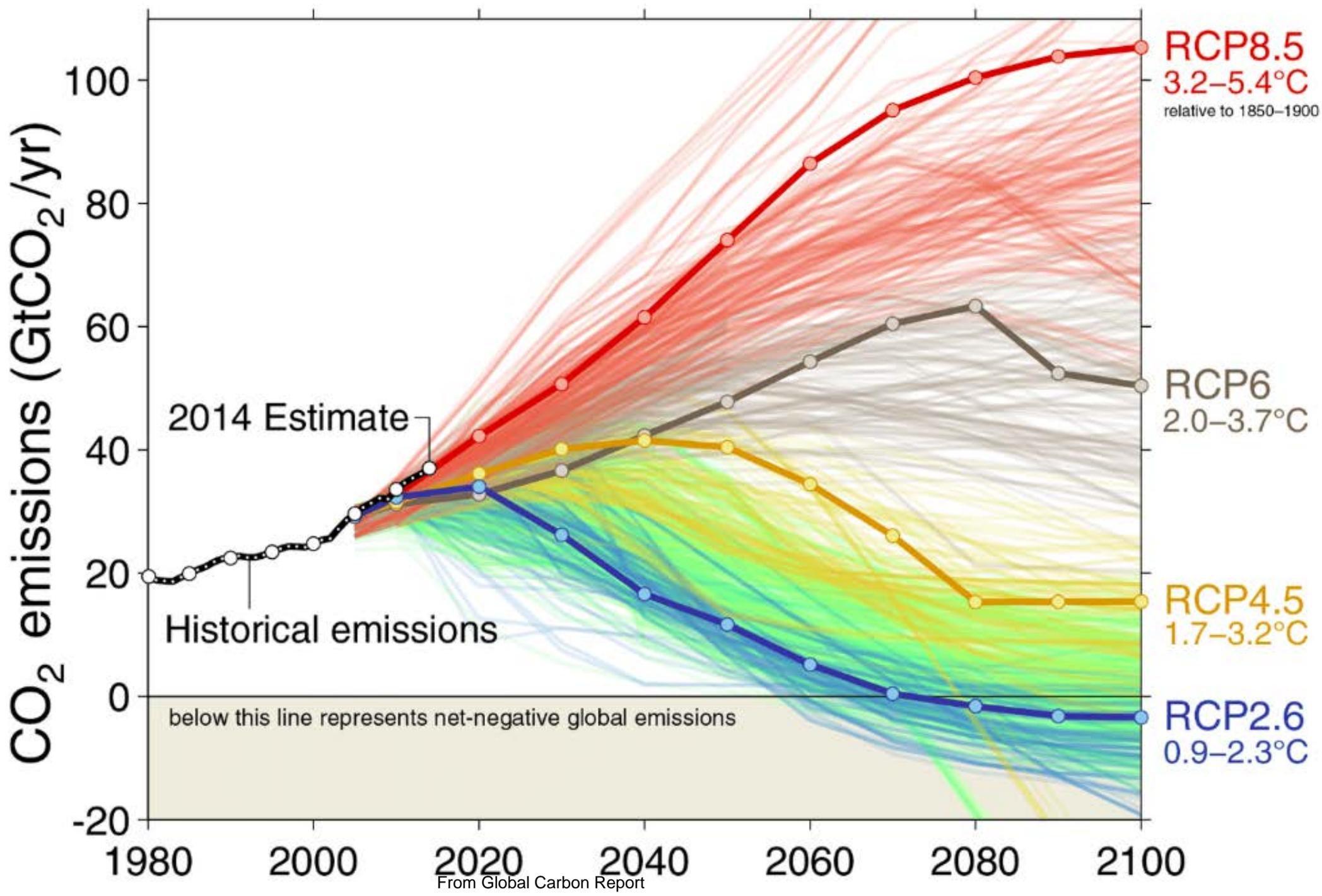


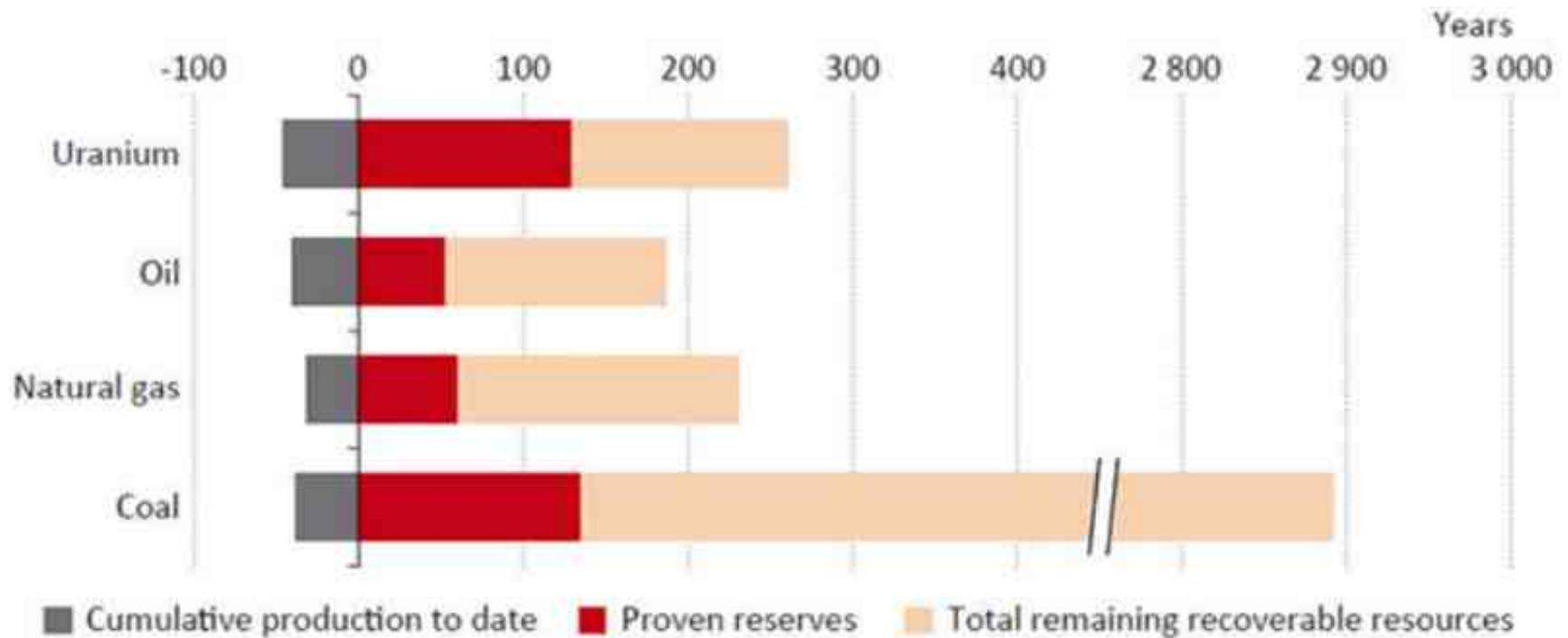
# Managing Resources and and Climate in a Time of Turbulences

Ugo Bardi  
Università di Firenze – Italy  
The Club of Rome





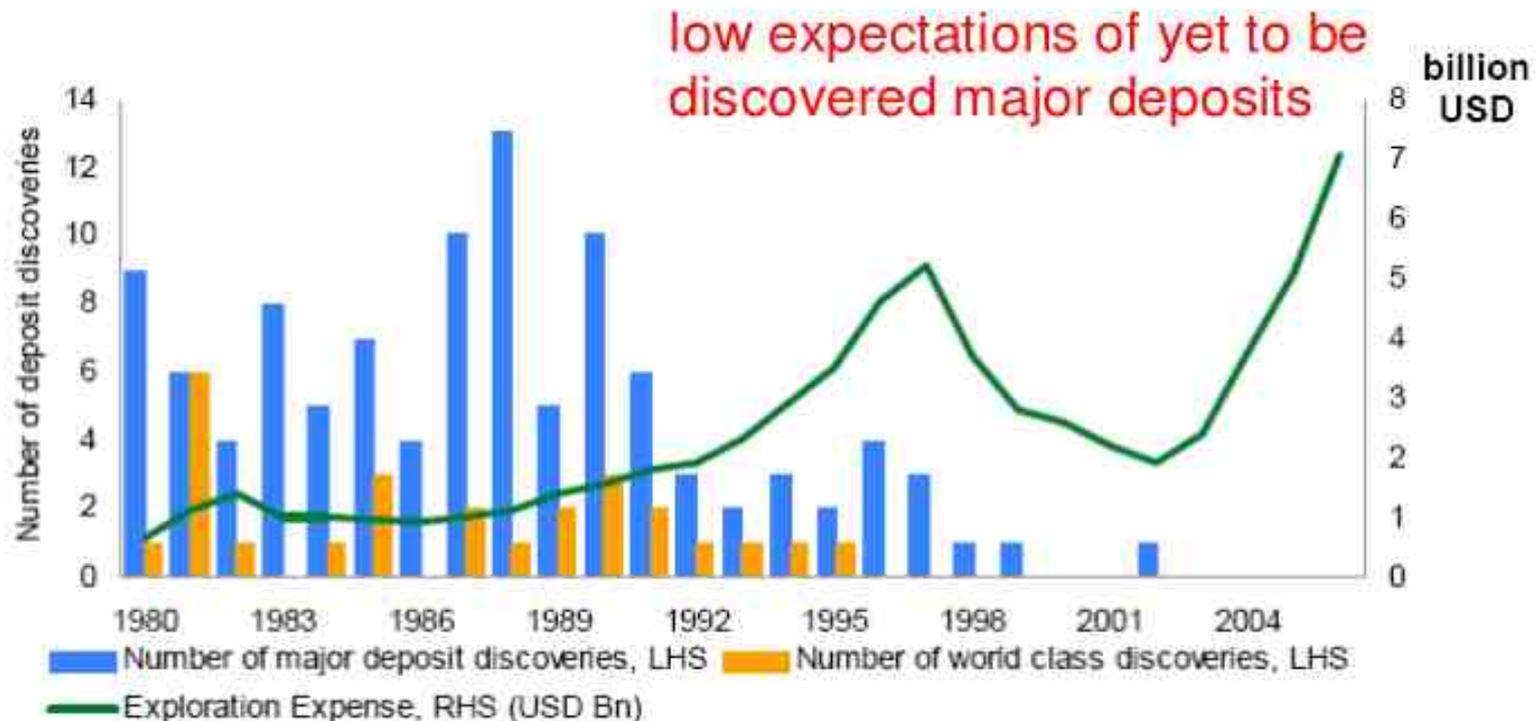
# Fossil Resources: still abundant?



**Lifetimes of fossil-fuel resources (expressed as # of years produced and remaining resources based on production rates in 2013)**

Source: BGR, 2013; O&GJ, 2013; USGS, 2012; USGS, 2012; BP, 2014; NEA/IAEA, 2014; IEA World Energy Outlook 2014

# Exploration of major mineral deposits and the “Law of diminishing returns”



Sources: BHP Billiton, MEG, UBS WMR.

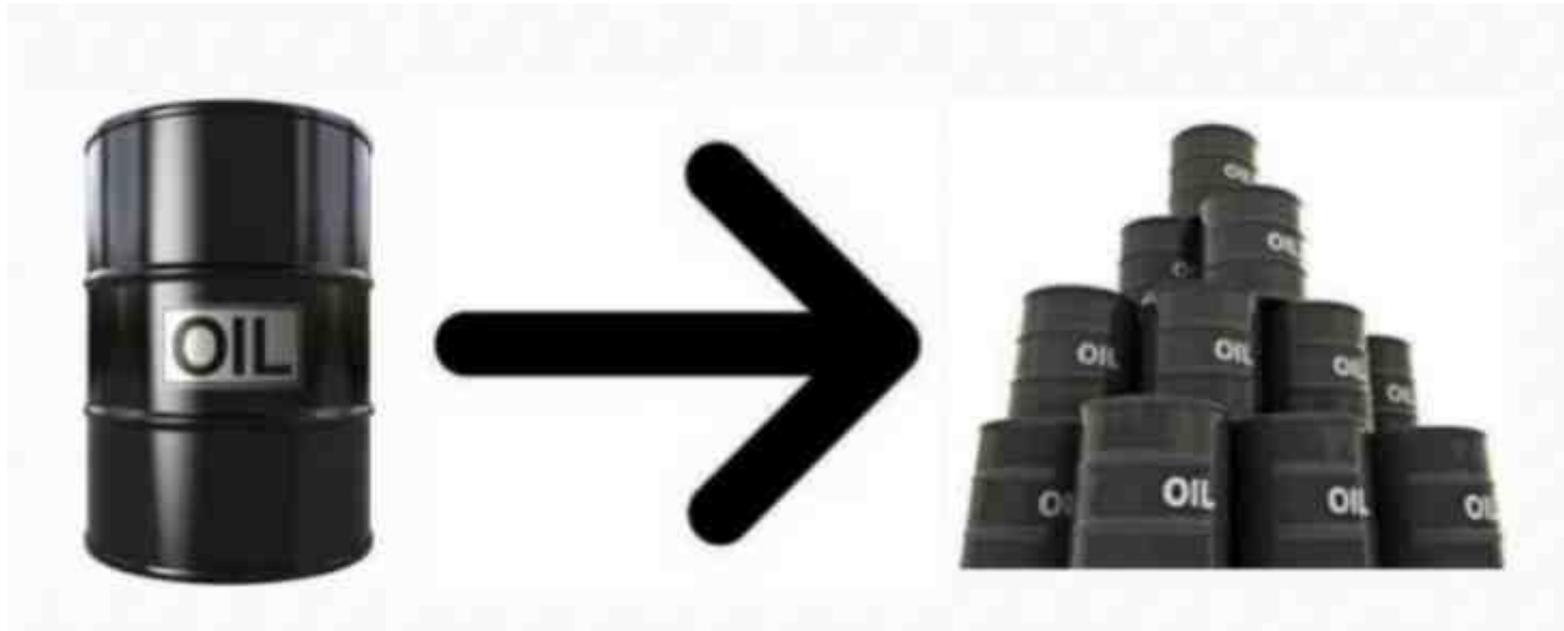
Graph: Raw Materials Group, Sweden

Graph courtesy of A. Diederer

**Depletion: as you eat the cake, it becomes less and less tasty**

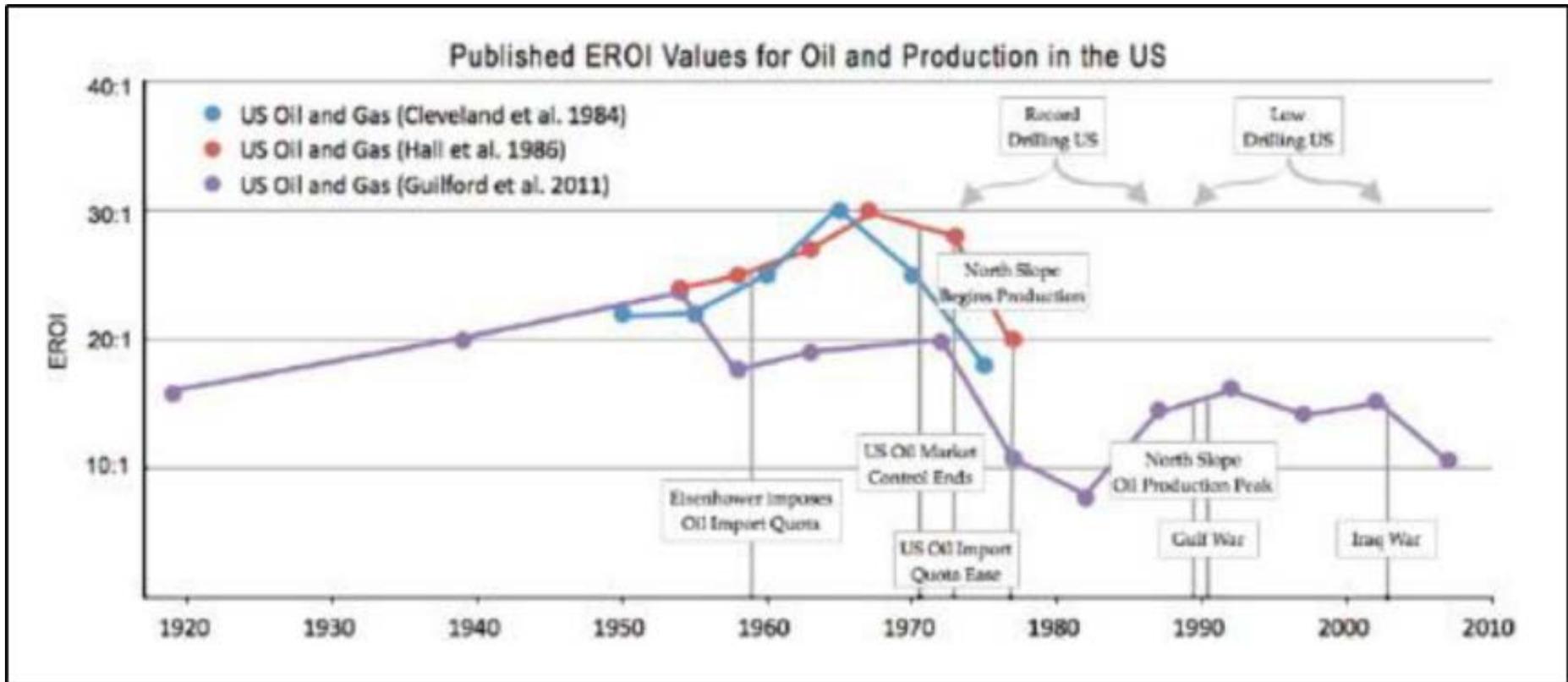


## Net Energy: the concept of EROEI

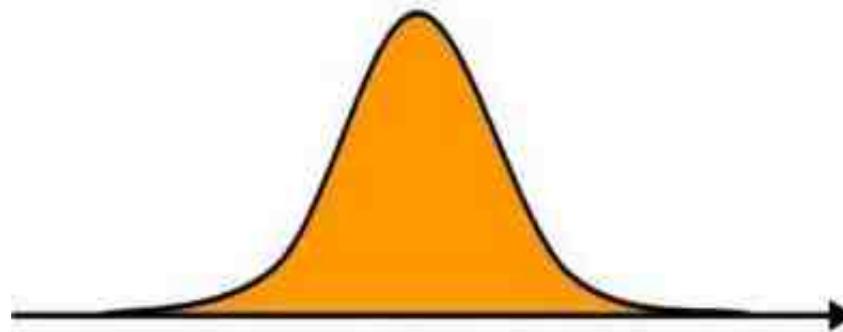
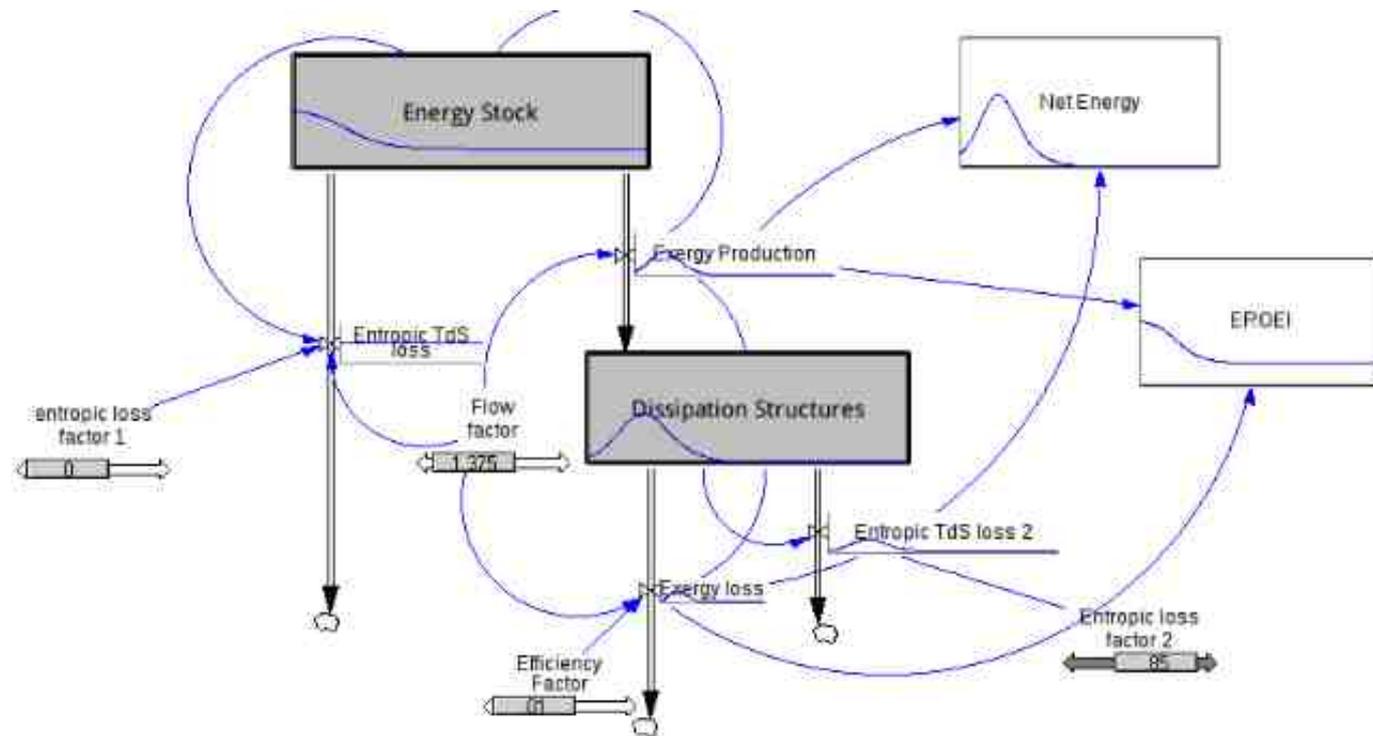


EROI (EROEI) – Energy Return of Energy Invested:  $(\text{Energy produced})/(\text{Energy Spent})$

Net Energy – Energy actually available:  $(\text{Energy Produced}) - (\text{Energy Spent})$



# The Hubbert Curve: a System Dynamics Simulation





# Turbulences: the Seneca Effect

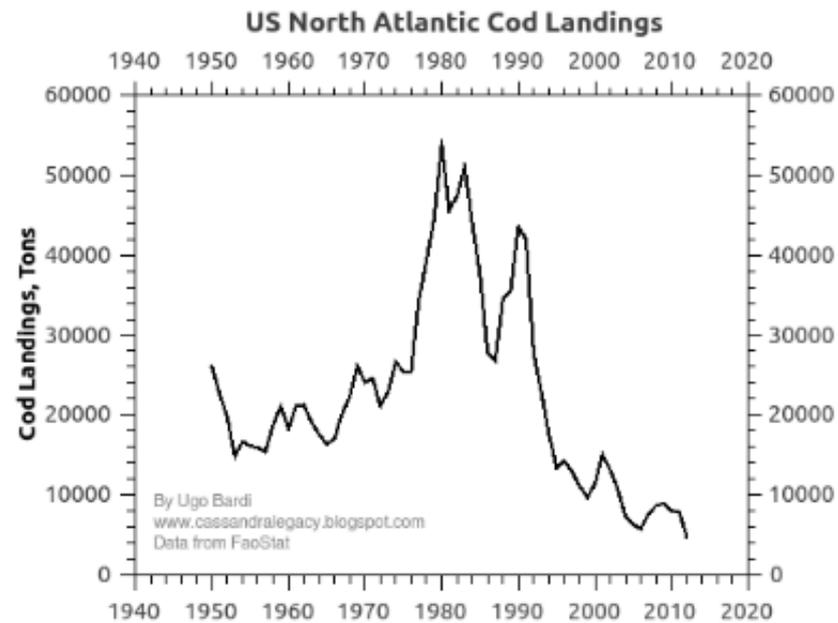
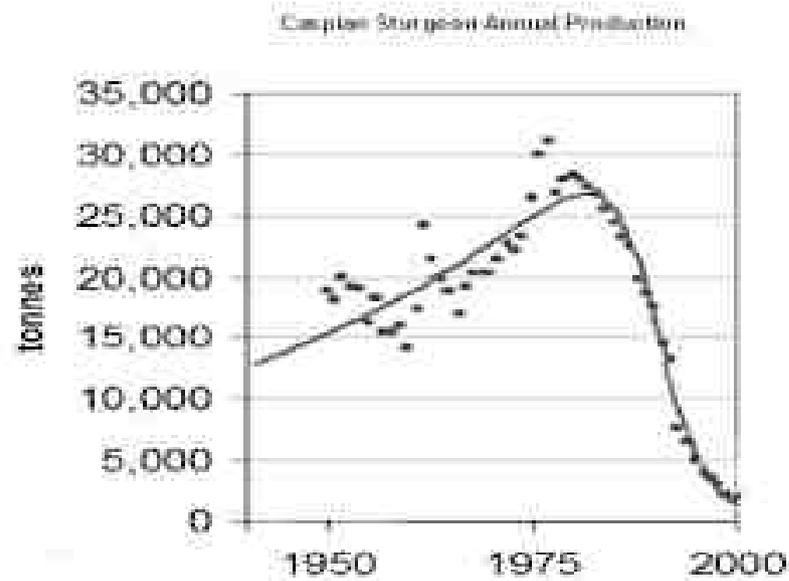
*"It would be some consolation for the feebleness of our selves and our works if all things should perish as slowly as they come into being; but as it is, increases are of sluggish growth, but the way to ruin is rapid."*



*(Lucius Anneaus Seneca (4 BCE – 65 CE), Letters to Lucilius, n. 91)*



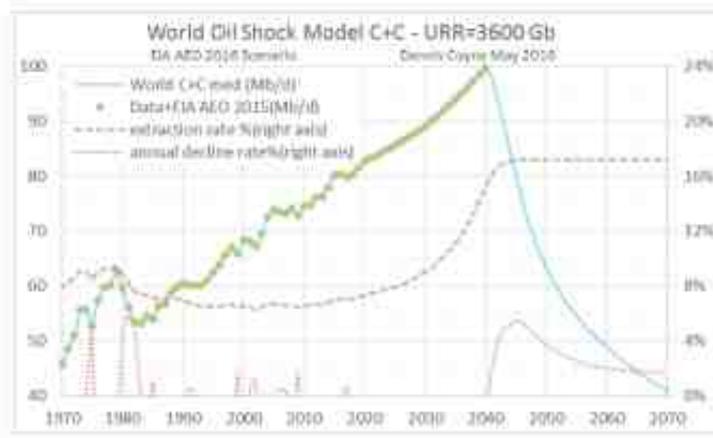
# The Seneca Collapse of Fisheries



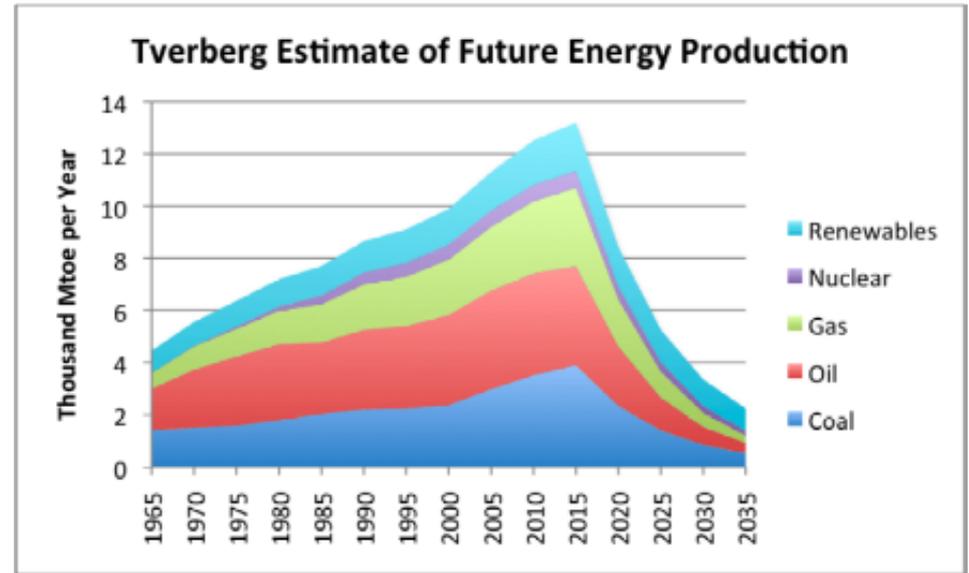
# The Seneca Cliff and Energy Production

## EIA's Annual Energy Outlook and the Seneca Cliff

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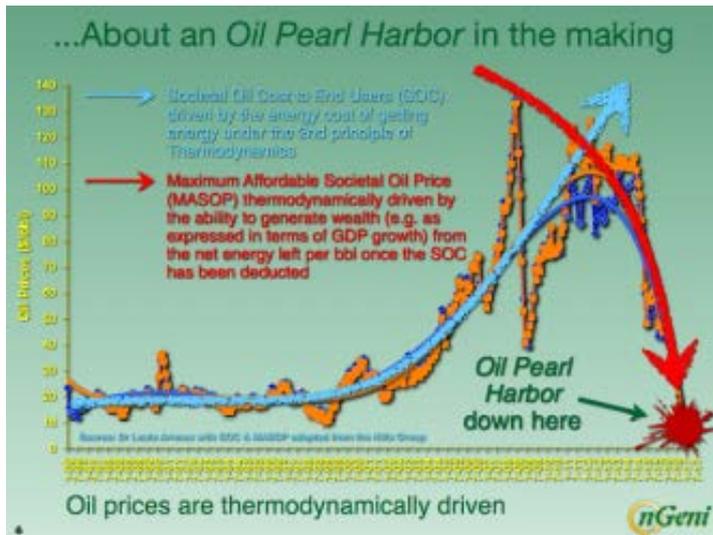
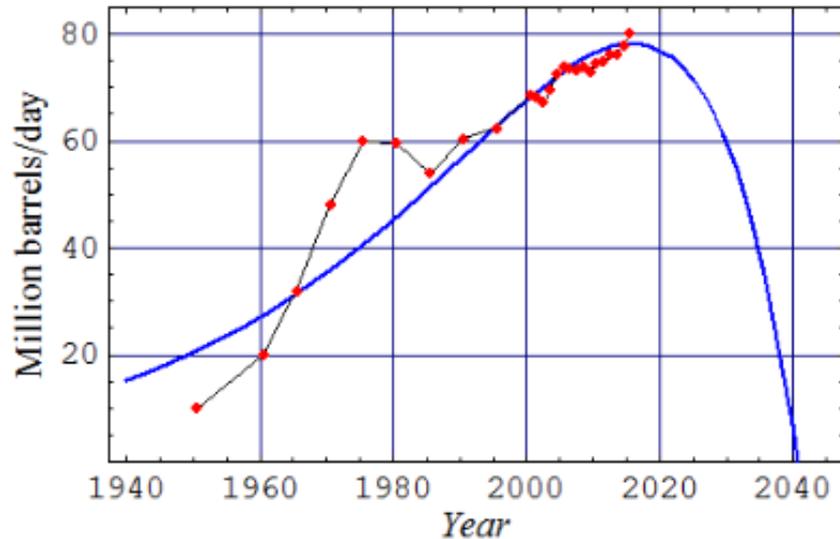
The scenario above shows an Oil Shock Model with a URR of 3600 Gb and EIA data from 1970 to 2015 and the Annual Energy Outlook (AEO) 2016 early release reference projection from 2016 to 2040. The oil shock model was originally developed by Wehnbubbelescope and presented at his blog [Multiplexor](http://multiplexor.com) and in a free book *The Oil Countdown*.



<https://ourfiniteworld.com/2015/01/06/oil-and-the-economy-where-are-we-headed-in-2015-16/>

<http://peakoilbarrel.com/eias-annual-energy-outlook-seneca-cliff/>

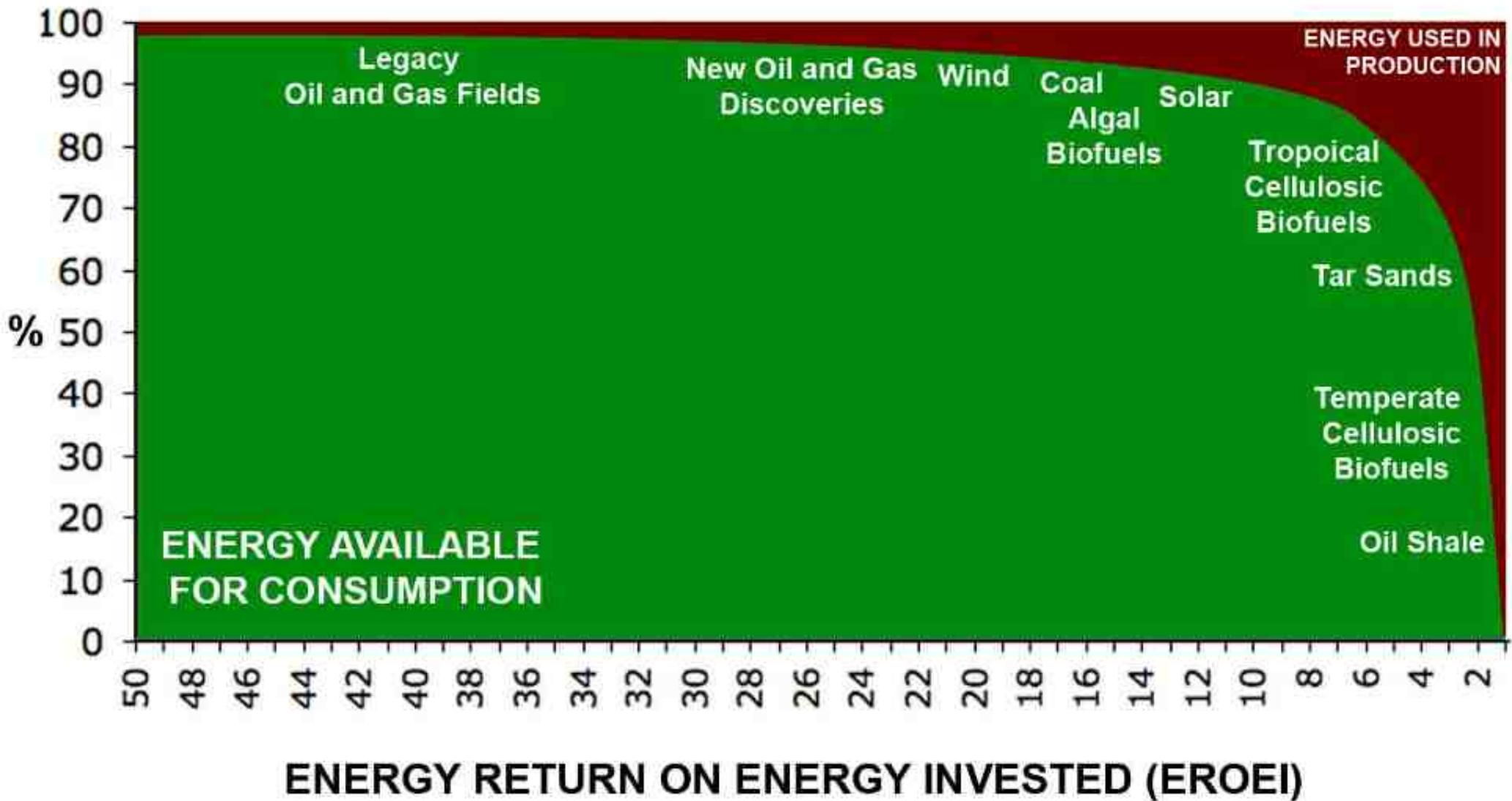
## World Crude Oil Production



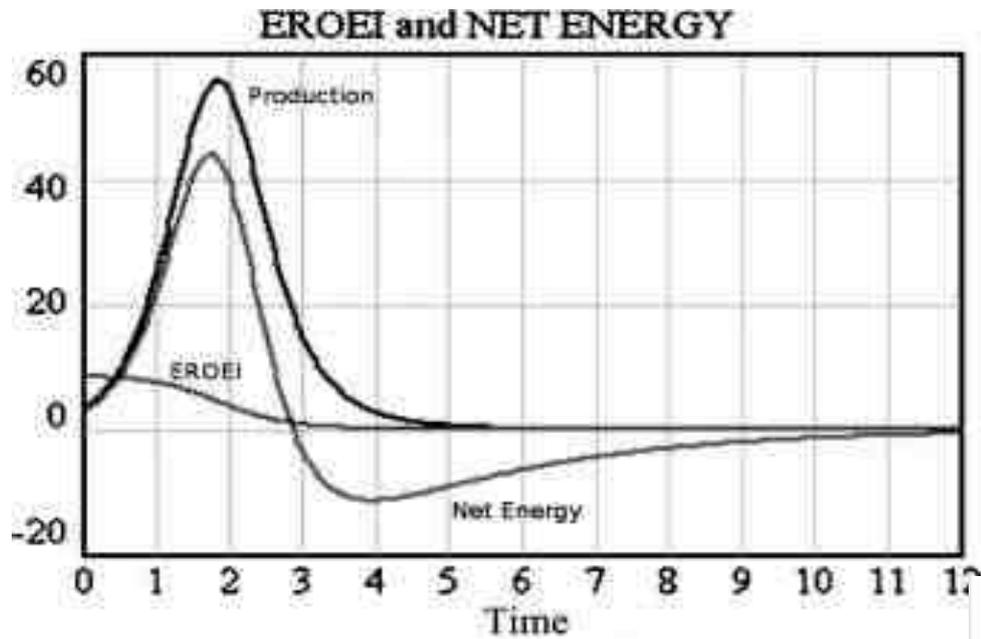
[https://cassandraleacy.blogspot.it/2016/07/some-reflections-on-twilight-of-oil-age\\_15.html](https://cassandraleacy.blogspot.it/2016/07/some-reflections-on-twilight-of-oil-age_15.html)

<http://davecoop.net/seneca.htm>

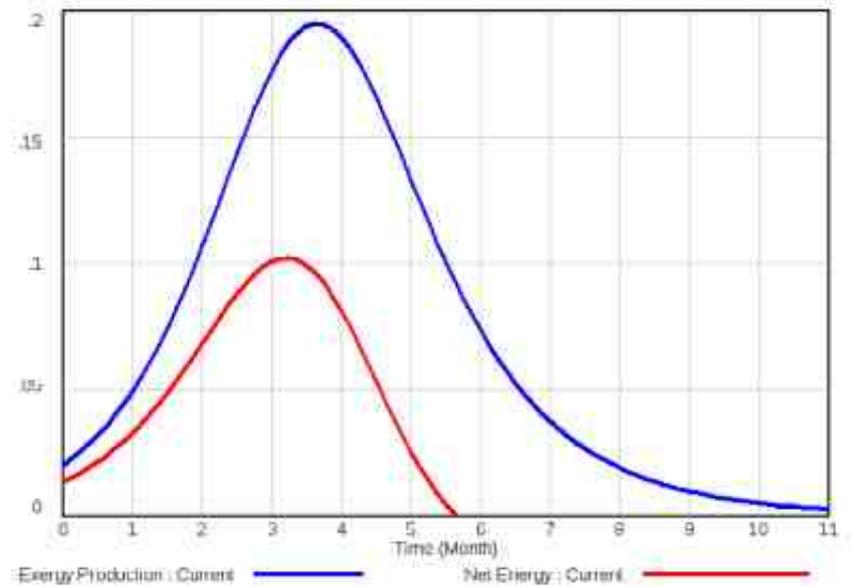
# THE NET ENERGY CLIFF



# The Seneca Curve of Net Energy Simulated by System Dynamics



Bardi, Lavacchi, and Yaxley - 2011

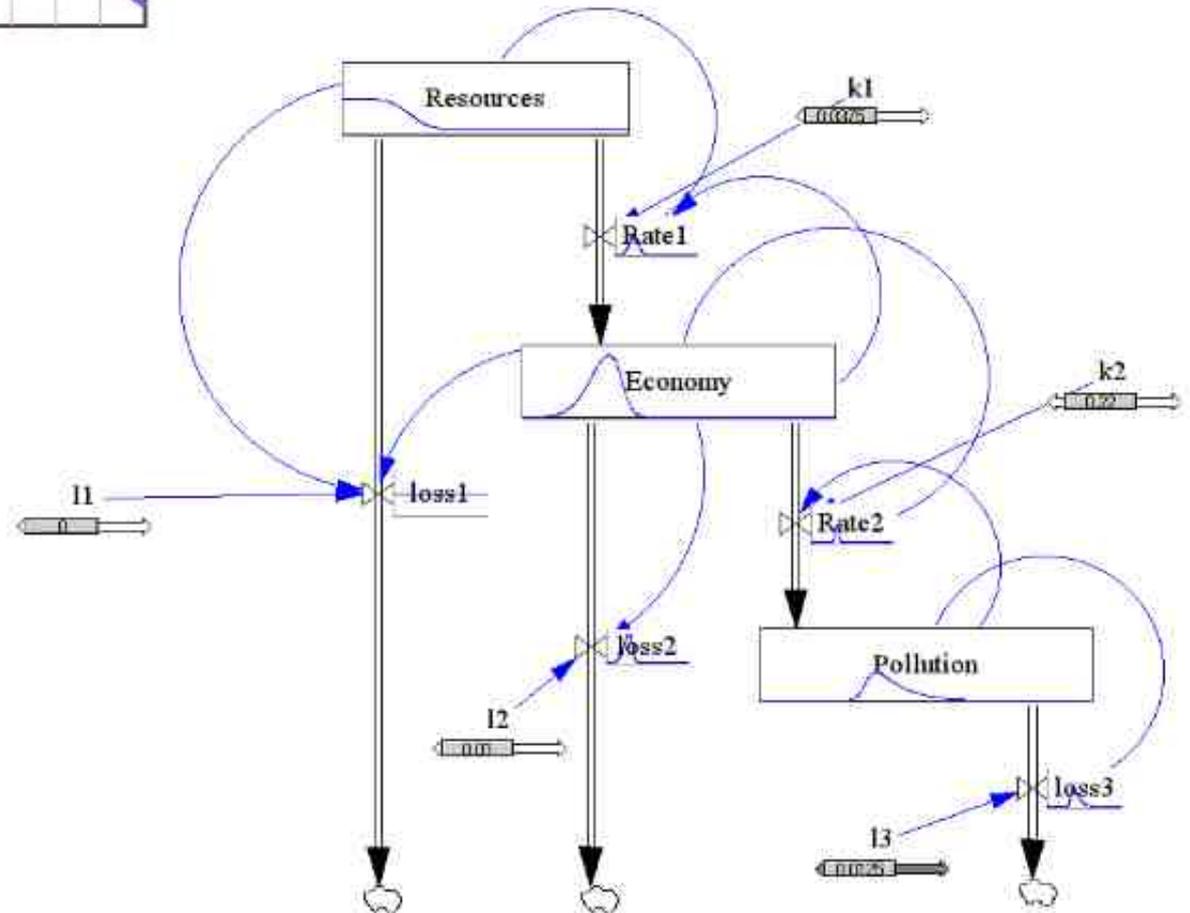


The Seneca cliff

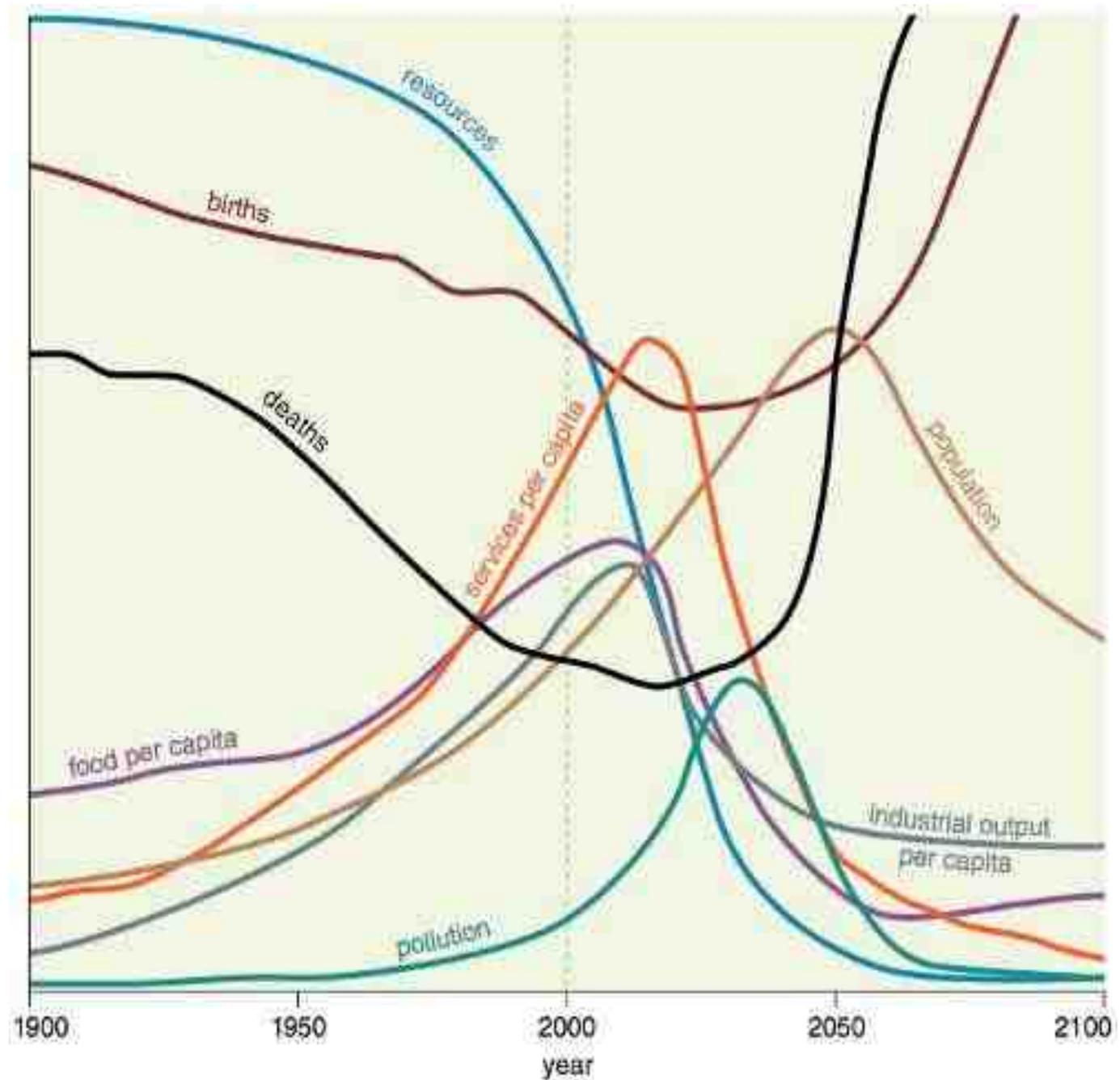


Time

# System dynamics simulation of The Seneca Effect

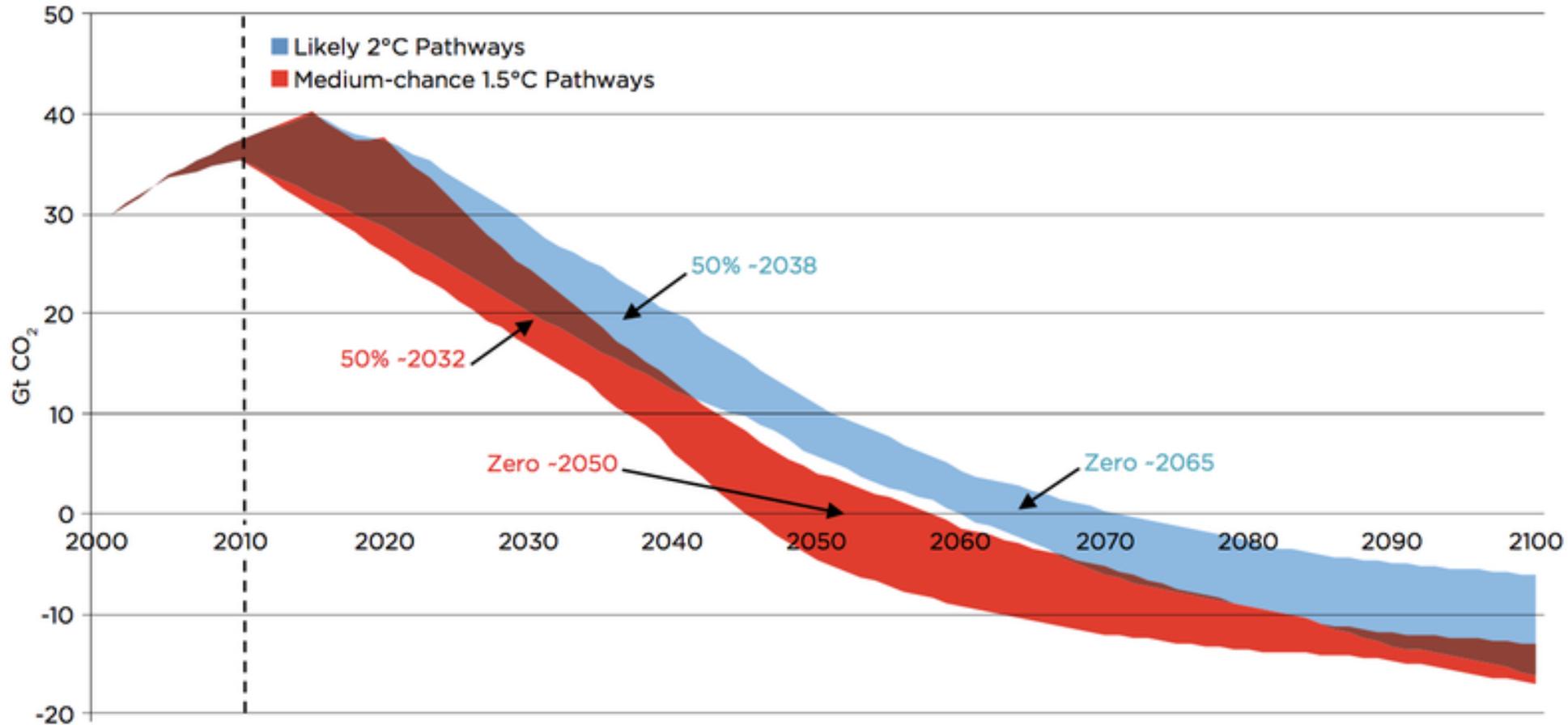


# The Limits to Growth, 1972



# Zero burning from 2050?

Figure 1: Range of Global Emissions Pathways in Scenarios Consistent with Likely Chance of 2°C or Medium Chance of 1.5°C<sup>18</sup>



Sources: Joeri Rogelj et al

# Energiewende

*Energy* in truth stands not beside but entirely above all other commodities.... With *energy* almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times.

William Stanley Jevons, 1866



## **The energy transition: necessary conditions**

**1. Use fossil energy to build the renewable infrastructure that will replace fossil energy**

**2. Do not exceed the safe limit of emissions**

**3. During the transition, maintain the minimum necessary energy services to society**



Whoever sows sparingly will also reap sparingly, and whoever sows bountifully will also reap bountifully.

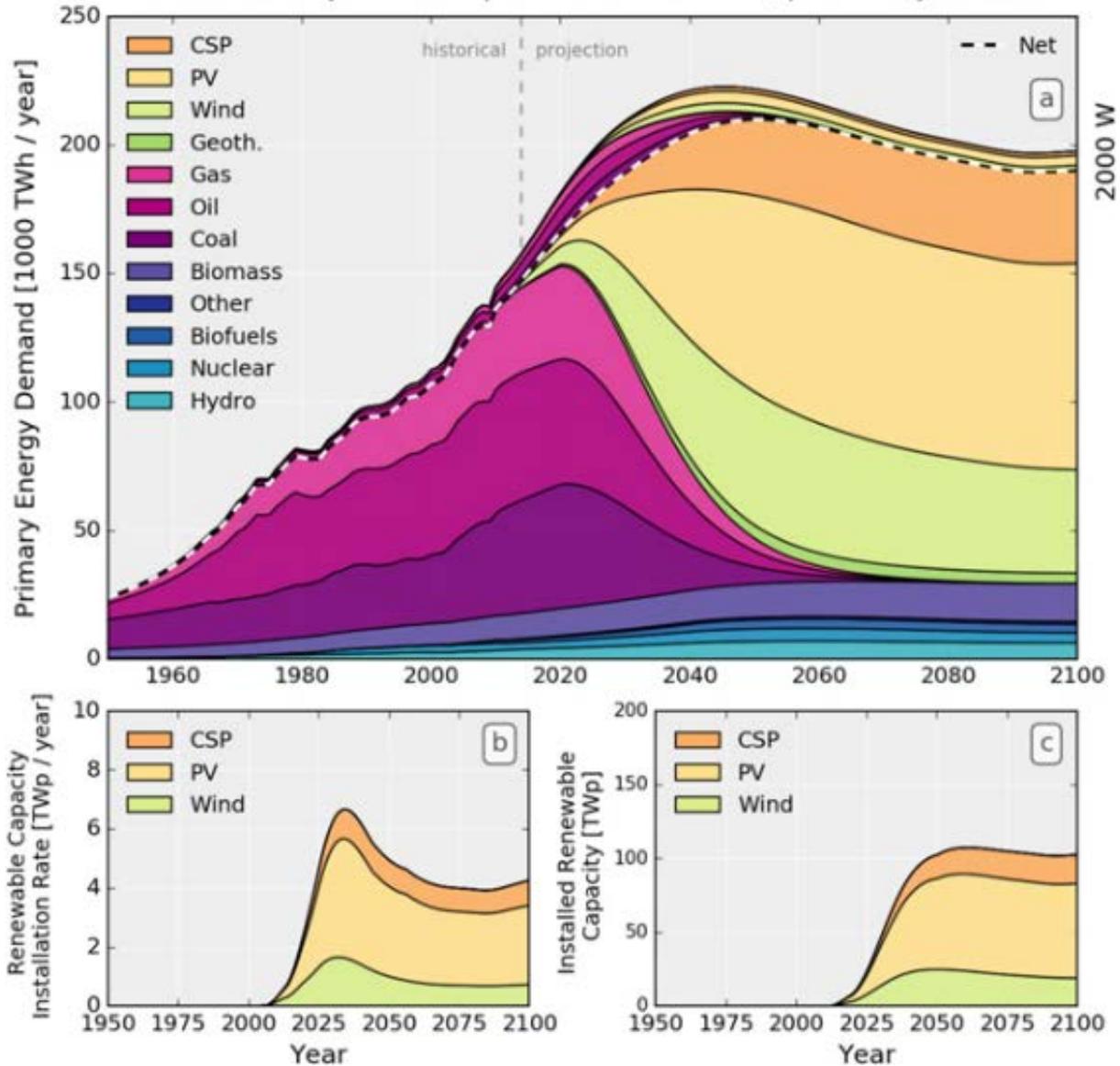
Corinthians 9:6



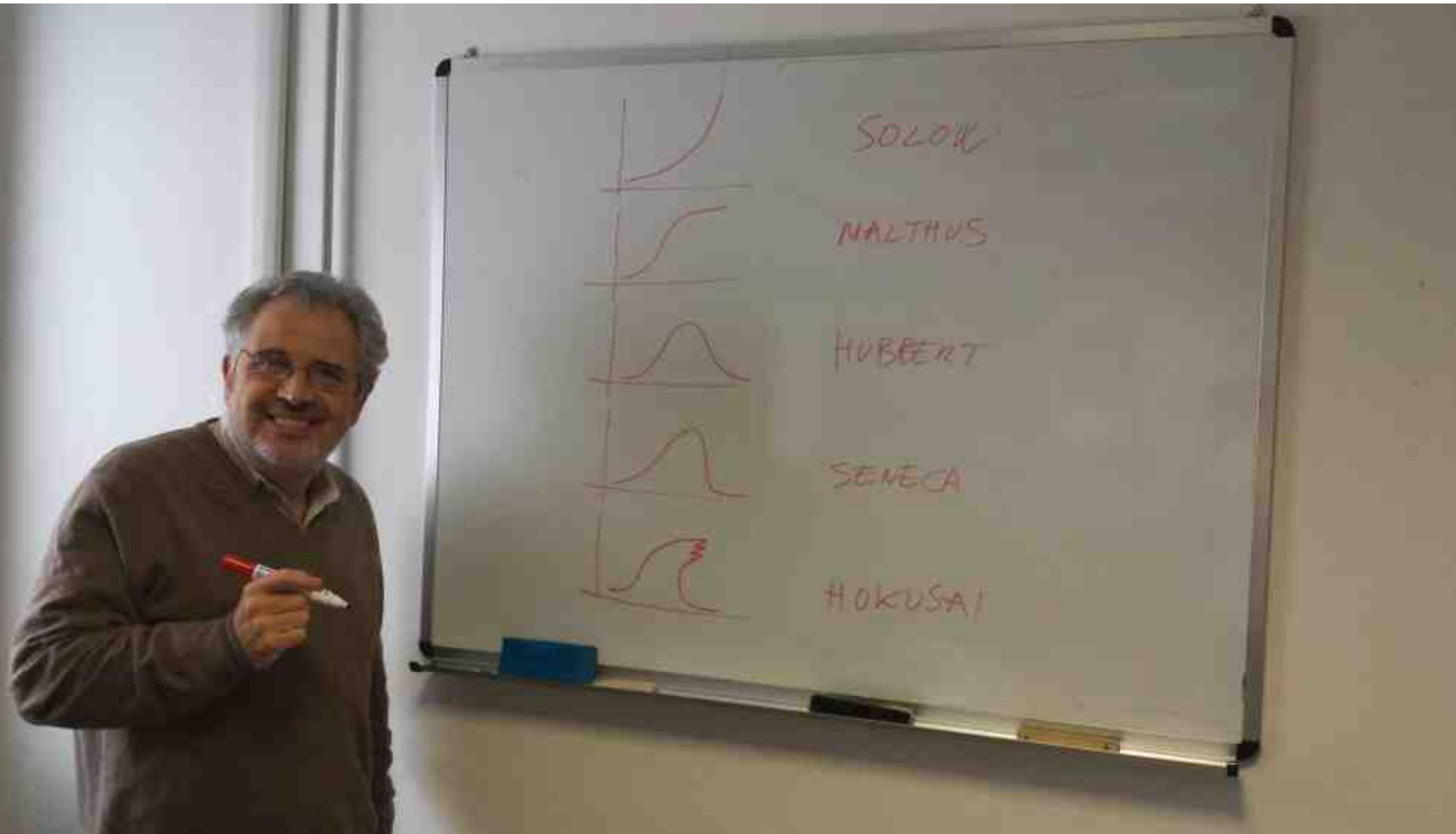
## Detailed Sustainable Energy Transition Path

Fossil phase-out: 2020 - 2075 | Emissions cap: 990 GtCO<sub>2</sub>

EROEI = 20 in year 2014 | Demand = 2000 W / person in year 2100



Thanks for your attention!



# *Cassandra's Legacy*



[www.cassandraleadership.blogspot.com](http://www.cassandraleadership.blogspot.com)

*Listen! for no more the presage of my soul,  
Bride-like, shall peer from its secluding veil,  
But as the morning wind blows clear the east,  
More bright shall blow the wind of prophecy,  
And I will speak, but in dark speech no more.*

(Aeschylus, Agamemnon)