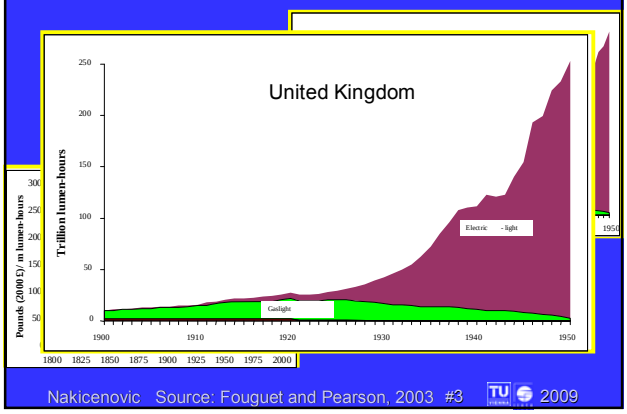
Dynamics of Technology Innovation and Diffusion

Nebojša Nakićenović
International Institute for Applied Systems Analysis
Technische Universität Wien
naki@iiasa.ac.at

Santa Fe Institute, Summer School on Global Sustainability – 22 July 2009

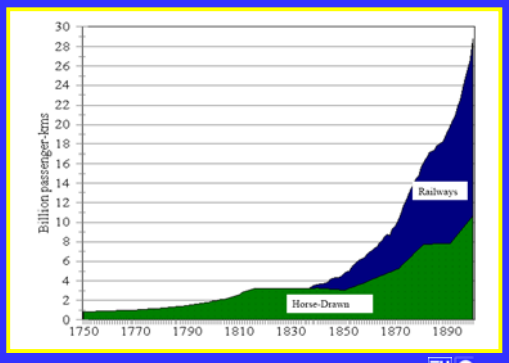
The Example of Lighting



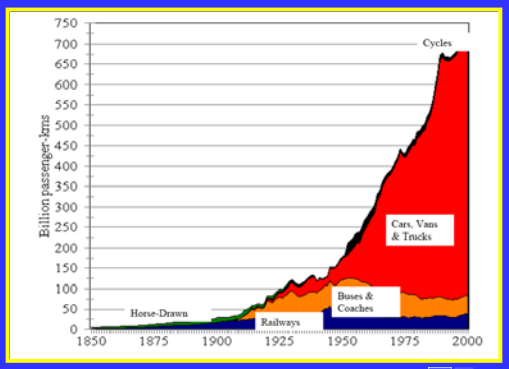
Technological Change: Dynamic, Cumulative, Systemic and Uncertain

- Incremental – gradual (continuous) and cumulative improvements
- Abrupt – radical, discontinuous and disruptive as "gales of creative destruction"

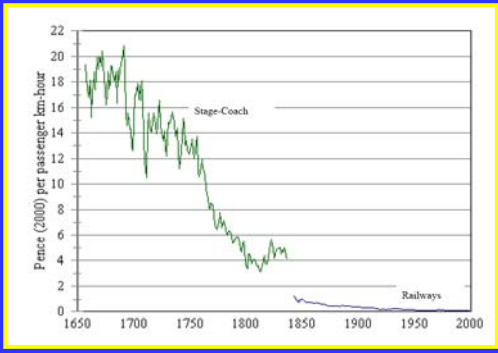
Use of Passenger Transport
(per passenger-kilometer)



Use of Passenger Transport
(per passenger-kilometer)

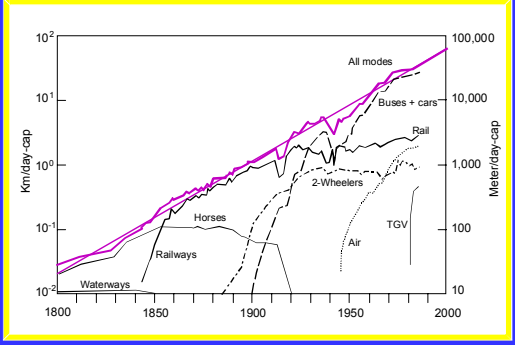


Price of Passenger Transport
(per passenger-kilometer-hour)



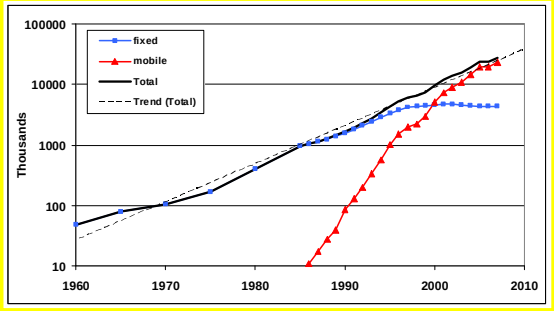
Nakicenovic Source: Fouguet and Pearson, 2003 #7 TU 2009

France – Mobility by Travel Mode
(passenger-kilometers per day per person)



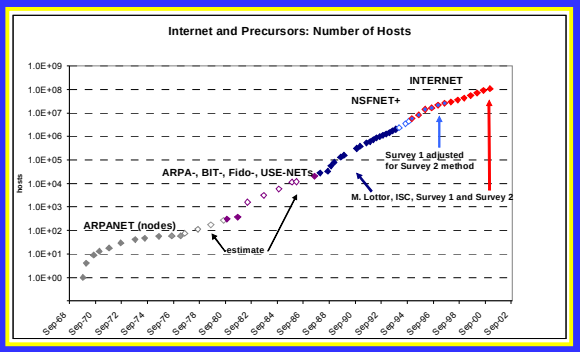
Nakicenovic Source: Grübler, 1998 #8 TU 2009

ITU Malaysia

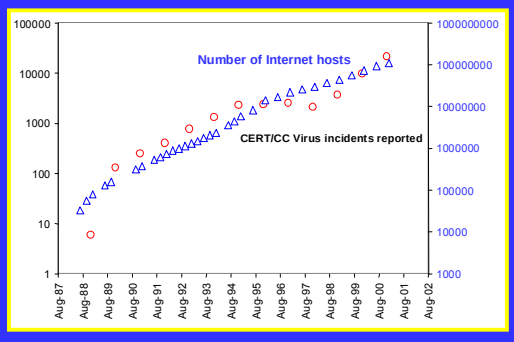


Nakicenovic Source: Grübler, 2009 #9 TU 2009

Growth of Interconnectivity

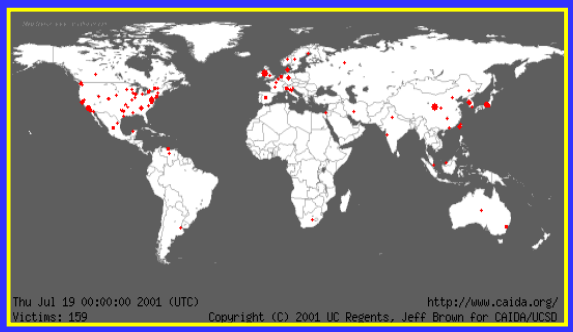


Virus Attacks and Network Growth



Data: Hostscount: M. Lottor, ISC, 1986-2001. Virus Incidents: CERT Coordination Center, Carnegie Mellon University.

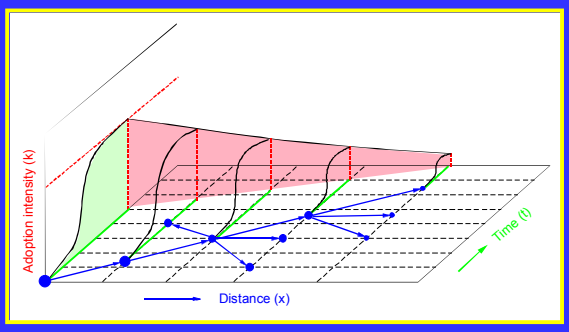
The Outbreak of Code Red Worm
A Spatial Diffusion Animation



Source: David Moore, CAIDA, 2001.
http://www.caida.org/analysis/security/code-red/newframes-small-log.gif

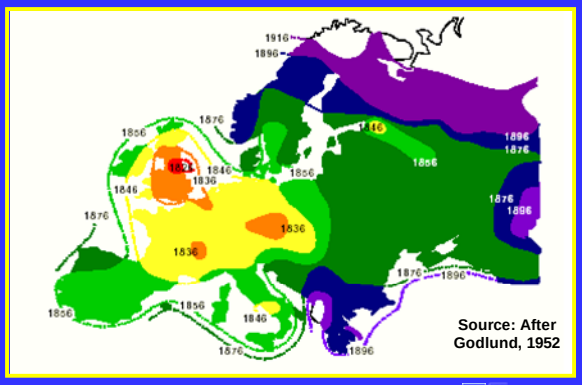
Diffusion in Space and Time

A Simple Conceptual Diffusion Model



Nakicenovic Source: Morill, 1968 #13 2009

Spatial Diffusion of Railways in Europe

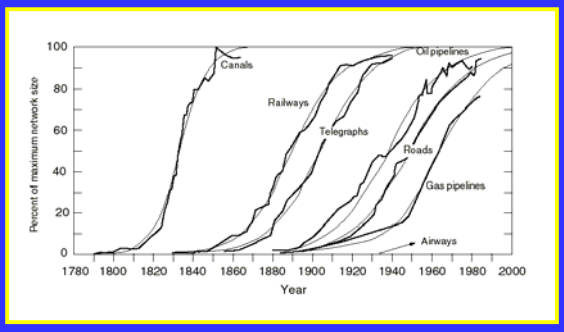


Nakicenovic Source: Grübler, 1998 #14 2009

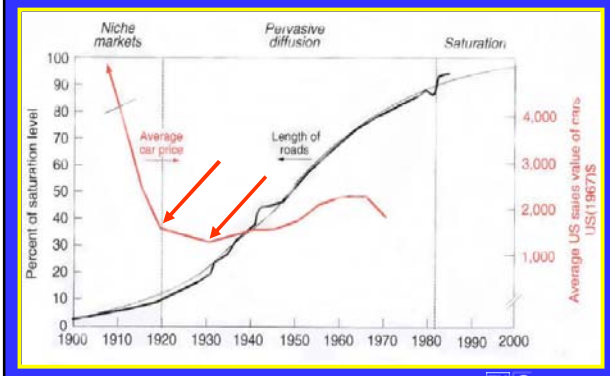
A Chronology of UK Railways

- **1769 Watt patents low-pressure steam engine -- invention**
- 1800 Watt patent expires
- 1820 40 km private horse railways
- **1824 Stevenson builds first locomotive plant -- (innovation)**
- 1825 Stockton-Darlington railway line opens
- **1830 Opening of Manchester-Liverpool, national railway network: 157 miles (niche market)**
- 1845 3931 km railways (.2% of coal to London transported by rail)
- 1875 23,365 km railways (65% of London's coal arrives by rail) – diffusion midpoint
- 1920s: 32,846 km railways (70-80% of all goods and passenger traffic by rail) – saturation and onset of decline

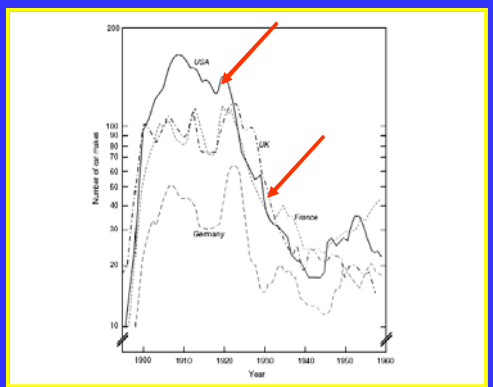
USA – Growth of Infrastructures



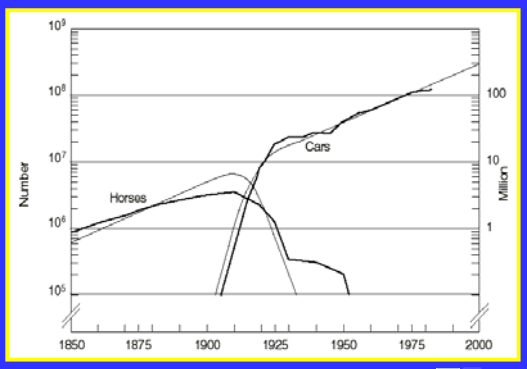
Car Prices and Diffusion



Number of Car Makes

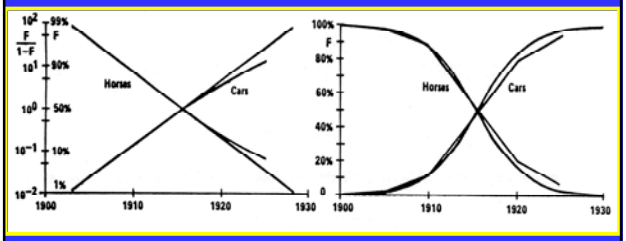


USA – Number of Horses and Cars

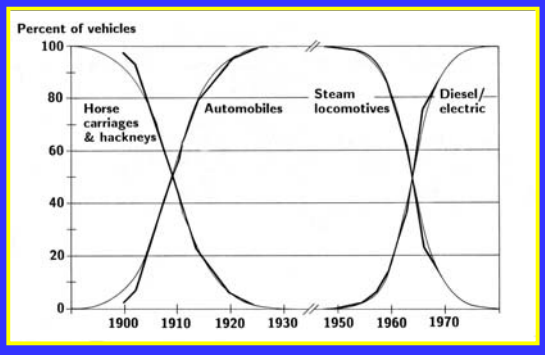


USA – Horses vs. Cars for Road Transport

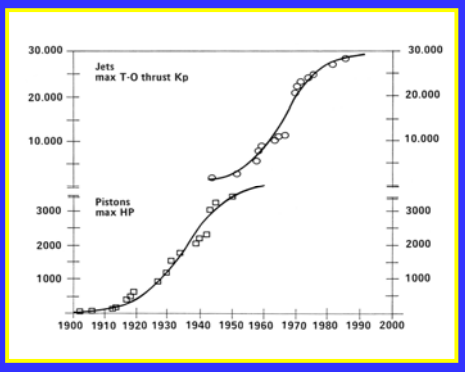
(fractional share F in total fleet; linear plot and logit transform)



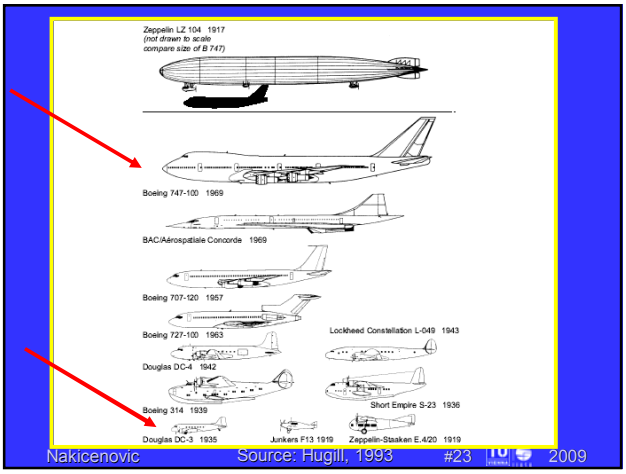
UK – Replacement within Vehicle Fleets



Aero Engines Best Performance



Nakicenovic Source: Grübler, 1987 #22 2009



Nakicenovic Source: Hugill, 1993 #23 2009

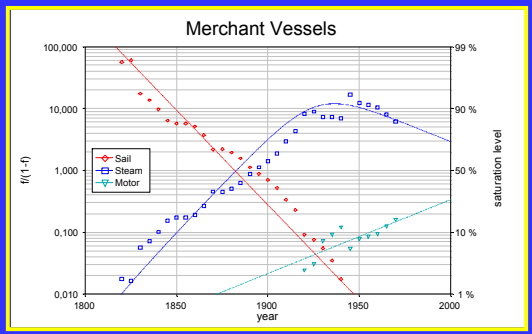
Energy Efficiency (%) and Emissions (g/km) for Horses, and Early and Contemporary Automobiles

	Horses	Cars (ca. 1920)	Cars (1995)
Engine efficiency, %	4	10	20
Wastes			
Solid	400	–	–
Liquid	200	–	–
Gaseous, including			
Carbon (CO_2)[d]	170	120	70
Carbon (CO)	–	90	2
Nitrogen (NO_x)	–	4	0.2
Hydrocarbons	2[e]	15	0.2

[d] Total carbon content of fuel
[e] Methane

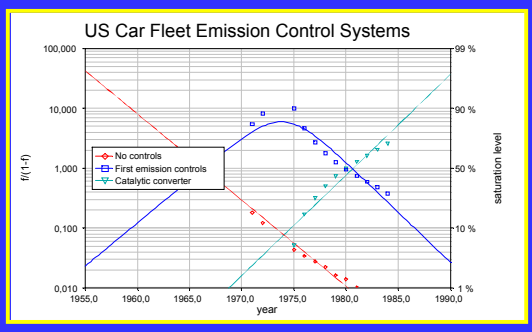
Nakicenovic #24 2009

US – Merchant Vessels



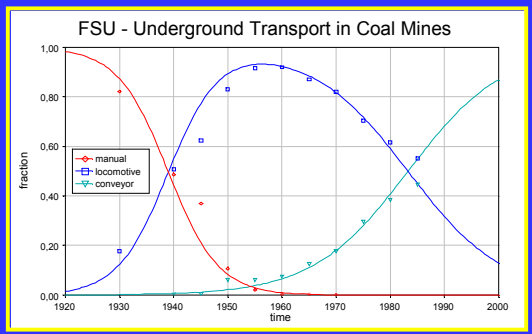
Nakicenovic Source: Nakicenovic, 1987 #25 TU 2009

US – Car Fleet Emissions Control



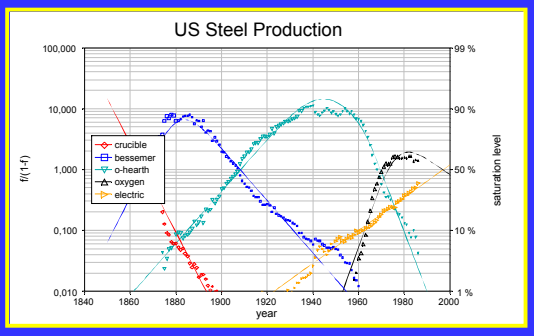
Nakicenovic Source: Nakicenovic, 1987 #26 TU 2009

FSU – Transport in Coal Mines



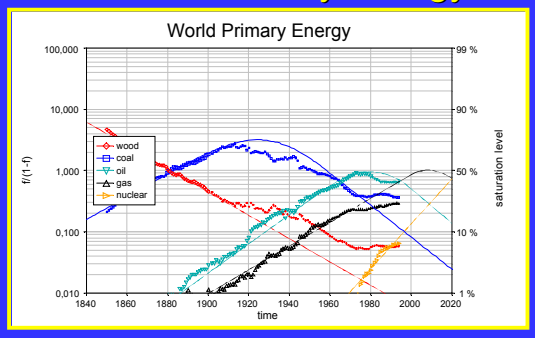
Nakicenovic Source: Grübler, 1990 #27 TU 2009

US – Steel Production Methods



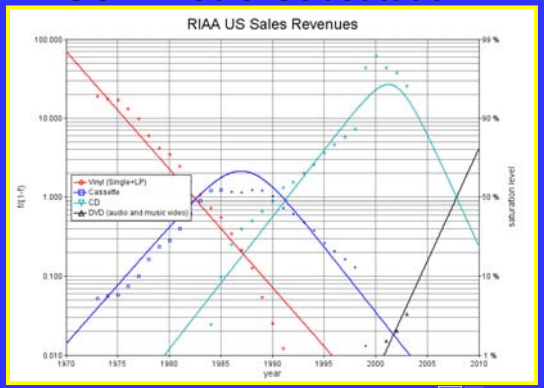
Nakicenovic Source: Grübler, 1990 #28 TU 2009

World – Primary Energy

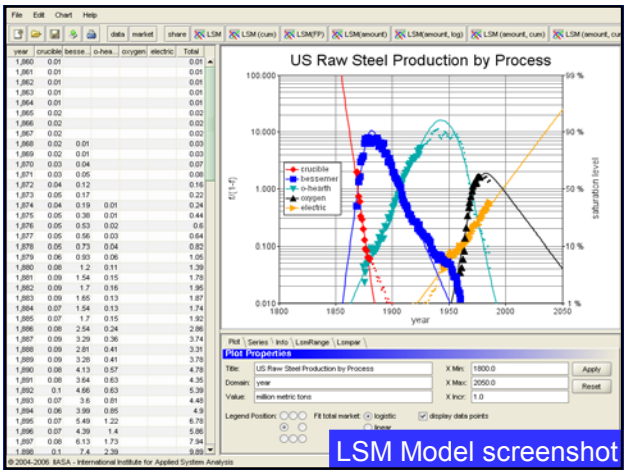


Nakicenovic Source: Nakicenovic, 1979 #29 TU 2009

US – Media Substitution

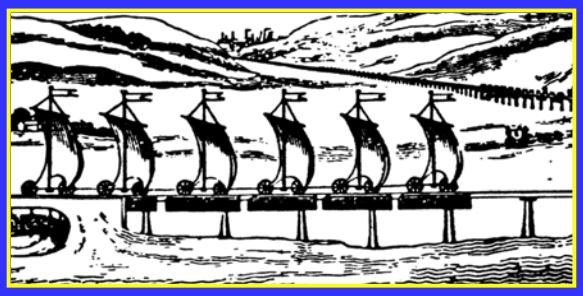


Nakicenovic #30 TU 2009



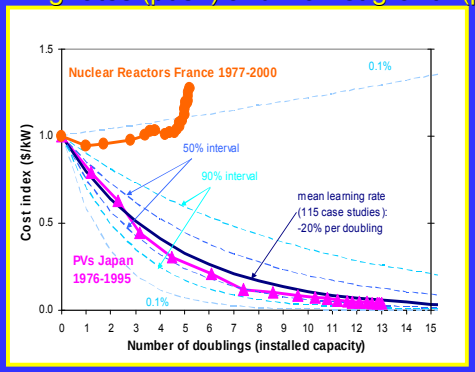
Vision of a Sailing Railway

Monorail using sails proposed by Henry R. Palmer in 1828



Nakicenovic Source: Marshall, 1938 #32 2009

Technological Uncertainties: Learning rates (push) and market growth (pull)

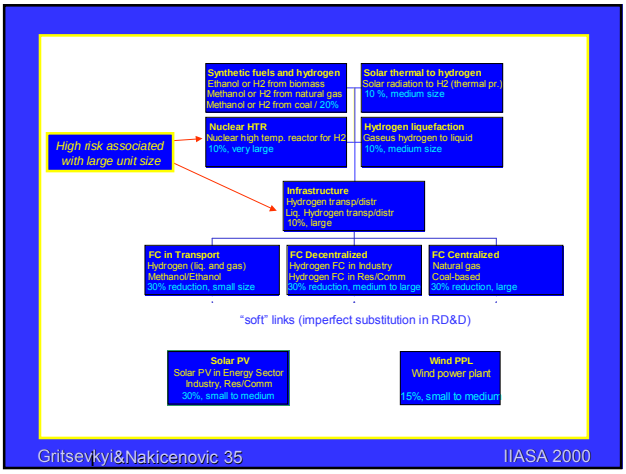


Nakicenovic #33 2009

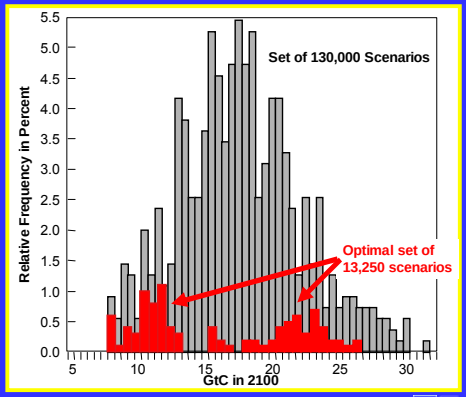
An "Endogenous" TC Approach

The objective is to explore:

- Uncertain technology characteristics as well as learning rates
- Sequential resolution of uncertainty with one deterministic demand
- Ensembles with different systems costs, development paths and technology portfolios



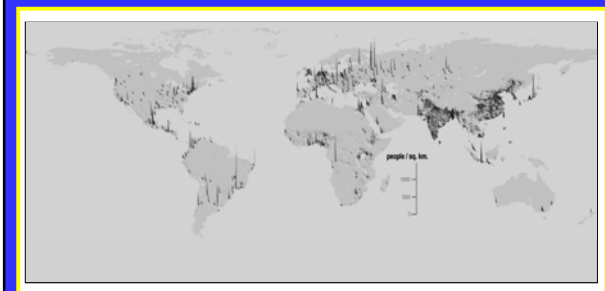
Energy Scenarios with Technological Uncertainty



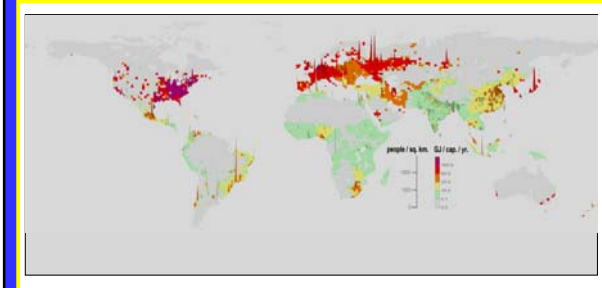
Spatial Heterogeneity

- New emphasis in technology studies
- Spatial diffusion and heterogeneity in adoption environment
- Spatially explicit scenarios (downscaling and modeling)
- Urbanization

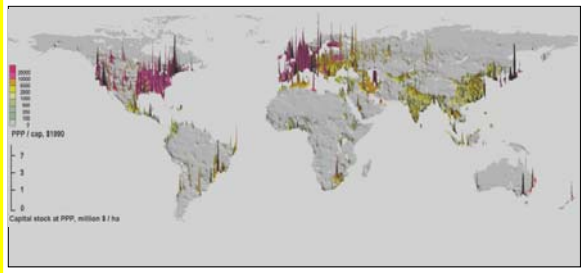
Global Population



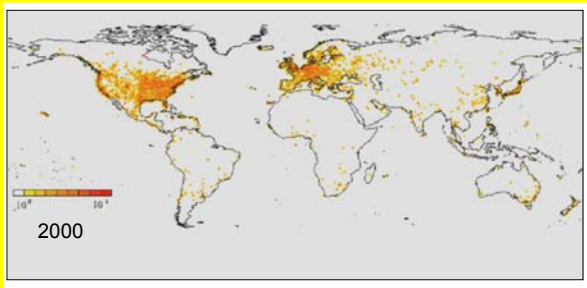
Global Final Energy



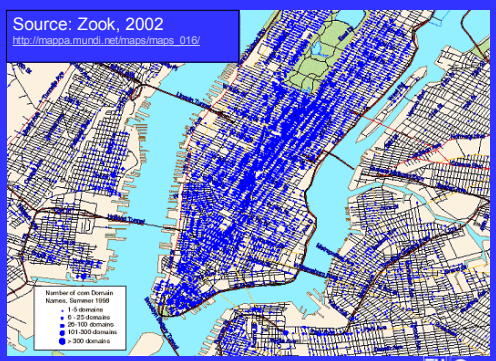
Capital Stock in PPP



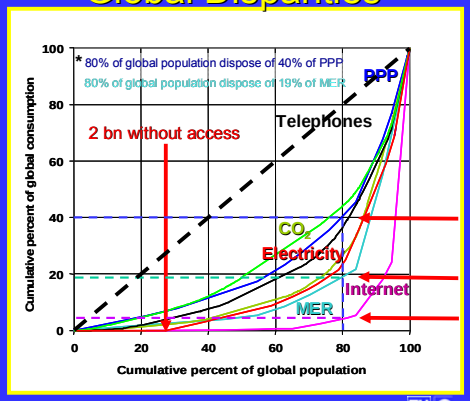
Internet



Heterogeneity in Technology Diffusion: Internet Domains



Global Disparities



Food for a Week, Darfur Refugees, Chad

Food for a Week, Germany