Inducing Socio-Technological Revolution in Energy Network Investment to address Climate Change: An Evolutionary Institutional Economics Model of Agent Behaviour

Nicholas Howarth

Oxford University Centre for Work, Employment and Finance; and
Oxford University Centre for the Environment

nicholas.howarth@chch.ox.ac.uk

The Challenge

Stabilization of CO_2 at ≈ 550ppm by 2050

- ⇨ ≈ 45% reduction off current levels

But

World energy demand increasing ≈ 50% by 2030

- ⇨ An *induced* technological revolution in energy networks

Why an evolutionary institutional economics approach?

Economists traditionally evaluate instruments for environmental policy under ideal theoretical conditions; however, those conditions are seldom met in practice, and instrument design and implementation must take political realities into account. In reality, policy choices must be both acceptable to a wide range of stakeholders and supported by institutions, notably the legal system. Other important considerations include human capital and infrastructure as well as the dominant culture and traditions (IPCC, 2007).

Policies which work for one sector may be inappropriate for another, although a common price is still needed across sectors for efficiency in the costs of mitigation. The relationship between climate change policy and other objectives, such as energy security and local air pollution is also important. For instance… regulation may be more effective in countries with a culture of using command and control methods, or where there are political or administrative problems with raising taxes or with tax collection. Specific national circumstances, including constitutional structures, the stability of political institutions and the quality of legal infrastructures and enforcement, play a key role…

Stern Review, 2007

Key features of the agent-based evolutionary institutional model developed in this paper

- Can model (energy) system change as distinct from system optimisation
- Explains prevalence of multiple possible technological equilibria across different nations energy systems
- Conceptually deals with issues of technological lock-in or path dependency
- Policy focus is on effectiveness at driving system transformation, rather than on more abstract notions of optimality or efficiency

Institutions defined:

They are the forms of social and technological organisation which through the operation of formal laws, technological constraint or informal norms such as tradition and custom frame agent behaviour and investment around a ‘common knowledge’ of what expected (risk adjusted) returns are

FIVE TECHNOLOGICAL REVOLUTIONS IN 240 YEARS (From Carlotta Perez's model)

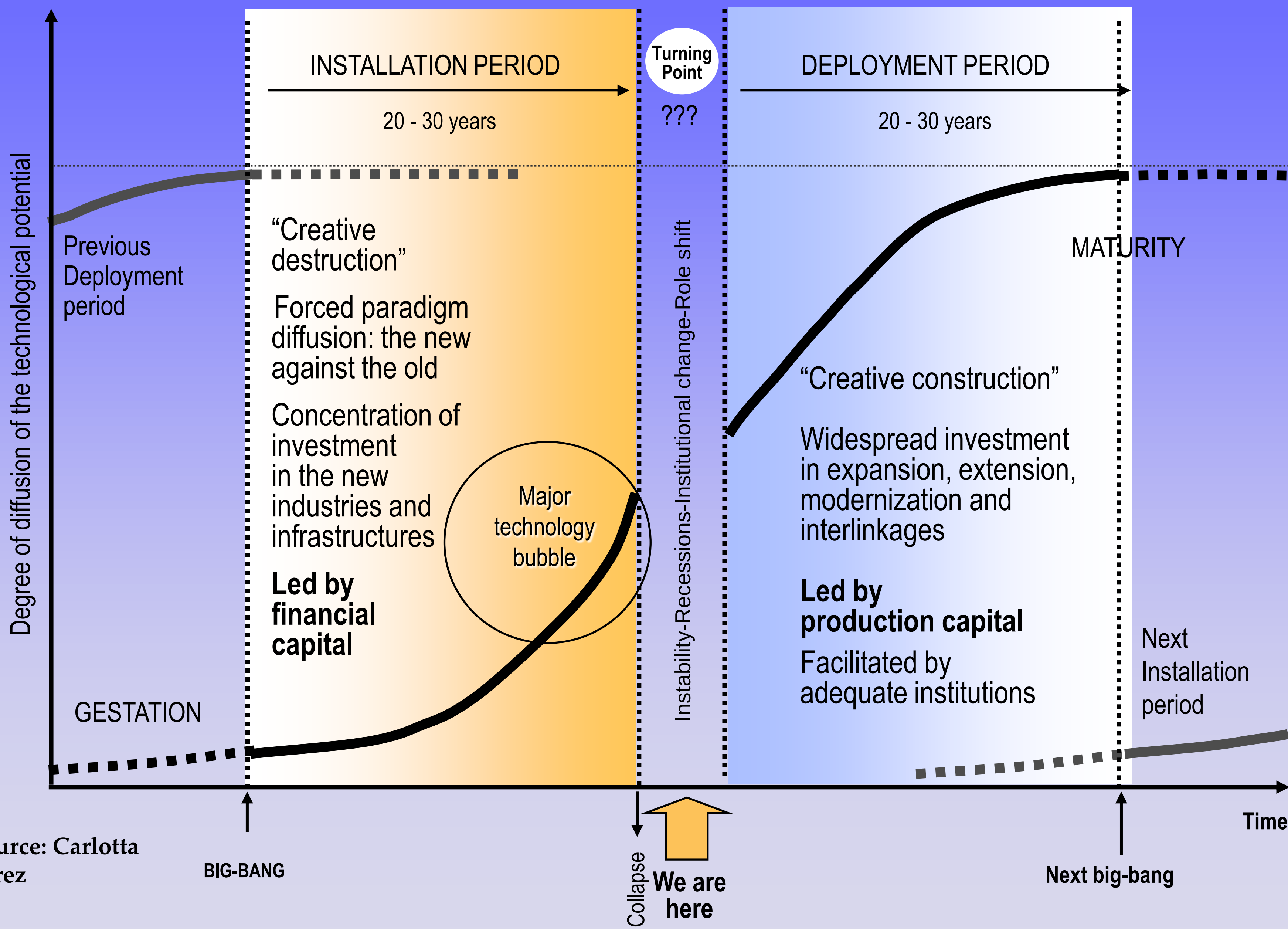
Each begins in a core country…

Core country	Year	Revolution
Britain	1771	The 'Industrial Revolution' (machines, factories and canals)
Britain	1829	Age of Steam, Coal, Iron and Railways
Britain USA Germany	1875	Age of Steel and Heavy Engineering (electrical, chemical, civil, naval)
USA	1908	Age of the Automobile, Oil, Petrochemicals and Mass Production
USA	1971	Age of Information Technology and Telecommunications
USA? Europe? Both? Other?	200??	Age of Biotech, Nanotech, Bioelectronics and new materials???

…and drives a **GREAT SURGE OF DEVELOPMENT** of 40 to 60 years

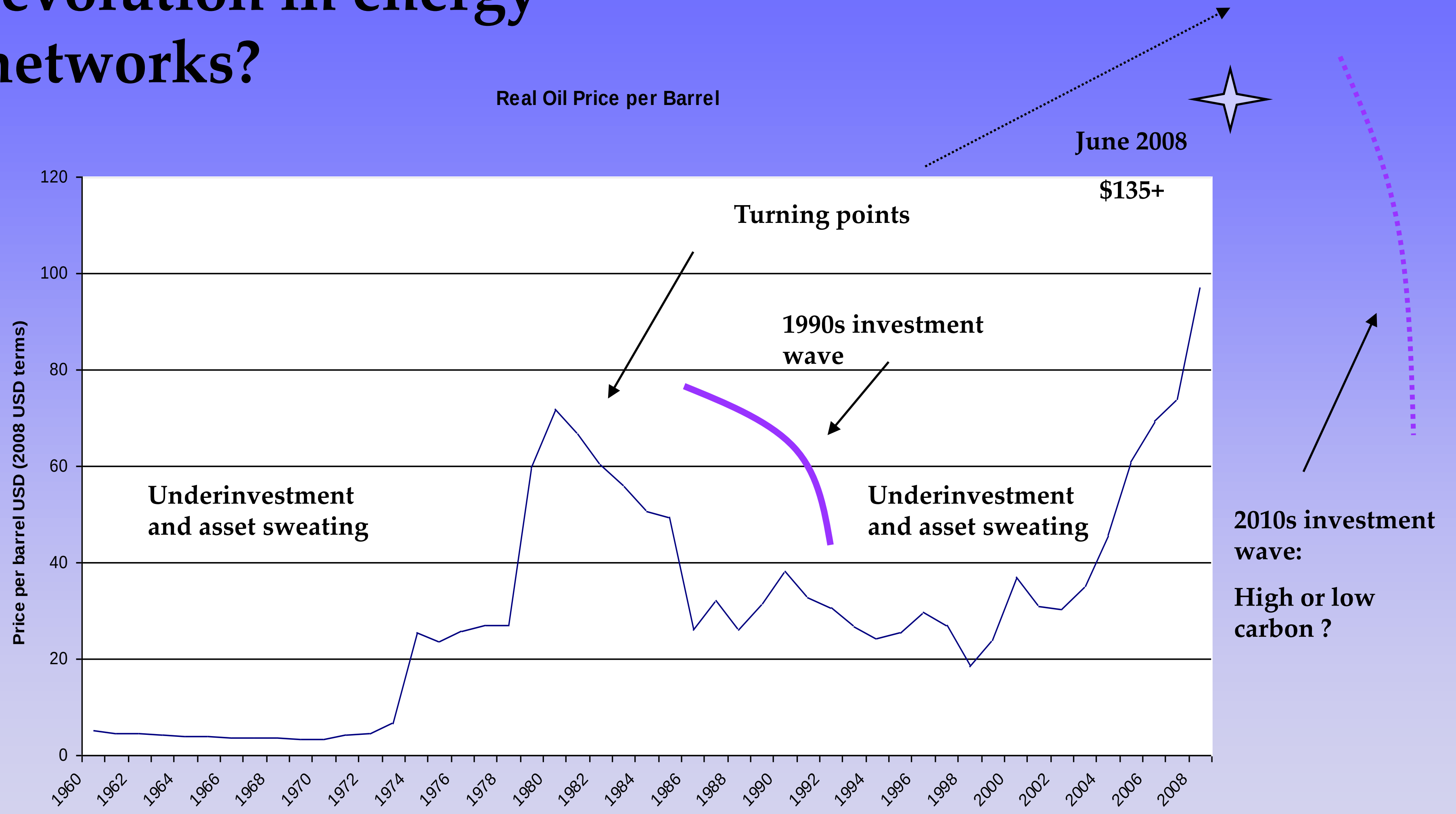
Due to the difficulty of social absorption of such major transformations

EACH GREAT SURGE IS BROKEN INTO TWO DIFFERENT PERIODS



Source: Carlotta Perez

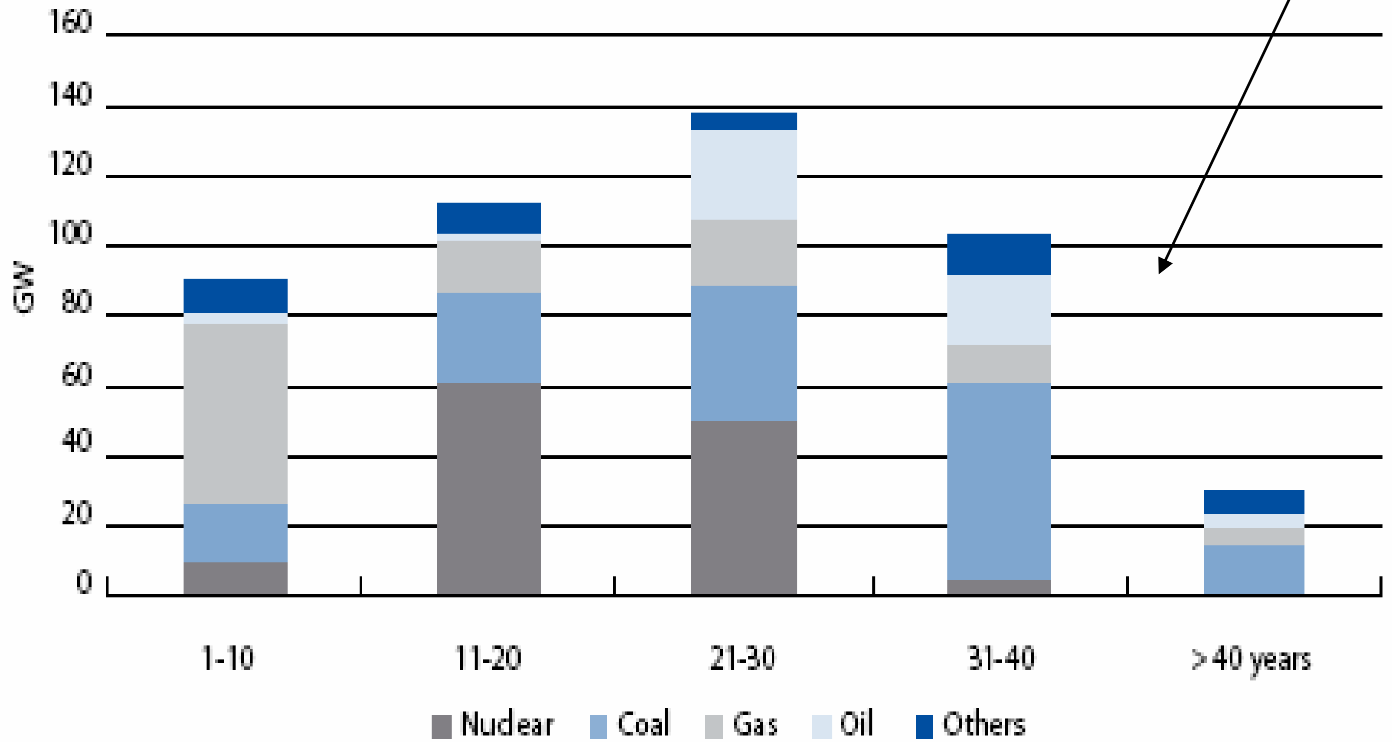
The foundation of a new revolution in energy networks?



Source: Oil price data IEA

Physical networks need replacing and new capacity brought online

Turning Point



Source: Güldner (2007).

A new set of policy and legal institutions are being laid out

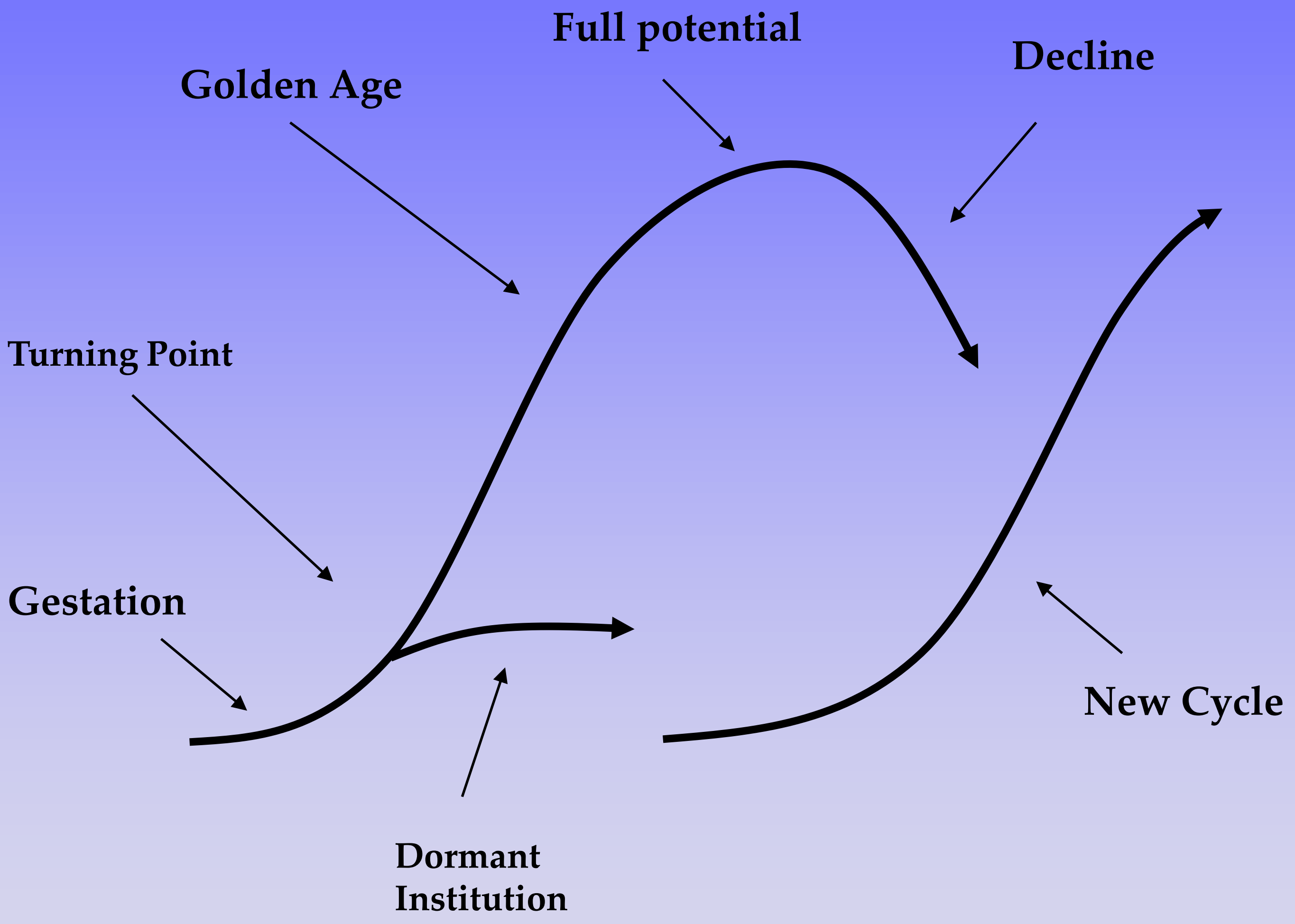
- At least 20% GHG reduction by 2020 compared with 1990, 30% if other developed countries adopt similar commitments

- At least 20% consumption of renewables in primary energy by 2020 (up from 7% in 2005)

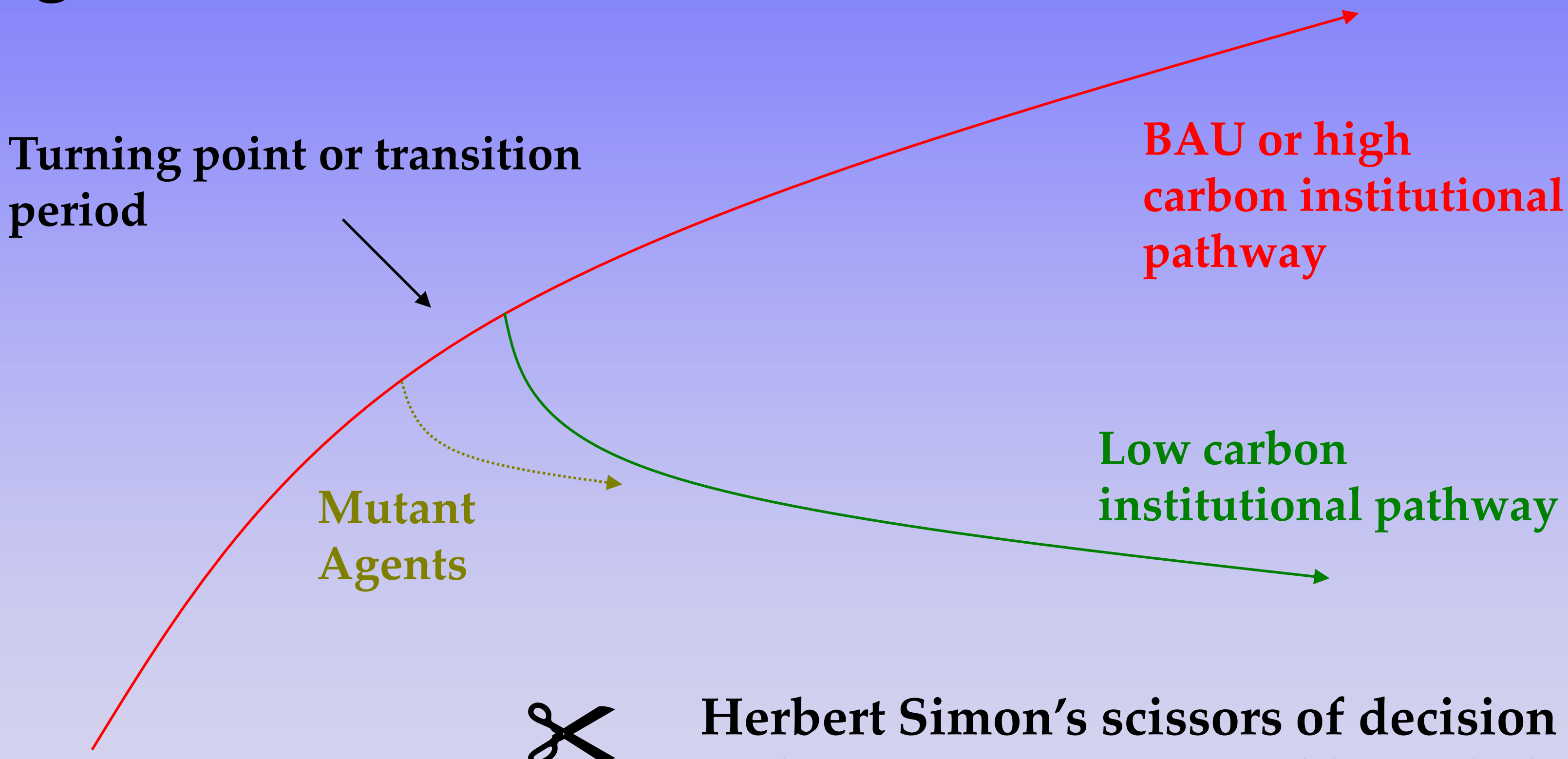
- A 20% *additional* improvement in energy efficiency by 2020

- Plus 12 large scale Carbon Capture and Storage Plants by 2020

The rise and fall of institutions

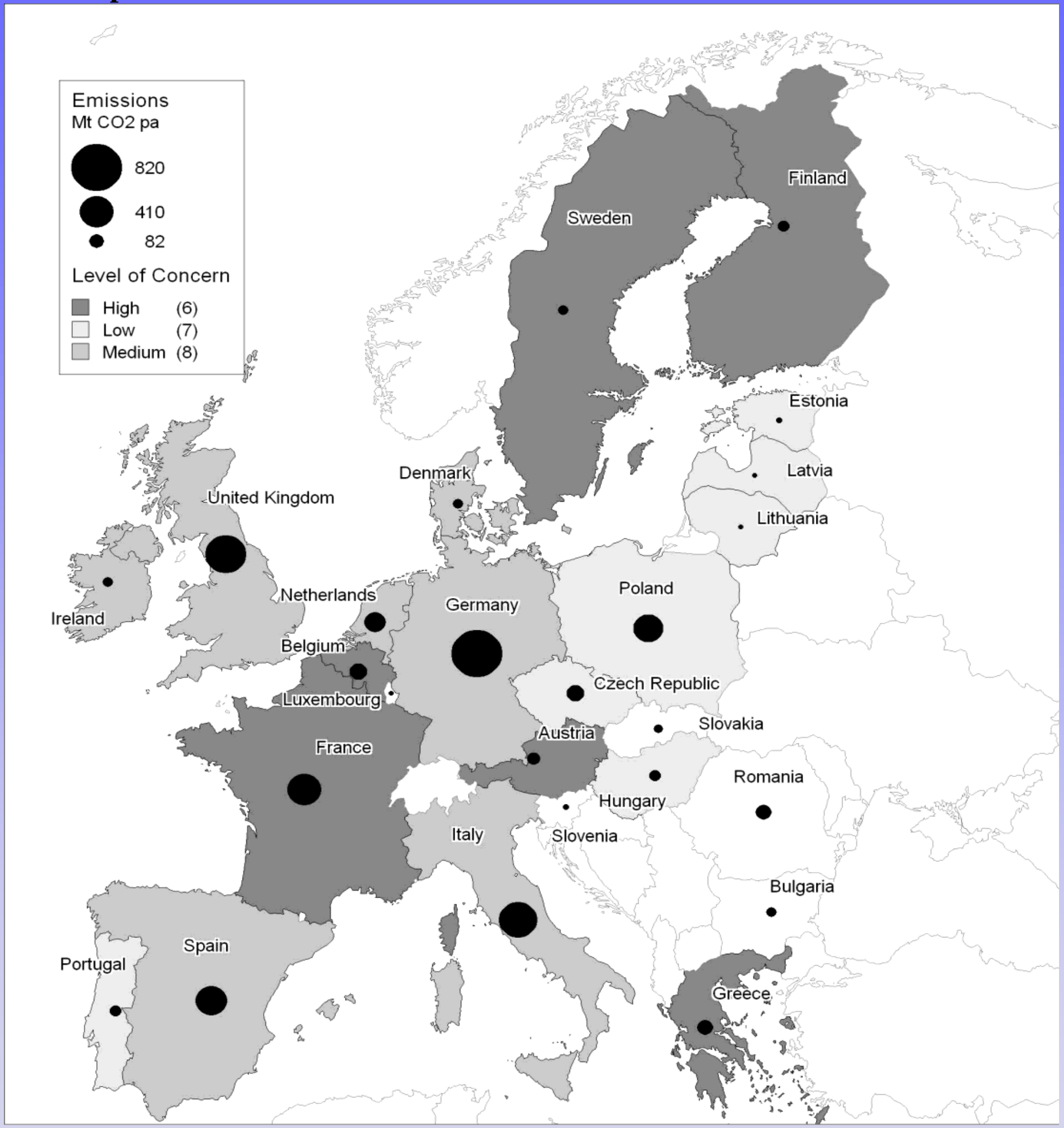


Breaking from path dependency: Institutional change driven by mutant actors and competitive forces across the social, economic, political and organisational domains



Herbert Simon's scissors of decision making – institutions and bounded rationality interacting

Figure 3: Public attitudes towards climate change and annual CO_2 emissions in Europe



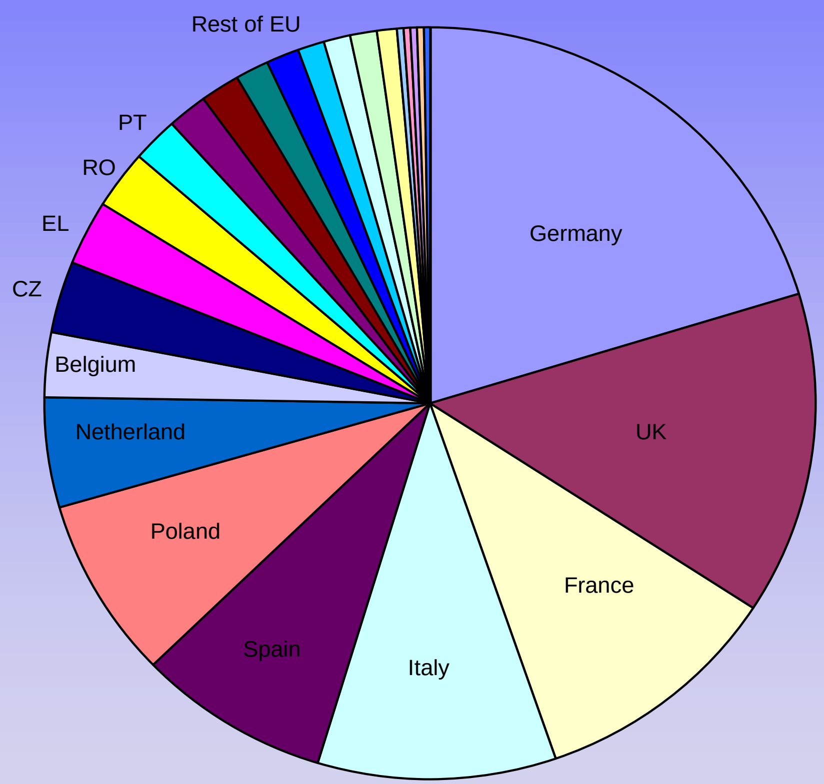
Sources:
Public Opinion Data: Neilson, ECI (2007)
EEA Online Emissions Database, for the year 2005 extracted Jan 08

Institutional forces:

Level of concern About climate change

A variable geometry of responsibility

Share of Total 2005 EU Emissions

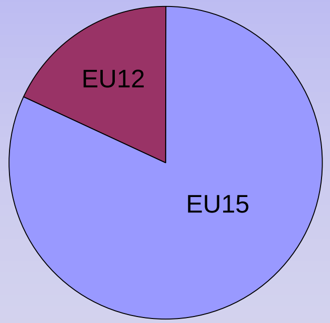


Source: EEA, 2006

Total EU27 Emissions

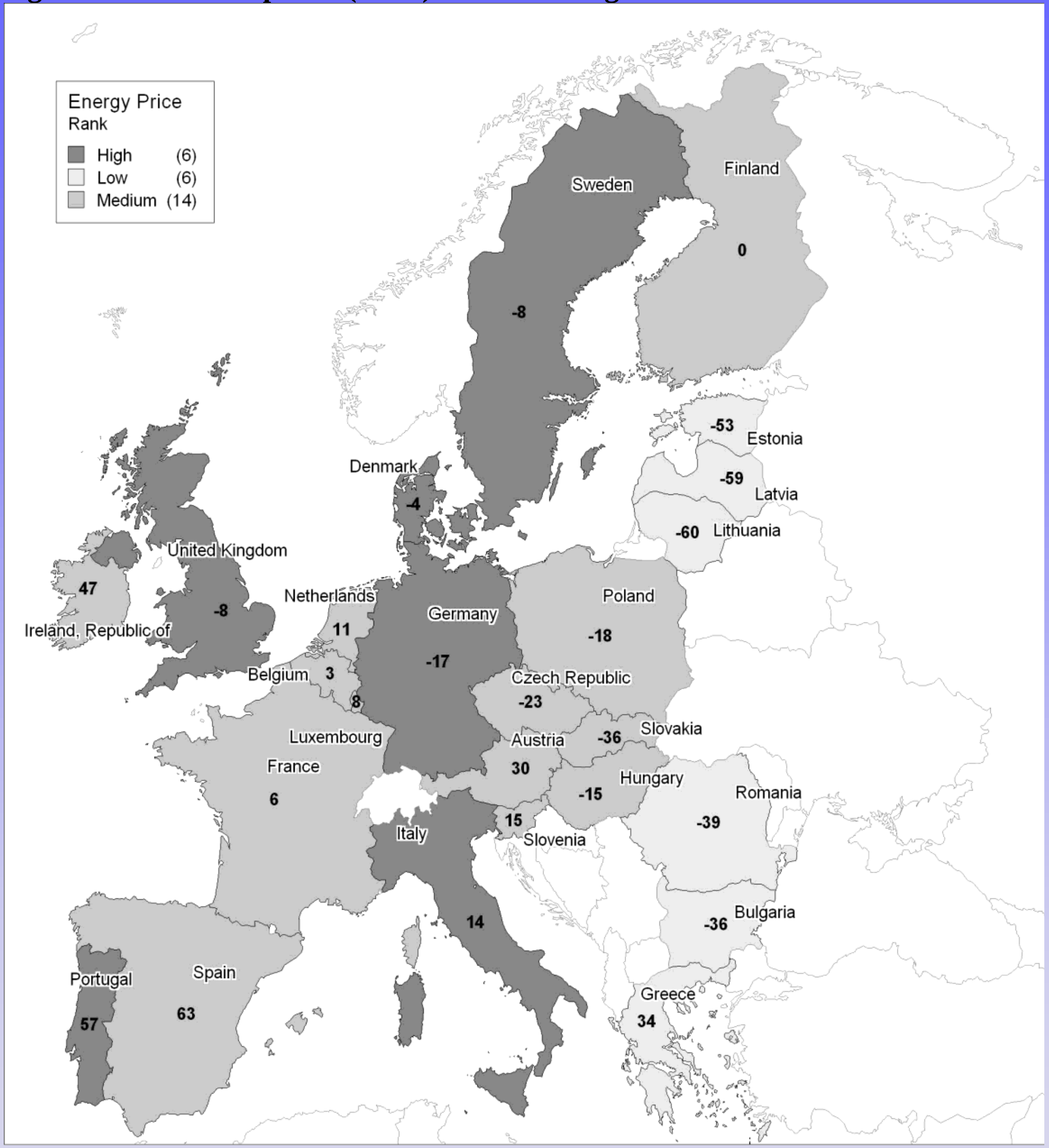
4726MtCO2e

Share of Total 2005 Emissions



2005 % total EU Emissions		Cumulative
Germany	20.42%	20.42%
United Kingdom	13.86%	34.29%
France	10.38%	44.66%
Italy	9.98%	54.64%
Spain	8.27%	62.91%
Poland	7.76%	70.67%
Netherlands	4.54%	75.21%
Belgium	3.04%	78.24%
Czech Republic	2.98%	81.23%
Greece	2.83%	84.06%
Romania	2.46%	86.52%
Portugal	1.89%	88.41%
Austria	1.61%	90.02%
Hungary	1.61%	91.63%
Ireland	1.47%	93.10%
Sweden	1.33%	94.43%
Denmark	1.32%	95.75%
Bulgaria	1.10%	96.85%
Slovakia	1.01%	97.86%
Finland	0.81%	98.67%
Slovenia	0.31%	98.99%
Lithuania	0.28%	99.27%
Estonia	0.27%	99.54%
Luxembourg	0.26%	99.80%
Cyprus	0.21%	100.01%
Latvia	-0.08%	99.93%
Malta	0.00%	99.93%

Figure 4: Fossil fuel prices (taxes) and the change in CO_2 emissions



Sources
Price data: Author's calculations based on (IEA, 2007) and (EU, 2006)
Emissions data: EEA Online Emissions Database, 1990-2005, extracted Jan 2008

Institutional forces:

Relative fossil fuel prices across Europe

EIB Investment in Combating Climate Change Technologies 2000-2007

Table 1 EIB Energy and Climate Change Investments, 2000-2007[1]

		Investment (€ m)	% Total (€25,783 m)	Number of projects
Renewable energy	Wind	2,162	8.4	22
	Solar	520	2.0	4
	Hydro	594	2.3	8
	Other	502	1.9	10
Fossil fuel generation and mining	Gas	5,812 (2,102)	22.5 (8.1)	32 (8)
	Coal	1,125 (140)	4.3 (0.5)	10 (3)
	Oil	954 (180)	3.7 (0.7)	8 (2)
	Combined Heat and Power	1,439 (1,155)	5.6 (4.5)	20 (15)
Transmission and distribution	Electricity	8,980 (903)	34.8 (3.5)	50 (9)
	Gas	3,956 (148)	15.3 (0.5)	20 (2)
Other		445	1.7	10

1. In addition to renewable energy projects, those in parenthesis were designated as contributing to EIB's climate change objectives. Values in parenthesis are a subset of the total spent in that category above.

- €8.2 billion in a €26 billion energy portfolio
- 2/3rds Investment occurs in Spain, Italy and the UK
- Transition to Gas dominates low-carbon investment, followed by wind and the combined heat and power
- Coal generation projects still important
- Price of wind projects inflated by shortage of suppliers and generous RE subsidies
- Heavy investment in transmission and distribution also important

Conclusions and implications for policy

- Carbon measurement - the creation and diffusion of an easily understood CO2 metric must be centre stage – particularly for long-term energy investment decisions.
- Carbon taxation is to be preferred over emissions trading
- An appreciation of the broader institutional milieu is important across nations in setting policies

Carbon measurement

- This should extend beyond narrowly defined carbon markets to be robust across different sectors, for example transport, electricity, heating; and be agent-based, for example from corporations, such as car manufacturers, power generators and banks to governments and households.
- It is necessary to capture the value that society places on reducing CO2;
- Enables Coasian solutions through the identification of property rights as a method of managing environmental externalities to emerge by facilitating communication between diverse agents in the socio-technological system;
- Builds capacity from the bottom up to manage and account for CO2 and is fundamental in managing risk in energy sector investment;
- Helps induce technical and social innovation in the same way the empirical method helped create a conducive milieu for the Industrial Revolution;
- Putting agent-based measurement centre stage in international agreements on climate change identifies opportunities for CO2 reductions and builds institutional capacity form the bottom up in a less confrontational way than top-down national government-based ‘targets and timetables’ approaches.
- Provides a robust institutional base for other combinations of policies such as carbon taxation, emissions trading or technology transfer agreements (for example a greater focus here would have mitigated the informational problems that continue to undermine the effectiveness of the EUETS).

Taxation preferred over emissions trading

- If the transformation to a low-carbon energy infrastructure is the objective, the forces of path dependency (such as network externalities, learning by doing and positive returns to scale) mean that by diluting the concentration of low carbon investment across often far flung geographic regions and sectors emission trading may reduce the likelihood of system change.

- Taxation arrangements can be set in a way to minimize social disruption while providing a strong signal to new investment by implementing a staged series of increasing carbon taxes over time with some contingency made for changes in the price of oil and other fossil fuels high-carbon energy so as to provide greater certainty for investment

(if oil prices more than double over a year what is the behavioural or political value of imposing extra tax in that year?!)

Considerations of the broader (non-climate) institutional milieu across nations and regions must be taken into account

- Dynamic institutional complementarities mean that it is combinations of institutions that act to induce agent behaviour toward low-carbon technology. For example, weak governance as measured by the World Bank's World Governance Indicators Project, might mean that the socio-technological system is less open to and has a lower capacity for change relative to systems with stronger governance.
- Existing technological infrastructure, financial and human capital are also important contingencies to take into account when assessing a system's capacity for change.

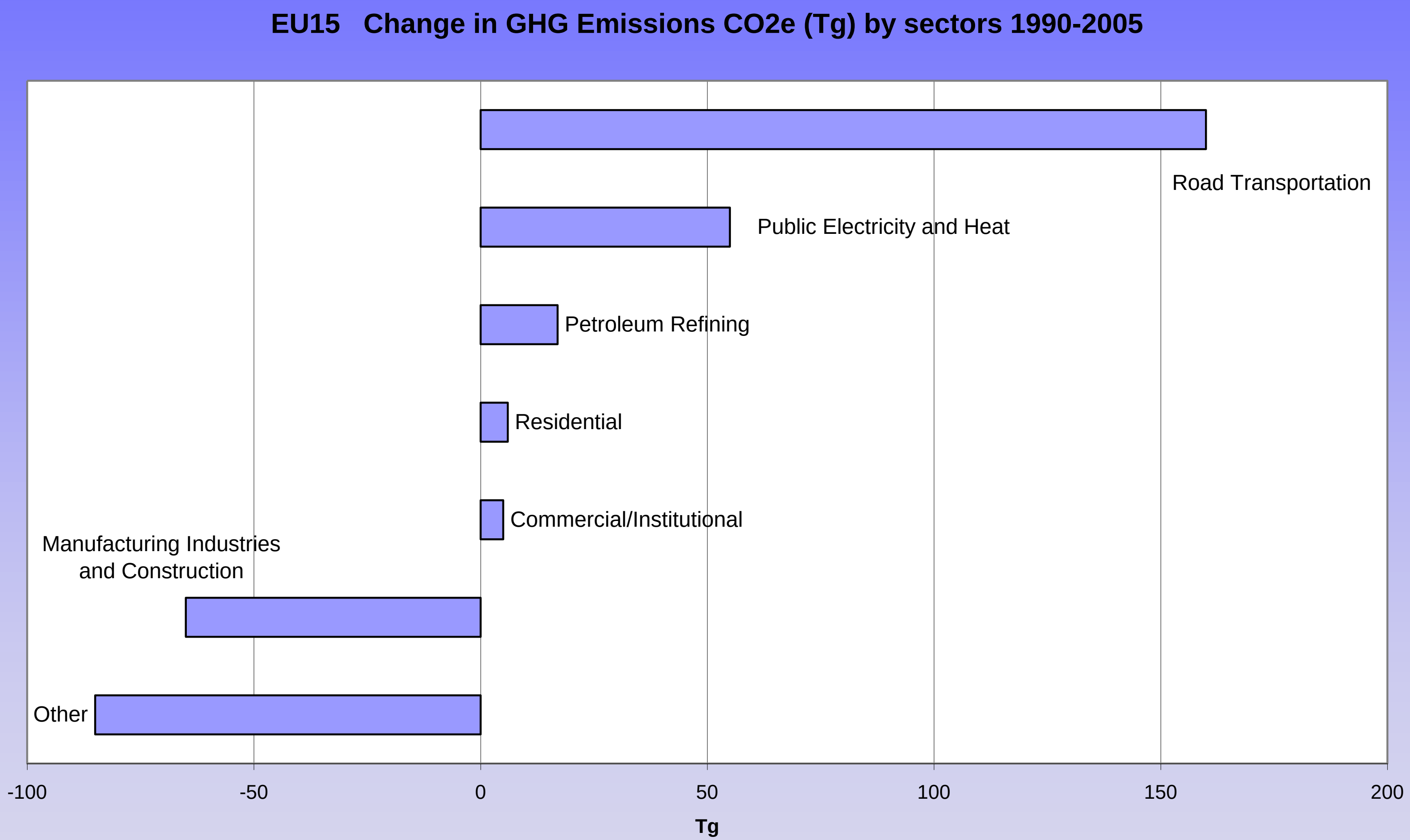
Summary conclusions

- Energy networks have entered a 'window' of opportunity for system change
- Due to the limited time to achieve goals, in contrast to other socio-technological revolutions this one must be *induced* with new policy, social and technological structures – active role for government
- Combinations of institutions are important eg. ICT, nanotech and biotech may provide the new structure – no silver bullet technology or policy
- Institutional analysis valuable – a bottom-up approach with focus on understanding system transformation, rather than marginal change – critical for long-term investment

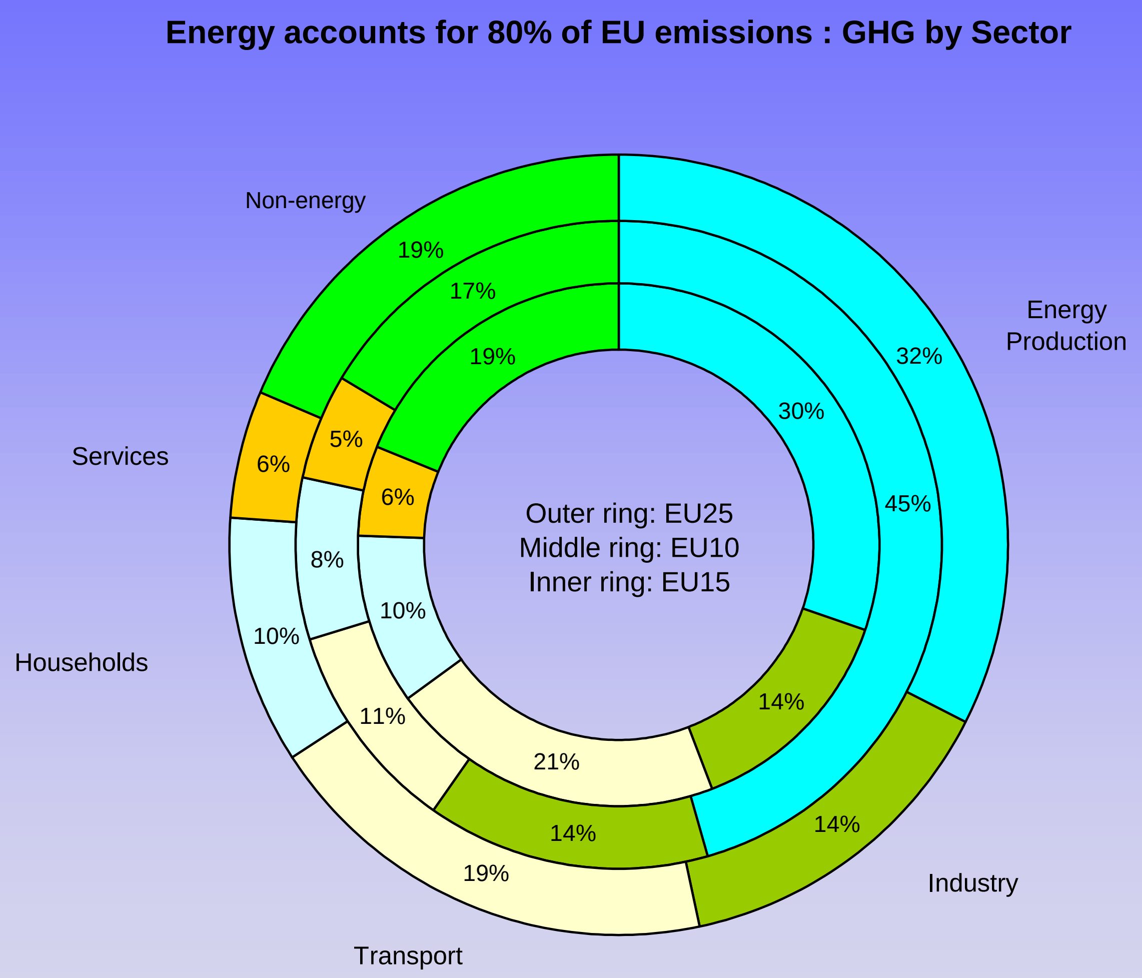
nicholas.howarth@chch.ox.ac.uk

Extra slides

Change in EU15 Energy Sector Emissions
Net change = +2.5% but not the whole story



- The Energy Sector = 80% of EU emissions (EEA, 2006)



Source: EEA, 2006