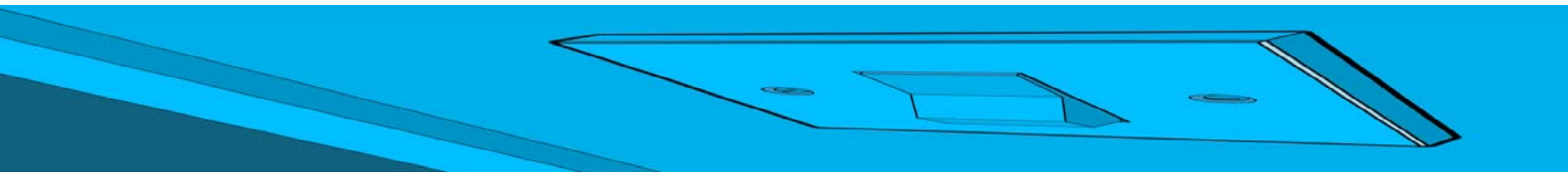

UKERC

INNOVATION IN ENERGY SYSTEMS: LEARNING FROM ECONOMIC, INSTITUTIONAL AND MANAGEMENT APPROACHES

Report on first of two workshops, 22nd - 24th March 2006,

UKERC Meeting Place, Lady Margaret Hall, University of Oxford

THE UK ENERGY RESEARCH CENTRE

The UK Energy Research Centre's (UKERC) mission is to be the UK's pre-eminent centre of research, and source of authoritative information and leadership, on sustainable energy systems.

UKERC undertakes world-class research addressing the whole-systems aspects of energy supply and use while developing and maintaining the means to enable cohesive research in energy.

To achieve this we are establishing a comprehensive database of energy research, development and demonstration competences in the UK. We will also act as the portal for the UK energy research community to and from both UK stakeholders and the international energy research community.

UKERC Energy Systems and Modelling (ESM) theme

ESM research activities are being undertaken by the Policy Studies Institute (PSI) and the Cambridge Centre for Climate Change Mitigation Research (4CMR) at the University of Cambridge, with collaboration from Cambridge Econometrics.

Aims of workshops

Innovation in energy systems will provide a core contribution to achieving national and international energy policy goals, including energy security and long-term reductions in CO_2 emissions. However, theoretical approaches to understanding innovation differ radically between separate disciplinary perspectives and there is a need for greater mutual learning between these approaches to take place. This workshop brought together leading representatives from economic, institutional and management perspectives to describe their respective approaches, share knowledge and insights and, hopefully, come to a greater degree of common understanding. The papers presented here will be further developed for the second workshop in September 2006, along with further papers on case studies.

The two workshops aim to:

- elaborate approaches to understanding innovation from different disciplinary perspectives;
- illustrate these approaches through the use of case studies from energy and, where appropriate, other sectors;
- generate common insights and understanding;
- assess policy implications from this understanding for promoting low carbon innovation;
- identify requirements for further research.

The full presentations are available on the UKERC Meeting Place website. This report provides a summary of the presentations and discussions at the first workshop.

DAY 1 – Wednesday 22nd March

The participants met for an informal dinner, at which they were welcomed by Prof. Jim Skea, Research Director of the UK Energy Research Centre (UKERC).

DAY 2 - Thursday 23rd March

Presentations were made by leading researchers from each of the three approaches on the key ideas and concepts for understanding innovation in energy systems within that approach, followed by responses from two discussants from each of the other approaches. This session aimed to highlight the range of ideas and their scope and provide theoretical discussion both within and between the different perspectives. Presenters circulated draft papers prior to the workshop to aid the discussions.

Session 1 - Economics of endogenous technical change:

Speakers:
Prof. Michael Grubb (Imperial College, Univ. of Cambridge and Carbon Trust)
Dr Clas-Otto Wene (Wenergy AB)
Discussants:
Dr Jim Watson (SPRU, Univ. of Sussex)
Prof. Christine Oughton (Birkbeck College, London)

Innovation analysis in theory and practice: A pragmatic and policy perspective
Michael Grubb

1) *Innovation conceptualisation and experience*:
Neither simple promotion of technology development through public R&D, nor pure price signals for carbon, through caps or taxes, are credible as the sole driver of innovation to achieve significant long-run carbon reductions. There is a lack of integration across the innovation chain in both technology and policy terms. 'Systems innovation' theories emphasise: the interrelation between market failures; the impact of network and related lock-in phenomena; and the need for goal-driven 'backcasting' strategies, wider mix of instruments, and more direct government involvement to nurture the industries and institutions that can tackle externalities.

2) *Getting specific – sectors and technologies*:
Actually energy systems are comprised by 6 macro systems, 3 end use systems: buildings and appliances; industry and transport, and 3 supply: direct fuels and heat; electricity system; and refined fuels system, which have different characteristics and largely different actors. Results from Innovation Modelling Comparison Project tend to emphasise need for: (a) pathways that include decarbonisation; (b) option generation through RD&D; (c) price induced investment/ redirection & learning; and (d) price expectations and consistency, in assessing costs of achieving carbon stabilisation targets.

3) *Innovation in power supply*:
The broad options are known: the challenge is systems change combined with industrial scale learning-by-doing.

4) *'Bridging the innovation chain'*:
Technology innovation policies, including market engagement and strategic deployment policies, need to span the innovation chain and lead from R&D through commercialisation to large scale markets.

5) *Policy implications*:
The core policy questions include how far can governments "drive", "plan", "facilitate" or "frame" technology..?

Michael closed his presentation with some questions for participants to consider:

- Can (and will) econometric techniques answer the big questions about experience curve data?
- How different is technological innovation from technological diffusion – is there scope for a 'unified theory'?
- How far should "innovation theories" seek to go in terms of policy advice (e.g. prioritisation, materiality, comparative advantage)?
- From a policy perspective:
  - how much do the limitations of the Innovation Chain approach matter?
  - [how] can governments combine a cost-benefit, risk-averse mentality with the fundamentals of option building that includes knowledge that "failure is a legitimate outcome"?

- How can governments shape expectations in ways that really impact investment ("Storyline 1" in Bergek et al)?
- .. Including, how do "macro" storylines link to "micro" incentives?

A Cybernetic Perspective on Technology Learning
Clas-Otto Wene

The key message from Clas-Otto's presentation was the importance of incorporating the experience feedback loop into learning curve models. At present this is usually neglected. He proposed a cybernetic perspective, which does incorporate feedbacks, which provides:
Theoretic legitimacy, through improved understanding of the phenomenon:

- The technology learning system is a 'non-trivial machine' and so is history dependent. Simplest assumption is performance depends on cumulative output.
- Structural coupling between energy system and energy technology learning system opens opportunity for *alternative* but *effective* energy technology paths.

This leads to a 2-pronged energy technology policy:

- Push of R&D programmes targeting the learning system.
- Pull of deployment programmes targeting the energy system, which require governments to incentivise significant levels of private funding.

Further issues for a cybernetic perspective:

- Scale and levels of learning.
- Relation between public and industry R&D.
- Learning in the whole market change.
- Deployment programmes and organisational structure.
- Suggested approach: viable system model (Beer 1979).

1st discussant - Jim Watson

1) Picking winners:
   - Both governments and markets try to pick winners – need more transparency and acknowledge that setting of priorities does occur.
   - Acknowledging failure must be part of process.

2) Experience curves:
   - Experience curves too deterministic:
     - irrespective of social factors and take away agency from people.
   - Why are curves the shape they are? Why are some faster/steeper than others and how can they be influenced?

- What about the examples that have not happened in this way:
  - nuclear – costs went up over time with increasing deployment
  - coal power stations
  - both cases, government regulation increases costs, increases prices. Why should new technologies be immune to these processes in the future? What about factors that could add to costs? What about unforeseen circumstances?

3) Coupled model:
   - Freeman and Rothwell 'coupling' model is third generation innovation model, fourth and fifth generation models were networked models.
   - 3rd generation model is too simplistic, but model is helpful, especially as regards understanding the valley of death.
   - many R&D programmes haven't got close to market despite cash, so feedbacks are probably more complex than models imply. The question is how to make complexity in a model usable.

4) Internationalisation issue:
   - Need to think how UK fits into international systems and the degree to which UK R&D involves collaboration, e.g. with US on carbon capture and storage.
   - Technology, firms and issues are international - setting priorities at international level is inevitable.

2nd discussant - Christine Oughton

1) Innovation chain model:
- The innovation chain model is not wrong but incomplete. Indeed there are many things that affect the innovation chain from research to commercialisation, including institutions. The institutions involved are very different and span across public and private sectors.
- Time horizons are important and should be acknowledged too, e.g. long time horizon from the basic research identifying DNA (1952) to biotech firms in 2000s. We need to identify how the process can be speeded up, whilst ensuring that industry is not able to distorting what happens in the science base. A range of technology transfer organisations in the middle of the chain are needed.
- The literature on the management approach to innovation focuses on how knowledge is transferred/absorbed. This stresses the importance of human capital in the innovation process. The speed of knowledge transfer depends on the extent to which people can absorb knowledge and this depends very much on internal capabilities.

2) Cumulative causation:
- Learning manifests itself in action and enhances the capacity for effective action
- In the case of technology learning, effective action is associated with cost reductions.
- Action may facilitate further learning so that there is a process of cumulative causation.
- There may be hiccups (failures), but competitive markets make sure that this iterative learning process continues.
- Circular causality of the technology learning process provides a rationale for government policies to create competitive markets for new energy technologies.

3) How might institutional aspects might be incorporated in Clas-Otto's cybernetic technology learning model?:
- Recognition that learning includes technology transfer across organisations with different objectives (universities, firms).
- Consideration of how technology is transferred across organisations.
- The role of cooperation and trust as well as the role of accidental spillovers.
- The role of absorptive capacity i.e. internal capability to absorb knowledge from external sources.

General discussion on Session 1:

1) Before we do further econometric analysis we need a better understanding of the phenomenon:
- Changes in competition
- Strategic choices and processes of alignment.

2) There were a number of comments on picking winners:
- Options range from minister picking technologies to no state intervention, so what is middle way, with the state somehow setting the limits (and setting some support)?
- Can regulatory system be used to push a specific sector?
- Are we picking technology or specific outcome?
- Don't we need Government to sometimes pick winners or indeed outcomes? We could not expect the market to address public policy objectives such as low carbon and secure energy. Surely the Government should aim to have innovation in all options. We have to make sure we understand this when making the choice between different energy options. Government incentives and institutional framework will determine whether capital will come forward or not. Investors have to pick winners. Government has an important role to shape choices – to pretend otherwise is ridiculous.

3) Using learning curves is more of an art than science. It is necessary to consider costs of technology, energy and money. Learning curves may be deterministic but they may inform about costs of technologies in the future. We are very bad at predicting the future costs of energy – perhaps learning curves can bring rationality into decision-making. When comparing costs of technologies, costs of money and the costs of energy – curves could help to pick winners. For example, the Government is currently picking nuclear – but use of learning curves might favour microgen instead.

4) One participant suggested more case studies are needed. Another participant responded that a good deal of case studies on learning curves is already available:

- so we should not be required to look at that from beginning;
- perhaps take a more sophisticated approach and go back to them, unpicking them.

5) Michael Grubb suggested neo-classic economics treats the two market failures (environmental externalities and innovation) as being separable and additive. But the theorem of the second best surely suggests that they should not be treated in this way – because a second best optimum is different from the first best optimum. Having said that, in practice- and possibly through a lack of systems thinking – it may be the case that economists often treat the two market failures in this additive and separable manner.

6) Aren't learning curves rather like other perhaps overly simple 2-dimensional relationships (such as the Phillips Curve and the Environmental Kuznets curve in economics) where the relationship is widely discussed – and the theory is back-filled later? There's surely a question about whether this is an efficient learning process? And isn't a very interesting aspect of learning curves the dynamic relationships between them? – specifically between the learning curves of novel and incumbent energy technologies. This matters because it can impact on: i) the time taken for new technologies to penetrate the market, ii) the funds needed to help the new technologies to get sufficiently far down their curves.

7) In relation to Clas-Otto's presentation, economics would say that what's going on inside the TLS box includes both shifts in the production frontier (i.e. technical progress) and where you are in relation to the frontier (technical efficiency). It would be interesting to see how these kinds of analyses might help to flesh out the analysis of what's inside the box.

8) We really don't know much about the effects of energy technologies and their uses on wider economic growth and productivity in the macro-economy. Isn't this a serious gap? Where is it proposed to achieve radical transitions to low carbon energy systems? If there are substantial effects, it would be helpful to know about them.

9) Thinking / behaviour processes of governments and companies. Major companies have systematic factors around learning systems, which they review systematically in a series of stages. It is integrated in a very tangible way.

10) We need to be aware of linguistic imprecision. What are cost reductions and effects that come from outside of the industry? What is learning and what is not? We have to be careful on this as it has implications for policy.

Concluding comments from Michael Grubb:

- On security externalities – strategic assessment yes, but starting point currently is market price.
- Need to separate apparently observed learning rate from real learning rate.
- Picking winners: The Government has a role to deliver good outcomes. But how far to go? E.g. It was initially thought that the Renewables Obligation regulation would provide a level-playing field, but onshore wind was the first technology up and running – so the Government was accused of picking winners.
- Indeed the cost of money changes over time but it changes hugely between different actors, places and sectors. E.g. The power sector involves low risk, low returns while the oil sector involves high risk, high returns - this may explain limited overlap?

Concluding remarks from Clas-Otto Wene:

- Unpacking the black box – deployment programs are continuing R&D by other means.
- Experience curves are learning by searching (in Japan, 70% responsible for cost reductions) as much as learning by experience/doing. Therefore 'learning curve' is not a good name.
- Historic experience – if government has consistent policy they can go into markets.
- Comparing paths - the cheapest option on the slide had $400m up front cost, even though NPV identical.
- Experience curves provide a way to legitimise government intervention in market, provided there is a consistent energy policy.

Session 2 - Innovation systems approaches

Speakers:
Prof Staffan Jacobsson (Chalmers University)
Dr Marianne van der Steen (Delft University of Technology)
Discussants:
Prof. Paul Ekins (Policy Studies Institute and UKERC)
Prof. Ken Green (University of Manchester)

Functions in Innovation Systems: A Framework for Analysing Energy System Dynamics
Anna Bergek (Linköping University); **Marko Hekkert** (Utrecht University); **Staffan Jacobsson** (Chalmers University).

Staffan presented a framework for understanding Technological Innovation Systems (TIS) dynamics. Energy system dynamics will involve formation and evolution of many TIS.The framework is intended to gain a better understanding of the innovation process and to guide policy-makers, firms and other organisations. Elements in a TIS include: firms in whole supply chain; institutions; learning networks; policy networks; other organisations. Guiding policy requires the identification of weaknesses in the particular TIS.
The presentation covered:

- Structural dynamics of TIS.
- Functional dynamics of TIS.
- Driving forces and blocking mechanisms:
  - Endogenous vs. exogenous forces of change.
- Some methodological issues:
  - Mapping functional patterns;
  - Assessing functionality;
  - Linking functional patterns to inducement/blocking mechanisms.
- Empirical illustrations.

Evolutionary Systems of Innovation: Insights about Institutional Change and Innovation
Marianne van der Steen (Delft University of Technology) - Tim Foxon presented Marianne's paper in her absence.

This paper focuses on:

- Institutions as an important aspect of National Systems of Innovation (NIS).
- Hierarchy of institutional layers as selection environment of innovation processes.
- Developing into a dynamic evolutionary framework.

Innovation occurs through interactions between: firms; education and research system; consumer and producer demand; infrastructure – technical and social; framework conditions – financial rules, taxes, entrepreneurship, etc..

The framework presents a layered picture of NIS which helps to better understand how NIS work and how they might evolve over time. Analysis using this framework has policy implications:

- Policy-making as a continuing evolutionary process of designing and re-designing institutional structures.
- Challenge existing habits and power structures which act to block innovation.

1st discussant - Paul Ekins

We need institutions because of our bounded rationality (limited capacity to take on information). By definition, institutions almost need to be conservative to allow society to function – norms are crucial. But institutions need to be adjusted to allow for innovation.

There has been shift in how innovation is perceived:

- Historically, innovation has been regarded as a good thing because it created economic growth – this explains the perspective on the national innovation system.
- Now, innovation perceived as a possible response to social problems, so can be policy driven:
    - Distinction between desirable innovation / directed innovation
    - e.g. Figure 1 of Staffan's paper -> demand driven innovation with the ultimate purpose to achieve a specific innovation
    - What is Figure 2 trying to do? Change - but change for what? Where are the key interventions? Who is defining and determining these? We want the energy system to be directed. Designing interventions in complex systems is difficult – Paul didn't feel this came through in the paper.
    - Conceptual difficulty – between the concept of evolution and the concept of designing institutions/innovation:
        - evolution, we don't just want to try
        - designing institutions/innovation -> tough part is to see how to do it, how does it feedback etc..

Between now and 2020 (perhaps 2030), 50% of the European energy system needs to be replaced. Under normal circumstances, private capital would have little difficulty to finance it. However, there is a problematic dislocation between what private capital would do and what we desire. Paul felt the paper did not address this issue. He went on to say that desired technology is not independent of the innovation system, that it depends crucially on perceptions of what is a 'desirable technology'. He thought there may be an assumption by the paper that renewables are desirable.

Paul felt Staffan's framework represented a system of picking winners and making sure the winner performed. While a refreshing approach, he pointed out that policy has limited purchase on some of the functions. Policy has to make markets function, which is fine if Government has deep pockets or if technology develops in the right or 'desired' way. But there can be lots of political opposition because of perceived costs – so this may not be sustainable. The framework seems to miss the science-technical dimension. There are five sub-systems: science, technology, economics, politics and culture (Freeman and Louca) and all five have to be broadly positive for innovation to take place. For example, there may be science-related problems so technologies don't deliver - not necessarily just policy that can fail. There is a crucial difference between mobile phones, where there was huge latent demand and renewable electricity generation, where market would fall like a stone without feed-in tariffs.

Paul agrees we must be aware of exogenous forces. However, he was not satisfied by the definition of a technology innovation system, TIS:

- "networks of agents interacting in a specific technology are under a particular institutional infrastructure to generate, diffuse and utilise technology..." because it does not say anything about innovation, could just as well be a definition of a socio-economic system.
- innovation should involve people doing things differently?.

2nd discussant - Ken Green

Ken began his commentary by agreeing with Paul's last point on the need to improve the definition of a technology innovation system, TIS. He also feels there is a need to stop the proliferation of frameworks analysing technological innovation. The research community needs to move towards a preferred model and should try and regularise and normalise some of the terms. Ken discussed the transitions framework of Rene Kemp and Frank Geels as an example of yet another model, which describes the innovation process in terms of three levels:

- Landscape development
- Socio technological regime
- Technological niches.

In the socio-technical regime, there are various institutional linkages. Dominant socio-technical regimes might prevent new technologies from emerging. This model focuses on the notion of stability. Slow change in most cases but over time new ideas emerge. Over time (perhaps 30 or 40 years), these ideas may breakthrough into the existing regime.

Ken pointed out some overlaps between Staffan and Frank's papers, particularly with respect to language used. Ken believes function analysis is useful and could help systematically analyse what needs to be changed to allow a new niche to become more mainstream. Ken pointed out that how we transform function analysis to policy discussions depends on the context – with country and political system being important aspects of the context – and appropriate application.

Commenting on Marianne's paper, Ken said he did not doubt need for institutional change. In the socio-technological regime, there is a whole series of institutional relationships which stay in place until the new regime emerges. But on the top layer of Rene Kemp's model, landscape changes drip through and influence the socio-technological. Marianne's framework had no connection with Staffan or Frank's model. Ken concluded there is a need for greater clarity on the meaning of innovation systems, the relationships within them and agreement on what research community would accept as a base (model/framework) before undertaking analyses.

General discussion on Session 2:

1) How and where do we get leverage within the system? Emphasising the importance of rules lends itself to a static view with no obvious way to break through.

2) Public policies are a subset of institutional change. Yes, norms hold society in place but where is the counterpart – i.e. values held internally by the entrepreneurs which can bring about change?

3) 7 functions is a bit too much. However, where is the interaction with the technological regime?

4) There is an assumption that a new technology means a new firm, which is not always true. Incumbents may sometimes be part of the solution.

5) The issue of role of Government has to be framed differently - there should be a critical assessment whether the innovation is beneficial to achieve the desired solution. Government has the task in testing policies ... and needs to put forward provisional support policies. “Better is the enemy of the best” - therefore we are lucky that we did not go completely for nuclear energy in the 50s.

5) Although it may be useful that different approaches exist to look at the same programme/problems – nevertheless there seem to be too many different concepts. We need to better compare frameworks and its important not to pick a winning framework. NIS is a poor fit to answering our questions - too static and no potential at micro level.

Response by Staffan Jacobsson:
The definition for his framework originated in 1991 and he believes it is similar to Rene Kemp’s three-level framework (see above). The key processes in Staffan’s framework relate to getting from technical niches to the socio-technological regime. He aims that his approach is hands on, using analyses to apply to policy. In the case of Germany, it chose the social positive solution and generated a supply industry.

Response by Tim Foxon:
Tim believes it is useful to have a diversity of approaches as long as there are interactions between them. We need to rise to the challenge of better understanding processes of institutional change and to look at organising the way we think about institutions. Marianne’s paper tries to look at institutional systems as part of a process. Tim feels the evolutionary approach is useful as it tries to provide a framework to help think about the dynamics of change.

Systems are in general not going towards equilibrium – they are in a constant process of change. Evolutionary frameworks help conceptualise this and allow you to ask certain questions, that other frameworks don't:

- How is the variety created?
- What is the process of different institutional frameworks?
- What is the process of selection that makes some institutions survive?
- Institution as a framework is useful, because the stability helps to make decisions.
- In terms of how we think about incentivising technological change, institutions are identified as a key factor.

Session 3 - Business/Management approaches

Speakers:

Prof. Jonathan Michie (University of Birmingham) and Prof. Christine Oughton (Birkbeck London)

Prof. Fred Steward (Brunel University and ESRC Sustainable Technologies Prog.)

Discussants:

Dr Rene Kemp (MERIT, University of Maastricht)

Understanding innovation from a management and business disciplinary perspective

Jonathan Michie and Christine Oughton

Jonathan and Christine set out the key elements of a business/management approach to understanding innovation. Their key points included:

- Weakness of systems approach is that it ignores what happens in firm. Policy needs to take account of managerial discretion and actual business processes. Managers matter. Managers influenced by corporate culture. Can not treat firms as a black box – need to understand what happens inside. Firms are more complex than just profit-maximisers.
- How firm interacts with external environment is important. Context is important e.g. characteristics of country, regions, sectors.
- Strategic environmental management and innovation are important competitive and environmental tools.
- Evolutionary game theory (Axelrod) using instrumental rationality suggests that co-operative strategy based on punishment and reward can be stable.
- Dynamic systems framework is needed, in which external environment influences firms, and managerial decisions within firms are incorporated into system framework.

Capabilities, networks and innovation
Fred Steward

Fred Steward emphasised the merits of the 'meso' level approach, i.e. looking at systems or domain of socio-technical practice, and analysing the components and dynamics of the system, e.g. niche actors; path creators; disruptive innovators. He analyses the fruitful interaction between organisation studies and science and technology studies, focussing on interactive models of innovation. He argued that this synthesis has produced insights relating to cognitive diversity, role of networks and the power of communicative action, but that it is not yet reflected in innovation policy.

He presented a number of measures identified by this approach for addressing the policy gap relating to firms as both market-based and science-based organisations:

- Stimulate new entrepreneurial 'agents' for sustainable innovation.
- Build dynamic capabilities.
- Promote sustainable innovation discourse.
- Facilitate social learning with lead entrepreneurs.
- Create transition arenas.
- Reorient innovation & entrepreneurship policies to sustainability.

Discussant – Rene Kemp

- No business managers are in the business of equating marginal revenue with marginal costs as they aim to sell as much as possible. Supply is constrained by demand.
- Businesses act differently – different shades of green for different reasons (not always regulation).
- Benchmarking would incentivise firms. Could be more forceful if coupled with economic incentives. . Individuals and entrepreneurs are important.
- Fragmentation impact on policy-making.of policy machine is problematic. Yes, must understand behaviour of components, including networks and organisations. Must combine approaches - more likely to have an impact on policy-making.

General discussion on Session 3:

1) In business schools, most courses include training in economics but economics departments are not so good at providing business training. The approaches put emphasis on firms, how they innovate and how there approaches are differentiated. These questions are important and should be included in economic courses.
2) Why can't we have company-led networks? The challenge is to bring economic rationality back into network/relationship models – we mustn't exclude economic rationality. To accelerate innovation – bring firms together in networks early on.
3) Presentations did not adequately stress constraints on business innovation and social goals. Indeed companies are different but there is a very strong imperative for profitability. Firms seem to have different strategies e.g. Exxon and BP. Exxon appears to focus on profit maximisation – they will buy in new

technologies if they become successful. However, BP interacts more with public policy. While Shell is experiencing record profits, there should be little constraint on innovation within Shell. However, Shell doesn't consider current incentives for offshore wind as sufficient, even though scope for innovation is significant. While we, academics, might think the risk of investing in offshore wind is a risk worth taking, Shell sees it differently. Indeed all companies take different approaches/strategies – not always predictable.

4) Do not want to facilitate lowest common denominator approach but want to facilitate networks with sustainable goal. This is not the same as picking winners as it involves being selective in messy world.
5) Individuals in firms matter. It is not a case of 'profit versus social' but rather managers internalising externalities.
6) Companies have a range of objectives, not just profit. The balancing of different objectives leads to different behaviours/outcomes.
7) Possible to get cooperation in pure profit-maximising approach. But this is not the only factor that would lead to cooperation. Short sighted profit-maximisation behaviour actually wouldn't deliver highest profit.
8) Shell's shareholders expect the company to invest in high risk and high return activities. Therefore why would an oil company want to go into the electricity industry which is low return and low risk? Capital and customers are important barriers to innovation and we need to understand such factors better.
9) Communicative action, as opposed to strategic action, may enable greater diversity of thought.

Session 4 - Discussion session

Topics for discussion

A. Different frameworks/approaches
   - different questions
   - synergies
   - energy systems

B. Specific issues
   - Learning
   - Expectations
   - Profitability
   - Dynamics of systems change
   - Actors

C. Implications for policy
   - How to guide policy?
   - What to engage with? Picking what?
   - How to engage with policy people?
   - Are frameworks appropriate for guiding policy?

B. Different frameworks/approaches

What do frameworks say about energy?

Role of evolutionary approaches

- do evolutionary study of populations
- what factors lead to survival?

Climate change represents greatest market failure

- government has job of changing institutional structures so that business have right incentives.

Problem is need to stimulate large amounts of investment, when investors see policy risks. Role of Carbon Trust as new entrepreneurial agent - identifies 'valley of death' as commercial reality.

It was pointed out that radical action is needed within the next 12 years if we have any chance of achieving 550ppm. Do frameworks tell us anything about the next 12 years? Action will require a global perspective and offsetting elsewhere in world.

What is special about the energy problem?

- homogeneous good, capital intensive, long-lived assets
- makes 'valley of death' a reality
- needs clear government policy
- need to create markets for solutions.

Energy system

- Who is going to pay?
  - consumers, rather than shareholders
- Niches
  - Tease out money from private sector
  - Sunset clause provided by experience curve
- Technology learning
  - Understand how firms reduce costs and increase profits
  - Shows effects of radical innovation, but not source
- What do we want to do with this framework?
  - Make clear to policy-makers that markets are needed.

Are these 3 literatures trying to do similar or different things? Should we try to bring them together? On economics, the model is about answering economic questions – how much will policy cost; how much money to invest in new forms of capital to achieve desired outcome. Can other approaches answer these same questions or contribute?

It was argued that the management and economic frameworks/literatures are trying to do similar things but in different ways. The management literature tries to explain why firms don't invest (because of barriers) although profitable investment opportunities may exist. Also relevant are time horizons which differ with different approaches. If we're looking at 6 or 12 yrs then existing

technologies and incremental change is likely to be the outcome. If companies are not investing in new technologies over this time, then the management literature can say way. The economics literature is more short-term than the management approach so may be not so good for analysing radical change over longer time frames. The innovation/evolutionary literatures look at longer time scales.

A participant pointed out that the problem of climate change has no precedent as we are looking at radical change within 6 to 12 years. Are there any examples of radical change over a short time period. What about WWII? What are the necessary conditions to bring about radical change – apart from war? One participant mentioned the election of Margaret Thatcher following 1970s social crises, and this led to radical institutional change which had not been foreseen.

Another participant suggested looking at rapid experience with large expenditure on energy R&D – there is some good data available on how countries responded to the 1970s oil shocks. There are also comparisons of R&D expenditures which may be useful, such as the technology to put man on the moon, military technological advances etc. (see forthcoming paper in Energy Policy by Gregory Nemet).

A participant pointed out that there three routes that can lead to a lower carbon world: accelerating technology development and deployment; reducing demand; sequestration. Do models help with different routes equally? Do models have different utility?

C. Specific issues

1. Learning

Learning is central to innovation systems, but our understanding is hollow. Distinction between 'learning curves', relating to reduction in costs of a technology, and 'sustainable innovation', where visions of future should guide long-term and short-term actions.

Transition Management: Why did Dutch govt. do this?

- Saw sustainability as creating economic opportunities for change
- Ministry of Economic Affairs responsible for energy, business and innovation
- 'accelerated evolution' to enhance power of markets
- Govt. perceived its own role in a different way
    - as facilitator
    - promoting joint public/private effort
    - getting change processes going in desired directions.

1. Expectations

Innovation is defined as 'exploitation of new ideas'.

What creates expectations of radical transformations?

- not just through investment in scientific research
- long time-scale is needed, but we are already 20 years down time scale of renewables and energy efficiency
- vision of future not reflected in political policies.

2. Other issues

What might cause radical changes in energy behaviour?

- behaviour is structured in various ways
- rapid technological and behavioural change is possible, e.g. take-up of PCs
- 'micro-generation' might help people feel connected to energy system

Can innovation theory paint a picture of how to realise radical innovation to achieve CO_2 reduction goal?

Experience from Sweden and Germany suggests more diversity as a policy goal, e.g.

CO_2 tax in 1991 was effective in promoting biomass energy. Technological specific programmes, e.g. feed-in tariff, are effective in providing higher profitability for firms; harnessing power of markets; getting rid of 'valley of death'.

There was a discussion on the problem of the aviation sector, in terms of how to reduce demand and improve technology. The low-cost airlines are geared towards expansion and increased take-up. The EU emissions trading scheme does not include aviation at the moment. The inadequacy of the allocation plans for the trading system is also problematic. What are the radical alternatives and what can innovation theory tell us for this case? One participant responded that personal carbon allowances (i.e. trading on the individual level) may help tackle the whole of the problem including aviation through demand reduction and improved supply, and create the markets needed for innovation. This policy idea would make use of existing but new technologies and would create need for better technologies.

A participant mentioned Rodgers work on the diffusion of innovation:

- E.g. accelerated programs in 1950s on encouraging use of contraceptives in developing countries
- Could this be a useful model? It might require significant level of investment in communication strategy. Would this be seen as falling into the undesirable category of 'social engineering'?

BREAKOUT SESSION
Four groups considered the same 2 questions:

How to accelerate diffusion of low carbon innovation in 6-12 years?
What is needed to promote radical decarbonisation in the long run?

For both questions groups considered:

- What do the different approaches (management; innovation systems; economics) say about these questions?

- Where do we need new theory?

- How can the three approaches complement each other?

GROUP A
Paul Ekins, Staffan Jacobsson, Ken Green, Peter Pearson, Alice Bows, Tim Foxon, Katja Schumacher

What is connection between short and long term options?

Short term assumes supply industry already there
- 6-12 years mainly existing technologies

But, this is focusing on electricity
What about demand?
- standby
- simple technology development
- technologies to reduce consumption

Do social scientists have anything to say about acceleration / diffusion on these time scales?

Can we envisage political developments without very negative consequences?
But, what do these 3 innovation processes tell us about the short term/long term?
If short term – changing behavior using existing technology better
Longer term – innovations in new technology.

I. Low carbonization in the short term (6-12 years)

Do approaches say anything on short term at all?
Systems thinking does – lock-in etc.
External effects can make quick, radical changes – e.g. huge hike in oil price.
Short term examples: oil shock etc. but this didn't change technologies, just shifted us to existing technologies

- in Sweden, 1970 experiments are now bearing fruit as oil price shifts us to those new, but less used technologies
- Was this a window of opportunity? E.g. if oil price had gone up then, would it have had same effect?
- What triggered early experiments?
- First reaction is to suddenly notice existing technologies
- To adopt these technologies **– need a 'shock' to shift out of current socio-economic regime**
- How do you get that stimulus going?
- But, is the latest science on climate change enough of a shock?
- Demand measures could provide savings in emissions of at least 20-30%
- Shock examples often involve war, even Thatchers programme of radical reform did
- What other than a moral sea change or a war will create the shock?
- **Threat is being well communicated but people are not listening.**

- What analysis has been done on the bottom of s-curves: analogy, disease curve
- S-curve for individual technologies is quite well understood
- But is this driven by something other than consumer demand
- Despite other drivers, consumers are not taking up energy efficiency measures
- Attributes are not attractive enough
- Technologies also not attractive

Innovation theory is supply-driven, helps to describe entrepreneurs. But, on demand and on the consumer, it offers little. Sociologists do do this kind of consumer behavior work.

- Innovation looks at supply, assuming demand is there
- There is more done, however, on business to business
- Entrepreneurial activity has active networks of actors
- Are there not links here with 'systems'. New ideas to break in, + become mainstream, + gain wide support
- Sociology literature on comfort, cleanliness etc. (e.g. Elizabeth Shove). Construction of demand, by the suppliers. E.g. Building industry critical in providing comfort in certain (often energy intensive) ways. Builders locked into this sort of delivery.
- The fact that consumer preferences can be dealt with by suppliers is missing link from innovation theory.

- E.g. Of intervention from top: appropriate clothing, but if perceived as 'dressing down' it might not take off. How was this justified tied to energy and probably climate change?
- Peer/neighbor preserve re: micro-generation.
- Demand articulation – can't demand something you don't know about Suppliers don't know what to make. Need to involve sociologists more.

Social developments – expect state sector to act. The state could be greener and more influence. But, not a great deal has happened (UK)

- Local country council in Sweden supplying organic milk for schools.
- Regions/local level very important.
- But if local initiatives good, still a problem with diffusion, despite claims of money savings.
- Need space for diversity, experiment and learning from bottom up. But also need top down direction to help with diffusion.
- Active local groups in Germany were disappointed in how ineffectual Green Party was at high government level. If groups feel like they are acting against govt they feel more spirited.
- England electoral system prevents many green MPs – unlike Scotland.

Michael Grubb's model (linear) does include demand at end of innovation chain. Maybe 'valley of death' not necessarily issue, as we just need to mobilize existing technologies.
Will labeling efficiency measures drive suppliers or consumers?

Need new theory? Need sociology to better interact with innovation theory. Difficult as 2 separate disciplines.

Management theory – how has it been explored. What are the drivers? Quite difficult to provide evidence base that can generalize DEFRA currently working on issue. Will present soon.

What is driving DEFRA? Food lobby, processing lobby etc. require evidence base to change and engage with stakeholders – including DTI and Treasury.

GROUP B
Marko Hekkert, Jonathan Michie, Markku Lehtonen, Jonathan Kohler, Mark Hinnells, Nicolai Lovdal

The group considered the question 'How do different mechanisms interact and reinforce each other?' The group discussed the role of different actors and the link between cultural change and institutional change.

Much discussion on creating markets: different instruments (e.g. taxes); functionality (special lanes for green vehicles). Group used example of a car manufacturer that has to make money by selling cars and how the manufacturer will choose what types of car to sell. Economics theory tells us that the manufacturer will produce models to satisfy demand, but will focus on those with

highest net present value. Given the current market, SUVs are the preferred car type, which are not attractive from a low-energy point of view.

The group considered how the system can be changed. Where are the pressure points to change things? The group discussed different policy measures including taxes, special lanes for low-carbon cars and how these various measures could reinforce one another. The group also considered the role of different stakeholders, especially the media, to accelerate societal movements by highlighting what is happening.

The group agreed the research question is, 'How does societal interaction take place?'. The group felt the innovation systems perspective is a good starting point, but not suitable to really understand what is going on. The group therefore thought it would be necessary to focus more on understanding the feedback loops. What is missing from the systems innovation literature is the perspective of the individual decision makers and more about the connections between the individual decision makers that should help us to make use of the feedback loops.

GROUP C

Anna Bergek, Kevin Anderson, Karsten Neuhoff, Gregory Nemet, Bridget Woodman, Erich Scherer

- System perspective argues that economic incentives are not sufficient.
- Economic perspective tells us we have to internalise externalities. So if we address them directly we are almost there.
- Systems perspective looks at specific technologies, whereas the economics perspective tries to use a more general framework.
- All approaches acknowledge that the role of expectations in the presence of fundamental uncertainty in various steps of the technology process (i.e. technology, market, regulatory) is important.
- The systems innovation approach acknowledges deep uncertainty and argues that this might restrict our ability to quantify the possible outcomes. In the economics perspective there is a tendency to use mean uncertainty, facilitating some quantification. The management approach might offer additional insights to understand the decision making .
- The systems approach might be more explicit about acknowledging ignorance.
- There is a challenge to find more of a link between niches and subsequent mass markets and to better understand the conditions which lead to mass markets.
- There seems to be an overemphasis on supply side technology relative to demand side.

GROUP D

Brenda Boardman, Rene Kemp, Clas-Otto Wene, Chris Hendry, Christine Oughton, Till Stenzel, Chris Taylor

What to do for rapid diffusion: Its deployment stupid!

Management science

- Teaches us that markets are multi-layered, looking at the learning in the whole value chain, from the factory to deployment. Group used the example of the heat pump deployment program in Norway (£75m). Norway is a leader in this research but had no industry. Sweden provided the industry and here learning was accrued. The main failure of the program was that maintenance (emergency) was ignored.

Economics

- focus on externalities and prices that matter.

Innovation system

- focus on the institutions.

System analysis (technology learning)

- emphasis on feed-back loop, no action, no learning.

The deployment program has to identify the barriers, design program elements and then develop packages.

Technology specific policies? Technology at early learning stage is in need of improvements and therefore needs support.

2nd Question – Evolution vs. Revolution

Its about evolution from existing radical innovation. There are technologies that have both huge potential and significant improvement requirements.

Diffusion is important for the development of low carbon technologies - not only of the technology but also of institutional mechanisms to reduce carbon emissions and share responsibilities.

A third line of diffusion is the diffusion of people taking responsibility.

Finally we are interested in the importance of economic incentives. They are important for the moving forward of existing technologies, but are less helpful for the development of new technologies - for these, innovation policy is required.

BREAKOUT SESSIONS: Common elements

Chair: Christine Oughton

- Innovation literature is focussed on supply and needs more focus on demand.
- Need more understanding on integrating approaches.
- Currently little crossover of marketing/demand/new product development literature and innovation literature.
- Company innovation processes are missing?
- Engineers constrain the degree of social possibilities?
- Group A suggested following a sociologist's approach to consumption.
- On the relationship between supply and demand a participant referred to the Rosenberg studies of the 1970s. Demand was considered in different ways. E.g. the demand for mobile phones was largely latent. Normally when we talk about 'demand' we're talking short-term about stuff we know people are buying now and want in the future. Policies can help people to switch to different products in the short term (but only products we know about). It is different in the longer run. In 50 yrs we will have radically different patterns of living that we can't possibly foresee at the moment. Need certain (blue-sky) R&D to deliver unknown technologies.
- Deployment creates markets.
- Government can set up test opportunities to discover problems e.g. standards.
- Don't have enough funded demonstrate projects.
- One participant thought that many low carbon technologies won't work – so we can't manipulate learning curves in a big way. Innovation moves on. Support to specific technologies should be limited. Technologies must prove themselves. Another participant agreed but pointed out that sometimes it is the system and not the technology which fails.
- Better feedback can improve learning. Need to improve feedback loop.
- With energy, it not just technology which is important – behaviour too.
- Prevention of energy profligate practices
- Target manufacturers; Permission to manufacture
- Need strong standards – increase/improved them over time
- In the case of organic, people are willing to pay more
- Company reporting and greater transparency needed
- Possibility of promoting services over products in future?
- How can we use non-energy historical case studies? There may be lessons to transfer.
- Must think about China and other rapidly developing countries as well as the industrialised world.
- Policy-makers are important; Do models adequately capture the way policy-makers work? Policy-makers are really the test as they are the consumers of the model.
- Political science looks at the decision-making processes; political scientists would say economics are important but power structures are also important.
- Validation of models important.
- Internal consistency is important for the economics approach.
- Which models actually have impact?

- Systems need boundaries as these are essential for getting conclusions. But sometimes conclusions can get applied to situations outside boundaries and this is problematic.
- Much innovation literature is based on economics discipline (not necessarily neo-classical economics).
- Policy-makers want more concrete examples using different approaches that are specific to energy.

Workshop Conclusions and Follow-Up
Chair: Jonathan Koehler

The following papers were volunteered for a special issue journal, with title something like 'Developing systems theory for low carbon innovation'

1) Tim Foxon, Jonathan Kohler, Karsten Neuhoff - Comparative study of three approaches and what they have to say about low carbon innovation.
2) Staffan Jacobsson, Anna Bergek and Marko Hekkert – Functions of innovation systems approach.
3) Jonathan Michie and Christine Oughton – Innovation from a business and management approach, with case study.
4) Clas-Otto Wene – Cybernetic perspective on technology learning.
5) Marianne van der Steen – Evolutionary systems of innovation, including case material
6) Michael Grubb/Carbon trust – Practical experiences of innovation?
7) Fred Steward – Capabilities, networks and innovation.
8) Chris Hendry – Fuel cells – comparison of developments in different countries.
9) Gregory Nemet – Experience of wind turbines in California.
10) Jim Watson – CCS, microgen.

The agreed 1st choice of journal was Energy Policy and 2nd choice was Global Environmental Change. Details of the special journal will be circulated once confirmed as well as info and guidance on contents. Contributions to add to the list above are invited. Authors will need to write a ½ page abstract/outline. Papers MUST show how their approach can be applied to low carbon innovation in particular. They must also at least situate their theory relative to economics, innovations systems and management approaches.

Draft papers will need to be complete by early September – to allow sufficient time for circulation prior to next workshop 14/15 September. Policy-makers, in addition to workshop participants, will be asked to comment on usefulness of papers.