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# Innovation Systems and Policy-Making Processes for the Transition to Sustainability

**Tim Foxon, Zen Makuch, Macarena Mata and Peter Pearson**
*Environmental Policy and Management Group, Dept. of Environmental Science and Technology, Imperial College London, U.K*

## 1. Introduction

The interactions between 'technological systems' and 'institutional systems' and the innovation processes occurring within them are a key factor in transitions to more sustainable socio-natural systems. Such transitions will be greatly influenced by how policies and regulatory frameworks (within the policy-making process) affect innovation in these systems, and, in turn, how innovation processes affect policy and governance frameworks. This chapter describes initial results from a research project being undertaken by the authors, under the UK ESRC Sustainable Technologies Programme, which is investigating the interaction between the policy-making process and the innovation process. The project is undertaking theoretical and empirical analyses of the interactions between policy-making processes and innovation systems in two case study areas - *low carbon innovation in the UK* and *alternative technologies for energy sources in vehicles at the EU policy level*. From these analyses, together with experience of direct involvement in producing policy advice for these two areas, a set of process guidelines will be developed for improving sustainable innovation policy processes, contributing to the design of a better mix of policy instruments for promoting innovation towards sustainability.

Section 2 of the chapter develops a framework for analysing interactions between innovation systems and policy-making processes, based on the interactions between technological systems and institutional systems. Section 3 reviews recent theoretical and empirical work describing innovation as a systemic, dynamic, non-linear process. Section 4 describes recent work which points to an improved rationale for sustainable innovation policy, based on ideas from innovation systems theory. Section 5 describes initial findings from the two project case studies, drawing out the implications for sustainable innovation policy processes. Section 6 concludes by presenting some emerging hypotheses, which draw on the previous theoretical and empirical work, for improving policy-making processes for promoting sustainable innovation.

**2. A Framework for Analysing Interaction Between Innovation Systems and Policy-Making Processes**

Until very recently, in the UK and many other countries, innovation policy and sustainability policy have been pursued separately. This is now changing as a result of greater understanding of innovation processes and recognition of their importance for sustainability. Recent theoretical and empirical advances paint a richer picture of innovation as a systemic, dynamic, non-linear process, involving a diverse range of actors, giving rise to both positive and negative feedback (see e.g. Kemp, 1997; Grubler, 1998; Hemmelskamp *et al.*, 2000; and Foxon, 2003 for a review). The new picture emphasises the roles of knowledge flows between actors; expectations about future technology, market and policy developments; political and regulatory risk; and the institutional structures that affect incentives and barriers. A similarly complex picture exists of the paradigms, principles and frameworks underlying the policy-making process (see Majone, 1989; Kingdon, 1995; Gunningham and Grabosky, 1998; John, 1998).

We are developing a framework for analysing the interaction between innovation systems and policy-making processes. This framework draws on previous work investigating the relation between environmental policy and innovation (Kemp *et al.*, 2000; Ashford, 2000; Janicke *et al.*, 2000), but develops a more explicitly systems based approach. There are two elements to the framework. The *first element* (see Figure 1) shows the broad overview of the transition from the current socio-natural system to a more sustainable one. The socio-natural system is composed of a number of interacting sub-systems. This study focuses on two of these subsystems -'technological systems' and 'institutional systems' - and their interactions.

The *second element* (see Figure 2) provides the methodological framework for the project. It illustrates two key interacting subsystems of institutional and technological systems, which may be involved in the transition of these systems towards greater sustainability. These are the 'policy-making process', within institutional systems, and 'sustainable innovation systems', within technological systems. The policy-making process may create opportunities for the innovation of technologies towards sustainability, by influencing the rate and direction of innovation. The sustainable innovation system may provide potential scope for improved policy targets and measures. For example, stringent targets for technology performance to meet certain social or environmental standards may be set if it is believed that the innovation system can deliver technologies meeting those targets.

This dynamic interaction between policy-making processes and sustainable innovation systems gives rise, at any point, to a particular mix of policy instruments for promoting sustainable innovation. As these instruments are implemented and experience of their effectiveness gathered and assessed, this feeds back – more or less effectively - into the further development of these processes and systems.

There are two parallel aspects to the analysis using this framework:

- The theoretical analysis of each process and the interactions between them.
- The empirical analysis of the two case studies - *low carbon technologies*, focussing on UK innovation systems and policy processes, and *alternative energy sources in vehicles*, focussing on policy-making and implementation processes, institutions and innovation at the EU level.

The case study analysis is drawing on stakeholder experience, through workshops and interviews. A report on the first stakeholder workshop, held in January 2003, is available on the Sustainable Technologies Programme web site (Foxon *et al.*, 2003); the second workshop on 'Improving policy-making for sustainable innovation: Learning from experience' was held in October 2003, with stakeholders from the business, policy-making, NGO and academic communities. A third workshop, which will explore a set of guidelines for developing better policy mixes, was held in June 2004.

**Figure 1: Overview of the transition towards a sustainable socio-natural system**

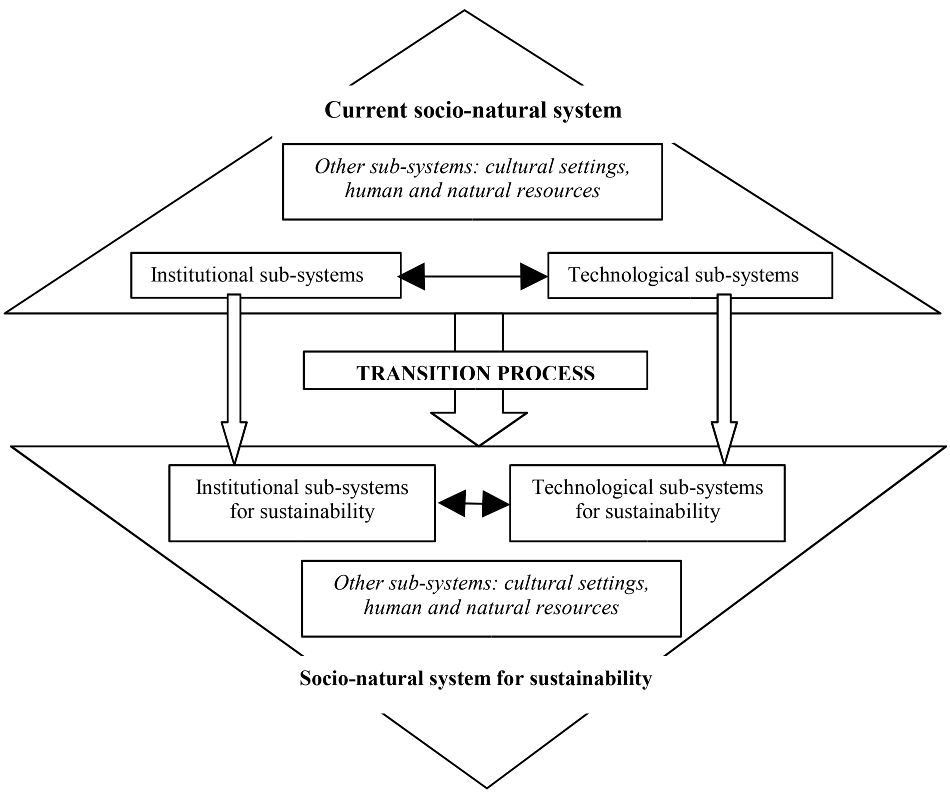
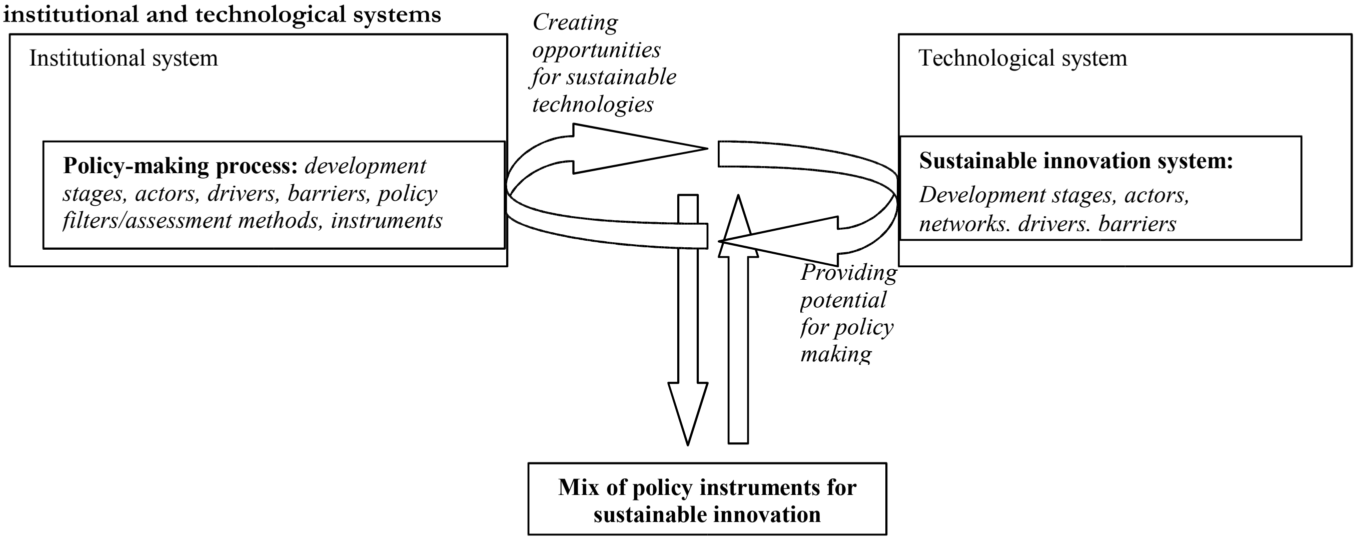



**Figure 2: Interaction of the policy-making process and the sustainable innovation system within the institutional and technological systems**



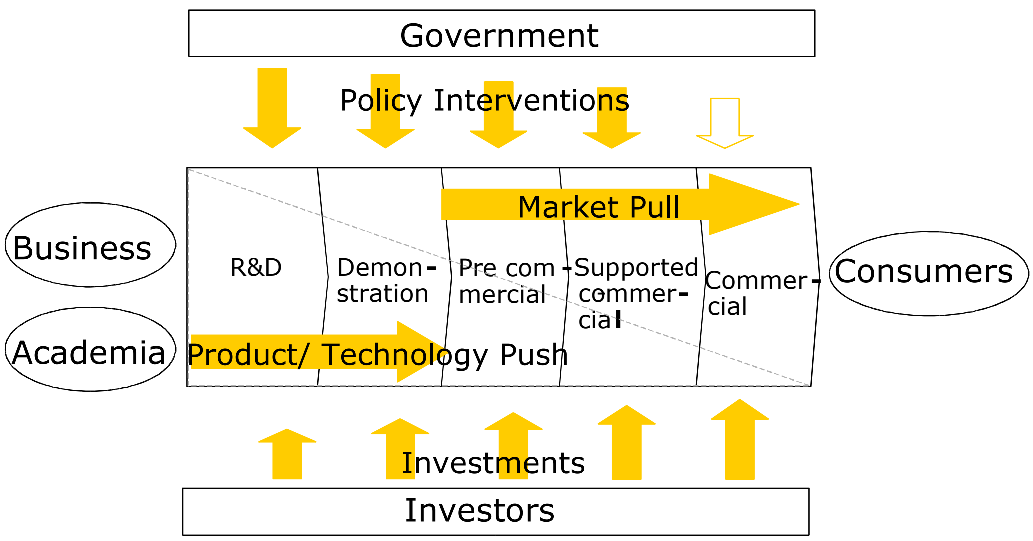
## 3. Understanding Innovation Processes

From the theoretical and empirical analysis undertaken so far in the project, we draw out a broad message that policy making, in the UK and at the EU level, has failed to take into account fully the complexity and dynamic nature of innovation processes. A range of recent work has enhanced our understanding of the richness of the innovation process, in relation to tackling environmental problems (see e.g. Kemp, 1997; Grubler, 1998; Hemmelskamp *et al.*, 2000; and Foxon, 2003 for a review), but, as described in Section 4, this understanding is not yet widely reflected in the rationale for or design of policy instruments.

### *The Innovation Chain*

Rather than being categorised as a one-way, linear flow from R&D to new products, innovation is now seen as a process of matching technical possibilities to market opportunities, involving multiple interactions and types of learning (Freeman and Soete, 1997). There are a number of clearly identifiable stages (shown in Figure 3) in the development of new technology: R&D, demonstration, pre-commercial (large scale demonstration), supported commercial (under generic support schemes) and commercial (Carbon Trust, 2002; Foxon et al., 2004). However, knowledge flows in both directions, for example, as information from early market applications feeds back into further product research. This means that the conventional drivers of *technology push*, from R&D, and *market pull*, from customer demand, can be reinforced or inhibited by *feedbacks* between different stages and by the influence of *framework conditions*, such as government policy and availability of risk capital. Thus, the dynamic nature of the innovation process is emphasised, with feedbacks between different stages, which can either amplify or inhibit the basic technology push and market pull drivers.

**Figure 3: Stages of the innovation chain (Source: adapted from Carbon Trust (2002)**




### *The 'Chain Linked' Model*

An early attempt to represent the systems feedbacks within the innovation process was made by Kline and Rosenberg (1986) in their 'chain linked' model. This was used as the conceptual framework in an influential report by the OECD (1992) on 'Technology and the Economy: The Key Relationships'. This model represents the feedback loops between: (i) research; (ii) the existing body of scientific and technological knowledge; (iii) the potential market; (iv) invention; and (v) the various steps in the production process. The model is shown in Figure 4.

**Figure 4: An interactive model of the innovation process: The chain-linked model (Source: Kline and Rosenberg (1986))**

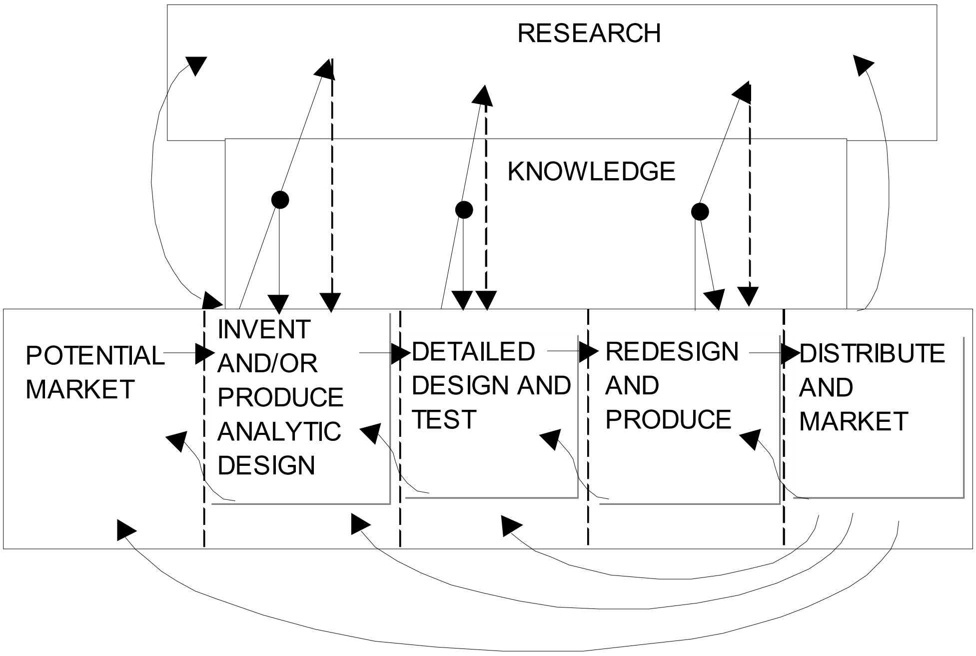



Figure 4 combines two different types of interaction. The first (in the lower part of the model) relates to the processes occurring within a given firm (or a network of firms acting together). The second expresses some of the relationships between the individual firm and the wider science and technology system within which it operates.

At the level of the firm, the innovation chain is represented as a process that starts from the recognition of a potential market opportunity together with a potential design for a new product or process to meet that opportunity. Building on existing scientific or technological knowledge and, where necessary, research to add to that knowledge, an 'analytic design' is produced. This leads to development, production and marketing, but there are feedbacks between each stage and, crucially, feedbacks between the product users and the design and production phases. A key feature is the uncertainty and unpredictable nature of both technological capabilities and user needs.

## *National Innovation Systems*

To apply this type of model, researchers initially focussed on individual and comparative analyses of the innovation systems in different countries, across a range of technologies, as it was argued that key institutional drivers would be found at the national level.

The concept of a 'national system of innovation' was first developed by Chris Freeman, working at SPRU, in a pioneering study of the then successful Japanese economy in the late 1980s. Freeman (1988) defined a national system of innovation as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." Freeman stressed the positive role of government, working closely with industry and the science base, to create a *vision* and provide *long-term support* for the development and marketing of the most advanced technologies; the *integrated approach* to R&D, design, procurement, production and marketing within large firms; and the high level of general *education* and scientific culture, combined with thorough practical *training* and frequent up-dating in industry.

Two major studies in the early 1990s by Lundvall (1992) and Nelson (1993) analysed national innovation systems in more detail. Lundvall (1992) defined a national system of innovation as constituted by "the elements and relationships which *interact* in the production, diffusion and use of new, and economically useful, knowledge … either located within or rooted inside the borders of a nation state." He stressed the role of interactions between *users* and *producers*, facilitating a flow of information and knowledge linking technological capabilities to user needs. Because of the fundamental *uncertainty* of innovation, these interactions go beyond pure market mechanisms, and rely on mutual trust and mutually respected codes of behaviour.

Nelson and collaborators (1993) conducted a major empirical study and comparison of the national innovation systems of 15 countries. They concluded that "to a considerable extent, differences in innovation systems reflect differences in economic and political circumstances and priorities between countries." Again, these differences reflected the differences in the institutional sub-systems between different countries, including systems of university research and training and industrial R&D, financial institutions, management skills, public infrastructure and national monetary, fiscal and trade policies.

The concept of national innovation systems has been taken forward and used extensively by the OECD (2002), following these early studies. The innovation process is seen as characterised by the different actors and institutions (small and large firms, users, governmental and regulatory bodies, universities, and research bodies), the interactions and flows of knowledge, funding and influence between them, and the incentives for innovation created by the institutional set-up.

Based on a review of innovation systems approaches, Johnson and Jacobsson (2001) identified a set of basic functions that need to be served in a technological innovation system, if a new industry surrounding that technology is to develop successfully. The five basic functions to be served in a technological system are identified as:

- To *create and diffuse 'new' knowledge*;
- To *guide the direction of the search process* among users and suppliers of technology, i.e. influence the direction in which actors deploy their resources (including providing recognition of growth potential, expectations of development, and choice of specific design configurations);
- To *supply resources*, including capital, competencies and other resources;
- To *create positive external economies* through the exchange of information, knowledge and vision;
- To *facilitate the formation of markets*.

Applying this approach to renewable energy technologies, Johnson and Jacobsson (2001) identify a number of mechanisms that induce or block the development of effective functions for particular technology systems. *Inducement mechanisms* may include government policy (e.g. R&D funding, investment subsidies, tax incentives), ease of firm entry, and feedback from market formation, and *blocking mechanisms* may include uncertainty, lack of support, poor connectivity of networks, opposing behaviour of established firms, and disincentives created by other government policies.

## 4. Rationale for Sustainable Innovation Policy

In this section, we argue that the above picture of innovation as a dynamic, systemic process has considerable implications for policy making that aims to promote more sustainable innovation.

The traditional economic argument for policy measures relating to sustainable innovation has been based on correcting for two principal market failures:

a) Firstly, because knowledge can easily be copied once it has been created, innovators cannot appropriate the full benefits of their investment in the creation of that knowledge, i.e. social returns to innovation exceed private returns, giving rise to a disincentive for private firms to undertake socially efficient levels of innovation (Arrow, 1962). This positive externality is the underlying rationale for public support for research and development (R&D) and for measures such as patent systems.
b) Secondly, the existence of negative externalities, for example, unpriced environmental impacts. This provides the rationale for economic instruments to internalise those externalities, such as environmental taxes or emissions trading schemes.

These arguments and measures remain valid, but we argue that they are insufficient, because they are explicitly or implicitly based on a conceptual framework with an inadequate representation of the innovation process. This sees innovation as a unidirectional process, with more R&D at one end naturally leading to more commercialisation of new products at the other end, with information about technical possibilities and user needs being easily available. Thus, these two types of intervention focus on the two ends of the innovation chain, shown in Figure 3, correcting for perceived market failures at the R&D and commercialisation stages, but neglecting the complexity of the innovation process, including the motivations of actors involved in the process.

Applying the concept of innovation systems, a number of authors have argued for the need to move to a notion of 'systems failure' as a rationale for policy interventions. For example, Edquist (1994, 2001) argues that, because of the evolutionary characteristics of innovation processes, a simple notion of 'market failure' as a comparison between conditions in the real world and an ideal or optimal system is no longer valid. Instead, he advocates concrete empirical and comparative analyses, using innovation systems concepts, to identify systems failures that can be rectified. He identifies two conditions that must be fulfilled for public intervention to be justified in a market economy:

1) a *problem* must exist, i.e. a situation in which market mechanisms and firms fail to achieve socially-defined objectives;
2) the state and its agencies must also have the *ability* to solve or mitigate the problem (i.e. the issue of potential government and bureaucratic failure must be addressed).

Smith (1991) and Metcalfe (2002) also stress that policy making should take an adaptive approach, and look for design and formulation of institutional arrangements that promote business experiments and generate a greater connectedness between organisations generating knowledge, e.g. universities, and those applying such knowledge, e.g. firms.

Previous work by the authors and collaborators (Anderson *et al.*, 2001; Gross and Foxon, 2003) has set out the case for appropriate levels of direct policy support for innovation to achieve environmental ends, including market development policies and financial incentives, as well as support for R&D. The case is based on four interrelated arguments: *The problem of time lags*; *Risks and uncertainties of costs and benefits*; *Value of* *creating options*; *Positive externalities of innovation*. For example, in the energy sector in addition to measures such as emissions taxes and pollution abatement regulation, the case is made for supporting innovation directly, so that environmental problems can be solved sooner, realising economic benefits given by option values and positive externalities.

These ideas can be used to inform debates about appropriate levels and mechanisms for policy support for more sustainable innovation, including conditions under which technologies should no longer receive support, i.e. 'exit strategies'. However, they do not provide simple formulas, and need to be supplemented by empirical data, and judgements about social acceptability of different technology and policy options, in order to be put into practice.

## 5. Some Lessons from the Case Studies

This section describes initial findings from the two case studies for our research project on 'Policy drivers and barriers for sustainable innovation'.

### *(1) Low Carbon Innovation in the UK*

The first case study is analysing the innovation of low carbon technologies in the UK, focussing on renewable energy technologies. A complex mix of policies has arisen in recent years to support the development of renewable technologies, principally for electricity generation. A target of 10% of electricity to be generated from renewables by 2010 was put in place in 2001, together with a specific policy instrument designed to achieve this – the Renewables Obligation (DTI, 2003). This is an obligation on electricity suppliers to supply an annually increasing proportion of electricity generated from renewable sources, reaching 10% by 2010. This has a number of interesting features:

- It is a long-term measure: remaining in place, at a minimum 10% level, until 2026;
- It has an additional economic incentive: Renewables Obligation Certificates (ROCs) are tradable, as a means of satisfying the obligation;
- There is a 'buy-out price': instead of achieving their targets, suppliers can choose to pay the buy-out price of 3 p/kWh, with the funds being recycled to other suppliers who have met their obligation.

Other relevant measures include a short-term programme of capital grants for offshore wind, biomass energy crops and solar PV; support for renewables R&D; exemption of renewable electricity and good quality CHP from the Climate Change Levy (business energy tax); and a strategic framework for support of offshore wind, including licencing arrangements.

However, concerns have been expressed that current and foreseeable levels of investment will not be sufficient to reach the 10% target by 2010. In particular, many in the renewables industry argue that, in order to secure long-term power purchase agreements with electricity suppliers at rates justifying investment, a renewable generation target of 20% by 2020 is needed (Renewable Energy Report, 2003). This is despite the recent Energy White Paper (DTI, 2003), which set an 'aspiration' of renewable generation of 20% by 2020, together with a long-term goal of reducing the UK's $CO_2$ emissions by 60% by 2050. Such political aspirations are not regarded as sufficiently 'bankable' by the investment community (Grubb, 2003). In partial response to these concerns, the UK government announced, in December 2003, that the level of the Obligation would be further increased in annual steps beyond 2010 to a level of 15% by 2015.

The case study is also drawing on work by the authors and colleagues for the UK Department of Trade and Industry (DTI) (ICEPT/E4tech, 2003; Foxon *et al.*, 2004), which analysed current UK innovation systems for six new and renewable energy technologies. This work combined expert knowledge and interviews with stakeholders who are active in these innovation systems. The study identified systems failures in moving technologies along the innovation chain at two key stages, and made recommendations for overcoming these failures:

*a. Moving from demonstration to pre-commercialisation*: There are obstacles to companies seeking to move from the first one or two demonstration projects to more substantial (though still small scale) levels of deployment. The incentives offered by generic measures, such as the Renewables Obligation, cannot attract investment into technologies that are in their early stages of development, and so are high risk, high cost and confined to small niches. These problems may be addressed as follows:

- Policy incentives to create early niche markets are needed, for example, through dedicated capital grants or a 'feed-in' price premium. Costs per unit may be high, but the total numbers installed and total costs, are small.
- Encouragement is needed for the involvement of larger players with the finance and skills base to fund and support larger scale installations.
- Technologies which fail to make it over this gap in a reasonable time period should no longer attract R&D support.

*b. Moving from pre-commercial to supported commercial*: Several types of risk are hindering the large-scale deployment of pre-commercial technologies (such as offshore wind and biomass). Other energy policy measures associated with liberalization are often focussed on maximising short-run (price) competition. In the electricity generation industry, the resulting fierce market competition has led to price falls, very low profit margins for some producers, and increased risk for long-term investment. At the same time, the rewards, in terms of potential markets, may not be large enough to incentivise long-term investment, particularly where the future market relies on regulatory measures to internalise externalities, which are seen as subject to political risk, as policy priorities or governments change:

- The potential for policy incentives to improve risk/reward ratios should be investigated. This may mean additional funds, e.g. larger capital grants. However, there is scope for regulation to provide for much larger potential long term rewards, such that the private sector is prepared to bear a more early stage risk.

Expectations of the continuity or durability of policy frameworks are exceedingly important. In order to attract sustained investment, rewards from the full range of instruments must be seen to be stable over a sufficiently long timeframe. Innovation succeeds through the 'perseverance' of innovators, and perseverance is also required in policy. It is important that a shared vision for the future of each area of technology between government, industry and the research community is developed.

Within a strategic approach, key priorities should be to ensure:

- Perseverance of policy frameworks – policy measures to support innovation should be stable over the long-term and be insulated from short term political changes.
- Regulatory consistency and synergy – measures should add to the functioning of innovation support as a strategic whole, by augmenting and not disrupting existing measures.
- Continuity of policy measures – measures should 'join up' across the stages of the innovation chain, so that a successfully performing technology can progress smoothly towards commercialisation in self-sustaining markets, which exist without policy support.

However, it is recognised that there will always be a tension between the creation of stable policy frameworks and the need for policy learning, which arises as experience is gained in the implementation of policies, and the potential is created for new ways of achieving policy ends by the development of novel techniques and technologies.

These issues are being further investigated in the case study, including analysis of the policy-making processes which gave rise to the current mix of instruments to promote renewables innovation in the UK.

*(2) EU Directives Relating to Alternative Energy Sources in Vehicles*

The second case study examines at the EU-level the role of policy-making processes, policy frameworks (e.g. integrated product policy), and policy assessment procedures (e.g. *extended impact assessment*, *comitology*, *regulatory impact assessment*) in promoting or inhibiting innovation of more sustainable technologies and techniques. The particular focus is on alternative energy sources for vehicles, and the main regulatory instruments considered are the Batteries Directive and the End-of-Life Vehicles (ELV) Directive.

If sustainable innovation policy is an ultimate goal, then:

- The policy-making process (including policy frameworks and assessment procedures) should have the goal of "sustainable innovation" itself in-built. This is partly achieved by considering the interaction between the policy-making process and innovation systems, and analysing the different 'windows of opportunity' in which they interact and can influence each other. A main objective of the second case study is to investigate whether this is indeed the case as regards European Community environmental policy-making processes.
- A mix of policy instruments combining legislation (command-and-control), economic instruments and voluntary agreements needs to be considered, within a more integrated strategic framework. It is submitted that instrument mixes are a key means of moving the sustainable innovation agenda forward, and that European Community institutions are sensing that stakeholder responsibility is an important way of achieving this.

The Integrated Product Policy (IPP) framework at EU-level is an example of a more integrated, systemic policy framework, aiming to improve environmental performance at all phases of a product's life cycle. It seeks to establish principles and boundaries within which product policies would be designed and implemented. However, many of the proposals in the Green Paper have been eliminated or made not legally-binding in the final IPP Communication adopted by the European

Commission (EC, 2003). The case study is analysing the causes and consequences of this, particularly, the extent to which the promotion of sustainable innovation has been attenuated, especially in relation to the Batteries and ELV Directives.

The Extended Impact Assessment (ExIA) methodology is a new policy assessment procedure, and the Batteries Directive will be the first legislative instrument to which it will be applied. This is in line with the Commission and the Council's Better Regulation Action Plan (EC, 2002). The case study will examine the potential for ExIA to advance environmental protection and sustainable innovation, as it seeks to marry cost-benefit analysis, social impacts and environmental impact assessment in novel ways.

The systemic nature of the innovation process requires a combination of policy instruments that will deal with a range of different aspects, in order to achieve environmental protection targets. There are at least two ways that a mix of instruments aimed at one policy goal might evolve:

a) Through a conscious decision of DG Environment, a group of policy analysts could deliberately construct a strategy for promoting, for example, new technologies in alternative energy vehicles, by drawing upon a large number of disparate individual initiatives, which when taken collectively, all aim at promoting these technologies.
b) Combining command-and-control instruments, economic instruments and voluntary agreements within a single legislative framework. This alternative comes closest to approximating a mix of instruments at the European Community level to date.

At present, the Batteries Directive (91/157/EEC) is in the midst of a European Commission-led consultation process (BDC, 2002). This consultation process is of particular interest because:

a) It is entirely possible that in part, a combination or mix of instruments will be agreed for implementing the revised Directive, including voluntary instruments (e.g. legally-binding new waste stream monitoring techniques and technologies, as well as collection targets to be implemented by firms), economic instruments (e.g. a charging system to determine battery company contributions to the scheme) and more traditional command-and-control measures (e.g. to punish free riders or non-compliant parties).
b) There are two key principles that the revised Batteries Directive will codify, which are in direct interest of sustainable innovation: the *substitution principle* and the *producer responsibility principle*.

The choice and balance of instruments will have an effect on sustainable innovation. For example, a ban on cadmium (being considered under the new revision) would temporarily end European companies' electric car production, as nickel-cadmium (NiCd) is the only battery technology in European mass produced electric vehicles. This could have at least two effects on alternative energy vehicle production compared to other technologically locked-in internal combustion engine and lead-acid battery production. In the short and medium term, locked-in technology market share will not significantly fall, and electric vehicle demand may not be stimulated. However, a vacuum in the electric vehicle market may provide a stimulus for emerging technologies, including other battery technologies (e.g., lithium ion and nickel metal hydride) and fuel cells, to press ahead more rapidly.

The substitution principle is arguably the single greatest legally binding mechanism in the service of sustainable innovation policy as promulgated by the European Community. If applied in a flexible manner, this principle allows for regulators to effectively phase out and ban certain locked-in technologies and techniques in the service of environmental protection provided that such a decision is based on sound science. It is anticipated that this principle will be applied to battery chemistries with dangerous substances in favour of emerging technologies. In relation to the key role of stakeholders, it is noteworthy that the Battery Directive consultations have not, so far, featured any lobby or stakeholder group that is seen to be acting in the interest of sustainable innovation.

The objective of the End of Life Vehicles Directive (2000/53/EC) is to prevent waste from vehicles and to foster reuse, recycling and recovery as alternatives to the disposal of vehicle-based waste, hence removing 8-9 million tones of waste annually. Though it is not directly articulated, the Directive features the substitution principle, as it seeks a prohibition on the use of certain substances (lead, mercury, cadmium and hexavalent chromium) in existing vehicle technologies to the extent that this is permitted by scientific and technical progress. Hence, more environmentally sustainable technologies and techniques must be invented to allow substitution of these materials at the car design stage, the so-called "conception phase".

The Directive also serves sustainable innovation policy by suggesting that the design and production of new vehicles must take account of dismantling, reuse, recycling and recovery of vehicles, their components and parts. This provides the ideal opportunity for the car industry to implement the European Commission's evolving policy on integrated product policy so that design stage decisions are consistent with the highest standards of waste management strategy and implementation.

This case study will further analyse and draw out the implications of these findings for the development of sustainable innovation policy processes.

## 6. Conclusion: Emerging Hypotheses for Sustainable Innovation Policy

Drawing on the above theoretical and empirical research, and other current work in this area (Rennings *et al.*, 2004; Zundel and Satorius, 2004), we now conclude the chapter by outlining some emerging hypotheses relating to sustainable innovation policy-making.

*(1) Policy-making in this area would be enhanced by taking into account the richness and complexity of innovation processes.*

Policy design and implementation needs to reflect the systemic, dynamic nature of the innovation process. Consequently, greater understanding of how innovation systems actually work is needed, relating to: the actors involved and the flows of knowledge and influence between them; the drivers and barriers for innovation; and the ways in which current systems fail to promote movement of more sustainable technologies along the innovation chain. Policies may then be designed to address these 'systems failures', which will include but are not limited to conventional market failures.

*(2) Effective policy-making requires a long-term strategic framework.*

The transition to more sustainable socio-natural systems is likely to require significant re-orientation of investment away from resource- and pollution- intensive industries and technologies and towards the innovation and diffusion of more sustainable technologies. In order to achieve this re-orientation, technology developers and investors need clear expectations that markets for technologies with appropriate attributes are likely to exist and that policy measures to support the transition will be stable over the long term. This implies the need for a long-term strategic policy framework, in order to improve coherence of policy measures, ensure continuity and perseverance of policies over a longer time frame, and improve expectations of stability. Such a framework would also need to make clear when support would be withdrawn from technologies, either because they have failed to make sufficient progress towards commercialisation, or, preferably, because they can have successfully progressed to the stage of being competitive without further public support.

The Dutch 'Transition Management' model (Kemp and Loorbach, 2003) provides an example of such a long-term strategic framework, in which policy-makers and stakeholders from industry, NGOs and wider society work together to:

- define a vision for the long-term future of an industry or sector;
- agree strategic goals for the medium term;
- set out transition paths or 'route maps' for how these might be achieved;
- agree support for the initial steps or 'learning experiments' along these paths.

Such a model would need to be adapted to fit the circumstances of particular countries, institutions and industries.

*(3) The details of the design and implementation of policy instruments can have a significant impact on the resulting pattern of incentives for innovation.*

Many current unsustainable technological systems have benefited from long periods of increasing returns to adoption, for both the technologies, leading to reduced costs and improved performance, and in the institutional structures of standards, rules and laws supporting them. This may result in 'lock-in' of these systems, because of the difficulties of entry faced by potential new competitors. Hence, the standard policy prescriptions of support for R&D and internalising externalities, though important, are unlikely to be enough in themselves to promote transitions to more sustainable systems. Specific support for the innovation of more sustainable technologies in the early stages of their development is likely to be needed. One good, through controversial, example is the support of renewable energy technologies, in Germany and other countries, through a 'feed-in' law, which guarantees a premium market price for electricity generated from these sources. In addition, the implementation of measures to internalise environmental externalities associated with less sustainable technologies may exert critical influences on promoting or inhibiting more sustainable innovation. For example, in setting tradable permit schemes to internalise the environmental costs of emissions, the extent to which permits are 'grandfathered' to existing polluters, rather than auctioned, can make a significant difference to the pattern of incentives.

*(4) There may exist 'windows of opportunity' for policy-makers to positively influence the innovation process.*

Policy-making processes are systemic and dynamic, and exhibit 'path dependency', i.e. subsequent policy choices may depend on the historical path of development of policies and so on previous choices made. One consequence of this is that there may exist particular and limited 'windows of opportunity' for policy-making to influence innovation processes (David, 1987; Perez and Soete, 1988; Kingdon, 1998; Nill, 2003), e.g. in the early stages of technology and policy development, or under particularly favourable economic conditions. In the European Community context, the determination of the European Parliament's legislative programme, the determination of annual policy programme goals by the European Commission and the development of Green Papers may serve as early windows. At a later stage, Directive drafting consultations and the tabling of initiatives before the European Parliament's Environment Committee offer strategic opportunities to influence the promotion of sustainable innovation.

*(5) Effective sustainable innovation policy is likely to feature a coherent and integrated mix of instruments, combining a variety of instrument types.*

Given the market driven nature of sustainable innovation policy, the integration of a mix of instruments based in part on their sensitivity to market considerations (i.e. economic instruments, voluntary agreements, eco-labels, investment strategies, environmental management systems and innovation network concepts) with sustainable innovation policymaking activities seems likely to be appropriate. The variety in this mix might usefully complement more traditional forms of command and control regulation. This could be achieved through a series of policy initiatives or through the establishment of an umbrella (legislative) instrument that features a combined mix of policy instruments.

*(6) At the institutional level, there is a need to achieve greater consistency in policy interventions towards sustainable innovation.*

This consistency might be achieved if European Community policy filters and procedures such as integrated product policy, extended impact assessment, regulatory impact assessment, comitology, co-decision, co-operation were to feature a check on the development of policy instruments to ensure that they maintain and advance sustainable innovation as a policy goal. Until these policy filters and procedures are reformed, this may require actions such as the formation of a special Unit charged with monitoring and addressing policy disfunctions that detract from sustainable innovation. Such a Unit might also seek to promote the integration of sustainable innovation policy development among the European Commission Directorates General.

*(7) There may be a role for stakeholders and 'enablers' to advance sustainable innovation throughout the policy-making and implementation process.*

Stakeholder consultation processes and policy development procedures that feature significant multi-stakeholder dialogue and foster a sense of common ownership of policies are likely to be appropriate and effective. This kind of approach might assist in correcting the environmental policy problems of locked-in technologies (where substitution is desirable) and the observable lack of a represented "innovation" constituency with the political capital to advance sustainable innovation as a strategic policy goal. Furthermore, multi-stakeholder "enablers" could play a key role in fostering policy uptake within the sustainable innovation system through direct interaction with innovators.

*(8) In a dynamic setting, a learning approach to policy-making may help to produce a better mix of policies that is not predicated on the achievement of an ideal, 'optimal' policy choice.*

Given the limited ability of policy-makers to gather and process all the relevant information ('bounded rationality'), and the inherent uncertainties of innovation processes, there seems little likelihood of developing 'optimal' solutions. In addition, the path dependency of policy making and the interaction between policies further increases the complexity of the task. This suggests the potential value of moving to a 'learning approach' to policy-making, situated within a stable strategic framework, e.g. by designing periodic "policy self-correction" mechanisms to address circumstances where the unintended consequences of policy choices outweigh their benefits, or novel techniques and technologies enable new ways of achieving policy ends.

These hypotheses will be subjected to further investigation and analysis in the course of developing the project case studies and formulating and testing the final guidelines for improving sustainable innovation policy processes.

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