« From end-of-pipe to system innovation »

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Abstract

The paper looks at patterns in eco-innovation and factors behind this. Special attention is given to the role of public policy. The paper examines the shift towards cleaner products and continuing importance of end-of-pipe solutions, national differences in eco-innovation use, issues of science push and market pull, lead market issues, and the growing attention to system innovation.

Key words: eco-innovation, end-of-pipe, cleaner production, green products, system-innovation

1. Definition and typology of eco-innovations

Eco-innovation is a recent concept. One of the first appearances of the concept of eco-innovation in the literature is in the book by Claude Fussler and Peter James (1996) where it appeared on the front cover but curiously enough not in the book itself. In a subsequent article, Peter James defines eco-innovation as 'new products and processes which provide customer and business value but significantly decrease environmental impacts' (James 1997).

Different from the concept of environmental technology, eco-innovation has the suggestion of a double win, which is why it holds great appeal to business and government. The OECD is using it as a central concept, alongside the term sustainable manufacturing (OECD, 2008). The provisional OECD working definition of eco-innovation is "the *creation* of new, or significantly improved, products (goods and services), processes, marketing methods, organisational structures and institutional arrangements which - with or without intent - lead to environmental improvements compared to relevant alternatives" (OECD, 2008 p 19). This definition however is likely to change as it conflicts with the Oslo Manual definition of innovation, which includes the *implementation* of a new technology that was developed by a different firm or institution (Arundel and Kemp, 2009). According to the Oslo Manual, a firm can innovate by purchasing production technology from a supplier and implementing the technology into its production line.

The lack of a common definition led the European Commission to fund two projects on measuring eco-innovation: Measuring Eco-Innovation (MEI) and Eco-Drive. The eco-innovation definition of the Eco-Drive is "a change in economic activities that improves both the economic performance and the environmental performance". The definition of MEI is "*the production, assimilation or exploitation of a product, production process, service or management or business method that is* ***novel to the organisation*** *(developing or adopting it) and which* ***results****, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use)* ***compared to relevant alternatives."***

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Key characteristics are:

- More environmentally benign than relevant alternatives
- Novel to the organisation developing or adopting it
- It is based on effects, not on intention.

The definition proposed by MEI researchers is considerably broader than the definition of ECO-DRIVE, which excludes pollution control technologies. The MEI definition follows the convention in innovation measurement specified in the Oslo Manual (OECD, 2005) that the innovation does not have to be new to the market; it only has to be new to the company developing or adopting it. [2]

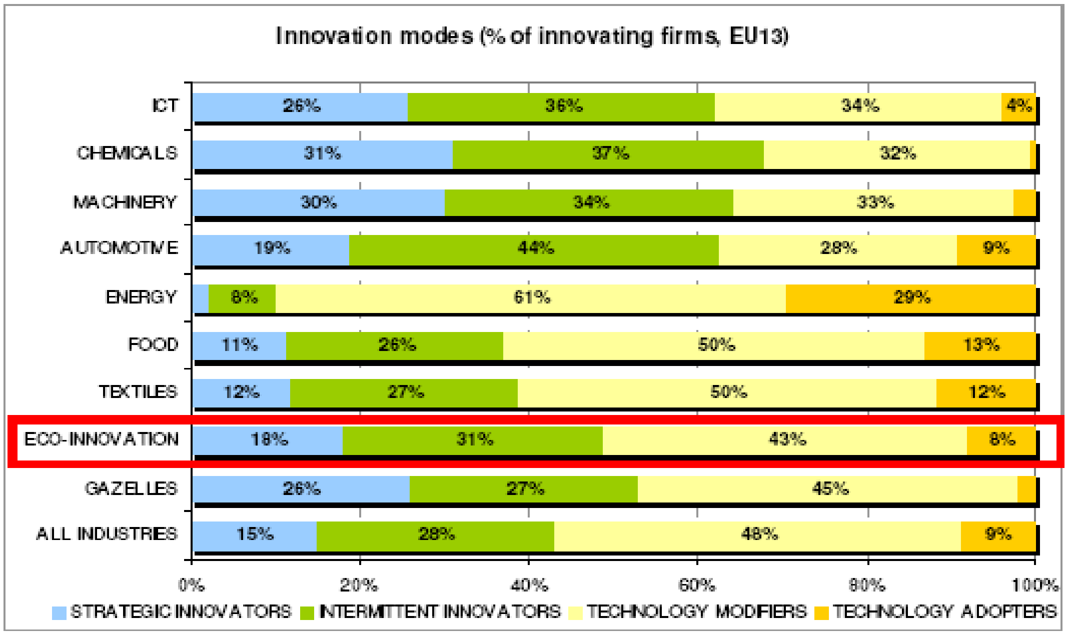
In this sense it differs from the definition of the SYSTEMATIC panel on eco-innovation who define eco-innovation as "*the creation of novel and competitively priced goods, processes, systems, services, and procedures designed to satisfy human needs and provide a better quality of life for everyone with a life-cycle minimal use of natural resources (materials including energy and surface area) per unit output, and a minimal release of toxic substances*" (Technopolis, 2008, p.2). In this definition, the implementation of something developed elsewhere apparently does not count as innovation. The criterion of "minimal use of resource" and "minimal release of toxic substances" appears unduly restrictive as it limits eco-innovation to the best in class.

To me the definition from MEI, which includes all innovations with environmental benefit compared to relevant alternatives, irrespective of the aim, is the most useful. Further categorisations are whether the innovation is an improvement of what exists or entirely new, whether the environmental benefit is an auxiliary benefit or a deliberate goal, whether it technological, organisational or a combination thereof (Arundel and Kemp, 2009, p. 2).

According to this broad definition, many companies will be eco-innovators. Information about eco-innovators across various EU countries can be obtained from the Community Innovation Survey, even when no question is asked if companies eco-innovate. Eco-innovators may be defined as those which had responded a high degree of impact of innovation on either "reduced materials and energy per produced unit" (EMAT) or "improved environmental impact or health and safety aspects" (EENV). This definition has been used by Technopolis (2008) and Horbach (2008). The profile of eco-innovating firms may be compared to that of innovative firms in various sectors. Such a comparison using data from CIS-3 has been undertaken by Technopolis in the Europe Innova project. General results are given in Figure 1.

[2] Results of the MEI project, including a description of discussions at workshops, can be found at http://www.merit.unu.edu/MEI/ and obtained from the project leader René Kemp. Reports from the ECO-DRIVE can be found at http://www.eco-innovation.eu/wiki/index.php/Ecodrive_Wiki_Mainpage

Figure 1: Innovation modes (% of innovating firms, EU13 based on data from CIS4)



Source: Presentation Viola Peter at ECO-DRIVE workshop,

We can see that about half of all eco-innovative firms innovate through creative innovative activities, the other half innovates through diffusion-based innovative activities. With a share of 18% the share of strategic innovators is slightly above the EU average of 15% for innovative firms. The results show that the profile of eco-innovators is actually very close to the EU average.

The MEI project also produced a classification of eco-innovation:

Box 1. MEI classification of eco-innovation

A. **Environmental technologies**

- Pollution control technologies including waste water treatment technologies
- Cleaning technologies that treat pollution released into the environment
- Cleaner process technologies: new manufacturing processes that are less polluting and/or more resource efficient than relevant alternatives
- Waste management equipment
- Environmental monitoring and instrumentation
- Green energy technologies
- Water supply
- Noise and vibration control

B. **Organizational innovation** for the environment:

- Pollution prevention schemes
- Environmental management and auditing systems: formal systems of environmental management involving measurement, reporting and responsibilities for dealing with issues of material use, energy, water and waste. Examples are EMAS and ISO 14001.
- Chain management: cooperation between companies so as to close material loops and to avoid environmental damage across the value chain (from cradle to grave)

C. **Product and service innovation** offering environmental benefits:

- New or environmentally improved products (goods) including eco-houses and buildings
- Green financial products (such as eco-lease or climate mortgages)
- Environmental services: solid and hazardous waste management, water and waste water management, environmental consulting, testing and engineering, other testing and analytical services
- Services that are less pollution and resource intensive (car sharing is an example)

D. **Green system innovations:**

- Alternative systems of production and consumption that are more environmentally benign than existing systems: biological agriculture and a renewables-based energy system are examples

Source: Kemp and Pearson (2008)

The classification includes the important category environmental technologies[3] but is not limited to it. It includes organizational innovations for the environment and environmentally beneficial product and service innovations including innovations for which the environmental

[3] Environmental technologies encompass technologies and processes to manage pollution (e.g. air pollution control, waste management), less polluting and less resource-intensive products and services and ways to manage resources more efficiently (e.g. water supply, energy-saving technologies) (definition of the European Environmental Technologies Action Plan). Environmental technologies are technologies whose use is less environmental harmful that relevant alternatives.

benefit is not a special aim. It also includes green system innovation. Eco-innovation is another term for "innovation for the environment".

Another list is the list of environmental goods prepared by the OECD (see OECD, 2001) based on the following categories:

A. Pollution management
- o Air pollution control
- o Wastewater management
- o Solid waste management
- o Remediation and clean-up of soil and water
- o Noise and vibration abatement
- o Environmental monitoring analysis and assessment

B. Cleaner technologies and products
- o Cleaner/resource-efficient technologies and processes
- o Cleaner/resource-efficient products

C. Resource management group
- o Indoor air pollution control
- o Water supply
- o Recycled materials
- o Renewable energy plant
- o Heat/energy saving and management
- o Sustainable agriculture and fisheries
- o Sustainable forestry
- o Natural risk management
- o Eco-tourism

The MEI list is broader than the OECD list. The categories from both lists may be used as categories of eco-innovation but it is dangerous to use trade data for these categories as measures for eco-innovation as *a conventional alternative may well be included in the very same classification* (an example is spark-ignition international combustion piston engines), which leads Johnstone and Hascic (2008a, p. 7) to the important conclusion that "commodity classification cannot be used to develop indicators of eco-innovation".

Whether something is an eco-innovation depends on the **overall assessment of environmental effects and risks**. Many criteria may be used to evaluate the environmental impact of an innovation: greenhouse gases emissions, air pollution, energy use, water pollution, noise, waste generation and soil contamination. Given the number of environmental criteria, the global environmental impact of an innovation is very difficult to assess. One may opt for special labels such as climate-friendly innovation or resource-efficient innovation.

2. Measuring eco-innovations: data and indicators

Eco-innovation can be analysed using the following four categories:

- **Input measures**: Research and development (R&D) expenditures, R&D personnel, and innovation expenditures (including investment in intangibles such as design expenditures and software and marketing costs);
- **Intermediate output measures**: the number of patents; numbers and types of scientific publications, etc;

- **Direct output measures**: the number of innovations, descriptions of individual innovations, data on sales of new products, etc;
- **Indirect impact measures** derived from aggregate data: changes in resource efficiency and productivity using decomposition analysis.

A discussion of the pros and cons of different measures is offered in a paper which I wrote with Anthony Arundel which draws very much on discussions in the MEI project. The general conclusion is that although some methods are better than others, no single method or indicator is ideal. One should apply different methods for analyzing eco-innovation – to see the "whole elephant" instead of just a part. A summary of the weaknesses and strengths is given in Table 1. One important conclusion is that the most used indicator for eco-innovation, which is patents, is a poor indicator for several reasons:

- Patents measure inventions rather than innovations. Patents are especially poor for measuring technology diffusion, the adoption of an innovation by a population.
- The value distribution of patents is highly skewed, only a few patents are commercially valuable, the majority of patents have little or no commercial value. The latter should be excluded when using patents as a measure for innovation.
- The propensity to patent is known to differ between sectors, and may change over time.
- In order to be picked up as an eco-patent, the environmental gain of the considered innovation must be explicit and described in the patent. If the environmental impact is a non-intentional side effect of the innovation, this effect will not appear in the claims and in the description of the patented technology.
- Organisational innovations and marketing innovations cannot be measured by patents because patents are mainly given for technical inventions.

When using patents as a measure for eco-innovation, one should carefully screen the patent descriptions for environmental aspects and eliminate patents with no commercial value. Suggestions for doing a patent analysis can be found in De Vries and Withagen (2005) and Oltra et al. (2009).

Another conclusion of MEI is that more efforts should be devoted towards *direct* measurement of innovation output using documentary and digital sources and surveys. The advantage is that they measure innovation *output* rather than innovation *inputs* (such as R&D expenditures) or an intermediary output measure (such as patent grants). Little use has been made of documentary and digital sources, primarily because of a lack of funding and absence of product databases with environmental information. Environmental reporting requirements may help to create relevant information, aiding innovation research. Innovation may also be measured *indirectly* from changes in resource efficiency and productivity (Kemp and Pearson, 2008).

A positive development is that the next Community Innovation Survey (CIS2008) will have a special module on eco-innovation, which in 2010 will produce important information about the nature of eco-innovation including output measures and the determinants. MEI researchers contributed to the formulation of questions. The module is voluntary and will not cover all Member States. Information will prove to be of great value for learning about the nature and magnitude of eco-innovation activities in European companies. A limitation remains that the CIS only provides general information for the company as a whole. It does not give information about specific technologies or products (Arundel and Kemp, 2009).

Table 1. Summary of methods for measuring eco-innovation

Mode of measurement	Data sources	Strengths	Weaknesses
Generic data sources			
Input measures	R&D expenditures, R&D personnel, other innovation expenditures (*e.g.* design expenditures, software and marketing costs)	Relatively easy to capture related data	Tend to capture only formal R&D activities and technological innovations
Intermediate output measures	Number of patents, numbers and types of scientific publications	Explicitly provide an indication of inventive output Can be disaggregated by technology groups Combine coverage and details of various technologies	Measure inventions rather than innovations Biased towards end-of-pipe technologies Difficult to capture organisational and process innovations No commonly agreed and applied category for environmental innovations The commercial values of patents vary substantially.
Direct output measures	Number of innovations, descriptions of individual innovations, sales of new products from innovations	Measure actual innovations Timeliness of data Relative ease to compile data Can provide information about types of innovations, *i.e.* incremental or radical	Need to identify adequate information sources Process and organisational innovations are difficult to be counted. The relative value of innovations hard to identify.
Indirect impact measures	Changes in resource efficiency and productivity	Can provide the link between product value and environmental impact Can be compiled at multiple levels: product, company, sector, region and nation Can depict various dimensions of environmental impact	Difficult to cover environmental impact over the entire value chain No simple causal relation between eco-innovations and eco-efficiency
Specialised surveys			
Large-scale surveys	EU Community Innovation Surveys, official questionnaire surveys performed regularly, PACE surveys	High response rates Can trace trends in innovation activities through time	Generally can include only a few questions of relevance to eco-innovation PACE surveys are not harmonised among countries; they do not differentiate capital expenditures for eco-innovation from those for line extension.
Small-scale surveys	One-off questionnaire surveys, interviews	Can focus on eco-innovation in far greater depth Possibility to ask about many aspects of eco-innovation	Low response rates Only a few international surveys exist.
Panel surveys	Gather information from the same firms over time	Can provide information about size, levels, direction and sources of innovation activities Can identify trends and changes in innovative behaviour over time	Costly to conduct

Source: OECD (2009) based on Arundel and Kemp (2008) drawing on discussions in MEI.

3. Determinants of eco-innovation

Motivations and facilitating factors for eco-innovation are various. Little systematic research has been done in terms of comparing the determinants for different types of eco-innovation. Probably the best attempt is the OECD study Environmental Policy and Firm-Level Management which systematically compared the drivers and facilitating factors for end-of-pipe abatement technologies and changes in production processes. The study finds that anticipated cost savings play a significant role in encouraging improved environmental performance with respect to natural resource use and waste generation but not waste-water effluent and air pollution (Johnstone et al., 2007, p. 22). The presence of an environmental management system is found to have "a significant positive influence on performance and innovation" (ibid, 23) and "flexible policy instruments such as performance standards and market-based instruments tend to encourage the use of change in production processes rather than end-of-pipe abatement" (ibid, p. 23). Such findings are in line with the econometric and case study literature surveyed in Del Rio (2009) and Kemp and Pontoglio (2008).

Eco-innovation is pulled and pushed by many factors. An attempt to list the most relevant factors for each type of eco-innovation is given in Table 1. They represent my understanding of them, based on my own studies and those of others.[4]

Table 1. Push and pull factors for different types of eco-innovation

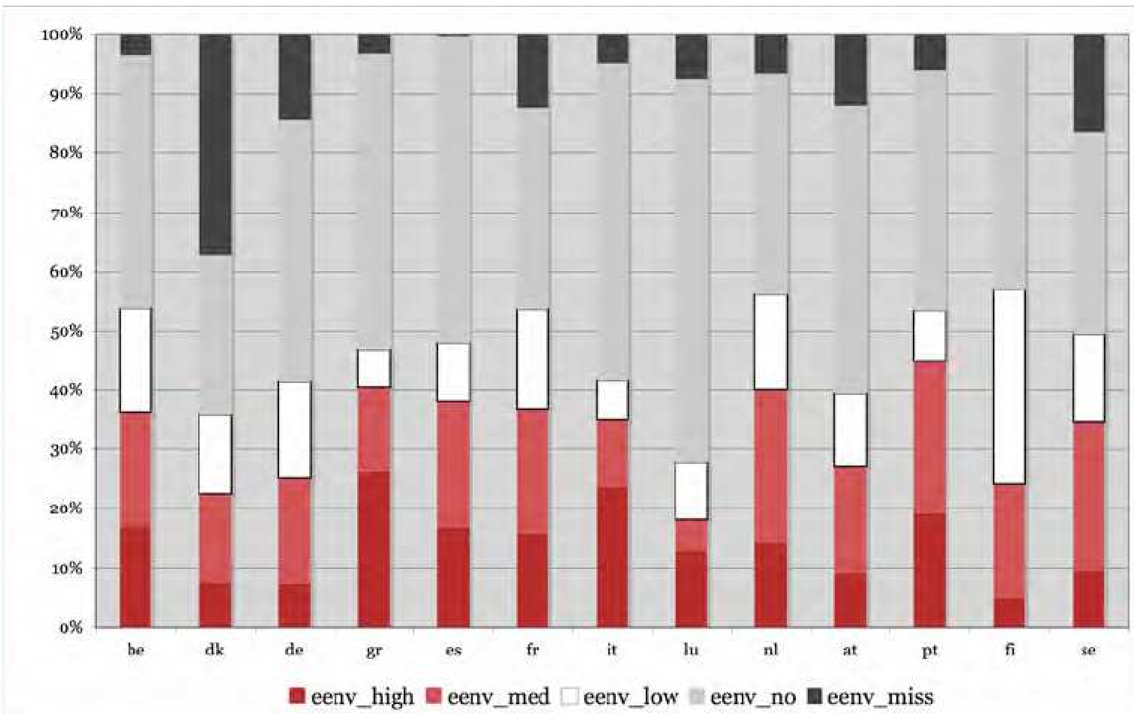
Type of eco-innovation	**Pulled/pushed by**
A. Environmental technologies	
Pollution control technologies	Environmental regulation, subsidies and environmental technology research programmes, ...
Cleaning-up technologies	Soil remediation programmes
Waste management systems	Resource prices, waste management requirements, EPR, ...
Cleaner process technologies	Cost minimisation, environmental policy, ...
Environmental monitoring and instrumentation	Environmental regulations and EMAS
Noise and vibration control	Noise regulations, research programmes
Water supply	Water supply programmes of water boards, research programmes
Green energy technologies	Environmental regulations, subsidies, taxes, ETS, ...
B. Organisational innovations for the environment	Regulations (directly or indirectly), management demand
C. Product changes	Regulations, green demand, competition
D. Green system innovations (industrial ecology, smart grids such as Vehicle-to-Grid (V2G))	GPT pushed by science, niche applications, visions, …

[4] It is impossible to list all relevant studies. Determinants of eco-innovation have been econometrically studied by Horbach (2008), Mazzanti and Zoboli (2006).

4. Patterns in eco-innovation and the reasons for observed differences

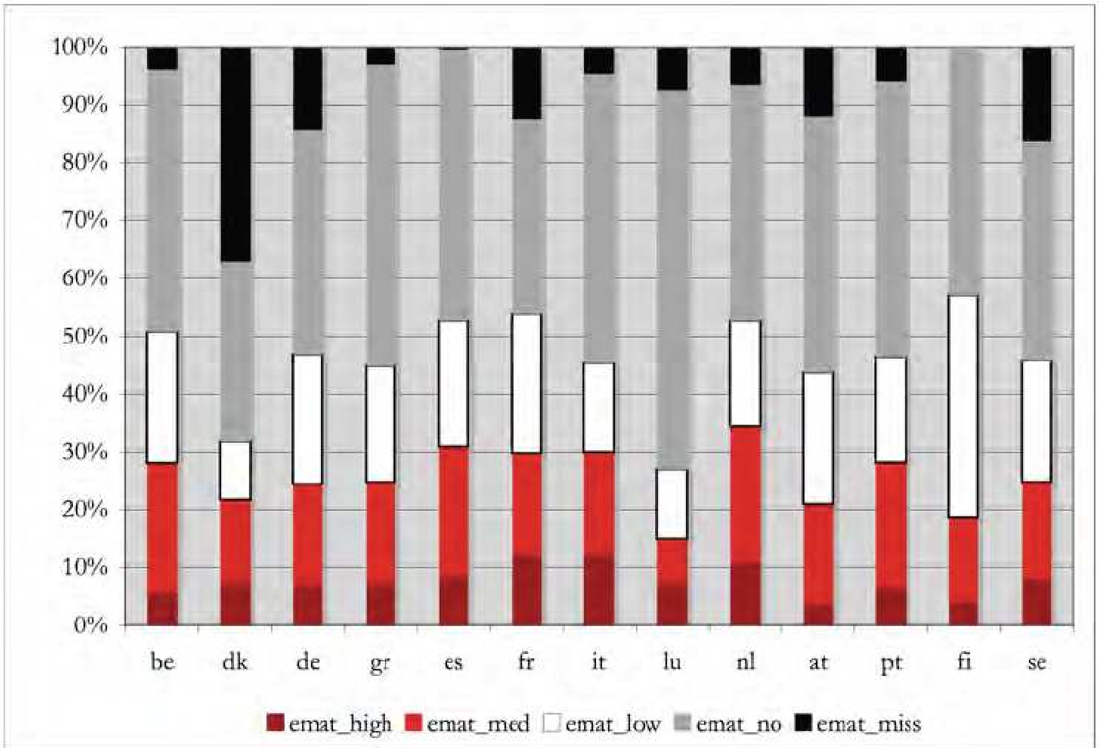
Eco-innovation -- understood as a process change, organisational change, product change or entirely new process, product, system or organisational measure of environmental benefit -- appears to be widespread. Over 40% of the innovators surveyed in the Community Innovation Survey of 2002-2004 reported a positive impact on environment, health and safety and reductions in material use and energy use. These percentages are for the EU15.

Figure 2. Effects of innovation activity on reduced environmental impacts or improved health and safety (EENV) - CIS3



Source: Technopolis (2008, p. 16) based on Eurostat data

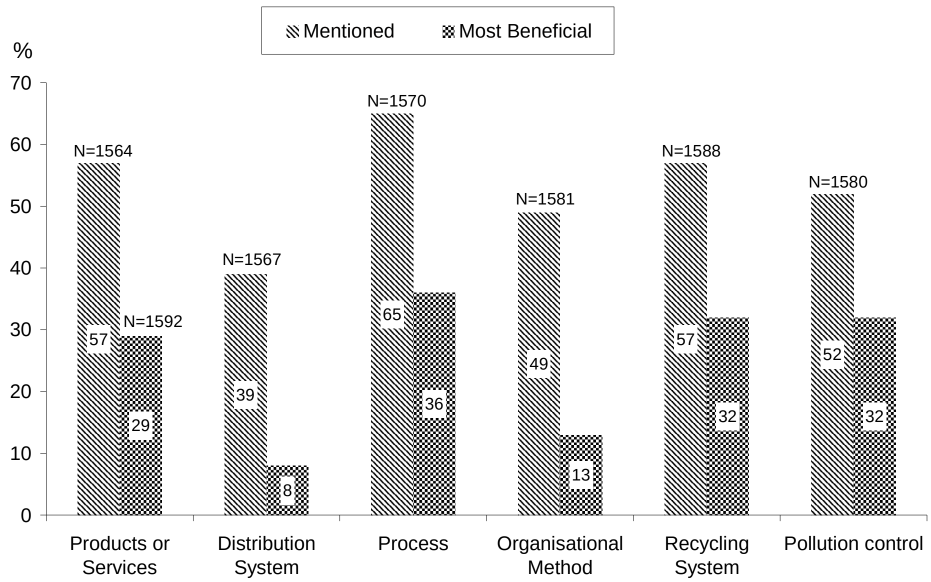
Figure 3. Effects of innovation activity on reduced materials and energy per unit output (EMAT) CIS3



Source: Technopolis (2008, p. 15) based on Eurostat data

Unfortunately, the questions about EENV and EMAS impacts was not retained in CIS4, which only inquired into whether innovation was having "an important impact" on EMAT and on EENV, finding an important impact for 14% of the companies (16% in industry and 11% for services) (Technopolis, 2008, p. 16). Deeper insights into the nature of eco-innovation are provided by the IMPRESS project for the European Commission (Rennings and Zwick, 2003). Using a broad definition of eco-innovation, it studied eco-innovation activities under 1594 establishments in five European countries (Germany, Italy, Switzerland, the United Kingdom, The Netherlands). IMPRESS asked companies whether they had adopted one of 6 environmental innovations in the past 3 years. The study found that in the 1998- 2000 period, in the 1594 establishments of the five countries, the most widely applied and important environmental innovation is a process change, followed by recycling and pollution control. Process innovations came out as the most beneficial environmental innovation from an *environmental* point of view. The study was based on eco-innovation firms in manufacturing and service sectors employing more than 50 people willing to participate in the survey.

Figure 4: The adoption of different types of environment innovation in 1998-2000



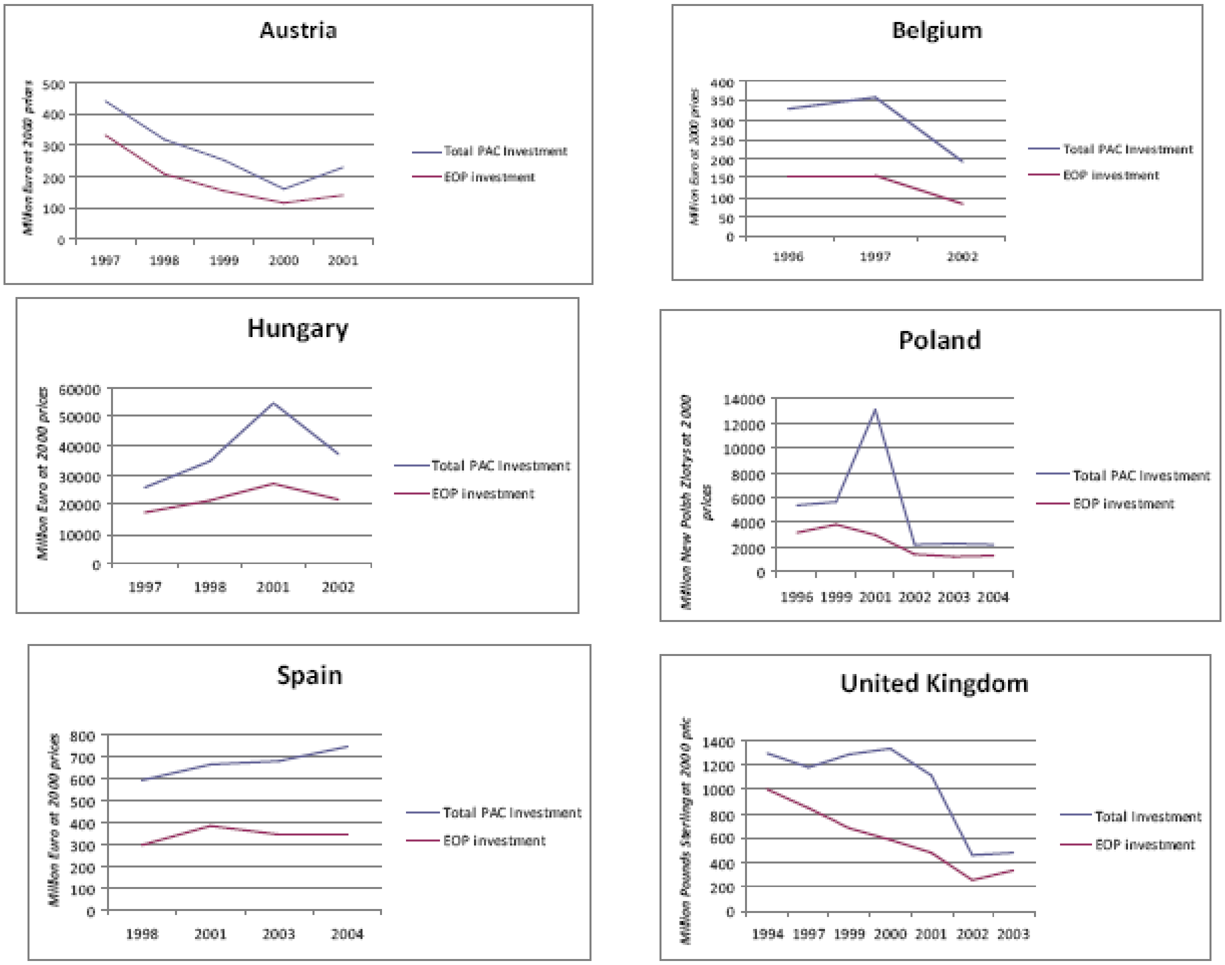
Source: IMPRESS survey under 1594 companies in five European countries (Germany, Italy, Switzerland, the United Kingdom, the Netherlands).

It was found that pollution control technologies are often combined with the use of other measures. It is unclear whether these other measures came to substitute for the use of end-of-pipe technologies or whether they were additional.

End-of-pipe technologies are generally believed to be the old response, but according to the PACE data about pollution abatement and control expenditure, end-of-pipe technologies account for the majority of the costs, even in the 1990s as we can see for selected countries. Pollution abatement and control expenditures consist of two types of costs: investment in end-of-pipe and the extra costs of process-in-change. The latter category is a difficult category for respondees as they have to measure the extra costs of process change to reduce environmental impact. It is a highly hypothetical question. In Germany apparently many respondees use a percentage of 20%, as a "reasonable" estimate.[5]

[5] Personal communication of eco-innovation survey expert Jens Horbach.

Figure 5. Total pollution abatement control investments and amount of end-of-pipe investment therein



Source: Based on data from OECD (2007)

According to the PACE data, end-of-pipe technologies account for more than 50% of the pollution abatement control investments by business. The PACE data also show that PAC investments have fallen in many countries. It is unclear whether total expenditures on eco-innovation (broadly defined) have fallen. It would be worth to find out.

A more systematic analysis of cleaner production changes is the earlier mentioned OECD study *Environmental Policy and Firm-Level Management* of 3,100 establishments in seven industrialized countries[6], which found that in all seven countries the share of cleaner production technologies exceeded that of end-of-pipe technologies. The study also learned that end-of-pipe technologies are typically introduced to cope with regulatory compliance, while the implementation of cleaner production technologies is driven by the potential for increasing manufacturing efficiency and reducing costs of operations (Frondel et al, 2004; 2007).

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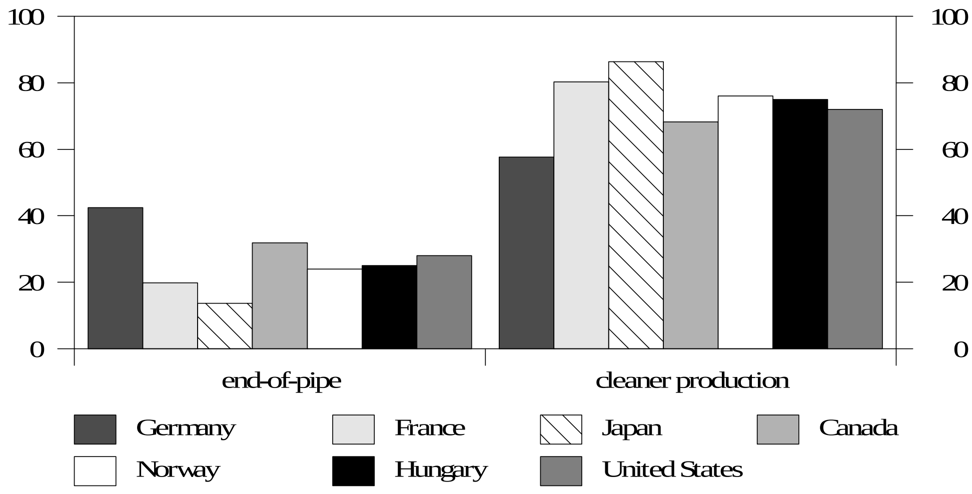
[6] The seven countries include Canada, France, Germany, Hungary, Japan, Norway and the United States. The project is called Environmental Policy and Firm-level Management. The sample consisted of facilities with more than 50 employees in all manufacturing sectors.

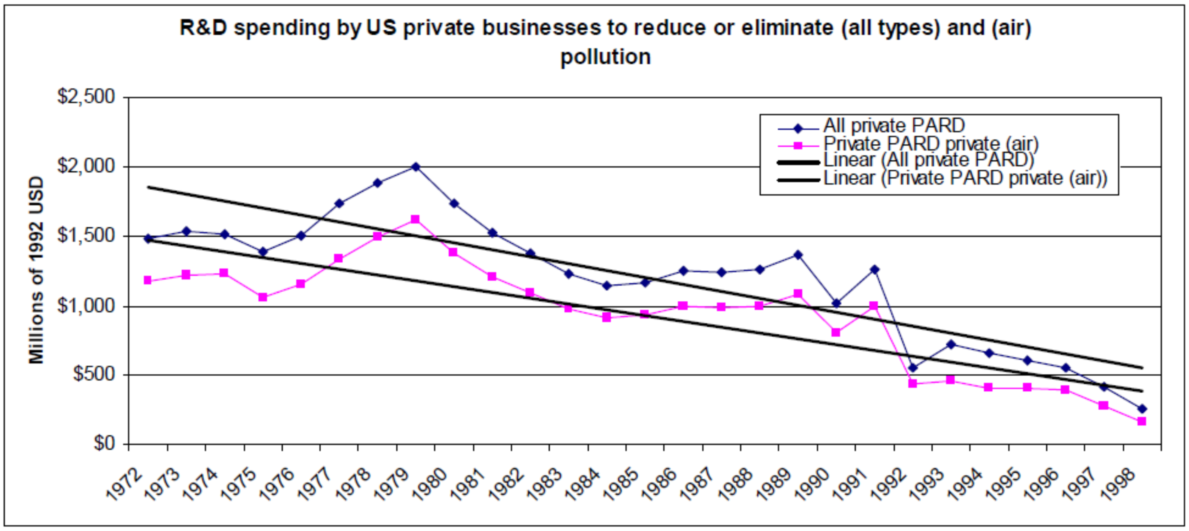
Figure 6: Types of environmental technologies implemented in 3,100 establishments in manufacturing in seven OECD countries (%)



Source: Frondel et al. (2004; 2007)

We lack systematically collected data on eco-innovation. The most important sources of information are patent data, sales and exports data of environmental goods and services, and capital investments and operating expenditures on pollution abatement and control. Attempts are being made to use NACE for measuring environmental technologies. Environmental technologies are divided in core ET and secondary ET. Data on environmental R&D only exist for a few countries (Canada, US and Japan, as far as I know). In the US private sector R&D spending in pollution abatement technologies has fallen enormously (Grover, 2009).

Figure 7. Private sector R&D spending in pollution abatement (total and air)



Source: Grover (2009, p. 10)

5. National strengths in environmental technology

If we look at the world market for environmental good and services, we observe that US firms are strong in air pollution technologies, European firms in waste-water technologies and waste management and Japanese firms in energy-efficiency and new materials.[7] Europe is leading in wind turbine technology and Japanese firms in solar energy.

The creation of competitive strengths owes a great deal to domestic policies. The US air emission limits introduced in the 70s helped to create a new industry in pollution control technology. Even today the US is a net exporter. In the Netherlands, the waste-water control policies introduced in the 1970s gave a boost to waste-water engineering companies, leading to a strong position in the 1980s (which somehow got lost in the past 10 years, see Appendix 1). Germany waste companies benefitted from the large waste market following the introduction of the DSD programme and the feed-in law for electricity gave a boost to German wind turbine manufacturing and solar PV.

The strong position of US firms in air pollution control, German companies in waste management and wind power and French companies in water almost certainly owes a great deal to national environmental policies but we lack detailed studies of the generation of those industries and international competition between those industries. The issue of lead markets creating sustained competitive advantages has been studied by Beise (2001) and others, finding that there is indeed evidence of such an effect.

Observing the link between national environmental policies and green business, several countries have made eco-innovation part of their industrial innovation policies. These policies are driven by multiple goals of environmental protection, business creation, employment and security in the case of energy. An example is the Dutch transition approach for sustainable energy and the Japanese approach for creating a low-carbon society. Such approaches have a very strong technology development component, with selected technologies being based on national strengths and views on critical technologies for the future.

[7] Further research is needed to establish this. We lack good and reliable statistics about the environmental goods and services market which has been variously estimated at 500 billion euro and 1,000 billion euro in 2005, with Berger consultants putting it at 1000 billion and predicting a market of 2,200 billion euro by 2020. In this scenario, the importance of eco-innovation is likely to grow, especially in emerging economies and developing countries.

Core Technologies to Achieve Low-Carbon Society (Fukuda Vision)

Area	Core Technologies
Power Generation and Transmission	Highly-efficient fire power based on natural gas and coal, Carbon Capture & Storage (CCS), solar power generation, nuclear power generation, highly- efficient electric power transmission, etc.
Transportation	Fuel cell vehicles, plug-in hybrid electric vehicles, biofuel, etc.
Industries	Innovative technologies for materials, manufacturing, and processing, innovative steel-making process, etc.
Public Livelihood	Energy-saving houses and buildings, high-efficiency lights, fixed-type fuel cells
Others	High performance batteries; manufacturing, transportation, and saving of hydrogen

Note: CCS is a technology that stores CO2 generated in the production process instead of releasing it into the atmosphere.
Source: Korea Institute for International Economic Policy.

Source: Lee (2008)

In the Netherlands the selection of these technologies is done by 7 transition platforms. This approach is discussed in the section 6.

The EU is using a lead market approach to promote 4 eco-innovation product areas for which there is a highly predicted demand, a strong technological and industrial base in Europe, an already existing market whose development and success depending more than other markets on the creation of favourable framework conditions through public policy measures.

The eco-innovation areas selected are sustainable construction, recycling, bio-based products and renewable energies. For each market, a plan of action for the next 3-5 years has been formulated. (see http://ec.europa.eu/enterprise/leadmarket/doc/com_07_en.pdf)

The success of these initiatives will depend on the extent to which they are able to create market pull, technological capabilities and remove obstacles to new technologies. To be successful, countries have to work on several fronts: the front of *specific technology innovation systems* (such as biorefineries, smart grids and hydrogen fuel cell vehicles) which have to be nurtured, the front of the *national system of innovation* which has to become more conducive for green development (through tax policies and other control policies, availability of venture capital, creation of skills, knowledge transfer, and so on), and the front of *sustainable development policy* at different levels (local, regional and national).

6. System innovation for the environment

Environmental benefits may also be achieved through altogether different systems of provision. Examples of system innovations offering environmental benefits are being identified in the Dutch sustainable technologies programme in the 1990s. These include: novel protein foods based on non-meat proteins (10-30 factor improvement), precision agriculture (up to factor 50 improvement), decentralised production of electricity using renewables and micro-turbines, underground transport of commodities in pipe lines (factor 10 improvement in energy efficiency), and industrial ecology (Weaver et al., 1999).[8] Cradle to cradle and vehicle to grid systems are two other examples, which are expected to bring significant benefits. cradle to cradle is a product design principle which says that every part of the product should be safe and designed for re-use (McDonough and Braungart, 2002). Vehicle-to-grid (V2G) uses vehicles as electrical storage, buying and selling power from the grid. Proposed by Amory Lovins in 1995 and further developed by William Kempton at the University of Delaware, the V2G concept has caught the interest of several utilities and several start-up companies.[9] Electric vehicles would store electricity generated during off-peak or from renewables, helping to reduce the need for extra load power to meet peak demand and helping renewables such as wind power which suffer from irregular supply. It could facilitate the transition to a low carbon energy system and produce significant air quality benefit in cities. It also would allow households to become carbon neutral and energy autonomous.

Such new systems are unlikely to emerge through the normal operation of markets or through business sustainability strategies. The creation of new system innovation is inexorably linked with institutional change, guiding images and joined up efforts (Kemp et al, 2007), different social practices and a new type of normality (Shove, 2003).

In the Netherlands system innovation is the stated aim of government-led "transition" initiative in the area of energy. It is believed that the use of fossil fuels is not sustainable environmentally and ultimately also not economically, which led policy makers to engage in a transition approach for system innovations. Transition management relies on guided processes of variation and selection. It makes use of "bottom-up" developments and long-term thinking. A set of 35 transition paths are being supported (including biomass for electricity, clean fossil, micro cogeneration but also radical things such as energy-producing greenhouses for growing crops). The government acts as a process manager, dealing with issues of collective orientation and interdepartmental coordination. It also takes on a responsibility for the undertaking of strategic experiments and programmes for system innovation.

Based on suggestions from the transition platforms a transition action plan was formulated in 2005 containing the following goals:

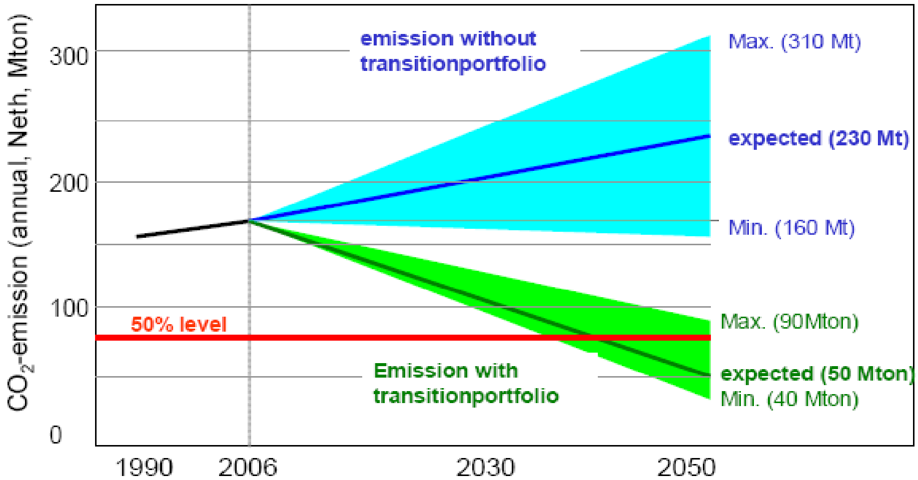
- -50% CO_2 in 2050 in a growing economy
- An increase in the rate of energy saving to 1.5- 2% a year
- The energy system getting progressively more sustainable
- The creation of new business

Through the transition approach the Dutch government hopes to achieve an extra 180Mton CO_2 reductions (see figure 4).

[8] Other examples of system innovation are: biomass-based chemistry, multiple sustainable land-use (the integration of the agricultural function with other functions in rural areas) and flexible, modular manufactured construction (Ashford et al., 2001).

[9] From http://www.smartgridnews.com/artman/publish/article_206.html

Figure 8: Time path for CO2 emissions in the Netherlands



Source: Presentation Hugo Brouwer in London (2005)

The whole approach is set up as a vehicle for sociotechnical change *and* policy change in a coordinated manner. This is evident from the following quote from policy makers Dietz, Brouwer and Weterings:

> "It is clear that working on fundamental changes to the energy system can only be successful if the government adjusts its policy instrumentarium accordingly. This means that the policy for research and development, the stimulation of demonstration projects, and the (large-scale) market introduction must be brought in line with the selected transition pathways. In addition, the suggestions for new policies put forward by the platforms must be taken seriously. At this point, the government faces a major challenge, because much of the current policy was formulated based on the classic way of thinking that is characterized by a top-down approach and dominated by short-term objectives, implemented by fragmented and individually-operating departments and Ministries, on which market influences do not or hardly have any effect" (Dietz et al., 2008, p. 238)

It is also evident from the activities of the RegieOrgaan and the platforms for 2009.

Platform	**Planned activities in 2009**
RegieOrgaan	• Production of an official advice on policy, in which they make recommendation for instrument choices
Green resources	• To follow the implementation of sustainability criteria for biomass • Position paper on CO2 allowances for biomass • To launch an explorative study into the macroeconomic effects of biomass production and use in the Netherlands. • To develop a systematique for measuring green resources
Sustainable mobility	• To make recommendations for fiscal treatment of clean vehicles • To discuss the action plan on alternative mobility with leasing companies • To examine how natural gas and green gas may pave the way for hydrogen. • Evaluate experiences with buss experiments funded in the first tender • To offer advice on how public transport concessions may be used for innovation • To assist in the implementation of 5 pilots about smart grids and

	electric mobility • To lauch or stimulate pilots for sustainable biofuels (high blends and biogas) and hydrogen in five cities in cooperation with Germany and Flanders in Belgium
New Gas	• To investigate product-market-combinations for decentralised gas use • To commission or undertake a study into the potential of gas motors and absorption heat pumps
Chain efficiency	• Starting the first phase of the programme for precision agriculture • Working out a development plan for process intensification
Sustainable Electricity Production	• Formulate platform positions on off shore energy, • rules for co-burning of biomass, cogeneration, and conditions for coal-fired plants • Implementation the earlier formulated action plan Decentralised infrastructure (smart nets) • To examine and utilise opportunities in blue energy
Built environment	• Platform advice about the restructuring of existing business parcs • Workplan (script) for achieving energy saving using a district-based approach. • Investigation of how local authorities may be involved, on a voluntary and less voluntary basis.

As one can see the platforms produce advice, they take stock of what has been achieved, they commission studies and are involved in all kind institutional alignment activities (also between the platforms). The platforms are currently working with municipal authorities and national government to create pilots for energy neutral living districts to learn about alternative energy systems (with the systems going beyond particular technologies from the platforms) and to create visibility for the energy transition.

Much is expected from the transition approach, in terms of CO2 reductions and the creation of new business. Expectations about transition management are thus rather high, even when transition research (Geels, 2005) strongly suggests that transitions in sociotechnical systems defy control and effective steering. Policy can do little more than increase the *chance* for a transition to occur and shape the features of it.

So far, the approach is viewed as very successful in stimulating business to engage themselves in radical innovation projects, something which was not happening before in any significant way. Immaterial innovations are the creation of an interdepartmental directorate for (horizontal) policy coordination, a special desk for innovators (for help and advice), the creation of 7 transition platforms and instruments such as the 45 million euro funding scheme for transition experiments (UKR).

The transition approach for system innovation is one of the pillars of the Dutch strategy to achieve carbon reductions. It is an open-ended approach: a flexible portfolio of 31 transition paths based on different visions is explored in an adaptive manner, using a probe and learn strategy.[10] System innovation possibilities are stimulated alongside system improvement options through a range of policies. The approach is mindful of sustainability risks. For biofuels sustainability criteria are formulated.

[10] Suggestions for transition management are offered by Loorbach (2007). A description and discussion of Dutch transition policies can be found in Kemp and Loorbach (2008) and Kern and Smith (2008).

7. Conclusions

In this paper I have examined the notion of eco-innovation and patterns in eco-technology. In developed countries attention shifted from end-of-pipe technologies to cleaner production, green product change and system innovation. Whether the same holds true for developing countries and New Industrialising Countries such China and India is unclear. These countries probably rely greatly on end-of-pipe solutions, which - as this paper discovered - also in developed countries continue to be important.

Eco-innovations are driven by environmental and economic concerns. Clean production process changes are mostly driven by cost concerns of reducing resource costs.

We lack systematic data in what ways countries and sectors are eco-innovating. It is unclear whether they are spending more or less on eco-innovation than 5 or 10 years ago. In the US private sector R&D expenditures in pollution abatement have fallen significantly. An interesting development is the growing attention to green system innovation in business and government. Examples are cradle-to-cradle products, vehicle-to-grid electricity systems, or customised mobility. This attention is both new and old. The closing of material loops is an old vision. The vision of decentralised electricity systems is old too, and the vision of vehicle-to-grid has been around for a while (at least since 1995). Advances in technology, new business models (such as pay per km for the use of electric cars) and concerns about fossil fuels availability and climate warming give new impetus to these older visions, sometimes under new names. More than in the past, governments appear willing to stimulate eco-innovation. They are doing this for environmental and economic reasons. Eco-innovation has become a pillar of the EU Lisbon competitiveness strategy, the EU Gothenburg sustainable development strategy and a target for industrial innovation policy in several countries. What will come from this is not clear. Truly radical change arguably requires sustained policy support and radical changes in prices (framing conditions). To achieve an absolute decoupling instead of just a relative decoupling through the use of eco-innovation governments have to work on three fronts: the front of *specific technology innovation systems* (such a biorefinery, smart grids, etc.) which have to be nurtured, the front of the *national system of innovation* which has to become more conducive for green development (through tax policies and other control policies, availability of venture capital, creation of skills, knowledge transfer, and so on), and the front of *sustainable development policy* at different levels (local, regional and national) (see Kemp, 2000; Butter, 2002, Kemp et al. 2004; Rennings et al., 2003; Reid and Miedzinski, 2008; Kemp and Pontoglio, 2008).

References

Arimura, T.; Hibiki, A.; Johnstone, N. (2007) An Empirical Study of Environmental R&D: What encourages facilities to be environmentally innovative?, in: Johnstone, N. (ed.): *Environmental Policy and Corporate Behaviour*, Edward Elgar, Cheltenham, UK.

Anthony A. and R. Kemp (2009) Measuring eco-innovation, paper for OECD.

Bartolomeo, M., Kemp, R., Rennings, K. and Zwick, T. (2003) Employment Impacts of Cleaner Production: Theory, Methodology and Results. In: Rennings, K., T. Zwick (eds.): Employment Impacts of Cleaner Production. ZEW Economic Studies 21, Physica Verlag, Heidelberg/New York.

Beise, M., (2001) Lead Markets: Country-specific Success Factors of the Global Diffusion of Innovations, ZEW Economic Studies, Vol. 14, Physica Verlag, Heidelberg/New York.

Beise, M. K. Rennings (2003): Lead Markets of Environmental Innovations: A Framework for Innovation and Environmental Economics. ZEW Discussion Paper No. 03-01, Mannheim

Butter, M. (2002): A Three Layer Policy Approach for System Innovations. Paper presented on the 1st Blueprint Workshop "Environmental Innovation Systems", Brussels, January 2002, www.blueprint-network.net

Darnall, N., Jolley, G. J., and B. Ytterhus (2007) Understanding the relationship between a facility´s environmental and financial performance, in: Johnstone, N. (2007): *Environmental Policy and Corporate Behaviour*, Edward Elgar, Cheltenham, Northhampton

De Vries, F. P. and Withagen, C. (2005): Innovation and Environmental Stringency: The Case of Sulphur Dioxide Abatement, Discussion Paper of the University of Tilburg No. 2005–18

Del Rio Gonzalez, P. (2009) The Empirical Analysis of the Determinants for Environmental Technological change: A Research Agenda, *Ecological Economics* 68(861-878.

Dietz, F, Brouwer, H., and Weterings, R (2008) Energy Transition Experiments in the Netherlands, in J. van den Bergh and F. Bruinsma (eds.) *Managing the transition towards renewable energy: Theory and practice from local, regional and macro perspectives*, Edward Elgar, Cheltenham, pp. 217-244.

Ecotec (2002) Analysis of the EU Eco industries, their employment and export potential, report for DG Environment of the European Commission.

Environmental Innovation Advisory Group (2006), *Environmental Innovation - Bridging the gap between environmental necessity and economic opportunity*, First report of the Environmental Innovation Advisory Group, Department of Trade and Industry, UK, http://www.dti.gov.uk/files/file34987.pdf

Eurostat/OECD (1999). *The Environmental Goods & Services Industry: manual for data collection and analysis.*

European Commission (2002) Environmental technologies for sustainable development, COM(2002) 122Final.

European Commission (2003): Developing an Action Plan for Environmental Technology. Website http://europa.eu.int/comm/environment/etap

European Commission (2004) Communication from the Commission to the Council and the European Parliament. Stimulating Technologies for Sustainable Development: An Environmental Technologies Action Plan for the European Union. COM(2004) 38 final.

European Commission (2005) Report on the Implementation of the Environmental Technologies Action Plan. COM(2005) 16 Final.

Ernst and Young (2006) Eco-industry, its size, employment, perspectives and barriers to growth in an enlarged EU, report for European Commission.

Frondel, M.; Horbach, J.; Rennings, K. (2007) End-of-Pipe or Cleaner Production? An Empirical Comparison of Environmental Innovation Decisions Across OECD Countries, in: *Business Strategy and the Environment*, Vol. 16/8, 571-584

Geels, F.W., 2005, *Technological Transitions and System Innovations: A Co-evolutionary and Socio-Technical Analysis*, Cheltenham: Edward Elgar.

Grover, D. (2009) Long term trends in environmental innovation investment by US industry 1972-1998: new evidence, description and analysis, paper for DIME – RAL2 Conference 2009 "Eco-Innovations and Global Sustainable Development", Maastricht, 29-30 April, 2009.

Horbach, J. (2005) *Indicator Systems for Sustainable Innovation*, Physica, Heidelberg, New York

Horbach, J. (2008) Determinants of Environmental Innovation – New Evidence from German Panel Data Sources, *Research Policy* 37 (2008), 163-173.

Interdepartementale Programmadirectie Energietransitie (2008) Werkplan 2009.

James, P. (2002) Integration of Environment into Technology Innovation Processes – Case Studies of "Lightweight" Innovation. Paper presented on the 2nd Blueprint Workshop on Business Strategies for Integrating Environmental and Innovation Management, Brussels, May 2002, www.blueprint-network.net

Johnstone, N. (2007) *Environmental Policy and Corporate Behaviour*, Edward Elgar, Cheltenham, UK.

Johnstone, N., and Hascic, I. (2008a) Preliminary indicators of eco-innovation in selected Environmental Areas, ENV/EPOC/WPNEP(2008)7, OECD, Paris.

Johnstone, N., and Hascic, I. (2008b) Eco-innovation: Environmental Policy and Technology Transfer, ENV/EPOC/WPNEP(2008)6, OECD, Paris.

Johnstone, N., and Hascic, I. (2008) Encouraging Sustainable Manufacturing and Eco-Innovation, DSTI/IND(2008)8, OECD, Paris.

Kemp, R. (2002) Synthesis report of 1st BLUEPRINT Workshop, Environmental Innovation Systems, Jan 23 to 24, 2002, Brussels

Kemp R (1997) *Environmental Policy and Technical Change. A Comparison of the Technological Impact of Policy Instruments*, Edward Elgar, Cheltenham

Kemp, R. (2000), Technology and Environmental Policy—Innovation effects of past policies and suggestions for improvement, OECD proceedings Innovation and the Environment, OECD, Paris, 35-61.

Kemp, René, and Maj Munch Andersen (2004) strategies for eco-efficiency innovation, report for informal environmental council of 16-18 July, 2004, Maastricht.

Kemp, R., D. Loorbach and J. Rotmans (2007) Transition management as a model for managing processes of co-evolution, *The International Journal of Sustainable Development and World Ecology* (special issue on (co)-evolutionary approach to sustainable development) 14: 78-91.

Kemp, R., and Pearson, P. (2008) Measuring eco-innovation, final report of MEI project for DG Research of the European Commission.

Kemp, R., and Pontoglio, S. (2008): The innovation effects of environmental policy instruments – a typical case of the blind men and the elephant, paper submitted to Environmental and Resource Economics

Kern, F. and Smith, A. (2007) Restructuring energy systems for sustainability? Energy transition policy in the Netherlands, Sussex Energy Group Working Paper. Submitted to Energy Policy

Loorbach, D., and Kemp R. (2008) Transition management for the Dutch energy transition: multilevel governance aspects, in: J. van den Bergh and F. Bruinsma (eds.) *Managing the* *transition towards renewable energy sources: Theory and practice from local, regional and macro perspectives*. (pp. 243-264). Edward Elgar, Cheltenham.

Labonne, J., and N. Johnstone (2006) Environmental Policy and Economies of Scope in Facility-Level Environmental Management, unpublished mimeo.

Lanjouw, J.O. and Mody, A. (1996) Innovation and the International Diffusion of Environmentally Responsive Technology, *Research Policy*, 25, pp. 549-571.

Lanoie, P.; Laurent-Lucchetti, J.; Johnstone, N.; Ambec, S. (2007) Environmental Policy, Innovation and Performance: New Insights on the Porter Hypothesis, Institut d´économie appliquée, Cahiers de recherche IEA-07-06, Montreal

Lee, J-H. (2008) Arrival of an Era of Green Growth, Korea Economic Trends, 13 October, 2008.

Legler, H.; Krawczyk, O.; Rammer, C.; Löhlein, H.; Frietsch, R. (2007) Zur technologischen Leistungsfähigkeit der deutschen Umweltschutzwirtschaft im internationalen Vergleich, in: Bundesministerium für Bildung und Forschung (BMBF) (Ed.), Studien zum deutschen Innovationssystem Nr. 20-2007, Berlin.

Loorbach, D. (2007). Transition Management: new mode of governance for sustainable development. International Books. Utrecht, the Netherlands.

Ministry of Economic Affairs. 2004. *Innovation in energy policy. Energy transition: state of affairs and continuation*. The Hague, the Netherlands.

Mazzanti, M.; Zoboli, R. (2006) Examining the factors influencing environmental innovations, FEEM working paper series 20.2006, Milano

McDonough, W., and M. Braungart (2002) *Cradle to Cradle: Remaking the Way We Make Things*, North Point Press.

OECD (1997), *The Measurement of Scientific and Technical activities: Proposed Guidelines for Collecting and Interpreting Technical Innovation data (The Oslo Manual),* Paris, OECD.

OECD, Eurostat (2005) Oslo Manual Guidelines for Collecting and Interpreting innovation data, third edition, Paris, Luxemburg.

OECD (2009) Sustainable Manufacturing and Eco-Innovation, Part IV: Existing Methods for Macro-Level Measurement of Eco-Innovation, DSTI-IND(2009)5-PART4-ENG

Porter, M. E.; van der Linde C. (1995): Toward a New Conception of the Environment-Competitiveness Relationship, in: Journal of Economic Perspectives 9, No. 4, 97-118

Reid, A. Miedzinski (2008) Eco-innovation. Final report for sectoral innovation watch, Technopolis.

Rennings, K. (2000) ‘Redefining Innovation-Eco-innovation Research and the Contribution from Ecological Economics, *Ecological Economics*, 32, 319-322.

Rennings, K., A. Ziegler (2003), *Employment Impacts of Cleaner Production*, ZEW Economic Studies, Physica Verlag, Heiderberg/New York.

Rennings, K., Kemp, R., Bartolomeo, M., Hemmelskamp, J. and Hitchens, D. (2003) Blueprints for an Integration of Science, Technology and Environmental Policy (BLUEPRINT), Final Report of 5th Framework Strata project, available at http://www.insme.info/documenti/blueprint.pdf

Shove, E. (2003) *Comfort, Cleanliness and Convenience: The Social Organization of Normality* (series New Technologies/New Cultures), Oxford.

Technopolis (2008) Eco-innovation. Final report for sectoral innovation watch.

Wagner, M. (2007): The Link between Environmental Innovation, Patents, and Environmental Management, DRUID Working Paper No. 07-14

Weaver, P., L. Jansen, G. van Grootveld, E. van Spiegel and P. Vergragt (2000) *Sustainable Technology Development* (Sheffield: Greenleaf Publishing)

APPENDIX 1. RPA values for environmental technologies of different countries from 1985 to 2004

Tab. A.3.1: Patentspezialisierung bei Umwelttechnologien ausgewählter Volkswirtschaften 1985-2004

	USA	GER	JPN	GBR	FRA	SUI	CAN	ITA	NED	SWE	FIN	KOR	DEN	AUT	EU15
Abfall															
85-87	-18	32	-57	-72	37	-73	56	43	-40	24	-5		52	54	19
93-95	-37	29	-38	-6	47	43	33	5	-43	-10	-33	-88	79	56	25
02-04	-34	36	42	-9	52	39	70	-72	-100	-11	-100	-100	22	-6	-31
Recycling															
85-87	-40	47	-74	-13	-19	42	75	-25	35	31	-7		-13	78	29
93-95	-32	38	-50	-14	-27	27	61	3	39	23	55	-93	59	82	25
02-04	-59	6	-8	-1	-34	-15	22	57	33	27	-30	-74	63	86	19
Lärm															
85-87	-36	40	-77	-14	-9	76	-100	-37	23	39	-100		-100	91	28
93-95	-48	49	-29	-26	18	-4	-69	10	43	57	41	-64	82	20	34
02-04	-36	43	-27	-45	31	43	-10	8	-25	39	-86	-57	-56	62	25
Luft															
85-87	-54	63	-17	-71	-58	-29	38	-87	-44	22	82		30	43	28
93-95	-49	44	43	-26	-46	-6	-69	-33	-74	46	-30	-75	13	17	10
02-04	-71	44	54	-32	16	-57	-85	-17	-79	48	-22	-100	2	26	18
Wasser															
85-87	-22	31	-70	0	-25	32	34	-35	33	20	88		56	77	23
93-95	-26	27	-51	16	5	-7	71	-33	-1	45	33	42	32	33	18
02-04	-6	0	-25	-14	25	-23	24	-33	-36	30	38	-42	74	53	9
Umweltmesstechnik															
85-87	29	12	-64	20	13	-84	-8	-50	-77	-58	-100		-100	-72	0
93-95	17	-21	-63	48	43	-51	-36	-43	-24	38	47	-60	84	-57	11
02-04	32	-32	-73	-32	21	-45	14	-42	25	6	30	-39	34	-100	-5
Rationelle Energienutzung und Klimaschutz															
85-87	6	1	-77	0	34	41	-62	98	-63	38	10		4	-91	16
93-95	-10	-37	-37	-26	-39	74	-43	92	-7	-17	49	91	4	-55	7
02-04	-22	1	-23	12	-28	58	-16	74	-87	-26	-99	93	-100	-38	0
Regenerative Energien															
85-87	18	5	6	-20	-51	1	-100	-60	-45	28	-11		48	-79	-14
93-95	-39	0	44	-18	-57	5	-70	-74	-3	-9	2	41	73	63	-11
02-04	-53	17	13	10	-31	-12	0	-3	20	6	-17	-78	93	43	19
Umweltanmeldungen															
85-87	-22	40	-52	-26	-12	12	30	43	-9	23	63		27	57	21
93-95	-30	26	-14	-4	-4	20	26	16	-5	29	26	10	59	47	16
02-04	-34	16	7	-6	1	5	-6	27	-28	18	-21	9	56	42	12
Brennstoffzellen															
85-87	72	-83	-1	-100	-88	-100	-2	-100	-100	-100	-100		-100	-100	-91
93-95	9	6	15	28	-100	53	91	-44	-29	-100	-100	27	59	-100	-28
02-04	-15	-26	69	-57	-61	-16	73	-54	-84	-100	-97	-4	22	-100	-50

Source: Legler et al. (2007, p. 150).

Appendix 2. Overview of transition platforms, pathways and experiments in the Netherlands for sustainable energy

Platforms	Pathways	Experiments/projects
Chain Efficiency Goal: savings in the annual use of energy in production chains of: - 40 à 50 PJ by 2010 - 150 à 180 PJ by 2030 - 240 à 300 PJ by 2050	KE 1: Renewal of production systems KE 2: sustainable paper chains KE 3: sustainable agricultural chains	Save 50% energy use along the production chain of paper by 2020
Green Resources Goal: to replace 30% of fossil fuels by green resources by 2030	GG 1: sustainable biomass production GG 2: biomass import chain GG3: Co-production of chemicals, transport fuels, electricity and heat via bio-refining (fractionation), fermentation, enzymatic/chemical conversion, gasification/pyrolysis /fermentation/co-fuel waste streams GG4: production of SNG GG 5: Innovative use of biobased raw materials for non-food/non-energy applications and making existing chemical products and processes more sustainable	Conversion of the MTBE (methanol tertiary butyl ether) production process to ETBE (ethanol tertiary butyl ether) based on bio-ethanol Bio-plastics: Breakthrough to self-sustaining growth Breakthrough for bio-plastics to high-value applications A factory for the production of bio-diesel from palm oil
New Gas Goal: to become the most clean and innovative gas country in the world	NG 1: Energy saving in the built environment NG 2: Micro and mini CHP NG 3: clean natural gas NG 4: Green gas	Buses on natural gas in Haarlem/Rijnmond Liquefied natural gas as a substitute for diesel Introduction of compressed natural gas as a mature car fuel in the North of the Netherlands Polder district in Zeewolde gets heating on biogas Pilot project of micro generation in households
Sustainable Mobility Goals: Factor 2 reduction in GHG emissions from new vehicles in 2015 Factor 3 reduction in GHG emissions for the entire automobile fleet 2035	DM 1: Hybrid and electric vehicles DM 2: Biofuels DM 3: Hydrogen vehicles DM 4: Intelligent transport systems	Realisation of the hydrogen cart (Formula 0) A sustainable petrol station in the North of the Netherlands A large-scale production facility for bio-diesel in Terneuzen
Sustainable Electricity Goal: A share of renewable energy of 40% by 2020 and a CO2-free energy supply by 2050	DE 1: Wind onshore DE 2: Wind offshore DE 3: solar PV DE 4: central infrastr. DE 5: decentralised infstr.	

Built Environment Goal: by 2030 a 30% reduction in the use of energy in the built environment, compared to 2005	GO 1: Existing buildings GO 2: Innovation GO 3: Regulations	Use of mine water for heating and cooling
		A good perspective can give an impetus for energy saving in council housing sector
		Heating in houses based on waste wood from pruning trees in Eindhoven
		heat transition in housing construction
		‘Geothermal heat for the whole Netherlands’ (heat pumps)
		Collective sustainable energy storage devices for heating and cooling
		Sustainable heat and cooling through the use of heat pumps
Energy-producing Greenhouse Goals for 2020: • Climate-neutral (new) greenhouses • 48% reduction in CO_2 emissions • Producer of sustainable heat and energy • A significant reduction in fossil fuel use	KE 1: Solar heating KE 2: Use of earth heat KE 3: Biofuels KE 4: Efficient use of light KE 5: Cultivation strategies and energy-low crops KE 6: Renewable electricity production KE 7: Use of CO2	Greenhouse which does not use natural gas in Ter Aar
		Use of earth heat in Bleiswijk
		Semi-closed greenhouse
		CO_2 delivery to greenhouses in horticulture sector (OCAP)

Source: Kern and Smith (2007), http://www.creatieve-energie.nl/