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Deliverable 1

Eco-innovation from an innovation dynamics perspective

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1. What is innovation?

Innovation is commonly understood as novelty leading to value creation on the market. According to the Oslo Manual (OECD 2005), innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practice. The innovation that is being developed or adopted may be new to the world or new to the company. Innovation does not require in-house investment in creative activities such as R&D. Firms can innovate by adopting technology developed by other firms or organizations.

Following the OECD Guidelines for Collecting and Interpreting Technological Innovation Data (OECD, 2005), we may distinguish between technical, marketing and organisational innovations. Technical innovations are divided into product and process innovations:

- Process innovations occur when a given amount of output (goods, services) can be produced with less input.
- Product innovations require improvements to existing goods (or services) or the development of new goods. Product innovations in machinery in one firm are often process innovations in another firm.
- Marketing innovations refer to the implementation of new marketing methods in order to increase firms' sales.
- Organisational innovations include new forms of management, e.g. total quality management.

The European Commission points to the changing competitive conditions of the knowledge economy in their communication to the Council on the Union's future approach to innovation policy. They argue for the need to take on a broader innovation concept and point to the following three types of innovation:

1. *Technological innovation*, primarily stemming from research
2. *Organisational innovation* or business model innovation, related to innovative ways of organising work in areas such as workforce management, distribution, finance and manufacturing.
3. *Presentational innovation*, covering innovations in design and marketing.

It underlines the decreasing role of productivity and the rising role of more "soft" parameters for competitiveness. While it by now is well recognized that *competition on knowledge* is central in the knowledge economy, the rising importance on *competition on values* is less recognized. The innovation type 3, presentation innovation, underlines this and may have implications for eco-innovations.

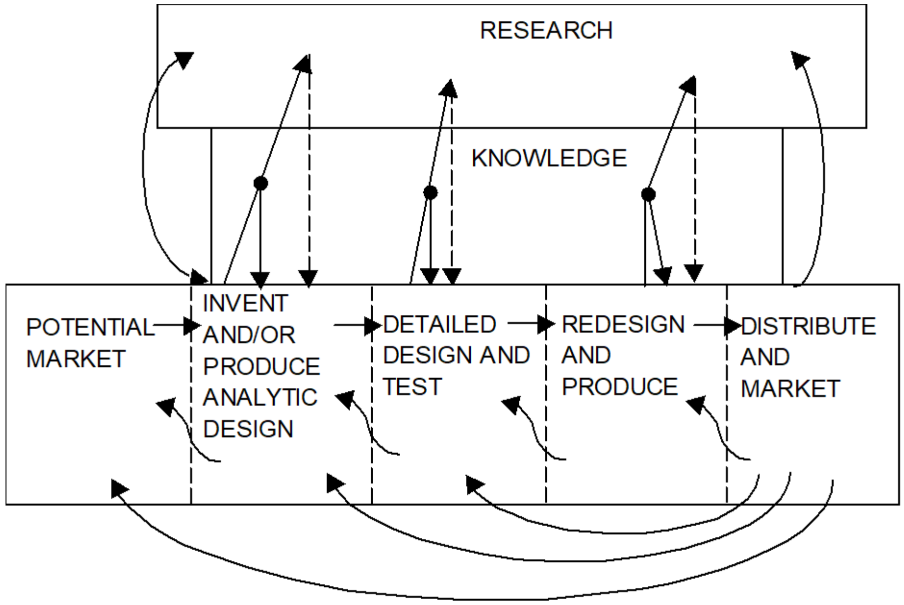
Presentational innovation relates to the rising role of branding, image and design for competitiveness. The identity a product gives, the story associated to it, is as important as its function to many (affluent) consumers. Even in poorer economies a brand such as

Coca Cola is capable of achieving rising market shares despite high costs because of its presentational value.

Innovation should be distinguished from invention. The concept *invention* refers to discovery. The overwhelming majority of innovations are not based on discovery but the outcome of applied R&D and search processes not resulting in discovery. The mountain bike is not based on a discovery. Halogen lightning is based on discovery but draws on much more than scientific discovery. It is based on understandings of user valuations, production technology and standards. In the creation of innovation, different types of knowledge are combined, which means that innovation is better understood as recombination rather than technical discovery, by drawing on technological advances, knowledge and skills from various areas (materials, electronics, software for design and testing, etc.) that are brought together in an organizational context. Advances in technology and feedback from users help product innovation vendors to improve their products and economies of scale and competition help to bring down prices for the innovation. The stage model of invention-innovation-diffusion should be understood as a model of **overlapping stages and interactions** instead of a model of separate (linear) stages.

The linear model of innovation is nowadays superseded by a chain-linked model, which sees innovation and diffusion as related rather than separable (see Figure 1). The ‘chain linked’ model of multiple feedback loops was made by Kline and Rosenberg (1986). 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.

Figure 1. An interactive model of the innovation process: The chain-linked model



Source: Kline and Rosenberg (1986)

Innovation involves learning and alignment of various activities: research, production, sourcing, distribution and marketing. Many actors are involved in it: company R&D departments, operators, plant managers, general management, marketing people, users, researchers in the public sector. Users are an important source of information. Users are an important source of learning and innovation. According to the Community Innovation Survey (CIS), users are the most important source of information for product innovation, before suppliers and public sector institutions [should give exact reference and look more deeply into this]

The innovation process is best viewed as a search and learning process, involving the management of multiple junctions; it is error-ridden with frequent setbacks and new directions opened by new ideas. Companies play a key role in the innovation process, not only as important developers of knowledge but because they are the ones transforming ideas for innovation into value creation on the market (Foxon and Kemp, 2004). An important in-depth study of the process of innovation is the Minnesota Innovation Research Programme (MIRP), under the direction of Andrew Van de Ven, in which 14 innovations were studied by thirty researchers over a 17 year period. The study was conducted in 'real-time' during the innovation process, enabling the researchers to observe and analyse events as they occurred. The aim of the study was to answer the encompassing question "How and why do innovations develop over time from concept to implementation?" The study helped to dispel many popular beliefs of innovation. Instead of being an orderly process based on the development of a single idea, the study disclosed that the ideas behind innovation projects were not singular and consistent from project start to finish but, rather, were multiple and constantly developing - diverging, converging, and ultimately cohering into new ideas. Outcomes gave rise to spin-off ideas and projects. The people in the innovation journey did not resemble a single entrepreneur leading a fixed set of people over time but, rather, were a fluidly forming and loosely bounded group with multiple members taking a variety of different roles over time. Transactions did not take place in an orderly and prespecified manner but among an expanding and contracting network of stakeholders. The context was not a static backdrop providing opportunities for innovation but a subjective enacted reality that both supported and constrained the innovation process. Finally, the process was not simple and cumulative but consisted of many divergent, parallel and convergent paths, some related, others not (Table 1.)

Table 1. A comparison of conventional wisdom and MIRP observations

	'Conventional wisdom'	**But the MIRP project finds that**
Ideas	One invention, being operationalised	Re-invention, proliferation, reimplementation, discarding, and termination
People	An entrepreneur with fixes set of full-time people over time	Many entrepreneurs, distracted, fluidly engaging and disengaging over time in a variety of organizational roles
Transactions	Fixed network of people/firms working out details of an idea	Expanding and contracting network of partisan stakeholders diverging and converging on ideas
Context	Environment provides opportunities and constraints on innovation process	Innovation process constrained by and creates multiple enacted environments
Outcomes	Final result orientation; a stable new order comes into being	Final result may be indeterminate; multiple in-process assessments and spinoffs; integration of new orders with old
Process	Simple cumulative sequence of stages and phases	From simple to multiple progressions of divergent, parallel, and convergent paths, some of which are related and cumulative, others not

Source: van de Ven et al (1989)

There exist few studies of innovation journeys of eco-innovations. But we can expect that the above insights pertain largely also to eco-innovations. Constraining and enabling factors may be different, though. In the case of pollution control, regulatory demand plays an important role, guiding research in terms of the design parameters and managerial decisions. Cleaner process technologies and product innovations still have to meet normal user requirements in order to be successfully taken up.

We lack however longitudinal studies of the generative process of eco-innovations and systematic comparisons between normal innovation and eco-innovation.

In the case of eco-innovation, policy in the form of environmental regulations and innovation support may play an important role. But such regulations are not defined independently from technology. There exists a complex interplay between the policy/politics and the techno-economic stream, with policies being based on techno-economic assessments and social demand for pollution control policies. An example of the dynamic interplay between the social system, political system and techno-economic systems can be found in Annex 2 for the example of electric vehicles in California. In this case, the Zero Emission Vehicle Mandate, created by the California Air Resources Board to reduce local air pollution, was originally based on an electric concept car of GM and created a market for battery electric vehicles but from which two other technologies profited (the hybrid electric car and fuel cell vehicles) as the mandate was defined in terms of environmental performance rather than a particular technology (adaptations in the mandate were also beneficial to the other 2 technologies).

The example shows that also in the case of eco-innovations we have competing technologies. Even the creation of a market especially for a technology is no guarantee for its successful diffusion.

Incremental versus radical

Innovations differ with respect to how and where they create novelty. Noticeably they differ with respect to how *radical* they are, i.e. to what degree they require new competencies, and with respect to how *systemic* they are, i.e. to what degree they require complementary innovations, e.g. in the adjacent steps in the value chain, in the wider technical infrastructure or in the consumption patterns of civil society.
Incremental innovations are an important source of productivity and environmental improvements and should not be considered of lesser importance than radical innovations.

Radical innovations may be used within an existing system or within a new one. Fuel-injection is an example of a radical innovation in the internal combustion engine regime but it is not a disruptive technology. A disruptive technology is direct drive in-wheel technology relying on electric propulsion which makes the internal engine and all the activities around it (of part manufacturing and systems of maintenance) obsolete. The fact that not all radical innovations are disruptive leads Christensen (1997) and Ashford (2002) to make a distinction between sustaining innovations and disruptive innovations.

Disruptive vs. sustaining innovation

Disruptive innovations are innovations that eventually overturn the existing dominant technologies or products in the market (Christensen, 1997). Disruptive innovations can be broadly classified into lower-end and new-market disruptive innovations. A new-market disruptive innovation is often aimed at special consumers, while a lower-end disruptive innovation is focused on mainstream customers who were ignored by established companies. Sometimes, a disruptive technology comes to dominate an existing market by either filling a role in a new market that the older technology could not fill (e.g. more expensive, lower capacity but smaller-sized hard disks did for notebook computers in the 1980s) or by successively moving up-market through performance improvements until finally displacing the market incumbents (e.g. digital photography replace film photography).

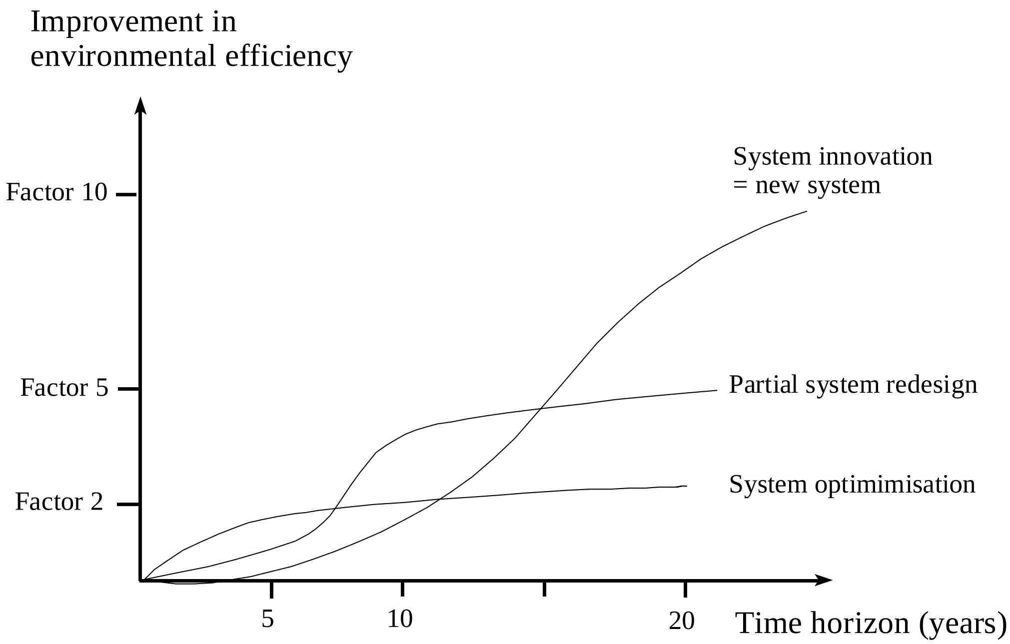
Sustaining innovations build on previous knowledge within the innovating company, servicing existing product markets and users. Sustaining technologies are often incremental improvements in performance of established products, however they can also be radical or discontinuous. An example of a sustaining innovation is the catalytic converter which helped to improve the environmental performance of the internal combustion engine and so maintain the dominance of that technology. They were developed however outside the car industry.

System innovation

Very radical innovations may entail the formation of new technological systems. An example is the centralised electric power system. Within the eco-innovation literature such new systems are often called system innovation for the reason that they are based on a set of innovations (Rennings et al., 2003, Arundel et al., 2005). They usually combine old and new elements. In the case of mobile phones, satellites are used for communications, rather than ground-based networks of antennas and telephone signal transmitters. The new service of sending text messages and the old service of photography being integrated into mobile phones. Mobile phones are a good example of a system innovation in which various features are being combined. System innovation involves major changes in market organization, new companies, mergers, market exits. They are often held back by regulation and the power of incumbents. Market liberalisation was needed for the mobile phone revolution.

System innovations may provide services in a more environmentally friendly way. Examples of new technology systems offering environmental benefits are being identified in the Dutch DTO programme. 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 microturbines, underground transport of commodities in pipe lines (factor 10 improvement in energy efficiency), and industrial ecology (Weaver et al., 1999). The *hypothesised* time path of improvement in environmental efficiency for different types of system change is visualised in Figure 2.

Figure 2: Hypothesised improvements in environmental efficiency



Source: Weterings et al. (1997)

System innovations have not received attention by statistical bureaus dealing with innovation measurement. They are not prone to easy measurement.

All types of innovation are important for achieving environmental improvement, and should be of concern to eco-innovation policy.

2. The innovation systems perspective

Innovation occurs in a context that shapes the processes of innovation and outcomes from these processes. No firm or researcher can innovate on its own: while individuals certainly can invent, only organisations can innovate. Innovation requires the combination of various types of knowledge and resources, and because of this many actors are involved in it. The (national) innovation system perspective, which dominates much RTD policy making, emphasizes how knowledge generation is an interactive process between many actors springing from multiple sources (Lundvall, 1988, 1992 (eds.), OECD 2000). Knowledge is distributed in society among the specialised knowledge producers who need to coordinate and collaborate with each other for efficient innovation. The innovation system perspective particularly emphasizes the central role of interactive learning between the companies (users and producers) in the value chain for the innovation process.

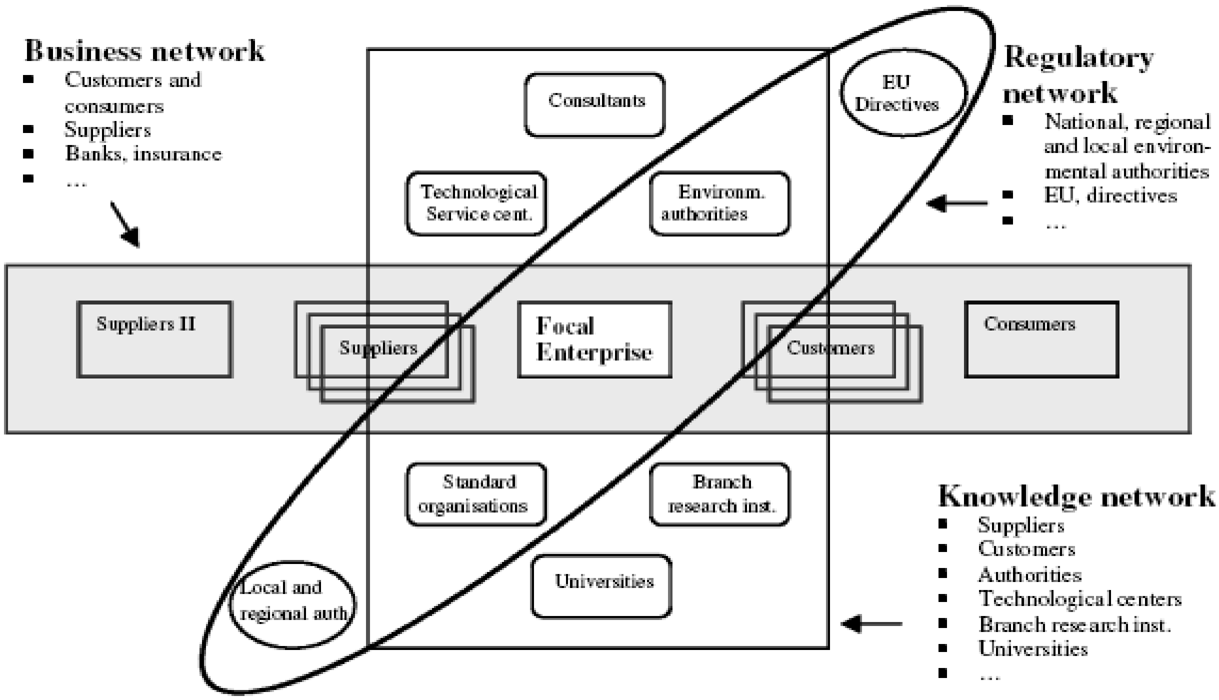
‘Systems’ approaches to innovation are founded on one of the most persistent themes in modern innovation studies, namely the idea that innovation by firms cannot be understood purely in terms of independent decision-making at the level of the firm. Rather, innovation involves complex interactions between a firm and its environment, with the environment being seen on two different levels. On one level, there are interactions between firms - between a firm and its network of customers and suppliers, particularly where this involves sustained interaction between users and producers of technology. Here, the argument is that inter-firm linkages are far more than arms-length market relationships - rather, they often involve sustained quasi-cooperative relationships which shape learning and technology creation. The second level is wider, involving broader factors shaping the behaviour of firms: the social and cultural context, the institutional and organizational framework, infrastructures, the processes which create and distribute scientific knowledge, and so on. (Kemp et al., 2000).

Interactive learning processes have been studied in surveys, for instance Commission Innovation Survey CIS4 where innovators are asked about information sources (internal, market, universities and public research institutes, and other sources such as conferences, journal, professional and industry associations), and co-operation partner (other enterprises, suppliers, clients, competitors, consultants, universities and higher education institutes, government or public research institutes). Companies are also asked which type of co-operation partner they found the most valuable for their innovation activities.

The reason for giving much attention to organizational innovations is that the gains from advanced technology depend upon the adoption of appropriate organisational structures and the formation of new skills. Without the alignment of the organisation to the new technologies the gains from new technologies will be limited or even negative. Changes in organisational systems may also be needed to take stock of new technological possibilities, and to design actions and policies to develop, adopt and use new and better technologies.

National innovation system approaches go beyond single companies to look at the interactions between various knowledge holders. For eco-innovation, important actors are: producing companies and their suppliers, banks, distributers and retailers (forming the business network), government at different levels (regulatory network) and all knowledge holders (the knowledge network).

Figure 3. The separate networks of business



Source: Hansen et al. (2002, p. 47)

To understand economic performance, an even wider perspective is needed, which includes product market conditions, factor market conditions, the education and training system, physical infrastructure and the macroeconomic and regulatory context (figure 3).

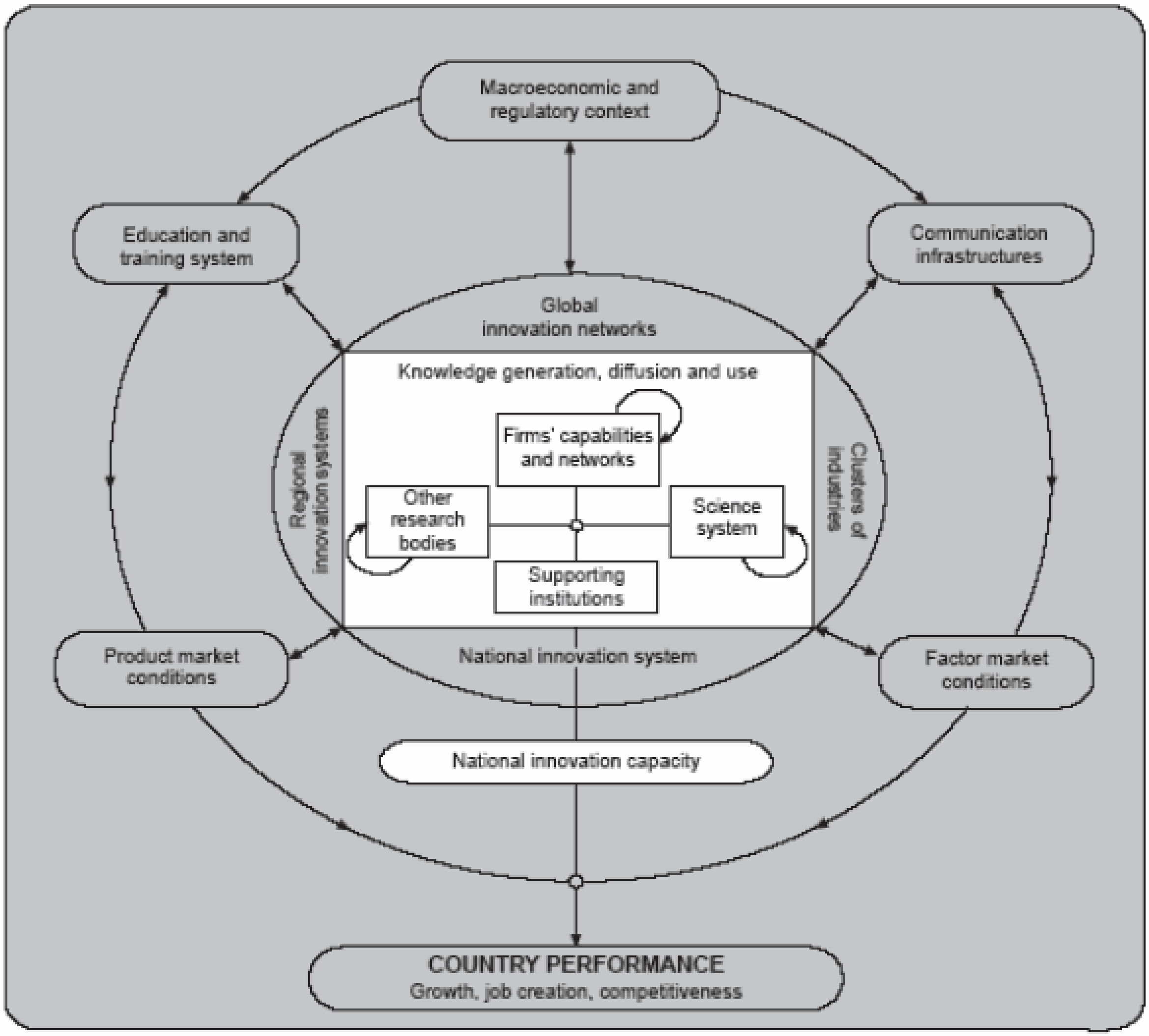
This wider framework includes (Kemp et al., 2000):

- the overall economic situation and development, such as the state of the economy, price stability, the development of exchange rates or the situation in the financial and labour markets,
- the availability of an efficient and complete tangible and intangible infrastructure,
- regulations contained in collective agreements and labour law,
- political determinants such as macroeconomic policy, financial policy or the vast sphere of regulations, for instance in the area of consumer protection, general health and safety, insurance, in banking and the transport sector, in the energy industry or in the field of environmental regulation,
- influences emanating from society and impacting the economic players, such as social stability and cohesion, a society's openness for technological innovations and for economic growth in general, consumer attitudes, social willingness to endure negative environmental impacts, or to bear risk, and so on.

These framework conditions are often seen as specific to regional or national contexts, but they are also dynamic: their forms of operation change with political conditions, changing technological opportunities, economic integration processes and so on. The basic argument of systems theories is that system conditions have a decisive impact on the extent to which firms can make innovation decisions, and on the modes of innovation which are undertaken.

What the above suggests is that we are not simply concerned with individual firms, or individual isolated decision-making. As noted in Kemp et al., (2000) innovation is a multi-faceted phenomenon, characterised above all by complexity in interactions between people and institutions. On one level it involves new thinking, new ideas and solutions to problems, and so it can be seen in terms of creativity and intellectual effort. On another, it involves marshalling financial and material resources, often on a large scale, and in conditions on serious uncertainty. But neither of these dimensions of innovation can realistically be seen in terms of purely individual effort, either by people or by organizations. Rather, innovation is a *distributed* process - its inputs in terms of knowledge and resources are distributed among many participants and contributors, linked to each other in networks of relationships. Moreover it is a dynamic process, one that involves learning and change within the social and economic spheres (from Kemp et al., 2000). An important challenge in eco-innovation analysis is to give these ideas an empirical basis.

Figure 4: The many determinants of a nation's economic performance



Source: OECD (1998)

The JRC has developed a scoreboard for national innovation, using CIS data from Eurostat and other data. The innovation indicators are assigned to five dimensions and grouped in two main themes: inputs and outputs. Innovation inputs include three dimensions:

- *Innovation drivers* (5 indicators), which measure the structural conditions required for innovation potential;
- *Knowledge creation* (4 indicators), which measure the investments in R&D activities, considered as key elements for a successful knowledge-based economy;
- *Innovation & entrepreneurship* (6 indicators), which measure the efforts towards innovation at firm level.

Innovation outputs include two dimensions:

- *Applications* (5 indicators), which measure the performance, expressed in terms of labour and business activities, and their value added in innovative sectors;
- *Intellectual property* (5 indicators), which measure the achieved results in terms of

successful know-how.

Porter and Stern (2001) calculated an innovative capacity index for nations based on 4 sub-indices. The starting point for this analysis is that national innovative capacity is determined by the nation's common innovation infrastructure, the innovation environment specific to particular industrial clusters, and the quality of the linkages between these. These are measure by the four sub-indices, for each of which key indicators were defined.

The first subindex measures the proportion of scientists and engineers in the workforce.

The innovation policy sub-index is measured by

- The effectiveness of intellectual property protection
- The ability of a country to retain its scientists and engineers
- The size and availability of R&D tax credits for the private sector.

The cluster innovation environment sub-index is measured by

- The sophistication and pressure to innovate from domestic buyers
- The presence of suppliers of specialized research and training
- The prevalence and depth of clusters

The linkages sub-index is measured by survey findings on

- The overall quality of scientific research institutions
- The availability of venture capital for innovative but risky projects

When the combined index of innovative capacity is plotted against a measure of national competitiveness, a clear positive correlation was found. The analysis suggests that a country's institutional and microeconomic environment play an important role in determining the productivity of investments in innovation.

3. The patterned nature of innovation

Technical change is the outcome of multiple decisions and highly cumulative. It is not a haphazard process but proceeds in certain directions along trajectories. Examples of patterns are the growing miniaturization of microelectronic components, the increasing speed and computer operations, the trend towards the use of lighter materials (in automobiles and aircraft), the use of electronic components in consumer products and equipment etc. We also can observe dominant sources, products and designs. In western countries gasoline-powered cars are the dominant mode of transport.

Economists, historians and more recently sociologists have studied these regularities in technological change and have come up with concepts to account for the ordering and structuring of technology. One such concept is the concept of a "technological regime" developed by Richard Nelson and Sidney Winter. The concept of a technological regime relates to technicians' beliefs about what is feasible or at least worth attempting – implying that cognitive aspects are considered important. Nelson and Winter give the example of the DC3 aircraft in the 1930s which defined a particular technological regime: metal skin, low wing, piston powered planes. Originally the term technological regime was used as the frame for research activities:

> A technological regime is a set of design parameters which embody the principles which will generate both the physical configuration of the product and the process and materials from which it is to be constructed. The basic design parameters are the heart of the technological regime, and they constitute a framework of knowledge which is shared by the firms in the industry. (Georghiou *et al* , 1986)

The above studies rightly corrected the simple view that most economists held about technology, as being fine-tuned to demand and cost conditions, or, as Donald MacKenzie (1992) puts it, "an entirely plastic entity shaped at will by the all-knowing hands of market forces". However, they suffer from "deterministic overtones". In the above models, engineering imagination causes technology to proceed a certain trajectory, more or less in the same way as a stone or rocket follows a trajectory once it has been launched. It fails to recognize that there is a clear *socio-economic* dimension involved in the stability of search activities and the patterns of technological change. One of the key reasons why technological progress often proceeds along certain trajectories is that the prevailing technology and design has already benefited from all kinds of evolutionary improvements, in terms of costs and performance characteristics, from a better understanding at the user side, and from the adaptation of socio-economic institutional environment to the prevailing technology in terms of accumulated knowledge, capital outlays, infrastructure, available skills, production routines, social norms, regulations and life styles.

There is a process of *mutual adaptation* of the innovation and the environment in which it is produced and put to use, which is emphasized in the literature on lock-in and regimes (Kemp, 1994, Rip and Kemp, 1998; Unruh, 2000). Products and systems of knowledge co-evolve with preferences and institutions, leading to socio-technical regimes (Nelson, 1994, Geels, 2004, Foxon, 2003, 2007).

A useful way of looking at this is in terms of increasing returns, or positive feedbacks, to the adoption of both technologies and the supporting institutions. Arthur (1994) identified four major classes of increasing returns: *scale economies, learning effects, adaptive expectations* and *network economies*, which contribute to this positive feedback to the adoption of technologies. The first of these, *scale economies*, occurs when unit costs decline with increasing output. *Learning effects* act to improve products or reduce their cost as specialised skills and knowledge accumulate through production and market experience. *Adaptive expectations* arise as increasing adoption reduces uncertainty and both users and producers become increasingly confident about quality, performance and longevity of the current technology. This means that there may a lack of ‘market pull’ for alternatives. *Network* or *co-ordination effects* occur when advantages accrue to agents adopting the same technologies as others. This effect is clear, for example, in telecommunications technologies, e.g. the more others that have a mobile phone or fax machine, the more it is in your advantage to have one (which is compatible). Similarly, infrastructures develop based on the attributes of existing technologies, creating a barrier to the adoption of alternative technologies with different attributes.

Arthur (1989) showed that, in a simple model of two competing technologies, these effects can amplify small, essentially random, initial variations in market share, resulting in one technology achieving complete market dominance at the expense of the other – referred to as technological 'lock-in'. Once this lock-in is achieved, this can prevent the take up of potentially superior alternatives. Historical examples of this include the QWERTY keyboard layout, the VHS video system and light-water nuclear reactors, originally developed for use on submarines.

North (1990) argued that all the features identified by Arthur as creating increasing returns to the adoption of technologies can also be applied to institutions. New institutions often entail *high set-up or fixed costs*. There are significant *learning effects* for organisations that arise because of the opportunities provided by the institutional framework. There are *co-ordination effects*, directly via contracts with other organisations and indirectly by induced investment, and through the informal constraints generated. *Adaptive expectations* occur because increased prevalence of contracting based on a specific institutional framework reduces uncertainty about the continuation of that framework.

In evolutionary economic terms, the prevailing institutions form a key part of the selection environment for technologies, and vice versa, leading to a process of co-evolution. The positive feedbacks of increasing returns both to technologies and to their supporting institutions can create rapid expansion in the early stages of development of technology systems. However, once a stable techno-institutional system is in place, it acquires a stability and resistance to change. Unruh (2000) argues that fossil-fuel based energy systems have undergone such a process of co-evolution, leading to the current dominance of high carbon technologies and the accumulated knowledge, capital outlays, infrastructure, available skills, production routines, social norms, regulations and life styles which support these, which he calls *carbon lock-in*.

Similar arguments could be made for technologies with high environmental impacts more generally. This leads to the conclusion that eco-innovation requires not only technological change but also institutional change and, hence, that measures of eco-innovation should encompass both technological and institutional factors.

4. Eco-innovation

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). 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).

Denmark's government defines eco-innovation as innovation leading to an eco-efficient technology in the white paper "Promoting Eco-efficient Technology - The Road to a Better Environment". Eco-efficient technology means all technologies which directly or indirectly improve the environment. It includes technologies to limit pollution, more environmentally friendly products and production processes, more effective resource management, and technological systems to reduce environmental impacts. Reduced environmental impacts must not necessarily be the primary objective of an eco-efficient technology.

Other labels are environment-friendly, environment-saving, eco-friendly or eco-intelligent.

Often eco-innovation is used as shorthand for environmental innovation (Rennings, 2000; Europe Innova). There exist various definitions of environmental innovation. One such definition says that environmental innovations are new and modified processes, equipment, products, techniques and management systems that avoid or reduce harmful environmental impacts (Kemp and Arundel, 1998, Rennings and Zwick, 2003). There is no reference to novelty in this definition. The distinguishing feature is environmental gain, which is also the defining feature of the concept of environmental technologies that is used in ETAP (the European Commission's Environmental Technologies Action Plan).

According to ETAP, 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). Environmental technologies are technologies whose use is less environmental harmful that relevant alternatives.

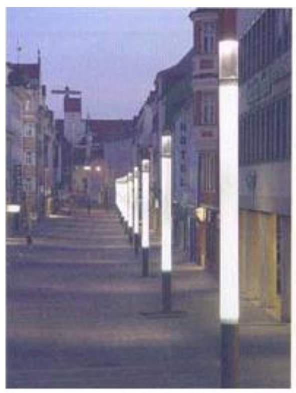
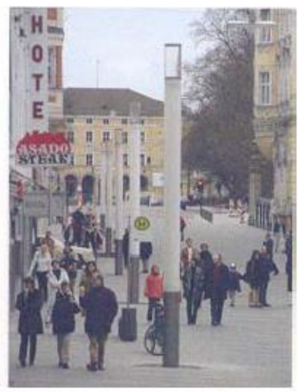
In environmental technologies themselves, we have innovation. The innovation may do one or two things: it may lower the costs of achieving an environmental improvement or it may offer a greater environmental gain than an old model. It may also be new technology for a new environmental problem

It is important to note that the widespread use of environmental technologies does not guarantee overall improvements in environmental quality. Cost-saving technologies give rise to increases in real wealth that will translate in extra consumption and associated emissions and resource use (rebound effect).

In the text of the call on which the project is based, the term eco-innovation is used: eco-innovation is the production, assimilation or exploitation of a novelty in products, production processes, services or in management and business methods, which aims, throughout its life cycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resources use (including energy use). Novelty and environmental aim are the two distinguishing features.

The environmental gains of normal innovations have never been the object of systematic study. It is being estimated however that 60% of the innovations of the Dynamo Database in the Netherlands offer environmental benefits. It also was found that 55% of the innovations supported by a general innovation scheme for research cooperation (IS) offered “sustainability benefits”. These two figures coming from the Netherlands suggest that the majority of technological innovations offer environmental benefits.

LED lamps are a mixed case. They have been developed for reasons of better light quality, longer lifetime and energy-efficiency.

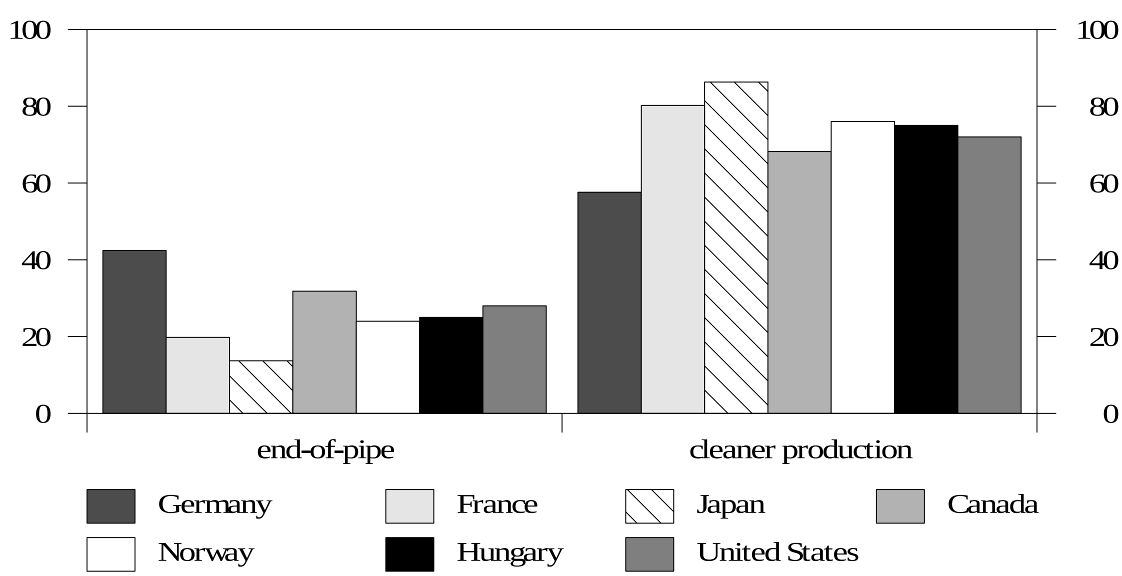
One of the aims of MEI is to develop a typology of eco-innovation. A first attempt at that can be found in the document A typology of eco-innovation (deliverable 2 of MEI). From a dynamic innovation point of view the shift from end-of-pipe to cleaner technology is interesting.

5. The shift from end-of-pipe to cleaner technology

In the past the focus of attention of policy and business was on end-of-pipe solutions. This is changing as shown by Rennings and Ziegler whose paper about green roads to growth offers important information about the choice of environmental technologies in seven OECD countries, showing that the shares of cleaner production are higher than those of end-of-pipe. The figures are in line with Arundel et al. (2003) who found that 71 per cent of Dutch firms in five sectors had introduced a production process change, compared to 52 per cent that had introduced an end-of-pipe solution. The figures differ from those in the European Commission report Environmental Technologies for Sustainable Development (COM2002 122 Final) which estimates that integrated solutions account for one-third of environmental investments, with end-of-pipe and clean-up accounting for two-thirds of such investments. Perhaps in investment terms end-of-pipe is more important than cleaner production measures that can be fairly minor in terms of investment. But in terms of achieving environmental benefits cleaner production is increasingly important. The IMPRESS study found that the most important environmental innovation in terms of environmental benefit is cleaner production (Rennings and Zwick, 2003).

A recent OECD study found that the share of cleaner production technologies ranges from 57.5% in Germany to 86.5% in Japan.

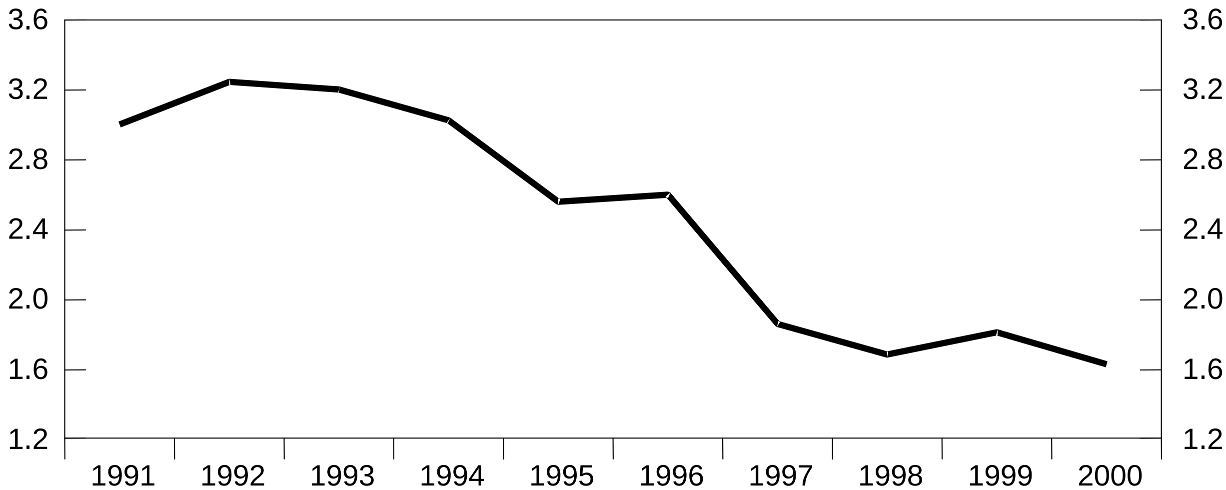
Figure 5: Choice of environmental technologies in seven OECD countries
In %



Source: Frondel et al. (2004).

Statistical data indicates that investments in end-of-pipe technologies decreased during the 1990s (for Germany, see Figure 6). The share of investments in environmental technologies decreased from around 4% to 3% of the total investments of the German industry. This observation raises the question as to whether this fact might be explained by the shift of investments to cleaner production technologies.

Figure 6: Investments in end-of-pipe technologies in German industry in the 1990s
In Billion Euros



Source: Becker and Grundmann (2002).

We lack good statistical information about cleaner production. Statistical offices have only counted investments in end-of-pipe technologies. This is due to methodological problems of separating cleaner production measures from investments in non-environmental technologies (Sprenger, 2004). Therefore, data on the use of cleaner production technologies have hardly ever, if at all, been included in official environmental statistics thus far. Although international statistical offices, such as the OECD and Eurostat , agreed to add cleaner production to environmental protection activities, official international statistics on the use of cleaner production technologies are still unavailable. For example, the ECOTEC (2002) report on the EU Eco-industries, their employment and export potential still focuses on end-of-pipe technologies.

Del Rio Gonzalez (2005) analysed the adopting cleaner technology in the Spanish pulp and paper industry. He found out that most of the environmental technologies introduced were of the EOP type (i.e. waste water treatment plants) or incremental clean technologies (small changes to close water circuits, mostly the type of so-called "picking up low hanging fruits).

6. Eco-efficiency

A broader notion than cleaner production and integrated production is the notion of eco-efficiency: "the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity, through the life cycle, to a level at least in line with the earth's estimated carrier capacity" (World Business Council for Sustainable Development, 2000).

Eco-efficiency is a broad concept that is usually measured at the product or service level. Eco-efficiency means *less environmental impact per unit of product or service value* (WBCSD, 2000).

$$\textbf{\textit{Eco-efficiency}} = \frac{\textbf{\textit{product or service value}}}{\textbf{\textit{environmental impact}}}$$

For product and service value, we may use value added figures (even when those figures do not include consumer surplus). Environmental impact is more difficult to measure. The environmental impact is measured on the basis of both resource use (the source side) as well as emissions to air, soil and water (the sink side) per produced unit/activity. Toxicity of resources may be taken into account. In so doing, it differs from material intensity per service (MIPS) which only looks at kilotons. In actual practice, eco-efficiency is not so easy to measure but the WBCSD has identified seven strategies to improve eco-efficiency:

- Reduce material intensity
- Reduce energy intensity
- Reduce dispersion of toxic substances
- Enhance recyclability
- Maximize use of renewables
- Extend product durability
- Increase service intensity

Product durability can only be calculated at the product level. Material intensity and energy intensity can be calculated at the firm, product, sector, region, and supraregion (national and international) level.

The eco-efficiency approach offers a different in-road into the issue of eco-innovation, followed in the ECO-DRIVE project where innovation could be conceptualised and measured as a change in resource productivity or eco-efficiency. This may be done in several ways. One approach to operationalising this is through the use of aggregate indicators for resource use of an economy. Indicators for measuring resource use and material flows have been developed largely by the Wuppertal Institute in Germany and are shown in Table 2. It has been argued that these indicators could form a useful way of establishing targets and indicators for the EU's Thematic Strategy on Sustainable Use of Natural Resources (Wuppertal, 2006).

Table 2: Macro-indicators for material flows

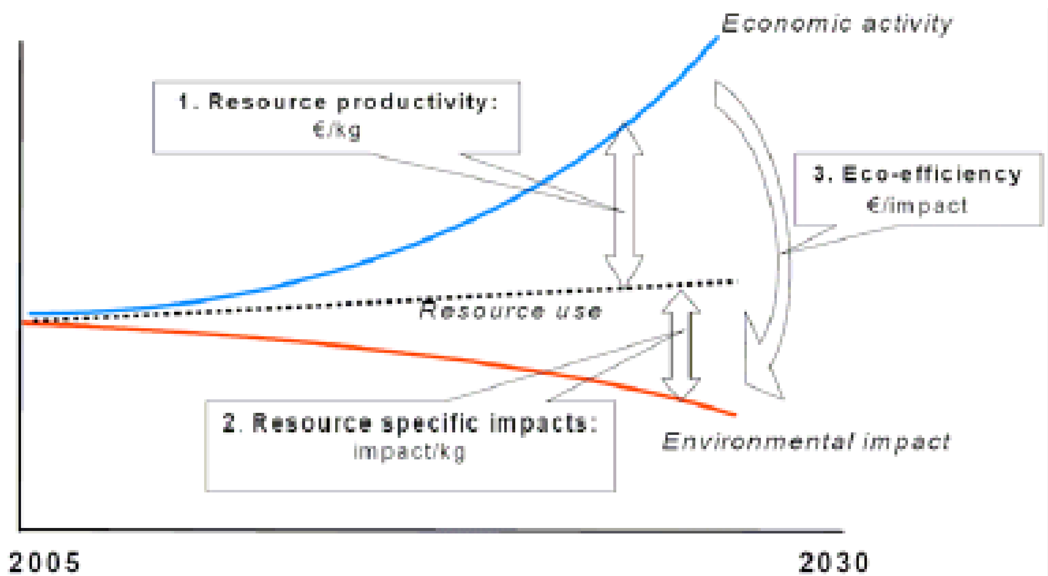
Indicator	Formula	Subject
Total Material Requirement (TMR)	DMI + indirect flows	Domestic and imported resources including their ecological rucksacks, which are required for domestic production and consumption.
Total Material Consumption (TMC)	TMR – (exports + indirect flows of exports)	Domestic and imported resources including their ecological rucksacks, which are required for domestic consumption only (excluding exports).
Domestic Material Input (DMI)	domestic material used + imports	Domestic and imported resources without ecological rucksacks, which are used for domestic production and consumption.
Domestic Material Consumption (DMC)	DMI - exports	Domestic and imported resources without ecological rucksacks, which are used for domestic consumption only (excluding exports).

Note: 'Ecological rucksacks' refer to materials which are extracted or otherwise moved by economic activities but which are not used in domestic production or consumption (mining waste such as overburden, erosion in agriculture etc.). These flows are not further processed and have no economic value, but impact on the environment.

For example, Resource Productivity and Material Productivity of a National or the European economy could be measured by GDP/TMR or GDP/DMI. These measures show that resource and material productivity of the EU-25 has increased over the last 10 years, as TMR and DMI have remained roughly constant. However, absolute reductions in TMR and DMI would be required to reduce overall environmental impacts.

The EU's Thematic Strategy on Sustainable Use of Natural Resources goes further than simply arguing for decoupling of resource use from GDP by proposing a 'double decoupling' of environmental impacts of resource use from economic growth.

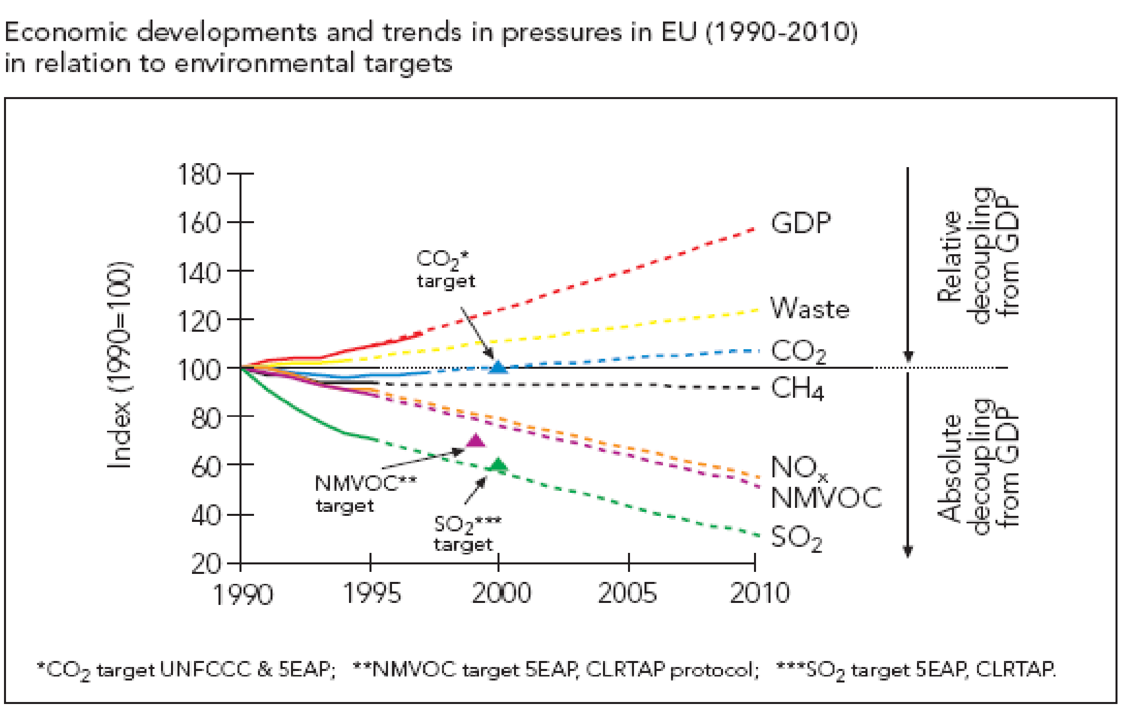
Figure 7: Decoupling economic activity, resource use and environmental impact



Source: COM (2005) 670

Instead of looking at resource productivity, one may look at the development of emissions and waste vis-à-vis GDP.

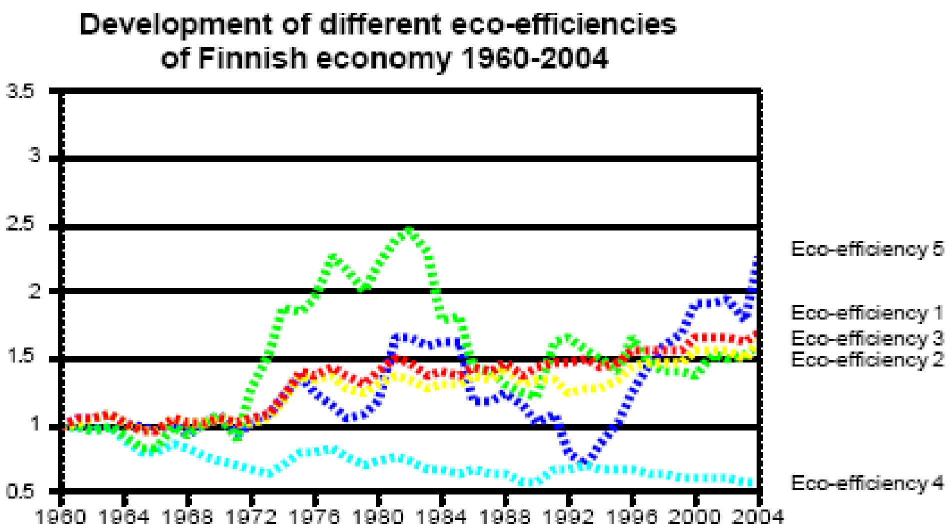
Figure 8: Absolute and relative decoupling



Source: Compiled from multiple sources

Jukka Hofrén (ref.) has used various measures to determine the eco-efficiency of the Finish economy.

Figure 9: Development of various eco-efficiency measures for Finland



Eco-efficiency formulas utilised :

$$\text{Eco-efficiency } 1 = \frac{GDP}{DMF} \text{ (= Eco-efficiency of production)}$$

$$\text{Eco-efficiency } 2 = \frac{EDP1}{DMF} \text{ (=Industrial eco-efficiency)}$$

$$\text{Eco-efficiency } 3 = \frac{ISEW}{DMF} \text{ (= Societal eco-efficiency)}$$

$$\text{Eco-efficiency } 4 = \frac{HDI}{DMF} \text{ (=Human eco-efficiency)}$$

$$\text{Eco-efficiency } 5 = \frac{SBM}{DMF} \text{ (=Potential eco-efficiency)}$$

GDP = Gross Domestic Product
DMF = Direct Material Flow
EDP1 = Environmentally adjusted Domestic Product 1
ISEW = Index of Sustainable Economic Welfare
HDI = Human Development Index
SBM = Sustainable Benefit Measure

Further work is needed to understand the decomposition of these aggregate indicators. For example, resource productivity of industrialised economies improves as they move from being manufacturing to service-based economies. However, this may largely involve transfer of the manufacturing base and associated environmental impacts to developing and emerging economies from which finished goods are imported for consumption.

A decomposition analysis may use the identity I = PAT, where I stands for Impact, P for population, A for affluence and T for technology. The I = PAT identity is best thought of as a high-level heuristic device for decomposing the components of environmental impact. As governments are generally reluctant to act to directly address increases in population or affluence, i.e. rate of consumption per person, attention has focused on the technological factor, which measures environmental impact per unit of consumption. The term “technology” is something of a misnomer because it also picks up change in industrial structures and also organizational and behavioural changes.

The ECODRIVE project aims to analyse eco-innovation on the basis of economic and environmental performance data (at the firm, sector and national level) and proxies for innovation. The aim to measure drivers for innovation for which they seek indicators. It is unclear whether they will do a decomposition analysis.

7. Economic benefits from eco-innovation

Eco-innovations help to reduce environmental burden or to reduce the costs of doing so. There is no guarantee that the use of eco-innovations will improve the quality of the air and the quality of other receiving media (water, soil). Environmental quality is often viewed in relation to growth. When the quality of the environment improves we speak of an absolute decoupling, when the quality of the air or water deteriorates despite the use of environmental technologies we speak of a relative decoupling.

For the eco-innovator there are both <u>direct</u> and <u>indirect</u> benefits
The *direct benefits* for the innovator consist of

- Operational advantages such as cost savings from greater resource productivity and better logistics
- Sales from commercialisation

The *indirect benefits* for the innovating company consist of

- Better image
- Better relations with suppliers, customers and authorities
- An enhanced innovation capability overall thanks to contacts with knowledge holders
- Health and safety benefits
- Greater worker satisfaction

These benefits must be weighted against costs for the company. Surveys show that the majority of companies know very little of either the costs or benefits of their environmental activities. Figures on benefits from eco-innovation are *not* collected by companies on their own or by statistical agencies. This leads many of them to believe that environment is a *burden* rather than an *asset*. This is an important barrier to eco-innovation. Own or others experiences (about net benefits from eco-efficiency) are instrumental in changing the mind set.

Of course, eco-innovations should be valued from a societal point of view, not just a business point of view. From a social welfare point of view, eco-innovations are desirable if they contribute to overall welfare in the sense of wellbeing (not economic growth). We have a net increase in welfare if the environmental benefits for society plus the benefits for companies exceed the costs of achieving those benefits (which consist of the costs for the companies involved and the administrative costs related to the use of policy instruments).

8. Drivers for eco-innovation

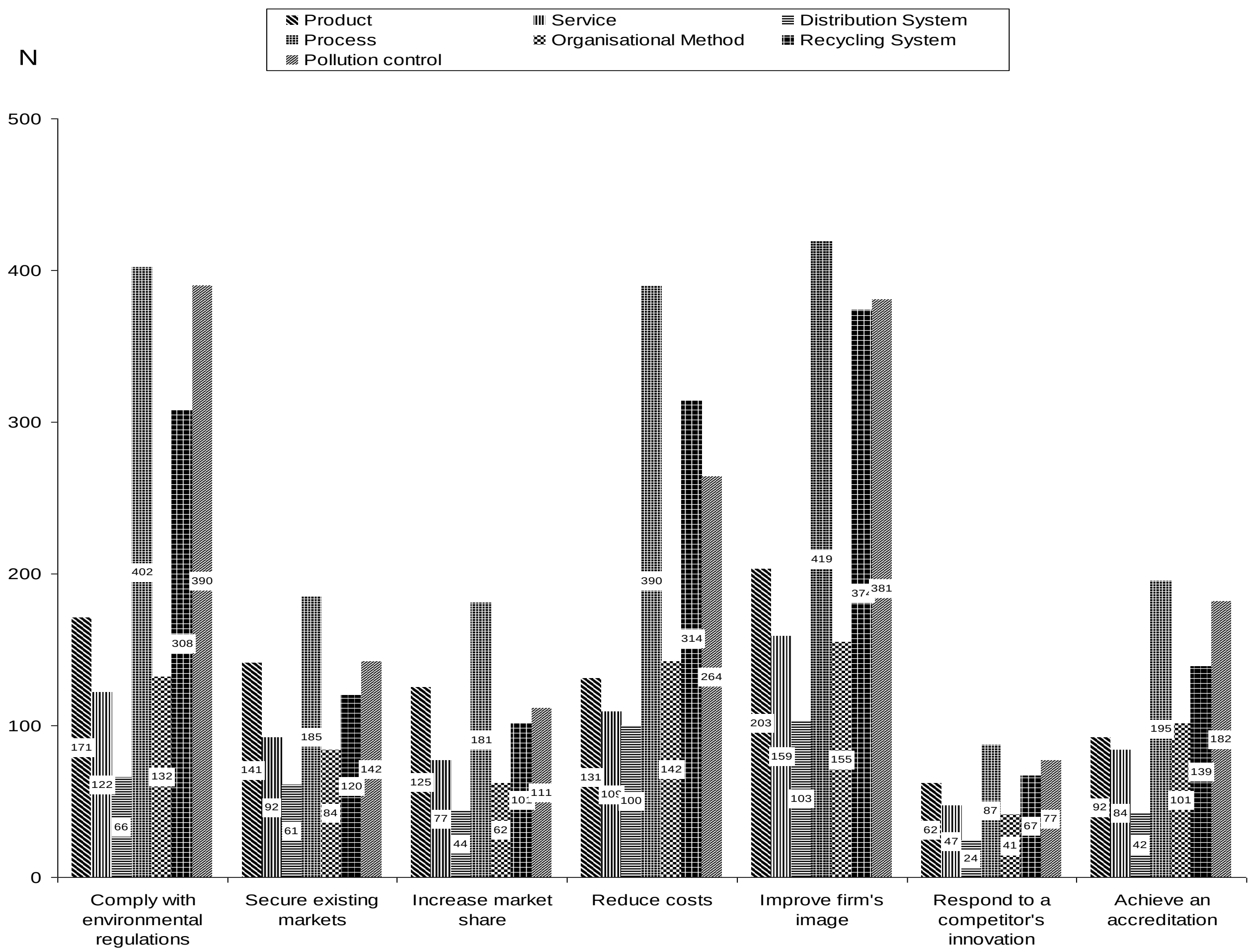
There are many drivers for eco-innovation: regulation, cost reduction, profits from commercialisation, pressure from communities, green ethos, improving the company image, [1] . In cases for which reducing environmental impact offers no operational benefits or commercialization benefit, then regulation may be the clearest driver for eco-innovation. For example, regulations to protect local air quality have stimulated innovation, such as of catalytic converters, which has led to dramatic reductions in emissions of pollutants such as NOx and SOx from vehicles. In the US and particularly California, a programme of progressive reductions in the permissible levels of exhaust pollutants has sparked a revolution in technologies and 1000-fold reductions in emissions at no higher cost in real terms than when originally introduced in 1975 (Environmental Innovation Advisory Group, 2006).

In other cases, however, many firms find that generation of waste and pollution in production processes is also inefficient from a cost view point and firms such as Dow Chemicals have achieved large cost savings through process and system innovations. Firms may also gain first mover advantage if an innovation is subsequently widely diffused. This is used by Porter to argue for countries to adopt innovation-forcing regulations for environmentally beneficial products and services, on the assumption that other countries will subsequently adopt equally strong regulations for limiting environmental impacts, so creating markets for these products and services (Porter and van der Linde, 1995a,b). Finally, as consumers become increasingly aware of the environmental impacts of their purchasing choices, they begin to exert pressure on firms to reduce these impacts. As brand recognition and acceptance is a key factor in purchasing decisions, having a ‘green brand’ will increasingly become important for companies. However, such claims must be credible and over-hyping of green credentials can have negative impacts for firms.

Determinants for different kinds of eco-innovation have been studied in the IMPRESS project. It shows that environmental regulations and improvement of firm’s image are the most commonly mentioned determinants (Figure 10).

[1] These are primary drivers, there also exist secondary drivers such as improving technical efficiency or increasing market share.

Figure 10: Determinants of Environmental Innovations



N stands for number of companies who mentioned it as a determinant
Data are from telephone survey with 1,594 environmentally innovative industrial and service firms in five European countries (Germany, Italy, Switzerland, United Kingdom, Netherlands)
Source: (Bartolomeo et al., 2003).

Bossink (2004) studied the drivers for ecological (housing) construction. He found many drivers and barriers (Table 7).

Table 3: Drivers of environmental innovations and managerial reactions in Dutch projects of ecological construction

Innovation drivers	Managerial reactions
Regulatory push/pull effects	
No pull effects from the private market Governmental guarantee for innovative firms Governmental clients with innovative demands Innovation stimulating regulations Subsidies for innovative applications and materials	Professional clients followed market demands The government funded the operations of innovative firms Municipal project managers stimulated innovative architects Organisations followed the rules Clients, architects used subsidised applications
Technological capability	
Product evaluating institutions Programmes promoting access to technology Finance for pilot projects Technology fusion Technology leadership strategy Technology push	Architects used approved applications and materials Consultants introduced innovation checklists The government subsidized demonstration projects Architectural firms co-created innovative design concepts Organisations searched for niches in the market Consultants used checklists to drive the innovations process
Possibility of appropriation, co-operation	
Stimulation of research Creation of knowledge stocks Programmes of promoting collaboration Effective information gathering Training of workers on the site Integration of design and build Involvement of the client Mechanisms for sharing financial risks and benefits Innovations from suppliers Strategic alliances and long term relationships	Consultants developed new applications Knowledge centres functioned as information brokers Architects and contractors joined collaboration programmes Contractors initiated and facilitated training Clients decided which innovative designs to build Clients hired architects and contractors Teams worked in conformance with the demands of the client Alliances developed and delivered sustainable innovation results

Source: Rennings and Ziegler (2006) based on Bossink (2004)

9. Barriers to eco-innovation

While market demand is a crucial factor for the success of innovations, the conventional view is that environmental products often have strong commercialisation problems. In a broad survey among German environmental product innovators, Rehfeld et al. (2004) asked companies whether they agree or disagree with the following three statements from their own customers: Environmental products are "more expensive", "of lower quality" or "less reliable" than corresponding conventional products. 53.0% of the companies reported that their own customers state that environmental products are more expensive than conventional substitutes. Therefore, price might be one explanation for weak market performance. In contrast, there is almost no confirmation (10.0%) of the statement that environmental products are of lower quality than conventional substitutes. This indicates that environmental product innovators often regard improved environmental performance of products as one component part of comprehensive quality management and strategy. Finally, only 24.7% of the environmental product innovators agreed with the statement that environmental products are less reliable than corresponding conventional products. The conclusion that is drawn from this is that economic rather than 'soft' factors appear to be the major obstacles to the commercial exploitation of environmental products and therefore also to environmental product innovations (Rennings and Ziegler, 2006).

ETAP (the European Commission's Environmental Technologies Action Plan) identifies the following barriers to environmental technologies

- **Economic barriers**, ranging from market prices which do not reflect the external costs of products or services (such as health care costs due to urban air pollution) to the higher cost of investments in environmental technologies because of their perceived risk, the size of the initial investment or the complexity of switching from traditional to environmental technologies;
- **Regulations and standards can also act as barriers to innovation** when they are unclear or too detailed, while good legislation can stimulate environmental technologies;
- **Insufficient research efforts**, coupled with inappropriate functioning of the research system in European countries and weaknesses in information and training;
- **Inadequate availability of risk capital** to move from the drawing board to the production line;
- **Lack of market demand** from the public sector, as well as from consumers.

A more elaborated scheme of barriers is offered by Nicholas Ashford (1993), making a distinction between the following types of barriers:

1. Technological barriers:

- Availability of technology for specific applications.
- Performance capability of technology under certain economic requirements and process design standards.
- Lack of (some) alternative substances to substitute for the hazardous components.

- Higher degree of sophistication with operation of some waste reduction technologies.
- Skepticism in performance of certain technologies and therefore a reluctance to invest.
- Process inflexibilities.

2. Financial barriers:

- Research and development costs of technology.
- Costs related to risk of process changes with regard to consumer acceptance and product quality.
- Noncomprehensive cost evaluations and cost-benefit analysis as well as cost calculation method.
- Lack of understanding and difficulty in predicting future liability costs (e.g., of waste disposal).
- Short-term profitability calculations resulting in low tolerance for longer payback periods of equipment investment.
- Alleged drawback in competitiveness as other companies are not investing in waste reduction technologies.
- Lack of capital investment flexibility due to low profit margin.
- Economies of scale preventing smaller companies from investing in waste reduction options (e.g., in-plant recovery technologies).
- Possibilities that investment in process modification can be inefficient for old companies.
- Company financially (and even technically) tied up due to recent investment in wastewater treatment plant.
- Actual cost of current technologies masked in operating costs.

3. Laborforce-related barriers:

- Lack of person(s) in charge of management, control, and implementation of waste reduction technology.
- Reluctance to employ trained engineers for the alleged time-consuming design of waste reduction technologies.
- Inability to manage an additional program within the company and, therefore, reluctance to deal with a waste reduction program.
- Increased management requirements with implementation of waste reduction technologies.

4. Regulatory barriers:

- Disincentives to invest in reuse and recovery technologies due to RCRA permit application requirements for recycling facilities in addition to compliance requirements, application costs, and so forth (work-intensive).
- Depreciation tax laws.
- RCRA waivers available only for hazardous waste treatment technology or process.
- Uncertainty about future environmental regulation.
- Regulatory focus on compliance by use of conventional end-of-pipe treatment technology (may result in investment in those treatment technologies rather than waste reduction technologies).
- Compliance with discharge standards, thus having "EPA off your back" provides no incentive to invest in waste reduction.

5. Consumer-related barriers:

- Tight product specifications (e.g., military purposes).
- Risk of customer loss if output properties change slightly or if product cannot be delivered for a certain period.

6. Supplier-related barriers:

- Lack of supplier support in terms of product advertising, good maintenance service, expertise of process adjustments, and so forth.

7. Managerial barriers:

- Lack of top management commitment.
- Lack of engineering cooperation to break hierarchical separation of areas of responsibility (e.g., production engineers do not cooperate with environmental engineers in charge of the treatment and disposal of hazardous substances).
- Reluctance on principle to initiate change in the company ("Uncle John did it this way; therefore we are doing it the same way!").
- Lack of education, training, and motivation of employees (e.g., in good housekeeping methods or operation and maintenance of recovery technologies).
- Lack of expertise of supervisors.

The barriers are interrelated. For instance a lack of top management commitment might be caused by various factors: (1) lack of information from the financial department to top management concerning the profitability of waste reduction technologies in general; (2) lack of confidence in performance of new technologies; (3) lack of managerial capacity and capital to deal with the transition costs of reorganizing the production process, educational programs, consumer demands, or discharge waivers; (4) lack of awareness of long-term benefits of waste reduction approach, resulting in waste reduction being a low-priority issue (Ashford, 1993).

Barriers differ among sectors and may differ among countries. The study by Hitchens et al. (2003) on environmental performance in EU countries found that there is **a national element in such barriers:** Financial barriers were more important in Germany than in the UK. Priority and lack of time was a greater barrier in the UK than in Germany. Information problems and regulatory obstacles were more pronounced in Germany. The data are for environmentally *non-sensitive* sectors (Furniture, Textile Finishing, and Fruit and Vegetable Processing) for companies with less than 500 employees (Table 4). The conclusions may not apply to environmentally sensitive sectors.

Table 4. The most important obstacles to the adoption of environmental initiatives as proposed by SME's

				Totals by country	
Barriers	Furniture	Textiles	Fruit&Veg.	(N=99)	(N=95)

	G	UK	G	UK	G	UK	G	UK
It is hard to find the capital for investment	19	13	19	19	18	20	56	52
Clean technology investments do not show an adequate return (payback period is too long)	8	3	12	4	12	13	32	20
Environmental consultancy services cost too much	1		4		4		9	0
Financial	*28*	*16*	*35*	*23*	*34*	*33*	*97*	*72*
Making a profit is more important than environ. protection		3	3	6	4	7	7	16
Management does not have enough time	5	5		7	4	15	9	27
Management has other priorities	3	6	1	3	3	17	7	26
Time / Priorities	*8*	*14*	*4*	*16*	*11*	*39*	*23*	*69*
It is hard to get good advice	2	9	2	3	1	7	5	19
Clean technology is still risky and unproven	11	1	7		8	1	26	2
We do not have the right skills and expertise in-house (e.g. R&D)	7	2	5	3	8	5	20	10
Information	*20*	*12*	*14*	*6*	*17*	*13*	*51*	*31*
Regulation does not support initiatives			8		5	1	13	1
The regulations are too uncertain to plan for new technology	16	9	10	1	9	2	35	12
Regulation	*16*	*9*	*18*	*1*	*14*	*3*	*48*	*13*

Suppliers do not provide any help in adopting environmental initiatives	1	3			1		2	3
Total	*83*	*54*	*71*	*46*	*76*	*88*	*221*	*188*

Source: Keil, Clausen, Hitchens, Konrad (2002)

10. Eco-industry and eco-jobs

It is difficult exactly to define the "eco-industry", and therefore also its growth and export potential. A recent EU study has made an estimation on the situation in the EU-15 and the Candidate Countries. The eco-industry is broadly defined as "activities which produce goods and services to measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and ecosystems. This includes cleaner technologies, products and services that reduce environmental risk and minimise pollution and resource use".

The total turnover in 2004 can be split into:

- € 144.9 billion for pollution management activities (64% of the total) and
- € 81.8 million for resource management activities (36% of the total).

The goods and services provided by eco-industries represent approximately 2.2% of GDP in the EU-25 area. The largest national markets for eco-industries are France and Germany which taken together account for 49% of total turnover in 2004. The three following countries (UK, Italy and the Netherlands) represent together another 24% of the EU-25 total expenditures. The 10 new member states represent only 5.7% of total turnover, of which half for Poland alone. Denmark and Austria have the highest expenditures of environment as a percentage of GDP followed by Poland and Slovenia.

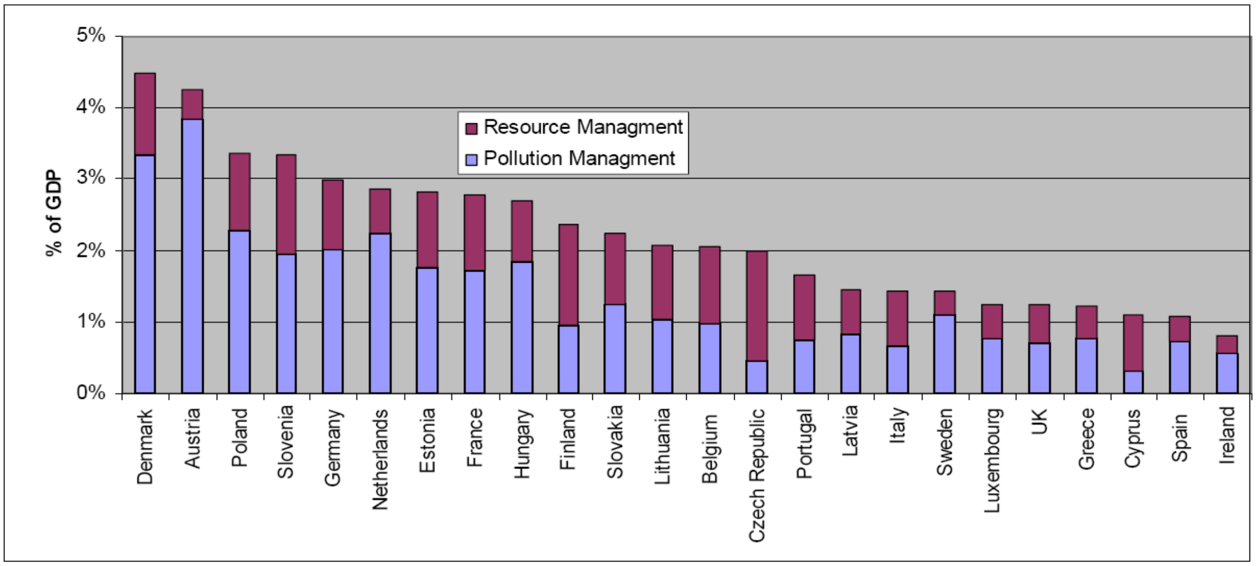


Figure 20: Turnover of the eco-industries expressed as a percentage of GDP in the EU-25, 2004

All countries except Greece and UK experienced growth in real prices

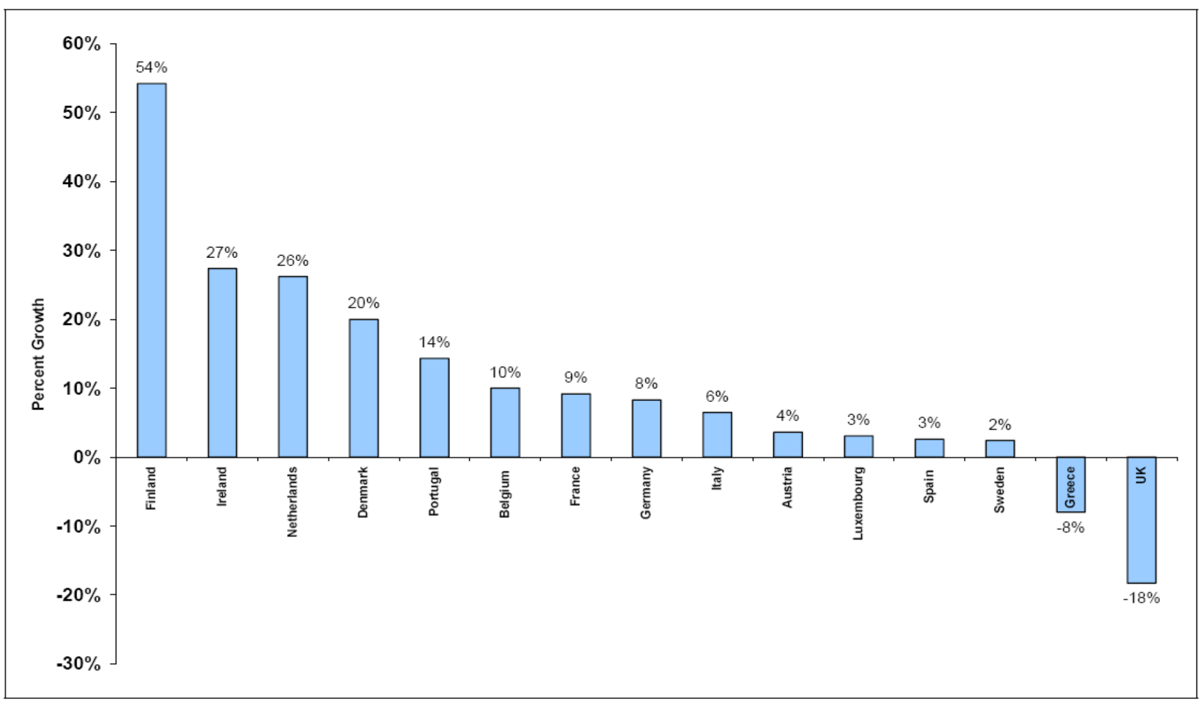


Figure 15: Variation of total turnover between 1999 and 2004 by country (in constant €)

Pollution management consists of nine eco-industry sectors that manage material streams from processes managed by humans (the technosphere) to nature, typically using "end of pipe" technology. It also includes cleaner technologies and products, which are mentioned in the definitions as "equipment". In order of turnover:

• Solid Waste Management & Recycling (€52.4 billion)
• Waste Water Treatment (€52.2 billion)
• Air Pollution Control (€15.9 billion)
• General Public Administration (€11.5 billion)
• Private Environmental Management (€5.8 billion)
• Remediation & Clean Up of Soil & Groundwater (€5.2 billion)
• Noise & Vibration Control (€2 billion)
• Environmental Research & Development (€0.11 billion)
• Environmental Monitoring & Instrumentation (€1 billion)

Resource management includes five eco-industry sectors that take a more preventive approach to managing material streams from nature to the technosphere:
• Water Supply (€45.7 billion)
• Recycled Materials (€24.3 billion)
• Renewable Energy Production (€6.1 billion)
• Nature Protection (€5.7 billion)
• Eco-construction (€40 billion)

Definitions are given in Annex 1.

The data are **demand-side data based on environmental expenditures**, except for environmental monitoring and instrumentation, water supply and recycled materials and eco-construction for which supply side data are used or estimated.

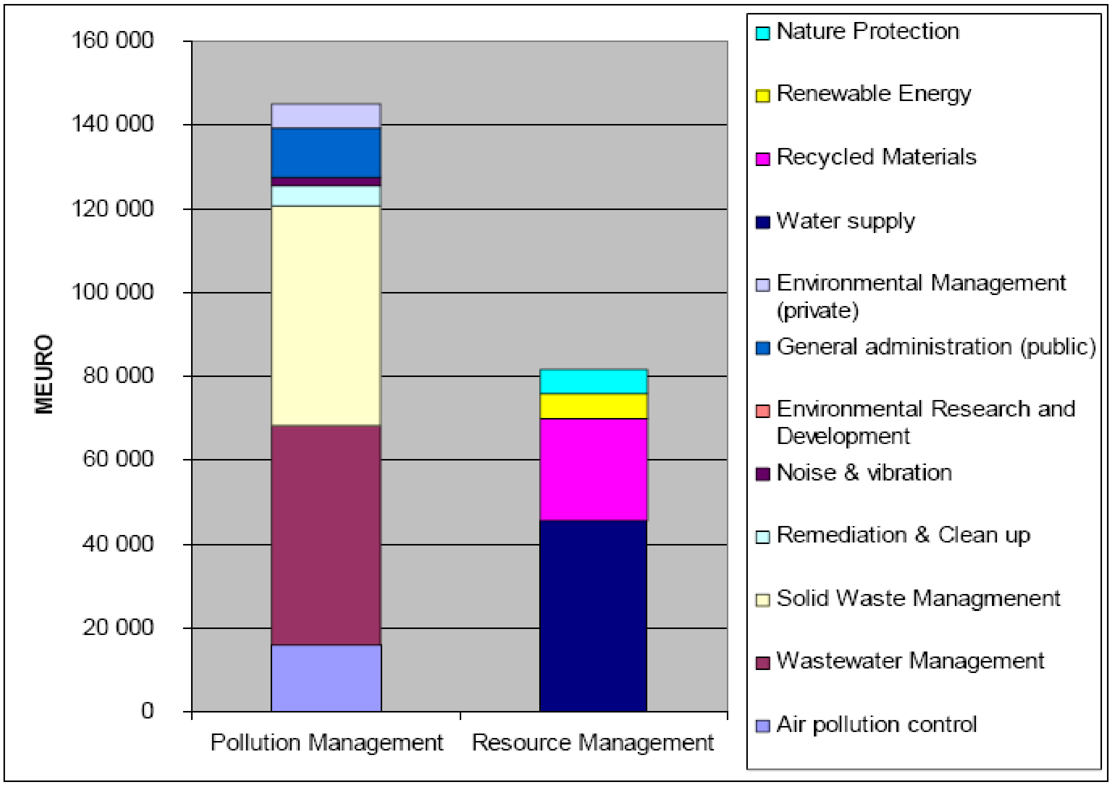


Figure 10: Breakdown of total turnover by sector for the pollution management and the resource management activities, EU-25, 2004

Employment

Direct employment

The direct employment resulting from the operating expenditure on environmental goods and services is estimated to be 1,415,000 jobs in the EU. Investments in EU environmental goods and services supported an additional 430,000 jobs in 2004 (see Table 12). The total **direct** employment in pollution management activities is estimated to be approximately **1,845,000 jobs** in the EU in 2004.

Around 46% of the total direct employment from pollution management is in the solid waste management sector. Another 32% are in the waste water treatment sector. Together these two sectors represent 78% of the environmental jobs from pollution management (see Figure 31). Air pollution control accounts for almost 6% of all environmental jobs. 74% of the jobs in air pollution control are investment-related.

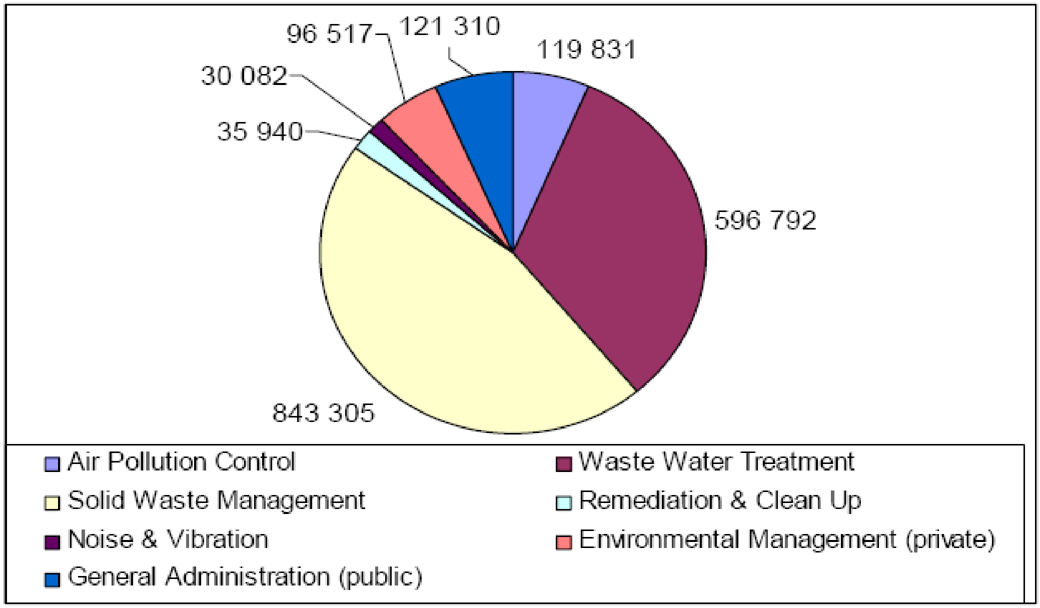


Figure 31: Direct employment by sector in theEU-25, 2004, for Pollution Management

Indirect employment is estimated at 500,000 jobs for pollution management.

The total calculated employment for resource management activities in the EU25 area amount to **approximately 1.04 million jobs**:
• water supply: approximately 502,000 jobs
• recycled materials: approximately 439,000 jobs
• nature protection: approximately 100,000 jobs
• renewable energy: no reliable aggregated data available

The total number of jobs for the recycled materials sector is the upper bound and is probably overestimated because using the growth rate of production value neutralizes the progress made in terms of productivity and the respective efficiency of each country.

The total estimated employment is:
• 1,845,000 direct jobs in pollution management,
• 500,000 indirect jobs in pollution management;
• 1,040,000 direct and indirect jobs in resource management (upper bound).

The estimated total of first round employment reaches 3,385,000 jobs.

Evolutions between 1999 and 2004:
The estimated number of jobs in the eco-industries varied considerably between 1999 and 2004. According to the calculations made based on the model, the total employment in eco-industries has increased as follows:
• Pollution management activities: from 1.45 million jobs in 1999 (EU-15) to 1.85 million jobs in 2004 (EU-25);

• Resource management activities: from 0.6 million jobs in 1999 (EU-15) to 1.04 million jobs in 2004 (EU-25).

A detailed estimate of environmental jobs is offered in a **study for London**, making a distinction between core environmental jobs and non-core ones. The non-core environmental jobs are the environmental goods and services activities in the non-environment sectors. They consist of environmental accounting, book-keeping, green finance provision, environment sector organizations (NGOs), environmental lawyers, researchers and the like. Employment in the core is estimated at 35,000 in 2001 (1% of London employment) whereas total employment in environmental activities is estimated at 140,000 in 2001 (3.4% of total employment in London), considerably higher than software development and consultancy (68,000). This suggests that environmental employment in the broadest sense (comprising all work activities that are concerned with dealing with environmental issues) is important.

Figure 12. Environmental jobs in greater London

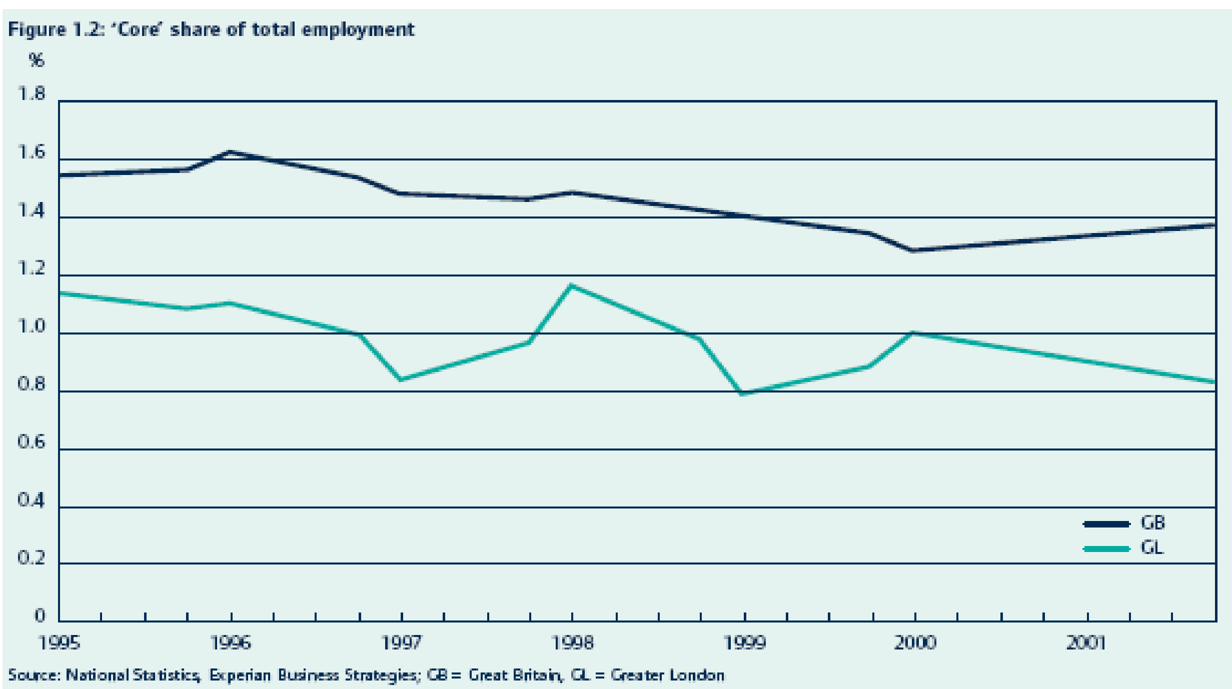
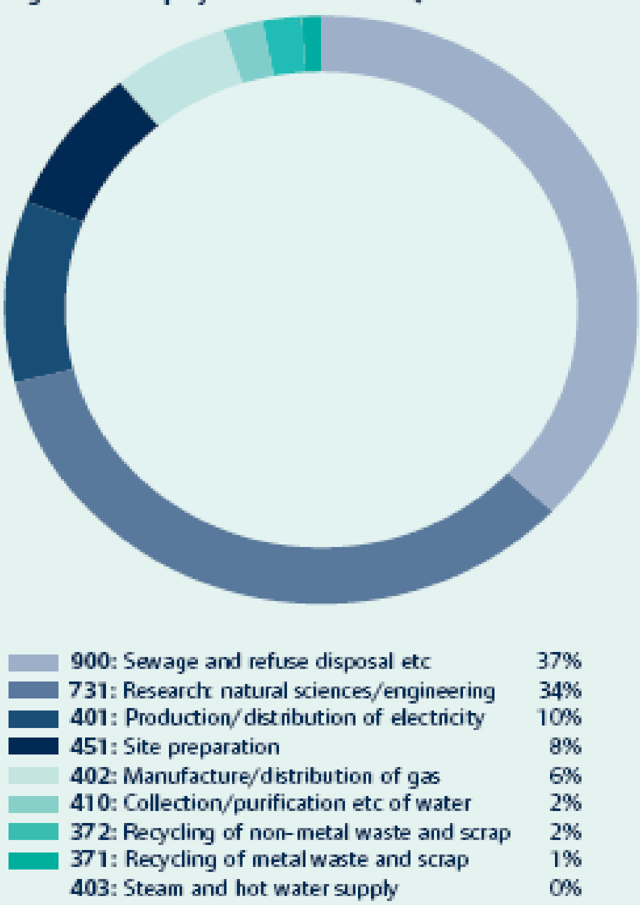


Table 1.3: Environment sector employment in London – estimates for 2001

Core commercial	15,400
Construction & civil engineering	34,000
Architecture & related engineering	17,300
Other commercial	40,100
Financial	4,800
Voluntary sector	1,700
Central Government	6,500
Local government	20,000
Education	>800
TOTAL	**140,600**

Figure 1.1: Employment in the 'core' (Greater London 2001)



Source: National Statistics, Experian Business Strategies

Source: London Development Agency (2003)

According to a study by the Swiss Federal Statistical Office, Switzerland employed approximately 50,000 people in the eco-industrial sector in 1998, equivalent to approximately 1.3% of all employees that year. This figure comprises 15,000 employees in fully eco-industrial activities and 35,000 employees in partially eco-industrial activities. In biological agriculture, which uses few environmentally harmful processes and is therefore on the edge of the eco-industrial sector, had 12,500 employees in 1998. In the fully eco-industrial sector, 77% of the employees were active in sewage purification, waste disposal and other disposal and 20% and 3% respectively in the areas of recovery and preparation for recycling and wholesale of scrap and waste material. Of the employees in the fully eco-industrial sectors, 6% were women and 94% men, of which only 53% of the women and 92% of the men were employed on a full-time basis.

Rennings and Ziegler offered estimates about employment effects of environmental innovations in the adopting company, which are found to be small. Overall 88 % of the eco-innovating firms said that the adoption of the most important eco-innovation had no notable effect on employment. In 9 % of the cases the number of long-term employees increased due to the innovation, in 3 % of the cases it decreased. This shows that there is a weak but positive relation between the introduction of eco-innovations and employment *at the company level*, with product innovations and service innovations having an above-average positive employment effect (18 % and 20 %).

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Annex 1.Definitions of eco-industry sectors

Solid Waste Management & Recycling is defined here as the production of equipment, technology or specific materials, or the design, operation of systems, plants and sites or provision of other services for the collection (waste and scrap), separation, sorting, handling, transport, treatment (thermal, biological and chemical), storage, disposal, recovery, recycling and management of hazardous and non-hazardous solid waste, including low level, but not high level, nuclear waste. It includes outdoor sweeping and watering of streets, paths, parking lots, etc.

Waste Water Treatment is the production of equipment, technology or specific materials, or the design, operation of systems, plants and sites or provision of other services for the collection, treatment, handling, transport, reuse and management of waste water, cooling water and sewage. The equipment includes pipes, pumps, valves, aeration, gravity sedimentation, chemical treatment and recovery, biological recovery systems, oil/water separation systems, screens and strainers, sewage treatment, waste water reuse, water purification and other water handling systems.

Air Pollution Control is the production of equipment, technology or specific materials, or the design, operation of systems or provision of other services for the treatment and/or removal of exhaust gases and particulate matter from both stationary and mobile sources. The equipment includes air-handling equipment, dust collectors, precipitators, filters, catalytic converters, chemical treatment and recovery systems, specialised stacks, incinerators, scrubbers, odour control equipment and environmentally less-damaging specialised fuels.

General Public Administration consists of national public administration teams and departments, including government departments, environmental protection agency inspection teams, environmental tax collection and administration, that bear responsibility for environmental management fields, the implementation and control of environmental regulations, monitoring of fundamental research and development efforts, reporting and follow-up on eco-industries performances and other duties.

Private Environmental Management includes all activities addressing environmental management issues within the private sector, in-house or through the provision of external assistance (expertise, consulting, etc.) including environmental management system design and operation, ISO 14 001 management and operation and environmental audit works.

Remediation & Clean Up of Soil & Groundwater is the production of equipment, technology or specific materials, or the design, operation of systems or provision of other services to reduce the quantity of polluting materials in soil and water, including surface water, groundwater and sea water. It includes absorbents, chemicals and bio-remediators for cleaning-up, as well as cleaning-up systems (in situ or installed), emergency response and spill cleanup systems, water treatment and dredging of residues.

Noise & Vibration Control is the production of equipment, technology or specific materials, or the design, operation of systems or provision of other services to reduce or eliminate the emission and propagation of noise and vibration both at source and dispersed. It includes mufflers and silencers, noise deadening material, noise control equipment and systems, vibration control equipment and systems, sound-proof screens and street covering

Environmental Research & Development is the research of environmental issues (air, soil, water, energy, waste, noise, etc.) and development of “end of pipe” pollution treatment and clean up solutions and “source prevention” solutions to prevent environmental impacts, through the development of “cleaner” technologies and the use of renewable raw materials, analyze environmental impacts (settlement of measurement and analysis instrumentation), clean up pollution (e.g. filtering or treatment processes).

Environmental Monitoring & Instrumentation includes the manufacturing, integration and distribution of components, equipment and systems for monitoring air quality, water quality, noise, industrial emissions, radioactivity levels, etc. It also includes laboratory analysis, data acquisition and management systems.

Water Supply is the production of equipment, technology or specific materials, or design, construction, installation, management or provision of other services for water supply and delivery systems (public and private) and the collection, purification and distribution of potable water to household, industrial, commercial or other users.

Recycled Materials is the production of equipment, technology or specific materials, or design, construction, installation, management or provision of other services for manufacturing new materials or products, separately identified as recycled, from recovered waste or scrap, or preparation of such materials or products for subsequent use. This category covers the production of secondary raw materials but not their subsequent use.

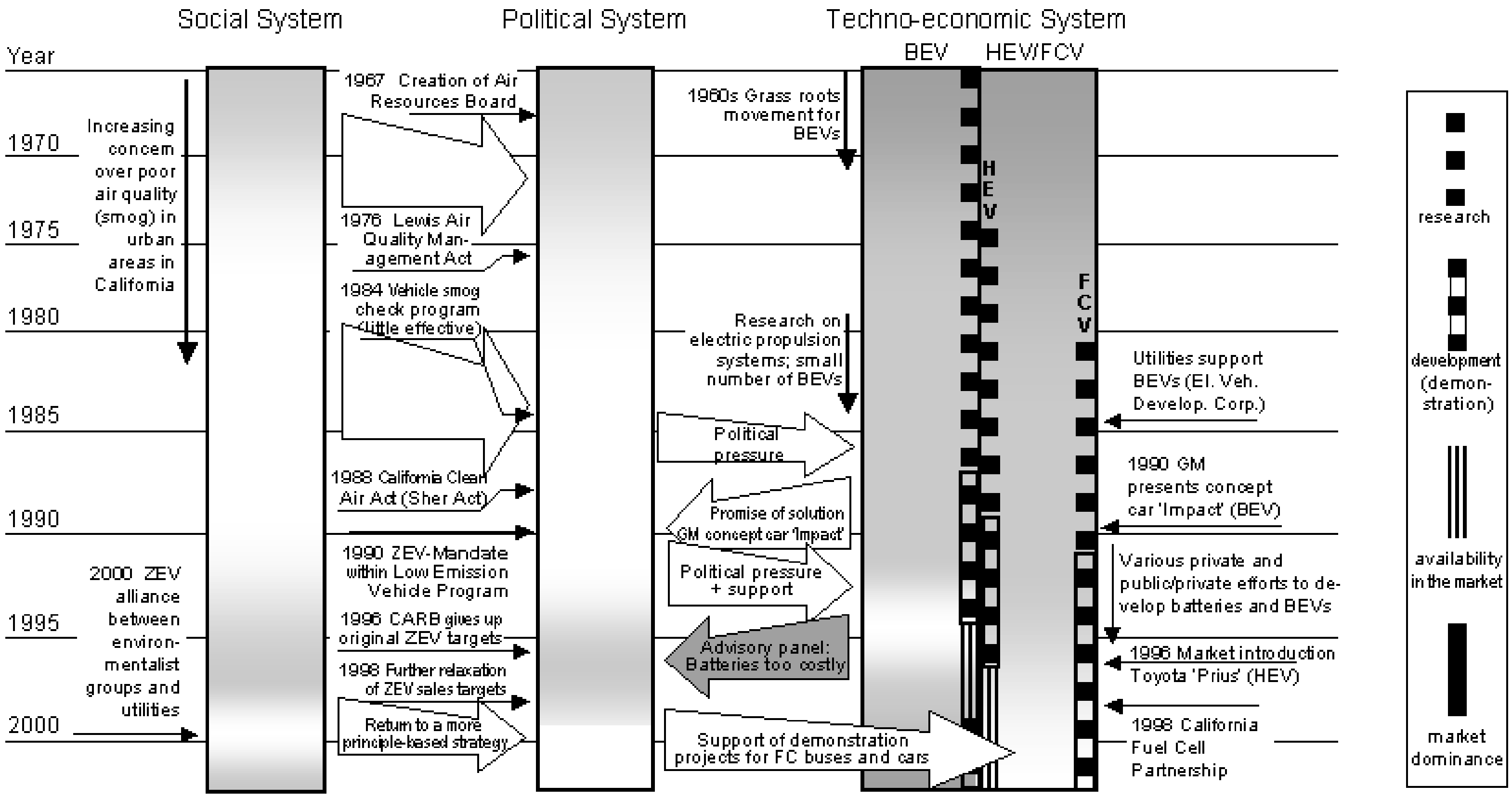
Renewable Energy is the production of equipment, technology or specific materials, or design, construction, installation, management or provision of other services for the generation, collection or transmission of energy from renewable sources, including biomass, solar, wind, tidal, or geothermal sources.

Nature Protection includes the administration, training, information and education activities to conserve or maintain the natural environment, and in particular, the protection and rehabilitation of fauna and flora species, ecosystems and habitats, natural and semi-natural landscapes.

Eco-construction consists of the production of equipment, technology or specific materials, or design, installation, management or provision of other services to minimize environmental impacts from building, construction and renovation, including the construction activity itself (workshop), selection of materials, consumption, emissions and other environmental impacts during use of the structure, management of construction waste. It does not include construction for an eco-activity facility.

Source: *Study on Eco-industry, its size, employment, perspectives and barriers to growth in an enlarged EU Final report, August 2006,* 17-18.

Annex 2. The interaction between social system, political system and techno-economic system in California as regards to automobile electric drive systems



Annex 3. European Innovation Scoreboard (EIS) Indicators

	INPUT – INNOVATION DRIVERS	
1.1	S&E graduates per 1000 population aged 20-29	EUROSTAT
1.2	Population with tertiary education per 100 population aged 25-64	EUROSTAT, OECD
1.3	Broadband penetration rate (number of broadband lines per 100 population)	EUROSTAT
1.4	Participation in life-long learning per 100 population aged 25-64	EUROSTAT
1.5	Youth education attainment level (% of population aged 20-24 having completed at least upper secondary education)	EUROSTAT
	INPUT – KNOWLEDGE CREATION	
2.1	Public R&D expenditures (% of GDP)	EUROSTAT, OECD
2.2	Business R&D expenditures (% of GDP)	EUROSTAT, OECD
2.3	Share of medium-high-tech and high-tech R&D (% of manufacturing R&D expenditures)	EUROSTAT, OECD
2.4	Share of enterprises receiving public funding for innovation	EUROSTAT (CIS4)
	INPUT – INNOVATION & ENTREPRENEURSHIP	
3.1	SMEs innovating in-house (% of all SMEs)	EUROSTAT (CIS3)[7]
3.2	Innovative SMEs co-operating with others (% of all SMEs)	EUROSTAT (CIS4)
3.3	Innovation expenditures (% of total turnover)	EUROSTAT (CIS4)
3.4	Early-stage venture capital (% of GDP)	EUROSTAT
3.5	ICT expenditures (% of GDP)	EUROSTAT
3.6	SMEs using organisational innovation (% of all SMEs)	EUROSTAT (CIS4)
	OUTPUT – APPLICATIONS	
4.1	Employment in high-tech services (% of total workforce)	EUROSTAT
4.2	Exports of high technology products as a share of total exports	EUROSTAT
4.3	Sales of new-to-market products (% of total turnover)	EUROSTAT (CIS4)
4.4	Sales of new-to-firm products (% of total turnover)	EUROSTAT (CIS4)
4.5	Employment in medium-high and high-tech manufacturing (% of total workforce)	EUROSTAT
	OUTPUT – INTELLECTUAL PROPERTY	
5.1	EPO patents per million population	EUROSTAT
5.2	USPTO patents per million population	EUROSTAT, OECD
5.3	Triadic patent families per million population	EUROSTAT, OECD
5.4	New community trademarks per million population	OHIM[8]
5.5	New community designs per million population	OHIM[7]

Source: Innometrics (2007)

Annex 4. Innovation capacity index and subindexes

	Innovative Capacity Index		Proportion of Scientists and Engineers Subindex		Innovation Policy Subindex		Cluster Innovation Environment Subindex		Linkages Subindex	
COUNTRY	RANK	INDEX	RANK	INDEX	RANK	INDEX	RANK	INDEX	RANK	INDEX
United States	1	30.3	6	4.3	1	8.1	1	10.9	1	7.1
Finland	2	29.1	7	4.2	4	7.3	2	10.9	3	6.7
Germany	3	27.2	11	4.1	7	7.0	4	9.9	10	6.1
United Kingdom	4	27.0	18	3.9	13	6.8	3	10.0	9	6.3
Switzerland	5	26.9	13	4.0	15	6.7	5	9.9	7	6.3
Netherlands	6	26.9	23	3.8	3	7.4	14	9.2	4	6.6
Australia	7	26.9	8	4.2	10	6.8	9	9.4	5	6.5
Sweden	8	26.9	2	4.5	21	6.1	6	9.8	6	6.5
France	9	26.8	9	4.1	6	7.1	10	9.3	8	6.3
Canada	10	26.5	14	4.0	5	7.3	12	9.2	11	6.1
Israel	11	26.5	19	3.9	14	6.8	15	9.1	2	6.7
Japan	12	26.4	1	4.5	12	6.8	7	9.7	21	5.4
Singapore	13	26.0	17	3.9	2	7.4	17	8.9	15	5.8
Taiwan	14	26.0	16	4.0	9	6.9	8	9.6	17	5.6
Belgium	15	25.4	15	4.0	11	6.8	19	8.8	14	5.8
Ireland	16	25.4	12	4.0	16	6.6	16	9.1	16	5.7
Austria	17	25.3	29	3.5	8	6.9	11	9.3	18	5.5
Norway	18	25.3	5	4.3	18	6.4	21	8.6	12	5.9
Denmark	19	25.2	10	4.1	19	6.4	20	8.8	13	5.9
Iceland	20	24.8	4	4.3	20	6.2	18	8.8	20	5.5
Spain	21	23.4	30	3.5	17	6.5	23	8.4	28	5.0
Italy	22	23.3	31	3.5	23	6.0	13	9.2	30	4.7
Korea	23	22.9	22	3.9	24	5.6	24	8.3	24	5.1
New Zealand	24	22.1	28	3.6	35	5.0	27	8.0	19	5.5
Portugal	25	21.6	35	3.3	22	6.0	33	7.7	31	4.7
Czech Republic	26	21.3	36	3.2	26	5.5	29	7.9	29	4.7
Estonia	27	21.2	25	3.8	36	5.0	36	7.4	27	5.0
Hungary	28	21.1	34	3.3	25	5.6	38	7.2	25	5.0
South Africa	29	21.0	38	3.1	40	4.7	26	8.1	26	5.0
Russia	30	20.6	3	4.4	52	4.1	30	7.8	42	4.3
Slovenia	31	20.4	20	3.9	32	5.2	50	6.8	33	4.5
Ukraine	32	20.3	21	3.9	56	4.1	28	7.9	35	4.4
Brazil	33	20.1	48	1.9	27	5.4	25	8.2	32	4.6
Slovakia	34	20.0	26	3.7	49	4.5	35	7.6	44	4.2
Chile	35	19.7	42	2.6	31	5.4	34	7.6	45	4.2
Poland	36	19.6	32	3.5	50	4.5	37	7.2	36	4.4
Lithuania	37	19.2	24	3.8	55	4.1	45	6.9	34	4.4
India	38	18.9	59	1.2	39	4.8	31	7.8	23	5.2
Costa Rica	39	18.8	41	2.7	38	4.8	42	7.0	38	4.3
Trinidad and Tobago	40	18.6	49	1.9	41	4.7	32	7.7	39	4.3
Latvia	41	18.5	37	3.1	51	4.2	43	7.0	47	4.1
Greece	42	18.4	39	3.0	33	5.1	60	6.3	50	4.0
China	43	18.1	44	2.3	46	4.6	44	6.9	41	4.3
Turkey	44	17.8	46	2.1	34	5.0	49	6.8	55	3.9
Panama	45	17.4	55	1.5	42	4.7	39	7.2	51	4.0
Thailand	46	17.4	60	0.8	30	5.4	40	7.1	49	4.1
Mauritius	47	17.2	45	2.1	43	4.7	59	6.4	52	4.0
Egypt	48	17.2	43	2.3	44	4.7	66	5.9	43	4.3
Argentina	49	17.0	40	2.9	54	4.1	48	6.8	68	3.3
Bulgaria	50	16.9	27	3.7	64	3.6	67	5.8	56	3.8
Uruguay	51	16.8	51	1.8	47	4.6	52	6.7	58	3.8
Malaysia	52	16.8	63	0.7	28	5.4	54	6.5	46	4.2
Mexico	53	16.8	50	1.8	45	4.6	46	6.9	63	3.5
Indonesia	54	16.4	47	1.9	48	4.6	58	6.4	62	3.5
Romania	55	16.3	33	3.4	65	3.6	53	6.6	73	2.7
Philippines	56	15.8	58	1.2	62	3.8	47	6.8	53	3.9
Sri Lanka	57	15.5	56	1.4	60	3.9	62	6.1	48	4.1
Venezuela	58	15.2	54	1.5	57	4.0	61	6.1	60	3.6
Colombia	59	15.1	53	1.5	58	3.9	63	6.1	61	3.5
Peru	60	14.3	52	1.6	71	3.4	65	6.0	64	3.3
Vietnam	61	13.8	70	0.0	69	3.5	55	6.5	57	3.8
Dominican Republic	62	13.6	68	0.0	61	3.9	57	6.4	65	3.3
Guatemala	63	13.2	66	0.4	70	3.5	64	6.0	66	3.3
Paraguay	64	13.1	64	0.7	66	3.6	68	5.8	72	2.9
Zimbabwe	65	13.0	69	0.0	63	3.6	71	5.5	54	3.9
Nicaragua	66	12.7	62	0.8	72	3.2	70	5.5	69	3.1
El Salvador	67	12.5	71	-0.2	59	3.9	69	5.8	71	3.0
Honduras	68	11.9	65	0.4	67	3.6	72	5.4	75	2.6
Ecuador	69	11.9	61	0.8	73	3.2	74	4.9	70	3.0
Bangladesh	70	11.6	67	0.1	74	3.0	73	5.2	67	3.3
Bolivia	71	11.6	57	1.4	75	2.8	75	4.8	74	2.6
Hong Kong SAR	NA	NA	NA	NA	29	5.4	22	8.6	22	5.2
Jamaica	NA	NA	NA	NA	53	4.1	51	6.7	37	4.3
Jordan	NA	NA	NA	NA	37	4.8	56	6.4	40	4.3
Nigeria	NA	NA	NA	NA	68	3.6	41	7.0	59	3.7

Source: Porter and Stern (2001)