Sustainable Manufacturing and Eco-Innovation

Framework, Practices and Measurement

Synthesis Report

eco-innovation

OECD

SUSTAINABLE MANUFACTURING AND ECO-INNOVATION

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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Foreword

In November 2007, the OECD Committee on Industry, Innovation and Entrepreneurship (CIIE) tasked the Secretariat to work on sustainable manufacturing and eco-innovation with a project proposal. This synthesis report extracts key findings from the analytical papers prepared during the first phase of this project. The full Phase I report will be published by the OECD in 2009.

The project has been managed by Tomoo Machiba under the supervision of Marcos Bonturi and Dirk Pilat at the OECD Directorate for Science, Technology and Industry. The CIIE agreed to declassify this paper at its April 2009 meeting.

This project's advisory expert group (Chair: Dr. Nabil Nasr, Rochester Institute of Technology) provided useful comments and guidance in the drafting of the papers. The authors would like to thank its members.

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Executive Summary

The OECD Project on Sustainable Manufacturing and Eco-innovation was launched in 2008. Its aim is the acceleration of sustainable industrial production through the diffusion of existing knowledge and the facilitation of the benchmarking of products and production processes. It also aims to promote the concept of eco-innovation and to stimulate the development of new technological and systemic solutions to global environmental challenges for the medium to long term.

As a first phase, to help policy makers and industry practitioners understand the relevant concepts and practices and to guide future work on the project, the OECD undertook to:

- Review the concepts of sustainable manufacturing and eco-innovation and build a framework for analysis.
- Analyse eco-innovation processes on the basis of existing examples from manufacturing companies.
- Benchmark the sets of indicators that have been used by industry to achieve sustainable manufacturing.
- Analyse the strengths and weaknesses of existing methodologies for measuring eco-innovation at the macro level.
- Take stock of national strategies and policy initiatives to promote eco-innovation in OECD countries.

This synthesis report presents a summary of the key findings from the initial phase of the project. The findings include the following:

1. Practices for sustainable manufacturing have evolved

In recent years, the efforts of manufacturing industries to achieve sustainable production have shifted from end-of-pipe solutions to a focus on product lifecycles and integrated environmental strategies and management systems. Furthermore, efforts are increasingly made to create closed-loop, circular production systems and adopt new business models.

2. Eco-innovation seeks more radical improvements

Much attention has been paid to innovation as a way for industry and policy makers to work towards more radical and systemic improvements in environmental performance. The term *eco-innovation* calls attention to the positive contribution that industry can make to sustainable development and a competitive economy.

3. Eco-innovation has three dimensions: targets, mechanisms and impacts

Based on an extension of the definition of innovation in the OECD *Oslo Manual* and on the existing literature, eco-innovation can be understood and analysed according to its *targets* (the main focus), its *mechanisms* (methods for introducing changes in the target) and its *impacts* (the effects on environmental conditions).

4. Sustainable manufacturing calls for multi-level eco-innovations

Sustainable manufacturing involves changes that are facilitated by eco-innovation. Integrated initiatives such as closed-loop production can potentially yield higher environmental improvements but require appropriately combining a wide range of innovation targets and mechanisms.

5. Current eco-innovations focus mostly on technological development but are facilitated by non-technological changes

While current eco-innovations in manufacturing tend to focus primarily on technological advances, organisational or institutional changes have often driven their development and complemented the necessary technological changes. Some advanced players started adopting new business models or alternative modes of provision.

6. Clear and consistent indicators are needed to accelerate corporate sustainability efforts

An appropriate combination of existing sets of indicators can help firms gain a more comprehensive picture of environmental effects across their value chain and product lifecycle. Companies along the supply chain, including small and medium-sized enterprises (SMEs), would make more use of clear and consistent sustainable manufacturing indicators.

7. Improved benchmarking and better indicators would help deepen understanding of eco-innovation

No existing measurement approach can capture the overall trends and characteristics of eco-innovation. Further progress in benchmarking and indicators might include the development of an "eco-innovation scoreboard" which combines different statistics or the design of a new dedicated survey. These could help improve understanding of the nature, drivers/barriers and impacts of eco-innovation and raise awareness among policy makers and industry.

8. Integration of innovation and environmental policies is crucial for promoting eco-innovation

OECD countries have addressed sustainable manufacturing and eco-innovation mainly through environmental policies. Innovation policy has so far not fully addressed environmental issues. Closer integration of innovation and environmental policies could benefit both policy areas and accelerate policy and corporate efforts towards sustainable development.

9. Creating successful eco-innovation policy mixes requires understanding the interaction of supply and demand

The countries surveyed do not all have a specific eco-innovation strategy, although various policy initiatives and programmes promote eco-innovation. While these include supply-side and demand-side measures, a fuller understanding of the interaction of supply and demand for eco-innovation would help achieve more successful policy mixes.

Given the above findings, the next phase of this project (2009-10), and possibly beyond, would seek to:

- **Provide guidance on indicators for sustainable manufacturing**: The OECD could bring clarity and consistency to existing indicator sets by developing a common terminology and understanding of the indicators and their use.

- **Identify promising policies for eco-innovation**: Careful evaluation of the implementation of various policy measures for eco-innovation would be helpful for identifying "promising eco-innovation policies".

- **Build a common vision for eco-innovation**: The OECD could help fill the gap in the understanding of eco-innovation by co-ordinating in-depth case studies. This could form the basis for developing a common future vision for environmentally friendly social systems and roadmaps to achieve this goal.

- **Develop a common definition and a scoreboard**: With the substantial insights obtained, the OECD could consider the development of a common definition of eco-innovation and an "eco-innovation scoreboard" for benchmarking eco-innovation activities and public policies by combining different statistics and data.

Synthesis

Introduction

In recent decades, the expansion of economic activity has been accompanied by growing global environmental concerns, such as climate change, energy security and increasing scarcity of resources. In response, manufacturing industries have recently shown more interest in sustainable production and have adopted certain corporate social responsibility (CSR) initiatives. Nevertheless, such efforts fall far short of meeting these pressing challenges. Moreover, improved efficiency in some regions has been offset by increases in consumption and growth in others.

The reduction of greenhouse gas (GHG) emissions has been a top priority for OECD governments, and many have adopted long-term frameworks and targets alongside the Kyoto Protocol to tackle global warming. Interestingly, the current economic crisis facing OECD countries has raised public expectations for greater industry efforts to achieve sustainable development. In the current economic crisis, a "Green New Deal" or a "green recovery" policy is being considered in several countries, and public investment in environmental technologies and other sustainability projects are a core part of their economic stimulus measures.

What is needed now is a new vision and policies that will enable the creation of business and job opportunities that go hand in hand with a reduction in negative environmental impacts. Today's short-term relief packages should help stimulate investments in environmental technologies and infrastructures that support innovative solutions and address long-term societal challenges, and thus help to realise such a vision.

In this context, *sustainable manufacturing* and *eco-innovation* are very much at the heart of this century's policy and industry practices. These concepts have become popular with policy makers and business leaders in recent years, and they encourage business solutions and entrepreneurial ideas for tackling environmental challenges.

Against this backdrop, *the OECD Project on Sustainable Manufacturing and Eco-innovation* was launched in early 2008 under the auspices of the Committee on Industry, Innovation and Entrepreneurship (CIIE). Its aim is to accelerate sustainable production by manufacturing industries as a new opportunity for value creation. This entails spreading existing knowledge and providing industry with a means to benchmark products and production processes. The project also seeks to promote the concept of eco-innovation and to stimulate new technological and systemic solutions to global environmental challenges in the medium to long term.

As a first phase, to help policy makers and industry practitioners understand the relevant concepts and practices and to guide future work on the project, the OECD undertook to:

- Review the concepts of sustainable manufacturing and eco-innovation and build a framework for analysis.
- Analyse eco-innovation processes on the basis of existing examples from manufacturing companies.

- Benchmark the sets of indicators that have been used by industry to achieve sustainable manufacturing.
- Analyse the strengths and weaknesses of existing methodologies for measuring eco-innovation at the macro level.
- Take stock of national strategies and policy initiatives to promote eco-innovation in OECD countries.

This synthesis report summarises the main findings from the first phase of the project, carried out during 2008. It aims to provide an overview of concepts and current practices in industry and government and to highlight gaps in understanding and areas which require further analysis and co-ordination.

Various opportunities for dialogue offered the possibility to benefit from industry and government insights. These include: the International Conference on Sustainable Manufacturing held on 23-24 September 2008 in Rochester, NY, United States; two questionnaire surveys (one for governments; one for leading companies); and two series of focus group meetings of industry experts (Rochester and Brussels). The project's Advisory Expert Group, which included government officials and industry practitioners, also provided the OECD with useful advice and guidance in the implementation of the project and the writing of this report.

Key findings

1. Practices for sustainable manufacturing have evolved

Manufacturing industries account for a significant part of the world's consumption of resources and generation of waste. Worldwide, the energy consumption of manufacturing industries grew by 61% from 1971 to 2004 and accounts for nearly a third of today's global energy usage. Likewise, they are responsible for 36% of global carbon dioxide (CO_2) emissions (IEA, 2007).

Manufacturing industries nevertheless have the potential to become a driving force for the creation of a sustainable society. They can design and implement integrated sustainable practices and develop products and services that contribute to better environmental performance. This requires a shift in the perception and understanding of industrial production and the adoption of a more holistic approach to conducting business (Maxwell *et al.*, 2006).

The environmental impact of industrial production has historically been dealt with by dispersing pollution in less harmful or less apparent ways (UNEP and UNIDO, 2004). Driven in part by stricter environmental regulations, industry has used various control and treatment measures to reduce the amount of emissions and effluents. More recently, its efforts to improve environmental performance have moved towards thinking in terms of lifecycles and integrated environmental strategies and management systems, and companies have also begun to accept larger environmental responsibilities throughout their value chains.

The adoption of more integrated and systematic methods to improve sustainability performance has laid the foundation for new business models or modes of provision which can potentially lead to significant environmental benefits. Efforts to create closed-loop, circular production systems have particularly focused on revitalising disposed products into new resources for production, for example by establishing eco-industrial parks where economic and environmental synergies between traditionally unrelated industrial producers can be harnessed (Figures 1 and 2; Box 1).

Figure 1. The closed-loop production system

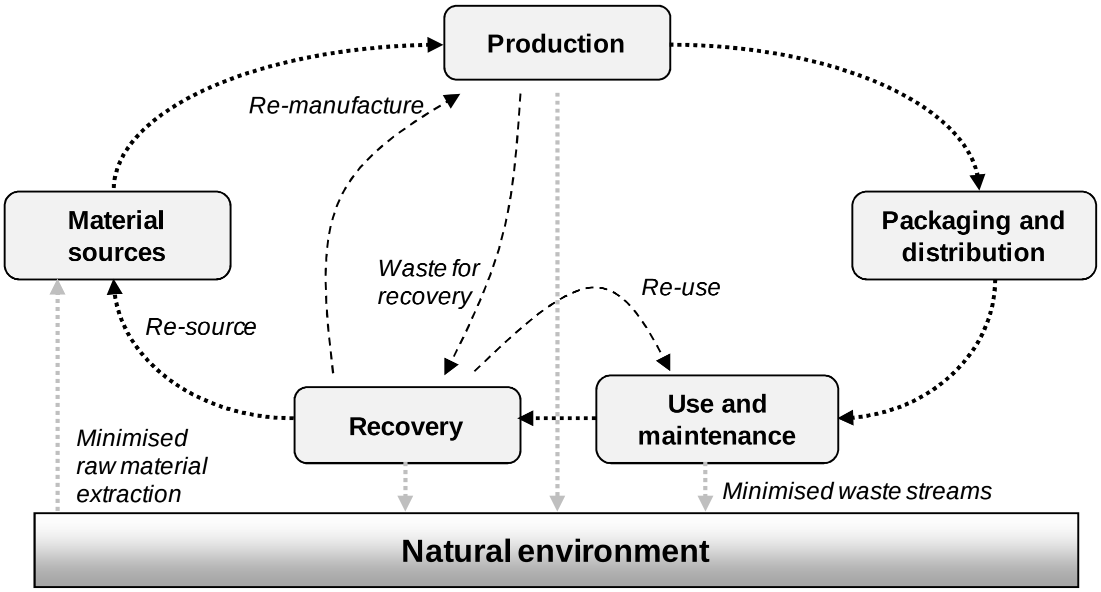
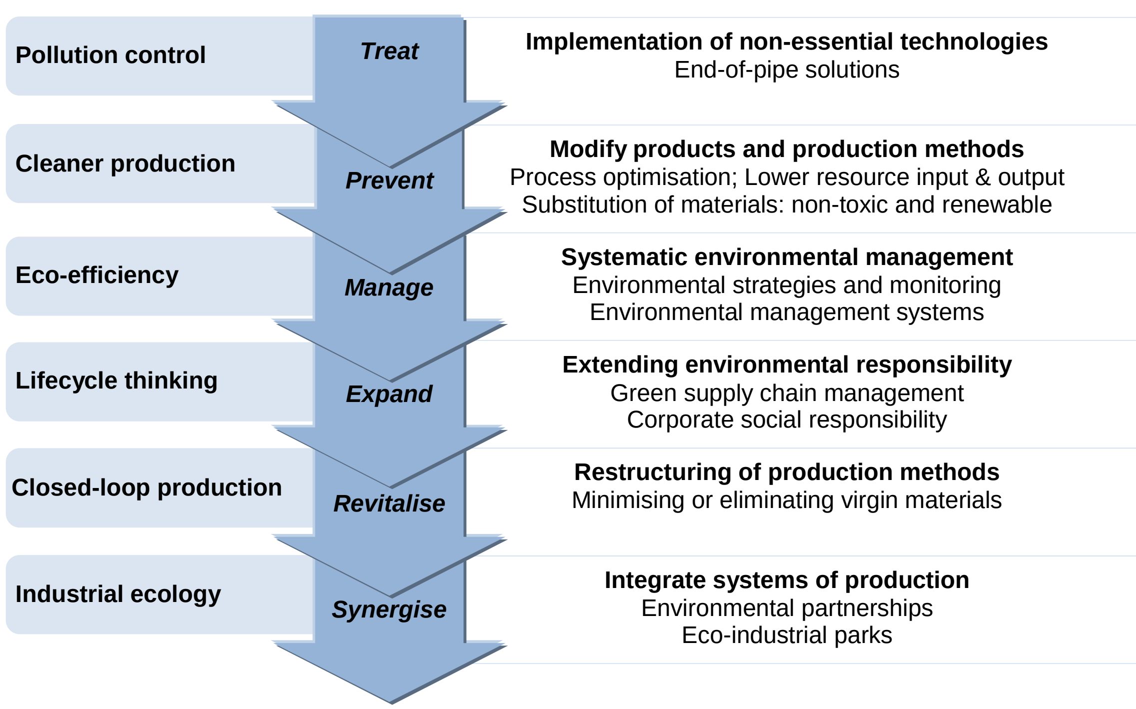


Figure 2. The evolution of sustainable manufacturing concepts and practices



Box 1. An eco-industrial park in Denmark

One of the earliest and best-known eco-industrial parks is located in Kalundborg, Denmark. Rather than the result of a carefully planned process, the eco-park developed gradually through co-operation by a number of neighbouring industrial companies. The main participating companies are a coal-fired power plant (Asnæsværket), a refinery (Statoil), a pharmaceutical and industrial enzyme plant (Novo Nordisk and Novozymes), a plasterboard factory (Gyproc), a soil remediation company (AS Bioteknisk Jordrens), and the municipality of Kalundborg through the town's heating facility.

The eco-park was initiated when Gyproc located its facility in Kalundborg in 1970 to take advantage of the butane gas available from the Statoil refinery. This also enabled Statoil to stop flaring this gas. Since then, the network has grown, and the participating companies are now highly integrated. For instance, surplus heat from the power plant is used to heat about 4 500 private homes and water for fish farming, and fly ash is supplied for cement production. Process sludge from fish farming is supplied to nearby farms as fertiliser. Novo Nordisk also supplies farms with surplus yeast from insulin production for pig food. The Statoil refinery supplies pure liquid sulphur from its de-sulphurisation operations to a sulphuric acid producer (Kemira).

These exchanges are only part of the material flow of the Kalundborg eco-park, which has been estimated at a total of around 2.9 million tonnes a year including fuel gases, sludge, fly ash, steam, water, sulphur and gypsum (Gibbs, 2008). This industrial symbiosis has led to significant economic savings and has reduced environmental impacts.

Source: Kalundborg Centre for Industrial Symbiosis, *www.symbiosis.dk*.

2. Eco-innovation seeks more radical improvements

Much attention has recently been paid to innovation as a way for industry and policy makers to achieve more radical, systemic improvements in corporate environmental practices and performance. Many companies have started to use *eco-innovation* or similar terms to describe their contributions to sustainable development. A few governments are also promoting the concept as a way to meet sustainable development targets while keeping industry and the economy competitive. However, while the promotion of eco-innovation by industry and government involves the pursuit of both economic and environmental sustainability, the scope and application of the concept tend to differ.

In the European Union (EU), eco-innovation is considered to support the wider objectives of its Lisbon Strategy for competitiveness and economic growth. The concept is promoted primarily through the Environmental Technology Action Plan (ETAP), which defines eco-innovation as "the production, assimilation or exploitation of a novelty in products, production processes, services or in management and business methods, which aims, throughout its lifecycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resource use (including energy)". Environmental technologies are also considered to have promise for improving environmental conditions without impeding economic growth in the United States, where they are promoted through various public-private partnership programmes and tax credits (OECD, 2008a).

To date, the promotion of eco-innovation has focused mainly on environmental technologies, but there is a tendency to broaden the scope of the concept. In Japan, the government's Industrial Science Technology Policy Committee defines eco-innovation as "a new field of techno-social innovations [that] focuses less on products' functions and more on [the] environment and people" (METI, 2007). Eco-innovation is thus seen as an overarching concept which provides direction and vision for pursuing the overall societal changes needed to achieve sustainable development (Figure 3). This extension of eco-innovation's scope corresponds to the more integrated application of sustainable manufacturing described above.

Figure 3. The scope of Japan's eco-innovation concept

Target / Field	Industry		Social infrastructure		Personal lifestyle
	Manufacturing	**Service**	**Energy**	**Transportation / urban**	
Technology	・Sustainable manufacturing ・Innovative R&D (energy saving, etc.) ・Green ICT ・Rare metal recycling	・Innovative R&D (Building Energy Management System)	・Innovative R&D (renewable energy, batteries) ・Superconducting transmission	・Innovative R&D (intelligent transport systems) ・Green automobiles ・Maglev	・Heat pump
Business model	・Green procurement (including BtoB) ・Green servicizing ・EMA ・LCA	・Energy services ・Environmental rating/green finance	・Green certification	・Modal shift	・Green procurement ・Cool biz ・Green finance
Societal system (institution)	・Environmental labeling system ・Starmark ・Green investment		・Top Runner Programme ・PRS Act (Renewables Portfolio Standard)	・Green tax for automobiles ・Next-generation vehicle and fuel initiative (METI)	・Telework, telecommuting ・Work-life balance

Source: METI.

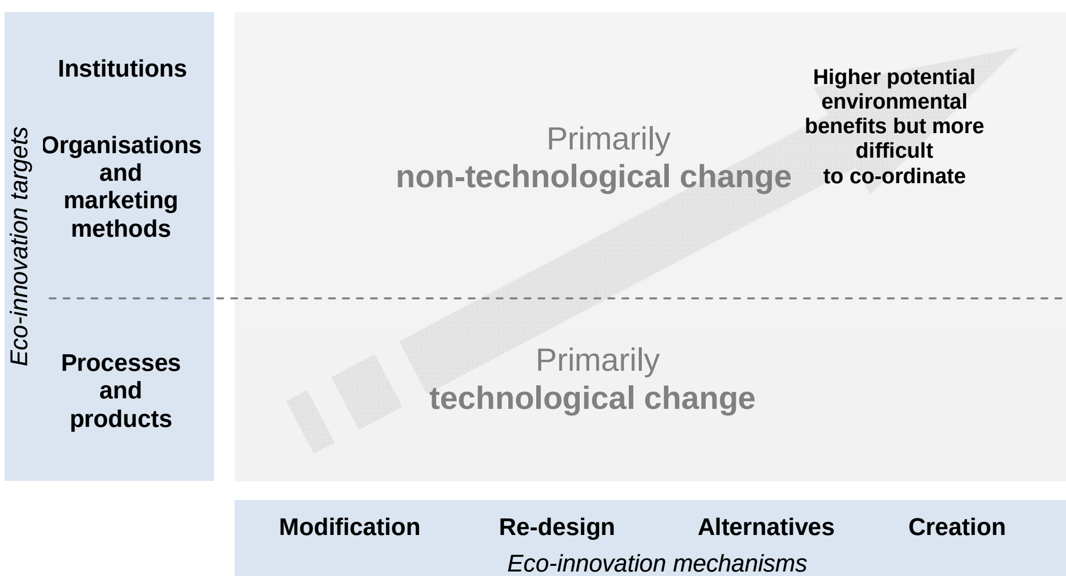
3. Eco-innovation has three dimensions: targets, mechanisms and impacts

The OECD *Oslo Manual* for the collection and interpretation of innovation data describes innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD and Eurostat, 2005, p. 46). Although this definition generally applies to eco-innovation, eco-innovation has two further significant, distinguishing characteristics:

- It is innovation that reflects the concept's explicit emphasis on a reduction of environmental impact, whether such an effect is intended or not.
- It is not limited to innovation in products, processes, marketing methods and organisational methods, but also includes innovation in social and institutional structures (Rennings, 2000). Eco-innovation and its environmental benefits go beyond the conventional organisational boundaries of the innovator to enter the broader societal context through changes in social norms, cultural values and institutional structures.

Building upon existing innovation and eco-innovation literature (*e.g.* Charter and Clark, 2007; Reid and Miedzinski, 2008), eco-innovation can be understood and analysed in terms of an innovation's 1) **target**, 2) **mechanism**, and 3) **impact**. Figure 4 presents an overview of eco-innovation and its typology:

Figure 4. The typology of eco-innovation



1) **Target** refers to the basic focus of eco-innovation. Following the *Oslo Manual*, the target of an eco-innovation may be:

   a. **Products**, involving both goods and services.

   b. **Processes**, such as a production method or procedure.

   c. **Marketing methods**, for the promotion and pricing of products, and other market-oriented strategies.

d. **Organisations**, such as the structure of management and the distribution of responsibilities.

e. **Institutions**, which include the broader societal area beyond a single organisation's control, such as institutional arrangements, social norms and cultural values.

The target of the eco-innovation can be technological or non-technological in nature. Eco-innovation in products and processes tends to rely heavily on technological development; eco-innovation in marketing, organisations and institutions relies more on non-technological changes (OECD, 2007).

2) **Mechanism** relates to the method by which the change in the eco-innovation target takes place or is introduced. It is also associated with the underlying nature of the eco-innovation – whether the change is of a technological or non-technological character. Four basic mechanisms are identified:

a. **Modification**, such as small, progressive product and process adjustments.

b. **Re-design**, referring to significant changes in existing products, processes, organisational structures, etc.

c. **Alternatives**, such as the introduction of goods and services that can fulfil the same functional need and operate as substitutes for other products.

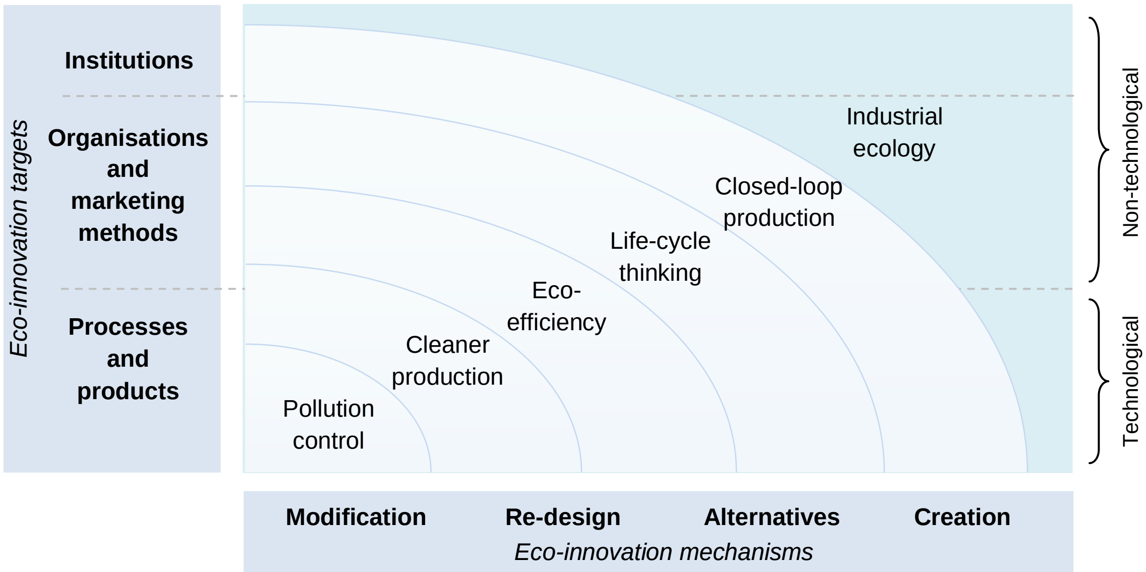
d. **Creation**, the design and introduction of entirely new products, processes, procedures, organisations and institutions.

3) **Impact** refers to the eco-innovation's effect on the environment, across its lifecycle or some other focus area. Potential environmental impacts stem from the eco-innovation's target and mechanism and their interplay with its socio-technical surroundings. Given a specific target, the potential magnitude of the environmental benefit tends to depend on the eco-innovation's mechanism, as more systemic changes, such as alternatives and creation, generally embody higher potential benefits than modification and re-design.

4. Sustainable manufacturing calls for multi-level eco-innovations

Both industry and government need to better understand and determine how to move towards a sustainable future. Innovation plays a key role in moving manufacturing industries towards sustainable production. Evolving sustainable manufacturing initiatives – from traditional pollution control through cleaner production initiatives, to a lifecycle view, to the establishment of closed-loop production – can be viewed as facilitated by eco-innovation. Figure 5 provides a simple illustration of the general conceptual relations between sustainable manufacturing and eco-innovation. The steps in sustainable manufacturing are depicted in terms of their primary association with respect to eco-innovation, *i.e.* with innovation targets on the left and mechanisms at the bottom. The waves spreading towards the upper right corner indicate the path dependencies of different sustainable manufacturing concepts.

Figure 5. Conceptual relationships between sustainable manufacturing and eco-innovation



While more integrated sustainable manufacturing initiatives such as closed-loop production can potentially yield higher environmental improvements in the medium to long term, they can only be realised through a combination of a wider range of innovation targets and mechanisms and therefore cover a larger area of Figure 5. For instance, an eco-industrial park cannot be successfully established simply by locating manufacturing plants in the same space in the absence of technologies or procedures for exchanging resources. In fact, process modification, product design, alternative business models and the creation of new procedures and organisational arrangements need to go hand in hand to leverage the economic and environmental benefits of such initiatives. This implies that as sustainable manufacturing initiatives advance, the nature of the eco-innovation process becomes increasingly complex and more difficult to co-ordinate.

These complex, advanced eco-innovation processes are often referred to as *system innovation* – an innovation characterised by fundamental shifts in how society functions and how its needs are met (Geels, 2005). Although system innovation may have its source in technological advances, technology alone will not make a great difference. It has to be associated with organisational and social structures and with human nature and cultural values. While this may indicate the difficulty of achieving large-scale environmental improvements, it also hints at the need for manufacturing industries to adopt an approach that aims to integrate the various elements of the eco-innovation process so as to leverage the maximum environmental benefits. The feasibility of their eco-innovative approach would then depend on the organisation's ability to engage in such complex processes.

5. Current eco-innovations focus mostly on technological development but are facilitated by non-technological changes

To better understand current applications of eco-innovation in manufacturing industries, a small sample of sector-specific examples were reviewed in light of the above framework. The sectors chosen were: *i)* the automotive and transport industry; *ii)* the iron and steel industry; and *iii)* the electronics industry. The examples draw mainly on a questionnaire survey and focus group meetings conducted among leading companies in OECD countries as part of this project (Table 1). The examples are not meant to represent best practices but were selected to illustrate the diversity of eco-innovation, its processes and the different contexts of its realisation.

Table 1. Eco-innovation examples examined in this project

Industry and company/association	Eco-innovation example
Automotive and transport industry	
The BMW Group	Improving energy efficiency of automobiles
Toyota	Sustainable plants
Michelin	Energy-saving tyres
Vélib'	Self-service bicycle sharing system
Iron and steel industry	
Siemens VAI, etc.	Alternative iron-making processes
ULSAB-AVC	Advanced high-strength steel for automobiles
Electronics industry	
IBM	Energy efficiency in data centres
Yokogawa Electric	Energy-saving controller for air conditioning water pumps
Sharp	Enhancing recycling of electronic appliances
Xerox	Managed print services

The automotive and transport industry has taken steps to reduce CO_2 emissions and other environmental impacts, notably those associated with fossil fuel combustion. Combined with the growing demand for mobility, particularly in developing economies, many eco-innovation initiatives have focused on increasing the overall energy efficiency of automobiles and transport, while heightening automobile safety. Eco-innovations have, for the most part, been realised through technological advances, typically in the form of product or process modification and re-design, such as more efficient fuel injection technologies, better power management systems, energy-saving tyres and optimisation of painting processes. Yet, there are indications that the understanding of eco-innovation in this sector is broadening. Alternative business models and modes of transport such as the bicycle-sharing scheme in Paris (Box 2) are being explored, as are new ways of dealing with pollutants from manufacturing processes of automobiles.

Box 2. *Vélib'*: Self-service bicycle-sharing system in Paris

In an attempt to reduce traffic congestion and improve air quality, the City of Paris introduced a self-service bicycle-sharing system *Vélib'* in the summer of 2007. The system consists of more than 1 450 stations open 24 hours a day year round, each containing 15 or more bicycle spaces. This amounts to about one station every 300 metres throughout the inner city, with a total of some 20 600 bicycles and 35 000 bike racks. Each station is equipped with an automatic rental terminal for hiring a bicycle, with a variety of options.

A subscription allows the user to pick up a bicycle from any station in the city and use it at no charge for 30 minutes. After that a charge is incurred for additional time in periods of 30 minutes. The payment scheme was designed to keep bicycles in constant circulation and increase intensity of use. To facilitate circulation, bicycles are redistributed every night to stations which have particularly high demand. Real-time data on bicycle availability at every station is provided through the Internet and is also accessible via mobile phones.

The start-up financing for the *Vélib'* project, as well as full-time operation for 10 years and associated costs, was undertaken entirely by the JC Decaux advertising company. In return, the City of Paris transferred full control of a substantial portion of the city's advertising billboards to this company.

The *Vélib'* system has been a great success and taking bicycles is also becoming fashionable. Part of this success is due to the system's design, with its strong focus on flexibility, availability and, not least, ease of use. According to one estimate, close to 150 000 trips are made each day on weekends and more than half that amount on weekdays (Britton, 2007). Building on this success, the city is now planning to expand the project with about 4 000 self-service electric hire cars by the end of 2010.

The iron and steel industry has in recent years significantly increased its environmental performance through a number of energy-saving modifications and the re-design of various production processes. These have often been driven by strong external pressures to reduce pollution and by increases in the prices and scarcity of raw materials. While most of the industry's eco-innovative initiatives have focused on technological product and process advances, the industry's engagement in various institutional arrangements has laid the foundation for many of these developments. For example, the development of advanced high-strength steel was made possible through an international collaborative arrangement between vehicle designers and steel makers and enabled the production of stronger steel for the manufacturing of lighter and more energy-efficient automobiles (Box 3).

Box 3. The development of advanced high-strength steel for automobiles

The introduction of new legislative requirements for motor vehicle emissions in the United States in 1993 intensified pressures on the automotive industry to reduce the environmental impact from the use of automobiles. In response, a number of steelmakers from around the world joined together to create the Ultra-Light Steel Auto Body (ULSAB) initiative to develop stronger and lighter auto bodies. From this venture, the ULSAB Advanced Vehicles Concept (ULSAB-AVC) emerged. The first proof-of-concept project for applying advanced high-strength steel (AHSS) to automobiles was conducted in 1999.

By optimising the car body with AHSS at little additional cost compared to conventional steel, the overall weight saving could reach nearly 9% of the total weight of a typical five-passenger family car. It is estimated that for every 10% reduction in vehicle weight, the fuel economy is improved by 1.9-8.2% (World Steel Association, 2008). At the same time, the reduced weight makes it possible to downsize the vehicle's power train without any loss in performance, thus leading to additional fuel savings. Owing to their high- and ultra-high-strength steel components, such vehicles rank high in terms of crash safety and require less steel for construction.

The iron and steel industry's continuing R&D efforts in this area also stem from its attempt to strengthen steel's competitive advantage over alternatives such as aluminium. The Future Steel Vehicle (FSV) is the latest in the series of auto steel research initiatives. It combines global steelmakers with a major automotive engineering partner in order to realise safe, lightweight steel bodies for vehicles and reduce GHG emissions over the lifecycle of the vehicle.

The electronics industry has so far mostly been concerned with eco-innovation in terms of the energy consumption of its products. However, as consumption of electronic equipment continues to grow, companies are also seeking more efficient ways to deal with the disposal of their products. As in the other two sectors, most eco-innovations in this industry have focused on technological advances in the form of product or process modification and re-design. Similarly, developments in these areas have been built upon eco-innovative organisational and institutional arrangements (see Box 4). Some of these arrangements have also been, perhaps unsurprisingly, among the most innovative and forward-looking. A notable example is the use of large-scale Internet discussion groups, dubbed "innovation jams" by IBM, to harness the innovative ideas and knowledge of thousands of people. Alternative business models, such as product-service solutions rather than merely selling physical products, have also been applied, as exemplified by new services in the form of energy management in data centres (IBM) and optimisation of printing and copying infrastructures (Xerox).

Box 4. Energy-saving controller for air conditioning water pumps

Air conditioners function by driving hot or cold water through piping to units located on each level of the building. The amount of cold water varies according to the desired temperature relative to the outside temperature. However, conventional air conditioners operate at the pressure required for maximum heating and cooling demands. Based on research revealing that in Japan air conditioning consumes half of a building's total energy, Yokogawa Electric, a Japanese manufacturer, sought to create a simple, inexpensive and low-risk control mechanism that would eliminate wasteful use of energy. The resulting product, Econo-Pilot, can control the pumping pressure of air conditioning systems in a sophisticated way and can reduce annual pump power consumption by up to 90%. It can be installed easily and inexpensively, precluding the need to buy new cooling equipment. The technology has been successfully applied in equipment factories, hospitals, hotels, supermarkets and office buildings.

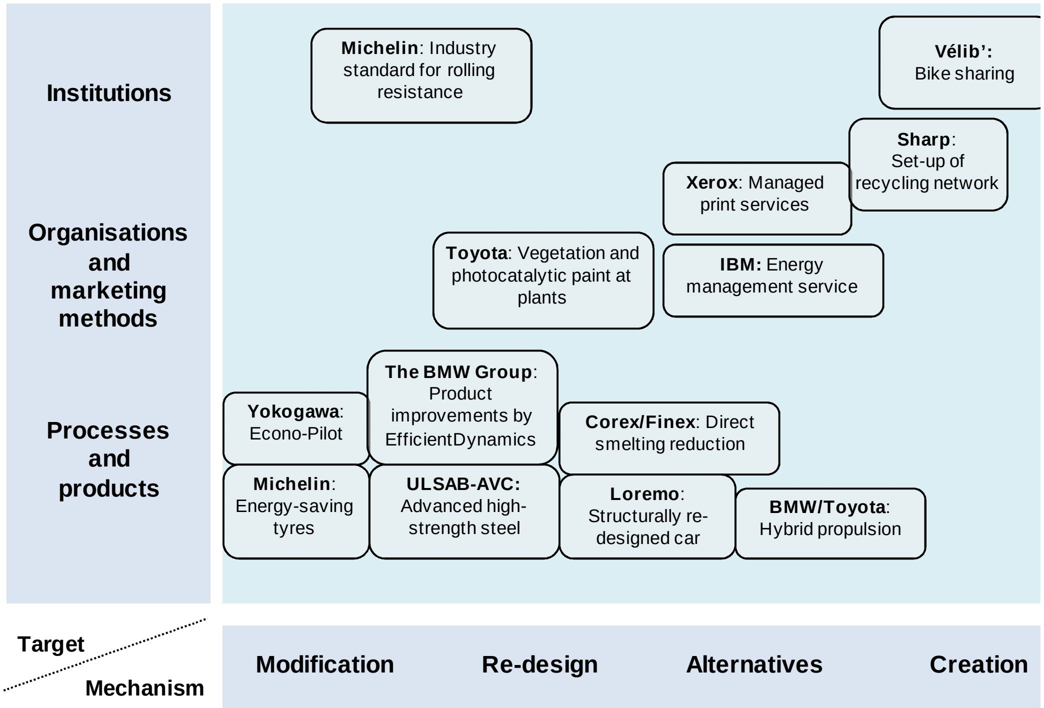
Econo-Pilot is based on the technology devised by Yokogawa jointly with Asahi Industries Co. and First Energy Service Company. It was developed and demonstrated through a joint research project with the New Energy and Industrial Technology Development Organization (NEDO), a public organisation established by the Japanese government to co-ordinate R&D activities of industry, academia and the government. NEDO researches the development of new energy and energy-conservation technologies, and works on validation and inauguration of new technologies. After the demonstration and piloting of this technology, various functions were incorporated in the final product.

Photo: Yokogawa Electric.

To sum up, the primary focus of current eco-innovation in manufacturing industries tends to rely on technological advances, typically with products or processes as eco-innovation targets, and with modification or re-design as principal mechanisms (Figure 6). Nevertheless, even with a strong focus on technology, a number of complementary changes have functioned as key drivers for these developments. In many of the examples, the changes have been either organisational or institutional in nature, such as the establishment of separate environmental divisions for improving environmental performance and directing R&D, or the setting up of inter-sectoral or multi-stakeholder collaborative research networks. Some industry players have also started exploring more systemic eco-innovation through new business models and alternative modes of provision.

Therefore, the heart of an eco-innovation cannot necessarily be represented adequately by a single set of target and mechanism characteristics. Instead, eco-innovation seems best examined and developed using an array of characteristics ranging from modifications to creations across products, processes, organisations and institutions. The characteristics of a particular eco-innovation furthermore depend on the observer's perspective. The analytical framework can be considered a first step towards more systematic analysis of eco-innovation.

Figure 6. Mapping the primary focus of example of eco-innovation



Note: This map only indicates the primary targets and mechanisms that facilitated the indicated examples of eco-innovation. Each was realised in combination with other innovation processes that involve different targets and mechanisms.

6. Clear and consistent indicators are needed to accelerate corporate sustainability efforts

Manufacturing industries are in a position to help overcome global environmental challenges, but their future contributions will depend on how well they adopt and integrate the eco-innovative approaches outlined above when modifying their production patterns (Charter and Clark, 2007). This requires a broad perspective on what is understood by the sustainability of manufacturing and a strong focus on identifying areas in which eco-innovative solutions can substantially reduce environmental impacts. Furthermore, industry must recognise that because the main features of any innovation are determined early in the innovation process (Reid and Miedzinski, 2008), important benefits of eco-innovation may be lost if broad environmental aspects do not have priority from the beginning of the process.

Indicators help manufacturing companies to understand environmental issues surrounding existing production systems, to define specific objectives and to monitor progress towards sustainable production. Therefore, the project reviewed existing sets of indicators that help industry and companies to track and benchmark different aspects of their environmental performance.

There are many indicators for sustainable manufacturing around the world. They are diverse in nature, and have been developed on a voluntary basis, or as a standard or as part of legislation. Table 2 shows the most common categories of indicators for sustainable manufacturing identified in this project.

Table 2. A list of categories of sets of indicators for sustainable manufacturing

Category	Description	Similar indicators or examples
Individual indicators	Measure single aspects individually	Core set of indicators Minimum set of indicators
Key performance indicators (KPIs)	A limited number of indicators for measuring key aspects that are defined according to organisational goals	
Composite indices	Synthesis of groups of individual indicators that is expressed by only a few indices	
Material flow analysis (MFA)	A quantitative measure of the flows of materials and energy through a production process	Material balance Input-output analysis Material flow accounting Exergy; MIPS; Ecological rucksack
Environmental accounting	Calculate environment-related costs and benefits in a similar way to financial accounting system	Environmental management accounting; Total cost assessment Cost-benefit analysis Material flow cost accounting
Eco-efficiency indicators	Ratio of environmental impacts to economic value created	Factor
Lifecycle assessment (LCA) indicators	Measure environmental impacts from all stages of production and consumption of a product/service	Ecological footprint Carbon footprint; Water footprint
Sustainability reporting indicators	A range of indicators for corporate non-financial performance to stakeholders	GRI Guidelines Carbon Disclosure Project
Socially responsible investment (SRI) indices	Indices set and used by the financial community to benchmark corporate sustainability performance	Dow Jones Sustainability Indexes FTSE4Good

Although it is not easy to compare these sets of indicators, since they differ in terms of their structure and application, they were reviewed from the viewpoint of their potential effectiveness in advancing sustainable manufacturing. Whereas each company has its own operating environment and capacity for dealing with indicators, the following six benchmarking criteria were identified as generally desirable. Table 3 summarises the benchmarking of existing sets of indicators according to these criteria:

- comparability for external benchmarking;
- applicability for SMEs;
- usefulness for management decision making;
- effectiveness for improvement at the operational level;
- possibility of data aggregation and standardisation;
- effectiveness for finding innovative products or solution.

Table 3. Summary of the analysis of sustainable manufacturing indicators

Criteria / Type of indicator sets	Comparability	Applicability for SMEs	Management decision-making	Operational performance improvement	Data aggregation and standardisation	Finding innovative products or solution
Individual indicators	*	***	*	**	*	*
Key performance indicators	*	*	***	*	*	*
Composite indices	**		**	*	**	*
Material flow analysis	*	*	*	***	**	***
Environmental accounting	**	*	**	***	**	**
Eco-efficiency indicators	**	*	**	***	**	***
LCA indicators	**	*	*	***	**	***
Sustainability reporting indicators	*	**	**	**	*	*
SRI Indices	**		**			*

***: Strongly suitable.
**: Suitable if certain conditions are met.
*: Applicable though not necessarily suitable.
Note: The usefulness of each indicator set may also be subject to the competence and context of the organisation using the indicators.

There is no set of indicators among those listed in Table 3 which can cover everything that manufacturing companies need to consider to improve their production processes and products with a view to sustainable development. Except for eco-efficiency indicators, each of the nine categories is mainly designed to help management decision making or to facilitate improvements in products or processes at the operational level. In reality, many companies use more than one set of indicators at management and operational levels, often without relating them.

An appropriate combination of existing indicator sets could help give companies a more comprehensive picture of economic, environmental and social effects across the value chain and product lifecycle. For example, it might be useful to combine material flow analysis, LCA indicators and environmental accounting. Eco-efficiency indicators are promising but those in use have incompatible conceptual approaches. The further development and standardisation of environmental valuation techniques could also help companies make more rational decisions on investments in sustainable manufacturing activities.

Lifecycle considerations have helped companies to consider environmental effects beyond their factory gates, but there is as yet no set of indicators that takes account of system-level impacts beyond a single product lifecycle. In order to encourage system innovations, as advocated by the "cradle to cradle" concept (McDonough and Braungart, 2002) for example, new system-level indicators may need to be developed to allow for identifying the system-wide impacts of new products and production processes.

7. Improved benchmarking and better indicators would help deepen understanding of eco-innovation

As noted above, the notion of eco-innovation has grown in importance in relation to sustainable manufacturing but its characteristics and impacts are often obscure to both policy makers and companies. Quantitative measurement of eco-innovation activities would improve understanding of the concept and practices and help policy makers to analyse trends and identify drivers and barriers. It would also raise awareness of eco-innovation among industry, policy makers and other stakeholders, and would make improvements achieved through eco-innovation more evident to producers and consumers alike.

To explore future opportunities for measurement, the project examined existing methodologies for measuring eco-innovation at the macro level (*i.e.* sectoral, regional and national) and analysed their strengths and weaknesses.

However, it should be kept in mind that eco-innovation may be environmentally motivated, but may also occur as a side effect of other goals, such as reducing production costs. It may also occur through institutional changes in values, knowledge, norms and administrative actions or the formation of collaborations with new stakeholders. Therefore, to capture the diversity and characteristics of eco-innovation activities without limiting the scope of the concept, it is important to collect data on:

a) How firms eco-innovate, or the **nature** of eco-innovation (target, mechanism, etc.)

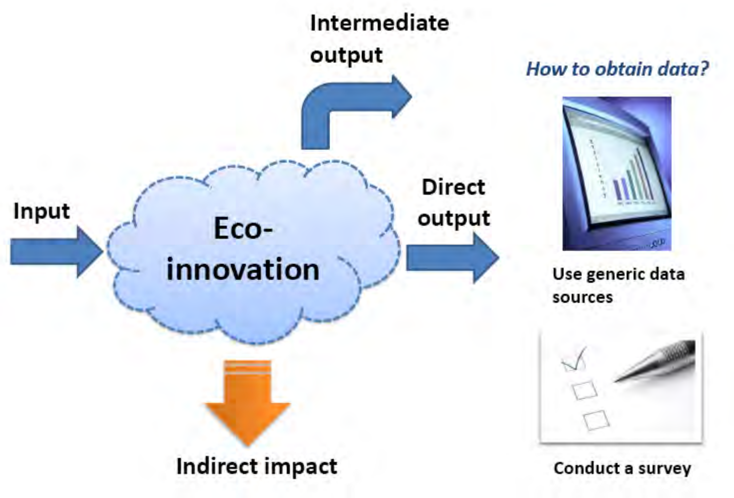
b) The **drivers and barriers** that affect different types of eco-innovations

c) The **impacts** of different types of eco-innovations.

The following types of data can be used to measure and analyse eco-innovation quantitatively:

1. **Input measures**: *e.g.* R&D expenditures, R&D personnel, other innovation expenditures (such as investment in intangibles, including design expenditures, software and marketing costs)
2. **Intermediate output measures**: *e.g.* number of patents; numbers and types of scientific publications
3. **Direct output measures**: *e.g.* number of innovations, descriptions of individual innovations, sales of new products from innovations
4. **Indirect impact measures**: *e.g.* changes in eco-efficiency and resource productivity.

Figure 7. Options for measuring eco-innovation



These categories of data can generally be obtained either by using widely available **generic sources of data** which are not specifically collected to measure eco-innovation, or by conducting **specifically designed surveys** (see Figure 7). An analysis of some methods for measuring eco-innovation by using information from those sources is provided below (Table 4 provides a detailed overview):

Generic data sources

Generic data sources can provide information on general aspects of eco-innovation, such as total investments in R&D, numbers of scientific publications or patents, numbers and descriptions of innovations, and sales of new products from innovations. However, as they are typically not designed to measure eco-innovation, the insights that can be extracted are limited. For example, there is no official statistical classification for eco-innovation in patent data, R&D statistics or trade statistics. No single indicator or method can be considered ideal and investigations of eco-innovation based on these sources are best undertaken by combining a number of different indicators.

That said, generic data sources can yield a wealth of information if an effort is made to extract more detail from the underlying data or complement these sources with other documentary and digital sources such as corporate annual reports, trade journals and websites. Eco-innovation can also be measured indirectly from changes in eco-efficiency and resource productivity. These avenues have been underexplored but could be investigated to augment the current narrow knowledge basis. Moreover, the ability to merge different databases could substantially improve eco-innovation analysis. For example, OECD (2008c) suggests that it should be possible to link firms in the EPO/OECD PATSTAT patent application database to other datasets that contain information on each firm's employment levels and profitability. This would permit an analysis of the impact of eco-innovation (proxied by patents) on firm performance.

Table 4. 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

Specialised surveys

Surveys can provide researchers with detailed and focused information on a number of specific aspects of eco-innovation. The insights into eco-innovation provided by surveys can be especially rich if they are conducted internationally on the basis of the same methodology.

New surveys designed for analysing eco-innovation could help to collect in-depth data on a number of specific aspects of eco-innovation, particularly those which are hard to extract from generic sources. These could include more specific information on the nature of the eco-innovation, the drivers of innovation, the barriers, and the final impacts of innovation. Such surveys should be careful to include questions that are relevant to the development of policies that can encourage eco-innovation.

Innovation surveys are typically conducted via official, large-scale projects or smaller one-off surveys. Large-scale national innovation surveys have a wider scope and are conducted on a regular basis, but may be more limited in their ability to provide specific and detailed information (an example may be the eco-innovation module introduced in the EU's Community Innovation Survey 2008). Smaller, more specialised surveys are often limited in their geographical or sectoral coverage, and may suffer from low response rates, but could provide more in-depth information.

The development of an "eco-innovation scoreboard" could greatly improve government and industry awareness of eco-innovation. This scoreboard could combine different statistics from generic data sources. Measuring the "greenness of national innovation systems" (*e.g.* environmental standards, environmental education, collaboration, venture capital, subsidy schemes and market-based instruments) could offer another avenue for benchmarking eco-innovation and could be linked to a scoreboard.

A new dedicated survey on eco-innovation or an addition to existing surveys may also prove useful. It would also be beneficial to conduct panel surveys or interviews to gather information from the same firms over time. Such in-depth surveys may make it possible to learn how the nature of eco-innovation changes over time and how it relates to overall performance.

8. Integration of innovation and environmental policies is crucial for promoting eco-innovation

Long-term policy frameworks and goals for sustainable development such as the Kyoto Protocol have led to the establishment of a wide variety of policy programmes, notably in the areas of energy, transport, building and manufacturing. Traditionally, OECD countries have mainly used environmental policies to address sustainable manufacturing and eco-innovation. Generally, innovation policy in most countries has been the responsibility of ministries for trade and industry and science and technology, while environmental policy has usually been developed by environment ministries. Few efforts have so far been made to integrate these two policy domains.

Environmental policies have traditionally focused on treatment of pollution and waste, and thus on end-of-pipe solutions, rather than on the whole production and disposal processes (Parliamentary Office of Science and Technology, 2004). Environmental policies have therefore had a relatively limited effect on innovation, since stringent regulations and standards do not give firms enough incentive to innovate beyond end-of-pipe solutions even though those policies have largely contributed to reducing environmental impacts. Moreover, conventional regulations and standards typically impose great costs on firms (OECD, 2008b). Recently, some market-oriented instruments, such as green taxes and tradable permits, have been introduced as measures that put a price on the "bad". However, to realise its potential, eco-innovation will require actions to ensure that the full cycle of innovation is efficient, with policies ranging from appropriate investments in research to support for commercialising existing and breakthrough technologies.

Box 5. Mutually reinforcing links between innovation and environmental policies

There are several good reasons why a more explicitly innovation-oriented environmental policy is needed:

- *Environmental effectiveness*: An innovation-oriented environmental policy is necessary to promote the development and introduction of a new series of techniques that make major improvements in environmental quality more attainable.
- *Decoupling economic growth from environmental pressure*: An innovation-oriented environmental policy is necessary to achieve simultaneously ambitious socio-economic and environmental objectives and substantially raise the eco-efficiency of the economy.
- *Cost-effectiveness*: An innovation-oriented environmental policy is necessary to reduce the cost of environmental measures and achieve more environmental results for the same level of costs.
- *Take advantage of win-win opportunities*: An innovation-oriented environmental policy is necessary to focus on win-win opportunities that have remained unused in order to lower production costs and at the same time pollute less.
- *Market and socio-economic benefits*: An innovation-oriented environmental policy is necessary to benefit from the promising market and socio-economic benefits of the fast-growing environmental industry.

At least three main reasons for a more explicitly environmentally oriented innovation policy can be mentioned:

- *Innovation policy promotes R&D on promising future technologies.* Given the scale and magnitude of environmental problems, technologies limiting the environmental damage of production and consumption are important. Such innovations are not only hampered by "positive" knowledge spillovers that discourage inventors in general but also by "environmental externalities" in the diffusion stage. In such a situation, there is obviously an important role for innovation policy in remediating these market failures.
- *Environmental innovations have some particular properties* compared to most other types of technologies. This is why there is relatively little environmental R&D. First is the importance of government policy in creating demand by regulatory and other environmental instruments. Second is the fact that R&D in environmental innovations is often very complex because it usually involves various scientific and technical disciplines and the necessary competence may not be available in the company undertaking the research.
- *Innovation policy needs to be internalised by other policy domains* to be comprehensive and perform through better integration with the demand side. Innovation becomes a pull factor if it is part of sectoral policies and if public tenders take it explicitly into account. These "third-generation" innovation policies have to become fully horizontal and support a broad range of social goals if they are to achieve their objective of increasing the overall innovation rate in societies.

Source: Dries *et al.* (2005), in OECD (2005b).

Innovation policy, on the other hand, has been too broad to address specific environmental concerns appropriately. It has focused on spurring economic growth by developing new technologies for improving productivity and new areas of functionality.

As a result, eco-innovation has not been a primary objective of environmental or of innovation policy. Yet both policy areas would benefit from closer integration. A 2005 OECD report on the governance of innovation systems listed a number of benefits arising from the integration of innovation and environmental policies (Box 5). From the environmental point of view, the benefits would include environmental effectiveness and cost effectiveness. A more innovation-oriented environment policy could make improvements in environmental quality more attainable through the application of new technologies and also reduce the costs of environmental measures. Closer integration could also help decouple environmental pressures from economic growth and hence achieve ambitious environmental and socio-economic goals simultaneously, while benefiting from new market opportunities in a growing eco-industry. From the innovation point of view, it is increasingly recognised that "third-generation innovation policies have to become fully horizontal and support a broad range of social goals if they are to achieve their objective of increasing the overall innovation rate in societies" (OECD, 2005a, p. 57).

9. Creating successful eco-innovation policy mixes requires understanding the interaction of supply and demand

A questionnaire survey was used to take stock of national strategies and initiatives with regard to eco-innovation and gain insight into current policies. Ten OECD countries participated: Canada, Denmark, France, Germany, Greece, Japan, Sweden, Turkey, the United Kingdom and the United States. The goal was to learn how innovation policy measures are currently utilised to promote eco-innovation and the extent to which environmental considerations are integrated into innovation policies. The following analysis was conducted according to the taxonomy of supply- and demand-side innovation policy measures introduced by Edler and Georghiou (2007):

Supply-side measures

- **Equity support**: Many governments have taken measures to ease access to finance through venture capital for firms developing innovative technologies or setting up new businesses. The focus is often on SMEs and entrepreneurs. However, there are few specific measures or instruments for firms developing environmental technologies or eco-friendly products and services, as most equity support measures target general business start-up and development.
- **Research and development** (R&D): R&D activities are at the heart of eco-innovation and are necessary for the development of environmental technologies. Most R&D programmes seem to be sector- or technology-specific, and few countries seem to focus on shifting R&D investments towards the environment or eco-innovation. It is currently not clear what proportion of total R&D expenditures is directed towards eco-innovation. Furthermore, R&D in general-purpose technologies, such as information technology, biotechnology and nanotechnology may be very relevant to eco-innovation but may not be identified as such.
- **Pre-commercialisation**: Many available environmental technologies have not been successfully introduced in the market, either because the market for them is not well developed or because existing infrastructure and production and consumption systems may be an obstacle to commercialisation. Consideration of the post-R&D stages of innovation, prior to commercialisation as marketable products and services, is thus particularly

important for eco-innovation. Many government initiatives have been introduced to help firms bring new environmental technologies to the market, though the current focus is sometimes limited to promising energy and transport-related technologies (see Box 6). Environmental technology verification (ETV) schemes have also been introduced in some OECD countries.

Box 6. Funding for successful deployment of eco-technologies

A number of the United States' R&D-related initiatives increasingly pay attention to the whole process of innovation. For example, the Environment Protection Agency's (EPA) Research and Development Continuum defines six stages in the progression of technology development from idea to diffusion in the marketplace.

The Department of Energy's (DOE) Technology Commercialization Fund (TCF) complements angel investment or early-stage corporate product development (USD 14.3 million in fiscal years 2007 and 2008). The TCF brings the DOE's national laboratories and industry together to identify promising technologies that face the "commercialization valley of death". It makes matching funds available to any private-sector partner wishing to pursue deployment of such a technology. Similarly, the DOE's Hydrogen, Fuel Cells and Infrastructure Technologies Program focuses on the development of next-generation technologies, establishment of an education campaign that communicates potential benefits and better integration of sub-programmes in hydrogen, fuel cells and distributed energy.

- **Education and training**: Education and training programmes are essential for developing the human capital needed to deliver eco-innovative solutions and create a potential labour force for "green jobs". A number of countries have taken measures to mainstream environmental education in the school curricula or vocational training. A few countries have also started to focus on creating specific skills and a knowledgeable workforce for emerging environmental industries.

- **Networks and partnerships**: In view of the recognised significance of networks and partnerships for innovation, many policy programmes have sought to influence the structure of innovation by requiring co-operation in research projects and by supporting network development. To improve the overall sustainability performance of products and services, eco-innovation activities need to address the entire value chain. Government can play a role as facilitator of networks of innovation actors, notably through public-private partnerships and networking platforms for eco-innovation. To date, a few networks specifically target the development of new environmental technologies and solutions (see Boxes 7 and 8).

Box 7. Knowledge networks for eco-innovation

The UK Technology Strategy Board, in charge of promoting technology-driven innovation, relies heavily on networking to drive innovation within UK businesses. It has set up:

- **Innovation platforms**, to pull together policy, business, government procurement, research perspectives and resources to generate innovative solutions for societal issues and harness the innovative capabilities of UK businesses. Innovation platforms focus on particular areas of innovation to identify available levers and funding streams, including two innovation platforms in the environment-related areas of low-impact buildings and low-carbon vehicles. The Low Carbon Vehicle Innovation Platform will provide GBP 40 million to support R&D and commercialisation of low-carbon vehicles.
- **Knowledge Transfer Networks (KTNs)**, to increase the depth and breadth of transfers of technology to UK-based businesses. Networks in the fields of technology and business applications include some environmental fields such as resource efficiency, environment and fuel cells. KTNs bring together people from business, universities, research, finance and technology organisations to stimulate innovation through knowledge transfer.

The Technology Strategy Board conducted a major review of the KTNs. It showed that 75% of business respondents rated KTN services as effective; 50% developed new R&D and commercial relationships with people met through these networks; and 25% made a change to their innovation activities as a result of their engagement. The most highly rated functions of the KTNs are monitoring and reporting on technologies, applications and markets, high-quality network opportunities, and identifying and prioritising key innovation-related issues and challenges. Given the increasingly global nature of innovation, the KTNs' support to international activities will be increased.

Box 8. Creating regional clusters for eco-innovation

"Competitiveness clusters" have been established since 2004 in various French regions to conduct innovative projects in partnership between businesses, research institutes and training organisations with a focus on one or more identified markets. Several of the 71 clusters are currently implementing common environmental technology projects with high-growth potential either in renewable energy and energy efficiency or in a specific sector. Examples include decentralised energy (Languedoc-Roussillon), chemistry and the environment (Rhône-Alpes), industry and agro-resources (Champagne-Ardennes), cities and sustainable mobility (Ile-de-France) and vehicles of the future (Alsace and Franche-Comté). Such initiatives are expected to bring growth and employment opportunities in the regions and increase the attractiveness of France through enhanced international visibility.

- **Provision of infrastructure**: Some types of infrastructure are essential for innovation activities. In particular, transport and communication infrastructures are increasingly considered a critical factor for economic success and raising productivity. Innovation related to alternative fuel vehicles, user-friendly public transport or renewable energy relies on infrastructure for new fuelling systems, sophisticated traffic control, diffused energy distribution systems, etc. However, this area has so far not been at the core of innovation policies of the countries reviewed, although a few take information and communication technology infrastructure into account as eco-innovation measures.[1]

1. Recent stimulus packages to address the economic crisis contain a wider range of measures in this area, however.

Demand-side measures

- **Regulations and standards**: Traditionally, industry has tended to view environmental regulations negatively as adding costs and creating an adverse effect on competitiveness. Forward-looking instruments based on best available technologies or overall environmental performance of products or companies, however, could guide the course of innovation and accelerate the creation of eco-innovative solutions by creating a "level playing field". Flexible and well-designed standards and regulations would also help the diffusion of advanced environmental technologies and eco-friendly products by creating demand. Some regulations and standards are emerging that aim at stimulating sustainable manufacturing and eco-innovation by creating demand both within firms and among consumers (see Box 9).

Box 9. Japan's Top Runner programme for energy efficiency

The Top Runner programme, launched in 1998 by the Japan's Ministry of Economy, Trade and Industry (METI), sets performance targets for enterprises. It adopts a dynamic process of setting and revising standards by taking the current highest energy efficiency rate of a product as a benchmark instead of setting fixed targets. The programme currently targets 21 product groups in the residential, commercial and transport sectors. This flexible, dynamic standard setting creates positive incentives and competition among manufacturers to improve their product performance without the need for financial support or a bias towards existing or outdated technologies that may cause innovation inertia. The programme is supplemented by the e-Mark voluntary labelling scheme to help consumer choices at the point of sale.

- **Public procurement and demand support**: As the public sector is a large consumer, public procurement represents a key source of demand for firms. As attention to demand-side policies increases, some governments have started to highlight procurement as a way to spur innovation. Some of the countries surveyed list green public procurement as a driver of eco-innovation, but there is little evidence on the extent of such procurement initiatives and their success in creating new eco-innovative solutions or lead markets. Governments may also directly support business and individual consumers with subsidies, tax incentives or other benefits for purchasing particular eco-products and services in order to stimulate demand. There are a few good examples of the proactive use of demand support measures for shifting the course of technology and product developments (see Box 10).

Box 10. Providing both "carrot and stick" for diffusing eco-products

In December 2007, France introduced the Bonus-Malus (reward-penalty) scheme for personal automobiles to support consumers' purchase of greener cars, while encouraging manufacturers to develop low-emissions vehicles. This scheme provides a subsidy or a penalty to any buyer of a new car depending on the amount of CO_2 emissions per kilometer as below:

Subsidies		Penalties	
Emission level (g CO_2/km)	Amount (EUR)	Emission level (g CO_2/km)	Amount (EUR)
121-130	200	161-165	200
101-120	700	161-165	750
61-100	1 000	201-250	1 600
<60	5 000	251<	2 600

In addition, the "Super Bonus" provides consumers with a subsidy for scrapping a car 15 or more years old linked to the purchase of a vehicle eligible for the above bonus. This subsidy was initially set at EUR 300 but has been increased to EUR 1 000 under the new economic recovery plan. The emission levels will decrease by 5 grams of CO_2 every two years. A new mechanism is being discussed to introduce an annual tax instead of the current one-time penalty. The extension of the scheme to other household equipment is under consideration.

- **Technology transfer**: The transfer of technology and know-how in the area of environmental technologies is a way for technology-importing countries to increase resource efficiency in a relatively short term. At the same time, it can offer exporting countries considerable market and innovation opportunities. Some countries seem to be more strategic than others, targeting specific countries as export partners or attracting foreign investment in domestic eco-industries.

Results from this stocktaking exercise show that an increasing number of countries rightly perceive environmental challenges not as a barrier to economic development but as an opportunity, whereby innovation can lead to economic growth and competitiveness. However, not all countries surveyed seem to have a specific strategy for eco-innovation and when they do, policy co-ordination between different government departments is limited.

Countries' policy initiatives and programmes to promote eco-innovation are diverse and include both supply-side and demand-side measures. Most countries surveyed recognise the need for a collaborative approach to develop the technologies required to face today's environmental challenges. Many government programmes that support the supply side involve the creation of networks, platforms or partnerships that engage businesses, academics, government representatives and other stakeholders.

Demand-side measures, such as green public procurement, regulatory instruments and technology transfer attract increasing attention, owing to the recognition that the existence and expansion of relevant markets for eco-innovative products and services is essential to meet environmental challenges. Yet, demand-side measures seem to need a more focused approach in order to leverage industry activities for eco-innovation. A fuller understanding of the interaction of supply and demand for eco-innovation – as well as the relationship between production and consumption of eco-innovative products and services – is a pre-requisite for creating successful eco-innovation policy mixes.

Conclusions and future work

In order to meet environmental challenges such as climate change, much attention has been paid to innovation as a way to develop sustainable solutions. The concepts of sustainable manufacturing and eco-innovation are increasingly adopted by industry and policy makers as a way to facilitate more radical and system-wide improvement in production processes and products and in corporate environmental performance. Eco-innovation can be understood in terms of its target, mechanism and impact, while sustainable manufacturing practices focus on lifecycle approaches.

To date, the primary focus of sustainable manufacturing and eco-innovation tends to be on technological advances for the modification and re-design of products or processes, as in conventional innovation. However, some advanced industry players have adopted complementary organisational or institutional changes such as new business models or alternative modes of provision, for example, offering product-service solutions rather than sale of physical products.

An appropriate combination of existing sets of indicators could help firms gain a more comprehensive picture of environmental effects across the value chain and product lifecycle. Clearer and more consistent indicators would increase their impact, particularly on supply chain companies and SMEs.

Quantitative measurement can also help policy makers and industry to better grasp overall trends and the characteristics of eco-innovation. Since no single measurement approach is sufficient to capture eco-innovation comprehensively, it is important to apply different analytical methods, possibly in combination, and view different indicators together.

Closer integration of innovation and environmental policies could benefit both policy areas and accelerate corporate efforts on sustainable manufacturing and eco-innovation. Survey results show that not all countries have a specific eco-innovation strategy. For those that do, there is limited policy co-ordination between different government departments. Current policy initiatives and programmes are diverse and include both supply-side and demand-side measures. A more comprhensive understanding of the interaction of supply and demand for eco-innovation is necessary to create a successful eco-innovation policy mix.

Based on the above research outcomes, promising areas for the work of the OECD Project on Sustainable Manufacturing and Eco-innovation in the next phase (2009-10), and possibly beyond, include:

- **Provide guidance on indicators for sustainable manufacturing**: The OECD could bring clarity and consistency to existing indicator sets by working with other stakeholders on developing a common terminology and understanding of the indicators and their usage. It could also play a role in providing supportive measures for increasing the use of indicators by supply chain companies and SMEs. Further down the line, the OECD could utilise its experience in leading the development of the Pollutant Release and Transfer Register (PRTR) system to standardise indicator sets and the methodology for both the micro level (facility, product or company) and the macro level (sectoral, local or national). To encourage system innovations, a framework for identifying system-wide impacts of new products and production processes could also be considered.

- **Identify promising eco-innovation policies**: Better evaluation of the implementation of different policy measures for eco-innovation would help to identify "promising eco-innovation policies" as well as the contexts in which specific policy instruments can be deployed effectively. The OECD can facilitate the sharing of best policy practices in this area among governments.

- **Build a common vision for eco-innovation**: The OECD could help fill the gap in understanding eco-innovations, especially those that are more integrated and systemic and have non-technological characteristics, by co-ordinating in-depth case studies. To guide industry and policy makers towards more radical and system-wide improvements, it could also work on the development of a common vision of environmentally friendly social systems and roadmaps for realising them. This exercise should involve member countries, industry experts, academics and NGOs.

- **Develop a common definition and a scoreboard**: Building upon its experience with innovation measurement and the *Oslo Manual*, the OECD could consider developing a common definition of eco-innovation and an "eco-innovation scoreboard" for benchmarking eco-innovation activities and public policies by combining different statistics and data. Such work could improve awareness and guide government efforts.

This project's Advisory Expert Group also recommended conducting the following activities for the next phase of work:

Sustainable manufacturing indicators

– Develop a toolbox or manual to help manufacturing companies use existing indicator sets to improve their environmental performance by providing guidance and general recommendations on the use, terminology, standard processes and methodologies of indicators.

– Standardise methodologies for material flow analysis at the micro level (*i.e.* at the corporate or product level), as this is considered as one of the most effective tools for improving energy and resource efficiency.

Global eco-innovation platform

– Collect interesting examples of different levels of eco-innovation from around the world and conduct an in-depth study on processes that help achieve eco-innovation in order to draw lessons for practitioners and policy makers.

– Collect good examples of policies that promote eco-innovation and conduct an in-depth study on how they function. This can be followed by the identification of result-oriented, dynamic new-generation innovation policies that encourage industry to lead eco-innovation efforts.

– The above industry and policy best practices could be compiled as a freely accessible online database for knowledge sharing and networking as well as shared through workshops, conferences, etc.

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