

**DIRECTORATE FOR SCIENCE, TECHNOLOGY AND INDUSTRY
COMMITTEE ON INDUSTRY, INNOVATION AND ENTREPRENEURSHIP**

**SUSTAINABLE MANUFACTURING AND ECO-INNOVATION: FRAMEWORK, MEASUREMENT
AND INDUSTRY AND POLICY PRACTICES**

Synthesis Report

The CIIE has tasked the Secretariat to work on sustainable production and eco-innovation [DSTI/IND(2007)24]. This document synthesises the five papers prepared for this project (see DSTI/IND(2009)5/PART1 – PART5) and highlights key findings from the first phase of work.

It is also intended to publish this document as a stand-alone brochure independently from the five papers.

This paper is submitted to Delegates for discussion and approval at the CIIE meeting of 2-3 April 2009.

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Executive Summary

The OECD Project on Sustainable Manufacturing and Eco-innovation was launched in 2008 with an aim to accelerate sustainable production among manufacturing industries by spreading existing knowledge and providing industry with a means to benchmark their products and production processes. The project also aimed at promoting the concept of eco-innovation and at stimulating new technological and systemic solutions to global environmental challenges, in particular from a medium to long-term point of view.

In the first phase of the project, the OECD reviewed the following aspects of sustainable manufacturing and eco-innovation in order to help policy makers and industry practitioners understand the concepts and practices as well as guide the future OECD work in this field:

- Review the concepts of sustainable manufacturing and eco-innovation and build up a common framework for analysis.
- Analyse the diverse nature and processes of eco-innovation in manufacturing industries from existing examples.
- Benchmark existing sets of indicators that have been applied by industry for realising sustainable manufacturing.
- Analyse the strengths and weaknesses associated with existing methodologies for measuring eco-innovation at the macro level.
- Take stock of existing national strategies and policy initiatives for promoting eco-innovation in OECD countries.

This synthesis report presents a summary of key findings from the first phase of work. These include the following:

1. *Practices for sustainable manufacturing have evolved*

In recent years, the efforts of manufacturing industries for sustainable production have shifted from end-of-pipe solutions to the adoption of lifecycle thinking and integrated environmental strategies and management systems. Furthermore, increasing efforts are made to create closed-loop, circular production systems as well as new business models.

2. *The concept of eco-innovation aims at driving more radical improvements*

Much attention has been paid to innovation as a response for industry and policy makers to drive more radical and systemic improvements in environmental performance. The term *eco-innovation* has emerged to represent the positive contribution that business can make to sustainable development and to keeping the economy competitive.

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

As an extension of the definition of innovation in the OECD Oslo Manual as well as based on existing literature, eco-innovation can be understood and analysed according to three axes – its *targets* (the basic focus area of eco-innovation), *mechanisms* (methods by which the change in the target takes place or is introduced) and *impacts* (the eco-innovation's effects on the environmental conditions).

4. *Sustainable manufacturing is realised through multi-level eco-innovations*

The advancement in sustainable manufacturing initiatives involves changes that are facilitated by eco-innovation. More integrated initiatives such as closed-loop production could potentially yield higher environmental improvements but can only be realised by appropriately combining a wider range of innovation targets and mechanisms.

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

While the primary focus of current eco-innovations in manufacturing industries tends to rest on technological advancements, organisational or institutional changes have functioned as key drivers for their developments and have often been complementary to the technological changes required. Some advanced players have adopted new business models or alternative modes of provision.

6. *Clarity and consistency of existing indicators is required to accelerate corporate sustainability efforts*

An appropriate combination of existing sets of indicators could help firms gain the most comprehensive picture of environmental effects across their value chain and product lifecycle. More clarity and consistency of existing indicator sets would increase the use of sustainable manufacturing indicators particularly among companies along the supply chain, including SMEs.

7. *Improvements in benchmarking and indicators would help deepen understanding of eco-innovation*

No single existing measurement approach is sufficient to capture the overall trends and characteristics of eco-innovation. Further progress in benchmarking and indicators is needed. This could include the development of an “eco-innovation scoreboard” that combines different statistics or the design of a new dedicated survey. Such efforts could help improve understanding of the nature, drivers/barriers and impacts of eco-innovation as well as raise awareness among policy makers and industry.

8. *Integration of innovation and environmental policies is key to promoting eco-innovation*

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

9. *Understanding of the demand-supply interaction is a pre-requisite for creating successful eco-innovation policy mixes*

Not all countries examined in the OECD study have a specific strategy for eco-innovation. Various policy initiatives and programmes have been introduced to promote eco-innovation including supply-side and demand-side measures. A more comprehensive understanding of the interaction between supply and demand for eco-innovation would help develop more successful policy mixes.

Based on the above findings, promising areas for the work of this OECD project in the next phase (2009-10), and possibly beyond, include the following:

- **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 usage.
- **Identify promising policies for eco-innovation:** A better evaluation of the implementation of different policy measures for eco-innovation would be helpful to identify “promising eco-innovation policies”.
- **Build a common vision for eco-innovation:** The OECD could help fill the gap in understanding eco-innovations by co-ordinating further in-depth case studies. It could aim to build a common future vision or scenarios for environmentally friendly social systems and draw roadmaps to realise such changes based on improved understanding.
- **Develop a common definition and a scoreboard:** After gaining substantial insights, 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.

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Introduction

1. Expanding economic activities have in recent decades been accompanied by growing environmental concerns at a global scale such as climate change, energy security and increasing resource scarcity. Responding to this, manufacturing industries have recently shown increased interest in sustainable production (*sustainable manufacturing*) and are also undertaking a number of corporate social responsibility (CSR) initiatives. Nevertheless, progress falls far short of meeting these pressing challenges. Furthermore, improvements in efficiency in some regions have in many cases been offset by increasing consumption volumes as well as by growth in other regions.

2. The reduction of greenhouse gas (GHG) emissions has been one of the top priorities 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 that most OECD countries are facing has raised public expectations for further boosting industry efforts for sustainable development. In several countries, a “Green New Deal” or “green recovery” policies are being considered and public investments in environmental technologies and other sustainability projects are a core part of economic stimulus measures.

3. What would be needed is the establishment of a new vision and accompanying policies that will enable the creation of business and job opportunities that can occur hand in hand with a reduction of negative impacts on the environment. Short-term relief packages deployed today can help stimulate investments in environmental technologies and infrastructures that support innovative solutions and long-term societal challenges, which can support the realisation of such a vision.

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

5. 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), with the aim to accelerate sustainable production among manufacturing industries as a new opportunity for value creation. This entails spreading existing knowledge and providing industry with a means to benchmark their products and production processes. This project also seeks to promote the concept of eco-innovation and to stimulate new technological and systemic solutions to global environmental challenges from a medium to long-term point of view.

6. As the first phase of the project, the OECD reviewed the following aspects of sustainable manufacturing and eco-innovation in order to help policy makers and industry practitioners understand the concepts and practices as well as guide the future OECD work in this field:

- Review the concepts of sustainable manufacturing and eco-innovation and build up a common framework for analysis.
- Analyse the diverse nature and processes of eco-innovation in manufacturing industries from existing examples.
- Benchmark existing sets of indicators that have been applied by industry for realising sustainable manufacturing.

- Analyse the strengths and weaknesses associated with existing methodologies for measuring eco-innovation at the macro level.
- Take stock of existing national strategies and policy initiatives for promoting eco-innovation in OECD countries.

7. This synthesis report presents a summary of key findings from the first-phase work carried out during 2008. It aims to provide readers with an overview of the concepts and current practices in both industry and government and to highlight existing gaps of understanding and areas where further analysis and co-ordination are required.

8. The project benefited from industry and government insights through various opportunities for dialogue. 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; the other for leading companies); and two series of focus group meetings of industry experts (Rochester, NY and Brussels). The project's Advisory Expert Group members consisting of both governmental officials and industry practitioners also provided the OECD with useful advice and guidance in the writing of this report as well as the implementation of the project.

Key findings

1. *Practices for sustainable manufacturing have evolved*

9. Manufacturing industries account for a significant part of the world's consumption of resources and generation of waste. On a global scale, for example, the energy consumption of manufacturing industries has grown 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 (CO₂) emissions (IEA, 2007).

10. Manufacturing industries nevertheless have the potential to become a driving force for the creation of a sustainable society by designing and implementing integrated sustainable practices, as well as by developing products and services that can contribute to better environmental performance. But such developments require 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).

11. Environmental impact caused by 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 regulation, industry has moved towards increasing their efforts to reduce the amount of emissions and effluents by using various control and treatment measures. In more recent years, efforts to improve environmental performance have moved towards the adoption of lifecycle thinking and integrated environmental strategies and management systems, and companies have likewise begun to take larger environmental responsibilities throughout their value chains.

12. The adoption of more integrated and systematic methods to improve sustainability performance has laid the foundation for new business models such as product-service system (PSS)¹ which could potentially lead to significant environmental benefits. Aiming to create closed-loop, circular production

¹ PSS is a business model which focuses on the delivery of consumer utility and product functionality instead of focusing on the production and supply of physical goods to consumers as seen in the traditional model. For example, when producing and supplying photocopiers to their consumers, a company based on a PSS model retains product ownership by supplying the photocopiers as a function such that consumers purchase the copying service, not the physical product itself.

systems, efforts have particularly focused on revitalising disposed products into new resources for production through, for example, establishing eco-industrial parks where economic and environmental synergies between traditionally unrelated industrial producers can be harnessed (Figure 1; Figure 2; Box 1).

Figure 1. Closed-loop production system concept

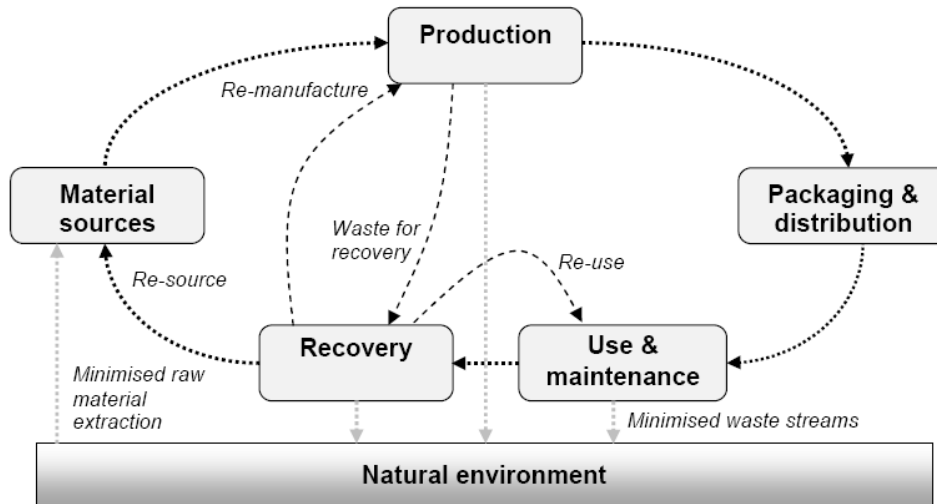
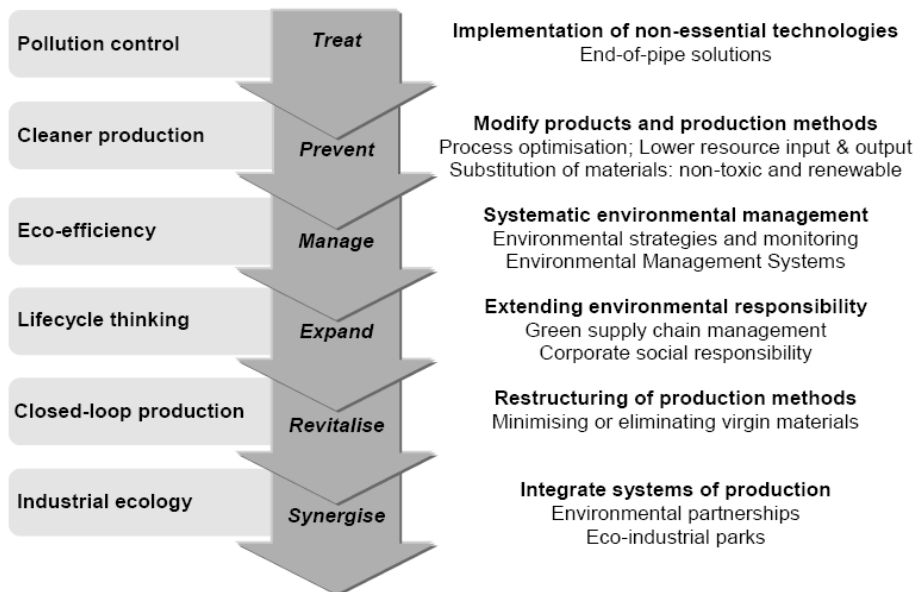


Figure 2. The evolution of sustainable manufacturing concepts and practices



Box 1. Eco-industrial park in Denmark

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

The evolution of 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 and at the same time enabling Statoil to stop flaring this gas. Since then, the network has grown and today the participating companies are 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 production of cement. Process sludge from fish farming is supplied to nearby farms as fertiliser. Novo Nordisk also supplies farms 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).

The exchanges above only describe a part of the material flow of the Kalundborg eco-park, which in total has been estimated to be around 2.9 million tonnes per year including fuel gases, sludge, fly ash, steam, water, sulphur and gypsum (Gibbs, 2008). This industrial symbiosis has led to significant economic savings as well as served to reduce environmental impacts.

Source: Kalundborg Centre for Industrial Symbiosis website www.symbiosis.dk.

2. *The concept of eco-innovation aims at driving more radical improvements*

13. Much attention has recently been paid to innovation as a response for industry and policy makers to facilitate and drive more radical and systemic improvements in corporate environmental practices and performance. Many companies have over the past few years started using *eco-innovation* or similar terminologies to present their contributions to sustainable development. Even a few governments are now promoting the concept as a way to meet sustainable development targets while keeping industry and the economy competitive. However, while the aims for promoting eco-innovation share the pursuit of economic and environmental sustainability, the scope and application of the concept tend to differ.

14. 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 being 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 life cycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resource use (including energy)”. Environmental technologies are also seen as providing promising potential for improving environmental conditions without impeding economic growth in the United States, where they are being promoted through various public-private partnership programmes and tax credits (OECD, 2008a).

15. Thus far, the promotion of eco-innovation has focused mainly on environmental technologies; yet, the tendency to broaden the scope of the concept is growing. 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 here seen as an overarching concept which provides the direction and vision for pursuing overall societal changes needed to achieve sustainable development (Figure 3). This extension of eco-innovation's scope corresponds to the better understanding and more integrated application of sustainable manufacturing as reviewed above.

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

target field	industry		social infrastructure		personal life style
	manufacturing	service	energy	transportation / urban	
technology	<ul style="list-style-type: none"> • sustainable manufacturing • innovative R&D (energy saving etc.) • green ICT • rare-metal recycle 	<ul style="list-style-type: none"> • innovative R&D (Building Energy Management System) 	<ul style="list-style-type: none"> • innovative R&D (renewable energy, battery) • superconducting transmission 	<ul style="list-style-type: none"> • innovative R&D (Intelligent Transport Systems) • green automobile • maglev 	<ul style="list-style-type: none"> • heat pump
business model	<ul style="list-style-type: none"> • green procurement (including BtoB) • green servicing • EMA • LCA 	<ul style="list-style-type: none"> • energy services • Environmental Rating / green finance 	<ul style="list-style-type: none"> • green certification 	<ul style="list-style-type: none"> • modal shift 	<ul style="list-style-type: none"> • green procurement • cool biz • green finance
societal system (institution)	<ul style="list-style-type: none"> • Environmental Labeling System • starmark • green investment 		<ul style="list-style-type: none"> • Top-Runner program • PRS Act (Renewables Portfolio Standard) 	<ul style="list-style-type: none"> • Automobile Green • Next-Generation Vehicle and Fuel Initiative (METI) 	<ul style="list-style-type: none"> • Tax • telework, telecommuting • work-life balance

Source: METI.

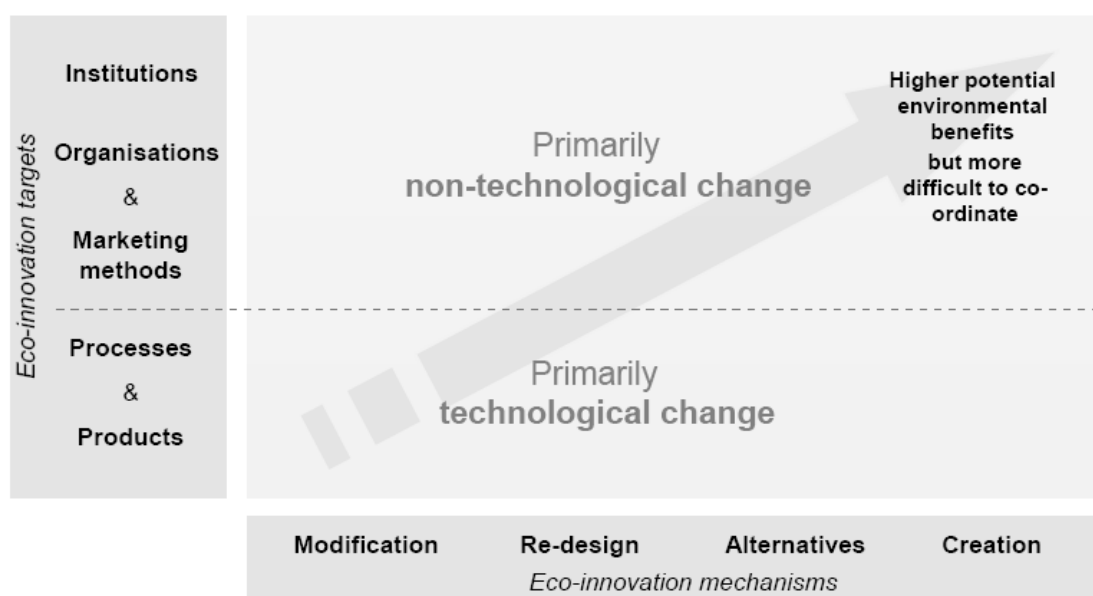
3. *Eco-innovation involves three dimensions: targets, mechanisms and impacts*

16. The OECD Oslo Manual for collecting and interpreting 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: 46). Although this scoping and categorisation of innovation can generally be applied also for eco-innovation, eco-innovation is distinguished from conventional innovation in two significant ways:

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

17. 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 according to three key axes, which refer to the innovation's 1) **target**, 2) **mechanism**, and 3) **impact** (Figure 4 draws an overview of eco-innovation and its typology):

Figure 4. The typology of eco-innovation



- 1) **Target** refers to the basic focus area of eco-innovation. Following the typology defined in the Oslo Manual, the target of an eco-innovation can be categorised into:
- a. **Products** involving both goods and services.
 - b. **Processes** such as a production method or procedure.
 - c. **Marketing methods**, referring to 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 broader societal areas beyond a single organisation's control such as institutional arrangements, social norms and cultural values.

The target of the eco-innovation can generally be of a **technological** or **non-technological** nature. Whereas 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).

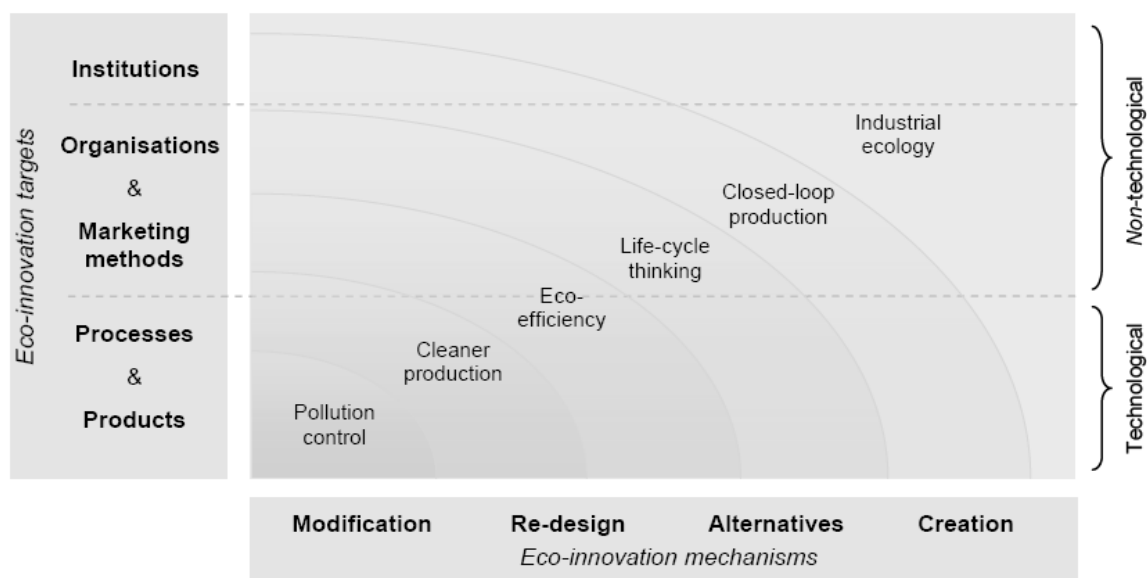
- 2) **Mechanism** relates to the method by which the change in the eco-innovation target takes place or is introduced. It is also associated with the underlying nature of the eco-innovation – whether the change is of technological or non-technological character. Four basic mechanisms are identified:
- 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 needs and operate as substitutes for other products.
- d. **Creation**, comprising 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 conditions, across its lifecycle or some other focus areas. 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 follow the eco-innovation's mechanism as more systemic changes such as alternatives and creation generally embody higher potential benefits compared to modification and re-design.

4. **Sustainable manufacturing is realised through multi-level eco-innovations**

18. There is a need for both industry and government to better understand and determine how to realise progressive changes towards a sustainable future. Innovation plays a key role for moving manufacturing industries towards sustainable production. Every main shift in sustainable manufacturing initiatives — from traditional pollution control through cleaner production initiatives and lifecycle thinking to the establishment of closed-loop production — can be characterised as shifts facilitated by eco-innovation. Figure 5 provides a simple illustration of the general conceptual relations between sustainable manufacturing and eco-innovation. In this figure, the evolutionary steps of 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



19. While more integrated sustainable manufacturing initiatives such as close-loop production could potentially yield higher environmental improvements in the medium to long term, such initiatives can only be realised through a *combination* of a wider range of innovation targets and mechanisms, and therefore cover a larger area in the figure. For instance, an eco-industrial park cannot be successfully established by

simply co-locating manufacturing plants in one place, if no technology or procedure for exchanging resources exists. 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 from such advanced 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.

20. Such co-creative eco-innovation processes are often referred to as *system innovations* — an innovation characterised by foundational shifts in how societal functions and needs are being fulfilled (Geels, 2005). Although the source of system innovations may arise from technological developments, technology alone cannot make large differences. It has to be harnessed in association with organisational and social structures, and human nature and cultural values. While this may highlight the difficulty of achieving large-scale environmental improvements, it also hints at the need for manufacturing industries to adopt an approach that seeks to integrate the various elements of the eco-innovation process in a way to leverage maximum environmental benefits. The feasibility of these eco-innovative solutions would then be determined according to the organisation's co-creative competency.

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

21. To better understand current applications of eco-innovation in manufacturing industries, a small sample of sector-specific examples from three sectors were reviewed in light of the above framework. The three sectors include: *i)* the automotive and transport industry, *ii)* the iron and steel industry, and *iii)* the electronics industry. The identification of examples were mainly based on a questionnaire survey and focus group meetings conducted among leading companies in OECD countries under this project (Table 1). The examples are not meant to represent “best practices” but were selected to illustrate the diverse nature and process of eco-innovation, and the different contexts that surround its realisation.

Table 1. Eco-innovation examples examined in this project

Industry and company/association	Eco-innovation example
<i>Automotive and transport industry</i>	
The BMW Group	Improving energy efficiency of automobiles
Toyota	Sustainable plants
Michelin	Energy saving tyres
Vélib'	Self-service bike sharing system
<i>Iron and steel industry</i>	
Siemens VAI, etc.	Alternative iron-making processes
ULSAB-AVC	Advanced high-strength steel for automobiles
<i>Electronics industry</i>	
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

22. **The automotive and transport industry** has taken several steps to reduce CO₂ emissions and other environmental impacts, notably those associated with fossil fuel combustion. Combined with growing demands for mobility, particularly in developing economies, many eco-innovation initiatives have focused on increasing overall energy efficiency of automobiles and transportation, while heightening automobile safety at the same time. Eco-innovations have, for the most part, been realised through technological advancements, 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 also indications that the understanding of eco-innovation in this sector is broadening. Alternative business models and modes of transportation such as the bike-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 bike sharing system in Paris

In attempts to reduce traffic congestion and improve air quality, the City of Paris introduced a self-service bike-sharing system *Vélib'* in the summer of 2007. The system consists of more than 1 450 stations located in conjunction with metro and bus stations and opens 24 hours a day all year round, each containing 15 or more bike 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 from where people can hire a bicycle through different subscription options.



Holding a subscription allows the user to pick up a bike from any station in the city and use it freely for 30 minutes after which a charge will be incurred for additional time in chunks of 30 minutes. Such a payment scheme was designed to keep bicycles in constant circulation and increase the bike-sharing intensity. To facilitate circulation, bikes are also redistributed every night to stations where they are particularly high in demand. Real-time data on bicycle availability at every station is provided through the Internet and 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 turned out as a great success with taking bicycles also becoming fashionable. Part of this success has been made possible through the system's design and application with a strong focus on flexibility, availability and, not the least, ease of use. According to one estimate, close to 150,000 trips are being carried out 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.

23. **The iron and steel industry** has in recent years made significant progress in increasing its environmental performance through a number of energy-saving modifications and re-designs of various production processes, particularly driven by strong external pressure to reduce pollution and by increasing raw material prices and scarcity. While most eco-innovative initiatives in the industry have focused on technological product and process advancements, 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 on motor vehicle emissions put forth in 1993 in the United States intensified the pressure on the automotive industry to reduce the environmental impact associated with the use of automobiles. As a response, a number of steel makers from around the world jointly formed the Ultra-Light Steel AutoBody (ULSAB) initiative to develop stronger and lighter auto-bodies. From this venture, the ULSAB - Advanced Vehicles Concept (ULSAB-AVC) emerged with the first proof-of-concept project for applying advanced high-strength steel (AHSS) to automobiles conducted in 1999.

By replacing and optimising the car body with AHSS (at little additional cost compared to conventional steel), the overall weight saving could reach nearly 9% of the typical five-passenger family car's total weight. It is estimated that for every 10% reduction in vehicle weight, the fuel economy is improved by 1.9-8.2% (world steel, 2008). At the same time, because of the reduced weight, the power train of the vehicle can also be downsized without any loss in the vehicle's performance, thus leading to additional fuel savings. Due to high and ultra high-strength steel components, such vehicles rank high on crash safety and require less steel for construction.

Continuing efforts by the iron and steel industry's for R&D in this area also stem from the industry's attempt to strengthen steel's competitive advantage over alternative materials such as aluminium. The Future Steel Vehicle (FSV) is the latest in the series of auto steel research, which combines global steel makers with a major automotive engineering partner, aiming to demonstrate safe, light-weight steel bodies for future vehicles that reduce GHG emissions over the lifecycle of the vehicle.

24. **The electronics industry** has so far mostly been concerned with eco-innovation in terms of 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 its products. Like the previous two sectors, most eco-innovations in this industry have focused on technological advancements in the form of product or process modification and re-design. Similarly, developments in these areas build upon a number of eco-innovative organisational and institutional arrangements (*e.g.* Box 4). Some of these arrangements have, perhaps unsurprisingly, also been among the most innovative and forward-looking. A notable example is the use of large-scale Internet discussion groups dubbed “innovation jams” by IBM, with the capacity to harness innovative ideas and knowledge among thousands of people. Alternative business models, such as the provision of product-service solutions rather than physical products, have also been applied in the industry as exemplified by new services in the form of energy management in data centres (IBM) and 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 structures 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 maintain operation at the pressure required for maximum heating and cooling demands. Based on research revealing that air conditioning consumes half of total energy consumption of a building in the country, a Japanese manufacturer Yokogawa Electric sought to create a simple, inexpensive and low-risk control mechanism which could eliminate wasteful use of energy. The resulting product was Econo-Pilot which can control the pumping pressure of air conditioning systems in a sophisticated manner and can reduce the annual pump power consumption by up to 90%. This can be installed easily and inexpensively, precluding the necessity of buying new cooling equipment. The technology has been successfully applied in equipment factories, hospitals, hotels, supermarkets and office buildings.



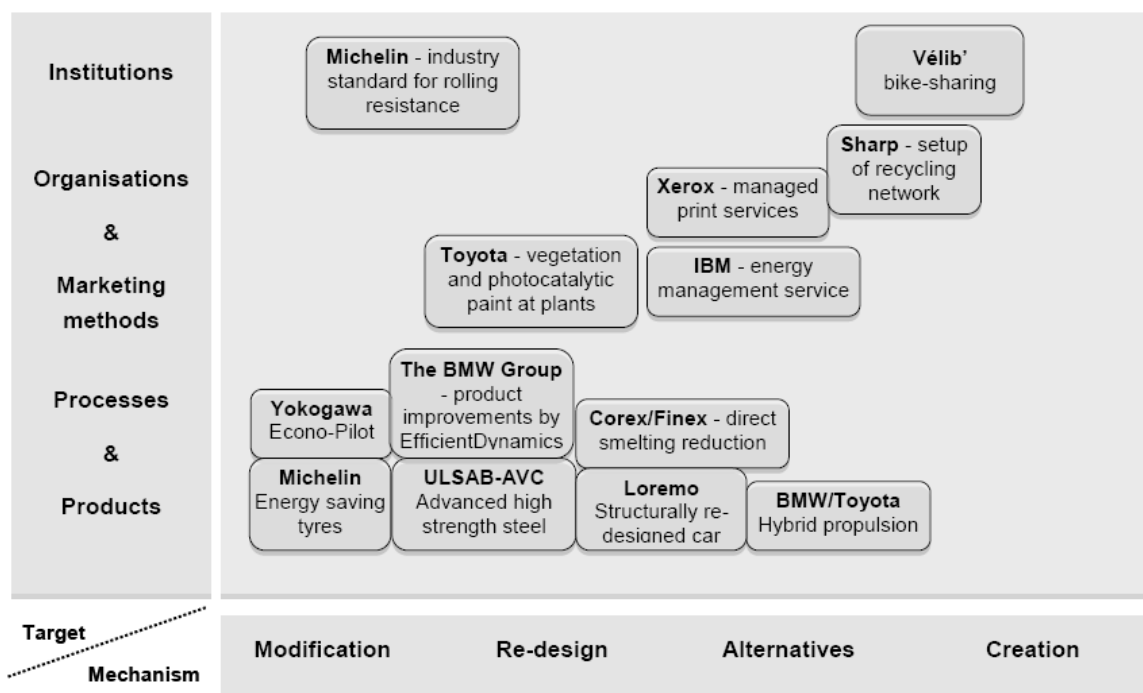
Image from Yokogawa Electric's website www.yokogawa.co.jp.

Econo-Pilot was 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. The NEDO researches the developments 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 to complete the final product.

25. To sum up, the primary focus of current eco-innovation in the manufacturing industries tends to rest on technological developments and advancements, 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 such technological advancements, a number of complementary changes have been required that have functioned as key drivers for these developments. In many of the examples, these changes have been of either organisational or institutional character, including the establishment of separate environmental divisions for improving environmental performance and directing R&D, or the foundation of inter-sectoral or multi-stakeholder collaborative research networks. Some industry players also started exploring more systemic eco-innovation through new business models and alternative modes of provision.

26. The heart of an eco-innovation can therefore not necessarily be represented adequately by a single set of target and mechanism characteristics. Instead, eco-innovation seems best examined and created using an array of characteristics — ranging from modifications to creations, across products, processes, organisations as well as institutions. The characteristics of a particular eco-innovation furthermore depend on the perspective from which the eco-innovation is looked upon. The analytical framework can, therefore, be considered as a first step towards a more systematic analysis of eco-innovation.

Figure 6. Mapping primary focuses of eco-innovation examples



Note: This map only indicates primary targets and mechanisms that facilitated the listed eco-innovation examples. Each example was realised by a combination with other innovation processes that extend to different targets and mechanisms.

6. *Clarity and consistency of existing indicators is required to accelerate corporate sustainability efforts*

27. Manufacturing industries are in a key position to help overcome the global environmental challenges, but their future contributions will depend on how well they adopt and integrate eco-innovative approaches outlined above in shifting their production patterns (Charter and Clark, 2007). This requires an expansive view on how to analyse the sustainability of manufacturing and a strong focus on identifying areas where eco-innovative solutions can reduce environmental impacts and improve environmental performance. Furthermore, industry must recognise that because the key features of any innovation are determined in the early phases of the innovation process (Reid and Miedzinski, 2008), important benefits from eco-innovation could be missed if broad environmental aspects are not given priority from the beginning of the process.

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

29. To date, there are a multitude of indicator sets for sustainable manufacturing around the world with diverse natures, which have been applied either on a voluntary basis, or as a standard or part of legislation. Table 2 shows the most common categories of such indicator sets for sustainable manufacturing identified in this project.

Table 2. A list of categories of indicator sets 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

30. Although it is not easy to compare the above categories of indicator sets since they have different structures and a diverse scope of applications, they have been reviewed from a viewpoint of their potential effectiveness in realising and advancing sustainable manufacturing. Whereas each company's operating environment and its capacity for dealing with indicators are unique, the following six benchmarking criteria have been identified as generally desirable for companies' usage of indicator sets. Table 3 provides a summary of the benchmarking of existing indicator sets made according to these criteria:

- Comparability for external benchmarking
- Applicability for SMEs
- Usefulness for management decision-making
- Effectiveness for actual improvement at the operational level
- Possibility for data aggregation and standardisation.
- Effectiveness for finding innovative products or solutions

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	**		**			*

Note:***: Strongly suitable

**: Suitable if certain conditions are met

*: Applicable though not necessarily suitable

The usefulness of each indicator set may also be subject to the competency and context of the organisation using the indicators.

31. To conclude, there is no ideal single set of indicators among the existing nine categories that can cover all aspects that manufacturing companies need to address to improve their production processes and products with a view to sustainable development. With the exception of eco-efficiency indicators, each of the nine categories of indicator sets is mainly designed to either help decision-making by management or facilitate improvements in products or processes at the operational level. In reality, many companies have been utilising more than one set of indicators at management and operational levels, often without relating them.

32. An appropriate combination of the existing indicator sets could help companies gain the most comprehensive picture of economic, environmental and social effects across the value chain and product lifecycle. For example, it could be valuable to consider combining MFA, LCA indicators and environmental accounting. Eco-efficiency indicators are promising but there are various sets in use with incompatible conceptual approaches. The further development and standardisation of environmental valuation techniques could also help companies make more rational and positive decisions on investments in sustainable manufacturing activities.

33. Lifecycle thinking has helped companies to consider environmental effects beyond their factory gates, but to date there is no indicator set that takes into account 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, which would allow for the identification of system-wide impacts of new products and production processes.

7. ***Improvements in benchmarking and indicators would help deepen understanding of eco-innovation***

34. As outlined above, the notion of eco-innovation has grown in importance in relation to realising sustainable manufacturing but its characteristics and impacts often remain obscure to policy makers as well as companies. The quantitative measurement of eco-innovation activities would help a better understanding of the concept and practices through assisting policy makers to analyse trends and identify their drivers and barriers. It would also raise awareness of eco-innovation among industry, policy makers and other stakeholders, and would make the improvement through eco-innovation more tangible to producers and consumers alike.

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

36. In this context, it should be recognised that eco-innovation is not necessarily limited to environmentally motivated innovations, as the environmental benefits of an innovation might be a side-effect of other goals such as reducing costs for production. Institutional eco-innovations through changes in values, knowledge, norms and administrative actions, as well as building up new stakeholder collaborations are also included. This implies a broad definition of eco-innovation, which describes the broad scope of the concept and is not aimed at measurement or empirical analysis.

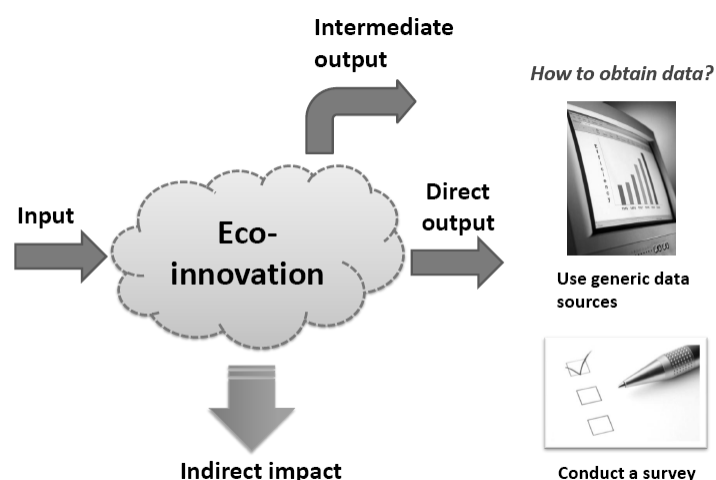
37. To capture diverse areas and characteristics of eco-innovation activities without limiting the scope of understanding, it is important to collect sufficient data that allows identifying the following three aspects:

- 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.

38. The following four categories of data can be applied for quantitatively measuring and analysing eco-innovation:

1. **Input measures:** *e.g.* R&D expenditures, R&D personnel, other innovation expenditures (such as investment in intangibles including design expenditures and software and marketing costs).
2. **Intermediate output measures:** *e.g.* the number of patents; numbers and types of scientific publications.
3. **Direct output measures:** *e.g.* the 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



39. These categories of data can generally be obtained either by using widely available **generic sources of data** that are not collected specifically to measure eco-innovation, or by conducting **specifically designed surveys** (see Figure 7). Some analysis of the methodologies 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, they are limited in the insights that can be extracted. This is exemplified by the fact that 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 more effort is devoted towards extracting more detail from the underlying data or complementing it 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 and can be given more attention 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.

Specialised surveys

Surveys are well suited to provide researchers with detailed and focused information on a number of specific aspects regarding eco-innovation. The insights into eco-innovation provided by such a survey can be especially rich if it is conducted internationally on the basis of the same methodology.

Conducting 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. This could include more specific information on the nature of the eco-innovation, the drivers of innovation, the barriers involved, and the final impacts and effects of the innovation. The primary goal for such surveys would be to include questions with relevance to developing policies that can encourage eco-innovation.

Eco-innovation surveys are typically conducted via official, large-scale projects or through smaller one-off surveys. Large-scale national innovation surveys have a wider scope and are conducted on a consistent 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.

40. The development of an “eco-innovation scoreboard” could greatly improve awareness of eco-innovation among governments and industry. This could be developed by combining 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 constitute another avenue for benchmarking eco-innovation and could be linked to a scoreboard.

41. Designing a new dedicated survey on eco-innovation, or supplementing existing surveys, may also prove useful. It could also be beneficial to conduct panel surveys or interviews that gather information from the same firms over time. Such in-depth surveys may enable analysis of how the nature of eco-innovation is changing over time and how eco-innovation relates to overall 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>i.e.</i> 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

8. *Integration of innovation and environmental policies is key to promoting eco-innovation*

42. The establishment of long-term policy frameworks and goals for sustainable development such as the Kyoto Protocol has led to the establishment of a great variety of policy programmes, notably in the areas of energy, transport, building and manufacturing. Traditionally, OECD countries have addressed policies relevant to sustainable manufacturing and eco-innovation mainly through their environmental policies. Generally innovation policy in most countries has been the responsibility of the ministries for trade and industry and science and technology. Environmental policy, on the other hand, has usually been developed by environment ministries. Only few efforts have been made so far to integrate these two policy domains.

43. Environmental policies traditionally focused on treatment of pollutions and wastes, and despite the recent recognition of the role of technologies for environmental protection, the focus has been to a large extent on end-of-pipe solutions, rather than on encompassing the whole production and disposal processes (Parliamentary Office of Science and Technology, 2004). The positive effects on innovation stemming from environmental policy have been relatively limited, since stringent regulations and standards do not provide firms with enough incentives to innovate beyond end-of-pipe solutions even though they have largely contributed to reducing environmental impacts. Moreover, they typically impose greater costs on firms than other policies to reduce environmental impacts (OECD, 2008b). Recently, market-oriented instruments such as green taxes and tradable permits have started to be introduced as more cost-effective measures that put a price on the “bad”. However, realising the potential for eco-innovation will also require actions to ensure that the full cycle of innovation is efficient, with policies ranging from appropriate investments in research to support in commercialising breakthrough technologies.

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

45. Eco-innovation has thus not been the primary objective of environmental policy nor innovation policy to date. There are several reasons why both policy areas could benefit from closer integration. A 2005 OECD report on the governance of innovation systems listed a number of benefits from integrating innovation and environmental policies (Box 5). From the environmental viewpoint, one of those benefits would be the realisation of both environmental and cost effectiveness. A more innovation-oriented environment policy could make improvements in environmental quality more attainable through the application of new technologies, which will also reduce the costs of environmental measures. Secondly, a closer integration could help decouple environmental pressures from economic growth and hence achieve ambitious environmental and socio-economic goals simultaneously, while benefiting from new market opportunities in the 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, 2005: 57).

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 : OECD (2005).

9. *Understanding of the demand-supply interaction is a pre-requisite for creating successful eco-innovation policy mixes*

46. To enhance insights in policies with regards to eco-innovation, a stocktaking of existing national strategies and overarching initiatives was undertaken through a questionnaire survey, in which ten OECD countries took part (Canada, Denmark, France, Germany, Greece, Japan, Sweden, Turkey, United Kingdom and United States). The analysis examined which and how innovation policy measures are currently utilised for promoting eco-innovation, and to what extent 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 for firms developing innovative technologies through venture capital. The focus is often put on SMEs. However, few specific measures or instruments have been introduced for firms developing environmental technologies or eco-friendly products and services, as most equity support measures target general business start-up and development.
- **Research & development:** 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 mainly sector or technology specific and few countries seem to focus on shifting R&D investments towards environment or eco-innovation. It is currently not clear what proportion of the total R&D expenditures is directed towards eco-innovation. Furthermore, R&D in general-purpose technologies, such as information technology, bio-technology and nano-technology, could be of great relevance to eco-innovation, but may not be identified as such.
- **Pre-commercialisation:** Many available environmental technologies have not been successfully introduced into the market, since the market is not yet well developed or since existing infrastructures and production and consumption systems may become an obstacle for commercialisation. The consideration of post-R&D stages of innovation before successful commercialisation as marketable products and services is thus particularly relevant to eco-innovation. Many government initiatives have been introduced to help firms bring their new environmental technologies to the market, though the current focus is sometimes limited to promising energy and transport-related technologies (*e.g.* 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 US's R&D-related initiatives increasingly pay more attention to the whole process of innovation towards successful commercialisation. The Environment Protection Agency (EPA)'s Research and Development Continuum defines six different stages that describe the progression of technology development from idea to diffusion in the marketplace.

The Department of Energy (DOE)'s 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 technologies that are promising, but face the "commercialization valley of death". It makes matching funds available to any private sector partner that wishes to pursue deployment of the technology identified. 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 & training:** Education and training programmes are critical to develop the human capital needed for the delivery of eco-innovative solutions as well as to 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 started to focus on creating specific skills and a knowledgeable workforce for emerging environmental industries.
- **Networks & partnerships:** Realising the significance of networks and partnerships for innovation, many policy programmes have been directed towards influencing the structure of innovation by requiring co-operation in research projects and supporting network development. To improve the overall sustainability performance of products and services, eco-innovation activities need to address the entire value chain. Government has a role to play as a facilitator of networks grouping diverse innovation actors, notably through public-private partnerships and networking platforms for eco-innovation. To date, there are a few of successful networks specifically targeted at developing new environmental technologies and solutions (*e.g.* Box 7; Box 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 knowledge transfer of technology into UK-based businesses. Networks exist in the fields of technology and business application including some environmental fields such as resource efficiency, environment and fuel cells. KTNs bring together people from businesses, universities, research, finance and technology organisations to stimulate innovation through knowledge transfer.

The Technology Strategy Board conducted a major review which confirmed the value of the KTNs. 75% of the business respondents rated KTN services as effective and 50% developed new R&D and commercial relationships with people met through these networks. 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, providing high quality network opportunities and identifying and prioritising key innovation related issues and challenges. Acknowledging the increasingly global nature of innovation, there will be an increase in the support given by KTNs to international activities.

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 focusing on one or more identified markets. Several of 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), city 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 regions as well as increase the attractiveness of France through enhanced international visibility.

- **Information services:** Government could play an essential role in diffusing knowledge and information concerning environmental issues and eco-innovation. For example, information centres can be designed to provide information and promote transfer of knowledge on resource efficiency and environmental technologies. So far, information for firms on environmental issues has been provided mainly through Internet websites. Most advisory services for SMEs have not specifically targeted environmental issues, let alone eco-innovation.
- **Provision of infrastructure:** Some types of infrastructure are key for supporting innovation activities. In particular, transportation and communications infrastructures have increasingly been considered as a critical factor for economic success and in 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 thus far not been at the core of innovation policies of the countries reviewed, although a few countries take into account infrastructural elements of ICTs as eco-innovation measures.²

Demand-side measures

- **Regulations & standards:** Traditionally, environmental regulations tended to be seen negatively by industry 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 could also help the diffusion of advanced environmental technologies and eco-friendly products by creating demand. Some regulations and standards are emerging that are aimed at stimulating sustainable manufacturing and eco-innovation by creating demand both within firms and among consumers (*e.g.* 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 in principle taking the current highest energy efficiency rate of the products 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 for quickly improving their product performance without the need to provide financial support or 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.

² Recent stimulus packages to address the economic crisis contain a wider range of measures in this area, however.

- **Public procurement & demand support:** As the public sector is a large consumer, public procurement represents a key source of demand for firms. As the attention to demand-side policies is gradually increasing, some governments have started to highlight procurement as a measure to spur innovation. A certain number of the countries surveyed list green public procurement as a driver of eco-innovation, but little evidence is available thus far on the extent of the procurement initiatives and on their success in creating new eco-innovative solutions or lead markets. Government 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 demands. There are a few good examples that proactively use demand support measures for shifting the course of technology and product developments (e.g. Box 10).

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

In France, the Bonus-Malus (reward-penalty) scheme was introduced for personal cars in December 2007 to support consumers for the purchase of greener cars and replacing old cars, while encouraging manufacturers to further develop low-emissions vehicles. This scheme provides a subsidy or a penalty to any buyer of a new car depending on the amount of CO₂ 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 sending a car of 15 or more years old to the breakers yard and buying a vehicle eligible for the above bonus. This subsidy was initially set at EUR 300 but has just been increased to EUR 1 000 under the new economic recovery plan. The quota of emission levels will decrease by 5 grams CO₂ every two years, while a new mechanism is being discussed to introduce a yearly tax instead of the current one-time penalty. This scheme is under consideration for extending to other household equipment.

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

47. 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, where innovation could lead to economic growth and competitiveness. However, not all countries surveyed seem to have a specific strategy for eco-innovation and when they do, only limited policy co-ordination exists between different government departments.

48. Policy initiatives and programmes introduced by countries to promote eco-innovation are diverse and include both supply-side and demand-side measures. As most countries surveyed recognise the need for a collaborative approach to develop the technologies needed to face the today’s environmental challenges, many government programmes in support of the supply-side involve the creation of networks, platforms or partnerships that engage businesses, academics, government representatives and other stakeholders.

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

Conclusions and future work

50. In order to meet the growing 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 have been increasingly adopted among industry and policy makers alike as a way to facilitate more radical and system-wide improvement in corporate environmental performance of production processes and products. Eco-innovation can be understood and analysed according to three axes – target, mechanism and impact –, while sustainable manufacturing practices have focused on lifecycle-based integrated approaches.

51. So far, the primary focus of sustainable manufacturing and eco-innovation efforts tends to rest on technological advancements in the form of product or process modifications and re-designs as is the case with conventional innovation. However, even with a strong focus on technologies, a number of organisational or institutional changes have been complementary to the development of eco-innovations. Some advanced industry players have adopted new business models or alternative modes of provision such as product-service solutions rather than selling only physical products.

52. Although various sets of indicators are available for firms to implement sustainable manufacturing, there is no ideal single indicator set to date among the existing categories that can cover all environmental aspects. Rather, an appropriate combination of the existing indicator sets could help firms gain the most comprehensive picture of environmental effects across the value chain and product lifecycle. More clarity and consistency of existing indicator sets would be required to increase the use of indicators particularly among supply chain companies and SMEs.

53. Quantitative measurement is also an important means for both policy makers and industry to better grasp the overall trends and characteristics of eco-innovation. Since no single existing measurement approach is sufficient to capture eco-innovation comprehensively, it is important to apply different analytical methods, possibly in a combined manner, and view different indicators together.

54. A closer integration of innovation and environmental policies could benefit both policy areas to accelerate corporate efforts for sustainable manufacturing and eco-innovation. Results from a survey show that not all countries have a specific strategy for eco-innovation and when they do, only limited policy co-ordination exists between different government departments. The current policy initiatives and programmes are diverse and include both supply-side and demand-side measures. A more comprehensive understanding of the interaction between supply and demand for eco-innovation would be a pre-requisite for creating successful eco-innovation policy mixes.

55. 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 the following:

- **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 previous experience in leading the development of the Pollutant Release and Transfer Register (PRTR) system for standardising indicator sets and methodology applicable for both the micro level (facility, product or company) and the macro level (sectoral, regional 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 policies for eco-innovation:** A better evaluation of the implementation of different policy measures for eco-innovation would be helpful to identify “promising eco-innovation policies” as well as appropriate contexts in which specific policy instruments can be deployed effectively. This exercise can be undertaken by the OECD in facilitating the sharing of best policy practices among governments.
- **Build a common vision for eco-innovation:** The OECD could help fill the gap in understanding eco-innovations, especially those of more integrated, systemic approaches accompanied with non-technological characteristics, by co-ordinating in-depth case studies. In order to guide industry and policy makers towards more radical and system-wide improvements, it could aim to develop a common future vision or scenarios for environmentally friendly social systems and draw roadmaps to realise such changes based on improved understanding. This exercise should involve multiple stakeholders such as member countries, industry experts, academics and NGOs.
- **Develop a common definition and a scoreboard:** Building upon its experience in innovation measurement and the development of the Oslo Manual, 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. Such work could be done to improve awareness and guide government efforts.

56. 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 that helps manufacturing companies utilise 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), which is considered as one of the most effective tools to improve energy and resource efficiency.

Global eco-innovation platform

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

- Collect good policy examples that promote eco-innovation and conduct an in-depth study on their functioning. 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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