Knowledge Economy Indicators

Workpackage 1

Policy Scenarios: Environmental innovation

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Executive Summary

A major goal of European governments is to encourage the transition of the European Union to a knowledge-based economy and more specifically to meet the Lisbon and Barcelona agendas. Environmental innovation, both intentional and unintentional, makes economies more efficient by encouraging and facilitating the use of fewer material or energy inputs per unit of output. In effect, environmental innovation involves using inputs more 'intelligently', so that the level of inputs used is reduced through the application of knowledge. Environmental innovation can thus be considered the link between the EU's sustainable development strategy and the Lisbon agenda to make the Union "the most competitive and dynamic knowledge-driven economy by 2010".

This report explores and identifies relevant indicators for environmental innovation, so that these indicators could be used for developing innovation policy for all economic sectors, as well as for the field of environmental technologies. Where adequate indicators are missing, usually due to problems of definition or measurement, better indicators are recommended.

What makes a group of indicators generally relevant depends on how well the available *input* indicators correlate with, and are causally related to, the desired *output* indicators. Innovation input indicators usually include activities that support innovation, such as R&D, patents, or investment, and outputs include indicators on results of innovation expenditures, such as sales or profits from, or trade in innovative products.

In the case of environmental innovation, certain additional *pressures*, for example, environmental regulation can be considered to affect the level of inputs. Moreover, certain organizational or management changes can influence the level of eco-innovation inputs. We call such indicators *facilitators*. Finally, the eco-innovation output indicators relate to desired environmental *effects*, such as fewer material resources consumed, or less pollution or greenhouse gases generated.

This report explores - with the help of discussion and correlation data analysis - a large number of potential indicators that could be used to measure various aspects of eco-innovation. In addition, we discuss the definition and location of such innovation (see Section 2), and conclude that it takes place in the whole economy, although it is more concentrated in the environmental goods and services sector (EGSS), which can, however, be hard to define. In Section 2.3 we also sketch a scenario which illustrates the process of eco-innovation.

Following this scenario, we divide the 45 (see Annex II for a complete list) included indicators into the five different types mentioned above: pressures, facilitators, inputs, outputs and effects, and discuss each indicator in some detail in Section 4. The correlation analysis in Section 5 includes all those 39 indicators for which we have been able to obtain national level data for the EU member states.[1] Sectoral level data were in many cases unfortunately not available. The correlations we focus on are between different types of eco-innovation indicators, e.g. between innovation pressures and inputs, or between outputs and environmental effects, following our eco-innovation scenario. Strong and rational relationships between indicators from these groups help us identify a number of key eco-innovation indicators.

[1] However, Table 2 with the correlation results only includes a condensed version of the original results, which were too large to include in this report.

The correlation results are mixed. Much of them follow the lines of the discussion and literature, often showing interesting evidence for links between the indicators. A few of the established relationships are not found in these data. However, there are a couple of issues that most likely contribute to this: firstly, in some cases, the data coverage of the EU countries is poor, and secondly, it is not always possible to obtain data following the flow of time in the innovation chain.[2]

Table 1 below includes those 15 indicators that we consider - based on both literature and our data analysis - to be the key indicators for measuring innovation with environmental benefits. In choosing the key indicators, we have tried to take into account several aspects particular to eco-innovation to have maximum possible coverage. These characteristics include:

- Different types of indicators: pressures, inputs, etc.
- Intentional and unintentional eco-innovation
- Intentional eco-innovation within the EGSS, but also elsewhere in the economy
- Different types of innovation: product, process etc.[3]

Our main recommendations, included in Table 1, concentrate on improving data collection and data availability. Some of the recommended key indicators still need further exploration and development, and refining the questions on eco-innovation in the Community Innovation Survey should also be considered. Last but not least: an overall recommendation for developing data collection for eco-innovation related indicators would be that much more sectoral level data should be made available.

[2] For example, some data on environmental effects were too old, and some data on innovation pressures were too new to fit well in the scenario.
[3] More and more of eco-innovation is taking place, for example, within improved processes.

Table 1. Summary table of key indicators for measuring innovation with environmental benefits.

Indicator (indicator number in this study)	Indicator type	Results from this study	Future potential	Recommendations
Part I. Indicators for which data are currently available				
1. Environmental regulatory regime index (ERRI) or something similar on the stringency, clarity and stability of environmental regulations (2.2 to 2.4)	Pressure	Reasonable and strong correlations with several types of indicators.	Important pressure factor, although captures only regulation related eco-innovation (but across sectors).	Regulatory indicators should be further developed, so that they are consistently available on a yearly basis.
2. Publications in specialized journals in 'environment /ecology' in the EU per capita (4.5)	Input	Some reasonable and strong correlations, especially with effect indicators.	Potentially good indicator, but mostly only captures (intentional) product innovation, and may not do so evenly.	Should be explored further.
3. Patent counts in the EGSS or outside it (5.1)	Input	Some correlations, but data quality is poor, due to a small number of included countries (further data collection was not possible for this project).	Fairly established eco-innovation indicator, which also captured diffusion, but up-to-now mostly confined to the EGSS. Also, focus on product innovation.	Existing patent databases should be further developed to allow for easier access to eco-innovation related patents.
4. Intermediate material or energy inputs (IIM and IIE) at current purchasers' prices per GDP (6.2 & 6.3)	Output (inter mediate input)	IIM correlated well with some, especially effect indicators.	Measures an important factor in the eco-innovation process between inputs, outputs and effects. Captures also unintentional eco-innovation.	Data collection should be maintained on a yearly basis and extended to all EU countries.
5. Exports in EU eco-industry products to large developing economies, such as China and India (as share of total exports to these countries) (9.1)	Output	Reasonable and strong correlations with several types of indicators. However, the current product classification systems are not well designed to include only EGSS related exports.	Potentially a good indicator, also measuring diffusion. Confined to the EGSS and product innovation.	Further refinement of EGSS product code lists or product classification systems should be explored (already supposedly under way at the World Bank).
6. Relative world shares (RWS) – relative position of a nation in international trade in EGS (export orientation), or revealed comparative advantage (RCA) – EGS export-import ratio compared to the pattern of all traded goods (9.2 & 9.3)	Output	Both correlate well with the EGSS export indicator (see above), however, otherwise not very many correlations found in this study, but the data were for 2000, and therefore old.	Not as sensitive to the EGSS product code list issue discussed above. Include some measure of diffusion. Confined to the EGSS and product innovation.	Could be used instead of the EGSS export indicator, at least until the EGSS export classification is better developed.
7. Energy intensity of the economy - Gross inland consumption of energy divided by GDP (10.1)	Effect	Strong and mostly reasonable correlations with several types of indicators.	Important effect indicator on energy use. Measures also effects from unintentional eco-innovation.	To be used as one of the key indicators.
8. Resource productivity of the economy – GDP per direct material consumption (DMC) (10.2)	Effect	Strong and mostly reasonable correlations with several types of indicators. However, the data used were for 2000, and therefore old.	Important effect indicator. Measures also effects from unintentional eco-innovation, as well as decoupling of economic growth from resource use.	This indicator should be developed further, also so that annual data would be available.
9. Survey data on the effects from product or process innovation in terms of reduced materials and energy per produced unit, or highly improved environmental impact (10.3 & 12.1)	Effect	These two indicators based on CIS questions did not correlate well with the other included indicators, except with other CIS-based indicators. The impact question includes improved impact for health and safety.	Potentially valuable indicators, as the data are collected at a detailed sectoral level, and these indicators should capture also unintentional eco-innovation across sectors, as well as process innovation.	Further development of the CIS survey, improvement in response rates. Environmental effects should be separated from health and safety effects in the questionnaire.

Indicator (indicator number in this study)	Indicator type	Results from this study	Future potential	Recommendations
10. Weighted emissions of greenhouse gases per capita (11.1)	Effect	Almost no relevant correlations in this study. However, actual consistent reductions in greenhouse gases still mostly to take place.	Important effect indicator for the future. Measures also effects from unintentional eco-innovation.	To be used as one of the key indicators, although a longer time lag may still be needed to see the effects from intentional eco-innovation to reduce greenhouse gases.
11. Weighted emissions of acidifying pollutants per GDP (11.2)	Effect	Strong and reasonable correlations with many indicators from all types.	Important effect indicator. Measures also effects from unintentional eco-innovation, although to a lesser extent, as most pollution reductions are made to meet regulations.	To be used as one of the key indicators.
Part II. Indicators for which data are not currently available				
12. Venture capital for firms in the EGSS (2.7)	Pressure	Not included, as no data are available at the European level.	Important pressure factor, although confined to the EGSS.	Data collection should be developed (supposedly already ongoing at EVCA).
13. Business environmental R&D, as a share of total business expenditure on R&D (BERD) (4.2)	Input	Not included, as no data are available at the European level (for a large enough number of countries).	Although R&D data are generally considered far from innovation outputs, this could be a useful eco-innovation indicator, with a link to regulation.	Data collection should be further developed.
14. Sales or profits from environmentally beneficial innovation across sectors (7.1)	Output	Not included as no data are available at an international level.	Potentially very valuable indicator, as would measure eco-innovation across sectors (including unintentional eco-innovation).	Data collection should be developed. The topic could be included in the CIS.
15. Foreign direct investment in EGSS (outside the EU) (8.1)	Output	Not included, as FDI data are only available by aggregate sectors, and therefore identification of EGSS not possible at the moment.	Potentially a good indicator, and would also measure diffusion. However, this indicator is confined to the EGSS.	Data availability should be developed based on a sectoral identification of the EGSS, if possible.

1. INTRODUCTION

The main goal of this report is to explore and identify relevant indicators for environmental innovation that could be used to develop innovation policy for all economic sectors, as well as for the field of environmental technologies. Where adequate indicators are missing, due to problems of definition or measurement, better indicators are recommended.

What makes a group of indicators generally relevant depends on how well the available *input* indicators correlate with, and are causally related to, the desired *output* indicators. Innovation input indicators usually include activities that support innovation, such as R&D, patents, or investment, and outputs include indicators on results of innovation expenditures, such as sales or profits from, or trade in innovative products.

In the case of environmental innovation, we can consider additional *pressures*, for example, environmental regulation or public opinion, which may affect the level of inputs. Moreover, certain organizational or management changes can influence the level of eco-innovation inputs. We call such indicators *facilitators*. Finally, the eco-innovation output indicators relate to desired environmental *effects*, such as fewer material resources consumed, or less pollution or greenhouse gases generated. We may be able to link, with the help of correlations, some of the pressure or input indicators to desired outputs or positive environmental effects. Such links could then help us pinpoint the key indicators.

Environmental innovation is an essential part of a knowledge based economy (KBE) because environmental innovation makes economies more efficient by encouraging and facilitating the use of fewer material or energy inputs per unit of output. In this respect, environmental innovation replaces material inputs with knowledge. Environmental innovation and eco-technologies can thus be considered the link between the EU's sustainable development strategy and the Lisbon agenda to make the Union "the most competitive and dynamic knowledge-driven economy by 2010".

Environmental innovation should also result in fewer externalities, or negative environmental impacts, which ultimately affect our health and well-being, not to mention the potentially huge impact of global climate change. Our society will be more prepared for significant global changes, environmental or otherwise, if we employ environmental technologies as far as possible. Furthermore, technology shifts caused by technological breakthroughs, rapid changes in demand for resources, or environmental imperatives could impel societies to invest more heavily in research on how to use energy and other resources more efficiently.

Finding key eco-innovation indicators is therefore important to a KBE, as such indicators measure factors that either help or hinder meeting societal, (sustainable) economic growth and environmental goals.

The report is structured in the following way. In Section 2, we discuss some definitional issues, such as what is currently considered environmental innovation on the one hand, and where it takes place, on the other. We will also present a scenario on eco-innovation, i.e. how various factors are linked to each other in theory. Section 3 will move on to discuss the issues with availability of indicators for environmental innovation and describe the methodology used in the analyses in this report. Potential indicators will then be discussed in detail in Section 4. Section 5 touches on the problem of causality and continues by presenting and discussing our correlation results. Finally, Section 6 will conclude the report and give some recommendations for relevant key indicators.

2. THEORY OF ENVIRONMENTAL INNOVATION

2.1 Non-intentional eco-innovation and economy-wide environmentally motivated innovation

Section 2.2 will discuss how the eco-sector, or the environmental goods and services sector (EGSS) can be defined. However, environmental innovations are also made outside the EGSS, and they do not need to even be environmentally motivated innovations. In fact, more than half of all technological innovations have been estimated to have beneficial effects on the environment (see e.g. Kemp, 2007)[4]. Two recent studies, for the European Commission and the OECD, have also indicated that the share of firms that do not 'eco-innovate' in any form (intentionally or unintentionally) is only between 20-30% (Kemp, 2007).

Environmental innovation, in its broadest form, includes any innovation that reduces environmental harm. More specifically, environmental innovation can be defined as 'the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the firm and which results, throughout its life cycle, in a reduction of environmental risk pollution and other negative impacts of resource use compared to relevant alternatives' (Kemp, 2007). Every investment that an organization makes includes a choice (intentional or not) between more or less environmentally beneficial technologies. Total investment in all technology forms about 20% of GDP (EC, 2001).

Measuring the non-intentional environmental innovation activity is therefore crucially important, but there are some challenges to this. Throughout the innovation chain (from R&D and other innovation expenses to sales of innovative products or use of innovative processes, or organizational methods), it may be difficult for either interested researchers looking from the outside, or managers looking from the inside of an organization to identify something that is not intentional in the first place. Secondly, giving a monetary value for such environmentally beneficial innovation can also be difficult, since it has not originally been identified as 'eco-innovation'.

There have been attempts to measure the effect of product and process innovations on reducing inputs per output or on other environmental impacts, for example by the CIS (Community Innovation Survey). We are also use some of these data in this report.

In addition to such indicators, we can also measure certain environmentally-related innovation pressures, facilitators or inputs (such as environmental regulation or environmental R&D) against certain environmentally-related innovation outputs and effects in the environment (such as more efficient processes or less pollution), and draw conclusions about links with (mostly) intentional eco-innovation in the economy as a whole.

2.2 The environmental goods and services sector (EGSS)

Although environmental innovation can occur anywhere in the economy, it is also important to look at the environmental sector. Firstly, because such innovation can be expected to be more concentrated there, and secondly, because some of the environmental innovation indicators are very specific to the EGSS. Moreover, if we are to say anything more exact about the EGSS, it needs to be defined in some clear way.

[4] Additionally, some intentional eco-innovation can also have negative environmental consequences. For example, growing grain to make bio-fuels can create additional pressures on agriculture to produce enough food for human consumption, as well as require intensive agriculture (with high greenhouse gas emissions) to produce the fuel (Doornbosch and Steenblik, 2007).

The OECD and Eurostat defined the environmental goods and services sector (EGSS) in 1999 as: 'activities to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems. This includes cleaner technologies, products and services that reduce environmental risk and minimize pollution and resource use'. This is still the most used overall definition of the sector, and it is relatively wide in its scope. Eurostat is in the process of updating the definition slightly to also clearly include resource management activities, such as renewable energy and water management and conservation (ICEDD et al., 2006).

In order to measure the EGSS, we need not only the basic definition, but preferably also detailed information on which firms can be classified as belonging to the EGSS, otherwise we have to rely on small-scale surveys and estimates, which has, indeed, been the case (see e.g. Ernst & Young, 2006, Peter, 2006 or ECOTEC, 2002).[5]

The first issue in terms of the general sectoral or product classification systems is that when they were first constructed there was no obvious need to classify activities or products in terms of their environmental impact. Secondly, the environmental industry is rather pervasive, covering areas that fall within many different areas of the economy. This is similar to, biotechnology, which can be used in many different technological areas. As a result, there are few 'dedicated' sectoral classes belonging to just the EGSS (an example is NACE37 – recycling), and a large number of classes, where often only a minor part belongs to the EGSS (e.g. a fairly detailed, 4-digit NACE class 29.12 – Manufacture of pumps and compressors, which includes wind turbines). So, even the 4-digit level of NACE codes - the most detailed level used internationally - does not, in most cases, allow one to separate eco-industry sectors from other sectors. The update to the NACE codes (rev. 2) published in 2007 is only marginally better[6].

The EGS sector can be looked at either in terms of producers of environmental technology and services (the traditional way), or in terms of the main sectors of application, e.g. those sectors which would most benefit from environmental technology by being very polluting. Often, the same actors can both produce and use their own environmental technology, especially within process innovation.[7]

Annex I discusses these and other approaches (looking at products or patents, or searching through a list of NACE codes) to define the 'environmental sector', but in relation to the main producers of environmental technology, Eurostat is currently drafting a compilation guide for collecting statistics on the EGSS, so they are also in the process of trying to define the sector from the activities point of view (NACE codes). In their draft compilation guide, Eurostat (2007) defines the 'core' EGS sector as:

- DH25.12 Retreading (recycling tires)
- DN37 Recycling
- E41 Collection, purification and distribution of water,

[5] For example, Ernst & Young (2006) estimated that 2.2% of European GDP is due to the core EGSS. In fact, the core EGSS could amount to an even larger share of the economy. Currently, the total turnover of the EGSS in the EU is estimated to be over 200 billion euro, nearly all of it currently within the EU-15.

[6] The CEPA 2000 (Classification of Environmental Protection Activities and Expenditure, UN, 2001) developed by the UN and Eurostat is a very detailed classification system for the environmental sector, and it can also be used to classify products. It uses 2 and 3-digit classes and covers also cleaner technologies and cleaner products. However, there is no correspondence table between the CEPA and other, more general classifications systems, such as NACE, used by e.g. Eurostat to classify activities, or HS (Harmonized System) used to classify products.

[7] For example, a large petroleum refining firm can probably develop environmentally beneficial improvements in-house, without needing to go to the EGSS.

- G51.57 Wholesale of waste and scrap
- O90 Sewage and refuse disposal, sanitation and similar activities.

Of these five core sectors, mostly in services, only three are defined at the 2-digit level, which means that currently, there are mostly no data for the other two sectors available from general databases, such as the Eurostat NewCronos. These three 2-digit sectors for which data are generally more easily available are DN37, E41 and O90.

The 'non-core' EGS sector has not yet been formally defined by Eurostat, but it covers firms that are at least partly active in the environmental or resource domain, but do not belong to the 'core' industry, and includes firms from a large variety of NACE groups[8].

In our report, some of the indicators are specific to the EGSS, but this term is often not used entirely consistently for lack of better data. Therefore, sometimes we have data for a specific part of the EGSS, such as renewable energy, or pollution control technology, and at other times we include data that is more general to the EGSS, such as exports in EGSS-related products.

2.3 Inputs, outputs and impacts – The eco-innovation scenario

Figure 1 explains how the different processes of environmental innovation can be linked, as well as showing some of the available indicators. Section 4 discusses the indicators in more detail.

To illustrate the scenario in Figure 1, we use an environmental innovation, namely supporting the farming and production of bio-fuels for beneficial environmental effects.

Biofuels, such as ethanol, are not a new invention.[9] However, current concerns related to the *state of the environment* such as the problem of climate change, have bought biofuels back in fashion. Through *science* on climate change and *media* reporting on the science, the *public opinion* as well as decision-makers have put some additional pressure on reducing CO_2 emissions from general fuel use. *Regulation,* in terms of required minimum amounts of biofuel content in fuels and subsidies for producing biofuels, has created advantageous *market conditions* for producing biofuels (i.e. their price has gone up), and together these factors have resulted in more biofuel related innovation inputs, such as *R&D* to improve the efficiency of amylase conversion of starch to fermentable sugars. As a further consequence, the innovation outputs, i.e. biofuel production has started to rise markedly in various countries and the *growth of this sector* and *profits* from selling biofuel have increased.

Presumably, the beneficial environmental impact of this change is then the *reduced amount of* CO_2 *pollution* from transport and other fuel use, which then again affects the *state of the environment* in a positive way. What firms do with their increased *income* from making biofuels can then be positive for the environment, e.g. they can invest in more efficient production processes, or negative, e.g. with increased shareholder income resulting in more consumption, which is generally bad for the environment. Last but not least, there are *wider economic changes* that can either be linked to the biofuel innovation process, or be totally exogenous to it, e.g. the price of food production going up (or more space required for food production) as a consequence of producing large amounts of biofuels, or some new invention to produce liquid fuel in a more efficient way, or sharp economic growth from e.g. China that

[8] Including Agriculture; Fishing; Mining and quarrying; Manufacturing; Electricity, gas and water supply; Construction; Wholesale and retail trade; Repair of motor vehicles and motorcycles; Hotels and restaurants; Transport, storage and communication; Financial intermediation; Real estate, renting and business activities etc..
[9] The first car of Henry Ford was fuelled by ethanol (Sasson, 2005).

results in even more demand for biofuels. Such changes would then again have an impact on the environment.[10]

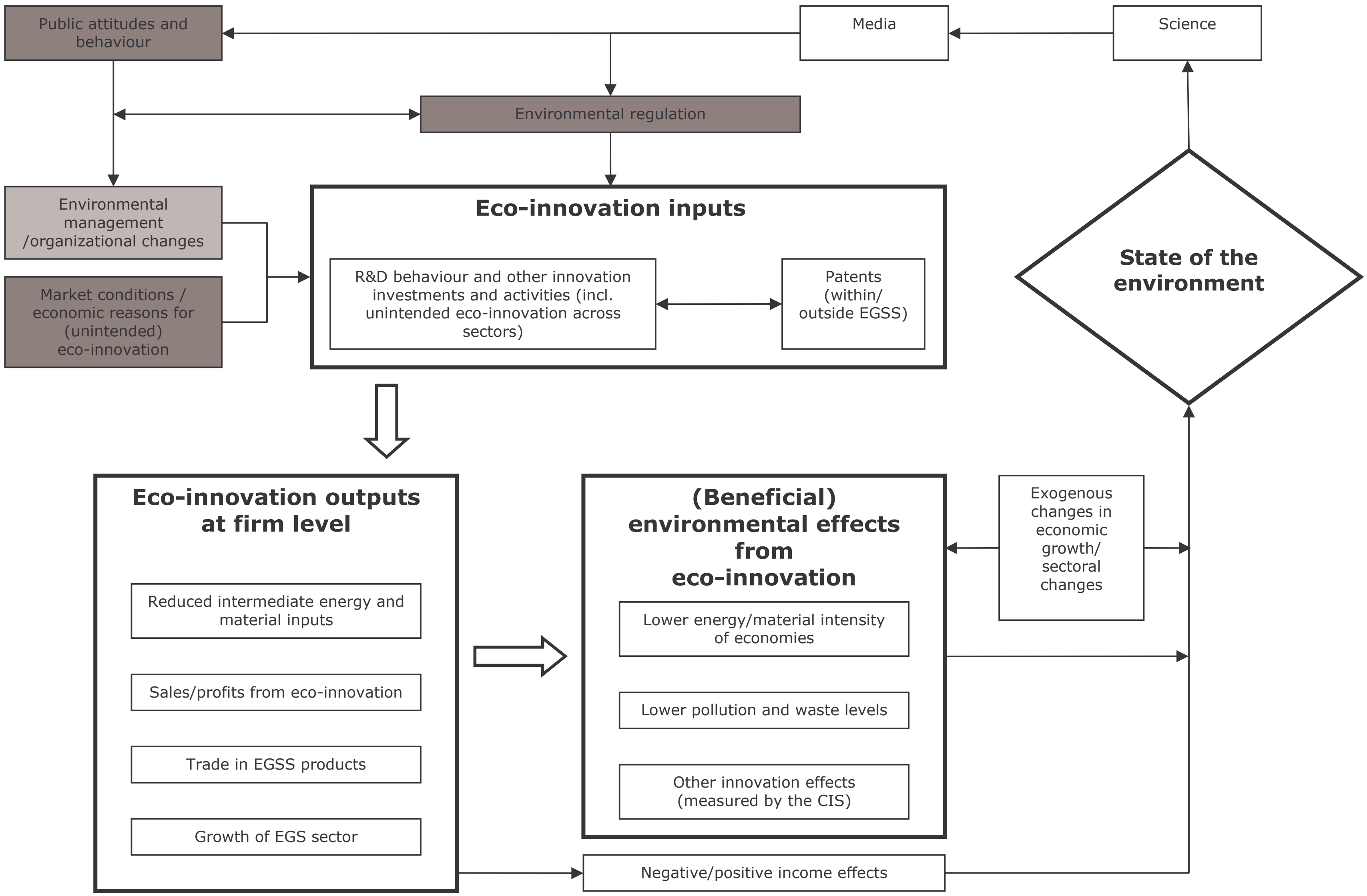
Not included in the above description are innovation facilitators, or changes in environmental management or organisational systems. These cannot be said to be a necessary part of the innovation process, or to automatically lead to actual eco-innovation, but they have been shown in several recent studies to encourage such innovation.[11]

This eco-innovation scheme includes some time dimensional aspects as well, as going though the whole circle from pressures to impacts etc. takes a number of years. In the data that we include in our analysis, we try to take this into account to the extent possible. Data availability poses some problem here though.

[10] Additionally, biofuel production can have direct negative environmental impacts, as it is often likely to require intense (mono-)agriculture with pesticides and fertilizers (Sasson, 2005).

[11] Horbach and Rennings (2007) contains an overview of studies related to this and other eco-innovation determinants.

Figure 1. Scenario for environmental innovation. Key: dark shading = pressures, light shading = facilitators. Source: in consultation with Rene Kemp, September 2007.



3 DATA ISSUES

3.1 Data availability

3.1.1 Non-intentional eco-innovation and eco-innovation outside the EGSS

Section 4 discusses indicators and their availability in detail. There are, however, a couple of issues on data availability to consider. First, there is the question of what exactly are we measuring, i.e. defining eco-innovation, as discussed in Section 2. Second, general economic data sets are usually not designed to include environmental issues, so some data are difficult or impossible to find. Third, the available data are often only available at an aggregate level, such as by country.

In some cases aggregate data are a problem, but in others, not necessarily so. For example, if we look at patent counts, exports, foreign direct investment (FDI) or EMAS certifications, it would be very useful to have detailed sector level data, which currently do not exist.[12] On the other hand, if we look at the energy intensity of whole economies, sector level data are not necessarily required (although they could, of course, be used for sector level analysis). Finally, as discussed in Annex I and in Section 4, some data such as trade, and especially patent data, can be relatively precise, but they do not necessarily translate well into NACE sectors.

Looking at the country level and more general eco-innovation indicators, there are a variety of indicators to choose from. Figure 1 shows the main factors and indicator types (pressures, facilitators, inputs, outputs and effects) under which eco-innovation indicators fall, and we currently have some available indicators for most of these factors, as discussed further in Section 4.

3.1.2 Environmental goods and services sector

The EGSS is yet to be defined in a precise way from the sectoral activities point of view. An additional problem is that generally available databases (such as the Eurostat NewCronos or the EUKLEMS databases) do not offer NACE 4-digit level data (or other similarly precise data), and mostly not 3-digit level data either. This means, for example, that we cannot get data for sectors such as NACE 51.57 (wholesale of waste and scrap), which is entirely in the EGSS, or 29.12 (manufacture of pumps and compressors, including wind turbines), which is only partly in the EGSS.

The only NACE 2-digit sectors for which data are available and which are almost totally within the EGSS are: DN37 (recycling), E41 (collection, purification and distribution of water) and O90 (sewage and refuse disposal, sanitation and similar activities).[13] This group could then form the ‘core of the core’ of the eco-industry. However, as these are mostly in the area of services, we do not get information on innovations with environmental benefits related to processes or manufactured goods from data on these sectors. So, until there is a much more detailed sectoral level classification scheme available (with at least 4, but preferably more digits), with identified EGS sectors, we can only get a glimpse of the true EGSS by using NACE codes.[14]

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[12] In some cases, such as with FDI related to environmental technologies, there is no point in looking at data that are not disaggregated enough to include separate data for EGS sectors.

[13] In fact, for a lot of indicators available from NewCronos, O90 is not included, as it is considered to be mostly in the area of public services, and a lot of the available data covers only private services.

[14] For example, there are data on national investment in the two core EGS sectors of DN37 and E41.

3.1.3 Impacts and the time dimension

It would be most useful if indicators for both eco-innovation inputs and outputs were available for the same industry and over several years. This would enable us to track the effect, over time, of eco-innovation on outcomes. In most cases, however, time series data are unavailable. We can assume that any eco-innovation is a good thing, but we may not be able to establish a cause and effect relationship with outputs.

The need for a time dimension poses some additional problems, as sometimes there are only very recent data available for a pressure indicator, and only somewhat dated data for an effect indicator. Looking at the relationship between such indicators is often irrelevant, as the pressure factor should precede the impact factor and not the other way around.

All the indicators considered in this report can be found in Annex II, which also includes some availability issues with the indicators.

3.2 Methodology

The indicators for environmental innovation cover five main categories. The first consists of *pressures*, for example, environmental regulation or public opinion, which can affect the level of innovation *inputs,* which include environmental R&D and patents, among others. Moreover, certain organizational or management changes (such as EMAS or ISO14001 certifications) can influence the level of eco-innovation inputs. We call such indicators *facilitators*. Finally, the eco-innovation *output* indicators, such as investment in the eco-sector or trade in eco-goods and services, relate to desired environmental *effects*, such as fewer material resources consumed, or less pollution or greenhouse gases generated. We may be able to link, with the help of correlations, some of the pressure or input indicators to desired outputs or positive environmental effects. Such links, if found, could then point to the key indicators.

In our report, we have concentrated the indicator analysis on looking at the correlations between various indicators (see Annex II for the indicators themselves) following these general guidelines:

- Check for clear outliers in the data
- Run correlations with all indicators for which we have data
- Include indicators for final analysis with the following criteria:
    - Moderate to strong correlation with correlation coefficient greater or equal to 0.5 at 1% level, and greater or equal to 0.65 at 5% level.
    - Number of data points greater or equal to half of the maximum possible number.
    - In the case of similar indicators (same or similar indicator for different years, preferably with strong correlation between them) – leave only one or two with the strongest correlations with other indicators to exclude those that are possibly redundant.
    - Exclude indicators that do not follow the above criteria for any correlations.

As discussed earlier, the time dimension poses an additional problem, as time lags should be included to capture the effects of change between the different types of indicators (pressures, inputs, outputs etc.). For example, a pressure indicator for 2006 correlating with an effect indicator for 2000 does not really tell us much. Therefore, in our final analysis of the correlations, such positive or negative correlations must sometimes be ignored.[15]

Regarding the final correlation results, relevant correlations between the following indicator categories are used to identify key indicator for environmental innovation:

- Pressures and inputs, outputs & effects
- Facilitators and inputs & outputs
- Inputs and outputs & effects
- Outputs and effects

Finally, a rational basis for the indicators and their relationships also needs to be established. The fact that two indicators correlate (even when the time flow is taken into account) does not prove a causal relationship. This issue is further discussed in Section 5.1.

[15] However, some correlations between data for year X and data for, say, year X+1 could be relevant.

4. SPECIFIC INDICATORS

Annex II shows all the indicators considered in this report, grouped into ten categories according to the factors considered in Figure 1. We evaluate 45 indicators in total and have data for 39 of them (12 pressure indicators, 3 facilitator indicators, 5 input indicators, 11 output indicators and 8 effect indicators). The final correlation table in this report (Table 2) includes correlations results with 26 distinct indicators.

This section looks at the indicator categories in more detail.

4.1 Pressures

4.1.1 Public attitudes and behaviour

The Eurobarometer surveys measure public opinion in the EU on a wide variety of issues. Some of the surveys include questions of relevance to research on environmental innovation. We have extracted the results of Eurobarometer questions on the following: preparedness to pay for renewable energy, acceptance of renewable energy sources, importance of reducing national energy consumption, importance of energy related research in the EU (2 surveys); and the importance of factors in choosing one car model over another (factors such as whether the cars are environmentally clean and how much fuel they consume).

Public opinion, of course can be far from concrete actions taken by the same public. For example, are public attitudes to renewable energy resources positively correlated with people's choices of energy for their homes? Are average car fuel consumptions related to the public attitude question on choice of car models, or do people still prefer to buy SUVs, even if they say they do not?

Figure 2 on how concerned Europeans are about climate change shows also that a number of factors can influence public attitudes. The higher the latitude of each nation's capital, the lower the concern, when all EU citizens should probably be concerned more or less equally about such a global problem.

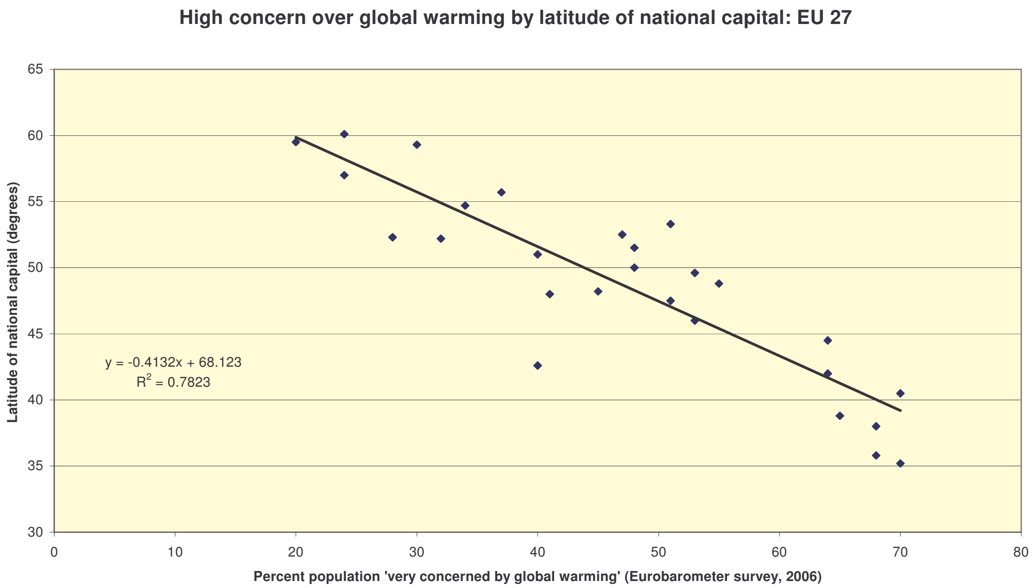
Ideally then, data on public attitudes should always be compared to hard data on actions, in order to see whether attitudes are followed up by decisions.

Incentives offered by governments to change behaviour would probably bring the public more in line with what they say they would *ideally* do. In any case, public attitudes (and behaviour) are likely to have some effect on government regulations, as well as public and private investment in eco-innovation.

For this report, we obtain data from six surveys (as specified above), but unfortunately we have not been able to find adequate data on relevant behavioral aspects. Nonetheless, the available data can be examined against other available indicators.[16]

[16] A problem with the current data is that two thirds of them are from 2006, which does not fit the pressure => input-output-effect time lag.

Figure 2. Warming by concern.



4.1.2 Environmental regulations

Government actions in their various forms (from 'command-and-control' regulations to incentive schemes and subsidies) have a significant influence on environmental innovation. There is still an ongoing debate about whether strict regulation based on limits such as pollution caps works better than economic incentives to improve the state of the environment, without discouraging innovation. However, there is a substantial body of literature (see Taylor et al., 2005 for an overview) that considers regulatory stringency and anticipation of regulation to be important drivers of innovation, and there are even those who think that some degree of uncertainty about future regulation is good for innovation (see Taylor et al., 2005). On the other hand, not all eco-innovation takes placed to comply with regulation. According to the results of the IMPRESS survey (ZEW, 2001), about a third of the most environmentally beneficial innovations were not introduced for regulatory reasons (Arundel, 2005).

We have included six different indicators to represent the regulatory push factor of environmental innovation: indicator on energy tax rates, three separate indexes from the Global Competitiveness Report on regulatory stringency and clarity,[17] and two indicators on perceived competitive disadvantage from the need to meet environmental regulations.[18]

4.1.3 Market conditions

Market conditions regarding, for example, the competitiveness of environmental technologies, whether it is economical for large firms to develop new (environmentally beneficial) process technologies, or whether venture capital firms will invest in certain new technologies, are an important pressure factor in the process of environmental innovation, either intentional or unintentional.

[17] Only one of these indicators is old enough to fit the time flow aspect of pressure => input-output-effect scheme.
[18] The last two indicators are from the 2004 Innobarometer survey of the Eurostat/European Commission, and therefore also somewhat 'too late'.

We are not including any actual data of this kind in our report, due to the fact that such data are rather difficult to come by. However, to give an example of data that could be available on an EU-wide scale soon, data on venture capital could be used to track environmentally innovative start-ups. No data are currently publicly available at the required level, but according to Hernesniemi and Sundquist (2007), the European Venture Capital Association (EVCA) is in the process of adjusting its data collection to include information on investments in the environmental sector.[19]

4.2 Facilitators

4.2.1 Environmental management and organizational changes

There is a relatively established source of data for records of voluntary environmental management systems for firms. There are two increasingly popular standards, namely the EMAS (Eco-Management and Audit Scheme), which only applies in Europe, and the ISO14001, which is a worldwide scheme.[20] Marinova & McAleer (2006) use these data to look at country performances, and we have included them in our report to see how they fair against other eco-innovation indicators.

We have also included some data on the Community eco-label scheme awarded to products and services with reduced environmental impacts. This scheme has been operational in Europe since 1993, with the first EU eco-label awarded in 1996.[21]

Such voluntary schemes cannot be said to be a necessary part of the innovation process, but they have been shown in several recent studies to encourage such innovation (see Rennings et al., 2003, Rehfeld et al., 2004, Frondel et al. and Horbach, 2006).[22] They should also help us get a picture of how firms in general are willing to change to a more environmentally friendly direction, and how well they respond to public demand for such a change.[23]

4.3 Inputs

4.3.1 Environmental R&D and other innovation investments and activities

Although there is considerable controversy regarding the usefulness of R&D data to study innovation, since R&D is far from general innovation outputs,[24] R&D data are widely used to

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[19] Nonetheless, some general data are available from the venture capital companies and analysts. Cleantech, for example, says that European clean energy venture capital investment fell by 20% in 2006 to around US$500 million, when in North America it almost trebled to US$2.1 billion. Similar figures are available also from New Energy Finance, UK VC analysts (Europe lags, China catches up in clean energy race, story by G. Wynn for the Reuters Environmental News Service on 16/05/07). Ernst & Young (2006) argue that the development of environmental technologies has historically suffered from uncertainties regarding potential markets, and that this has hampered financing research activities for such technologies.

[20] The downside to these data is that their popularity from one country to another seems to vary widely, and that sectoral level data are not publicly available. Some sectoral level data for the ISO14001 can be obtained from the ISO Central Secretariat in Geneva, but this is not free. Furthermore, EMAS data are, in practice, currently only available for the EU-15, as the new member states were able to receive certifications only from the start of their EU memberships.

[21] Again, the same issue as in footnote 17 with the 12 new member states arises here, as they have only been able to receive awards from the start of their EU membership.

[22] See Horbach and Rennings (2007) for a literature overview.

[23] However, as the IMPRESS survey for the European Commission (see ZEW, 2001) found, firms are only likely to develop environmental innovations voluntarily if there are no substantial negative impacts on costs or quality.

[24] Moreover, the standard R&D surveys are criticized for underestimating R&D performed in smaller firms and overestimating R&D elsewhere due to definitional issues (Kleinknecht et al., 2002). In fact, Kleinknecht et al.

measure innovation. However, business environmental R&D has been found to be induced by government regulations and such data, if widely collected, could provide another link between environmental regulation and innovation inputs (see e.g. Arimura et al. 2007). Unfortunately, data on R&D expenditures for environmental innovation are rarely collected from businesses (see Fukasaku, 2005 for a discussion with some data)[25], and the collected data can also be unreliable.

Some public environmental R&D data do exist, mainly in the form of government budget appropriations and outlays (GBAORD). Public environmental R&D is usually firmly linked to environmental regulations. The only data provided by Eurostat are on regulation-related environmental R&D. We have included such data from Eurostat in this report to look at how it correlates with other eco-innovation indicators.[26]

Another reflection of the science base for environmental innovation are publication data, also called LBIO (literature-based innovation output) or, specific to the eco-industry, EPD (environmental product declarations). Such data offer the benefit of identifying specific technologies, and being an indicator for the market in environmental technologies. The downsides to LBIO data are that not all firms publish or market their eco-innovation products equally, and moreover, that process innovation – particularly important for environmental innovation - tends to be omitted from such data.[27] In this report we have used publication data from Peter (2006) for the EU-25 to see how it compares with other eco-innovation indicators.

Finally, not all innovation requires R&D, or results in publications. For example, production engineering, or relatively costless changes to production processes or organizational methods, could have large environmental benefits and not require any R&D. Additionally, firms can buy new technologies developed by suppliers, most of which will be better for the environment than older technology. To include some data on these forms of innovation investments, we use two indicators from the Community Innovation Survey (CIS) on firms' engagement in acquisition of machinery.

4.3.2 Patents – within or outside EGSS

Patent databases are a well-known source of innovation indicators, including data for environmental innovation[28]. However, it is difficult to obtain patent data for environmental innovation other than for EGSS.

One of the benefits of using patent data to study environmental innovation is that the detailed classification systems make it comparatively easy to identify intentional eco-innovation. Moreover, patent data can help track global diffusion of technologies, which is particularly important in eco-innovation. Lastly, patent data - although still considered to represent an input indicator here - are closer to markets and the outcomes of eco-innovation than many other input indicators, such as R&D data.

(2002) argue that innovation surveys, which could also easily include questions on environmental innovation, may provide more accurate data on R&D.

[25] The few exceptions of countries which collect data on business environmental R&D include Canada (Arundel et al., 2006).

[26] The Stern Review (Stern, 2007) includes a discussion on the trends and quality of data in both business and public R&D on energy. The author also reviews the reasons why firms might not be willing to invest in energy R&D. Fukasaku (2005) includes data which indicates that private environmental R&D expenditures are in some countries larger than public government budget appropriations.

[27] On the other hand, Peter (2006) notes that environmental service innovation, which would mostly not show up in patent data, can potentially be captured by using publication data.

[28] Oltra and Kemp (2007) offer a thorough overview of using patents as an indicator for eco-innovation.

One of the main limitations of patent data is that patents vary greatly in their importance and probability of commercialisation. This can partly be corrected by using patent citation data or triadic patent families,[29] which generally include only the more economically important patents.[30] Particular to environmental technologies is the issue that patenting seems to focus on products, rather than processes, whereas environmental innovation is currently particularly important for process innovation based on clean production rather than end-of-pipe solutions (Popp, 2005).[31]

Both the OECD and Eurostat have recently set up large patent databases with data download possibilities.[32] However, it is still difficult to identify patents for environmental inventions. Researchers must either perform labour intensive patent searches or rely on others who have done so before. Unfortunately, this group of researchers is still relatively small. One pioneering work is by Lanjouw and Mody (1996), where a list of some 40 IPC patent codes for various environmental technologies is provided.

This report uses data from the OECD (2006) to calculate country specific indexes for specific environmental technologies. The results show that Germany was the top patentee in environmental technologies between 2001 and 2003. Weighted by population size, the top patentees were Finland, Germany and Austria. The OECD (2006) report also found that patent counts for environmental technologies have gone up globally in the past 10 years or so and can be expected to climb further. This is due to an increase in clean production processes and clean products, as patents for end-of-pipe technologies have been declining.

4.4 Outputs

4.4.1 Intermediate energy and material inputs

We have included data in our analysis from the EUKLEMS database on intermediate energy (IIE) and material (IIM) inputs into the economy. These data are available at both the national and broad sectoral levels.

We have also included data from Eurostat NewCronos on renewable energy shares in total electricity consumption. These data are available by very broad industry categories, but for our purposes, we have downloaded them at the national level. Similar to the intermediate energy and material input data (IIE and IIM), this indicator can be used either as an eco-innovation input indicator (as energy in general is an input factor), but it can also be seen as an intermediate output indicator for environmental innovation – the higher the share of renewable energy inputs, the lower the environmental impacts from production, households etc. This share is expected to increase in the future, partly due to EU targets.

4.4.2 Sales and profits from environmentally beneficial innovation

[29] However, when using triadic patent family data, one must bear in mind that the patent counts are likely to be considerably lower than those from single national patent offices (Popp, 2005).
[30] Kleinknecht et al. (2002) discuss other problems with patent data, such as under or over estimation due to higher or lower patenting thresholds for certain kinds of companies or certain kinds of technologies.
[31] Furthermore, as environmental innovation is often influenced by regulation, there may be problems using international patent offices or triadic patent family data for eco-innovation research. Environmental patents are likely to appear there only once it pays to patent in more than just one country, e.g. once specific related regulations apply elsewhere as well. Such patent data may therefore not be ideal for identifying first-movers in environmental technology (Popp, 2005).
[32] Within the Eurostat PATSTAT database, data can be identified based on nationality, 2 or 3-digit NACE manufacturing class, 2 or 3-digit IPC class, or certain high-tech fields.

There are some estimates at a country level for sales of EGSS products, but no estimates (or actual hard data) exist for profits from environmentally beneficial innovation across all sectors of the economy. This type of data would be very valuable, and the topic could perhaps be included in one of the EU-wide surveys on innovation.

4.4.3 Growth of EGSS

Data on the narrowly-defined eco-industry do not capture larger environmentally beneficial (unintended) innovation. However, they do provide some insight into the growth of eco-innovation.

There are several kinds of investment that are relevant to the EGSS, although data availability poses serious limitations.

Data on foreign direct investment (FDI) in environmental technologies would be very interesting to have, as it would also capture diffusion. However, the sectoral disaggregation available from international sources, such as Eurostat or UNCTAD, is not detailed enough to look at even the 'core' EGS sectors (with NACE codes DN37, E41 and O90).[33]

There are some data available on national investment in the EGSS. Eurostat provides data for two of the 'core' EGS sectors (DN37 and E41). These data are included below.

Another way to look at investment in the EGSS is to look at environmental protection expenditures at a sectoral or national level. This also covers PACE (pollution abatement costs and expenditures), and is a rather common measure of environmental innovation used to indirectly estimate the effect of government regulation on innovation (see e.g. Arundel et al., 2006, Brunnermeier & Cohen, 2003 and Lanjouw & Mody, 1996).[34]

Eurostat provides data for three indicators under this category collected mainly by surveys: investment in equipment and plants for pollution control, investment linked to cleaner technology, and total current expenditure on environmental protection. All data are provided for total industry (NACE C, D and E) and at the national level (or both), and are used in this report to evaluate the usefulness of such indicators for tracking environmental innovation.

Generally, a link between increased environmental innovation (measured by patents) and pollution abatement expenditures has been established in the literature (see e.g. Brunnermeier & Cohen, 2003).

Yet another way to look at investments in the EGSS that could be more useful in the future, is to look at projects under international schemes such as the Kyoto Protocol. The international clean development mechanism (CDM) projects that fall under this Protocol are registered by the UN and represent environmental investments from developed economies to developing economies. They would therefore be particularly interesting for studying innovation. Currently, however, there are only a few hundred projects registered, and although national level data are available in terms of numbers of projects, the sizes of the projects vary greatly, and cannot be accurately allocated to any one country.[35] If more detailed data become available, and if the numbers build up over the next few years,[36] this could be a valuable data source for measuring the diffusion of environmental innovation.

[33] Some data for NACE O90 (sewage and refuse disposal) are available.
[34] Lanjouw and Mody (1996) note that these data are particularly useful, as they capture 'not just regulation but monitoring, enforcement, and the strength of marketplace signals' (p. 554). However, Arundel et al. (2006) make the point that such expenditure costs do not reflect savings made by eco-innovation.
[35] However, if country level data were available, it would be possible to calculate the size of projects by CERs (certified emission reductions), each of which equals to one tonne of CO_2 reduced. This could then be divided, for example, by each country's CO_2 emissions.
[36] Currently, only 8 EU countries appear to be represented in the data.

Finally, there are some ways to measure the pervasiveness of the EGSS, in other words, how large the core EGSS itself is, how widely certain methods to measure all firms' environmental performance have spread, or how many industrial firms take producing environmentally friendly products seriously.

One way suggested by Marinova & McAleer (2006) to explore the first point above is to look at long-established internet sites providing information about the eco-industry. The Green Pages (www.eco-web.com) (based in Switzerland) has provided a high quality database for environmental technologies since 1994, with listings of thousands of eco-industry companies from all over the world, with 2,600 (38%) based in Europe.[37] Marinova used data from this website to analyse eco-innovation at a country level, and similarly we have extracted data for this report for all 27 EU countries.[38]

4.4.4 Trade in EGSS products

International trade in environmental technologies provides a measurement of diffusion. Exports from the EU-27 to the large and rapidly growing economies of China and India seems particularly useful, especially since the EU eco-industry is export-oriented and China has long been an important trading partner.[39] The current WTO trade negotiations are meant to make international trading in environmental goods and services easier, although the recent stalling of these negotiations probably has hurt the exports industry due to high tariffs for environmental goods in most developing countries (Kennett and Steenblik, 2005).[40]

Several large databases contain fairly detailed data on such exports (most importantly, the UN COMTRADE database and the OECD international trade statistics database). The main limitation is that trade data are based on product classifications and there is no agreed and high quality list of product codes for the EGSS. The OECD and APEC, among others, have each produced a separate list of products that have environmental uses. The two lists are together called the OECD/APEC list, with nearly 200 unique HS 6-digit codes (see e.g. Steenblik, 2005, for the lists). However, the main drawback of such lists is that many of the products have multiple uses, only one of which may be environmental.[41]

If we assume that the product code list provides a relatively good representation of the EGSS, we can calculate export statistics for the EGSS from each EU country to China and India. Such data from the COMTRADE database are used in this report.[42]

Other ways to get around the product orientation of trade statistics include constructing indicators such as 'revealed comparative advantage' (RCA) and 'relative world shares' (RWS) (see Legler et al, 2003). Peter (2006) notes that such indicators can be considered more meaningful, being that the EGSS product groupings are not accurate. We also use RCA and RWS data in this report.[43]

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[37] The database is vigorously updated, with an average age of listings of only 253 days.
[38] However, these data are for 2007, which does not leave any room for the time lag between outputs and effects.
[39] Europe lags, China catches up in clean energy race, story by G. Wynn for the Reuters Environmental News Service on 16/05/07.
[40] There are, however, arguments that in the future, China may be concentrating on creating its own technology more than importing it (see source in previous footnote), and furthermore, that selling high tech products, including environmental technology, to China is becoming increasingly risky, due to violations of intellectual property rights inside China (Copyright fear hampers West's climate work in China, story by G. Wynn for the Reuters Environmental News Service on 17/05/07).
[41] Trade and Development Board (2003) discusses the limitations of the list in more detail. The WTO is currently attempting to update or improve this list.
[42] Since a product code list is far from accurate, taking a sample of a few core eco-industry products might provide more accurate, although giving more limited results. A report by Ernst & Young (2006) has compiled a list of 20 or so EGSS product codes and uses this list to estimate trade statistics for the EGSS.
[43] However, the problem is that these data are for 2000, and this does not fit the time dimension of our study.

4.5 Effects

4.5.1 Energy and material intensity

Several indicators have been developed to measure the energy or material intensity of our economies, both in terms of what goes into the economy and what comes out of the economy. The 'input' indicators can be used as intermediate eco-innovation output indicators (as above in Section 4.4.1), and the 'output' indicators can be used as effect indicators to evaluate the likely environmental impacts of economies in general, and environmental innovation, in particular.

These data are extracted from the following sources:

- NewCronos: energy intensity of economy (national level);
- Data in van der Voet (2005) on resource productivity of the economy (GDP per DMC – direct material consumption, data available for EU-27 at national level);[44] also measures decoupling between economic growth and environmental impact;
- NewCronos: CIS-3 and CIS-4 data on environmentally beneficial effects from product and process innovation (reduced materials/energy per unit output).[45]

The benefit of the CIS data is that they are also provided at fairly detailed sectoral level, as well as national level. However, as most other included indicators are only provided at national (or very broad sectoral) level, this is less useful.

4.5.2 Pollution and waste levels

Another output measure for environmental innovation is the level of pollution or waste and changes in such levels.

In this report, we have included weighted data for the EU-27 on air emissions, namely greenhouse gas emissions (including all six gases in the Kyoto 'basket') and emissions of acidifying pollutants (ammonia, sulphur oxides and nitrogen oxides), as well as data on amounts of waste generated.[46]

4.5.3 Other innovation effects

The Community Innovation Surveys (CIS-3 and CIS-4) include questions on effects from product and process innovation, namely, on reduced environmental, health or safety impacts and on meeting regulatory requirements. We have included these data in our report to see how they correlate with the other indicators.[47] The data on environmental impacts could also be used to identify unintentional eco-innovators in all sectors of the economy. The disadvantages of these data are that the impact question also refers to health and safety impacts, and the regulation question refers to all regulation, not just environmental regulation.

[44] These data are for 2000, again, a problem, as this is an effect indicator.
[45] These data can also be used to identify unintentional eco-innovation.
[46] A common problem with these data is that they do not extend beyond 2004 (waste until 2003). This does not, in some cases, allow for a time lag between pressures, inputs and outputs on the one hand, and effects on the other.
[47] In particular, the CIS-3 data do not allow for a time lag, as they are for 2000. CIS-4 data are for 2004.

5. IDENTIFYING KEY ECO-INNOVATION INDICATORS

5.1 Issues with causal linkages and correlations

A positive or a negative correlation does not prove a causal relationship between two indicators. To give some examples related to the topic at hand:

- Increases in income usually result in greater ecological damage, even as per unit damage may decline. Income increases would therefore be positively correlated with ecological damage, although they do not directly *cause* it. Rather they cause more consumption, which then tends to increase pollution;
- An indicator on trade might correlate positively with an indicator on greenhouse gases, although increased trade as such would not *cause* the GHG increases (compare trade across a border with trade across continents), but the general increase in transport from trade does;
- Data on patent counts might correlate positively with GDP data, but this does not mean that more patents *cause* GDP to rise (or the other way around), they can just be linked with another indicator, such as increases in innovation expenditures.

Moreover, two indicators often share a common denominator, which causes the correlation. Some examples include:

- An indicator on investments in pollution control equipment might correlate positively with amounts of acidifying pollutants, which seems rather odd. However, looking further into the indicators, this correlation could be caused by the fact that both indicators include elements of, say, GDP in them;
- Many index indicators have been built in quite a complex way, and it can be difficult to exclude correlations between such indexes and other indicators that might be caused by some common data used in both.

Other factors that make it hard to see whether a correlation (or the absence of one) is true or not include:

- Too few cases;
- Outliers in the data.

Finally, this report looks at a rather complex chain of factors potentially influencing each other (from *pressure* to *input* (with *facilitators* in between) to *output* to *effect*), and the further from each other any two indicators are in that chain, the less clear it is that correlations are in fact proof of *any* kind of a relationship between the two indicators.

5.2 Correlations from current data

Given the above constraints for the analysis, Table 2 shows a reduced version of the original correlation table for the data used in this report. The original correlations included all the indicators for which we had data, and all the years (from 2000 onwards) for which we had data. The reduced version has been produced based on the principles stated in Section 3.2, so, only higher correlation coefficients are considered.[48]

[48] A number of outliers were removed from the data, in total eight data points. These mostly include data on the smaller (Malta, Cyprus) or newer (Bulgaria, Romania) EU member states.

Table 2. Pearson correlation results between eco-innovation indicators. Key: bold = strong correlations; italics = no. of cases < half of the max. possible; shading = 'negative' indicator.

Indicator name (vertically and horizontally)	Indicator year	Indicator type	att_clean_tr_RD_02	att_wind_energy_06	energy_tax_02	ERRI_01	reg_comp_prod_04	EMAS_00	ISO14001_03	ISO14001_00	eco_lbl_04	publications_01	public_env_RD_05	public_env_RD_02	env_patents_99_03
Indicator number (horizontally)			1.4	1.2	2.1	2.2	2.5	3.1	3.2	3.2	3.3	4.5	4.1	4.1	5.1
			Pressure					Facilitator				Input			
att_clean_tr_RD_02	2002	Pressure	1			**.664(**)**						.579(*)			
att_wind_energy_06	2006	Pressure		1							.569(*)				
energy_tax_02	2002	Pressure			1	.503(*)	.417(*)					**.633(**)**		-.506(*)	
ERRI_01	2001	Pressure	**.664(**)**		.503(*)	1				**.553(**)**		**.841(**)**			*.783(**)*
reg_comp_prod_04	2004	Pressure			.417(*)		1		-.490(*)		**-.650(*)**				
EMAS_00	2000	Facilitator						1							*.748(**)*
ISO14001_03	2003	Facilitator					-.490(*)		1	**.580(**)**			**.540(**)**		
ISO14001_00	2000	Facilitator				**.553(**)**			**.580(**)**	1		**.615(**)**			
eco_lbl_04	2004	Facilitator		.596(*)			**-.650(*)**				1				
publications_01	2001	Input	.579(*)		**.633(**)**	**.841(**)**				**.615(**)**		1			
public_env_RD_05	2005	Input							**.540(**)**				1	.582(*)	
public_env_RD_02	2002	Input			-.506(*)								.582(*)	1	
env_patents_99_03	1999-2003	Input				*.783(**)*		*.748(**)*							1
share_renew_en_04	2004	Output						**.681(**)**						**-.603(**)**	
IIM_04	2004	Output			**-.626(**)**	-.514(*)	-.493(*)							.552(*)	
IIM_00	2000	Output			-.561(*)		-.452(*)							.536(*)	
nat_inv_EGSS_04	2004	Output				**-.681(**)**									
nat_inv_EGSS_01	2001	Output				**-.645(**)**									
inv_clean_tech_04	2004	Output													
inv_clean_tech_03	2003	Output							**.583(**)**						
inv_poll_ctr_04	2004	Output	*-.683(*)*			-.496(*)	**-.625(**)**								
green_pages_07	2007	Output				-.410(*)									
expts_india_02	2002	Output													
expts_china_04	2004	Output			**.707(**)**	**.533(**)**						.416(*)			
expts_china_02	2002	Output			**.693(**)**	**.612(**)**		.561(*)				**.621(**)**			
RWS_00	2000	Output	.641(*)												
energy_intens_05	2005	Effect			**-.688(**)**	**-.588(**)**	**-.589(**)**	-.587(*)	.438(*)			-.458(*)		**.614(**)**	
resource_prod_00	2000	Effect	**.653(*)**		**.758(**)**	**.766(**)**	**.602(**)**					**.653(**)**		-.529(*)	
reduc_mat_energy_04	2004	Effect													
ghg_04	2004	Effect													
acid_poll_04	2004	Effect	**-.748(**)**		**-.686(**)**	**-.728(**)**	**-.612(**)**					**-.517(**)**		.509(*)	
acid_poll_01	2001	Effect	**-.775(**)**		**-.688(**)**	**-.747(**)**	**-.623(**)**					**-.556(**)**		.511(*)	
impr_ehs_impct_00[#]	2000	Effect					.495(*)								
impr_ehs_impct_04[#]	2004	Effect													
reg_reqs_met_00[#]	2000	Effect	-.614(*)				.515(*)								
reg_reqs_met_04[#]	2004	Effect													

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

[#] Indicators impr_ehs_impct and reg_reqs_met are similar, but not entirely the same between the two CIS rounds (2000 and 2004).

Table 2 continued.

Indicator name (vertically and horizontally)	Indicator year	Indicator type	share_renew_en_04	IIM_04	IIM_00	nat_inv_EGSS_04	nat_inv_EGSS_01	inv_clean_tech_04	inv_clean_tech_03	inv_poll_ctr_04	green_pages_07	expts_india_02	expts_china_04	expts_china_02	RWS_00	energy_intens_05	resource_prod_00	reduc_mat_energy_04	ghg_04	acid_poll_04	acid_poll_01	impr_ehs_impct_00#	impr_ehs_impct_04#	reg_reqs_met_00#	reg_reqs_met_04#
Indicator number (horizontally)			6.1	6.3	6.3	8.2	8.2	8.4	8.4	8.5	8.8	9.1	9.1	9.1	9.2	10.1	10.2	10.3	11.1	11.2	11.2	12.1	12.1	12.2	12.2
			Output													Effect									
att_clean_tr_RD_02	2002	Pressure								*-.683(*)*					.641(*)		**.653(*)**			**-.748(**)**	**-.775(**)**			-.614(*)	
att_wind_energy_06	2006	Pressure																							
energy_tax_02	2002	Pressure		**-.626(**)**	-.561(*)								**.707(**)**	**.693(**)**		**-.688(**)**	**.758(**)**			**-.686(**)**	**-.688(**)**				
ERRI_01	2001	Pressure		-.514(*)		**-.681(**)**	**-.645(**)**			-.496(*)	-.410(*)		**.533(**)**	**.612(**)**		**-.588(**)**	**.766(**)**			**-.728(**)**	**-.747(**)**				
reg_comp_prod_04	2004	Pressure		-.493(*)	-.452(*)					**-.625(**)**						**-.589(**)**	**.602(**)**			**-.612(**)**	**-.623(**)**	.495(*)		.515(*)	
EMAS_00	2000	Facilitator	**.681(**)**											.561(*)		-.587(*)									
ISO14001_03	2003	Facilitator							**.583(**)**							.438(*)									
ISO14001_00	2000	Facilitator																							
eco_lbl_04	2004	Facilitator																							
Publications_01	2001	Input											.416(*)	**.621(**)**		-.458(*)	**.653(**)**			**-.517(**)**	**-.556(**)**				
public_env_RD_05	2005	Input																							
public_env_RD_02	2002	Input	**-.603(**)**	.552(*)	.536(*)											**.614(**)**	-.529(*)			.509(*)	.511(*)				
env_patents_99_03	99-03	Input																							
share_renew_en_04	2004	Output	1																						
IIM_04	2004	Output		1	**.971(**)**							**-.648(**)**	-.523(*)			**.765(**)**	**-.681(**)**			.578(*)	**.607(**)**				-.487(*)
IIM_00	2000	Output		**.971(**)**	1							**-.606(**)**				**.734(**)**	**-.606(**)**			**.562(**)**	**.622(**)**		-.544(*)	-.466(*)	-.496(*)
nat_inv_EGSS_04	2004	Output				1	**.863(**)**				.471(*)					**.623(**)**	**-.611(**)**			**.759(**)**	**.752(**)**	**-.652(**)**		**-.617(**)**	
nat_inv_EGSS_01	2001	Output				**.863(**)**	1												**-.542(**)**	.431(*)	.483(*)				
inv_clean_tech_04	2004	Output						1			.558(*)		-.564(*)												**.686(**)**
inv_clean_tech_03	2003	Output							1	**.619(**)**		.481(*)													
inv_poll_ctr_04	2004	Output							**.619(**)**	1	.478(*)					.593(*)	-.551(*)								
green_pages_07	2007	Output				.471(*)		.558(*)		.478(*)	1		**-.543(**)**	-.424(*)			**-.511(**)**								
expts_india_02	2002	Output		**-.648(**)**	**-.606(**)**				.481(*)			1	.551(**)		.482(*)										
expts_china_04	2004	Output		-.523(*)				-.564(*)			**-.543(**)**	**.551(**)**	1	**.809(**)**	.548(*)	-.440(*)	**.654(**)**			**-.503(**)**	-.498(**)				
expts_china_02	2002	Output									-.424(*)		**.809(**)**	1	**.807(**)**		**.614(**)**			-.481(*)	**-.524(**)**				
RWS_00	2000	Output										.482(*)	.548(*)	**.807(**)**	1							**-.678(**)**		**-.769(**)**	
energy_intens_05	2005	Effect		**.765(**)**	**.734(**)**	**.623(**)**				.593(*)			-.440(*)			1	**-.787(**)**			**.807(**)**	**.856(**)**	-.488(*)		**-.566(**)**	
resource_prod_00	2000	Effect		**-.681(**)**	**-.606(**)**	**-.611(**)**				-.551(*)	**-.511(**)**		**.654(**)**	**.614(**)**		**-.787(**)**	1			**-.726(**)**	**-.747(**)**				
reduc_mat_energy_04	2004	Effect																1					**.587(**)**		
ghg_04	2004	Effect					**-.542(**)**												1						
acid_poll_04	2004	Effect		.578(*)	**.562(**)**	**.759(**)**	.431(*)						**-.503(**)**	-.481(*)		**.807(**)**	**-.726(**)**			1	**.986(**)**				
acid_poll_01	2001	Effect		**.607(**)**	**.622(**)**	**.752(**)**	.483(*)						-.498(**)	**-.524(**)**		**.856(**)**	**-.747(**)**			**.986(**)**	1		-.438(*)		
impr_ehs_impct_00#	2000	Effect				**-.652(**)**									**-.678(**)**	-.488(*)						1		**.888(**)**	
impr_ehs_impct_04#	2004	Effect			-.544(*)													**.587(**)**			-.438(*)		1	.437(*)	**.687(**)**
reg_reqs_met_00#	2000	Effect			-.466(*)	**-.617(**)**									**-.769(**)**	**-.566(**)**						**.888(**)**	.437(*)	1	.417(*)
reg_reqs_met_04#	2004	Effect		-.487(*)	-.496(*)			**.686(**)**															**.687(**)**	.417(*)	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

\# Indicators impr_ehs_impct and reg_reqs_met are similar, but not entirely the same between the two CIS rounds (2000 and 2004).

The indicator numbers given in Table 2 can be compared with the indicator table in Annex II to see precisely which indicators are in question. Annex II also gives results for country availability for each indicator. The indicators in Table 2 are also divided into groups based on the type of indicator in question (pressure, input, etc.). Finally, the years for which the data refer are also indicated (both in a separate column, and in each indicator name in Table 2: 00, 01, 02, and so forth).

In general, if the pressure, facilitator and input indicators are adequately measuring the output and effect indicators, we should detect some positive or negative correlations between indicators belonging to these groups.[49] Negative correlations are appropriate in cases where an input indicator is measuring some aspect of innovation, and an effect indicator is measuring pollution. Those indicators which we would expect to correlate negatively with innovation-related indicators have been marked accordingly in Table 2.

Based on the strongest correlations in Table 2, the following observations are made.[50] For ease of reference, Table 2 has been divided into Tables 2a to 2e, and these subtables are included under each section 5.2.1 to 5.2.5.

5.2.1 Pressures

Table 2a. Significant correlations between pressure indicators and other indicators.

Indicator name (vertically and horizontally)	Indicator year	Indicator type	att_clean_tr_RD_02	att_wind_energy_06	energy_tax_02	ERRI_01	reg_comp_prod_04
Indicator number (horizontally)			1.4	1.2	2.1	2.2	2.5
att_clean_tr_RD_02	2002	Pressure	1			**.664(**)**	
energy_tax_02	2002	Pressure			1	.503(*)	.417(*)
ERRI_01	2001	Pressure	**.664(**)**		.503(*)	1	
reg_comp_prod_04	2004	Pressure			.417(*)		1
ISO14001_03	2003	Facilitator					-.490(*)
ISO14001_00	2000	Facilitator				**.553(**)**	
eco_lbl_04	2004	Facilitator		.569(*)			**-.650(*)**
publications_01	2001	Input	.579(*)		**.633(**)**	**.841(**)**	
public_env_RD_02	2002	Input			-.506(*)		
env_patents_99_03	1999-2003	Input				*.783(**)*	
IIM_04	2004	Output			**-.626(**)**	-.514(*)	-.493(*)
IIM_00	2000	Output			-.561(*)		-.452(*)
nat_inv_EGSS_04	2004	Output				**-.681(**)**	
nat_inv_EGSS_01	2001	Output				**-.645(**)**	
inv_poll_ctr_04	2004	Output	*-.683(*)*			-.496(*)	**-.625(**)**
green_pages_07	2007	Output				-.410(*)	
expts_china_04	2004	Output			**.707(**)**	**.533(**)**	
expts_china_02	2002	Output			**.693(**)**	**.612(**)**	
RWS_00	2000	Output	.641(*)				
energy_intens_05	2005	Effect			**-.688(**)**	**-.588(**)**	**-.589(**)**
resource_prod_00	2000	Effect	**.653(*)**		**.758(**)**	**.766(**)**	**.602(**)**
acid_poll_04	2004	Effect	**-.748(**)**		**-.686(**)**	**-.728(**)**	**-.612(**)**
acid_poll_01	2001	Effect	**-.775(**)**		**-.688(**)**	**-.747(**)**	**-.623(**)**
impr_ehs_impct_00#	2000	Effect					.495(*)
reg_reqs_met_00#	2000	Effect	-.614(*)				.515(*)

[49] Time lags between the groups of indicators also have to be taken into account, as a pressure indicator should not follow an output indicator, rather, the order should be the other way around. In many cases we cannot assume that an indicator value for year X (which we do have) is close to a value for year X+4 (which we do not have), and therefore we have to ignore some of the positive or negative correlations as possibly not descriptive of the true situation.

[50] Some of the results are also based on the entire correlation table which is not included in this report to save space. To explain, in some cases, a clearer pattern between indicators may be visible in the larger table. This pattern will then be noted on, but may not be evident in the condensed version presented in Table 2.

The following indicator groups are considered here:

- **Attitudes**: The two attitude indicators (*att_clean_tr_RD* for research on clean transport and *att_wind_energy* for acceptance of domestic wind energy) show a few strong correlations. When taking the time dimension into account, the best correlation is between the clean transport research indicator (*att_clean_tr_RD*) and the indicator *acid_poll* measuring acidifying pollutants (negative correlation). Even if we don't look at the time flow, the correlations make sense, although they are not numerous. A relationship between attitudes and investment in the eco-industry is not really visible in these data.

- **Regulation**: The three indicators measuring aspects of regulation (*energy_tax* for implicit energy tax, *ERRI* for the ERRI index and *reg_comp_prod* for perceived negative impact on competitiveness from having to meet environmental regulations for products or services) have many strong correlations, especially with the innovation output and environmental effect indicators, as might be expected. There are also a couple of interesting correlations with the facilitator indicators. Firstly, there is some evidence of a positive relationship between the ERRI index and the ISO14001 (*ISO14001*), although the correlation does not fit the time dimension. Secondly, notable is also the correlation between the competitiveness indicator (*reg_comp_prod*) and the indicator on eco-labels (*eco_lbl*). There also appears to be a positive relationship (visible partly also across years) between environmental regulation and publications (*publications*). Moving on to the output indicators, the first two regulation indicators (*energy_tax* and *ERRI*) correlate fairly strongly with the indicator on EGSS-related exports to China (*expts_china*). This could be interesting, as it gives support to the argument that stronger environmental legislation in EU countries results in more technology transfer into developing countries. The two unexpected negative correlation coefficients between the regulation indicators and national investment in EGSS (investment in recycling and water management, indicator *nat_inv_EGSS*) could simply be explained by earlier stronger regulations already taking care of most of the need for national investment.

  Regarding the environmental effect indicators, the first two regulation indicators correlate, as could be expected, with the indicators on energy intensity (*energy_intens*) and acidifying pollutants (*acid_poll*). The third of the regulation indicators (*reg_comp_prod*) shows some unexpected correlation results with the effect indicators. However, this is at least partly explained by there simply not being enough time to allow for effects of a pressure indicator for 2004 on an effect indicator for 2005.[51] Overall, there is some evidence in these results of regulation driving innovation.

[51] Most of the data for the indicators in question fit the time dimension even worse than this.

5.2.2 Facilitators

Table 2b. Significant correlations between facilitators and other indicators.

Indicator name (vertically and horizontally)	Indicator year	Indicator type	EMAS_00	ISO14001_03	ISO14001_00	eco_lbl_04
Indicator number (horizontally)			3.1	3.2	3.2	3.3
att_wind_energy_06	2006	Pressure				.569(*)
ERRI_01	2001	Pressure			**.553(**)**	
reg_comp_prod_04	2004	Pressure		-.490(*)		**-.650(*)**
ISO14001_03	2003	Facilitator		1	**.580(**)**	
ISO14001_00	2000	Facilitator		**.580(**)**	1	
publications_01	2001	Input			**.615(**)**	
public_env_RD_05	2005	Input		**.540(**)**		
env_patents_99_03	1999-2003	Input	*.748(**)*			
share_renew_en_04	2004	Output	**.681(**)**			
inv_clean_tech_03	2003	Output		**.583(**)**		
expts_china_02	2002	Output	.561(*)			
energy_intens_05	2005	Effect	-.587(*)	.438(*)		

Environmental management and organizational changes: Apart from what has already been discussed, these three indicators (*EMAS* for EMAS, *ISO14001* for ISO14001 and *eco_lbl* for eco-labels) show strong correlations mostly only with some input indicators. This seems reasonable, as these indicators would not be expected to have very strong influences on environmental innovation, and their potential impact would therefore be felt much closer in the eco-innovation chain. There are no strong relationships with effect indicators. Two strong coefficients are included here for the output indicators. The positive relationship between the EMAS indicator and the indicator on the share of renewable energy in energy use (*share_renew_en*) holds across the years, whereas the link between ISO14001 and investments in clean technology (*inv_clean_tech*) is not visible across the years. Looking at the input indicators, the number of ISO14001 certifications seems to have a positive relationship with the number of environmental publications (*publications*), and the ISO14001 indicator also correlates positively with public environmental R&D (*public_env_RD*). Based on these results, such innovation facilitators could be considered beneficial for innovation (inputs).

5.2.3 Inputs

Table 2c. Significant correlations between inputs and other indicators.

Indicator name (vertically and horizontally)	Indicator year	Indicator type	publications _01	public_env_ RD_05	public_env_ RD_02	env_patents _99_03
Indicator number (horizontally)			4.5	4.1	4.1	5.1
att_clean_tr_RD_02	2002	Pressure	.579(*)			
energy_tax_02	2002	Pressure	**.633(**)**		-.506(*)	
ERRI_01	2001	Pressure	**.841(**)**			*.783(**)*
EMAS_00	2000	Facilitator				*.748(**)*
ISO14001_03	2003	Facilitator		**.540(**)**		
ISO14001_00	2000	Facilitator	**.615(**)**			
public_env_RD_05	2005	Input		1	.582(*)	
public_env_RD_02	2002	Input		.582(*)	1	
share_renew_en_04	2004	Output			**-.603(**)**	
IIM_04	2004	Output			.552(*)	
IIM_00	2000	Output			.536(*)	
expts_china_04	2004	Output	.416(*)			
expts_china_02	2002	Output	**.621(**)**			
energy_intens_05	2005	Effect	-.458(*)		**.614(**)**	
resource_prod_00	2000	Effect	**.653(**)**		-.529(*)	
acid_poll_04	2004	Effect	**-.517(**)**		.509(*)	
acid_poll_01	2001	Effect	**-.556(**)**		.511(*)	

The following indicators are included as inputs:

- **Environmental R&D and other innovation investments:** Somewhat unexpectedly, our eco-innovation input indicators do not correlate as well as expected with our eco-innovation output and effect indicators.[52] This may be partly due to the fact that although the type of the input indicators is traditional (publications, R&D, machinery, patents) the quality of the data is not always good, in particular regarding environmental R&D and for patents (discussed separately below). Unfortunately therefore, we cannot draw many conclusions from these relationships, except to say that better data are needed to measure (public and private) environmental R&D[53] and environmentally beneficial patents.[54]

  There are strong correlations between the environmental publications indicator (*publications*) and other indicators. We have already discussed some above, but in addition to those, we can see from the results that there is a moderate to strong positive relationship (visible across years) between this indicator and EGSS exports to China (*expts_china*), a mild positive relationship (visible across years) between this indicator and the energy intensity of economies (*energy_intens*), and a fairly strong negative relationship

[52] Similarly, there is little evidence in these results of the established link between environmental R&D and regulation.

[53] The two strong relationships between the indicator on public environmental R&D (*public_env_RD*) and the indicators on share of renewable energy (*share_renew_en*) and energy intensity of the economy (*energy_intens*) are somewhat odd, as the first would be expected to be positive (when it is negative) and the second negative (when it is positive). As said, this may be explained by poor data. Also, we could expect a relationship between the regulation indicators and public environmental R&D, but this is not visible in the data.

[54] We also included two indicators related to the acquisition of machinery in our correlation analysis. The results showed no correlations that would have been above the threshold, but one of the indicators (number 4.4) did have some weaker correlations with IIE_00 and IIE_04 (positive) and with the regulatory indicators, ISO14001, publications and exports to India and China (negative). However, as the data for this input indicator were for 2000, only really the correlation with exports is somewhat relevant. The link between firms that acquired a lot of machinery in 2000 and firms that did not export much EGS to China or India (or vice versa) is not obvious though.

(again, visible across years) between this indicator and acidifying pollutants (*acid_poll*). Additionally, there is a strong positive correlation between the publication indicator and the resource productivity measure (*resource_prod*).[55] All in all, it seems that such publication data could be of some value in reflecting or predicting changes in the environmental innovation chain (from environmental regulation to innovation impacts in the environment), and such data could also be an indicator for the market in environmental technologies.

- **Patents:** As discussed earlier, patent data are valuable in measuring eco-innovation, especially innovation specific to the EGSS, but collecting the data is still very time-consuming. Therefore, we have included some patent data in our analysis, but the data are incomplete, with results available for only a few EU countries. Although there are two strong positive relationships between the patent indicator (*env_patents*) and one regulation indicator (*ERRI*) and one facilitator indicator (*EMAS*), we cannot really say that the relationships are reliable.

5.2.4 Outputs

Table 2d. Significant correlations between outputs and other indicators.

Indicator name (vertically and horizontally)	Indicator year	Indicator type	share_renew_en_04	IIM_04	IIM_00	nat_inv_EGSS_04	nat_inv_EGSS_01	inv_clean_tech_04	inv_clean_tech_03	inv_poll_ctr_04	green_pages_07	expts_india_02	expts_china_04	expts_china_02	RWS_00
Indicator number (horizontally)			6.1	6.3	6.3	8.2	8.2	8.4	8.4	8.5	8.8	9.1	9.1	9.1	9.2
att_clean_tr_RD_02	2002	Pressure								*-.683(*)*					.641(*)
energy_tax_02	2002	Pressure		**-.626(**)**	-.561(*)								**.707(**)**	**.693(**)**	
ERRI_01	2001	Pressure		-.514(*)		**-.681(**)**	**-.645(**)**			-.496(*)	-.410(*)		**.533(**)**	**.612(**)**	
reg_comp_prod_04	2004	Pressure		-.493(*)	-.452(*)					**-.625(**)**					
EMAS_00	2000	Facilitator	**.681(**)**											.561(*)	
ISO14001_03	2003	Facilitator							**.583(**)**						
Publications_01	2001	Input											.416(*)	**.621(**)**	
public_env_RD_02	2002	Input	**-.603(**)**	.552(*)	.536(*)										
IIM_04	2004	Output		1	**.971(**)**							**-.648(**)**	-.523(*)		
IIM_00	2000	Output		**.971(**)**	1							**-.606(**)**			
nat_inv_EGSS_04	2004	Output				1	**.863(**)**				.471(*)				
nat_inv_EGSS_01	2001	Output				**.863(**)**	1								
inv_clean_tech_04	2004	Output						1			.558(*)		-.564(*)		
inv_clean_tech_03	2003	Output							1	**.619(**)**		.481(*)			
inv_poll_ctr_04	2004	Output							**.619(**)**	1	.478(*)				
green_pages_07	2007	Output				.471(*)		.558(*)		.478(*)	1		**-.543(**)**	-.424(*)	
expts_india_02	2002	Output		**-.648(**)**	**-.606(**)**				.481(*)			1	.551(**)		.482(*)
expts_china_04	2004	Output		-.523(*)				-.564(*)			**-.543(**)**	**.551(**)**	1	**.809(**)**	.548(*)
expts_china_02	2002	Output									-.424(*)		**.809(**)**	1	**.807(**)**
RWS_00	2000	Output										.482(*)	.548(*)	**.807(**)**	1
energy_intens_05	2005	Effect		**.765(**)**	**.734(**)**	**.623(**)**				.593(*)			-.440(*)		
resource_prod_00	2000	Effect		**-.681(**)**	**-.606(**)**	**-.611(**)**				-.551(*)	**-.511(**)**		**.654(**)**	**.614(**)**	
ghg_04	2004	Effect					**-.542(**)**								
acid_poll_04	2004	Effect		.578(*)	**.562(**)**	**.759(**)**	.431(*)						**-.503(**)**	-.481(*)	
acid_poll_01	2001	Effect		**.607(**)**	**.622(**)**	**.752(**)**	.483(*)						-.498(**)	**-.524(**)**	
impr_ehs_impct_00#	2000	Effect				**-.652(**)**									**-.678(**)**
impr_ehs_impct_04#	2004	Effect			-.544(*)										
reg_reqs_met_00#	2000	Effect			-.466(*)	**-.617(**)**									**-.769(**)**
reg_reqs_met_04#	2004	Effect		-.487(*)	-.496(*)			**.686(**)**							

The following indicators are included as outputs:

[55] Although the time dimension is not 'right' between these two indicators, it could be expected that the resource productivity data for 2000 would correlate positively with such data for later years.

- **Intermediate energy and material inputs:**[56] The indicators included here (*share_renew_en* for the share of renewable energy in energy inputs to the economy, *IIM* for intermediate material inputs to the economy, and IIE for intermediate energy inputs[57]) show a number of strong relationships, mostly in expected ways. In addition to what has been discussed above, the IIM indicator correlates negatively with the indicator on EGSS-related exports to India (*expts_india*), and from the larger correlation table (results not shown) some significant negative correlation can be seen with exports to China. This could reflect the structure of economies: the more material intensive economies do not (yet) export as much environmental technology to developing countries such as India and China.[58] The IIM indicator shows a strong positive relationship with the effect indicator on total energy intensity of the economy (*energy_intens*), as could be expected, and a somewhat less strong negative relationship with the resource productivity indicator (*resource_prod*), again, this result could be expected. The better an economy is in turning resources into income, the less material intensive it needs to be. Finally, we can see a relatively strong positive correlation between the IIM indicator and the indicator on acidifying pollutants (*acid_poll*). In other words, the more material(/energy) intensive the economy, the bigger the externalities, such as pollution. The results here support this statement.

- **Growth of EGSS:** In this category, we have included indicators on national investments in some EGS sectors (*nat_inv_EGSS*), investment in clean technology (*inv_clean_tech*), investment in pollution control equipment (*inv_poll_ctr*) and an indicator on the growth of the number of EGSS firms (*green_pages*).[59],[60] In addition to a small number of correlations with pressure indicators or facilitators discussed above, the indicator on national investment in 2004 (*nat_inv_EGSS_04*) correlates rather unexpectedly (e.g. positively with pollutants (*acid_poll*) and negatively with the CIS-3 indicator on high environmental impacts from innovation (*impr_ehs_impct*)), although there is also a time flow problem with this indicator and some of the effect indicators. These unexpected results could be explained by the duality of this indicator: on the one hand, it reflects the growth of the EGS sector, and on the other hand, it may show some previous laxness in environmental protection.[61] It is therefore not clearly a 'positive' eco-innovation indicator (i.e. one that correlates positively with other innovation indicators and negatively with pollution indicators).[62] Otherwise, the investment indicators show only one other significant correlation, that between the indicator on clean technology investment (*inv_clean_tech*) and the indicator on meeting (environmental) regulations (*reg_reqs_met*). This is a reasonable relationship, possibly reflecting investments made to meet environmental regulations.

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[56] For output indicators, we should only include data for more recent years. However, due to restrictions in data availability and to show some of the relationships between outputs and effects, we have included also one earlier indicator here: *IIM_00*.
[57] IIE is not included in Table 2d.
[58] Also the indicator measuring intermediate energy inputs to the economy (IIE) shows a similar (but milder) negative relationship with the EGSS exports to India and China.
[59] This refers to the number of firms listed in www.eco-web.com.
[60] Initially, we also looked at an indicator on total expenditure on environmental protection, but the data quality was poor, and most of the correlations could be explained by common denominators related to GDP.
[61] Many of the higher values for the national EGSS investment indicator (*nat_inv_EGSS*) are for the newer EU member states.
[62] Also, this indicator and the indicator on acidifying pollutants (*acid_poll*) both share elements of GDP, which helps to explain the strong correlation between the two. Of note, the greenhouse gas indicator (*ghg*) does not include GDP, and also does not show any positive relationship with the EGSS investment indicator (*nat_inv_EGSS*).

Finally, the indicator on EGSS company listings (*green_pages*) has only two moderately strong correlations in these data, both of which seem somewhat strange. However, the first one with exports to China, *expts_china* (and also India, from the larger correlation table) could be explained by the orientation of the exporting firms. The listings on www.eco-web.com possibly have a bias towards more developed economies, and therefore a firm concentrating on exports to China or India might not find it useful to list themselves. The negative correlation with the resource productivity indicator (*resource_prod*) does not fit the time dimension of the innovation process at all, as these data are for 2000. The more general problem with the EGSS company listings data is that they are too recent (from 2007) to reflect any impact on other output or effect indicators.[63]

- **Trade in EGSS products:** These indicators (*expts_china* and *expts_india* for exports to China and India, and *RWS* for general export orientation (relative world shares)) do show several strong correlations with the other eco-innovation indicators, many of which have already been discussed. Regarding their impact on the effect indicators, we can see that there is a moderately strong negative relationship (holding across years) between exports to China and the indicator on acidifying pollutions (*acid_poll*). This is again interesting and indicates that countries strong in technology transfer to the developing economies are themselves already rather advanced in terms of reducing pollution levels. As could be expected, the export indicators on China and India correlate positively with the indicator on general export orientation in EGSS products (*RWS*). Exports to China are also positively correlated with the resource productivity indicator (*resource_prod*). However, it is doubtful whether any conclusions should be drawn from this, as the data for the productivity indicator precede the export data (even though the relationship does hold across years).[64] Finally, the RWS indicator on export orientation in the EGSS products correlates significantly (but negatively) only with the two CIS-3 indicators on positive (environmental) impacts from innovation (*impr_ehs_impct*) and meeting (environmental) regulations (*reg_reqs_met*). This seemingly unexpected result could be explained by the focus of the firms in question: the less export oriented firms probably focus more on meeting domestic regulation and similarly perhaps also see more immediate environmental impacts from their innovation.[65]

[63] Unfortunately, no link could be found between patents and the investment indicators, possibly due to poor data quality.
[64] If the relationship were real, an explanation could be that the more ‘efficient’ economies are more focused on technology transfer to e.g. China than less ‘efficient’ economies.
[65] The other related indicator RCA (revealed comparative advantage) correlates highly with RWS, and has been excluded from Table 2d. However, RCA correlates positively with the indicator on energy taxes (something RWS does not do), although this relationship does not fit the time dimension, as the tax data are from 2000 onwards, and the RCA data are for 2000 only.

5.2.5 Effects

Table 2e. Significant correlations between effects and other indicators.

Indicator name (vertically and horizontally)	Indicator year	Indicator type	energy_intens_05	resource_prod_00	reduc_mat_energy_04	ghg_04	acid_poll_04	acid_poll_01	impr_ehs_impct_00#	impr_ehs_impct_04#	reg_reqs_met_00#	reg_reqs_met_04#
Indicator number (horizontally)			10.1	10.2	10.3	11.1	11.2	11.2	12.1	12.1	12.2	12.2
att_clean_tr_RD_02	2002	Pressure		.653(*)			-.748(**)	-.775(**)			-.614(*)	
energy_tax_02	2002	Pressure	-.688(**)	.758(**)			-.686(**)	-.688(**)				
ERRI_01	2001	Pressure	-.588(**)	.766(**)			-.728(**)	-.747(**)				
reg_comp_prod_04	2004	Pressure	-.589(**)	.602(**)			-.612(**)	-.623(**)	.495(*)		.515(*)	
EMAS_00	2000	Facilitator	-.587(*)									
ISO14001_03	2003	Facilitator	.438(*)									
Publications_01	2001	Input	-.458(*)	.653(**)			-.517(**)	-.556(**)				
public_env_RD_02	2002	Input	.614(**)	-.529(*)			.509(*)	.511(*)				
IIM_04	2004	Output	.765(**)	-.681(**)			.578(*)	.607(**)				-.487(*)
IIM_00	2000	Output	.734(**)	-.606(**)			.562(**)	.622(**)		-.544(*)	-.466(*)	-.496(*)
nat_inv_EGSS_04	2004	Output	.623(**)	-.611(**)			.759(**)	.752(**)	-.652(**)		-.617(**)	
nat_inv_EGSS_01	2001	Output				-.542(**)	.431(*)	.483(*)				
inv_clean_tech_04	2004	Output										.686(**)
inv_poll_ctr_04	2004	Output	.593(*)	-.551(*)								
green_pages_07	2007	Output		-.511(**)								
expts_china_04	2004	Output	-.440(*)	.654(**)			-.503(**)	-.498(**)				
expts_china_02	2002	Output		.614(**)			-.481(*)	-.524(**)				
RWS_00	2000	Output							-.678(**)		-.769(**)	
energy_intens_05	2005	Effect	1	-.787(**)			.807(**)	.856(**)	-.488(*)		-.566(**)	
resource_prod_00	2000	Effect	-.787(**)	1			-.726(**)	-.747(**)				
reduc_mat_energy_04	2004	Effect			1					.587(**)		
acid_poll_04	2004	Effect	.807(**)	-.726(**)			1	.986(**)				
acid_poll_01	2001	Effect	.856(**)	-.747(**)			.986(**)	1		-.438(*)		
impr_ehs_impct_00#	2000	Effect	-.488(*)						1		.888(**)	
impr_ehs_impct_04#	2004	Effect			.587(**)			-.438(*)		1	.437(*)	.687(**)
reg_reqs_met_00#	2000	Effect	-.566(**)						.888(**)	.437(*)	1	.417(*)
reg_reqs_met_04#	2004	Effect								.687(**)	.417(*)	1

The following indicator groups are included for environmental effects:

- **Energy and material intensity of economies:** Apart from what has already been discussed above, the three effect indicators (*energy_intens* for energy intensity, *resource_prod* for resource productivity and *reduc_mat_energy* for innovation effects in terms of reduced materials and energy per produced unit (from the CIS)) correlate strongly, and as expected, with several of the other effect indicators. The strongest links can be found between the indicators on energy intensity and resource productivity on the one hand, and the indicator on acidifying pollutants (*acid_poll*) on the other. This is not surprising, as the most energy intensive and least resource productive economies (Bulgaria, Romania and many other newer EU member states) often also have the most pollution. The other correlations are between two CIS indicators (*reduc_mat_energy* and *impr_ehs_impct*), and between the energy intensity indicator and the CIS indicator for meeting regulation requirements (*reg_reqs_met)*. The former indicates consistency in the CIS data (the firms reporting less material and energy inputs also report general positive environmental effects), and the latter shows an expected negative relationship between meeting (environmental) regulations and higher energy intensities.[66]

[66] This relationship holds across years in the larger results table.

- **Pollution and waste levels:** These indicators (*ghg* for greenhouse gases and *acid_poll* for acidifying pollutants[67]) are important effect indicators together with the 'intensity indicators'. The indicator on acidifying pollutants has already been discussed in connection with many correlations with other indicators. However, the greenhouse gas indicator shows only one correlation with the other indicators. It correlates moderately strongly and negatively with the national EGSS investment indicator (*nat_inv_EGSS*). This relationship seems reasonable, but considering several problematic correlations between the national investment indicator and other indicators, perhaps not too much attention should be paid to the relationship. It may simply be that as the true efforts to reduce greenhouse gases are only really beginning, there cannot be any real relationship between this indicator and other eco-innovation indicators as of yet.[68] It will therefore be interesting to examine such correlation results in a few years.

- **Other innovation effects:** This category includes four CIS indicators for positive environmental (and health and safety) impacts from innovation (*impr_ehs_impct*) and for meeting regulation requirements (*reg_reqs_met*). These are quite interesting indicators, as they measure more general environmentally beneficial innovation.[69] Looking at the correlation results, the data for 2000 and 2004 for the same type of indicator do not, however, correlate well with each other. The actual correlations have mostly already been covered in the above discussion.

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[67] An indicator on waste levels was originally included, but data quality was so poor (small number of included countries) that this indicator was left out from the final analysis.
[68] Also, these data only cover emissions until 2004.
[69] However, they also include data on other impacts (health and safety) and other than environmental regulation.

6. CONCLUSIONS

This report has explored - with the help of discussion and correlation data analysis - a large number of potential indicators that could be used to measure various aspects of innovation with beneficial impacts on the environment. In addition, we have discussed the definition and location of such innovation, and concluded that it takes place in the whole economy, although it is more concentrated in the environmental goods and services sector, which can, however, be hard to define. Finally, we have also sketched a scenario which illustrates the process of eco-innovation.[70]

Following this scenario, we classified the 45 indicators into five different types: pressures, facilitators, inputs, outputs and effects, according to where they best fit in the eco-innovation chain. The correlation analysis has included all those indicators (39 in total) for which we were able to obtain national level data for a minimum of 11 EU member states.[71] [72]

Our correlation results have been mixed. Much of the results have followed the lines of the discussion and literature, often showing interesting evidence for links between, for example, innovation pressures and inputs, or innovation outputs and environmental effects. A few of the established relationships have not been found in these data. However, there are a couple of issues that have most likely contributed to this. First, in some cases (especially with patent data), the data coverage of the EU countries has been poor, and second, we have not always been able to obtain data that follow the time flow in the innovation chain.[73]

Table 3 includes those 15 indicators that we consider - based on both literature and our data analysis - to be the key indicators for measuring innovation with environmental benefits. We have tried to balance different types of indicators (pressures, inputs etc.), recognizing also that both intentional and unintentional eco-innovation should be covered. Similarly, the key indicators should not only measure innovation within the EGSS, but across all sectors of the economy.[74] Finally, the key indicators should also cover innovation types other than product innovation.

The indicators that were not included in the key indicators were mostly those with either a weak grounding in the literature and/or no strong correlation results from our analysis. For example, we did not include an indicator on public attitudes among the key indicators, as it is somewhat questionable how strong an influence public attitudes can really have on eco-innovation, especially when they may not be followed by public action. We also left out an indicator on environmental management systems and organizational changes, although they have been found to facilitate eco-innovation. They are, however, not a very strong influence, or a necessary part, in the eco-innovation process.

Our main recommendations, included in Table 3, mainly concentrate on improving data collection and data availability. Some of the key indicators still need further exploration and development, and refining the questions on eco-innovation in the Community Innovation Survey should also be considered. Last but not least: an overall recommendation for developing data collection for eco-innovation related indicators would be that much more sectoral level data should be made available.

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[70] See Section 2.3 for the scenario.
[71] Only two indicators (4.3 and 5.1) had as few as 11 countries included. Otherwise, 15 was the minimum.
[72] Sectoral level data were in many cases not available. Therefore, we concentrated on the national level.
[73] For example, some data on environmental effects were too old, and some data on innovation pressures were too new to fit well in the scenario.
[74] Most effect indicators measure innovation effects from all parts of economies. Taking an effect indicator on energy intensities as an example, the effects from increased use of traditional environmental technologies cannot easily be separated from the effects from energy savings from more efficient processes across the economy.

Table 3. Key indicators for measuring innovation with environmental benefits.

Indicator numbers in this study	Indicator	Indicator type	Unintentional /Intentional innovation	Results from this study	Future potential	Recommendations
2.2 to 2.4	Environmental regulatory regime index (ERRI) or something similar on the stringency, clarity and stability of environmental regulations	Pressure	Intentional	Reasonable and strong correlations with several types of indicators.	Important pressure factor, although captures only regulation related eco-innovation (but across sectors).	Regulatory indicators should be further developed, so that they are consistently available on a yearly basis.
2.7	Venture capital for firms in the EGSS	Pressure	Intentional	Not included, as no data are available at the European level.	Important pressure factor, although confined to the EGSS.	Data collection should be developed (supposedly already ongoing at EVCA).
4.2	Business environmental R&D, as a share of total business expenditure on R&D (BERD)	Input	Intentional	Not included, as no data are available at the European level (for a large enough number of countries).	Although R&D data are generally considered far from innovation outputs, this could be a useful eco-innovation indicator, with a link to regulation.	Data collection should be further developed.
4.5	Publications in specialized journals in 'environment /ecology' in the EU per capita	Input	Intentional	Some reasonable and strong correlations, especially with effect indicators.	Potentially good indicator, but mostly only captures (intentional) product innovation, and may not do so evenly.	Should be explored further.
5.1	Patent counts in the EGSS or outside it	Input	Intentional	Some correlations, but data quality is poor, due to a small number of included countries (further data collection was not possible for this project).	Fairly established eco-innovation indicator, which also captured diffusion, but up-to-now mostly confined to the EGSS. Also, focus on product innovation.	Existing patent databases should be further developed to allow for easier access to eco-innovation related patents.
6.2 and 6.3	Intermediate material or energy inputs (IIM and IIE) at current purchasers' prices per GDP	Output (inter mediate input)	Unintentional /Intentional	IIM correlated well with some, especially effect indicators.	Measures an important factor in the eco-innovation process between inputs, outputs and effects. Captures also unintentional eco-innovation.	Data collection should be maintained on a yearly basis and extended to all EU countries.
7.1	Sales or profits from environmentally beneficial innovation across sectors	Output	Unintentional /Intentional	Not included as no data are available at an international level.	Potentially very valuable indicator, as would measure eco-innovation across sectors (including unintentional eco-innovation).	Data collection should be developed. The topic could be included in the CIS.
8.1	Foreign direct investment in EGSS (outside the EU)	Output	Intentional	Not included, as FDI data are only available by aggregate sectors, and therefore identification of EGSS not possible at the moment.	Potentially a good indicator, and would also measure diffusion. However, this indicator is confined to the EGSS.	Data availability should be developed based on a sectoral identification of the EGSS, if possible.

Indicator numbers in this study	Indicator	Indicator type	Unintentional /Intentional innovation	Results from this study	Future potential	Recommendations
9.1	Exports in EU eco-industry products to large developing economies, such as China and India (as share of total exports to these countries)	Output	Intentional	Reasonable and strong correlations with several types of indicators. However, the current product classification systems are not well designed to include only EGSS related exports.	Potentially a good indicator, also measuring diffusion. Confined to the EGSS and product innovation.	Further refinement of EGSS product code lists or product classification systems should be explored (already supposedly under way at the World Bank).
9.2 and 9.3	Relative world shares (RWS) – relative position of a nation in international trade in EGS (export orientation), or revealed comparative advantage (RCA) – EGS export-import ratio compared to the pattern of all traded goods	Output	Intentional	Both correlate well with the EGSS export indicator (see above), however, otherwise not very many correlations found in this study, but the data were for 2000, and therefore old.	Not as sensitive to the EGSS product code list issue discussed above. Include some measure of diffusion. Confined to the EGSS and product innovation.	Could be used instead of the EGSS export indicator, at least until the EGSS export classification is better developed.
10.1	Energy intensity of the economy - Gross inland consumption of energy divided by GDP	Effect	Unintentional /Intentional	Strong and mostly reasonable correlations with several types of indicators.	Important effect indicator on energy use. Measures also effects from unintentional eco-innovation.	To be used as one of the key indicators.
10.2	Resource productivity of the economy – GDP per direct material consumption (DMC)	Effect	Unintentional /Intentional	Strong and mostly reasonable correlations with several types of indicators. However, the data used were for 2000, and therefore old.	Important effect indicator. Measures also effects from unintentional eco-innovation, as well as decoupling of economic growth from resource use.	This indicator should be developed further, also so that annual data would be available.
10.3 and 12.1	Survey data on the effects from product or process innovation in terms of reduced materials and energy per produced unit, or highly improved environmental impact	Effect	Unintentional /Intentional	These two indicators based on CIS questions did not correlate well with the other included indicators, except with other CIS-based indicators. The impact question includes improved impact for health and safety.	Potentially valuable indicators, as the data are collected at a detailed sectoral level, and these indicators should capture also unintentional eco-innovation across sectors, as well as process innovation.	Further development of the CIS survey, improvement in response rates. Environmental effects should be separated from health and safety effects in the questionnaire.
11.1	Weighted emissions of greenhouse gases per capita	Effect	Unintentional /Intentional	Almost no relevant correlations in this study. However, actual consistent reductions in greenhouse gases still mostly to take place.	Important effect indicator for the future. Measures also effects from unintentional eco-innovation.	To be used as one of the key indicators, although a longer time lag may still be needed to see the effects from intentional eco-innovation to reduce greenhouse gases.
11.2	Weighted emissions of acidifying pollutants per GDP	Effect	Unintentional /Intentional	Strong and reasonable correlations with many indicators from all types.	Important effect indicator. Measures also effects from unintentional eco-innovation, although to a lesser extent, as most pollution reductions are made to meet regulations.	To be used as one of the key indicators.

REFERENCES

Arimura, T.H., Hibiki, A. and N. Johnstone, 2007. An empirical study of environmental R&D: What encourages facilities to be environmentally innovative? In *Environmental policy and corporate behaviour*, by N. Johnstone (Ed.). Cheltenham, UK: Edward Elgar and Paris: OECD.

Arundel, A., 2005. *Lessons from innovation indicators: What can we ask in a survey?* Maastricht: MERIT.

Arundel, A., Kemp, R. and S. Parto, 2006. Indicators for environmental innovation: What and how to measure, in *The international handbook on environmental technology management*, by Marinova, D., Annandale, D. and J. Phillimore (Eds.). Cheltenham, UK: Edward Elgar.

Brunnermeier, S.B. and M.A. Cohen, 2003. Determinants of environmental innovation in US manufacturing industries, *Journal of Environmental Economics and Management,* 45, pp. 278-293.

Doornbosch, R. and Steenblik R., 2007. *Biofuels: Is the cure worse than the disease? Round Table of Sustainable Development, Paris, 11-12 September*. Paris: OECD.

ECOTEC, 2002. *Analysis of the EU eco-industries, their employment and export potential – A final report to DG Environment.* London: ECOTEC.

Ernst & Young, 2006. *Eco-industry, its size, employment, perspectives and barriers to growth in an enlarged EU – Final report*. Brussels: European Commission, DG Environment.

European Commission, 2001. *European economy, no. 73*. Brussels: EC.

European Commission, 2006. Use of intelligent systems in vehicles. *Special Eurobarometer 267*. Brussels: EC.

European Commission, 2007. Energy technologies: Knowledge, perception, measures. *Special Eurobarometer 262*. Brussels: EC.

Eurostat, 2007. *Draft compilation guide on environmental sector, version 4*. European Commission, Luxembourg: Eurostat.

Frondel, M., Horbach, J. and K. Rennings, 2005. End-of-pipe or cleaner production? An empirical comparison of environmental innovation decisions across OECD countries, *Business Strategy and the Environment* (forthcoming).

Fukasaku, Y., 2005. The need for environmental innovation indicators and data from a policy perspective, in *Towards environmental innovation systems* by Weber, M. and J. Hemmelskamp (Eds.). Berlin: Springer.

Hernesniemi, H. and H. Sundquist, 2007. *Rapidly growing environmental business needs monitoring*. Helsinki: SITRA.

Horbach, J., 2006. *Determinants of environmental innovation – New evidence from German panel data sources.* Presentation at the FEEM Nota di Lavoro conference in Milano.

Horbach, J. and K. Rennings, 2007. (Panel-) survey analysis of eco-innovation: Possibilities and Propositions, *Deliverable 4 and 5 of MEI project*. Centre for European Economic Research (ZEW).

ICEDD, Wuppertal Institut and Institute of Social Ecology – IFF, 2006. *Supply of the statistical services in the field of the environment – Final report for the European Commission and Eurostat.*

Kemp, Rene, 2007. *Workshop meeting report for the MEI project*, May. UNU-MERIT.

Kennett, M. and R. Steenblik, 2005. Environmental goods and services: A synthesis of country studies, *OECD Trade and Environment Working Paper No. 2005-3.* Paris: OECD.

Kleinknecht, A., van Montfort, K. and E. Brouwer, 2002. The non-trivial choice between innovation indicators, *Economics of Innovation and New Technology*, 11(2), pp. 109-121.

Lanjouw, J.O. and A. Mody, 1996. Innovation and the international diffusion of environmentally responsive technology, *Research Policy*, 25, pp. 549-571.

Legler, H., Schmoch, U., Gehrke, B. and O. Krawczyk, 2003. Innovationsindikatoren zur Umweltwirtschaft, *Studien zum deutschen Innovationssytem,* Nr. 2. Hannover: NIW and Karlsruhe: Fraunhofer Institut.

Marinova, D. and M. McAleer, 2006. Comparison of international strenghts in sustainable technological solutions, in *The international handbook on environmental technology management*, by Marinova, D., Annandale, D. and J. Phillimore (Eds.). Cheltenham, UK: Edward Elgar.

OECD, 2006. *Compendium of patent statistics*. Paris: OECD.

Oltra, V., Kemp, R. and de Vries, F., 2007. *Patents as a measure for eco-innovation,* report for the MEI project. University of Bordeaux, UNU-MERIT and University of Stirling.

Peter, V., 2006. *Eco-industries – Scoping paper for the Systematic project*. Technopolis.

Popp, D., 2005. *Using the triadic patent family database to study environmental innovation.* OECD.

Rehfeld, K.-M., Rennings, K. and A. Ziegler, 2004. Integrated product policy and environmental product innovations: An empirical analysis. *ZEW discussion paper no. 04-71,* Mannheim: ZEW.

Rennings, K., Ziegler, A., Ankele, K., Hoffmann, E. and J. Nill, 2003. The influence of the EU Environemntal Management and Auditing Scheme on environmental innovations and competitiveness in Germany: An analysis on the basis of case studies and a large-scale survey. *ZEW discussion paper no. 03-14,* Mannheim: ZEW.

Sasson, A., 2005. Industrial and environmental biotechnology – Achievements, prospects and perceptions. *UNU-IAS Report.* Yokohama: UNU-IAS.

Stanners, D. and P. Bourdeau (Eds.), 1995. *Europe's environment – The Dobris assessment.* Copenhagen: European Environment Agency.

Steenblik, R., 2005. Environmental goods: A comparison of the APEC and OECD lists, *OECD Trade and Environment Working Paper No. 2005-4.* Paris: OECD.

Stern, N., 2007. *The economics of climate change – The Stern review*. Cambridge University Press.

Taylor, M.R., Rubin, E.S. and D.A. Hounshell, 2005. Regulation as the mother of innovation: The case of SO_2 control, *Law and Policy*, 27(2), pp. 348-378.

Trade and Development Board, 2003. *Environmental goods: Trade statistics of developing countries.* UN.

ZEW, 2001. *The impact of clean production on employment in Europe – An analysis using surveys and case studies (IMPRESS).* Final report, coordinated by K. Rennings, ZEW. Mannheim: ZEW Centre for European Economic Research.

United Nations, 2001. *Classification of Environmental protection activities and expenditure (CEPA 2000) with explanatory notes, ESA/STAT/AC.78/5.* UN.

van der Voet, E., van Oers, L., Moll, S., Schutz, H., Bringezu, S., de Bruyn, S., Sevenster, M. And G. Warringa, 2005. *Policy review on decoupling: Development of indicators to assess decoupling of economic development and environmental pressure in the EU-25 and AC-3 countries*. Report commissioned by the European Commission.

World Economic Forum, 2001. *Global Competitiveness Report 2001-2002*. Geneva: WEF.

World Economic Forum, 2006. *Global Competitiveness Report 2006-2007*. Geneva: WEF.

Annex I

Defining the EGSS

Looking at the environmental sector from the point of view of the main users, and therefore potentially also the main producers of environmental technology, especially process technology, Stanners and Bourdeau (1995) identified the following NACE manufacturing sectors as the *most polluting* (so, quickest and most efficient benefit from eco-innovation):

- DC19 Leather and tanning
- DE21 Pulp and paper
- DF23 Refineries, petroleum products
- DG24 Chemicals (industrial inorganic and organic compounds)
- DI26 Cement, glass and ceramics industries
- DJ 27 Basic metals (iron, steel and non-ferrous metals)

However, from the point of view of the *most sizeable impact on the environment*, EEA (2005), among others, identifies the biggest sectors as transport, agriculture, energy production, total industry and households. In other words, apart from the service sectors, most major sectors have a very big impact, and trying to classify the users of environmental goods and services in this way soon becomes meaningless.

Two separate organizations, the OECD and APEC, produced in the late 1990s a list of *products that have environmental uses*. The lists have attracted attention for notable effort to achieve something almost not achievable. They differ to a large extent and therefore, together they are called the OECD/APEC list, with nearly 200 unique HS 6-digit codes (see e.g. Steenblik, 2005, for the list(s)). However, the main drawback of this (combined) list is that many of the products have multiple uses, only one of which may be environmental. Trade and Development Board (2003) discuss the limitations of the list in more detail. The WTO is currently attempting to update, or improve this list.

If we do take such a product code list as a relatively good representation of the EGSS, we can calculate some statistics for the sector, such as trade statistics. In principle, the HS product codes could also be translated to NACE codes via a correspondence table, but the same drawbacks as with the original product code list would probably reappear.

Another approach to the problem of defining the EGSS could be looking at *patent data*. There exist a number of patent code lists for narrowly defined areas of environmental technology. Putting these all together could produce a somewhat better defined list of products from the sector, which could then be translated to NACE codes. However, there are some drawbacks to using patent data to study the eco-sector. In general, firms are less likely to patent research that results in new processes (rather than new products), and therefore much of the stock of environmental patents are related to end-of-pipe treatment of pollution, rather than cleaner production (see Section 3.1 of this report and Popp (2005?) for more detail).

Finally, *code lists, such as NACE codes, can be searched with keywords*, in order to arrive to an appropriate list for the EGSS. With an extensive and good quality list of keywords (including keywords such as ‘photovoltaic’ or ‘waste’), the NACE code database, which has detailed descriptions of each NACE class at the 4-digit level, in Eurostat’s metadata server can be searched, and a list of NACE classes relevant to the EGS can be created. But this list has its limitations as well, as not all environmental goods or services can be identified via such keywords.

Following is a list of some of the sectors (with NACE codes) that can be classified as belonging to the EGSS. This list is partly created with the keyword search method described above, and partly just looking at the main sectors that include environmental goods and services. It is just a quick attempt to look at how the EGSS could possibly be defined using sector codes, such as the NACE codes. Ideally, the next NACE revision, would include much more detail (at 5 or 6-digit level) of various activities, so that also sectors such as 'sustainable agriculture' could have their own NACE codes.

Some of the main EGS sectors

Category	**NACE code**	**Description of the NACE code (as it appears in the 4-digit code list), and examples of EGS within the sectors[75]**
Agriculture	A1	Agriculture, hunting and related service activities (incl. sustainable agriculture and fishing)
	A2	Forestry, logging and related service activities (incl. sustainable forestry)
Construction	F45	Includes environmental construction
Energy	E40	Electricity, gas, steam and hot water supply (incl. supply of energy from renewable sources)
	E41	Collection, purification and distribution of water
	DK29.12	Manufacture of pumps and compressors (incl. wind turbines)
	DL31	electrical machinery and apparatus (incl. e.g. energy-saving appliances)
	DL32.10	Electronic valves and tubes and other electronic components (incl. photovoltaic cells)
Industrial processes	DL33.2	Instruments and appliances for measuring, checking, testing, navigating etc.
	DL33.3	Manufacture of industrial process control equipment
Resource management	DH 25.12	Retreading and rebuilding of rubber tyres
	DN37	Recycling
	G51.57	Wholesale of waste & scrap
	K74.2	Architectural and engineering activities and related technical consultancy (incl. consultancies for pollution control)
	K74.3	Technical testing and analysis (incl. pollution control)
	O90	Sewage and refuse disposal, sanitation and similar activities
Transport	DM34	Manufacture of motor vehicles, trailers and semi-trailers (incl. hybrid or electric vehicles)
	DM35	Manufacture of other transport equipment
	I60	Land transport (incl. use of intelligent transport systems)
	I61	Water transport
	I62	Air transport
Research & development	K73	Includes public environmental R&D

[75] Please note that the examples of eco-sectors in the last column have no separate NACE codes.

Annex II

Eco-innovation indicators considered

Indicator category		Indicator *(indicator name used in Table 2, Section 5)*	Pressure /Facilitator /Input /Output /Effect	Unintentional /Intentional innovation with beneficial effects on the environment	Sector level data available (importance of sector level data)	National level available (for EU-27)	Source, data years included	Comments
Public attitudes and behaviour	1.1	Preparedness to pay more: Public opinion in favour of paying more for energy produced from renewable sources than for energy produced from other sources	Pressure	Intentional	N/A	Yes, but NMS not covered	Eurostat: Eurobarometer 57.0;2002	
Public attitudes and behaviour	1.2	Acceptance of renewable energy sources: Public opinion strongly in favour of using domestic wind energy in the EU-25 countries *(att_wind_energy)*	Pressure	Intentional	N/A	Yes (except BG, RO)	Eurostat: Special Eurobarometer 262;2006	
Public attitudes and behaviour	1.3	Importance of reducing energy consumption: Public opinion strongly in favour of reducing domestic energy consumption in the EU-25 countries	Pressure	Intentional	N/A	Yes (except BG, RO)	Eurostat: Special Eurobarometer 262;2006	
Public attitudes and behaviour	1.4	Importance of energy-related research in the EU: Public opinion in the EU in favour of more energy-related research in the EU in cleaner means of transport *(att_clean_tr_RD)*	Pressure	Intentional	N/A	Yes, but NMS not covered	Eurostat: Eurobarometer 57.0;2002	
Public attitudes and behaviour	1.5	Importance of energy-related research in the EU: Public opinion in the EU-25 countries strongly in favour of such research being a priority in the EU	Pressure	Intentional	N/A	Yes (except BG, RO)	Eurostat: Special Eurobarometer 262;2006	
Public attitudes and behaviour	1.6	Factors affecting the choice of car – which matter most: Public in the EU-25 countries considering one of the following as most important for themselves: cars with low fuel consumption and environmentally clean cars	Pressure	Intentional	N/A	Yes (except BG, RO)	Eurostat: Special Eurobarometer 267;2006	
Environmental regulations	2.1	Implicit tax rate on energy (ratio of energy tax revenues to final energy consumption) *(energy_tax)*	Pressure	Intentional	N/A	Yes (except BG, RO, SK)	Eurostat;2000-2004	Tax revenues not by sector, final energy cons data totals various sectors, excluding energy industries themselves.
Environmental regulations	2.2	Environmental regulatory regime index, ERRI *(ERRI)*	Pressure	Intentional	N/A	Yes (except CY, LU, MT)	Global Competitiveness Report 2001-02	
Environmental regulations	2.3	Stringency of environmental regulations – index	Pressure	Intentional	N/A	Yes	Global Competitiveness Report 2006-07	

Environmental regulations	2.4	Clarity and stability of regulations - index	Pressure	Intentional	No (medium)	Yes (except BG, RO)	Global Competitiveness Report 2006-07	
R&D and other innovation investments and activities	4.5	Publications (in specialized journals) in 'environment/ecology' in the EU-25 per 100,000 capita *(publications)*	Input	Intentional	N/A	Yes (from this source no data for BG, RO)	NSB, Thomson-ISI, from Peter, 2006; data for 2001	
Environmental regulations	2.5	Perceived competitive disadvantage from the need to meet environmental regulations for new products or services *(compt_prod)*	Pressure	Intentional	Very aggregate (medium)	Yes (except BG, RO)	Eurostat: Innobarometer 2004	
Patents (within/outside EGSS)	5.1	Patent counts in the EGSS based on priority dates of patent applications (included here: environmental technology, wind energy, fuel cell technology) – national indexes relative to population size *(env_patents)*	Input	Intentional	Some (medium)	Yes (for data included here only 11 out of EU-27)	OECD, 2006; only totals for 1999-2003 included	Data in this report cover only EGSS related patents. Aggregate level data for manufacturing and certain high-tech fields is available from e.g. Eurostat. However, separating eco-innovation related patents outside the EGSS from the rest would be difficult.
Environmental regulations	2.6	Perceived competitive disadvantage from the need to meet environmental regulations for new or improved processes ('negative' indicator)	Pressure	Intentional	Very aggregate (medium)	Yes (except BG, RO)	Eurostat: Innobarometer 2004	
Market conditions	2.7	Venture capital for firms in the EGSS	Pressure	Intentional	No (medium)	No	EVCA	Currently, there are no data at a European level available for this indicator. However, EVCA is planning on providing such data in the future (Hernesniemi & Sundquist, 2007). DATA NOT INCLUDED.
Intermediate energy and material inputs	6.1	Share of renewable energy - Contribution of electricity from renewables to total electricity consumption (%) *(share_renew_en)*	Output	Intentional	Very aggregate (medium)	Yes	Eurostat; 2000-2005	
Intermediate energy and material inputs	6.2	Intermediate energy inputs (IIE) at current purchasers' prices per GDP (NACE A to O) ('negative' indicator)	Output	Unintentional /Intentional	Aggregate (medium)	Yes (except BG, CY, IE, LT, LV, PT, RO)	EUKLEMS database (http://www.euklems.net/euk0307.shtml); data for 2000 and 2004	Coverage for the new member states is rather poor.
Environmental management/organizational changes	3.1	EMAS certifications per billion euro GDP *(EMAS)*	Facilitator	Intentional	No (medium)	Yes, but NMS not covered	Eurostat; 2000-2004	For the New Member States, EMAS registrations only started from 1 May 2004, therefore data for these countries is not yet available or not comparable to the EU-15.
Intermediate energy and material inputs	6.3	Intermediate material inputs (IIM) at current purchasers' prices per GDP (NACE A to O) ('negative' indicator) *(IIM)*	Output	Unintentional /Intentional	Aggregate (medium)	Yes (except BG, CY, IE, LT, LV, PT, RO)	EUKLEMS database (http://www.euklems.net/euk0307.shtml); data for 2000 and 2004	Coverage for the new member states is rather poor.
Environmental management/organizational changes	3.2	ISO 14001 certifications per million euro GDP *(ISO14001)*	Facilitator	Intentional	No (medium)	Yes	Eurostat; 2000-2004	All EU-27 covered.
Environmental management/organizational changes	3.3	Community eco-label awards per billion euro GDP *(eco_lbl)*	Facilitator	Intentional	No (medium)	Yes, but NMS not covered	Eurostat; 2001-2005	For the New Member States, Community eco-label awards only started from 1 May 2004, therefore data for these countries is not yet available or not comparable to the EU-15.
Sales/profits from environmentally beneficial innovation	7.1	Sales from eco-innovation across sectors	Output	Unintentional /Intentional	No (medium)	No	N/A	This data do not exist at any international level, but the topic could be included in the CIS or another EU-wide survey. DATA NOT INCLUDED.
R&D and other innovation investments and activities	4.1	Public environmental R&D (GBAORD) as a share of total public R&D (GOVERD) *(public_env_RD)*	Input	Intentional	N/A	Yes	Eurostat; 2000-2005	
Growth of EGSS	8.1	Foreign direct investment (FDI) in EGSS	Output	Intentional	Aggregated (high)	Yes	UNCTAD	This is an EGSS indicator. However, data for even the core EGSS are mostly not available. DATA NOT INCLUDED.
R&D and other innovation investments and activities	4.2	Business environmental R&D, as a share of total business expenditure on R&D (BERD)	Input	Intentional	No (medium)	No	N/A	Data are not yet consistently collected at an international level. DATA NOT INCLUDED.
Growth of EGSS	8.2	National investment (gross investment in tangible goods) in EGSS (DN37 and E41) per gross fixed capital formation (GFCF) *(nat_inv_EGSS)*	Output	Intentional	Aggregated (high)	Yes	Eurostat; 2000-2004	Data for two out of the core EGSS NACE sectors are available from Eurostat.
R&D and other innovation investments and activities	4.3	Engaged in acquisition of machinery, as a share of all innovating firms (weighted by share of innovative firms)	Input	Unintentional /Intentional	Aggregate (medium)	Yes (but NMS not included)	Eurostat; CIS-3 data for 2000	
Growth of EGSS	8.3	Total current expenditure on environmental protection per value added	Output	Intentional	C, D, E, aggregated, mostly 2-digit NACE	Yes, but only country totals for C to E from Eurostat	Eurostat; 2004, or most recent available	Indicator for environmental protection investment by all sectors. Not all countries covered. Data availability poor, especially prior to 2004.
R&D and other innovation investments and activities	4.4	Expenditure in acquisition of machinery, as a share of total turnover of all innovative firms (weighted by share of innovative firms)	Input	Unintentional /Intentional	Aggregate (medium)	Yes (except AT, IE, LU PL, SE)	Eurostat;CIS-3 data for 2000	

Growth of EGSS	8.4	Investment in equipment and plants linked to cleaner technology per value-added *(inv_clean_tech)*	Output	Intentional	C, D, E, aggregated, mostly 2-digit NACE (medium)	Yes, but only country totals for C to E from Eurostat	Eurostat; 2002-2004	Indicator for clean technology investment by all sectors. Not all countries covered.
Growth of EGSS	8.5	Investment in equipment and plants for pollution control per value-added *(inv_poll_ctr)*	Output	Intentional	C, D, E, aggregated, mostly 2-digit NACE (medium)	Yes, but only country totals for C to E from Eurostat	Eurostat; 2002-2004	Indicator for pollution control investment by all sectors. Not all countries covered.
Growth of EGSS	8.6	Clean Development Mechanism (CDM) – number of registered projects	Output	Intentional	Some aggregate level sectoral data, but not available per country and sector (medium)	Yes (only some EU countries participating so far)	UNFCCC website cdm.unfccc.int/Statistics/index.html	This data are new, and the numbers of projects have not build up sufficiently yet. EU country coverage is also poor. Finally, the projects are of very different sizes. DATA NOT INCLUDED.
Growth of EGSS	8.7	Clean Development Mechanism (CDM) – number of certified emission reductions (CERs) issued per total national greenhouse gas emissions	Output	Intentional	No (medium)	Yes (only some EU countries participating so far)	UNFCCC website cdm.unfccc.int/Issuance/cers_iss.html	This data are new, and the numbers of projects have not build up sufficiently yet. EU country coverage is also poor. This is however a better alternative for the number of registered CDM projects, as it takes account of project size. However, currently data per individual country is not yet available from the UNFCC website. DATA NOT INCLUDED.
Growth of EGSS	8.8	Country rankings in Green Pages per billion euro GDP *(green_pages)*	Output	Intentional	Yes (EGSS sectors included only)	Yes	Green Pages website www.eco-web.com; 2007 Eurostat estimate for 2007 GDP	Firms are classified based on their environmental field. Possible bias for the UK (website is in English only).
Trade in EGSS products	9.1	Exports in EU-27 eco-industry products to China and India (as share of total exports to these countries) (*expts_india* and *expts_china*)	Output	Intentional	Yes, but by product groups (e.g. 6-digit HS-codes) (high)	Yes	COMTRADE, OECD; 2002-2005	The OECD/APEC combined list of products is used. Although the list is created in order to capture trade in the eco-industries, most of the products have other uses besides those beneficial for the environment.
Trade in EGSS products	9.2	Relative world shares (RWS) – relative position of a nation in international trade in EGS (export orientation) *(RWS)*	Output	Intentional	N/A	Yes	Legler et al., 2003; data for 1991, 1999 and 2000	Only 2000 data used.

Trade in EGSS products	9.3	Revealed comparative advantage (RCA) – export-import ratio compared to the pattern of all traded goods	Output	Intentional	N/A	Yes	Legler et al., 2003; data for 1991, 1999 and 2000	Only 2000 data used.
Energy and material intensity	10.1	Energy intensity of the economy - Gross inland consumption of energy divided by GDP, kgoe (kilogram of oil equivalent) per 1000 euro ('negative' indicator) *(energy_intens)*	Effect	Unintentional /Intentional	No (medium)	Yes	Eurostat; 2000-2005	
Energy and material intensity	10.2	Resource productivity of the economy – GDP per direct material consumption (DMC) (euro/kg) *(resource_prod)*	Effect	Unintentional /Intentional	No (medium)	Yes (except LU)	van der Voet, 2005; data for 2000	
Energy and material intensity	10.3	Effects from product or process innovation – reduced materials and energy per produced unit (weighted by share of innovative firms) *(reduc_mat_energy)*	Effect	Unintentional /Intentional	Aggregate (medium)	Yes	Eurostat; CIS-3 (2000) and CIS-4 (2004) data	Sector detail is better in CIS4 than in CIS-3. Not all service sectors are covered.
Pollution and waste levels	11.1	Weighted emissions of greenhouse gases (Million tonnes of CO2 equivalent) per capita ('negative' indicator) *(ghg)*	Effect	Unintentional /Intentional	Some very aggregate level data (medium)	Yes	Eurostat; 2000-2004	
Pollution and waste levels	11.2	Weighted emissions of acidifying pollutants (1 000 tonnes of acid equivalent) per GDP ('negative' indicator) *(acid_poll)*	Effect	Unintentional /Intentional	Some very aggregate level data (medium)	Yes	Eurostat; 2000-2004	
Pollution and waste levels	11.3	Amount of waste generated (1 000 t) per GDP ('negative' indicator)	Effect	Unintentional /Intentional	Some very aggregate level data (medium)	Yes, but data only for 15 countries at the most (for 2002)	Eurostat; 2000-2002 (2003)	Data coverage poor, especially for 2003. No later data available from Eurostat (NewCronos). Data includes countries in both EU-15 and the new member states.
Other innovation effects	12.1	Effects from product or process innovation – highly improved environmental impact or health and safety aspects (weighted by share of innovative firms) *(impr_ehs_impct)*	Effect	Unintentional /Intentional	Aggregate (medium)	Yes	Eurostat; CIS-3 (2000) and CIS-4 (2004) data	The question is only partly related to environmental effects. Sector detail is better in CIS4 than in CIS-3. Not all service sectors are covered.
Other innovation effects	12.2	Effects from product or process innovation – met regulation requirements (weighted by share of innovative firms) *(reg_reqs_met)*	Effect	Intentional	Aggregate (medium)	Yes	Eurostat; CIS-3 (2000) and CIS-4 (2004) data	The question is only partly related to environmental effects (here: environmental regulations). Sector detail is better in CIS4 than in CIS-3. Not all service sectors are covered.