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Environmental innovation: Using qualitative models to identify indicators for policy

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Using qualitative models to identify indicators for policy[1]

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Abstract

Environmental innovation is an essential part of a knowledge based economy, as 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 should also result in fewer externalities, or negative environmental impacts, which affect our health and well-being, also in terms of global climate change. Technology shifts caused by technological breakthroughs, rapid changes in demand for resources, or environmental imperatives could also impel societies to invest more heavily in research on how to use energy and other resources more efficiently. The main goal of this paper 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. This is done firstly with the help of a qualitative model presenting the eco-innovation chain. Based on both literature and our data analysis, our chosen key indicators include measures on: environmental regulations and venture capital for the eco-industry; environmental publications, patents and business R&D; eco-industry exports and FDI; sales from environmentally beneficial innovation across sectors; and environmental impacts related to energy intensity and resource productivity of economies. Finding key eco-innovation indicators related to such factors is important for policy makers, as environmental innovation policy is required to counter the two market failures associated with environmental pollution and the innovation and diffusion of new technologies.

Keywords: Environmental innovation; environmental goods and services; innovation indicators; CIS; environmental impacts; European Union

JEL codes: O14, O30, O33, O38, Q51, Q55, Q58

[1] This paper has also contributed to a European Commission project Knowledge Economy Indicators (KEI) in 2007.

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1. Introduction

The main goal of this paper 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 of value to policy development 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 in innovative activities and output indicators on the results of innovation expenditures, such as sales or profits from innovation, or trade in innovative products.

In addition to indicators on inputs and outputs, understanding environmental can require indicators on drivers, facilitators and effects. *Drivers* include environmental regulations and 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, eco-innovation can lead to desired environmental *effects*, such as fewer material resources consumed per unit of production or a decline in pollution or greenhouse gases. Correlation analysis can help explore the links between drivers and facilitators on inputs, outputs, and effects. Identifying these links can help us pinpoint the key indicators.

Environmental innovation is an essential part of a knowledge based economy (KBE) - it 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.

There is much interest in the role of environmental policy in encouraging environmental innovation, and also some empirical evidence for the importance of policy actions (see e.g. Ashford et al, 1985; Jaffe et al., 2002; Kemp and Pontoglio, 2008; Lanoie et al., 2007; OECD, 2005; and Vollebergh, 2007). As Rennings (2000) and Jaffe et al. (2004) argue, there are two kinds of interacting market failures involved, one to do with environmental pollution and the other with the innovation and diffusion of new technologies. Environmental innovation policy can help counter these two market failures, but the development of such policies requires information on eco-innovation activities. It is here where indicators can help by measuring factors that help or hinder the social goals of environmentally sustainable economic growth.

This paper is structured in the following way. In Section 2 we discuss some definitional issues, such as what is currently considered environmental innovation and where it takes place. We will also present a qualitative model of eco-innovation that explores the links between different factors. Sections 3 and 4 discuss the availability of indicators for environmental innovation and describe the methodology used in the analyses in this paper. Potential environmental indicators are described in Section 5. Section 6 touches on the problem of causality and continues by discussing our correlation results. Finally, Section 7 concludes by giving some recommendations for relevant key indicators and discussing policy implications.

2. Theory of environmental innovation

2.1 Non-intentional eco-innovation

Environmental innovations do not need to be explicitly designed to address environmental issues. In fact, more than half of all technological innovations have been estimated to have beneficial effects on the environment (see e.g. Kemp, 2007). Two recent studies for the European Commission and the OECD report that the share of *innovative* firms that do not 'eco-innovate' in any form (intentionally or unintentionally) is only between 20%-30% (Kemp, 2007). Conversely, intentional eco-innovation can have unintended or unseen negative environmental consequences. For example, growing crops to make biofuels can lead to the destruction of forest land to grow biofuel crops, releasing substantial quantities of greenhouses gases (Doornbosch and Steenblik, 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 and Pearson, 2008). Every investment that an organization makes includes a choice (intentional or not) between more or less environmentally beneficial technologies.

Measuring non-intentional environmental innovation activity is therefore crucially important, but there are some challenges to this. Throughout the innovation chain (including R&D, other innovation activities, the diffusion of innovative products and the 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 non-intentional environmental innovations. Secondly, estimating a monetary value for these innovations can be difficult, since they are often not seen by firms as 'eco-innovations', nor can they be identified by using national accounts for sector outputs, since they occur in all economic sectors.

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 Goods and Services Sector (EGSS). Innovation in this sector can be

assumed to predominantly produce environmental innovations. When adopted, they count as eco-innovation (in the sector of use) but the EGGS sector may also produce eco-innovations in the form of environmentally improved products and services and create altogether new products and services. Some of these innovations can be unique to the EGSS.

The Eurostat recently defined the EGSS (Eurostat, 2009) to consist of "a heterogeneous set of produces of technologies, goods and services that:

> Measure, control, restore, prevent, treat, minimise, research and sensitise environmental damages to air, water and soil as well as problems related to waste, noise, biodiversity and landscapes. This includes 'cleaner' technologies, goods and services that prevent or minimise pollution.
>
> Measure, control, restore, prevent, minimise, research and sensitise resource depletion. This results mainly in resource-efficient technologies, goods and services that minimise the use of natural resources." (p. 29)[2]

Therefore, the EGSS is defined to include both environmental protection and resource management. Eurostat goes on further to say that:

> "These technologies and products (i.e. goods and services) must satisfy the end purpose criterion, i.e. they must have an environmental protection or resource management purpose (hereinafter 'environmental purpose') as their prime objective." (p.29)

Eurostat thus defines EGSS to only include intentional eco-innovation, presumably to facilitate quantifying the EGSS.

In order to measure the EGSS, however, we need not only a 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 until recently (see e.g. Ernst & Young, 2006, Peter, 2006 or ECOTEC, 2002).[3]

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 or

[2] The previous definition from the Eurostat and the OECD was from 1999, and did not include these resource management activities (ICEDD et al., 2006).

[3] For example, Ernst & Young (2006) estimated that 2.2% of European GDP is due to the core EGSS. In fact, the main 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 within the EU-15.

nanotechnology, which can be used in many different technological areas. As a result, there are few 'dedicated' sectoral classes belonging to just the EGSS. However, the latest update to the NACE codes, revision 2 (Eurostat, 2008),[4] is slightly better than the previous NACE revision 1.1 in that it combines a number of environmental activities under section E 'Water supply, sewerage, waste management and remediation activities'. This section regroups most of the environmental activities that were previously classified under NACE rev. 1.1 divisions E41, O90, DN37 or K74 (Eurostat, 2008 and 2009). Even so, there are a large number of NACE codes, where often only a minor part belongs to the EGSS (e.g. a fairly detailed, 4-digit NACE rev. 2 class C28.11 – Manufacture of engines and turbines, which includes wind turbines). So, even the 4-digit level of NACE codes - the most detailed level used internationally - does not, in a large number of cases, allow one to separate the eco-industry sectors from other sectors.[5]

The EGSS 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, for example, those sectors which would most benefit from environmental technology by being very polluting,[6] or the sectors that have the most sizeable impact on the environment in terms of resource use.[7] Often, the same actors can both produce and use their own environmental technology or products.[8] Importantly, Eurostat has recently produced a handbook (Eurostat, 2009) for collecting statistics on the EGSS, and an integral part of the process is a bottom to top approach of defining the EGSS separately for each EU country. The defining is to be done by using a

[4] Whenever this paper makes references to NACE sections (letters), divisions (2-digit level), groups (3-digit level) or classes (4-digit level), it specifies whether they are references to the new NACE rev. 2 or the previous NACE rev. 1.1.

[5] 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 as regards environmental protection activities. Similarly, Eurostat (2009) proposes CReMA (Classification of Resource Management Activities), adopted by Eurostat from CRUMA (Classification of Resource Use and Management Activities, Ardi and Falcitelli, 2007), to be used for the resource management activities. However, there are no correspondence tables between CEPA or CReMA, and other, general classifications systems, such as NACE, used to classify activities, or CPA (Classification of Products by Activity) and HS (Harmonized System), used to classify products.

[6] Stanners and Bourdeau (1995) identified the following NACE rev. 1.1 manufacturing sectors as the most polluting, and thus with the quickest and most efficient benefit from eco-innovation (rev. 2 codes in brackets): DC19 Leather and tanning (C15); DE21 Pulp and paper (C17); DF23 Refineries, petroleum products (C19); DG24 Chemicals - industrial inorganic and organic compounds (C20); DI26 Cement, glass and ceramics industries (C23); DJ 27 Basic metals - iron, steel and non-ferrous metals (C24).

[7] EEA (2005) summarizes several studies which try to identify priority areas in terms of environmental impact. Taken together, the list of sectors becomes very long and so, trying to classify the users of environmental goods and services in this way is challenging.

[8] For example, a large petroleum refining firm can often develop environmentally beneficial improvements in-house, and the paper industry regularly produces the energy it needs from its own renewable energy sources.

number of different methods, looking at producers, users, technologies, goods, services and other activities. The end result should be a dataset containing individual producers, firms and other relevant establishments, with their specific NACE codes and other related statistics.[9]

As regards the analysis in this paper, whenever the data include specific EGSS related NACE sectors, the references are to NACE rev. 1.1, as the data used for the analysis have only been available according to this revision.[10] Of the sectors in NACE rev. 1.1 that are mostly within the EGSS, only three have been defined at the 2-digit level, for which data have been generally more easily available, for example, from Eurostat NewCronos. These three sectors are DN37, E41 and O90, now mostly part of NACE rev. 2 section E.[11] As discussed earlier, much of other EGSS escapes precise definition within the NACE system. It covers firms that are at least partly active in the environmental protection or resource management domain, and it includes firms from a large variety of NACE groups.

In our paper, some of the indicators are specific to the EGSS, but the definition of EGSS varies due to inconsistent data. For example, sometimes there are only data for a specific part of the EGSS, such as renewable energy, or pollution control technology, and at other times the data cover several EGS (environmental goods and services) sectors, such as exports of EGSS-related products. Annex I gives details of the indicators considered.

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

Figure 1 explains how the different processes of environmental innovation are linked, as well as showing some of the available indicators. We use an environmental innovation, namely supporting the farming and production of bio-fuels for beneficial environmental effects. Section 5 discusses the indicators in more detail. As an illustrative example, we explain the different components of Figure 1 using bioethanol and other biofuels.

Concerns over the effects of greenhouse gas production on the *state of the environment* have bought biofuels back in fashion.[12] As a result of *scientific* research on climate change and *media* reporting on the science, *public opinion* as well as decision-makers have put additional pressure

[9] The process of collecting these data is only starting in the EU member countries.
[10] NACE rev. 2 will be applied to all economic activities performed from 1 January 2008. The analysis for this paper was conducted in 2007.
[11] A straightforward translation between 2-digit level divisions in revisions 1.1 and 2 is not possible, however.
[12] Not all biofuels are current innovations. The first car of Henry Ford was fuelled by ethanol (Sasson, 2005).

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, produce biodiesel from algae, or to produce high energy-density biofuels from sugar cane. As a result, the output of innovative biofuels increased markedly in several countries and the *profits* from selling biofuel increased until the start of the current financial crisis.

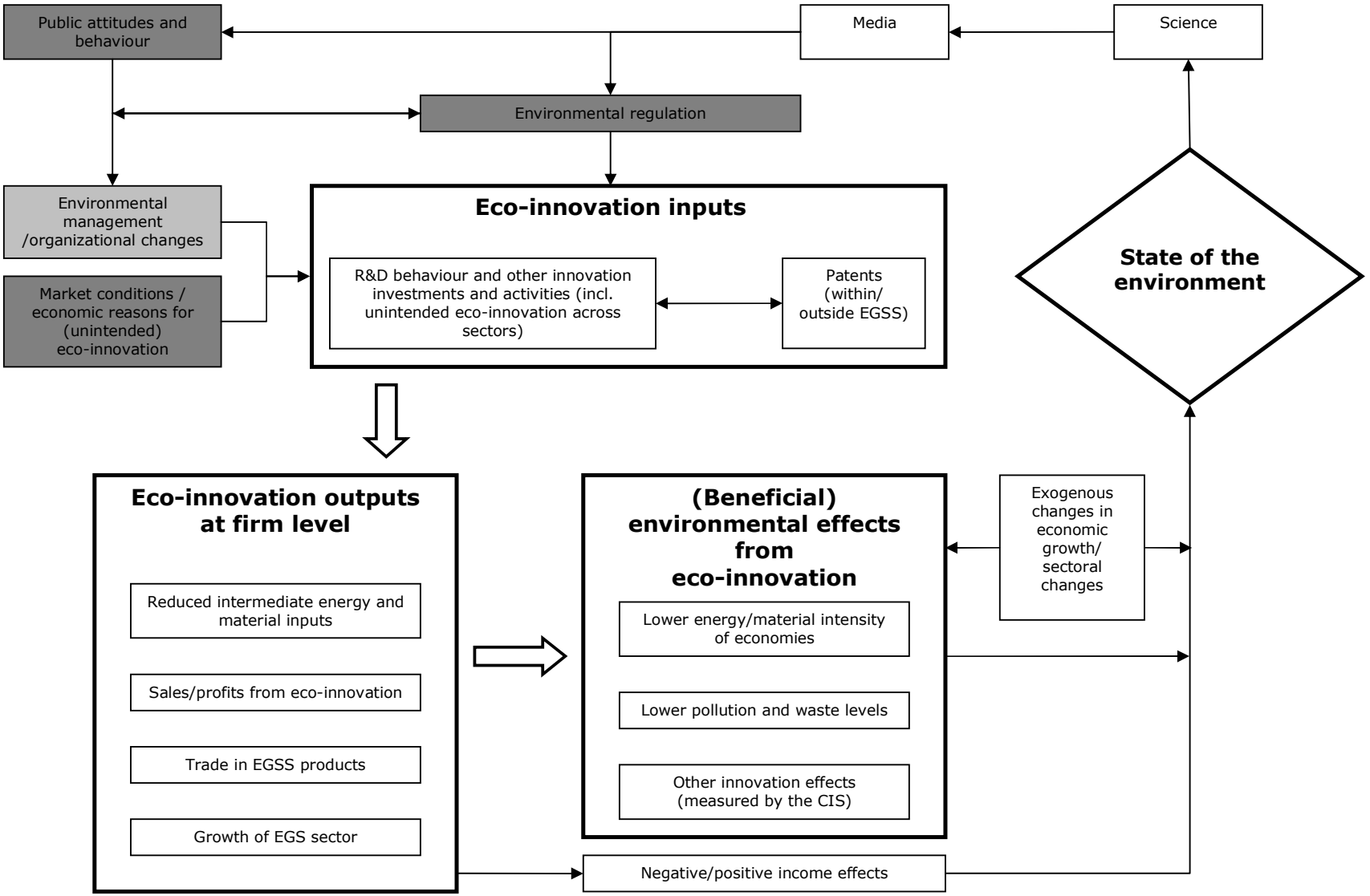
Presumably, the beneficial environmental impact of this change is a *reduced amount of CO_2 pollution* from transport and other fuel use, which positively affects the *state of the environment*. What firms do with their increased *income* from making biofuels can then be positive for the environment, 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. Examples of endogenous effects include increased food prices as a consequence of diverting food crops to biofuel production and investment in developing improved biofuels that can capture some of the subsidies that currently go to bioethanol. An exogenous effect is an increase in demand for biofuels as a result of rapid economic growth in India and China.[13]

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.[14]

This eco-innovation scheme requires time: the loop from science, drivers and impacts etc. can take many years. In the data that we include in our analysis, we try to take this into account. Data availability poses some problem here though.

[13] 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).
[14] Horbach and Rennings (2007) contains an overview of studies related to this and other eco-innovation determinants.

Figure 1. Qualitative model for environmental innovation. Key: dark shading = drivers, light shading = facilitators.



3. Methodology

Our proposed indicators for environmental innovation cover five main categories. The first consists of *drivers*, 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 drivers or inputs to desired outputs or positive environmental effects. Such links, if found, could then point to the key indicators.

In our paper, we have concentrated the indicator analysis on looking at the correlations between various indicators (see Annex I for a full list of the indicators) following these general guidelines:

- Check for normality of the data, and detect clear outliers (using skewness values and scatter plots)[15]
- Run correlations with all indicators for which we have data
- Include indicators for final analysis with the following criteria:
    - Moderate to strong correlation with the correlation coefficient greater or equal to 0.5 at 1% level, and greater or equal to 0.65 at 5% level.
    - Number of available 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.

[15] In a small minority of cases, data were rescaled, either to comply with the normality assumption of Pearson correlations, or to observe the potential differences between using raw data vs. rescaled data.

As discussed earlier, the time-causality dimension poses an additional problem, as time lags should be designed to capture the effects of a change between the different types of indicators (drivers, inputs, outputs etc.). For example, a driver for 2006 correlating with an effect indicator for 2000 does not provide useful information.[16]

With an eye on potential causation, the following correlations between different indicator categories are used to identify key indicators for environmental innovation:

- Drivers 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.

Of note, the selection of key environmental indicators is only based on simple correlation analysis, instead of full regressions to identify the factors that influence desirable outcomes. We do not conduct full regressions because of the large number of indicators that are evaluated in this report and because we do not want to prematurely exclude indicators that may be of value to policy. For instance, a specific indicator may not have a large effect on outcomes, but it may be of interest to policy as part of telling the story of how environmental innovation occurs or it may be amenable to policy intervention.

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

4. Data availability

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

There are 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 earlier. Second, widely available economic data are rarely designed for research into environmental issues. Some data are consequently 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.[17] 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). Data such as trade, and especially patent data, can be relatively precise, but they do not necessarily map onto NACE classes. Several indicators are available by country for drivers, facilitators, inputs, outputs and effects, as discussed further in Section 5.

4.2 Environmental goods and services sector

As noted above in Section 2.2, the EGSS is a concept in progress rather than a precisely defined set of sectors. An additional problem is that public databases (such as the Eurostat NewCronos or the EUKLEMS databases) do not currently offer NACE 4-digit level data (or other similarly precise data), and often not 3-digit level data either. This means, for example, that we cannot get data for sectors that are defined at the 4-digit level.[18]

Most sectors such as recycling or sewage treatment[19] that are entirely within EGSS are service sectors. This means that data availability problems will cause the EGS sector to fail to capture innovative processes or products with environmental benefits, as most of these will be produced in four digit manufacturing sectors, for which data are not available. The new

[17] 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.

[18] For example, no data are available for NACE rev. 2 class G46.77, wholesale of waste and scrap - entirely in the EGSS - or NACE rev. 2 class C28.11, manufacture of engines and turbines, including wind turbines - only partly in the EGSS.

[19] In fact, for a lot of indicators available from NewCronos, NACE rev. 1.1 division O90 (part of section E in NACE rev. 2) is not included, as it is considered to be mostly in the area of public services, and a lot of the available data cover only private services.

method of collecting statistics for the entire EGSS outlined in Eurostat (2009) will therefore hopefully be a major improvement and offer more than just a glimpse of the true EGSS.[20]

4.3 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 driver and only dated data for an effect indicator. Looking at the relationship between such indicators is often irrelevant, as the driver should precede the effect and not the other way around.

[20] For example, up to now, there have been data available on national investment in the two main EGS sectors of NACE rev. 1.1 divisions DN37 and E41 (both part of section E in NACE rev. 2), but as mentioned these are only a part of the EGSS.

5. Examining the indicators

We evaluated forty-five indicators in total and have data for thirty-nine of them (twelve drivers, three facilitator indicators, five input indicators, eleven output indicators and eight effect indicators). All the indicators considered in this paper are described in Annex I. The correlation tables (Tables 1a to 1e) in Section 6 include correlation results with twenty-six separate indicators.

5.1 Innovation drivers

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 differ from the 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 level of concern over global warming. Scandinavians are among the least concerned, even though they are widely perceived as strongly in favour of reducing greenhouse gas production. Expressions of people's concerns may be conflicting and not be wholly consistent with their true preferences.

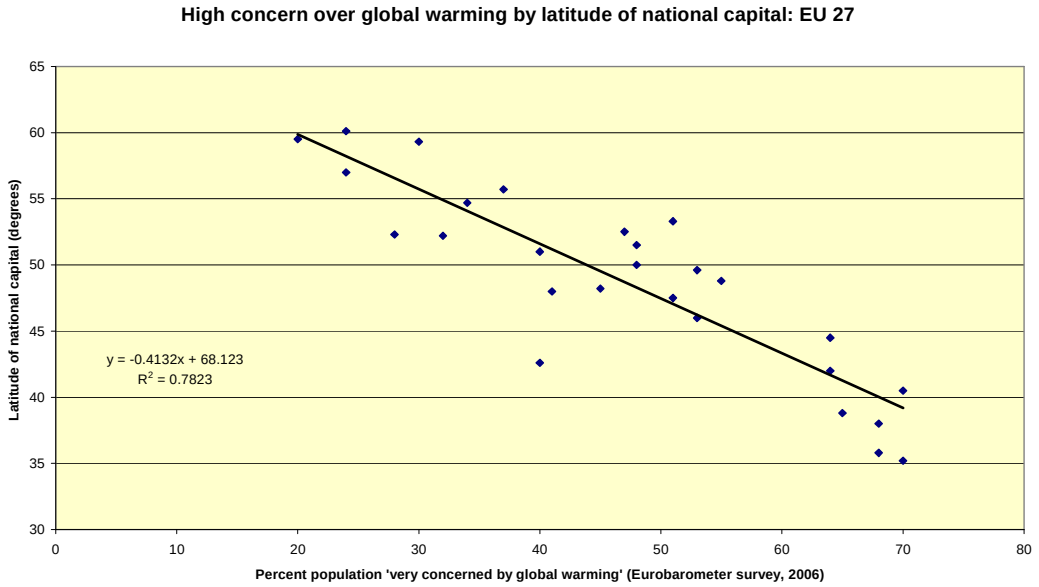
Ideally then, data on public attitudes should always be compared to hard data on actions, in order to see whether attitudes are followed up by decisions.

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 paper, we obtained data from six surveys (as specified above), but unfortunately we have not been able to find adequate data on relevant behavioural aspects. Nonetheless, the available data can be examined against other available indicators.[21]

Figure 2. Warming by concern.



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, along the lines of the Porter hypothesis, 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 Ashford, 2000; 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

[21] A problem with the current data is that two thirds of them are from 2006, which does not fit the driver-input-output-effect causation assumptions.

survey (ZEW, 2001), about a third of the most environmentally beneficial innovations were not introduced for regulatory reasons (Arundel, 2005).

Another important consequence of stringent environmental regulation is argued to be the diffusion of environmental technologies to less developed countries. For example, Constantini and Crespi (2007) offer some empirical evidence of this in connection with the Kyoto Protocol and technologies for the production of renewable energies and energy saving.

We have included six different indicators to represent the regulatory push factor of environmental innovation: an indicator for energy tax rates, three separate indices from the Global Competitiveness Report on regulatory stringency and clarity,[22] and two indicators on the perceived competitive disadvantage from the need to meet environmental regulations.[23]

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 driver of both intentional and unintentional environmental innovation.

Such data are rather difficult to come by and are therefore not evaluated here. However, data on venture capital could be used to track environmentally innovative start-ups. No data seem to be currently publicly available at the required (European) level, but the European Venture Capital Association (EVCA) has provided, since 2007, some data under the term 'energy and environment' which includes information on investments in the environmental sector, although the data may not yet cover all EU countries, and the precise definition of 'energy and environment' is not publicly available.[24], [25]

[22] Only one of these indicators is old enough to fit the time flow aspect of driver => input-output-effect scheme.
[23] The last two indicators are from the 2004 Innobarometer survey of the Eurostat/European Commission, and therefore also somewhat 'too late'.
[24] However, according to Hernesniemi and Sundquist (2007), EVCA has engaged in international cooperation to produce guidelines on what the environmental sector consists of.
[25] 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). More recently, Cleantech Group (Christensen, 2009) has estimated that US$1.2 billion were invested in just three months globally (in the 2nd quarter of 2009). Christensen (2009) provides a recent case study of Denmark in terms of venture capital investments in EGSS.

5.2 Facilitators

Environmental management and organisational 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.[26] Marinova and McAleer (2006) use these data to look at country performances, and we have included them in our paper 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.[27]

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., 2007, and Horbach, 2006).[28] 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.[29]

5.3 Inputs

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,[30] R&D data are widely used to 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

[26] 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.

[27] The twelve new EU member states have only been able to receive awards from the start of their membership.

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

[29] 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.

[30] 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. (2002) argue that innovation surveys, which could also easily include questions on environmental innovation, may provide more accurate data on R&D.

from businesses (see Fukasaku, 2005, for a discussion with some data),[31] 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 paper to look at how it correlates with other eco-innovation indicators.[32]

One option for measuring the science base for environmental innovation is to use data on environmental innovations from trade and other publications. Examples include the LBIO (literature-based innovation output) method based on product announcement sections and/or advertisements for new technology in trade publications or EPD (environmental product declarations). Such data offer the benefit of identifying specific technologies and providing 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 that process innovations – particularly important for environmental innovation - tend to be omitted from such data.[33] In this paper, 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 the acquisition of innovative machinery by firms.

[31] The few exceptions of countries which collect data on business environmental R&D include Canada (Arundel et al 2006) and the United States. The US Department of Commerce included questions on the percentage of domestic and foreign funded R&D that 'had environmental protection applications, including pollution abatement' in the 2008 Business R&D and Innovation Survey.

[32] 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 indicate that private environmental R&D expenditures are in some countries larger than public government budget appropriations.

[33] 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.

Patents – within or outside EGSS

Patent databases are a possible source of indicators of environmental innovation.[34] However, it is difficult to use patent data to construct environmental innovation indicators, with the exception of the EGS sectors.

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 other input indicators such as R&D expenditures.

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,[35] which generally include only the more economically important patents.[36] 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).[37]

Both the OECD and Eurostat have recently set up large patent databases with data download possibilities.[38] 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), who provide a list of 40 IPC patent codes for various environmental technologies.

This paper 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

[34] Oltra et al. (2007) offer a thorough overview of using patents as an indicator for eco-innovation.
[35] 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).
[36] 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.
[37] 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).
[38] 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.

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.

5.4 Outputs

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 level and for 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.

Sales and profits from environmentally beneficial innovation

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 could be very valuable, and the topic could perhaps be included in one of the EU-wide surveys on innovation.

Growth of EGSS

There are several kinds of investment data 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, up to now the sectoral disaggregation available from international sources, such as Eurostat or UNCTAD, has not

been detailed enough to look at even the main EGS sectors (with NACE rev. 1.1 codes DN37, E41 and O90, currently section E in NACE rev. 2).[39]

There are some data available on national investment in the EGSS. Eurostat has provided data for two of the main EGS sectors (NACE rev. 1.1 DN37 and E41, now section E in NACE rev. 2). 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 and Mody, 1996).[40]

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 rev. 2 sections B, C and D) and at the national level (or both), and are used in this paper 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, the number of projects registered is still not very large, 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.[41] If more detailed data

[39] Some data for NACE rev. 1.1 division O90 (sewage and refuse disposal) have been available.
[40] 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.
[41] 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 CO2 reduced. This could then be divided, for example, by each country's CO2 emissions.

become available, and if the numbers build up over the next few years,[42] this could be a valuable data source for measuring the diffusion of environmental innovation.

Finally, there are some ways to measure the pervasiveness of the EGSS, in other words, how large the main EGSS 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.[43] Marinova used data from this website to analyse eco-innovation at a country level, and similarly we have extracted data for this paper for all 27 EU countries.[44]

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 seem particularly useful, especially since the EU eco-industry is export-oriented and China has long been an important trading partner.[45] 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 (OECD, 2005).[46]

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

[42] Currently, only 8 EU countries appear to be represented in the data.
[43] The database is vigorously updated, with an average age of listings of only 253 days.
[44] However, these data are for 2007, which does not leave any room for the time lag between outputs and effects.
[45] Europe lags, China catches up in clean energy race, story by G. Wynn for the Reuters Environmental News Service on 16/05/07.
[46] 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).

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.[47]

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 paper.[48]

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 paper.[49]

5.5 Effects

Energy and material intensity

Several indicators have been developed to measure the energy or material intensity of an economy, both in terms of what goes into the economy and what comes out of it. The 'input' indicators can be used as intermediate eco-innovation output indicators, 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: national energy intensity;
- Data in van der Voet et al. (2005) on national resource productivity (GDP per DMC – direct material consumption, data available for EU-27 at national level);[50] 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).[51]

[47] Trade and Development Board (2003) discusses the limitations of the list in more detail. The World Trade Organisation (WTO, 2005) has produced a similar list with similar drawbacks, discussed e.g. in Eurostat (2009).
[48] Since a product code list is far from accurate, taking a sample of a few core eco-industry products might provide better, although 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. Once the Eurostat (2009) handbook is in use in all EU countries, more precise numbers will be available for the EGSS.
[49] However, the problem is that these data are for 2000, and this does not fit the time dimension of our study.
[50] These data are for 2000, again, a problem, as this is an effect indicator.

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

Pollution and waste levels

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

In this paper, 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.[52]

Other innovation effects

The Community Innovation Surveys (CIS-3, CIS-4 and CIS 2006) 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 CIS data in our paper to see how they correlate with the other indicators.[53] 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.[54]

[51] These data can also be used to identify unintentional eco-innovation.
[52] 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 drivers, inputs and outputs on the one hand, and effects on the other.
[53] The CIS-3 data do not allow for a time lag, as they are for 2000. CIS-4 data are for 2004. The CIS 2006 data were not yet available for most EU countries when the analyses were conducted.
[54] The question on impacts has been corrected for CIS 2008, which also includes a separate module on environmental innovation. The results are not expected until late 2010 at the earliest.

6. Identifying key eco-innovation indicators

6.1 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, we are examining a rather complex chain of factors potentially influencing each other (from *drivers* to *inputs* (with *facilitators* in between) to *outputs* to *effects*), 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.

6.2 Correlations from current data

Given the above constraints for the analysis, Tables 1a to 1e show some of the correlations for evaluating environmental innovation indicators. The full correlation table included all the indicators for which we had data and for all years (from 2000 onwards). The reduced tables have been produced based on the principles stated in Section 3, so, only higher correlation coefficients are reported.[55]

The full definition of each indicator in Tables 1a to 1e can be found in Annex I, using the indicator number. Annex I also gives results for country availability for each indicator.

In general, if the driver, 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.[56] 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 Tables 1a to 1e.

The following discussion is based on indicators with the strongest correlations.[57]

Drivers

Table 1a. Significant Pearson correlations between drivers 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 (vertically and horizontally)				1.4	1.2	2.1	2.2	2.5
att_clean_tr_RD_02	1.4	2002	Driver	1			**.664(**)**	
energy_tax_02	2.1	2002	Driver			1	.503(*)	.417(*)
ERRI_01	2.2	2001	Driver	**.664(**)**		.503(*)	1	
reg_comp_prod_04	2.5	2004	Driver			.417(*)		1
ISO14001_03	3.2	2003	Facilitator					-.490(*)
ISO14001_00	3.2	2000	Facilitator				**.553(**)**	
eco_lbl_04	3.3	2004	Facilitator		.569(*)			**-.650(*)**
publications_01	4.5	2001	Input	.579(*)		**.633(**)**	**.841(**)**	
public_env_RD_02	4.1	2002	Input			-.506(*)		

[55] 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.

[56] Time lags between the groups of indicators also have to be taken into account, as an innovation driver 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.

[57] Some of the results are also based on the entire correlation table which is not included in this paper. 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 versions presented in Tables 1a to 1e.

env_patents_99_03	5.1	1999-2003	Input				*.783(**)*	
IIM_04	6.3	2004	Output			**-.626(**)**	-.514(*)	-.493(*)
IIM_00	6.3	2000	Output			-.561(*)		-.452(*)
nat_inv_EGSS_04	8.2	2004	Output				**-.681(**)**	
nat_inv_EGSS_01	8.2	2001	Output				**-.645(**)**	
inv_poll_ctr_04	8.5	2004	Output	*-.683(*)*			-.496(*)	**-.625(**)**
green_pages_07	8.8	2007	Output				-.410(*)	
expts_china_04	9.1	2004	Output			**.707(**)**	**.533(**)**	
expts_china_02	9.1	2002	Output			**.693(**)**	**.612(**)**	
RWS_00	9.2	2000	Output	.641(*)				
energy_intens_05	10.1	2005	Effect			**-.688(**)**	**-.588(**)**	**-.589(**)**
resource_prod_00	10.2	2000	Effect	**.653(*)**		**.758(**)**	**.766(**)**	**.602(**)**
acid_poll_04	11.2	2004	Effect	**-.748(**)**		**-.686(**)**	**-.728(**)**	**-.612(**)**
acid_poll_01	11.2	2001	Effect	**-.775(**)**		**-.688(**)**	**-.747(**)**	**-.623(**)**
impr_ehs_impct_00[#]	12.1	2000	Effect					.495(*)
reg_reqs_met_00[#]	12.2	2000	Effect	-.614(*)				.515(*)

Key: bold = strong correlations; italics = no. of cases < half of the max. possible; shading = 'negative' indicator.

*. 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).

- **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, the correlation between the competitiveness indicator (*reg_comp_prod*) and the indicator on eco-labels is of interest (*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 could be partly explained by a lack of enough time to allow for the effects of a driver from 2004 on an effect in 2005.[58] Overall, there is some support in these results for regulation driving innovation.

Facilitators

Table 1b. Significant Pearson 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 (vertically and horizontally)				3.1	3.2	3.2	3.3
att_wind_energy_06	1.2	2006	Driver				.569(*)
ERRI_01	2.2	2001	Driver			**.553(**)**	
reg_comp_prod_04	2.5	2004	Driver		-.490(*)		**-.650(*)**
ISO14001_03	3.2	2003	Facilitator		1	**.580(**)**	
ISO14001_00	3.2	2000	Facilitator		**.580(**)**	1	
publications_01	4.5	2001	Input			**.615(**)**	
public_env_RD_05	4.1	2005	Input		**.540(**)**		
env_patents_99_03	5.1	1999-2003	Input	*.748(**)*			
share_renew_en_04	6.1	2004	Output	**.681(**)**			
inv_clean_tech_03	8.4	2003	Output		**.583(**)**		
expts_china_02	9.1	2002	Output	.561(*)			
energy_intens_05	10.1	2005	Effect	-.587(*)	.438(*)		

Key: bold = strong correlations; italics = no. of cases < half of the max. possible; shading = 'negative' indicator.

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

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

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 with a few 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

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

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).

Inputs

Table 1c. Significant Pearson correlations between input indicators 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 (vertically and horizontally)				4.5	4.1	4.1	5.1
att_clean_tr_RD_02	1.4	2002	Driver	.579(*)			
energy_tax_02	2.1	2002	Driver	**.633(**)**		-.506(*)	
ERRI_01	2.2	2001	Driver	**.841(**)**			*.783(**)*
EMAS_00	3.1	2000	Facilitator				*.748(**)*
ISO14001_03	3.2	2003	Facilitator		**.540(**)**		
ISO14001_00	3.2	2000	Facilitator	**.615(**)**			
public_env_RD_05	4.1	2005	Input		1	.582(*)	
public_env_RD_02	4.1	2002	Input		.582(*)	1	
share_renew_en_04	6.1	2004	Output			**-.603(**)**	
IIM_04	6.3	2004	Output			.552(*)	
IIM_00	6.3	2000	Output			.536(*)	
expts_china_04	9.1	2004	Output	.416(*)			
expts_china_02	9.1	2002	Output	**.621(**)**			
energy_intens_05	10.1	2005	Effect	-.458(*)		**.614(**)**	
resource_prod_00	10.2	2000	Effect	**.653(**)**		-.529(*)	
acid_poll_04	11.2	2004	Effect	**-.517(**)**		.509(*)	
acid_poll_01	11.2	2001	Effect	**-.556(**)**		.511(*)	

Key: bold = strong correlations; italics = no. of cases < half of the max. possible; shading = 'negative' indicator.
*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

- **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.[59] This may be partly due to noise in the input indicators for publications, R&D, machinery, and patents, due to these indicators covering inputs that are not relevant to environmental innovation. Therefore, we cannot draw many conclusions from these relationships, except to say that better data are needed to

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

measure (public and private) environmental R&D[60] and environmentally beneficial patents.[61]

In contrast, 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 (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*).[62] 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 in Section 5.3, 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.

[60] 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.

[61] 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 (given in Section 3), but one of the indicators (number 4.4, see Annex I) 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.

[62] 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.

Outputs

Table 1d. Significant Pearson correlations between output indicators 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 (vertically and 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	1.4	2002	Driver								*-.683(*)*					.641(*)
energy_tax_02	2.1	2002	Driver		**-.626(**)**	-.561(*)								**.707(**)**	**.693(**)**	
ERRI_01	2.2	2001	Driver		-.514(*)		**-.681(**)**	**-.645(**)**			-.496(*)	-.410(*)		**.533(**)**	**.612(**)**	
reg_comp_prod_04	2.5	2004	Driver		-.493(*)	-.452(*)					**-.625(**)**					
EMAS_00	3.1	2000	Facilitator	**.681(**)**											.561(*)	
ISO14001_03	3.2	2003	Facilitator							**.583(**)**						
Publications_01	4.5	2001	Input											.416(*)	**.621(**)**	
public_env_RD_02	4.1	2002	Input	**-.603(**)**	.552(*)	.536(*)										
IIM_04	6.3	2004	Output		1	**.971(**)**							**-.648(**)**	-.523(*)		
IIM_00	6.3	2000	Output		**.971(**)**	1							**-.606(**)**			
nat_inv_EGSS_04	8.2	2004	Output				1	**.863(**)**				.471(*)				
nat_inv_EGSS_01	8.2	2001	Output				**.863(**)**	1								
inv_clean_tech_04	8.4	2004	Output						1			.558(*)		-.564(*)		
inv_clean_tech_03	8.4	2003	Output							1	**.619(**)**		.481(*)			
inv_poll_ctr_04	8.5	2004	Output							**.619(**)**	1	.478(*)				
Green_pages_07	8.8	2007	Output				.471(*)		.558(*)		.478(*)	1		**-.543(**)**	-.424(*)	
Expts_india_02	9.1	2002	Output		**-.648(**)**	**-.606(**)**				.481(*)			1	.551(**)		.482(*)
Expts_china_04	9.1	2004	Output		-.523(*)				-.564(*)			**-.543(**)**	**.551(**)**	1	**.809(**)**	.548(*)
Expts_china_02	9.1	2002	Output									-.424(*)		**.809(**)**	1	**.807(**)**
RWS_00	9.2	2000	Output										.482(*)	.548(*)	**.807(**)**	1
energy_intens_05	10.1	2005	Effect		**.765(**)**	**.734(**)**	**.623(**)**				.593(*)			-.440(*)		
resource_prod_00	10.2	2000	Effect		**-.681(**)**	**-.606(**)**	**-.611(**)**				-.551(*)	**-.511(**)**		**.654(**)**	**.614(**)**	
ghg_04	11.1	2004	Effect					**-.542(**)**								
acid_poll_04	11.2	2004	Effect		.578(*)	**.562(**)**	**.759(**)**	.431(*)						**-.503(**)**	-.481(*)	
acid_poll_01	11.2	2001	Effect		**.607(**)**	**.622(**)**	**.752(**)**	.483(*)						-.498(**)	**-.524(**)**	
impr_ehs_impct_00[#]	12.1	2000	Effect				**-.652(**)**									**-.678(**)**
impr_ehs_impct_04[#]	12.1	2004	Effect			-.544(*)										
reg_reqs_met_00[#]	12.2	2000	Effect			-.466(*)	**-.617(**)**									**-.769(**)**
reg_reqs_met_04[#]	12.2	2004	Effect		-.487(*)	-.496(*)			**.686(**)**							

Key: bold = strong correlations; italics = no. of cases < half of the max. possible; shading = 'negative' indicator.

*. 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).

- **Intermediate energy and material inputs:**[63] 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[64]) show a number of strong relationships, mostly in expected ways. In addition to what has been discussed above, the IIM indicator[65] correlates negatively with the indicator on EGSS-related exports to India (*expts_india*), and from the larger correlation table (results

[63] 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*.

[64] IIE is not included in Table 1d.

[65] IIM and IIE are 'negative' indicators, in that a high score in either of them is due to high levels of inputs (of materials or energy) per unit of output (here, GDP).

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.[66] 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*).[67],[68] In addition to a small number of correlations with drivers 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.[69] 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).[70] Otherwise, the investment indicators show only one other significant

[66] 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.
[67] This refers to the number of firms listed in www.eco-web.com.
[68] 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.
[69] Many of the higher values for the national EGSS investment indicator (*nat_inv_EGSS*) are for the newer EU member states.
[70] 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*).

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.

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 negative correlation 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.[71]

- **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).[72] 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)

[71] Unfortunately, no link could be found between patents and the investment indicators, possibly due to poor data quality.
[72] 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.

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.[73]

Effects

Table 1e. Significant Pearson correlations between effect indicators and other indicators.

Indicator name (vertically and horizontally)		Indicator year	Indicator type	energy_intens_05	resource_prod_00	reduc_mat_enrgy_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 (vertically and 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	1.4	2002	Driver		**.653(*)**			**-.748(**)**	**-.775(**)**			-.614(*)	
energy_tax_02	2.1	2002	Driver	**-.688(**)**	**.758(**)**			**-.686(**)**	**-.688(**)**				
ERRI_01	2.2	2001	Driver	**-.588(**)**	**.766(**)**			**-.728(**)**	**-.747(**)**				
reg_comp_prod_04	2.5	2004	Driver	**-.589(**)**	**.602(**)**			**-.612(**)**	**-.623(**)**	.495(*)		.515(*)	
EMAS_00	3.1	2000	Facilitator	-.587(*)									
ISO14001_03	3.2	2003	Facilitator	.438(*)									
Publications_01	4.5	2001	Input	-.458(*)	**.653(**)**			**-.517(**)**	**-.556(**)**				
public_env_RD_02	4.1	2002	Input	**.614(**)**	-.529(*)			.509(*)	.511(*)				
IIM_04	6.3	2004	Output	**.765(**)**	**-.681(**)**			.578(*)	**.607(**)**				-.487(*)
IIM_00	6.3	2000	Output	**.734(**)**	**-.606(**)**			**.562(**)**	**.622(**)**		-.544(*)	-.466(*)	-.496(*)
nat_inv_EGSS_04	8.2	2004	Output	**.623(**)**	**-.611(**)**			**.759(**)**	**.752(**)**	**-.652(**)**		**-.617(**)**	
nat_inv_EGSS_01	8.2	2001	Output				**-.542(**)**	.431(*)	.483(*)				
inv_clean_tech_04	8.4	2004	Output										**.686(**)**
inv_poll_ctr_04	8.5	2004	Output	.593(*)	-.551(*)								
green_pages_07	8.8	2007	Output		**-.511(**)**								
expts_china_04	9.1	2004	Output	-.440(*)	**.654(**)**			**-.503(**)**	-.498(**)				
expts_china_02	9.1	2002	Output		**.614(**)**			-.481(*)	**-.524(**)**				
RWS_00	9.2	2000	Output							**-.678(**)**		**-.769(**)**	
energy_intens_05	10.1	2005	Effect	1	**-.787(**)**			**.807(**)**	**.856(**)**	-.488(*)		**-.566(**)**	
resource_prod_00	10.2	2000	Effect	**-.787(**)**	1			**-.726(**)**	**-.747(**)**				
reduc_mat_energy_04	10.3	2004	Effect			1					**.587(**)**		
acid_poll_04	11.2	2004	Effect	**.807(**)**	**-.726(**)**			1	**.986(**)**				
acid_poll_01	11.2	2001	Effect	**.856(**)**	**-.747(**)**			**.986(**)**	1		-.438(*)		
impr_ehs_impct_00#	12.1	2000	Effect	-.488(*)						1		**.888(**)**	
impr_ehs_impct_04#	12.1	2004	Effect			**.587(**)**			-.438(*)		1	.437(*)	**.687(**)**
reg_reqs_met_00#	12.2	2000	Effect	**-.566(**)**						**.888(**)**	.437(*)	1	.417(*)
reg_reqs_met_04#	12.2	2004	Effect								**.687(**)**	.417(*)	1

Key: bold = strong correlations; italics = no. of cases < half of the max. possible; shading = 'negative' indicator.

*. 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).

- **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

[73] The other related indicator RCA (revealed comparative advantage) correlates highly with RWS, and has been excluded from Table 1d. 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.

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.[74]

- **Pollution and waste levels:** These indicators (*ghg* for greenhouse gases and *acid_poll* for acidifying pollutants[75]) 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.[76] 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.[77] 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.

[74] This relationship holds across years in the larger results table.
[75] 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.
[76] Also, these data only cover emissions until 2004.
[77] However, they also include data on other impacts (health and safety) and other than environmental regulation.

7. Conclusions

A major goal of European governments is to encourage the transition of the European Union to a knowledge-based economy, and in the short run, this means trying 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 paper 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 in Section 2.3 a qualitative model which illustrates the process of eco-innovation.

7.1 Main results

Following the qualitative eco-innovation model, we classified forty-five indicators into five different types: drivers, facilitators, inputs, outputs and effects, according to where they best fit in the innovation chain. The correlation analysis has included all those indicators (thirty-nine in total) for which we were able to obtain national level data for a minimum of eleven EU member states.[78] [79]

Our correlation results have been mixed. Many of the results support the literature, often showing interesting evidence for links between, for example, innovation drivers 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

[78] Only two indicators (4.3 and 5.1) had as few as eleven countries included. Otherwise, fifteen was the minimum.

[79] Sectoral level data were in many cases not available. Therefore, we concentrated on the national level.

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.[80]

Table 2 below includes those fifteen indicators that we consider - based on both the literature and our data analysis - to be key indicators for measuring innovation with environmental benefits. In choosing the key indicators, we have tried to take into account several aspects, some of which are particular to eco-innovation, to maximize the possible balance and coverage. We have paid attention to:

- Different types of indicators: drivers, inputs, etc.
- Intentional and unintentional eco-innovation
- Intentional eco-innovation within the EGSS, but also elsewhere in the economy[81]
- Different types of innovation: product, process etc.[82]

The indicators that have not been included in the key indicators are 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 are often not 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 2) 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.

[80] For example, some data on environmental effects were too old, and some data on innovation drivers were too new to fit well in the model.
[81] 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.
[82] More and more of eco-innovation is taking place, for example, due to improved processes.

Table 2. Summary table of key environmental innovation indicators.

Indicator (indicator number in this study – see Section 6 and Annex I)	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)	Driver	Reasonable and strong correlations with several types of indicators.	Important driver, 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.
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.

Indicator (indicator number in this study – see Section 6 and Annex I)	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)	Driver	Not included, as no data have been obtained at the European level.	Important driver factor, although confined to the EGSS.	Data availability from EVCA (or elsewhere) should be developed further.
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.
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.

* CIS 2008 questionnaire separates environmental effects from health and safety effects. The results of CIS2008 are not expected until late 2010 at the earliest.

7.2 Policy implications

Environmental policy, largely through environmental regulation, has positive overall effects on the environment, especially in terms of reducing pollution. On the other hand, general innovation policy has sometimes been criticized for not focusing on the right issues, for example, it has been claimed to have too much of a focus on increasing R&D expenditures, as opposed to encouraging other innovation inputs (such as research cooperation, adequate supply of highly skilled workforce, or inputs more typical for services or low-technology industries), or focusing on getting sufficient outputs. Good *environmental innovation policy* has the dual effect of increasing innovation across all economic sectors and improving the state of the environment for the benefit of citizens and the rest of the planet. It also helps to deal with the two interacting market failures discussed by Rennings (2000) and Jaffe et al. (2004), associated with environmental pollution on the one hand, and innovation and diffusion of new technologies on the other hand.

Our correlation results suggest that there are a number of old and new indicators – on innovation drivers, inputs, outputs and effects - that could be relevant for monitoring in order to track progress in environmental innovation and its impacts (see Table 2 above for such indicators). Importantly, surveying all economic sectors on environmentally beneficial innovation would provide direct evidence of such impacts. The environmental module in CIS 2008 could provide very valuable information on this issue.

We also identify several areas where potentially valuable indicators are simply not available. These include data on EGSS venture capital (not available publicly at the European level), business environmental R&D, sales from environmentally beneficial innovation activity across sectors, and FDI in EGSS. Additionally, many existing indicators should be further developed, as outlined in Table 2. These also include some effect indicators.

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Annex I - Eco-innovation indicators considered[83]

Indicator category		**Indicator** ***(indicator name used in Tables 1a to 1e in Section 6)***	**Driver /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	Driver	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)*	Driver	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	Driver	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)*	Driver	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	Driver	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	Driver	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)*	Driver	Intentional	N/A	Yes (except BG, RO, SK)	Eurostat;2000-2004	Tax revenues not by sector, final energy consumption data total various sectors, excluding energy industries themselves.
Environmental regulations	2.2	Environmental regulatory regime index, ERRI *(ERRI)*	Driver	Intentional	N/A	Yes (except CY, LU, MT)	Global Competitiveness Report 2001-02	-

[83] The analysis for this paper has been conducted in 2007.

Environmental regulations	2.3	Stringency of environmental regulations – index	Driver	Intentional	N/A	Yes	Global Competitiveness Report 2006-07	-
Environmental regulations	2.4	Clarity and stability of regulations – index	Driver	Intentional	N/A	Yes	Global Competitiveness Report 2006-07	-
Environmental regulations	2.5	Perceived competitive disadvantage from the need to meet environmental regulations for new products or services *(reg_comp_prod)*	Driver	Intentional	Very aggregate (medium)	Yes (except BG, RO)	Eurostat: Innobarometer 2004	-
Environmental regulations	2.6	Perceived competitive disadvantage from the need to meet environmental regulations for new or improved processes ('negative' indicator)	Driver	Intentional	Very aggregate (medium)	Yes (except BG, RO)	Eurostat: Innobarometer 2004	-
Market conditions	2.7	Venture capital for firms in the EGSS	Driver	Intentional	No (medium)	No	EVCA	Currently, there do not seem to be any publicly available data at a European level for this indicator. However, since 2007, EVCA has been publishing data for 'energy and environment'. These data are not free, and the country or sector coverage is not known to the authors of this paper. DATA NOT INCLUDED.
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 are not yet available or not comparable to the EU-15.
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;2001-2004	For the New Member States, Community eco-label awards only started from 1 May 2004, therefore data for these countries are not yet available or not comparable to the EU-15.
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	-
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.
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	-
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	-

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	No (medium)	Yes (from this source no data for BG, RO)	NSB, Thompson-ISI, from Peter, 2006;data for 2001	-
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 paper cover only EGSS related patents. Aggregate level data for manufacturing and certain high-tech fields are available from e.g. Eurostat. However, separating eco-innovation related patents outside the EGSS from the rest would be difficult.
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 rev. 1.1 A to O) ('negative' indicator)	Output	Unintentional /Intentional	Aggregate (medium)	Yes (except BG, CY, IE, LT, LV, PT, RO)	EUKLEMS database (www.euklems.net/euk08i.shtml); data for 2000 and 2004	Coverage for the new member states is rather poor.
Intermediate energy and material inputs	6.3	Intermediate material inputs (IIM) at current purchasers' prices per GDP (NACE rev. 1.1 A to O) ('negative' indicator) *(IIM)*	Output	Unintentional /Intentional	Aggregate (medium)	Yes (except BG, CY, IE, LT, LV, PT, RO)	EUKLEMS database (www.euklems.net/euk08i.shtml); data for 2000 and 2004	Coverage for the new member states is rather poor.
Sales/profits from environmentally beneficial innovation	7.1	Sales from eco-innovation across sectors	Output	Unintentional /Intentional	No (medium)	No	N/A	These 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.
Growth of EGSS	8.1	Foreign direct investment (FDI) in EGSS	Output	Intentional	Aggregated (high)	Yes	Eurostat, UNCTAD	This is an EGSS indicator. However, data for even the main EGSS are mostly not available. DATA NOT INCLUDED.
Growth of EGSS	8.2	National investment (gross investment in tangible goods) in EGSS (NACE rev. 1.1 DN37 and E41) per gross fixed capital formation (GFCF) *(nat_inv_EGSS)*	Output	Intentional	Aggregated (high)	Yes	Eurostat; 2000-2004	Data for two of the NACE rev. 1.1 classes belonging mostly to the EGSS are available from Eurostat.
Growth of EGSS	8.3	Total current expenditure on environmental protection per value-added	Output	Intentional	NACE rev. 1.1 sections C, D, E, aggregated, mostly 2-digit NACE (medium)	Yes, but only country totals for NACE rev. 1.1 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.
Growth of EGSS	8.4	Investment in equipment and plants linked to cleaner technology per value-added *(inv_clean_tech)*	Output	Intentional	NACE rev. 1.1 sections C, D, E, aggregated, mostly 2-digit NACE (medium)	Yes, but only country totals for NACE rev. 1.1 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	NACE rev. 1.1 sections C, D, E, aggregated, mostly 2-digit NACE (medium)	Yes, but only country totals for NACE rev. 1.1 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	These data are relatively new, and the numbers of projects have not build up sufficiently yet. EU country coverage is also fairly 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 would be a better alternative for the number of registered CDM projects, as it takes account of project size. However, currently data per individual country are 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 (EGS 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 were available from Eurostat (NewCronos) at the time of the data analysis. Data include 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.

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