Maastricht Manual on Measuring Eco-innovation for a Green Economy

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Innovation for Sustainable Development Network

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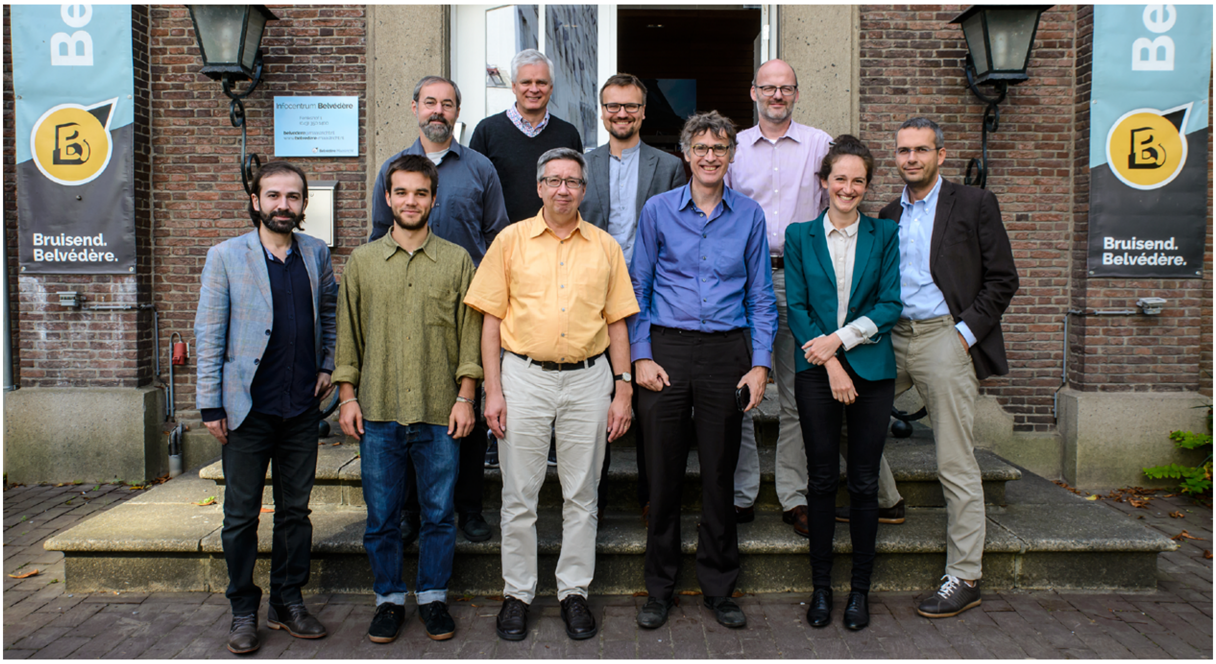

Participants at the first workshop about the Maastricht Manual for eco-innovation held in Maastricht on 26-27 September 2016)

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Abbreviations

APEC: Asia-Pacific Economic Cooperation
ASEI: Asia-Europe Meeting Eco-Innovation Index
ASEIC: Asia-Europe Meeting Eco-innovation Centre for Small and Medium-sized Enterprises

ASEM: Asia-Europe Meeting
BEV: Battery Electric Vehicle
BNEF: Bloomberg New Energy Finance
BOD: Biochemical oxygen demand
BRIICS: Brazil, Russia, India, Indonesia, China, South Africa
CAPI: Computer assisted personal interviews
CATI: Computer assisted telephone interviews
CCGT: Combined Cycle Gas Turbine
CCS: Carbon Capture and Storage
CE: Circular Economy
CEM: Clean Energy Ministerial
CH4: Methane
CIS: Community Innovation Survey
CIW: Canadian Index for Well-being
CO: Carbon Monoxide
CO2: Carbon dioxide
COD: Chemical oxygen demand
CPC: Cooperative Patent Classification
CSR: Corporate Social Responsibility
CTG: Cleantech Group
DDT: Dichlorodiphenyltrichloroethane
DMC: Domestic material consumption
DO: Dissolved oxygen
DPSIR: Driving Forces - Pressures - States - Impacts - Responses
EAPI: Energy Architecture Performance Index
EC: European Commission
ECLA: European Classification system
Eco-IS: Eco-Innovation Scoreboard
EEA: European Energy Agency
EGA: Environmental Goods Agreement
EGSS: Environmental goods and services sector
EIO: Eco-innovation Observatory
E-LCA: Environmental Life Cycle Assessment
EMAS: Eco-Management and Audit Scheme
EMInInn: Environmental Macro Indicators of Innovation Project
EPA: Environmental Protection Agency
EPO: European Patent Office
EPR: Extended Producer Responsibility
EPS: Environmental Policy Stringency Index
ERE: Environmental Rebound Effects
ETS: Emissions trading schemes
EU: European Union
EU-SILC: European Union Statistics of Income and Living Conditions
FAO: Food and Agriculture Organization
FDES: Framework for the Development of Environment Statistics
FDI: Foreign Direct Investment
FoEG: Friends of Environmental Goods
GBAORD: Government Budget Appropriations or Outlays Allocated to Research and Development
GCII: Global Cleantech Innovation Index
GDP: Gross Domestic Product

GEP: Green Economy Progress Index
GGEI: Global Green Economy Index
GGKP: Green Growth Knowledge Platform
GHG: Greenhouse gas emissions
GSM: Global System for Mobile Communications
HCB: Hexachlorobenzene
HFCs: Hydrocarbons
HM: Heavy metals
ICEV: Internal combustion engine vehicles
ICT: Information Communication Technology
IEA: International Energy Agency
IGEM: Integrated Green Economy Modelling
IP: Intellectual Property
IPC: International Patent Classification
IRES: International Recommendations for Energy Statistics
ISIC: International Standard Industrial Classification
ISO: International Organization for Standardization
MEI: Measuring Eco-Innovation Project
N20: Nitrous oxide
NABS2007: Nomenclature for the Analysis and comparison of Scientific programmes and Budget
NGOs: Non-governmental organisations
NMVOC: Non-methane volatile organic compounds
NO2: Nitrogen dioxide
NPISH: Non-profit institutions serving households
NSO: National Statistical Office
NUTS: Nomenclature of Territorial Units for Statistics
O3: Ozone
OCGT: Open Cycle Gas Turbine
OECD: Organisation for Economic Co-operation and Development
PACE: Pollution Abatement Costs and Expenditures Survey
PAH: Polycyclic aromatic hydrocarbon
PBL: Planbureau voor de Leefomgeving (Netherlands Environmental Assessment Agency)
PFCs: Perfluorocarbons
PM: Particulate matter
POPs: Persistent organic pollutants
PPP: Purchasing Power Parity
R&D: Research and development
RMC: Raw Material Consumption
RREUSE: Reuse and Recycling EU Social Enterprises network
SEEA: System of Environmental-Economic Accounting
SGI: Sustainable Governance Index
SNA: System of National Accounts
SO2: Sulphur dioxide
SOER 2010: The European environment – state and outlook 2010
STEEP: Social, technological, environmental, economic, political
STIR: Sustainability Transitions and Innovation Review
SUV: Sport-utility Vehicle
TH: Total hardness
TPES: Total Primary Energy Supply
UCL: University College London

UN: United Nations
UNEP: United Nations Environment Programme
UNFCCC: United Nations Framework Convention on Climate Change
UNU-MERIT: United Nations University - Maastricht Economic and Social Research Institute on Innovation and Technology
USPC: United States Patent Classification
UU: Utrecht University
VOC: Volatile organic compounds
WBCSD: World Business Council For Sustainable Development
WEF: World Economic Forum
WIPO: World Intellectual Property Organisation
WTO: World Trade Organisation

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5

INPUTS TO ECO-INNOVATION AND GREEN ECONOMY

Christian Rammer, Nicolò Barbieri and Massimiliano Mazzanti

This chapter discusses the measurement of inputs to eco-innovation. Next to traditional indicators (R&D, patents and publications) the chapter discusses new eco-focussed indicators (eco-design, labels, knowledge networks, eco-literacy and the use of trade and FDI data).

5.1. Traditional indicators

Indicators of inputs to eco-innovation can be measured at the level of industries, regions and countries. Three groups of indicators are discussed:

- **Traditional eco-innovation indicators** have been available for some time and include R&D (see the OECD's Frascati Manual), innovation (see the OECD/Eurostat's Oslo Manual), patents and scientific publications. Indicators for eco-innovation are obtained by identifying the eco-innovation component of these indicators. For example, R&D is limited to R&D for developing new environmental technologies or patents are limited to patents of relevance to environmental technology.

- **New eco-innovation indicators** develop new measurement concepts that are deliberately designed to capture eco-innovation. These concepts are better-suited than the traditional indicators to measuring eco-innovation in all its dimensions, but they require separate data collection efforts.

- **Indicator systems** have been developed to provide comprehensive measurement of eco-innovation activities, capturing different dimensions and actor groups. These systems usually employ traditional and new eco-innovation indicators and sometimes aggregate them to create composite indicators or indexes. The Eco-Innovation Score board of the Eco-Innovation Observatory, the ASEM) Eco-Innovation Index (ASEI), and the Global Cleantech InnovationIndex (GCII) are prominent examples of this approach (details of which can be found in Annex 1).

5.1.1. R&D for eco-innovation

R&D activities are relevant to the scientific and technological dimensions of innovation. R&D comprises "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD, 2015; p: 30). R&D expenditures are usually provided as 'intramural' or 'extramural' activities depending on whether they are performed inside or outside the boundaries of a unit. Data on intramural expenditures tracks R&D performed within the focal unit, irrespective of the source of funds, whereas the extramural expenditures covers what the focal unit pays to obtain the results of R&D activities performed by other units (OECD, 2015).

R&D expenditures measure current costs and capital expenditures such as instruments, equipment, etc. An important part of current costs concerns labour costs, including wages, salaries and benefits for human resources devoted to R&D activities. Statistics on R&D investments and R&D personnel are usually provided by sector and are used to gauge trends in R&D activities by the government, business, and NPISHs sectors. R&D by universities and publicly funded PRIs (public research institutes) are often separated out from the government sector. Since R&D expenditure measures the generation of new knowledge, it represents an imperfect measure of one step (creation of new knowledge) in an innovation process that may or may not lead to an innovation. Furthermore, a large percentage of innovation activities do not use R&D (Cainelli et al., 2015; Rammer et al. 2009), particularly in the services industries or for organisational innovation (Arundel and Kemp, 2009).

Almost all R&D is performed by the government and business sectors. R&D expenditures can have several socio-economic objectives. When they are aimed at reducing the environmental pressure of economic activities, R&D expenditures can be employed as an input to eco-innovation. In this case, creative activities increase the stock of knowledge that can be used to create new products, services and processes to reduce environmental impacts over their life-cycle.

Two eco-innovation input indicators can be derived for R&D: expenditures and R&D personnel, although data availability limits the use of the latter.

The only consistent data across OECD countries is for government budget appropriations for R&D (GBARD) in “control and care for the environment”. These refer to budget provisions instead of to actual expenditure. Eurostat provides GPBARD data for European Union countries for different environmental objectives (see Figure A5.1). Government budget expenditures on R&D for eco-innovation are spent by universities, publicly funded research institutes, and by some government ministries. The International Energy Agency (IEA) provides statistics on government expenditures on R&D for multiple countries for different environmental purposes, including energy efficiency, renewable energy, hydrogen and fuel cells, etc.

There is poorer coverage of business expenditures on R&D for eco-innovation. Most data sources do not differentiate between business R&D expenditures for eco-innovation and for other purposes. There are only a few limited sources of business R&D expenditures on eco-innovation for individual firms. One source is the OECD project Environmental Policy and Firm-Level Management, which provides data on R&D expenditures for environmental conservation, but only for the year 2003. The project defined environmental R&D in the business sector in two ways: the share of R&D that is environmentally motivated and the share that is environmentally relevant in reducing environmental impacts either in the company or elsewhere (at the point of use) (Johnstone, 2007). Another option is to use total R&D expenditures for environmental industries such as the renewable energy industry or the water and sewage industry. This requires the unrealistic assumption that the entire amount of R&D expenditures in the industry is for eco-innovation (Barbieri et al., 2016).

There are several other limitations to measuring R&D as an input to eco-innovation. First, R&D expenditures cannot be easily disaggregated across regions, sectors and enterprises due to the difficulties in ascribing R&D activities to multi-plant companies, especially when R&D collaboration occurs between several firms (De Marchi, 2012). Second, data on the number of R&D personnel active in environmental-related R&D are not publicly available. Third, by focusing on formal R&D, these indicators substantially underestimate the role of small and medium enterprises in which knowledge creation typically takes the form of informal R&D (Kleinknecht et al., 2002).

In addition, the classification system employed to link R&D to socio-economic objectives influences the amount of R&D expenditures for eco-innovation. Figure A5.2 gives government R&D appropriations for the EU-28 by NABS2007 (i.e. Nomenclature for the Analysis and comparison of Scientific programmes and Budget). This classification method is more parsimonious than the previous one (Figure A5.1) and does not differentiate between environmental objectives. Possible future changes in classification systems could affect data on R&D expenditures for eco-innovation.

Even with the limitations of R&D data for eco-innovation, tracking total public and private expenditures on eco-innovation R&D is useful as a measure of the priority given by both governments and businesses to environmental issues. However, for micro-level research on eco-innovation, data availability is a serious limitation, particularly in the business sector. This could require specialised surveys or improvements to the data collected in national R&D surveys. Furthermore, to build useful and comprehensive eco-innovation indicators, surveys on green R&D should break down the term ‘environment’ into different categories such as reductions in resource use, pollution prevention, etc., in order to effectively capture the knowledge efforts in each environmental field (Arundel and Kemp, 2009).

5.1.2. Patents for eco-innovation

Patents provide exclusive intellectual property rights to patent holders for a defined period of time (usually 20 years). In return, patent applicants must disclose the technicalities of inventions. In addition, patents are examined for novelty and other characteristics, which ensure the originality of the invention.

Patents provide extensive structured and unstructured data that supports their use as an input indicator for eco-innovation (Tseng et al., 2007). The structured data covers the name and geographical location of the applicant/assignee and inventors, filing dates, technology classification codes, citations to earlier patents and non-patent literature, and the length of the examination process. These data can be readily extracted from patent databases. Unstructured data covers the textual description of the invention and its claims. This information can be extracted using text-mining techniques.

Two main approaches are employed to identify green patents. The first uses the information provided by the technology classification codes. Several classification systems are available, but the most widely used are the International Patent Classification (IPC), the Cooperative Patent Classification (CPC), the European Classification system (ECLA) and the United States Patent Classification (USPC). All classification systems use a list of hierarchical codes whose technological specificity grows with the number of digits. Green patents can be identified by using keywords to search for green technologies in the descriptions of the technological codes. The OECD and the World Intellectual Property Organisation (WIPO) provide lists of CPC and IPC codes for climate change adaptation and mitigation technologies. A widely used list of environmental technological codes is the ENV-TECH (OECD) that detects green patents in the following macro technological fields: environmental management, water-related adoption technologies, climate change mitigation technologies related to energy generation, transmission or distribution, capture, storage, sequestration or disposal of GHG; and climate change mitigation technologies related to transportation, buildings, wastewater treatment or waste management and production or processing of goods. Figure A5.3 shows the trends in patenting activities for different categories of environmental technologies in the EU-28.

The second approach is based on keyword searches (e.g. photovoltaic panels, water management, etc.) within the title and abstract of patent documents (de Vries and Withagen, 2005). Both approaches are often combined to reduce errors from including irrelevant patents or excluding relevant patents. Ignoring this source of error can create an upward or downwards bias in a patent indicator for eco-innovation.

The widespread use of patents as a proxy for inventions of relevance to eco-innovation is mainly due to data availability, increasing computational performance for analysing large databases, and the availability of analytical methods for data extraction. A major advantage is that patent data are available at the micro level and can be aggregated to the sector, industry, region or country level. The European Patent Office maintains a concordance table between patent and industrial classification codes, which can be used to estimate the number of green patents in specific industries. The information on applicants allows for patents to be aggregated by sector and sub-sector (governments, higher education, businesses and NPISH sectors. Figure A5.4 shows the geographical distribution of green patents at NUTS2 level over the period 1980-2012 using PATSTAT 2016. Patents contain data that can be used to address the issue of large differences in patent quality. Data on the number of patent citations, the breadth of the technological content, the number of renewals, and the number of countries for which a patent application is made can be used as measures of patent quality, either in terms of novelty (citations and technological breadth) or commercial value (number of renewals and countries of application).

Patents are public information. Several web platforms provide free access to the patent documents (e.g. Google Patents, Espacenet, etc.), while raw data are available at reasonable cost from subscriptions (i.e. to PATSTAT). The OECD and Eurostat provide aggregated indicators for environmental patents.

Patents have two major limitations as input measures for eco-innovation. First, although frequently described as proxies for innovation, this is incorrect.

Patents measure inventions, whereas an innovation, by definition, must be made available on the market or used within the organisation. Many patents are never used in an innovation. Strategic patents to block competitors, but never used in an application, will be included in patent counts and overestimate inputs to eco-innovation.

Second, not all eco-innovations, including both technical processes and organisational innovations, are patented (Arundel and Kemp, 2009). Innovators can choose alternative methods to protect their innovation from imitation (e.g. secrecy), or the cost of a patent application can exceed the benefits to a firm. Furthermore, patents only capture the generation of new knowledge that can be used for innovation, but not the diffusion of innovations. This is relevant for eco-innovation since many process-related eco-innovations are not developed by the innovator, but by a specialised technology producer (e.g. a mechanical engineering firm) and purchased by the innovator from a supplier. The patent (if any) associated with this eco-innovation will be owned by the specialised technology producer and not by firms that adopted the technology. In addition, patent-based indicators are biased towards the manufacturing sector because most services and service processes cannot be patented.

5.1.3. Publications for eco-innovation

Scientific publications can be used as an indicator for research results of relevance to eco-innovation. Relevant indicators are obtained from bibliometric analysis and capture one output of scientific research. As for patent data, bibliometric indicators can be produced for different fields of environmental research and citations can be used to identify high-impact publications. Unstructured textual information in the title, abstract, and acknowledgements can be used to identify publications related to the environment, energy efficiency, resource efficiency, energy productivity, material productivity, eco-innovation, etc. Barbieri et al. (2016) used the scientific literature on eco-innovation to identify the main topics of research and knowledge trajectories. Scientific publications can capture knowledge diversification across a variety of research fields (Kwon et al., 2016; Türkeli et al., 2018a, Türkeli and Kemp, 2018b) and data on the affiliation of authors can measure collaboration between science and industry. Citations are of value for assessing knowledge flows across countries and regions.

The main databases used to create bibliometrics are Web of Science and Scopus. The majority of the studies employ keyword searches to identify environmental-related publications. Examples of eco-innovation indicators include the number of environmental-related scientific publications and the number per capita, co-authorship of scientific articles, and co-occurrence of research areas within publications. Figure A5.5 shows the trends in published scientific articles on eco-innovation between 1976 and 2016.

An advantage of bibliometric indicators as inputs to eco-innovation is the capability to measure the social and institutional dimensions of eco-innovation dimensions. Relevant publications on eco-innovation are found in diverse research fields, including social science, law and basic sciences. This can reduce a bias towards the manufacturing sector. The main disadvantages are similar to those for patents. Automated keyword searches can include papers that are not relevant to eco-innovation and fail to identify relevant papers.

5.1.4. Eco-innovation input indicators from innovation statistics

Innovation statistics following the Oslo Manual are collected in many European and other countries. For some countries, data are available for one input indicator for eco-innovation:

- The number (share) of firms by industry with innovation activities to reduce environmental impacts (objectives of innovation).

The advantages of innovation statistics based on the Oslo Manual is that they are available for representative samples of firms, often in both the manufacturing and services industries, and they directly cover the production and diffusion of eco- innovations. Unfortunately, only one input indicator is currently produced for eco-innovation, but other indicators are available for drivers **(see Chapter 3)** and for outputs **(see Chapter 6).**

Innovation surveys such as the CIS could be used to collect data on non-R&D inputs into eco-innovation. The following expenditure categories can be used (see also OECD 2018):

- Acquisition of capital goods (machinery, equipment, vehicles, buildings, software, intellectual property rights) used for process technology eco-innovation or for setting up production facilities to produce product eco-innovations
- Cost of own personnel (excluding R&D personnel) engaged in eco-innovation activities
- Cost of material and other supplies (excluding material and other supplies for in-house R&D) that were used for eco-innovation activities
- Purchase of external services (excluding contracted-out R&D) required for eco-innovation activities

5.2. New eco-innovation indicators

5.2.1. Eco-design tools

Firms and organisations can reduce the environmental impact of their products and processes by adopting 'eco-efficiency' design, such as 'Design for Environment' or 'Eco-design'. These methods can reduce material consumption and improve reuse and disposal. Although eco-design is defined as 'the systematic integration of environmental considerations into product and process design' (NCR Canada, 2003), its application has significant economic effects for firms and organisations. Eco-design can improve market appeal and reduce production and delivery costs for goods and services (Knight and Jenkins, 2009). In addition, eco-design can use Life Cycle Assessment (LCA) tools to assess the environmental burden of products (Bovea and Pérez-Belis, 2012).

To date, the use of eco-design has mainly been studied through case studies, but questions on eco-design could be included in surveys and used to create indicators for the number and share of firms that use eco-design as a tool for eco-innovation. Additional questions could capture data on the effects of eco-design on material use, environmental impacts in the production, distribution and consumption phase, product life spans, and reuse and recycling (see Chapter 6). A problem that must be addressed before including eco-design in surveys is the lack of a shared and comprehensive definition of eco-design and the variety of methods that can be included under this rubric. However, these issues can be addressed by asking questions on the use of specific eco-design activities and eco-design goals.

There are several advantages to collecting data on the use of eco-design. First, eco-design is relevant to goods, services, process and organisational innovations, in part because it covers non-technological design and incorporates social and ethical factors. Second, it directly targets innovations. Third, it embraces different aspects of environmental sustainability, such as the impacts of product production and use on material, energy, water, etc.

5.2.2. Eco-knowledge networks and collaboration

Knowledge networks and collaborations can create new environmental-related knowledge for future exploitation. This type of input indicator heavily relies on network and cluster analysis and on the idea that individuals, firms and institutions are embedded in webs of exchanges and collaborations. Depending on the interaction under analysis, this indicator sheds light on the dynamic knowledge process that stands at the heart of the development and diffusion of eco-innovation.

Once networks are identified using different data sources, the objective is to study the shape or structure of the network. The strength of such an approach relies on the possibility to investigate graph-theoretic properties of the network. Some of these properties are: connectedness of nodes, network density, cohesion, centrality, betweenness, etc. Different indicators can be built in order to capture a variety of dimensions. For example, citation networks can be created using scientific publications as nodes and citations between them as ties between network vertices (Epicoco et al., 2014; Barbieri et al., 2016). Moreover, network and cluster analysis can be employed to assess the shape of networks whose nodes are represented by patent documents and the citations between patents as the links between these nodes (Cecere et al., 2014a, 2014b).

The advantage of using eco-knowledge networks and collaborations resides mainly in the accessibility of the information these tools provide, thanks to the graphical representation of the input data. In addition, qualitative research can be carried out in order to provide policy implications.

Additional data can be collected on collaboration for eco-innovation, either through surveys or from corporate annual reports of firms, government agencies, and university knowledge transfer offices. The data can be used to construct indicators for the number and share of firms and organisations active in collaboration on eco-innovation. Surveys will provide the most reliable data, but other data sources can indicate where there are clusters of collaborative activity on eco-innovation.

5.2.3. Eco-innovation related trade

International trade in eco-innovations is one of the main transfer channels for green knowledge embodied in goods and services. The main international lists associated with international green trade, such as OECD-164, FoEG-153, APEC-54 and EGA-165, focus on environmental goods and services on the basis of their end use. Therefore, they capture the adoption of environmental goods and services through imports, competitive pressure on domestic firms to innovate, and a source of knowledge via reverse engineering or imitation.

Vendors of environmental technology can opt for third party verification of their claims for the performance of their environmental technologies. Environmental Technology Verification (ETV) is a new tool to help innovative environmental technologies reach the market. The “Statement of Verification” delivered at the end of the ETV process can be used as evidence that the claims made about the innovation are both credible and scientifically sound[27]. The performance is not assessed against the performance of alternatives and does not consider rebound effects.

Eco-innovation goods and services (EGSS) imports by industry or governments is an activity indicator of eco-innovation from the point of use, and exports of eco-innovative goods and services can be categorised as socio-economic outcomes with environmental benefits. The Eco-Innovation Scoreboard uses an annually updated indicator for “Exports of products from eco-industries” (percentage of total exports) based on Eurostat data and a “selected list of 25 trade codes referring to “environmental goods and services”” as a component of socio-economic outcomes (Giljum et al., 2014). No indicator system has yet provided information on “imports of products from eco-industries elsewhere by industries, governments or households”. Data on the “net trade balance of eco-industries” (measured as the total value of exported goods and services minus the total value of imported products) are also available.

The knowledge spillovers from green trade are a topic in need of deeper research, for instance to compare knowledge spillovers from imported goods and services, with the spillovers from domestically produced eco-innovations and those based on a combination of foreign and domestic knowledge.
Trade indicators for eco-innovation inputs include:

- Imports of products from eco-industries elsewhere (% of total imports) by industry, government, households
- Imports of environmental goods and services (EGSS) by industry, government, households

5.2.4. Eco-innovation related foreign direct investments

Foreign direct investment (FDI) is a transfer channel for eco-innovation knowledge and technologies. Green FDI can be considered as FDI that advances progress towards reaching environmental and climate goals, including environmental protection and resilience (UNEP, 2017). Eco-innovation-related FDI can transfer clean technologies that are relatively less polluting (e.g. end-of-pipe abatement) and more input-efficient compared to domestic production. Eco-innovation related FDI can also support technology leapfrogging, whereby FDI transfers state-of-the-art production and pollution-control technologies to FDI recipient countries. Finally, it can create knowledge spillovers to domestic firms by encouraging the adoption of best practices in environmental management by affiliates, domestic competitors and suppliers (Golub et al., 2011).

Research to define and measure green FDI is at a relatively early stage. At the international and national levels, the most common approach is to include FDI in environmental goods and services (EGS) as a component of the green FDI definition. While comprehensive data collection for EGS is not widespread, the 2012 System of Environmental-Economic Accounting: Central Framework (CF) is expected to enable progress in this field (UNEP, 2017). (Please refer to Annex 5 for different definitions and measures).

5.3 Comprehensive indicator systems for eco-innovation

The Eco-Innovation Scoreboard (Eco-IS) measures eco-innovation performance across EU Member States. The 16 indicators are grouped into five areas: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency and socio-economic outcomes. The innovation inputs consist of commonly-used indicators for R&D investments and human capital investments in R&D in general. Innovation sources other than those based on R&D are not included. This means that the indicator is biased towards favouring countries with a high share of manufacturing in GDP that rely more on R&D investments than the service sectors. The indicators for innovation activities concern firms only and include survey results on their energy, material efficiency, and management of environmental impacts and responsibilities. The 'innovation outputs' are measured through green patents, academic publications and media coverage.

The ASEM Eco-Innovation Index (ASEI) measures the status and level of eco-innovation of ASEM member countries. The scope of the 2015 ASEI is considerably broader than the Eco-IS by including the 28 Member States of the EU, Norway, Switzerland and 21 Asian countries (ASEM, n.d.). The ASEI website uses the definition of the European Commission from 2012, which states that 'progress towards the goal of sustainable development' should be the aim or result of eco-innovations. This is reflected in the broad choice of indicators categorized into four sub headings: Eco-innovation capacity, eco-innovation activity, eco-innovation supporting environment, and eco-innovation performance. The scale of the index varies from 0 (minimum) to 100 (maximum).

In contrast to the Eco-IS, the ASEI includes policy-relevant indicators for the implementation of environmental regulations (indicator 2.2 in Table 2) and public expenditures on green R&D (indicator 2.1). An indicator for private sector R&D is not provided, but there is an indicator for awareness level of company's sustainable management (number of United Nations Global Compact participant firms, ASEI 2015, pg. 158). Important new categories are: eco-innovation support environment and capacity. While the focus of the Eco-IS is stricter on eco-innovation, the ASEI also includes more general aspects such as the economic competitiveness and general innovation capacity of a country. It also has a special focus towards SMEs.

A comparison of Asian countries with those in Europe shows that Europe scores higher in Eco-innovation Capacity and Activities, and significantly higher in the Supporting Environment. Asia displays a good eco-innovation capacity score but scores relatively low in terms of policy support for eco-innovation (Jo et al., 2015).

The Global Cleantech Innovation Index (GCII) is developed by the Cleantech group. The GCII consists of five sub-categories: general innovation drivers, cleantech-focussed innovation drivers, evidence of emerging cleantech innovation, evidence of commercialized cleantech innovation. The report defines clean technology innovation as "doing more with less (e.g. fewer materials, less energy expenditure, reduced water availability), while making money doing so". The indicators focus mostly on the activities of companies and businesses. The second and latest GCII from 2014 covers 40 countries (including the G20). Of the 40 countries covered by the GCII, 9 countries are not included in the Eco-IS or the ASEI (namely Argentina, Canada, Brazil, Israel, Mexico, Saudi Arabia, South Africa, Turkey and USA).

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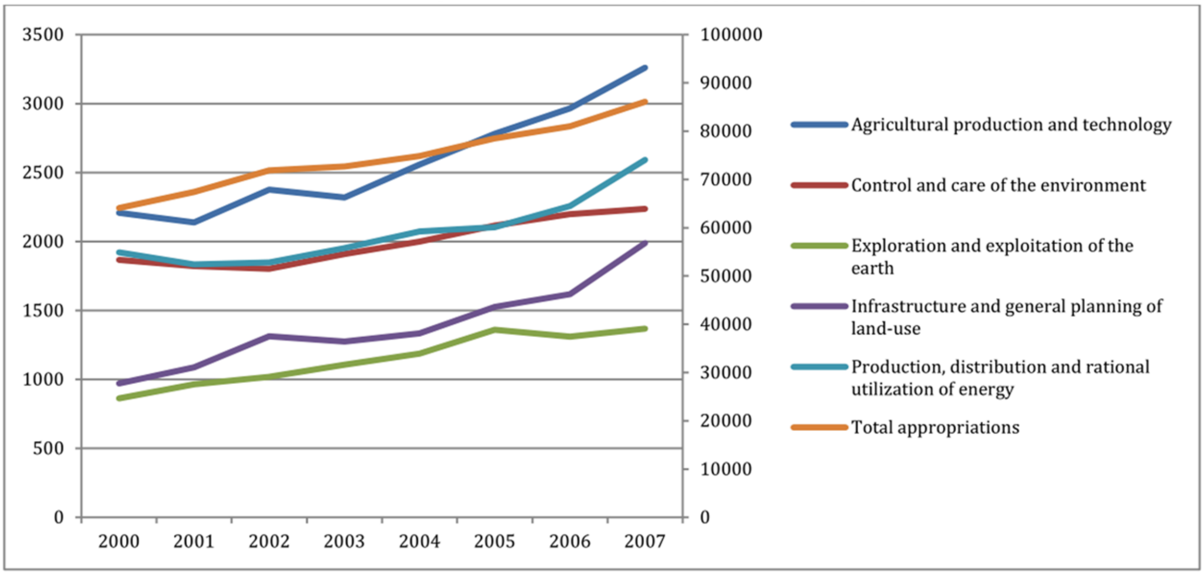
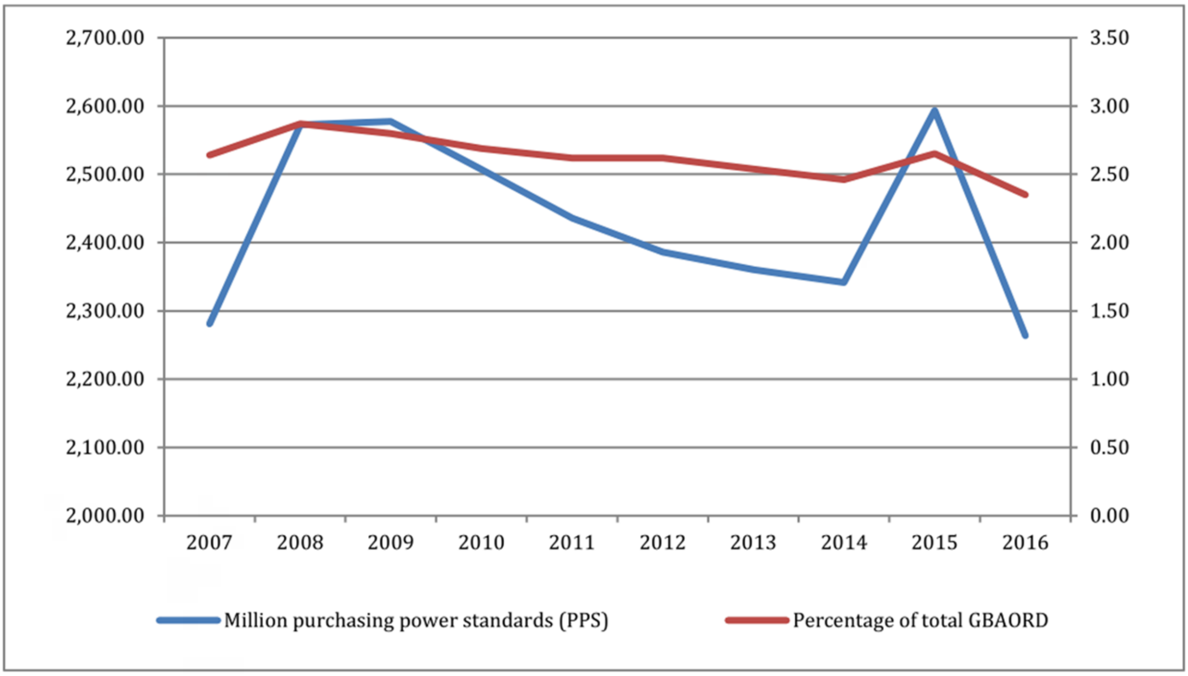
ANNEXES - Annex Chapter 5

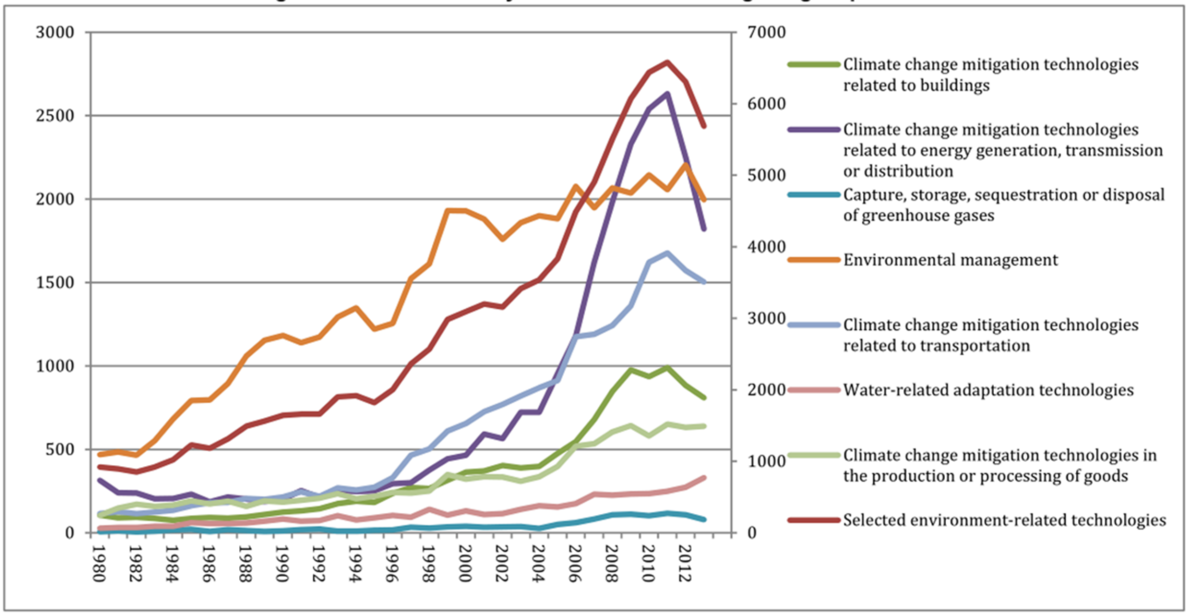
Figure A5.1 – Government Budget Appropriations on R&D (GBARD) trends for the EU-27 (Million purchasing power standards (PPS) and Percentage of total GBAORD (NABS1992)





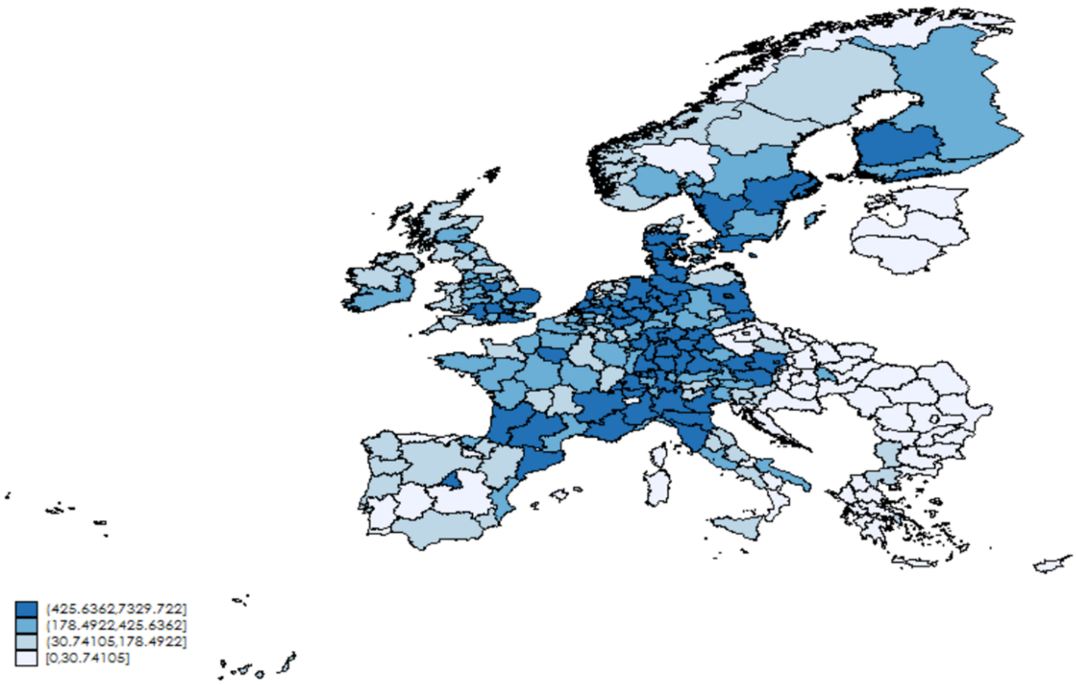
Source: Eurostat (November 2017)

Figure A5.3 – Patents by ENV-TECH technological group EU-28



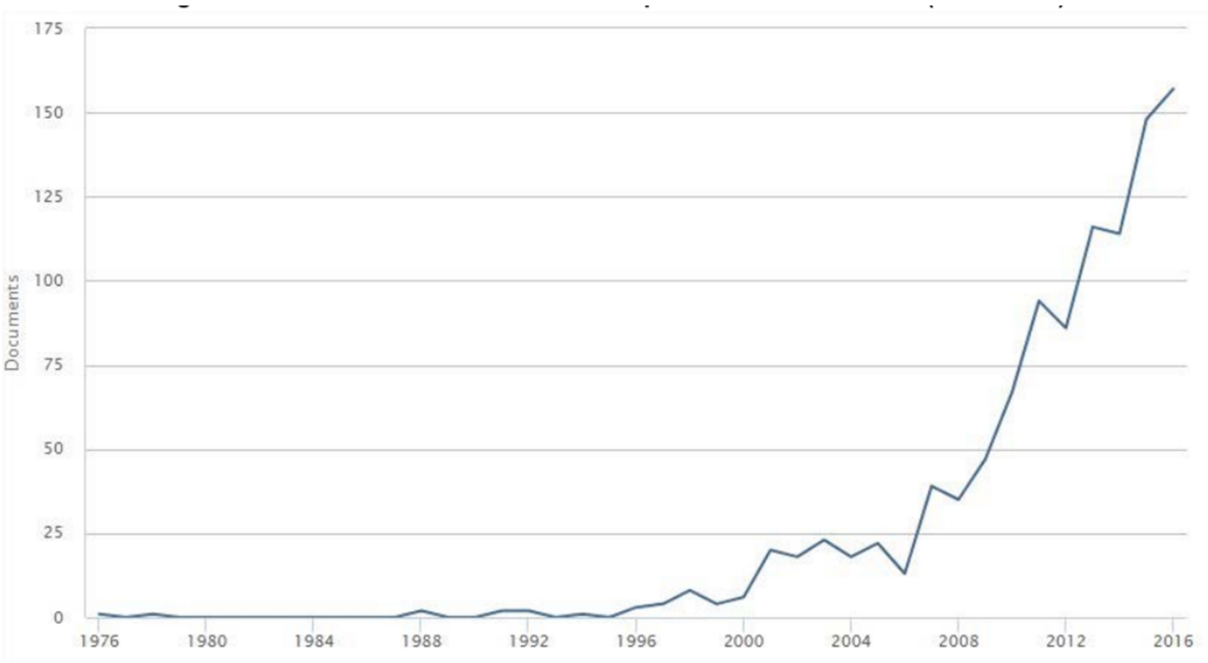
Source: OECD (2017)

Figure A5.4 – Geographical distribution of green patents fractional count at NUTS2 (1980-2012)



Source: Authors' elaboration from PATSTAT 2016

Figure A5.5 – Number of environmental publications over time (1976-2016)



Source: Authors' elaboration from Scopus

Foreign Direct Investment (FDI) as Inputs

Table A5.1- Green Foreign Direct Investment – Definitions and Measures

Source	Term	Definition and Measures	Calculated Amount
UNCTAD Roundtable Note (2008)	Low-carbon FDI	(1) FDI that applies higher environmental standards than required by host-country law (2) FDI into production of EGS	n.a.
UNCTAD (UNCTAD, 2010)	Low-carbon FDI	Greenfield FDI in renewable energy, recycling activities and low-carbon technology manufacturing. Consists of transfer of technologies, practices or products by MNEs to host countries – through equity FDI and non-equity forms of participation – such that their own and related operations, as well as use of their products and services, generate significantly lower GHG emissions than would otherwise prevail in the industry under business-as-usual circumstances.	US$90 billion (2009) US$82 billion (2016)
OECD (Golub et al. , 2011)	Green FDI	FDI in Environmental Goods and Services (EGS), proxy by FDI in electricity, gas and water sectors.	US$41 billion (2005-2007 average)
OECD Policy Framework for Investment (2015)	Green FDI	(1) Green infrastructure or greening of existing infrastructure (2) Sustainable management of natural resources and services they provide (3) Activities in EGSS and across green value chains	n.a.
fDi Intelligence (fDi Intelligence, 2016)	FDI in Renewa-ble Energy	Greenfield FDI in solar, wind, biomass, hydroelectric, geothermal, marine and other renewable power generation	US$76 billion (2015)
Bloomberg New Energy Finance Bloomberg New Energy Finance (2017)	Green FD Investment	Global investment in clean energy, low carbon services and energy smart technologies. Greenfield and M&A activity in renewables (e.g., biofuels, small hydro, wind and solar), clean energy services (e.g., carbon markets), and energy smart technologies (e.g., digital energy, energy efficiency, and energy storage)	US$287 billion greenfield FDI (2016
Related concepts			
System of Environmental-Economic Accounting: Central Framework (CF) EGSS	EGSS	Goods and services produced for (1) environmental protection and (2) resource management	
Climate Bonds Initiative	Climate Bonds	List of 47 investment areas in eight sectors (energy, transport, water, low carbon buildings, ITC, waste and pollution control, nature based assets, industry and energy-intensive com-mercial), with specific criteria for certification.	
Green Bond Principles, 2016	Green Bonds	Recognizes several broad categories of projects eligible for funding from green bonds. The-se categories include, but are not limited to renewable energy; energy efficiency; pollution prevention and control; sustainable management of living natural resources; terrestrial and aquatic biodiversity conservation; clean transportation; sustainable water management; climate change adaptation; eco-efficient products, production technologies and processes.	
Government Policies	Measures to attract green FDI	Means used by governments to attract Green FDI	

Source: Authors' compilation

Advancing the state-of-the-art in innovation for global sustainability

The Innovation for Sustainable Development Network (inno4sd.net®) brings together networks dedicated to innovation for sustainable development with the aim of reducing fragmentation and supporting collaboration, whilst engaging policy-makers, research & development, and businesses to achieve the sustainable development goals.

The H2020 Green.eu project and inno4sd® network was coordinated by the Netherlands Organisation for applied Scientific research TNO in the period March 2015- January 2019. As of February 2019 the inno4sd Steering Board oversees the activities and management of the network.

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