HOW

to measure eco - innovation and assess its impacts?

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Innovation for Sustainable Development Network

ISSN: **pending. Brussels, Belgium. March 2019**

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Outlook 7

How to measure eco-innovation and assess its impacts?

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Key messages

- Eco-innovation is key for the green economy and for achieving green growth.
- Measurement approaches should avoid over-emphasis on indicators for specific technological solutions, as measured through R&D investments, patents and publications.
- Measurement should capture activities that unintentionally result in environmental benefits as a by-product.
- Rebound effects should be anticipated for cost-saving innovations.
- The challenges for measuring eco-innovation policy for a green economy are more complex than those for innovation policy. Policy evaluation needs to pay attention to the context-specific mechanisms through which a policy wields influence and assess, where relevant, and the reasons why a policy lacks influence.

1 INTRODUCTION

In this outlook we discuss indicator systems for measuring eco-innovation and monitoring progress to a green economy. A four-pillar indicator systems is proposed for assessing the contribution of eco-innovation to the green economy, including eco-innovation, environmental, eco-policy and socio-economic well-being indicators.

As for eco-innovation measurement, the use of direct indicators is especially welcome. This includes green product changes and the diffusion of proven and innovative technologies in the domestic economy, such as investments in photovoltaics, wind power, energy storage for renewables, zero energy housing, electric vehicles, or an indicator for the percent of firms that have implemented eco-innovations.

The environmental indicators provide the baseline for measuring the effects (with suitable time lags) of eco-innovation activities and eco-policies. Measures of eco-policies are needed to determine the influence of policies on environmental performance via eco-innovation and for identifying policy gaps where policy action is needed. Indicators on socio-economic well-being constitute a fourth type that do not cover the innovation-outcome chain, but which can play a valuable role in ensuring that shifts to a sustainable economy do not result in undesirable side-effects such as greater inequality.

2 WHY MEASUREMENT OF GREEN ECONOMY AND ECO-INNOVATION MATTERS?

The 2015 Sustainable Development Goals (SDGs) aim to provide rising prosperity for all without passing ecological barriers. However, current economic growth is driven by resource extraction and fossil fuel emissions. Thus, if there is to be progress towards the SDGs, then much progress will need to be made in how goods and services are produced within an economy. Eco-innovation stands as one solution to this issue, by delivering new products, processes, organisations or marketing tools that have less environmental impact than the relevant alternative (Kemp and Pearson, 2007; Kemp, 2010). Regarding greenhouse gas (GHG) emissions, the world faces a stark challenge: to keep temperature rises to 2°C, experts predict that global GHG emissions in 2050 must be between 41% and 70% less than in 2010 (IPCC, 2014).

In Europe, North America and Japan, problems of air and water pollution have been reduced through the use of regulation and technology but in many parts of the world, levels of pollution are above safe levels. Pressures on biodiversity have remained high or continued to increase, leading to ongoing degradation of ecosystems, reductions in species populations and increasing extinction risks, as well as erosion of genetic variety. There are also issues of overexploitation of wild species (UNEP, 2012).

In light of these aforementioned trends and to more effectively move towards sustainable development, several organizations and international actors have developed the concepts of Green Economy (GE) and Green Growth (GG) as action-oriented approaches, or vehicles, to transition to a more sustainable economy[1]. The concept of a "green economy" was introduced over 20 years ago in the book Blueprint for a Green Economy (Pearce et al., 1989). It is a central concept of The United Nations Environment Programme (UNEP) which defines the green economy as "an economy where growth in income and employment is driven by investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services". At the same time as reducing environmental risks, the green economy is expected to lead to "improved human well-being and social equity" (UNEP, 2011).

At the operational level, the green economy is seen as one whose growth in income and employment is driven by investments that:

- Reduce carbon emissions and pollution;
- Enhance energy and resource efficiency;
- Prevent the loss of biodiversity and ecosystem services.

Eco-innovation is very relevant to the Green Economy approach and for achieving green growth. In fact, eco-innovation can support the greening of existing sectors as well as trigger new growth in emerging clean tech sectors (e.g. through technology development, with R&D and patenting activities). Environmental pressures may also be reduced through systemic forms of eco-innovation may achieve environmental improvements at multiple points. An example is the closing of material loops which leads reduced environmental pressures in upstream and downstream activities. A circular economy is an example of a green system innovation "that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times" (EMF, 2016: 19). Resources are regenerated or recovered and business models seek to maximise the value extracted from finite stocks of technical assets and materials (EMF, 2016: 22). In addition to a circular economy, the transition to a green economy would require several other system innovations, including a renewables based energy system, e-mobility, and ecological precision farming. Eco-innovation may find application in business and farms but also in communities, government and households (Arundel et al., 2017: 20).

Measurement of eco-innovation is crucial for policy monitoring and evaluation. The policy process should be a reflective system where policy makers can learn from past policy success and failures. Eco-innovation measurement can help answer questions such as: are firms innovating? What proportion of firms are innovating? What types of innovation are firms investing in? What motivates firms to innovate? What are the barriers to eco-innovation? How is eco-innovation financed? How does the firm benefit from eco-innovating? Are there spillover effects to other firms within the same sector/country? What is the result of the eco-innovation at the firm level? How do eco-innovations perform for the firm? For the sector? For the country? What are the major benefits at the country level resulting from eco-innovation? What eco-innovations are most effective for the firm, sector, and a country?

Eco-innovation indicators should guide policy by identifying and estimating the potential contribution of different types of technological and organizational innovation and investments on the gap between current emissions and safe emission levels, with the latter measured through the environmental indicators (Miedzinski et al., 2016). The measurement of the inputs, outputs and outcomes of interest are therefore vital for sound, objective, evidence based policy making.

3 THE PRACTICE OF ECO-INNOVATION MEASUREMENT

Eco-innovation is measured for products in dedicated studies (mostly with the help of patent data). A more systematic approach is provided by the score-board metrics developed by the Eco-innovation observatory in Europe, ASEIC in Asia and the Clean Technology Group. The Eco-Innovation Scoreboard (Eco-IS) displays the strengths (index>100), weaknesses (index<100) and overall performances of EU Member States compared to an EU average of 100. The index is supplemented by qualitative analysis of the country-specific institutional and economic context through annual country reports available at European Commisison's website[2].

Box 1: Eco-innovation Scoreboard, European Union

The eco-innovation scoreboard is managed by the Eco-Innovation Observatory, an EU funded project. There are 16 indicators which are split into five areas: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency and socio-economic outcomes. The scoreboard assigns scores to countries relative to the EU average, which scores 100. Indicators that score less (greater) than 100 are considered weaknesses (strengths). An overall score for each country is calculated based on an unweighted average of all 16 indicators.

The indicators are compiled from a number of different sources, and as a result, the reference year is not consistent. For example, indicator 4.2 Water productivity uses data last collected in 2005. Indicators 2.1 and 2.2. are based on Community Innovation Survey (CIS) results, for which questions relating to eco-innovation appear only occasionally, first in 2008 and then again 2014. Thus, up-to-date scores will be reliant on eco-innovation making an appearance in future CIS questionnaires.

Eco-IS Indicators:

1. Inputs
1.1. Governments environmental & energy R&D appropriations and outlays
1.2. Total R&D personnel and researchers (% of total employment)
1.3. Total value of green early stage investments (USD/capita)

2. Activities
2.1. Firms that have implemented innovation activities aimed at a reduction of material input per unit output (% of total firms)
2.2. Firms that have implemented innovation activities aimed at a reduction of energy input per unit output (% of total firms)
2.3. ISO14001 registered organisations (per million population)

3. Outputs
3.1. Eco-innovation related patents (per million population)
3.2. Eco-innovation related academic publications (per million population)
3.3. Eco-innovation related media coverage (per numbers of electronic media)

4. Resource efficiency outcomes
4.1. Material productivity (GDP/Domestic material consumption)
4.2. Water productivity (GDP/water footprint)
4.3. Energy productivity (GDP/gross inland energy consumption)
4.4. GHG emissions intensity (CO2 equivalent / GDP)

5. Socio-economic outcomes
5.1. Exports of products from eco-industries (% of total exports)
5.2. Employment in eco-industries and circular economy (% of total employment across all companies)
5.3. Revenue in eco-industries and circular economy (% of total revenue across all companies)

The ASEIC (ASEM SMEs Eco-Innovation Center)[3] developed the ASEM Eco-Innovation Index (ASEI) that measures the status and level of eco-innovation of ASEM member countries. The scope of the 2015 ASEI is broader than the Eco-IS by including the 28 Member States of the EU, Norway, Switzerland and 21 Asian countries (ASEM, n.d.).

Table 1. ASEM Eco-Innovation Index (ASEI) Indicators

Criteria	**2015 ASEI Indicators**	**Source**	**Year**
Eco-Innovation Capacity	**1-1. Country's economic competitiveness** **1-2. Country's general innovation capacity** 1-3. Green technology R&D institution capacity 1-4. Green technology possessed/acquired firms **1-5. Awareness of sustainability management**	GCI (WEF) GII (INSEAD) Cleantech Cleantech UN Global Compact	2014-2015 2014 2015.03
Eco-Innovation Supporting Environment	2-1. Government's R&D expenditure in green industry **2-2. Implementation of environmental regulations** 2-3. Maturity of investment setting for green technology industry 2-4. Investment scale of green technology SMEs	OECD WEF Cleantech Cleantech	2013 2014-2015
Eco-Innovation Activities	3-1. Commercialization level of green technology **3-2. Firms' participation on environmental management system** 3-3. Economic influence of leading environmentally responsive firms **3-4. Green patents** **3-5. Activeness of renewable energy utilization**	Cleantech ISO Trucost&Sustainalytics OECD/WIPO IEA	2013 2014 2011 2014
Eco-Innovation Performance	**4-1. Level of environmental impact on society** **4-2. CO2 emission intensity** **4-3. Country's energy sustainability level** **4-4. Water consumption intensity** 4-5. Jobs in green technology industry **4-6. Green industry market size**	EPI IEA ESI (WEC) IMD Cleantech UK BIS	2014 2014 2014 2014 2012

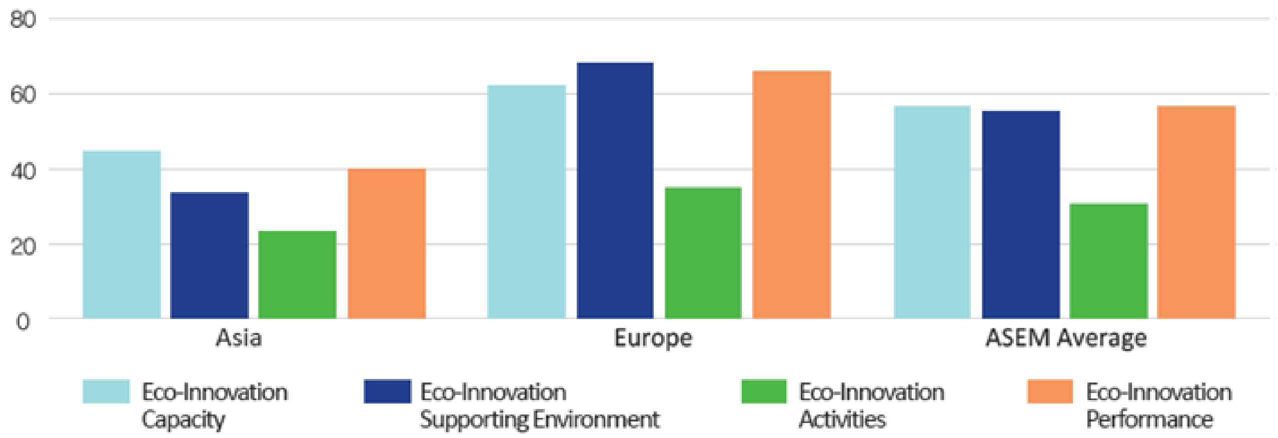
The ASEI website uses the definition of the European Commission from 2012, which states that 'progress towards the goal of sustainable development' should be the aim or result of eco-innovations. This is reflected in the broad choice of indicators categorized into four sub headings: Eco-innovation capacity, eco-innovation activity, eco- innovation supporting environment, and eco-innovation performance. The scale of the index varies from 0 (minimum) to 100 (maximum). Indicators in bold are included in the ASEI 2015.

In contrast to the Eco-IS, the ASEI includes policy-relevant indicators for the implementation of environmental regulations (indicator 2.2 in Box 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).

Other important new variables 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 while the Eco-IS does not make a distinction in the type of firm. Further interesting variable includes quality of life related to environmental factors, measuring: Health Impacts (probability of dying between a child's first and fifth birthdays (between age 1 and 5); Indoor Air Quality (percentage of the population using solid fuels as primary cooking fuel; population weighted exposure to PM2.5 (three-year average); proportion of the population whose exposure is above WHO thresholds (10, 15, 25, 35 micrograms/m3); Water and Sanitation (percentage of population with access to improved drinking water source; percentage of population with access to improved sanitation) (ASEI 2015: 163).

A comparison of Asian countries with those in Europe shows that Europescores 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 (a discussion of the differences can be found in Jo et al., 2015).

Figure 1. ASEI Results: Asia vs. Europe



Source: http://www.aseic.org/resources/download/asei/result_2015/ASEM_Eco-Innovation_Poster_Fin.pdf

Box 2: Global Cleantech Innovation Index

Indicator	Source	Date	Definition	Weight
General innovation drivers				
General innovation inputs	INSEAD Global Innovation Index	2013	Insitutions, human capital, infrastructure, market sophistication and business sophistication facilitating innovation	50%
Entrepreneurial culture	Global Entrepreneurship Monitor	2013	Positive attitudes towards entrepreurship and early stage entrepreneurial activity	50%
Cleantech-focused innovation drivers				
Cleantech-friendly government policies	The Pew Charitable Trusts Clean Energy Race Report and Cleantech Group research	2013	Government policies supporting clean energy including tax incentives, feed-in tariffs, renewable energy mandates and others	25%
Government R&D expenditure in cleantech sectors	International Energy Authority (IEA) RD&D budget data ; IEA Report - Tracking Clean Energy Progress	2011	Total budget for cleantech R&D as a proportion of GDP (PPP)	25%
Access to private finance for cleantech start-ups	Cleantech Group data	2011 - 2013	Number of cleantech investors and cleantech-focused funds recently raised weighted by GDP	25%
Country-attractiveness of Renewable Energy Infrastructure	Ernst & Young Renewable Energy Country Attractiveness Index	2013	National renewable energy markets, renewable energy infrastructures and their suitability for wind, solar, biomass and other renewable energy technologies	20%
Cleantech cluster programs & initiatives	Cleantech Group research	2013	Number of industry associations, physical clusters and economic initiatives supporting the cleantech industry as a proportion of GDP (PPP)	5%
Evidence of emerging cleantech Innovation				
Patents in cleantech sectors	OECD database	2011	Environment-related technology patents filed under the Patent Cooperation Treaty weighted by GDP (PPP)	45%
Early-stage private investment	Cleantech Group data	2011 - 2013	Amount of venture capital invested in cleantech companies as a proportion of GDP (PPP)	45%
High impact cleantech start-ups	Cleantech Group data	2011 - 2013	Number of companies included in the Global Cleantech 100 weighted by GDP (PPP)	10%
Evidence of commericalised cleantech innovation				
Revenue of cleantech companies	WWF/Roland Berger Clean Energy, Living Planet and UK Department for Business Innovation & Skills, Low Carbon and Environmental Goods and Services report	2012	Value-added from cleantech manufacturing as a proportion of GDP and revenue of Low Carbon and Environmental Goods and Services companies as a proportion of GDP (PPP)	50%
Renewable energy consumption	BP Statistical Review of World Energy 2013	2013	Renewables as % of Primary Energy Consumption	20%
Late-stage private investment and exits	Cleantech Group data	2011 - 2013	Number of cleantech private equity deals M&As, and IPOs weighted by GDP (PPP)	15%
Successful publicly traded cleantech companies	Cleantech Group, FTSE, Ardour and WilderHill indices of publicly traded cleantech companies	2013	Number of listed cleantech focused corporates weighted by GDP (PPP)	10%
Renewable Energy Jobs	IRENA Renewable Energy and Jobs Annual Review	2014	Number of direct and indirect employees related to renewables by total labor force	5%

Source: https://www.cleantech.com/wp-content/uploads/2014/08/Global_Cleantech_Innov_Index_2014.pdf

The Global Cleantech Innovation Index (GCII) was developed in 2012 by the Cleantech group. The GCII has a narrower scope and focus compared to the Eco-IS and the ASEI. 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).

The Cleantech group also developed a list in 2015 of 100 companies in the world "that are best positioned to solve clean technology challenges - and disrupt the markets they innovate in" (i3 Connect, 2016). Out 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). The GCII consists of four sub-categories: general innovation drivers, cleantech specific innovation drivers, evidence of emerging cleantech innovation, evidence of emerging cleantech innovation.

4 ECO-INNOVATION MEASUREMENT CHALLENGE

4.1 Definition of eco-innovation

The term 'eco-innovation' entered the public debate in the second half of the 1990s on the wave of the sustainable development debates preceding and following the Rio Earth Summit in 1992 (Fussler and James, 1996; Rennings, 1998; Rennings, 2000). The debate on eco-innovation picked up after the Rio Summit and has attracted increasing policy attention over the last decade, notably in Europe and the OECD. The debate was reinforced by the explicit recognition of the role of innovation in meeting sustainable development goals (UN, 2015).

The novelty of the concept of eco-innovation was an equal emphasis on the business and environmental features of eco-innovations for products and processes, as well as positioning eco-innovation as a major driver of socio-technical shifts (Fussler and James, 1996). This win-win narrative for businesses and the environment remained a key part of eco-innovation debates, which in the 2000s focused on businesses and other actors in research and innovation systems. More recently, the debate moved to the role of system eco-innovations as part of wider societal transitions to green socio-technical regimes (Geels, 2005; Steward, 2008; Kemp, 2011).

Many definitions of eco-innovation have been proposed since the mid-1990s.Most definitions do not include an explicit baseline, target or benchmark that must be exceeded in order to qualify as eco-innovation and often fail to recognise the trade-offs between improvements to various environmental di-mensions (Miedzinski et al, 2018).

Following discussions about the different indicators, the following definition for eco-innovation for use by statistical agencies is proposed by eco-innovation experts in the green.eu project (Kemp et al., 2018):

An eco-innovation is a new or improved product or practice of a unit that generates lower environmental impacts, compared to the unit's previous products or practices, and that has been made available to potential users or brought into use by the unit.

The definition is aligned with the fourth edition of the Oslo Manual guidelines for measuring innovation in the business sector. This facilitates the measurement of eco-innovation in data collection activities based on the Oslo Manual, such as the Community Innovation Survey in Europe and national innovation surveys in Argentina, Australia, Brazil, Canada, Chile, China, Japan, Korea, New Zealand, the United States and many other countries.

For measurement purposes, a unit is innovative if it implements a new or improved product or practice during a given time period, which is defined in the Oslo Manual as the observation period. The Oslo Manual recommends an observation period of between one and three years. For example, a public sector agency can be asked if it had any eco-innovations over the two-year period before the time of measurement, or a household can be asked it had any eco-innovations in the previous three years.

An eco-innovation does not require an explicit intention to reduce environmental impacts. Eco-innovations also include the unintentional reduction of environmental impacts. The essential characteristic that distinguishes an eco-innovation from other innovations is that it actually resulted in lower environmental impacts. For example, if a firm replaces an old machine by a new machine in order to increase its production capacity or flexibility, and the new machine has a higher environmental efficiency than the old one, this constitutes an eco-innovation.

Eco-innovations are interrelated. For example, a product change can require a process change and draw on eco-design tools as a design innovation. Furthermore, the introduction of environmental management systems helps companies to identify and implement measures for achieving environmental improvements. Eco-innovations in a sector can compete with one another. Solar energy competes with wind power. When practiced on a large scale, recycling can hinder repair, remanufacturing and re-use. Product manufacturers can prefer recycling if product repair and re-use cause a decline in product sales.

4.2 Environmental rebound effects

Eco-innovations can create environmental rebound effects in response to cost savings or increases. An Environmental Rebound Effects analysis tracks the environmental pressures as a result of demand changes and other second round effects of money saved due to the adoption of an eco-innovation. Font Vivanco et al. (2014) estimated that the 35% lower transport costs per kilometre for diesel cars, compared to petrol vehicles, "liberated on average 1200 euro per user a year, money which was spent on goods with CO2 emissions". The environmental rebound effect was so strong as to cause an absolute increase in emissions. Conversely, the high price for electric vehicles creates a negative rebound effect (Font Vivanco et al., 2015), but the high price discourages adoption.

The presence of rebound effects underscores the importance of reducing environmental impacts in all sectors. Possible ways to achieve this are carbon prices, resource taxes, and anti-landfill policies that promote recycling. Global carbon pricing could curtail carbon emission leakages between countries (Baranzini et al., 2017). The rebound effect also draws attention to the environmental performance of higher levels of consumption, such as higher levels of car mobility and increases in the consumption of meat in emerging economies.

In addition to the rebound effects for low-cost eco-innovations, other problems are associated with the use of green technologies. Examples of negative side-effects are visual intrusion and noise from wind turbines, health and safety hazards associated with unprotected forms of recycling, and the danger of carbon leaks in the case of carbon capture and sequestering.

4.3 Barriers and drivers of eco-innovation measurement

Eco-innovations stems from various stimuli or drivers (Kemp, 2000; Rennings, 2000; del Río González, 2005; Horbach, 2008; del Río González, 2009;Kesidou and Demirel, 2012). In the literature on eco-innovation drivers it is common to distinguish between internal stimuli and external stimuli. Horbach (2008) distinguishes technological opportunities (science push) as a third stimulus and Aggeri (1999) and Mazzanti and Zoboli(2009) distinguish network-based stimuli. Examples of internal stimuli are environmental responsibility (green ethos) and environmental management systems. External stimuli are: environmental regulations, innovation subsidies, pollution taxes, demand from users, and pressure from local communities (Kemp et al., 2013).

The importance of stimuli differs between different types of innovations. Hor-bach et al (2012), find that current and expected government regulations are particularly important for pushing firms to reduce air (e.g. CO2, SO2 or NOx) as well as water or noise emissions, avoid hazardous substances and increase recyclability of products. Cost savings are found to be an important motivation for reducing energy and material use, pointing to the role of energy and raw materials prices as well as taxation as drivers for eco-innovation. Customer requirements are particularly important for green product innovation and for process innovations that increase material efficiency, reduce energy consumption and waste and the use of dangerous substances (Horbach et al., 2011). The results are based on an econometric analysis of information from the Community Innovation Survey in 2008 for Germany.

Economic development requires something more than the stimulus of innovation. Innovation does not act as a separate growth factor operating alongside other growth factors (such as education or capital investment) but as something that is entwined with it.

ETAP (the European Commission's Environmental Technologies Action Plan) identifies the following barriers to environmental technologies:

- Economic barriers, ranging from market prices which do not reflect the external costs of products or services (such as health care costs due to urban air pollution) to the higher cost of investments in environmental technologies because of their perceived risk, the size of the initial investment or the complexity of switching from traditional to environmental technologies;

- Regulations and standards that can act as barriers to innovation when they are unclear or too detailed, while good legislation can stimulate environmental technologies;

- Insufficient research efforts, coupled with inappropriate functioning of the research system in European countries and weaknesses in information and training;

- Inadequate availability of risk capital to move from the drawing board to the production line;

- Lack of market demand from the public sector, as well as from consumers.

A more elaborated scheme of barriers is offered by Ashford (1993), making a distinction between the technological, financial, labour-force related, regulatory, managerial, consumer-related and supplier-related barriers.

The barriers are interrelated. For instance a lack of top management commitment might be caused by various factors: **(1)** lack of information from the financial department to top management concerning the profitability of waste reduction technologies in general; **(2)** lack of confidence in performance of new technologies; **(3)** lack of managerial capacity and capital to deal with the transition costs of reorganizing the production process, educational programs, consumer demands, or discharge waivers; **(4)** lack of awareness of long-term benefits of waste reduction approach, resulting in waste reduction being a low-priority issue (Ashford, 1993).

Barriers differ among sectors and may differ among countries. The study by Hitchens et al. (2003) on environmental performance in EU countries found that there is a national element in such barriers – which is in line with discussions on National Innovation Systems and the growth theories: Financial barriers were more important in Germany than in the UK. Priority and lack of time was a greater barrier in the UK than in Germany. Information problems and regulatory obstacles were more pronounced in Germany.

Barriers to innovation in resource efficiency have been studied in a Flash barometer study. The survey study covers all of the new Member States and old Member States, recalculations are given in the Table 2.

All barriers are more significantin the new MS except for limited access to information and technology support services. For old MS the greatest barrier is uncertainty about market demand, for new MS the greatest barrier is lack of funds within the enterprise (followed by uncertain demand from the market). It should be noted that the innovation activities in old MS differ from those in new MS. Old MS are more likely to be working on eco-innovations new to the world, which require special capabilities. This may explain the higher percentage for lack of collaboration with research institutes and universities and lack of qualified personnel and technological capabilities within the enterprise.

Table 2. Barriers and Divergence in Old and New EU Member States

Barrier	Old Member States	New Member States	Divergence (Descending)
Lack of funds within the enterprise	56.40%	70.80%	14.40%
Insufficient access to existing subsidies and fiscal incentives	56.70%	66.20%	9.50%
Technical and technological lockins (e.g. old technical infrastructures)	49.20%	56.30%	7.10%
Lack of external financing	52.90%	59.65%	6.75%
Existing regulations and structures not providing incentives to eco-innovate	56.20%	62.50%	6.30%
Lack of suitable business partners	41.20%	46.80%	5.60 %
Uncertain return on investment or too long a payback period for eco-innovation	63.60%	68%	4.40%
Uncertain demand from the market	64.50%	68.90%	4.40%
Reducing material use is not an innovation priority	44.75%	45.65%	0.90%
Market dominated by established enterprises	51.80%	52.65%	0.85%
Reducing energy use is not an innovation priority	54.80%	53.90%	(-) / 0.90 %
Lack of qualified personnel and technological capabilities within the enterprise	53%	51%	(-) / 2.00 %
Lack of collaboration with research institutes and universities	35.60%	32.70%	(-) / 2.90 %
Limited access to external information and knowledge, including a lack of well-developed technology support services	44.40%	41.40%	(-) / 3.00 %

Source: Flash Eurobarometer on attitudes of European entrepreneurs towards eco-innovation, 2011

Problems with indicators used in existing studies are (Arundel et al., 2007):

- R&D, number of researchers: inputs do not necessarily lead to outputs. Furthermore, a large amount of R&D spending may indicate a high degree of inefficiency in R&D. Also, R&D is often biased towards the manufacturing sector. For Eco-IS, indicator 1.2 includes all researchers, not just those dedicated to R&D.

- Publications and patents: They do not measure actual eco-innovation outputs, only the generation of new knowledge. In contrast, eco-innovation outputs attempt to measure the commercialisation of an eco-innovation. They are biased towards certain innovations (e.g. products), industries (e.g. manufacturing) and against incremental improvements.

- Eco-innovation implementation: This is generally measured using questionnaires. However, this involves subjective assessment by firm managers, and thus it is open to much bias and measurement error. The irregularity of its collection also makes it unreliable as a regular indicator.

- Eco-innovation outcomes: Outcomes are generally measured at the sector or country level, since individual firm level data is difficult to collect.

In each of these categories, there exists one or more flaws that make drawing conclusions based on these indicators difficult. As much as this is true for all indicators, it is particularly true for eco-innovation indicators due to the nature of its definition. To be considered an eco-innovation, the activity must demonstrate improved environmental performance over its entire life cycle.

Life Cycle Analysis helps to determine this but should account for environmental rebound effects (ERE) that stem from behavioural changes sparked by money being saved (or expended) (Vivanco et al., 2016). An assumption of ERE is that money that is saved from using a green alternative will give rise to increased use of the alternative (such as energy saving lamps which burn all night outside a house) and induced spendings on other goods and services. Such behavioural changes are associated with additional environmental pressures which can be captured by ERE analysis (calculations of the ERE are provide in Font Vivanco et al., 2014, 2015 for the case of transport). Cost differences do not entirely stem from the technical characteristics of new technologies, but also from external factors, such as fuel prices or the relative impact with respect to other products from the consumption basket. These aspects have thus a notable influence in the overall environmental performance of transport innovations and should be seen as active elements of policy rather than a fixed background. This gives a wider range of possible policy actions to improve the environmental performance of current transport systems, such as green taxes or sustainable consumption policies aimed at key consumption sectors (e.g. food production).

4.4 Eco-innovation measurement gap?

The conclusion of a green.eu report on eco-innovation measurements and green growth is that efforts to measure eco-innovation and the green economy must include fourtypes of indicators: eco-innovation, eco-policy, environmental indicators, and well-being indicators. The reasoning behind this is as follows: The environmental indicators provide the baseline for measuring the effects (with suitable time lags) of eco-innovation activities and eco-policies, where the environmental indicators need to be measured in absolute terms, such as total national GHG emissions in a target year and the percentage change in these emissions over a defined time period.

Absolute indicators are necessary to track progress in achieving sustainable (or acceptable) emission levels. Measures of eco-policies are needed to determine the influence of policies on environmental performance via eco-innovation and for identifying policy gaps. Indicators on socio-economic well-being constitute a fourth type that do not cover the innovation-outcome chain, but which can play a valuable role in ensuring that shifts to a sustainable economy do not result in undesirable side-effects such as greater inequality (Arundel et al., 2017). Well-being indicators are necessary for avoiding tradeoffs in terms of well-being.

There are a number of challenges for eco-innovation indicators, of which the following are mentioned in the report. The first is to avoid over-emphasis on indicators for specific technological solutions, as measured through R&D investments, patents and publications. The second is to find indicators for innovation activities that unintentionally result in environmental benefits as a by-product. For instance, process innovations that are focused on reducing material costs and wastage can unintentionally reduce total material use. The environmental modules in the 2008 and 2016 European Community Innovation Surveys (CIS) were designed to capture innovations with both intentional and unintentional environmental benefits, but these indicators are not available for many of the non-European countries in the G20. A third challenge is that rebound effects should be anticipated for cost-saving innovations. The rebound effects will curb the environmental gains and may even lead to an overall increase in environmental pressures for certain emissions ("take-back" or "backfire" effect, Saunders, 2000).

In general, eco-innovation is a poor predictor of resource efficiency. This is because eco-innovation is a relative indicator. Whether or not an innovation is an eco-innovation depends on whether the innovation on a life cycle basis isless environmentally harmful than the use of relevant alternatives (Kemp and Pearson, 2007, Kemp et al., 2018)[4]. Economic growth and rebound effects will mitigate the gains from green innovations. Correlations between eco-innovation indicators and environmental performance indicators are found to be weak and often not significant in a study for green.eu (Arundel et al., 2017), which shows that the causal links between eco-innovation and environmental performance are complex and in need of further research. High levels of eco-innovation may stem from demand abroad, besides from domestic demand and from national capabilities for eco-innovation.

To assist policy on GHGs, eco-innovation indicators are needed for the residential, transportation, industrial and commercial sectors. For instance, it would be useful to have indicators of value to the household sector, such as the share of products sold (dishwashers, fridges, etc.), by energy efficiency and changes in household, business and government consumption patterns. For the transportation sector, an indicator for the share of electric vehicles would help in planning for the construction of vehic le charging stations (Arundel et al., 2017, p. 58).

5 WHAT CAN POLICY MAKERS DO?

Green growth policies and frameworks reflect concerns of relevant stakeholders. Environmental policy stems from pressures from environmental groups and works via politics, science and capable agencies. Environmental policy is resisted by manufacturing companies, on account that environmental action will cost jobs through higher prices that stem from the costs of environmental action. A politically organized environmental good and service sector offers a counterbalance to this, in drawing attention to the jobs associated with environmental action.

There are many considerations behind environmental policy. Behind South Korea's green growth policies are the following national goals: achieving energy independence and climate mitigation, economic gains from producing and exporting green technology, quality of life improvements for its citizens and enlarging South Korea's importance in the international community (L. Kemp, 2013).

For companies, sustainable development is a difficult concept, a 'wrap around' whatever the company does in terms of eco-efficiency, business ethics and corporate social responsibility (Porritt, 2007, p. 41). Government action is thus essential for stimulating eco-innovation. Innovation policy has an important role to play for creating innovations new to the world. And environmental policy is needed for making companies adopt environmental technologies, especially pollution control technologies (clean technologies may be adopted for economic reasons of reduced resource use).

Innovation policy does not lend itself easily to rational choice, because of uncertainty and information asymmetries between policy makers and actors in industry and research. As discussed in the article "10 Themes for eco-innovation policies in EU" (Kemp, 2011), policy should evolve with experience and involve critical evaluation of the system of innovation governance in which policy choices are made. It is important that policy isnot viewed purely in instrumental terms but as a trajectory in itself (see Voss, 2007). To make effective policies it is necessary that government officials have a correct understanding of eco-innovation barriers and of innovation dynamics in general. Blind technology support, favoured by economists, is found to generate windfall profits to recipients and to be unsuccessful in stimulating radical change.

Policy interventions for eco-innovation may be ineffective or give rise to unintended effects, called "escape routes" by van den Bergh (2012). Examples of escape routes are:

- Direct market support of clean energy leading to more energy use because of lower prices of clean energy and lower prices for fossil fuels because of competition from clean energy (green paradox)

- Ecolabels and regulations offering no encouragement for further environmental improvements in the absence of dynamic adjustments

- Carbon policies causing production to shift to countries with less stringent carbon policies, causing an increase in carbon emissions (carbon leakage)

- Carbon policies creating new risks and increases in other pollutants (transfer of problems).

Such escapes should be anticipated and dealt with.

Different types of eco-innovation require different policies. Ingeneral, incremental improvements of commercial productsdo not require special support. Companies are perfectly capable of producing and funding these. Radical innovations and system innovation are much more in need of support, butthe barriers to them and the level of support needed will differ. Radical innovations that are transformative require moresupport than technical fixes for problems of well-established regimes.
Support for transformative innovation should go beyond the financial as it requires institutional change in the economic and social world.

For dealing with the grand challenges of climate change and energy/resource security, EU policy makers have expressedan interest in "mission" policies (without using the word mission). As mentioned in Policy Outlook 1, there is a role for innovation missions, but the key challenge is not to develop technologies but to get innovations adopted, which is very much a matter of incentives, institutional change and appropriate innovation designs (tailored to the context of application) rather than an issue of technology development. To avoid lock-in,- the missions should be based on a portfolio of technologies with the innovations subjected to on going evaluation, to circumvent policy capture by special interests, an issue which is given little attention in current discussions on eco-innovation policy. In general, eco-innovation policy is very much oriented towards high-technology options, as a result of demand from actors (companies and researchers) interested in those options (Kemp, 2011).

There is also need for better indicators of eco-innovation. Proposals for this are being developed in the green.eu project. The group of indicators needs to cover the activities of businesses, governments and households to reduce environmental pollution[1]. These activities can include the application of good practice to existing sectors of the economy and the development, implementation and diffusion of new technologies or organizational methods. Relevant categories include:

1. Indicators for recycling that improve environmental outcomes by producing lower emissions than alternatives.

2. Indicators of resource intensity and productivity that measure the extent to which resources are used to carry out social and economic activities.

3. Energy and air emissions productivity and intensity. As for material, water and waste productivity, energy productivity is measured by dividing total economic output by energy consumption. Production-based indicators can be complemented with consumption-based (demand) indicators. Production-based measures capture the total amount of energy consumed during production processes relative to produced GDP, while demand-based energy productivity is the real disposable income generated per unit of energy consumed during all of the various stages of production of the goods and services consumed in domestic final demand, irrespective of where the stages of production occurred. A comparison of these two indicators permits an assessment of the extent to which a country produces or imports more (or less) resource intensive production processes.

4. The diffusion of proven and innovative technologies in the domestic economy, such as investments in photovoltaics, wind power, energy storage for renewables, zero energy housing, electric vehicles, etc., or an indicator for the percent of firms that have implemented eco-innovations. These indicators can determine if eco-innovation is a mainstream activity or if it is limited to specific sectors. Diffusion indicators also need to cover government organisations and households, next to businesses[6].

5. Public and private sector investments in environmental R&D and innovation.

6. Indirect indicators for potential improvements to the environment, such as indicators for the economic contribution of the Environmental Goods and Services Sector (EGSS) and patents for environmental technologies.

Environmental indicators should be measured in absolute terms and not only in relevant terms. Negative environmental impacts depend on absolute emissions and consequently their elimination requires reductions in absolute emissions. A set of eco-innovation indicators needs to contain direct measures for eco-innovation (i.e. investment in renewable energy), in addition to indirect measures and inputs (i.e. patents). Eco-innovation requires continuous improvement. More attention should therefore be given to systemic conditions that affect the performance of eco-innovations.

In the manual about measuring eco-innovation, a four-pillar measurement system is being proposed for assessing the contribution of eco-innovation to the green economy:

- Environmental indicators
- Eco-innovation indicators
- Eco-policy indicators,
- Socio-economic well-being indicators.

The logic behind the 4-pillar indicator systems is as follows. The environmental indicators provide the baseline for measuring the effects (with suitable time lags) of eco-innovation activities and eco-policies. Measures of eco-policies are needed to determine the influence of policies on environmental performance via eco-innovation and for identifying policy gaps where policy action is needed. Indicators on socio-economic well-being constitute a fourth type that do not cover the innovation-outcome chain, but which can play a valuable role in ensuring that shifts to a sustainable economy do not result in undesirable side-effects such as greater inequality.

The inclusion of eco-policies as a pillar allows for policy learning. However, producing eco-policy indicators is a challenge. Policies, even with the same objective, such as R&D tax credits, are implemented in different ways in different countries. Nevertheless, efforts to obtain policy data are likely to be worthwhile, since the cost of policy measurement and evaluation is considerably less than the costs of policy failure. The STIR framework developed in green.eu (Miedzinski et al., 2017) can be used to analyse policy effects, appraise policy mixes and build capacities for better policy making.

The challenges for eco-innovation policy are more complex than those for innovation policy because it is not a simple matter of producing innovations and encouraging their uptake. Eco-innovation policy needs to avoid rebound effects while replacing less environmentally benign processes, goods and services. The latter requires control policies that are bound to meet with resistance and require special knowledge of sectors. Policy evaluation needs to pay attention to the context-specific mechanisms through which a policy wields influence and assess, where relevant, and the reasons why a policy lacks influence. The data and research requirements of dealing with those challenges are formidable but necessary to undertake, given the need for change and costs of policy failure. Eco-innovations address wide-ranging environmental problems, calling for eco-innovation assessment and appropriate policy mixes.

End notes

[1] This policy outlook is based on two reports for green.eu: "Measuring eco-innovation, green growth and the green economy" (Arundel et al., 2017) and Kemp, R., Arundel, A., Rammer, C., et al., (2018) Maastricht Manual on Measuring Eco-Innovation for a Green Economy, Deliverable 2.5 for green.eu.

[2] See https://ec.europa.eu/environment/ecoap/country_profiles_en

[3] ASEIC is an international platform with the aim to promote cooperation between Europe and Asia in crea-ting and enhancing eco-innovation in small and medium sized enterprises (ASEIC, 2011).

[4] Based on the following definition of eco-innovation: "The production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organi-sa-tion(developing or adopting it) and which results, throughout its life cycle, in a reduction of environmen-tal risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives"(Kemp and Pearson, 2007).

[5] The last section is from Arundel et al. (2017) and serves as the basis for future work on eco-innovation measurement in the green.eu project.

[6] EG imports are positively correlated with resource productivity and negatively corre-lated with energy intensity and emission intensity. See Appendix C of Arundel et al. (2017).

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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.

The inno4sd network was initiated by the green.eu project, which received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 641974. The views expressed in this document are those of the authors and does not necessarily reflect those of the European Commission.

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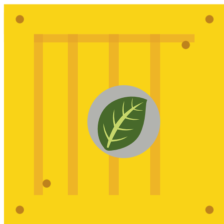

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