Measuring eco-innovation for a green economy

René Kemp/Anthony Arundel/Christian Rammer/Michal Miedzinski/Carlos Tapia/Nicolò Barbieri/Serdar Türkeli/Andrea M. Bassi/Massimiliano Mazzanti/Donald Chapman/Fernando J. Díaz López/Will McDowall

René Kemp is Professorial fellow at UNU-MERIT and Professor of Innovation and Sustainable Development at ICIS, Maastricht University. He coordinated the work for the Manual.

Anthony Arundel is Professorial Fellow at UNU-MERIT and adjunct professor at the University of Tasmania

Christian Rammer is Senior researcher at ZEW Department of Economics of Innovation and Industrial Dynamics, and director of ZEW annual innovation survey, the Mannheim Innovation Panel

Michal Miedzinski is Senior Research Associate, University College London, Institute for Sustainable Resources

Carlos Tapia is Senior researcher at TECNALIA Research & Innovation, Energy and Environment Division

Nicolò Barbieri is Researcher at the Department of Economics and Management – University of Ferrara

Serdar Türkeli is Post-doctoral researcher at UNU-MERIT, Lecturer in Science, Technology and Innovation Policy and Coordinator of Innovation, Institutions and Development specialisation at UNU-MERIT/MGSoG, Maastricht University

Andrea M. Bassi Founder and CEO of KnowlEdge Srl, Extraordinary Associate Professor of System Dynamics Modelling at Stellenbosch University, and Associate at the International Institute for Sustainable Development (IISD)

Massimiliano Mazzanti is Professor of Economic Policy and Lecturer in Environmental Economics, University of Ferrara

Donald Chapman PhD research fellow in Ecological Economics and Sustainability Transitions at KU Leuven

Fernando J. Díaz López is Director of the Innovation for Sustainable Development Network and Associate Professor Extraordinary on Sustainable Systems, at Stellenbosch University

Will McDowall is Lecturer and Researcher, University College London, Bartlett School Environment, Energy & Resources
This paper, written by experts of eco-innovation, offers guidance on the measurement of eco-innovation for a green economy. This is done through definitions, an explanation of important issues for understanding, a discussion of the various ways in which eco-innovation (in its different forms) can be measured, and a proposal for a four-pillar indicator system.

1. Introduction

A green economy requires the replacement of current practices by those whose environmental impact is less negative. In this paper, we offer guidance on the measurement of eco-innovation for a green economy. This is done through definitions, an explanation of important issues for understanding, a discussion of the various ways in which eco-innovation (in its different forms) can be measured, and a proposal for a four-pillar indicator system:

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

The logic behind the 4-pillar system is as follows. 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 (areas 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 play a valuable role in ensuring that shifts to a sustainable economy do not result in undesirable side-effects such as greater inequality.

Absolute environmental indicators (rather than efficiency indicators) are necessary to track progress in achieving sustainable (or acceptable) emission levels. Direct indicators of eco-innovation are strongly preferred over indirect measures and input indicators. An example of a direct indicator is the number of battery electric vehicles (BEV) in the car fleet and the share of BEV in total vehicle kilometres.

Figure 1 shows the forward and backward linkages between eco-innovation inputs, capacity, outputs and performance and is a useful framework for thinking and measurement. Eco-innovation performance depends on eco-innovation outputs from eco-innovation activities. Sales from commercialisation aid companies to further pursue innovation. All elements are affected by boundary conditions (framework conditions) which include global influences. The different feedback loops make the system non-linear and complex.

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1 The paper summarizes the main findings of the Maastricht Manual on eco-innovation measurements for a green economy, produced by the authors (published as Kemp et al, 2019).
2. From environmental technologies to eco-innovation

The first green technologies were pollution control technologies that helped companies to meet environmental regulations, but present day green technologies include renewables, technologies for recycling, products that use less energy and platforms for product sharing. When the environmental impact is lower than that of a relevant alternative (the product previously produced or used), we speak of an eco-innovation. They may be developed or adopted for reasons of reducing the green impact of products and processes, but this is not a requirement.

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, 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 newness of the concept of eco-innovation was to give attention to the positive business aspects of reducing resources (by reducing the costs of resource use and waste minimization) and the jobs involved in the commercialization of environmental products (goods and services). Eco-innovation contributes to a political agenda in support of the green economy and green growth.

The prevalence of different types of eco-innovations was measured in Europe by the 2008 and 2014 Community Innovation Surveys (CIS). The 2014 survey asked respondents if their business had one or more innovations between 2012 and 2014 that provided environmental benefits during its use within the enterprise or during its consumption or use by the end user. Descriptions of specific types of benefits were provided, including reductions in material and energy use per unit of output and in total CO2 emissions.

3. Systems aspects of eco-innovation

Eco-innovation is either a response to environmental problems brought to the attention of policy makers, operating in a political and institutional environment or a normal market response to high resource prices. A common scheme for understanding the environment-economy relationship is the Driving Forces – Pressures – States – Impacts – Responses (DPSIR) model. According to the DPSIR system analysis view, social and economic developments drive changes that exert pressure on eco-systems in the form of pollution and waste. Depending on the natural assimilation capacity of eco-systems, pressure can lead to changes in the state of the environment that cause impacts on human health, ecosystem functions, materials (such as historic buildings), and the economy. These dynamics are intermediated by responses in the form of regulation and eco-innovation that directly or indirectly affect earlier parts of the system (Stanners et al, 2007).

Figure 2 illustrates the DPSIR model for eco-innovation with rebound effects (the negative environmental effects from expenditures induced by cost-savings from eco-innovations). The graph includes a policy making model of how environmental degradation leads to eco-policies via media articles on environmental problems, capable agencies for environmental protection, international treaties, and eco-innovation organisations lobbying for pro-environment policies. The multitude of eco-innovations means that in a sector they compete with one another. Solar energy competes with wind power and recycling competes with product repair and re-use. The terms of competition are unequal when one technology has gained an advantage through an early start and/or being favoured by incumbents. Over time, the price-performance ratio tends to improve over time thanks to dynamic scale and learning economies (Kemp, 1994) and price competition. Progress rates and learning curves are important issues for measurement. Some eco-innovations are systemic and this creates a particular challenge for eco-innovation measurement.
Figure 2: DPSIR Framework and Eco-Innovation

Source: Authors' elaboration
4. A definition and stylized facts

A useful definition for statistical measurement, consistent with the definition for innovation in the Oslo Manual for innovation measurement, is the following: **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.**

Practices includes the activities described as ‘processes’ in the Oslo Manual as well as any activities of individuals. Products comprise goods and services.

Whether a product or practice results in a reduction in environmental impacts needs to be based on the environmental impacts associated with all stages of a product’s life, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling (life-cycle assessment).

An eco-innovation only needs to be new or improved for the unit that offers or uses the product or practice. Eco-innovations hence include the adoption of products or practices that have previously been used by others. An eco-innovation also includes the introduction of products or practices which are inferior in terms of their environmental performance compared to other products or practices available in the market, but which are superior over the products and practices used by the innovating organisation or individual so far. For example, if a household buys a new refrigerator of eco-efficiency class B to substitute an old refrigerator of eco-efficiency class C, this constitutes an eco-innovation despite the fact that more eco-efficient refrigerators were available on the market at the time of purchase. At the same time, introducing a product or practice with a superior environmental performance compared to similar products or practices available in the market so far is not an eco-innovation if it substitutes a product or practice with lower environmental impact per activity or output. For example, if an individual replaces a compact car by a new sport-utility vehicle (SUV) with the most efficient engine technology for SUVs, this will not be an environmental innovation if the life-time environmental impact of the new SUV is higher than that of the compact car.

Stylized facts about eco-innovation are:

- Eco-innovation requires identification of opportunity, capability and positive expectations about economic gains and reduced environmental impacts. Each of these is a necessary element.

- Pro-environmental behaviour depends on managerial responsiveness to regulations and environmental groups, effort to identify win-win solutions, and the criteria used to evaluate the benefits of investment in environmental innovations (Gunningham et al, 2003).

- Eco-innovation is influenced by framework conditions such as regulations, informal institutions and current (and expected) market prices.
The anticipation of regulation, such as a future product or substance ban, can drive eco-innovation.

Incremental innovations with environmental benefits are less driven by regulation and less likely to be the result of dedicated innovation projects.

Reasons for a problem sector not to eco-innovate (more) include the absence of an economic incentive to go beyond standards required by law; poor innovation capabilities of the problem sector; and the problem sector’s preference for non-disruptive technology responses (Kemp and Pontoglio, 2011).

Consumer frames of evaluation differ from those of organisations. The non-adoption of a good or service that helps a household save money is often viewed as an example of irrational behaviour, but this is because other relevant issues are left out of the equation (such as other expenditures being more appealing).

5. Enablers and hindering factors for eco-innovation

The innovation literature commonly discusses innovation development and adoption in terms of drivers and barriers. The literature on drivers distinguishes between internal drivers within a firm, government agency, or household; and external drivers (del Rio et al, 2017). Horbach (2008) adds technological opportunities (science push), but this can be treated as a specific class of external drivers.

- Internal drivers include environmental awareness, green ethos, knowledge, resources, skills, and capabilities, which can influence all sectors. Environmental management systems such as ISO 14001 can act as an internal driver by providing an ongoing framework for eco-innovation in the business and government sectors.

- External drivers that potentially affect all sectors include regulations, pollution taxes, demand from users (market opportunities), access to financing schemes, subsidies for the adoption of environmentally preferable products or processes, availability of ‘enabling infrastructures’ (eg charging stations for electric vehicles) and institutional and community pressure. An external driver that is largely limited to firms and public research institutes is direct and indirect government subsidies for investment in eco-innovation.

Important issues with measuring the concepts of innovation drivers and barriers include:

- The concept of an innovation driver requires a causal relationship, such that a focus organisation intentionally reacts to one or more drivers by developing or adopting an innovation. For example, organisational size
is not a driver, but simply a variable that has a correlation (usually positive) with eco-innovation. Proving causality is always far more difficult than proving association.

- Similarly, the concept of an innovation barrier requires that a focus organisation takes one or more actions in response to one or more real or potential barriers. Otherwise, a specific barrier, although it may be relevant to other firms, is not a barrier for the focus organisation.

- Research has mostly examined the proximate drivers of eco-innovation adoption, neglecting the influence of distal factors (Hojnik and Ruzzier, 2016) such as education, general environmental awareness, a good governance system and a culture of entrepreneurship.

- Drivers and barriers are context-specific. Similar combinations of concurrent forces may lead to different outcomes depending on different organizational cultures, mind-sets and contextual settings that characterize the temporal and spatial geographies where the companies operate.

- Policy actions such as subsidies, regulations, or environmental taxes can act as drivers, but under many conditions they may not be sufficient, by themselves, to change behaviour. Likewise, the existence of an environmental management system within a firm is unlikely to be the reason for engaging in a process change.

For assessing technology-specific blocking mechanisms, the technology innovation system framework may be used (Bergek et al, 2008, Hekkert et al, 2007). For evaluating the extent to which public policy is supporting innovations to enable transition towards sustainability, the Sustainability Transition Innovation Review (STIR) can be used (Miedzinsky et al, 2017).

6. A discussion of eco-innovation indicator sets

To provide a full picture of eco-innovation, measurement is required for inputs, activities, performance and shaping factors, which often can only be met through combining data from multiple sources. Examples for combining data sources on eco-innovation are as follows:

- Survey a sample of inventors with a patent of relevance to eco-innovation in order to query if the patented invention was spurred by specific regulations, environmental concerns, economic gains for the inventor, etc.

- Link patent and R&D data on eco-innovation with data on economic outcomes collected from administrative data, surveys, digital sources, etc in order to determine the role of eco-innovation inputs on economic performance.
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- Combine meso and macro information on eco-efficiency with micro data from firms on organizational and technological eco-innovation to better understand the links between micro and macro measures.

Several data sources compile relevant data from multiple sources. Examples are the EIO index, the ASEM Eco-Innovation Index (ASEI) and the Global Cleantech Innovation Index (GCII). All are limited to eco-innovation in the business sector.

The EIO index provides indicators for eco-innovation inputs, activities, outputs, resource efficiency outcomes, and socio-economic outcomes. The innovation inputs are restricted to R&D data (derived from surveys) and the activities from the 2008 European Community Innovation Survey module on environmental innovation. This provides data on the percentage of firms that introduced a product, process, organisational or marketing innovation that resulted in lower energy or material inputs and the share of companies with ISO 14001 certification. Data are also provided for green patents and for academic publications on eco-innovations.

The ASEM Eco-Innovation Index (ASEI) provides indicators for eco-innovation capacity, activity, performance, and supporting environment. It includes indicators from the Environmental Performance Index (EPI) system of the World Economic Forum on environmental policy and quality of life related to environmental factors. It has a focus on SMEs.

The Global Cleantech Innovation Index (GCII) covers ‘cleantech innovation’, defined as “doing more with less (eg fewer materials, less energy expenditure, reduced water availability), while making money doing so”. The GCII covers cleantech-focussed innovation drivers, emerging cleantech innovation, and commercialised cleantech innovation. Novel indicators include early stage private investment (amount of venture capital invested in cleantech companies as a percentage of GDP in PPP), cleantech-friendly government policies in the field of energy (government policies supporting clean energy including tax incentives, feed-in tariffs, renewable energy mandates and others) and four indicators on commercialised cleantech innovations: revenues of cleantech companies, renewable energy consumption and renewable energy jobs, late-stage private investment and exits, and the number of successful publicly-traded cleantech companies.

The OECD’s (2009) Green Growth indicators are comparable to the Oslo Manual’s model of business innovation. It includes inputs such as R&D, patents and publications; outputs such as the number of innovations, and outcomes such as sales of eco-innovations and resource efficiency. A similar approach is used in the Eco-innovation Observatory’s eco-innovation scoreboard, which includes indicators for inputs (government expenditures on environmental R&D, patents and publications); outputs (the share of firms with an eco-innovation); and outcomes including resource efficiency, the intensity of GHG emissions by GDP, and the employment, sales, and exports of the eco-industry (EIO, 2013).
7. **Data on eco-innovation policies**

Reliable policy evaluation requires attention to contextual factors that influence in policy effectiveness in encouraging investment in eco-innovation, eco-innovation outputs, or eco-innovation outcomes. Knowledge of contextual factors is necessary to identify variables that need to be measured to produce accurate evaluations (for instance to control for confounding factors). Qualitative contextual data can be obtained from interviews and focus groups on the why and how of eco-innovation activities by organisations and households. In most cases purposeful sampling rather than random sampling is used to select interview or focus group respondents.

Data on policy impacts can be obtained from generic innovation surveys that include questions on the use of and influence of different types of policies (regulation, environmental taxes, etc) or from dedicated surveys to evaluate specific policy instruments. Generic innovation surveys can be used to evaluate the effect of general policy types on eco-innovation outputs such as product or process eco-innovations, but due to a lack of detail they are unsuited for examining the effect of specific policy instruments on outputs or the effect of policy on environmental outcomes. Dedicated policy evaluation surveys on specific instruments can include questions on environmental outcomes and enabling and hindering factors (including policy instruments).

Expert-based methods such as expert interviews, panels or surveys of experts are a useful tool to interpret quantitative data on policy effects and to identify variables for measurement. Independent experts can also critically examine claims about the costs of regulation, the benefits of particular eco-innovations and capabilities for change. Expert knowledge of a sector, including consumer demand, is critical to the choice and design of appropriate policy instruments.

8. **Evaluation system as a policy learning system**

Policy evaluation systems need to be designed for policy learning. This requires formal monitoring and evaluation studies, deliberative reflection, and the use of research results in the design of further policies. Developing an evidence base for transformative policies is not only about the technical capacity to collect and analyse data, but also about appreciating different methods for analysing data, embracing risk and uncertainty, and building a shared understanding among key stakeholders (Miedziński, 2015). In the context of future challenges, the process needs to focus on shared understanding of the implications of what is known and what remains uncertain about societal challenges and their impacts. This calls for an integrated approach to monitoring and evaluation of policies that incorporates both a system of data collection and dedicated policy arenas to discuss the evidence.

Despite studies and research projects implemented in recent years, measuring the policy effects on eco-innovation still poses methodological challenges. Data collection is required to meet several key challenges:
Improving conceptual and methodological approaches linking eco-innovation to other key indicators, most notably to those measuring the UN's Sustainable Development Goals.

Improving and developing new methods, models and indicators to anticipate and measure trade-offs between economic and environmental effects of public intervention.

Improving data aggregation methods on meso- and macro scale impacts, taking into account the risk of rebound and other undesired effects.

Clarifying different analytical scales and scope of eco-innovation analysis, notably in relation to the meso-level analysis (e.g. value chains, functional areas).

9. Recommendations

Our knowledge of eco-innovation largely comes from the extensive case study literature and from a few one-off surveys that focus on management and organizational responses to environmental issues (Arundel et al., 2006). In the last 10 years, three national sets of indicators on eco-innovation have been developed, based on available data. This work has contributed to our understanding of the differentiated nature of eco-innovation and its historical evolution. But more is needed.

First, a standard definition of eco-innovation, accepted and applied by all countries, is needed to provide guidance for collecting and interpreting eco-innovation data and to ensure international comparability. This requires an equivalent of the Oslo Manual definition of innovation. The definitions provided in the Maastricht Manual follow the Oslo Manual definitions while focusing on eco-innovation. They will therefore be familiar to National Statistical Offices and to innovation researchers. However, to keep the work current, there must be a body, similar to the National Experts and Science and Technology Indicators (NESTI) responsible for the Oslo Manual, to monitor and evaluate the use of the definition and guidelines proposed in this manual and to update them when necessary. To ensure legitimacy, the body that maintains the definition and the guidelines must have international support.

Second, statistical agencies and research organisations should collect data on the following topics for research and benchmarking:

- System innovations and social innovations. Examples include the circular economy, decentralized renewable energy systems, zero carbon transportation systems, product sharing systems, green lifestyles involving co-housing, product sharing and down shifting, etc.

- Life Cycle Assessment data for innovations and existing goods and services. These data can be used in economic and socio-technical system analysis to determine whether a good, service or system is an eco-
innovation and for obtaining information about the nature and magnitude of environmental benefits.

- The characteristics of product and process eco-innovations (emission and resource use, staff involved, difficulties encountered, organizational enablers, management of trade-offs, product design tools, economic benefits and costs, critical events and spill-over effects).
- Rate of replacement of current products or processes by eco-innovations, for instance by sector and industry, the ratio of eco-innovations to non-green innovations by number, percentage of sales, process output, etc.
- Information on stocks of capital goods and products with details on their environmental characteristics.
- Eco-innovation improvements (increases in energy efficiency, pollution control efficiencies, improvements in resource efficiency, etc).
- Undesirable externalities and side-effects of eco-innovations.
- Trade-data about eco-innovations which are not included in Environmental Goods and Services (EGSS).
- Environmental health conditions.
- Policies relevant to eco-innovation (as drivers or barriers, etc).
- Time series for environmental indicators.

Third, data collection for policy evaluation should be designed as part of a policy learning system. To ensure systemic learning, the system has to include formal monitoring and evaluation studies as well as a learning environment in which research results are interpreted and used in policy design.

Fourth, data collection should support both quantitative and qualitative research methods. While quantitative methods (e.g., modelling) are useful for predicting environmental impacts under specific scenarios, their applications may be limited in practice by context-specific variables. Qualitative data are often necessary to understand contexts and the variety of contextual factors that can influence eco-innovation or environmental outcomes. In particular, policy evaluation needs to pay more attention to the context-specific mechanisms through which a policy wields influence and assess, where relevant, the reasons why a policy lacks influence. The data and research requirements of dealing with those challenges are formidable but necessary to undertake. Eco-innovations address wide-ranging environmental problems, calling for eco-innovation assessment and appropriate policy mixes.

Fifth, progress to a green economy has been slow because of the continuation and growth of many non-green practices. Eco-innovation can only achieve an absolute decoupling between economic growth and emissions if environmentally harmful activities are discontinued and if the eco-innovations diffuse widely. This requires policies to discourage harmful activities in addition to eco-innovation promotion policies. Socio-economic well-being depends on other factors unrelated to eco-innovation. For achieving a green economy, the stimulation of eco-innovations will not be enough. We especially
need system changes involving new ways for meeting key human needs such as food, mobility, energy and housing (EEA, 2015). Next to measures on eco-innovation, we need measures on environmental indicators (especially pressure indicators and state indicators), eco-policy indicators and socio-economic well-being indicators (four-pillar indicator system).

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Abstract J

Messung von Umweltinnovationen für ein “Grünes Wirtschaften”