**Environmental Macro Indicators of Innovation**
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**EMInInn** Policy Brief

# INNOVATION POLICIES

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INNOVATION NEEDS ORIENTATION

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# Environmental Macro Indicators of Innovation

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It is difficult to assess the positive or negative macro-environmental impacts of innovations, because they are not inherent to a technology, but a product of physical, behavioural, social and economic conditions. A "green" car may be an additional car instead of a substitute. Money saved through energy-saving will result in shifted expenditures with low or high negative environmental impacts. Positive micro or meso impacts of eco-innovation may be outweighed at the macro level by larger-scale processes which they may have catalysed.

The European research project EMInInn has tracked the past development and diffusion through the economy of pervasive innovations that can be expected to have had an appreciable positive or negative environmental impact. The aim of the project has been to generate deeper insights into the role of innovation in decoupling environmental impacts from economic growth, helping policy makers to both assess the benefits from past innovations as well as maximize benefits from present and emerging innovations in sustainable consumption and production systems (SCP).
Focussing on environmental pressures, the project has analysed macro-environmental impacts of innovations in five sectors: energy, transport, construction, ICT and waste.

**The main objectives of EMInInn are to:**

- Deliver accurate and comprehensive information on the environmental impacts of innovation;
- Strengthen the science-policy link
- Develop physical indicators to monitor the macro-level the ex-post impacts of innovation processes, including diffusion of innovations into society, their economic impacts, and their impacts on key environmental categories
- Identification of drivers and barriers relating to eco-innovation, thereby facilitating the full recognition of eco-innovation potential
- Support for the decision-making process on policy targets and evaluation



# How innovation policies can contribute to achieving environmental targets

Eco-innovation holds the promise of facilitating the achievement of environmental goals while supporting economic welfare.  This idea has been appealing to policy makers and politicians, as it resolves an apparent trade-off between environmental quality and economic prosperity.

### Defining Eco-innovation

The EMInInn definition of eco-innovation focuses on whether an innovation results in environmental improvement. Eco-innovation is defined as *"the production, application or exploitation of a good, service, production process, organisational structure, or management or business method that is novel to the firm or user and which results, throughout its life cycle, in a reduction of environmental risk, pollution and the negative impacts of resources use (including energy use) compared to relevant alternatives."*

Based on: Kemp & Pearson, MEI Project Final Report

Eco-innovation policies aim to stimulate the development and deployment of innovations that reduce environmental pressures compared to a relevant alternative. In order to do so, such policies rely on the assumption that it is possible to identify such innovations ex ante.

The EMInInn project has explored the challenges of identifying whether specific innovations actually generate environmental savings, and it has developed a variety of tools for improving assessments of the environmental consequences of specific innovations. An important conclusion is that it is not always straightforward to identify the environmental consequences that arise from specific innovations, either ex ante or ex post. Unintended consequences are a real risk for technology-specific policies. Detailed assessments of the indirect effects of specific innovations, across the life-cycle and incorporating various economic feedback effects, can help avoid such unintended consequences.

It is important to recognise that the environmental consequences arising from the diffusion of a specific innovation depend, in part, on the wider policy conditions. Strong environmental policies, including regulations and emissions pricing policies, can limit the risk that indirect effects result in worse environmental outcomes. In short, eco-innovation policy must be complemented by environmental policy if it is to contribute effectively to environmental improvements at the macro-level.

# Assessing the "green-ness" of a given good or service is not always straightforward

The ultimate test of eco-innovation is whether the development and deployment of new products, processes and business models result in decreases in environmental pressures, relative to a relevant alternative. However, the environmental outcomes associated with the diffusion of a given good or service can be difficult to assess, even ex post, because:

3 **Environmental pressures arise across the life-cycle of a product or service.** Eco-innovations should be assessed on a cradle-to-grave basis.

3 **There are trade-offs between environmental pressures.** For example, diesel engines reduce carbon emissions but release more air pollutants per kilometre.

3 **Environmental savings from a given eco-innovation may be context-dependent**. For example, solar photovoltaics (PV) would certainly be an eco-innovation in Australia (a sunny country with largely fossil-fuel based electricity), but not necessarily in Iceland (a country with low sun and 100% renewable electricity). Shale gas might be considered an eco-innovation in the short-term if it results in reductions in the use of coal; but probably not in the long-term, since the carbon emissions from widespread natural gas use would breach 2050 carbon targets, unless combined with carbon capture and storage technology.

3 **Innovative technologies and processes change over time and as they are diffused.** This can change the expected future (or past) environmental pressures associated with those innovations, adding both complexity to the analysis and uncertainty to the outcomes.

3 **Economic feedbacks can create additional environmental pressures—** A major challenge in the assessment of an eco-innovation is the extent to which economic feedbacks are taken into account. Increases in the consumption of a particular product will have effects on other economic actors, supply chains and consumers, resulting in price and income changes. This includes the so-called 'rebound effect'.

**Economic feedbacks and 'rebounds' can undermine the 'green-ness' of innovations**

The analysis of transport innovations within EMInInn suggested that economic feedback effects could result in unintuitive results, with some apparently 'green' innovations inducing worse environmental outcomes, rather than improvements. In other cases, feedback effects enhanced, rather than undermined, the environmental savings associated with the innovation. This analysis used the innovative DILER[1] method, developed within EMInInn to combine life-cycle assessment with economic analysis of specific innovations.

1 Dynamic IPAT-LCA with environmental rebound effect

**The rebound effect**

The "rebound effect" refers to the effects of the changes in behaviour induced by an increase in efficiency. These changes can undermine environmental savings relative to the savings expected from a direct comparison of efficiencies. Definitions of rebound vary, and some include "negative" rebounds (which are feedbacks that improve environmental performance). The phrase "rebound effect" is often used loosely to refer to one effect or the combined result of many processes. It is also sometimes used to refer to psycho-social effects, rather than economic effects, such as the tendency for people to drive a fuel-efficient car more, not only because it is cheaper, but because they feel less guilt about polluting the environment.

**Key rebound issues for eco-innovation policy:**

3 Rebound effects can undermine the environmental savings from innovations that save money as well as reducing direct environmental pressures.

3 There is considerable disagreement over the scale and significance of rebound effects.

3 Rebound effects have been treated inconsistently in European impact assessments, perhaps as a result of the diverse and conflicting definitions, and uncertainties in measurement.

3 Rebound effects are generally welfare-enhancing. While attention often focuses on the environmentally negative effects of rebounds, they result from higher levels of consumption that people would have otherwise been unable to afford. From a social welfare perspective, rebounds are only undesirable where environmental externalities have a larger social cost than the welfare benefits of that increased consumption.

3 The environmental consequences of rebound effects depend on environmental policy. Eco-efficiency innovations save consumers and businesses money. That saved money is then spent elsewhere, resulting in new environmental impacts. Environmental policy—such as carbon prices—can result in that spending being directed towards activities that result in lower environmental impacts.

3 Macro-economic rebounds can only be estimated using macro-economic models, such as EXIOMOD used in EMInInn.

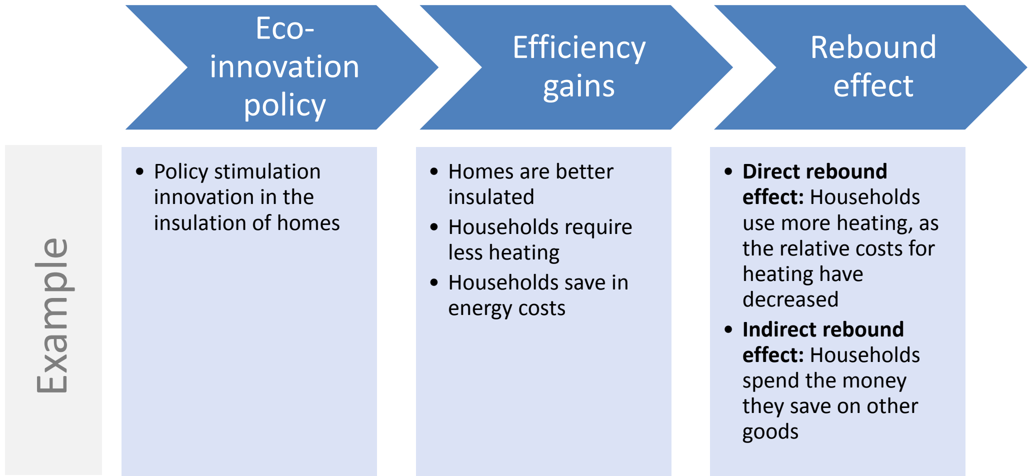


Figure 1 Example of the rebound effect: Insulation of homes


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# Eco-innovation policy requires accurate assessments of the environmental consequences of innovations

Many innovation and eco-innovation policies target specific technologies or technology fields; as do many environmental policies. Unintended consequences arising from such policies can be reduced with improved technology assessment processes that identify potential indirect effects.

Assessment methods used to inform eco-innovation policies do not always assess the full range of potential indirect routes by which unintended environmental effects might emerge. The treatment of economic feedbacks, in particular, is inconsistent in many impact assessments, and typically rather limited in scope. EMInInn has shown clearly that such indirect effects can have significant environmental implications. Of course, very detailed assessments are costly and create administrative burdens, and the degree of detail of assessments should be proportional to the potential impact of the policy change.

**Methods developed within EMInInn can help improve eco-innovation policy**

Several new methods were developed and demonstrated within EMInInn for conducting ex ante and ex post assessments of the environmental consequences of innovations. These include methods that extend life-cycle assessment to incorporate economic feedbacks, and that use macro-economic models with detailed representation of technologies. More information on these new analytic tools can be found in the reports on the EMInInn Website: www.emininn.eu

**Uncertainties should be made clear**

Assessments about whether an innovation generates net environmental benefits relative to alternatives are subject to uncertainty. Most assessments do not examine all potential feedback and induced effects, and data limits may also prevent detailed assessment. Such uncertainties should be clearly expressed, and information should be provided on how this might affect the outcome of the assessment, for example by conducting sensitivity analysis.

**The full environmental consequences of eco-innovation policies depend on wider policy conditions**

The significance of rebound effects for environmental outcomes depends partly on wider policy conditions. Indirect rebound effects arise when an efficiency innovation saves consumers money, and consumers then purchase other goods and services, which in turn generates environmental pressures. When strong environmental policies—particularly emissions pricing—are in place, those consumer purchases will be directed towards goods and services that have a less damaging environmental profile than would occur in the absence of such policies. EMInInn modelling, using EXIOMOD, has shown how the GHG emissions arising from indirect rebound effects is expected to decline as the carbon price increases.



# Indicators for monitoring eco-innovation

Most indicators of eco-innovation focus on measuring various activities of innovation systems (such as R&D funding, publications, and patents). These measures are based on judgements about whether particular technologies generate environmental savings when diffused into society. For example, measures based on green patents assume that the patented innovation will generate environmental benefits if it is commercialised and widely adopted.

However, judgements about whether any given technology will actually generate environmental savings may not be reliable without detailed assessment. EMInInn analysis has indicated that feedbacks and wider conditions matter. This has implications for attempts to monitor eco-innovation: methods that rely on indicators of innovation inputs (such as green R&D) and direct outputs (such as green patents) may measure the capacity or potential for eco-innovation—but may not always provide evidence that the innovation process is indeed resulting in environmental improvements. When assessing an eco-innovation policy or action, policy makers should therefore be cautious about using only one indicator as a proxy for eco-innovation, and recognise that it may be misleading.

**Does green patenting correspond to greener outcomes? Evidence from road transport**

EMInInn analysis of road transport shows that an increased number of green patents does not always correlate with improvements in environmental performance, even before any rebound or induced effects are taken into account (which may further weaken the link between patenting and environmental performance).

Eco-innovations may also arise from areas of science and technology not thought to be 'green', and which as a result lie outside attempts to measure eco-innovation. For example, the technology underpinning the combined cycle gas turbine, which has played a significant role in reducing the environmental impacts of the European power system, has its origins partly in jet engine technology from aircraft.

**Comparing eco-innovation across time or between countries**

Since eco-innovation is a relative concept, caution is also needed in using indicators based on specific technologies to make comparisons across space and time. The environmental performance of a given technology relative to alternatives—i.e. whether a given innovation is an eco-innovation—depends on the context, since the relevant alternative will differ in different contexts. For example, an indicator based on the diffusion of specific technologies might be unhelpful in comparing countries with very different contexts, since diffusion of those same technologies may result in quite different environmental outcomes—in short, a given technology may be an eco-innovation in one country but not in another.

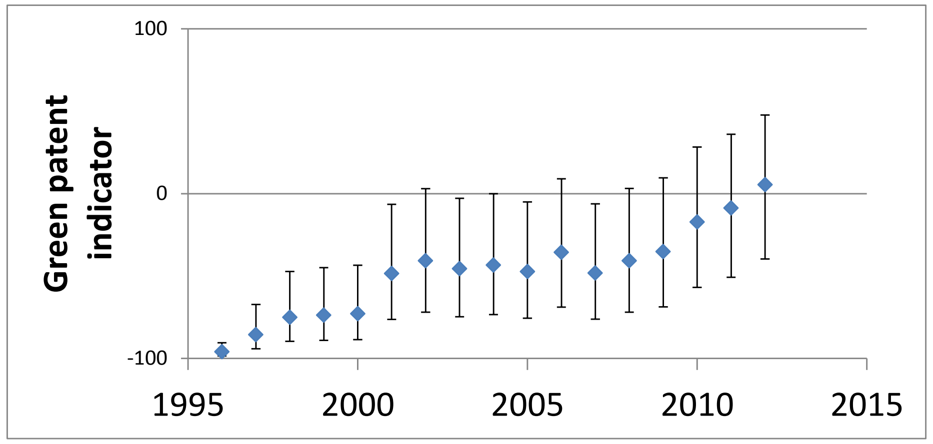


**Figure 2** Green patent indicator for Internet-related patents; shows that internet-related patents are increasingly green patents.

Source: EMInInn Deliverable 5.1

### Does green patenting correspond to greener outcomes? Evidence from internet innovation

Evidence from EMInInn suggested that internet-related patents are increasingly green patents (see figure 2). While this sounds encouraging, it is partly driven by the search for energy efficiency in smart phones and other networked devices, which are currently restricted by limited battery life. Greater battery life will enable much more use of such devices, stimulating higher levels of consumption, and very possibly higher absolute energy consumption and resulting environmental pressures. Energy efficient patenting in this case is likely to be associated with long-term increases in environmental pressures from this sector, not decreases. This is an example of one type of rebound effect, and illustrates that while green patenting often correlates well with environmental outcomes, this is not always the case.

### Monitoring eco-innovation from macro-environmental data

Eco-innovation can be identified from macro-environmental data, using statistical and decomposition methods, such as structural decomposition analysis. These methods can show that technological changes (or other forms of innovation) have resulted in decoupling of environmental performance from economic activity. These tools measure revealed eco-innovation at the macro-level.

When using such methods, it should be clear that the counterfactual scenario is often unknown—the rebound and systemic effects that the innovation may have induced are not reflected in decomposition analysis. Even where statistical methods are used, it is difficult to untangle the co-evolutionary dynamics of economic change, policy development and innovation.



# Key conclusions

Innovation policy is clearly an important strategy for achieving environmental policy goals cost-effectively. However, eco-innovation does not necessarily provide an 'easy way out'. Green innovations that save money are looked upon with great favour by users and policy makers alike because they constitute a win-win option. But it is not always straightforward to identify those innovations, and in any case the environmental wins may be low because of rebound effects.

Currently used analytic tools that assess the environmental impacts of specific technologies rarely account for the full range of potential indirect effects. Using improved technology assessment tools, including those developed within EMInInn, may change the assessment of the expected environmental savings associated with specific technological development plans, or policies that are expected to result in the diffusion of particular technologies. In particular, analytic tools that incorporate economic feedback effects and potential life-cycle effects can result in the identification of issues that are sometimes neglected within currently dominant approaches to technology assessment in technology policy formulation.

A key point is that the environmental performance of a given technology is not solely an inherent feature of the technology, but depends on wider conditions. In particular, the environmental consequences of 'rebound effects' will depend on carbon and energy prices, and policy options to address rebound effects need to be carefully considered. Current policy practice in impact assessment rarely makes such dependencies explicit. It makes sense for technology assessments to make clear where there are such dependencies, and to report a range of potential benefits of an eco-innovation policy package depending on the wider policy context, for example under differing carbon price scenarios. Most fundamentally, however, the analysis makes clear that while eco-innovation policy is an important part of environmental policy, it needs to complemented by other environmental policy instruments to ensure that it yields its potential environmental benefits.

Indicators of innovation system activity, such as patenting, may only provide a partial picture of the trends and drivers of the ultimate contribution of eco-innovation to reductions in environmental pressures. This is partly because such measures rely on an ability to distinguish 'green' innovation activities, and partly because of the complexity of the relationship between innovation system activities and environmental outcomes.

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