MEASURING ECO-INNOVATION: FRAMEWORK AND TYPOLOGY OF INDICATORS BASED ON CAUSAL CHAINS

FINAL REPORT OF THE ECODRIVE PROJECT

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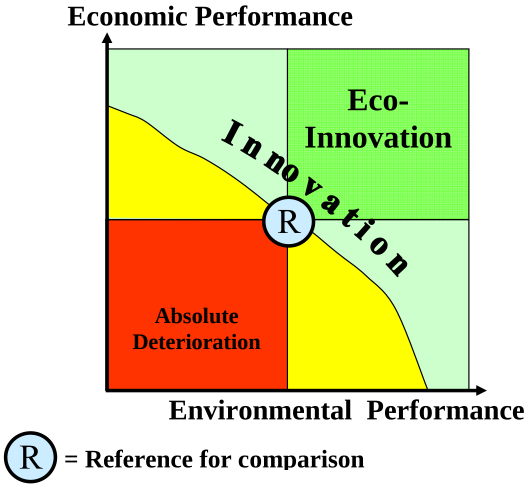
Contents:

Management summary

Definition of Eco-Innovation

Continued economic growth combined with improved environmental quality, often referred to as ***absolute decoupling***, form essential elements in sustainable development. It is clear that both for growth and for the accompanying environmental improvements, innovation is required, not as innovation per se but as eco-innovation. Hence we define eco-innovation as the combined improvement of economic and environmental performance of society. This performance is what counts, not good intentions or wishful thinking. The line between yellow and blue may be seen as the production possibility curve with current technologies. Moving towards environmental improvement at a cost is detrimental to economic growth, difficult to realise in a globalising world. Moving towards economic performance with increasing burdens on the environment is easy enough. The challenge is to move into the green right upper corner, as eco-innovation.



Micro and macro level eco-innovation

Innovations, as actual new applications of technologies, may seem to work out as eco-innovations at the micro level, relative to a reference technology. The ultimate criterion however is how such changes work out for society. Is society moving in a sustainable direction? There is not a straightforward relation between micro performance of a changed technology and macro performance of society, as combined improvement of economic and environmental performance, for several reasons. At a micro level, the introduction of the new technology may induce secondary effects, as rebound effects. Fuel efficient cars are less expensive and emit less. The consumer therefore tends to buy larger and heavier cars, and still has money left to spend on other activities. The income effect may be analysed at this micro level as well. The analysis next has to expand to cover the macro level performance of society. This step can take income effects into account more systematically. The innovation as economic improvement at the micro level is the contributing factor to economic growth at a macro level. This economic growth, combined with the marginal propensity to consume, tells how the overall performance of society is changing. For major environment related flows of resource use and emissions, it seems extremely difficult to increase their eco-efficiency enough to compensate for economic growth. The carbon efficiency of society increases by thousands of micro level eco-innovations, but not enough to compensate for the accompanying economic growth. Emissions still increase absolutely. Furthermore, the macro view points to other mechanisms for eco-innovation than implementation of inventions. Eco-innovation may for example result from structural change in markets, as by increasing market size through more uniform environmental regulations.

Chains of dynamic mechanisms

Rebound mechanisms, as mentioned, indicate dynamics induced by a new technology. More generally, the performance of today and tomorrow depends on past actions. When evaluating the course of development, we would like to know how future performance may be expected to develop; that is, what our score on eco-innovation will be. We need predictive indicators to see if we are on the right track. For sure, without shifts between existing technologies and without new technologies we cannot have both growth and environmental improvement. Having new technologies as such is not enough. They have to fit into markets; they have to lead to overall environmental improvement; the products resulting are to be acceptable; the alternative technologies and products should not have had better performance; effects on other consumption should not be negative through rebound mechanisms; etc.

Predictive knowledge on specific technologies

How can we know all this? There is a motor based on external combustion which is superior to the gasoline and diesel motors now used in transport. This Sterling engine has a substantially higher energy efficiency. So we may expect to see it on the road shortly? This will not be the case. Albeit huge investments in it of billions of Euro, this superior engine has been superior in principle now for nearly two centuries, being patented by the Scottish inventor Sterling in 1816. It has been used a bit in some stationary applications, while waves of myriads of other technologies have conquered the market successfully, and while the inferior German Diesel, Otto and later Wankel motors have dominated the transport world for over a century now. Could we have predicted this?

The answer of course is 'no'. In complex combined social, economic and technical processes regarding technologies and products, specific predictions are not possible, surely not on long term developments. So predicting the future of society in terms of specific technologies, firms and markets and their environmental performance is not possible. How then can we predict if society is on an eco-innovative path, with decoupled growth resulting? We cannot make that prediction either, but we may get closer, in specifying mechanisms conducive to eco-innovation. In this sense we can learn from economic history, where long term trends in economic development, and differing trends between countries, have been studied and explained, both by historians and economists.

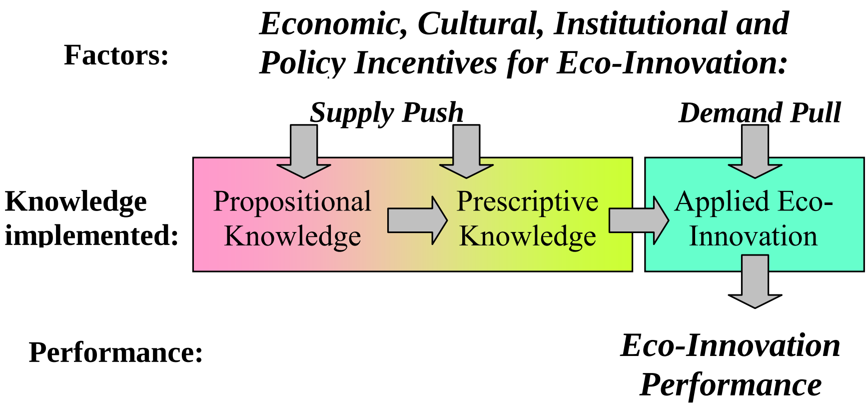
The general lines coming out of historical analysis and theory developments regarding economic growth do not give a full and clear picture. But they do give strong starting points.

Structural development towards a knowledge economy

Historical development has tended ever more to place economic growth in the realm of knowledge, with fixed cost increasingly being related to knowledge development and less to - of course also still necessary - investments in capital goods. These fixed costs of knowledge in technology development have an in increasing share in total costs. Obvious examples are computer operating systems, car navigation systems, and mobile phones in the IT domain. But also in physical production the share of fixed knowledge overheads is increasing in virtually all sectors. This development has deep consequences for explaining growth, and later on, for explaining and predicting eco-innovation. One marked characteristic of this knowledge based economy is that increasing returns to scale are becoming a dominant phenomenon. Guarding market positions while others globalize their operations definitely means loosing out in the end. Jumping on these developments through knowledge based specialization in a global context is jumping on the bandwagon of growth.

Knowledge and increasing returns

The economics of this new growth is different from the old production-function-demand optimization cycle, which is based on constant or decreasing returns to scale in a fully competitive market. Increasing returns to scale inevitably leads to specialisation in globalizing markets as the main road to growth, avoiding full competition but focussing on monopolistic competition. The nature of knowledge as a specific type of good relates to more deviations from the old ways. Two central characteristics define this good: its non-rivalness and its only partial excludability. Non-rivalness means that the knowledge you created does not decrease if others use it. It remains the same, or even grows. The second characteristic, partial excludability, means that reaping the fruits of your knowledge creation is only partially possible and only for a limited duration. Different kinds of knowledge may differ substantially in this respect. The unpaid use by others of your knowledge sometimes is named knowledge spillover, of disembodied knowledge, authorised or not, legal or not.. From a societal perspective, instead of a personal or business perspective, the spillover is part of the more generally available usable knowledge, the huge knowledge base of society which effectively is open to everybody, globally. The spillover is desirable from a societal point of view, as long as it is not detrimental to the generation of proprietary knowledge. It is not so much the externality or spillover as its prevention which is prime focus in earning back the fixed cost of innovation. On the other hand, the creation of general knowledge forms the general basis for innovation and economic growth. The knowledge involved can be graded into mostly publicly available propositional knowledge and mostly proprietary protected prescriptive knowledge on how to make a technology functioning.



A framework on innovation analysis for growth

How can a framework model on eco-innovation be developed from these rough and basic concepts and ideas? We follow two steps, first the lines towards innovation and growth and then adding the ecological lines, towards eco-innovation. The general line is that the mechanisms set in motion relate to institutions, institutions in economy, law and science. The prime focus of public policy is on these institutions, to make them conducive to growth. The second focus of public policy is on creating general knowledge, both as embodied knowledge in the heads of persons, and as non-appropriated knowledge available for all to use, also others in the global community. There is an intricate relation between general disembodied copyable knowledge, embodied knowledge in persons who may travel, and temporary and partially excludable knowledge, with firms and R&D organisations. They may apply that knowledge in any place in the world. Because of these mechanisms, the knowledge economy we are in is a very open globalising economy. You can join, or not, but then loose out in growth. Subsidizing export or hampering imports is a policy of the past, reflecting a conservative focus on non-growth, if only by complicating the institutions for exchange of knowledge and technologies. A policy focus on specific firms, technologies and products cannot be based on the relevant knowledge in what essentially is the edge of private knowledge. If your competitors knows, you cannot make a profit. Governments can hardly be as informed as your competitors. Policies preferably are to be at the level of meta-rules, creating the drivers and mechanisms without specifying the content.

A framework for eco-innovation analysis and indicators

Adding environmental aspects in this framework now is a more guided exercise, focussing on how the general approaches to innovation and growth can be directed also at environmental aspects so as to create eco-innovation and decoupled growth. The lines from policy again start at institutions, which now not only are to reflect and induce the knowledge base for growth but also to direct this growth in environmentally benign directions. Examples of recent policy development may show the fundamental difference between creating institutions guiding eco-innovation and supporting specific products and technologies. One of the brilliant examples of European policy development as institutional development is in the European carbon trading system ETS. It sets up a framework for effectively creating a market price for emissions. The tradable emissions part is open to international enlargement, with non-EU countries already joining. It starts with grandfathering to avoid transfer payments which are difficult to bear in an international context where others don't have the cost of transfer payments yet. And it gives a long term view on the price of the market, by charging those not having permits for their emissions with a predictable fine, as an ultimate highest market price. Reasons of old fashioned competitiveness make full application to arrive at the EU Kyoto goals difficult now, economically and politically. The system, as part of our institutions, is there however and can be made more effective on short notice as soon as other countries join, fully or partially. The second example is also in the domain of climate policy, with the focus on biofuels. There specific products, bioethanol and biodiesel, are the subject of policy. This EU policy is mirrored in US policies focussing on bioethanol. Together, these policies have set up a market distortion of unprecedented size. They have induced technologies which from a global perspective may even harm the climate as through shifts in land use and increased fertiliser use in agriculture in general; and which have created substantial changes in global staple food prices and land prices, with as yet unforeseeable socio-political consequences. When trying to get a view on the factors creating eco-innovation, be they present already or set in motion, it would be very useful to get such differences in mechanisms used for policies in view. In the next section we specify how to deal with economic and environmental performance.

Past and current economic performance

The framework as developed distinguishes between eco-innovation performance of society, and the factors conducive to that performance, as predictors of future performance. Past and current performance can be measured. Measuring economic performance is well established as far as economic growth in market terms is concerned. The sum of all value added or factor incomes earned is the Domestic Product or National Income, *Gross* or after subtracting capital depreciation *Net*, usually Gross as GDP. Growth can easily be measured as the change from year to year. The quite equivalent domestic product or national income measures can be transformed into a welfare measure, as by stating the GDP per head of population, or the production per working hour, as labour productivity. There are no conceptual problems here. There are several specialised subjects where further choices determine outcomes to some extent, like on price statistics; purchasing power parities; corrections for imperfect markets; and measuring capital and its investments and depreciation. These constitute subjects where differing options exist and hence data may differ somewhat. The concepts are clear in principle, as long as markets are concerned.

Efforts to measure a broader welfare concept, including measurement of human capital, natural capital and welfare effects of environmental degradation are much more open to contention. For environmental concerns, starting point of such broader analysis would be the measuring of environmental performance as such, before integrating it in broader concepts. We will keep the economic and the environmental performance as separate qualities, allowing for static eco-efficiency analysis and more dynamic eco-innovation analysis. Decoupling, as absolute sustainability, then can be specified regardless of how the economic and the environmental aspect might be combined in some overall measure on welfare.

Past and current environmental performance

Measuring environmental performance is less straightforward conceptually. The central issue here is the distinction between environmental quality and the interventions in the environment which determine quality with an often long time delay. Major concerns as on biodiversity may be quantified as to the interventions in the environment causing them. However, these consequences for environmental quality are spread out in time. Climate change is a main example. Current emissions exert their climate forcing influence for long periods of time, varying between a decade for methane, a few centuries for CO_2, several centuries for nitrous oxide, to several millennia for some fluor-carbon compounds. The climate change resulting also has a delay. Further effects, like sea level rise and land cover changes, also may take between decades and centuries. The ultimate effects on biodiversity hence are a dynamic magnitude, depending not only on current but also on past emissions. To some extent effects of current emissions depend even on future emissions, as the marginal effects depend on the total magnitudes involved.

There hence is a main choice between measuring current environmental interventions, indicative of the future environmental effects resulting from these, or measuring current environmental quality, which reflects past events in a not well specifiable way and not our current detrimental impacts on the environment. We choose for current interventions, also because these are well measurable. The disadvantage is that the welfare effects involved cannot be derived from these in a straightforward way. Specification of these effects depends on dynamic modelling of empirical mechanisms which in a substantial way is lacking; on assumptions for scenarios; and they depend on other developments taking place. If, for example, solar energy becomes less expensive than fossil and biomass resources for energy, there will be substantial land use shifts *back-to-nature*, not only compensating the losses due to climate change but reducing the effects of climate change because of the more resilient ecosystems then remaining. Currently, methods for specifying welfare effects of emissions in monetary terms mostly cannot take into account the dynamic effects on environmental quality as resulting from emissions.

Environmental performance indicators detailed

The choice for environmental interventions is linked to ultimate dynamic effects in a limited way, by quantifying some main environmental mechanisms linked to them, and leaving out the dynamics involved. Emissions are aggregated as to these environmental mechanisms, often referred to as indicating potential effects. Methane, carbon dioxide and nitrous oxide are added up as to their time integrated climate forcing, as global warming potentials, GWP. The GWP score of the activities of a country in the year 2008 indicates its contribution to climate change, and with much less certainty to the further effects on biodiversity. There are several environmental mechanisms which can be used to quantify environmental interventions. These include: *Climate Change; Stratospheric Ozone Depletion; Photo-oxidant Formation; Acidification; Terrestrial Eutrophication; Aquatic Eutrophication; Human Toxicity; and Ecotoxicity*. Depletion of materials resources and energy resources can be quantified in a similar way, indicating the speed of depletion resulting from the extraction in one year: *Abiotic Resource Depletion 1, minerals; Abiotic Resource Depletion 2, fuels. Biotic Resources Depletion* is as yet difficult to specify.

In supporting choices on eco-innovation, a detailed analysis per environmental item is useful at a micro level of technology development. For implementation and policy choices, the choice is on all aspects together, requiring some integrated view on the total of environmental interventions and impacts. This is very similar to the total economic performance, based for example on adding up value added in all activities.

Performance measurement within the economy

When measuring performance, society at large is the reference, usually taken over one year. This can be the EU, or the countries of the EU. Expressing absolute scores is often not easily interpretable so the EU share in the world, or inter-country comparisons may be used to give perspective. This empirical analysis is not the subject of this study, but some examples of dynamic eco-innovation performance of European countries will be given. When getting a more detailed picture, the aggregate of society can be disaggregated, in many ways. Some of these desagregations are straightforward. The activities in a country relating to market value and environmental interventions are the sum of all economic activities in production and consumption, with production specified in terms of sectors, or in more detail in terms of firms. The added value per firm can be added up into the added value of the sector it belongs to, and similarly the emissions of the firms can be added up to the total emissions of that sector. In getting insight in the internal relations, other units may be useful, like products and technologies. At that level it is possible to link to specific eco-innovations. These micro units do not add up nicely into sectors and totals. Much of the discussion on innovation relates to the dynamics of the operation of specific firms, with the micro level advantages spun out. The creative destruction it induces in other firms cannot be specified in a similar direct way. Only the aggregate total reflects also these induced effects. So, the totals always are the final reference for eco-innovation performance.

Measuring future eco-innovation performance

Having set up the framework thus far, a main tasks remains: How to measure future eco-innovation performance based on current performance in terms of predictive factors as indicators? The conceptual framework has been set out in main lines, and is to be filled with relevant and measurable indicators. Let us first return to the conceptual framework. A first step is to specify the eco-innovation of the economy as a whole. The second step is to specify the eco-innovation of constituting elements in the economy, of firms, products and technologies. These contribute to the current and future performance of society, albeit in a not direct and straightforward way. Clearly, business performance plays a central role in the eco-innovation process towards substantially increasing market volumes with substantial environmental improvements. Eco-innovative business performance depends on direct drivers, as cost and market demand, and on indirect drivers. Several lines of development have been set up for innovation, which for eco-innovation additional mechanisms. As with environmental effects, causalities are spread out in time, and often substantial amounts of time, with fundamental innovations taking longest. The Kondratiev cycles for long term economic growth last for fifty to sixty years, the most widely accepted cycle being the one starting at the end of the 19th century driven by the innovation clusters in transport, the car and the truck, and in electricity production, for distributed light and power. The drivers behind these developments, to be reflected in predictive indicators for eco-innovation, surely came well before in time.

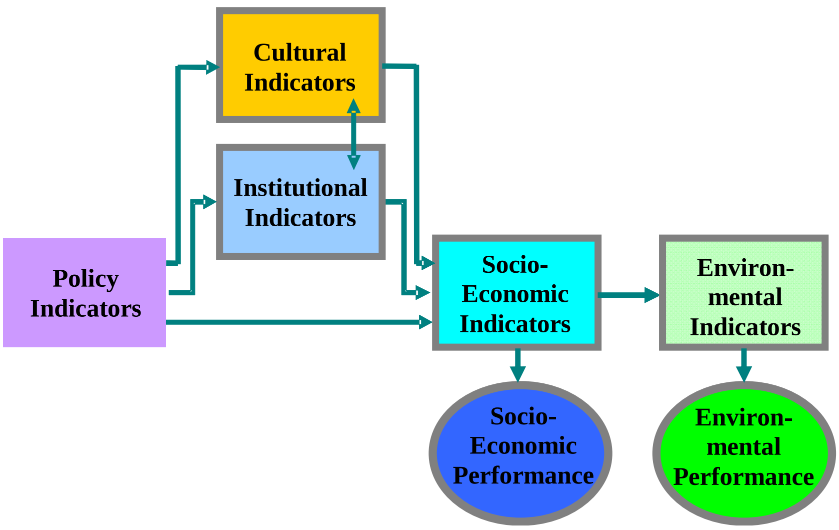
Stages in innovation and eco-innovation

An analytic view on the innovation process regarding technologies in a more limited sense distinguishes between four stages. First, the technology trajectory covers invention or discovery and lab scale elements of core technologies, as clusters. Next the prototype development stage goes beyond the conceptualization of ideas by realizing a first materialized prototypes of main technologies and parts and products involved, improving design by such practical development, and by getting a more precise view on its potential environmental and economic performance. The development trajectory continues with niche market introductions, and pilot plants for larger scale introduction. The diffusion trajectory is the stage where the influence on mass markets, society and environment takes place, by the mature product-technology combinations taking their share in the growth of the economy. This three-stage technology trajectory usually builds on preceding scientific developments of a more general nature. General knowledge of the non-rival, non-excluded type forms the blanket in which technology development takes place would constitute a first stage. This general knowledge ranges from pure science to practical knowledge on who can produce which types of product cheapest and most reliably in South-East Asia. Though there is extreme diversity in the length of innovation trajectories, vide the Sterling engine, they typically take a few decades from the development of first recognizable developed technology clusters to full market development. An elegant method shows that the two time lags involved between the three development stages of technology families have been rather constant over the last century. It shows that the practical development based on an already developed design in principle takes around three decades and next the large scale market diffusion, if occurring, takes a bit over a decade.

Measuring eco-innovation might be done through these development stages, starting at the development of pure science, of technologies with potential, of technologies with practical applications and finally covering the actual full scale performance. This might be the route to take but it is not an easy one. Measuring what will be relevant in the future requires the foresight which is lacking for fundamental reasons, in the beginning stages for sure but even after niche market introduction. We still don't know if and when solar photovoltaics will become competitive with fossil energy and with other renewable energy sources. So, also for these practical reasons of measurability, we have to go the meta-level, to factors conducive to the process of eco-innovation, as operant as drivers at all stages of knowledge development for eco-innovation.

Predictive indicators ordered

The predictive eco-innovation indicators are set up in a systematic way. First, there is a number of indicators within the economy, focusing at a more detailed level of development than overall macro level eco-innovation performance. Eco-efficiency indicators may to some extent link micro level performance to macro level performance. Next, there are the developments in knowledge and values for eco-innovation, in the cultural domain, leading to a number of predictive indicators for eco-innovation performance. At a more indirect level there are the institutions in society which guide the process of innovation and eco-innovation, like rules for intellectual ownership and liability for environmental damages. Covering the dynamics in these institutions and relating them to expected eco-innovation performance is a challenge. We have come up with some preliminary measures. The fundamental



drivers for eco-innovation reside in the integrated development of these institutions, is common wisdom of the last decade, but difficult to get the grips on. Finally, there is the domain of policy drivers for eco-innovation, either directly relating to economic activities of production and consumption, to specific developments of knowledge in the cultural domain, and as in helping create new institutions for eco-innovation. We will go through the three major areas of drivers for eco-innovation in turn, specifying the predictive indicators we think relevant and open to quantification. In setting up this structure, the prime driver for change is politics. It should be remembered that in a fundamental sense, culture is the ultimate driver, both for such policy development and also for institutional and for economic development taking place independently from specific policies.

Predictive indicators within the economy: a breakdown of totals.

Some meso and micro level indicators relate quite directly to the macro level. Value added per sector and emissions per sector add up to the GDP and the total emissions of society, as does regional GDP and regional emissions. Insight in this meso level development is useful and can be obtained now, albeit not at a level of detail and the coverage which would be more useful and well possible. This value added equals the proceeds of sales minus the cost of purchases from other sectors, usually specified per year. The breakdown to a meso level can be continued to the disaggregate micro level where data basically are gathered, at the level of firms and their activities and including also consumptive activities with direct environmental interventions. All these disaggregated measures may cover both economic and environmental performance.

Other measures at the level of the firm used are turnover and profits, which may be relevant in some contexts but not so much in the analysis of eco-innovation. Used in combination with a denominator, for example, number of employees, capital, R&D expenditure in total value added, or number of staff engaged in R&D as percentage of total staff, comparisons may be made between the yearly scores of firms and between different firms. See the next section on the firm.

Predictive indicators within the economy: the role of the firm.

As much of the innovation theory relates to firms, let us first specify the role of individual firms in the eco-innovation process. On the one hand it is plays in indispensable role, in the last part of the development process, in market creation. That is the undisputed domain of firms. On the other hand, individual firms usually are not at the source of the eco-innovation in a fundamental sense, where science and research organisations play a larger role, nor are they single players in pre-competitive Research & Development. Innovations are ever more created in an open innovation process involving various participants at different stages of innovation. The core actors who drive an eco-innovation differ depending on the stage of innovation. The eco-innovation indicators should consider the information needs of the addressees and key players who drive the innovation process in each stage. Also, individual firms starting in a market usually have to accept developments with consumers as given. So when looking at the firm as an individual actor, its role is mostly partial but in the final stage of successful eco-innovation it is indispensable.

The stages of development may be covered within one or several firms, with the early stages most relevant for larger firms with scientific development departments. Focussing at the firms, the knowledge development relates to the generation ideas; development of prototypes; introduction in niche markets; and diffusion in mass markets. These development stages each require specific activities, which can be mapped in indicators. These include knowledge management systems, employee training programmes and potential eco-efficiency scoring for

the idea generation stage; investments on eco-design and patents on eco-ideas the prototype development stage; number of potential eco-innovations and their eco-efficiency potential for niche market introduction stage; and realised eco-efficiency, market share of eco-innovation in the mass market stage.
The drivers for effective eco-innovation relate to actors involved and how they are influenced by economic drivers directly and by cultural, institutional and policy drivers at a meta level, as treated also at other places.

Combining economic and environmental performance as eco-efficiency

Decoupling, as combined economic growth with environmental improvement, is the key ingredient of the definition of eco-efficiency. Combining economic and environmental performance in one indicator can be done using a ratio, as eco-efficiency. Environmental impact per unit of value is environmental intensity and economic value per unit of environmental impact is environmental productivity. For society, eco-efficiency, as environmental intensity, has to decrease faster than economic growth for a net reduction of the environmental impacts on the environment. If eco-efficiency improves but not fast enough, there is soft decoupling, an improvement per unit of GDP more than compensated for by economic growth. These same ratios can be used at the disaggregated meso and micro level, with full correspondence to the macro level when adding things up adequately.
However, insight in developments as related to knowledge creation for new technologies and products would require different entities to measure. What is the eco-efficiency of this product as compared to products with similar function or compared to the average product in society? A bad eco-efficiency score, as a too high environmental intensity, would indicate that the product would not constitute an eco-innovation. A comparatively good score, however, might not be good enough, for two reasons. One is that the technological innovation involved has a very high contribution to economic growth, also raising consumption in *other* consumption domains. The other is that the use of the product may be specifically connected to other consumptive activities with a bad score. A clean barbecue may lead to increased consumption of meat. Finally, there is a technical reason which makes link to the macro level not straightforward. Adding up such product-technology combinations can now be based on LCA only, which gives a steady state over the life cycle which usually is spread out in time, that is over the years. How the effects are per year cannot easily be specified, and addition over all products consumed in a year surely will not give the total of environmental impacts in that year. As a first approximation, however, comparative eco-efficiency measures can be extremely useful as an estimate for eco-innovation potential.

Predictive cultural indicators for eco-innovation

At a most general level, the availability of such indicators is important for eco-innovation process, helping guide activities in the right direction. Similarly, the use of such indicators at a national level is a cultural indicator. At a still more meta-meta-level, the research done on developing indicators for eco-innovation is an eco-innovation indicator itself. Slightly more direct indicators relate to the extent of the use of eco-indicators by firms, whatever their exact nature.
As to the most relevant content this would refer to the state of knowledge on eco-innovation. Direct measurement of such knowledge is impossible though. What can be measured is related to the research on eco-innovation taking place, as in the number of journal papers, reports and workshops and conferences on eco-innovation, including directly related subjects as eco-efficiency. New bibliometric tools for this purpose seem to be coming up. Another entry is similar, focussed at knowledge transfer on eco-innovation. The number of networks

and their volumes of activities, and the volumes of the firms involved would have to be measured, as related to eco-innovation knowledge transfer between government, research and business. Finally, in addition to the values conducive to innovation currently measured by Eurostat for SMEs, values conducive to eco-innovation could be measured from behaviour as well. This would involve for example interactions between eco-innovative firms; eco-innovation expenditure, role of venture capital with an eco-innovation focus, and similar.
Moving towards measuring values directly could give further insight, for example as the presence in firms of eco-innovation value orientation; the percentage of persons in a firm with membership of environmental organisations; and the share of environmentally friendly products (as with Ecolabel) sold in a country. Also, the green procurement share in total public purchases can be used as a value indicator. This in to measure values, not performance which can be measured more straightforwardly.
Several interesting IT based developments take place which would be indicative of potential eco-innovation. Open innovation, most directly recognisable in open source software development, may be a key to fundamental increases in knowledge creation and technology development. The knowledge gained by many may more than compensate for the lack of monopolistic profits as a driver for privately appropriated technology development. Current open technology development at a pre-competitive stage falls in this category.

Predictive institutional indicators for eco-innovation

There is one overarching measure on innovation capacity, the *Global Competitiveness Index*. This might be expanded to a *Global Eco-innovation Capacity Index*. However, the insights and gut feelings of business as to how competitive countries are cannot easily be matched by such insights on how conducive to eco-innovation countries are. More focused institutional indicators are possible, first related to economic functioning directly. These relate to investment options as created by environment focused investment funds and venture capital availability. More indirect are reporting requirements on environmental performance, in addition to the usual economic performance requirements, and with similar requirements on public disclosure. The availability of environmental specialist, through educational programmes is at the boundary between institutional and cultural indicators. Such items could be related to the Innovation Scoreboard.
A further set is on the effectiveness of environmental policy, indicated by strong measures on enforcement, like the number of prosecutions and the fines for non-compliance. A further indicator in this domain is how the total of policy instruments relates to being technology binding or eco-innovation inducing. Part of this could be covered by an indicator on the amount of regulative taxes and similar payments. The effective implementation of environmental liability law, as the value of damage payments.
Environmental property rights, as institutions, can be judged in general based on the satisfaction of users, as patents in principle cover eco-innovations in the same way. The number or share of environment related patents may be indicative of an eco-innovative culture but also of special institutional mechanisms towards eco-innovation patenting. Similar holds for license payments on such green patents. Special arrangements for eco-innovation patenting might be present. The options for eco-innovation patents analysis have been worked out in more detail in the MEI project. How tendencies in patents can predict tendencies in eco-innovation performance is an open question. To some extent, the patents indicate research volume, which may be a causal parameter. The role of patents themselves, especially in relation to innovative persons and SMEs, remains at least a delicate subject. Some even advocate a strong reduction in patentability of inventions in order to increase innovation!

Finally there are institutions for organized pre-competitive knowledge exchange on eco-innovation. Their effects may be measured in terms of the volume of exchanges, which then also indicates a cultural tendency to eco-innovation.
The advise of new economists like Romer to carefully design institutions for growth in the knowledge economy as a deliberately designed and maintained set, would also hold for eco-innovation. Capturing such an as yet diffuse aim in indicators is not possible now.

Predictive policy indicators for eco-innovation

When thinking about policy in relation to the environment, the focus tends to be on environmental policy. However, the significance of eco-innovation policy may better be measured by a broader integration of environmental considerations in other policies, including the economic aspects of such broader policies. So a first indicator would be how broad eco-innovation considerations are woven into policies, to be specified per member state. Next, policy aims can be used, first in terms of eco-innovation targets specified and next as eco-innovation strategies worked out. The volume of policies relates to a next series of indicators relates to numbers of policies in place and the financial resources available for them.
The following question is as to the quality of these policies, for which an indicator would be very useful but also very difficult to design. A parallel with innovation policy can be made, as with the INNO-Policy TrendChart which tracks developments in innovation policy measures throughout Europe. An innovation policy measure is defined as any activity that mobilises:

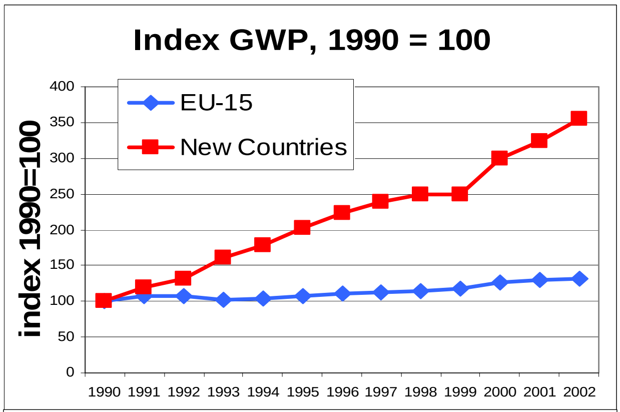
- Resources (financial, human, organisational) through innovation orientated programmes and projects;
- Information (road-mapping, technology diffusion activities, coordination) which is geared towards innovation activities;
- Institutional processes (legal acts, regulatory rules) designed to explicitly influence environment for innovation.

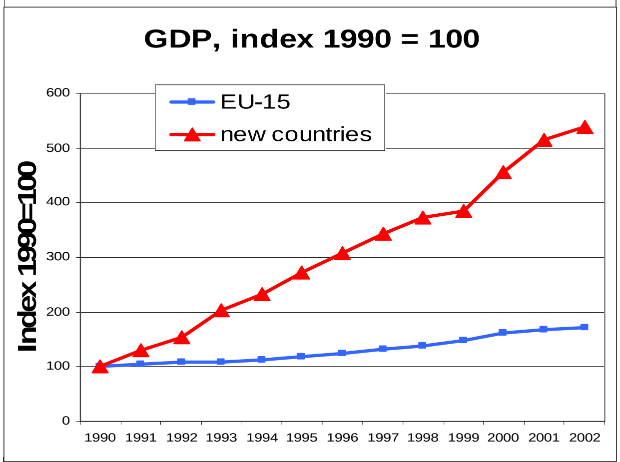
Given the convergence with growth economists on institutional development, the policies for institutional development could be lifted out for further analysis. It seems too early to think about such an analysis in terms of indicators. The broader options of modelling also do not seem apt for this as yet highly qualitative endeavour. Similarly, policies towards the cultural domain, in research and education on eco-innovation, would be the second focus, now still hidden in the more general category of ‘eco-innovation policy’.

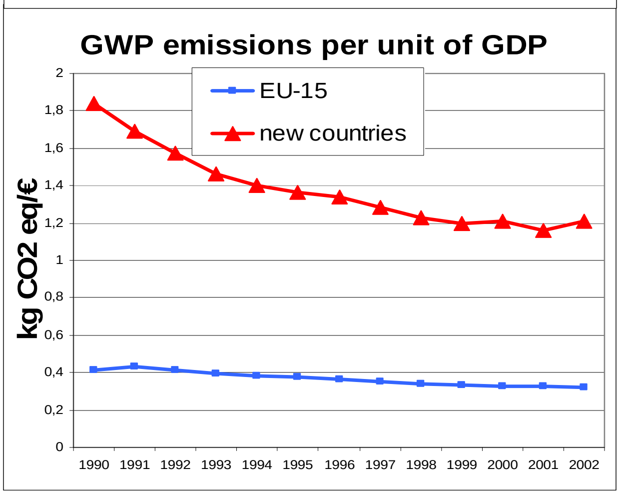
Preliminary quantification of performance indicators

The eco-innovation of countries can be measured in terms of the change in economic and environmental performance. Time series on economic development are well established, while a similar time series on not too small set of environmental parameters has recently been developed, much broader than the ESA95 based time series which are available at Eurostat for some countries only, and with a limited time coverage. We pick out the scores for global warming here.

The interesting outcome first is how the New Countries improved their combined economic environmental performance dramatically when they entered the institutional framework of the EU. Their eco-efficiency scores improved substantially, though not as fast as their enormous economic growth. The absolute amount of environmental impact went up substantially still, though environmental intensity, eco-efficiency as GWP emissions per unit of GDP was much improving. The institutional realignment created a clear example of fast decoupling, though still only the weak and not the absolute decoupling. Secondly, for the Old Countries, the eco-innovation performance was not impressive at all. For so me years the improvement per unit of GDP, that is the improvement in eco-efficiency at a country level, compensated for growth and in other years it does not. Overall effects on environmental quality remain as negative as a decade ago, being somewhere at the boundary between absolute and relative decoupling. The challenge to move really move towards eco-innovation still is there, sadly, as the environmental intensity of production remains too high.







Options for further quantification

Quantification of eco-innovation indicators is useful only if time series on the relevant variables are gathered. Consistent time series are based on the work of statistical bureaus, with substantial preparatory work to align different statistical bureaus and offices at the country level. We presented our draft indicator set to EUROSTAT and based on extensive discussions, the conclusion was that expanding the coverage by EUROSTAT from innovation to eco-innovation indicators is possible in a few cases only, to a limited extent and with a long time lag before actual data gathering may start. Data gathering on a project basis seems the only way out to get to more relevant data on indicators for eco-innovation.

Research priorities

One main item for research comes up: How to systematically link the micro level performance of technologies with the macro level eco-innovation performance of society, where aims of Lisbon, Gothenburg and Sustainable Development Strategy refer to. This is not just a question of the right frameworks and definitions but also of empirical analysis and policy views. A few examples. If increases in productivity are in the form of wage rises the income distribution resulting is different from increases in profits, with different reactions as to spending. Higher inequality will lead to different spending patterns. If wages increase, this may lead to increased spending, or to more leisure time. In the last option, the environmental impacts will be lower. This research programme will have to combine insights from the current ECODRIVE project, with those of the MEI project which has been focused more at micro level eco-innovation. The general framework would cover drivers for eco-innovation, of all sorts; the processes involved in knowledge and technology development and different steps in market implementation; the micro-level sustainability or eco-efficiency performance; and the ultimate effect on society as to sustainability and decoupling, as macro level eco-efficiency.

Discussion and conclusions

- The proof of the pudding is in the eating: The basic indicators for eco-innovation refer to eco-innovation performance of society directly. This performance is at the macro level, as the sum of myriad micro level activities.
- Linking micro level eco-innovation performance to macro level performance is not a self-evident step, as indirect effects of a rebound nature are to be considered and a adequate reference for comparison is to be made. Micro-economic indicators are most relevant for the monitoring of eco-innovation development if they can be associated with improved eco-efficiency performance.
- Derived indicators for eco-innovation are relevant for monitoring and for policy only if they are predictive for later performance.
- In the causal chains involved, factors conducive to eco-innovation can apply in the economy directly. The may reside in the cultural domain as in terms of development of eco-innovation knowledge and values. They may be in the institutions of society guiding both cultural and economic development. Or they may be in terms of policies directed at institutional development, cultural development or economic development towards eco-innovation.
- The nature of the economy is shifting, with cost of knowledge development becoming a main factor. This means that decreasing cost become a rule with full competition increasingly being replaced by monopolistic competition.
- Rules on intellectual ownership are essential in creating incentives for knowledge development on the one hand and for avoiding undue monopolistic profits on the other hand. Consistent sets of
- Time scales involved in major mechanisms in innovation are substantial: three decades from science to new technology and one decade from new technology to mature markets
- Private firms play a key role in the market implementation of technologies especially in the final stage of their development where performance becomes visible.

- The current set of predictive indicators is fuzzy, as quantified modelling of major mechanisms is lacking. This situation can be improved but major uncertainties on the potential of technologies will remain.
- The most practical indicators chosen by us mostly cannot be quantified systematically for the EU. This was the outcome of substantial discussions at Eurostat. For most indicators, more incidental project based data generation seems the best option.
- Current theory on innovation and our data on eco-innovation performance of EU countries suggest an extreme influence of institutional factors on changes in eco-innovation performance of countries. This shows especially in the eco-innovation development in the New Countries as compared to the Old countries after European institutions became implemented there.
- Short term policy considerations on eco-innovation are best focussed at institutional adaptations creating market activities and changed behaviour of firms and consumers. The short term incentives and drivers, if consistent and stable, also work on medium and long term eco-innovation development.
- Additionally, medium term considerations are best focussed at pre-competitive research programmes with high eco-innovation potential. Criteria for the assessment of the eco-innovation potential of technologies are to be actively developed.
- Additionally long term policy considerations are best supported by substantial basic free-and-open internationally oriented research, with some sustainability guidance in funding using the same framework but more cautiously as for the sustainability assessment of pre-competitive technologies.
- Setting up a consistent set of eco-innovation oriented institutions is a substantial task, both in an intellectual and in a policy development sense. The currently developing European Carbon Trading System is a major example of institutional development for eco-innovation. Catching such developments in indicators seems hard if possible at all; it is the development as such which counts.
- Promotion of bio-ethanol and biodiesel as direct interventions in the economy by both the EU and the US, would not count as eco-innovation because they are costly in terms of economic performance and may well have an even negative environmental performance at a macro level. Eco-innovation guidance and incentives, in stead of the direct interventions in the economy, seem more basic for effective eco-innovation policies.
- Current operational indicators have a limited predictive value and hence a limited policy relevance. This state of affairs may be improved upon. However, for many policy and monitoring purposes, "indicators in a framework", that is models, might be more relevant.
- A conceptual framework for long term modelling and scenario development is to be actively further developed, to align research and research & development programmes to some extent towards eco-innovation, and to allow for more reasoned long term indicator and policies development.

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1 Introduction.

1.1 Growth, innovation and eco-innovation

Globalisation has changed the landscape of economic advancement. The old views on international specialisation, starting with Ricardo, have received a different meaning. It is no longer distinct products that come to the market from one country. In a consumer product like audio-visual installations and PCs, parts are incorporated from large numbers of countries and even larger numbers of specialised activities. The design of the product and the overall production framework also are distributed over many countries, as are planning and marketing. There is not one type of coordination for these activities. There are markets, contractual relations and hierarchical organisations. The drivers for the development of the physical and organisational activities, and for the knowledge required in their operation and development are created by institutions, like markets and the legal systems creating these, and like research institutions creating knowledge. These institutions are not fixed but develop, both autonomously and as a result of policies. The EU directive on environmental liability[1] is an example of such an institutional change set into motion guiding actions in the processes of production and innovation towards eco-innovation. Making funding of research competitive, a move which is ongoing in most European countries is an example of institutional change towards higher quality research and knowledge creation. One main incentive in innovation is in the intellectual property rights which allow one to reap the fruits of always costly knowledge creation. The patent laws always give a limited protection as infringements cannot be prevented fully and the patent duration is limited. Making patent and copyright protection stronger creates a stronger incentive for innovation. However, tighter intellectual property rights could be counter-productive, as the broader use of previous inventions would be hampered, thus reducing economic growth (see Romer 2007).

More and more, the carrier of the processes involved is knowledge, knowledge on the markets and organisations involved, knowledge on how to organise the processes required in production and marketing, and most important in this context, knowledge on how to create new products and new ways to produce and market them. The move to knowledge is most clearly visible in the domain of services, where the material component may play a limited role in the product involved. Doctor’s advice, songs and computer games are quite dematerialised as services, though upstream, substantial amounts of material activities may be required, as in medical apparatus for diagnosis and treatment. Human nature may be more or less given, the way human ingenuity is set to work differs tremendously, between groups within countries and between countries. Explaining these differences is a key to improving performance, simple growth being closely related to plain innovation, and sustainable development, its economic and environmental component, being reflected in eco-innovation. Societal goals we take as starting points are economic growth, as market based welfare growth, and environmental quality. Improvement in both is the general aim, often referred to as absolute decoupling. This forms the first starting point for this study: How can we come to grips with the triad growth, knowledge and eco-innovation.

Growth in the global economy in the last decades has been combined with international integration in terms of technologies, products and markets, and increasingly in terms of labour organisation and the services required in business. The global competition involves low wage countries which out-compete European business where the newly emerging countries can produce the required quality using still cheap labour. The global competition also involves

[1] Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on Environmental Liability with regard to the prevention and remedying of environmental damage.

established industrialised countries, with the US leading in productivity growth and overall economic growth over the EU in the last decade and half, while Japan has been lagging behind in that period, after it had an exceptionally long high growth performance in the previous decades. The continuous restructuring and fundamental change in the global economy require an active orientation on strategy. Innovation plays a central role there as stated in the Lisbon Strategy of 2000.
The same developments create a new challenge on environmental performance, based on two different considerations. Firstly, the great improvements in environmental policy of the last decades are jeopardized by faster economic growth, especially for supra-local and supra-national problems like climate change, resource depletion and the loss of biodiversity. Secondly, the attractiveness of Europe for the increasingly mobile higher educated labour force depends on its environmental quality and more general amenity. A pleasant surroundings is a prerequisite for high quality economy and life. This second challenge, to increase environmental quality in a faster growing economy, has been worked out in the Gothenburg Strategy of 2001, which has been revised in 2006 into the new Sustainable Development Strategy for the EU.

There are many entries into this double challenge in the heart of public policy and societal development, ranging from educational reform and physical infrastructure development to legal reform and changes in the taxing system. In this vast area of societal dynamisms some major domains can be distinguished for guiding and checking developments. The amount of labour is one major factor determining total production. Population growth has ceased to be a major factor in economic growth in Europe, though it still is in major parts of the world. The life time working hours tend to decrease with rising educational levels and affluence, counteracted by current policies to increase the number of years worked and hours worked to compensate for the cost of aging populations and to increase capital productivity. Unemployment is to decrease structurally, leading to an increase in the amount of labour, though mostly involving lowly qualified labour types. Taken together, in Europe the amount of labour is not a major factor in economic growth nor in environmental quality. Economic growth is determined by the technologies actually applied as combinations of specific types of capital and labour, embedded in an organisational and market structure, and creating specific pressures on the environment. Hence, the central focus for both economic growth and environmental improvement lies in the innovations to create more wealth while improving the environment, that is in eco-innovation.

Taking eco-innovation as the central entry, all factors conducive to eco-innovation, or hindering its development, become relevant in principle. One may focus on the education and knowledge part, as very explicitly done in the Lisbon strategy, or on the institutional developments relating to public participation in decision making, as in the new Sustainable Development Strategy, or on the dynamics in organisations, as is the focus of much of innovation research, or on the market developments creating the Schumpeterian ***creative destruction***, or on the cost and incentives of regulation, as in the Porter school of growth by environmental policy. All these entries have their charm and relevance when analysing the factors conducive to eco-innovation. The questions to be answered here relate to which factors indeed are main drivers for eco-innovation and which factors are more, or less, important as drivers. There of course is quite some discussion possible on what constitutes economic growth and what constitutes environmental improvement, we will come to that. In principle these discussions can be resolved to a relevant extent. The central problem in the analysis here is how to disentangle the many factors which together may create more eco-innovation, or less. The actual knowledge of how societal development is determined is sketchy and limited by the open nature of the future. The future not only is determined by causative factors but actively made, with a substantial degree of ingenuity and creativity, with substantial but hardly known conditionalities, and with possibly a chance or chaos factor. So the analysis as to factors indicating eco-innovation will remain essentially open in nature. What we can do is distinguish main lines and conditions in a systematic way, using the framework developed in the first three chapters of the study in choosing most relevant but never ideal indicators for eco-innovation next.

1.2 Creating growth and environmental improvement

There has been a recent convergence between historians of economic history and economists involved in present day growth theory (see Helpman 2004 for a survey). The general lines developing are as follows. Economic growth increasingly is based on knowledge and less on increased amounts of capital goods. Ownership of knowledge has to be looked upon in more detail, distinguishing ownership of knowledge from other types of ownership in two respects: Knowledge as a product is non-rival, meaning that one's person's use of it does not diminish its availability to others, and knowledge ownership is never fully established exclusively. This excludability may range from temporary near full ownership to zero excludability, with knowledge freely and publicly available. Actual innovations require a mix of knowledge ranging from freely available general knowledge to privately kept in-house knowledge, protected by property rights or not. Knowledge as a good differs from usual market goods in these two respects. You can't eat the pie and have it, and the pie is yours, or mine.

There is a clear focus on institutions, and on that subject a clear focus on intellectual property rights, not as given institutions but as one main variable to use in creating knowledge and technological innovation for growth. Ownership rules on intellectual property create one key incentive for innovation and hence for eco-innovation. Ownership is created by law, protecting the owner against infringements on his rights, ultimately in court. Even small changes in procedural rules may have large consequences for the practice of invention and innovation. Patent ownership rights are continuously developing. In the US a change in patent rules is now taking place, seemingly as a mere procedural technicality. The House of Representatives has passed a bill changing procedures of litigation, with treatment in the Senate on the agenda for winter 2008[2]. There are two key elements in the new legislation. One is that compensation payment for infringement on the patent are based on the value of the component in the product falling under the patent, not the product value as such. The other is that users of the knowledge in the patented innovation denying the infringement can go to court not just once, but repeatedly, if using new grounds to challenge the validity of the patent. Two lobby groups have come up, one supporting and one opposing the bill. The Coalition for Patent Fairness supports the bill, safeguarding the position of large product makers. They do not want to be robbed by *patent trolls*, who just file patents strategically to earn on blocking other's innovations. One hand-held computer firm, for example, has paid half a billion US dollar for the patent on their hand-held owned by such a troll. The other is the Innovation Alliance, gathered around the Professional Inventors Association. They are opposing the bill as small inventors never would get paid effectively, even if successful applications would develop. They call for restricting ownership in a different way, by better quality control on patent applications, avoiding the strategic patenting not based on any own research. The US legislation has consequences for all inventors and all firms acting globally.

[2] See P. Marks (2007) Inventors cry foul over reform of US patent law. *New Scientist* 24 November 2007, pp28-9

Next to these opposed positions, there are voices to reduce the domain of patent applications substantially, if not abandoning the ownership of this by nature quasi public good altogether. Their reasoning is that patents hold up the application of useful knowledge; create defensive research to get around the patent by developing other technologies, and lead to high transaction cost especially in complex products where several patents are to be used together. The general background of this position is that knowledge is not a fully collective good, and hence can be sold in a market. Both acquiring it, assessing its potential in applications and preparing to use it takes time and money, giving the originator a position in the market, even without a patent. So innovation still pays, though maybe a bit less. Some research indicates that especially small inventors better don't go for patents but sell their idea by selectively giving ***early knowledge*** to one party in the market. As knowledge effectively is free when dissipated, the general speed of innovation will go up without a patent system, or with a much reduced one. These three incompatible positions all intend to change society for the best, or at least their reasoning is phrased in such terms.

The baseline in the reasoning with all three positions is that (1) a political decision is involved in (2) changing a legal institution on ownership of intellectual property, which leads to (3) a change in knowledge creation and to (4) a change in how new technologies are implemented in economic activities. Let us investigate the routes involved in a bit more detail, where they start and where they lead to. Knowledge is created by human curiosity but in an organised way, as a paid social activity, by supply push and by demand pull. Research institutions mostly depend on push, as through funding by universities and research councils. At the other end, knowledge creation is driven by the demand pull of market, by potentially creating advantages in existing markets or opportunities in new markets, with funding based on expected potential gains in markets.

The knowledge involved is of a different nature, with on the more general side *propositional knowledge* and knowledge of the facts of reality, and more close to markets the *prescriptive knowledge* specifying techniques, how they can work. The sum-total of propositional knowledge and prescriptive knowledge is what Mokyr (2002, Ch.1) names *useful knowledge*. Propositional knowledge has expanded since the scientific revolution and still is the ultimate driving force for substantial progress in technology. Relativity theory and quantum mechanics from the early 20th century have brought us atom bombs and nuclear power within half a century, have played a key role in the ongoing IT revolution now expanding up to a century, and may form the basis for the next IT revolution in data processing with the quantum computer for which elements of prescriptive knowledge are now starting to be built up.

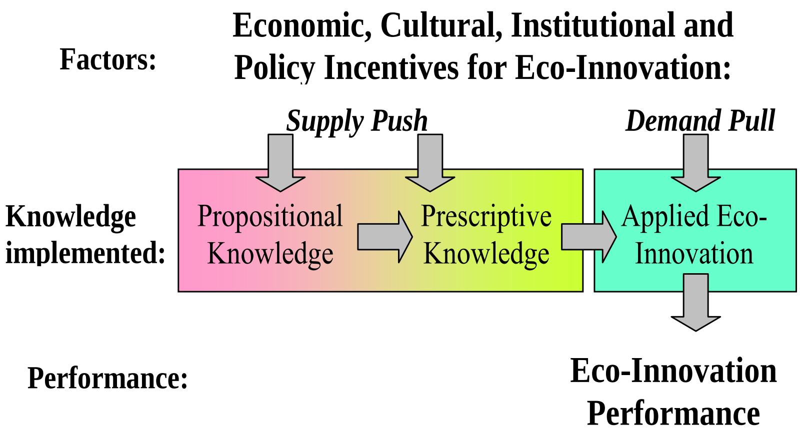
The more applied prescriptive knowledge encompasses the complexities of actual production processes and products, relating to the physical level, and is also related to social aspects such as industrial organisation, legal frameworks and safety requirements, and finally: to markets. That is where the demand pull originates, where individuals or organisations are willing to pay for products, both physical goods and services, because they need them, like them, or anyway: want them. "The market" is not an abstract entity of nature but a socially constructed reality, based on culture, human nature and on the frameworks created by institutions. The transport revolution and the IT revolution have created easy access to knowledge, creating the basis for knowledge based economic growth and, if directed adequately, for sustainable development.

Eco-innovation, involving the economic and environmental aspects of sustainability, is created through market incentives, positive ones reflecting sustainability considerations and negative ones, as constraints on production and consumption activities, the demand side. Also, sustainability considerations may have a direct influence on the creation of relevant propositional and prescriptive knowledge, in the supply of knowledge through research and education.

It may take decades to centuries before more basic propositional knowledge is combined and embedded with other knowledge domains to become practically applicable as prescriptive knowledge, and for a subset only, become applied in real applications, in technologies and products. What is not developed first cannot come to fruition later, so the creation of generalisable propositional knowledge is one clear measure on future sustainable performance of society. What is not combined into prescriptive knowledge cannot come to fruition either, so such developments are a clear measure on less distant future performance.

With this general picture in mind, how can we measure if society is developing eco-innovatively towards economic and environmental sustainability? There seem to be three basic approaches. One is the actual development in terms of economic and environmental performance. This is the ultimate proof, combining economic growth with environmental improvement. Second is the development of useful knowledge on eco-innovation itself, requiring some quantification of useful knowledge in general and on eco-innovation in particular. The third approach is to measure factors conducive to the development and application of knowledge for innovation and eco-innovation. This triple entry into eco-innovation forms the basis for the approach worked out in the ECODRIVE project. Combined with the continuum from propositional knowledge and prescriptive knowledge to practical application the following scheme results, see figure 1.1.

Figure 1.1 Eco-innovation performance, and knowledge creation, and factors conducive to knowledge creation and improved performance.



One might object, why go for indirect measures, why not stick to the proof of actual performance? The answer is that the feedback mechanisms required if things go wrong, or not right enough, involve such long periods of time that reactions will always be too late. Without active *autopoiesis* a term framed by the sociologist and administrative scientist Luhmann (1995), society will run into blind alleys and succumb. Empirical analysis of major innovations indicates that full market development typically takes two to five decades, after a first prototype has been developed, see Hirooka (2006) for the elegant analysis. The development of the propositional knowledge precedes this prescriptive knowledge. So monitoring the development of useful knowledge seems essential to see if we are *on track*. Why not stop there? The basic reason is that mapping the development of knowledge is extremely difficult. As indicated above, the reduction of patent applications by SMEs, relative to other countries, may not be bad at all, if shifting to other and better ways for marketing inventions forms the background of this development. So, insight in such routes to development and application of sustainability knowledge, and the incentives involved, may shed more light on future development of eco-innovation than measuring the growth of knowledge itself. Also, from a societal feedback point of view, insight in the factors conducive to knowledge development and application at the same time creates the opportunity to act, to actively work towards improved future eco-innovation performance.

Setting this objective for ECODRIVE is a challenge which can be met in the most general way only, as knowledge is limited and inhomogeneous. Which mechanisms are involved and how can we get some insight in the combined functioning of these mechanisms in society, ultimately quantified in terms of indicators? The answers are not self evident. Furthermore, the available knowledge on mechanisms and incentives in knowledge creation and application is inhomogeneous. It is not structured in a way that it can easily be reduced to indicators, let alone a limited set of non-overlapping indicators catching all developments for eco-innovation performance. Getting to grips with this subject is the first main part of the ECODRIVE report. The resulting preliminary indicators constitute the second part.

1.3 Why eco-innovation indicators?

In developing society towards sustainability, eco-innovation plays a central role, being linked directly to two pillars of sustainability, environmental quality and economic welfare, which together indirectly also constitute main indicators for social quality of life. Other entries to environmental improvement exist, especially changing the structure and volume of consumption. Eco-innovation has a prime relation to technologies and touches on such options only, as in developing new products, and improving labour productivity. Eco-innovation is not a neutral concept; it embodies the normative elements of sustainable development, as improving economic performance and improving environmental quality at the same time, leading to improved eco-efficiency. Innovation mostly is analysed from the angle of the innovation process, of how knowledge is applied in new technologies and brought into markets, and which impediments should be overcome. For analysing eco-innovation, a shift in focus is required to the consequences of the innovation process, in terms of both the environmental performance and the economic performance resulting. Eco-innovation thus is the process towards improved sustainability, and measured in these terms.

Given this basic position, why do we need eco-innovation indicators at all? Why not just measure the results in terms of what ultimately matters: growth in economic performance and improvement of environmental quality? Such *output measurements*, though currently improving substantially, have their drawbacks. The major one is that the time frames involved in the processes leading to economic and environmental performance improvement extend to extremely long periods. From a historical perspective, institutional, scientific and technology development, in the relevant cultural and institutional contexts, exert their influence over decades, or even longer. Some developments may be much faster, involving years. A current example is how, based on price adaptations, biofuels enter the market at a great pace, though not well founded in terms of the environmental advantages to be gained. Changed market incentives may shift the economy quantitatively in new directions, mostly based on already existing technologies with relatively small adaptations. See Edgerton (2007) for a survey of the role of existing technologies in the economic growth of the twentieth century.
So if we want to have the right feedback on guiding economic development towards sustainability, we need to know about *the mechanisms that eventually will lead* to economic and environmental improvement, before it has taken place and can actually be measured. Clearly, it is essential that such *intermediate indicators for later performance* derive their value from their predictive capacity. If we do not know how measures in the economy, or cultural

developments, or institutional changes, or policy decisions, work out as *drivers of change*, the indicators on such points within the social system have no value. As the time frame of indicators, that is the time period over which they have predictive value, may differ substantially between such drivers, this time frame element should be explicit when defining and using indicators. Stopping or redirecting basic research will hardly have any influence on economic and environmental performance in the next decade. Over decades some knowledge elements might well be essential for sustainable development. Reducing basic research, as by shifting to applied research, therefore might be the wrong thing to do, or the right thing if more applied research could still build on the fundamental research of the last century. The nature of society then would change from advancing to conserving, a fundamental cultural shift. Such considerations are unavoidable in the background of the discussions on eco-innovation.

The central question for this study is how to deal with the *empirical relation of elements in the social system leading towards improved economic and environmental performance*, while the future of society is basically undetermined. Indicators should be predictive in a fundamentally uncertain world, where developments are conditional on policies and are conditional on unknown events. Their *predictive value* therefore will always be limited. Making detailed models on the large scale introduction of the Sterling engine, a promising technology since patented in 1816, is futile. On the other hand, having no model at all is giving up the rationality of society. So the way out seems to have a rough model of society, as a modelling framework in which relevant drivers and indicators for eco-innovation can be specified. *Knowledge on specific mechanisms* can then be placed in this framework, thus receiving perspective.

The set up of the study follows these basic considerations. First there is some *definitional discussion*, in chapter 2, to specify *what eco-innovation is* and how it relates to innovation in general and to concepts like decoupling and strong and weak sustainability. Next, a rough *modelling* structure is sketched, in chapter 3. This conceptual structure or base model is not yet focussed on eco-innovation but depicts the mutual relations between the main elements of the societal fabric. Next, in chapter 4, these basic relations are used to set up a *framework* for those specific elements which may be expected to exert a positive influence on economic and environmental performance, with a very rough indication of the time frames involved. The next chapters then fill in the more detailed knowledge on *processes conducive to eco-innovation*, always placing them in this broader framework, always linking them to the 'end values' of economic and environmental performance, and always in a specified time frame.

So the typology on eco-innovation developed here differs fundamentally from the typologies related to the innovation as leading to new technologies and new product-market combinations. Market penetration and diffusion are an essential addition for linking the development process to economic and environmental outcomes, first expanding to markets, supply chains, product systems and other meso level units of analysis. Embedding of such market developments in the broader economy is an essential step, ultimately indicating how society grows economically and improves its environmental quality, combined as eco-innovation performance. Embedding both technology development and market development in their broader cultural and institutional context is an addition at the other side.

The focus of this study on policy requires a view on all the processes as may be conducive to eco-innovation. It is not only the Porter type of environmental policy induced economic development which may be used for furthering eco-innovation. Also more indirect cultural and institutional mechanisms may be essential for eco-innovation, especially in the longer run, and may be further developed. Also at that level, indicators for eco-innovation are developed in this study. Eco-innovation in the more restricted meaning, as micro level technology development and market introduction, of course remains a central part of the overall framework of eco-innovation.

1.4 Goal and scope

The aim of this study is to catch the *most relevant variables which are conducive to economic growth and environmental improvement* and to place them in a *framework* where their usefulness and relative importance can be evaluated.

The *perspective* primarily is a *European* one. However the context is essentially a global one, both in terms of increasingly international relations in science, technology and markets and in terms of the European responsibility for the global environment. The competitive relations with the rest of the world will be treated from a well understood long term European interest, involving a common global interest. Closing the borders for the export of ***free*** European knowledge is not an option. Reducing science and research and getting knowledge for free from abroad is not an option either. This is not only so because it will not work in terms of creating business opportunities, but also because Europe is a main producer of knowledge globally and the rest of the world, especially the US would retaliate. The breakdown of this aspect of globalisation would be disastrous.

The indicators of eco-innovation not only have a collective good character beyond Europe, they also have a long term component relating to future generations. Current scientific developments as in quantum computing or fusion technology will not come to market fruition in the coming decades; the year 2050 as often mentioned seems a symbolic date only. Redirecting research funds to market introduction of more close science applications as in some domains of biotechnology or nanotechnology would be conducive to eco-innovation on the shorter term. If then broad shifts in research funding would take place, this would kill long term eco-innovation. How research can be guided from not only leading to innovation but to eco-innovation, and how progress can be measured in relevant eco-innovation indicators remains one of the tasks ahead.

The third scope element is *measurability of indicators.* The feet have to stay on the ground at least some of time. This does not mean that we have to restrict ourselves to what is currently measured. This may be handy and hence will be one element in the analysis, but measurability-in-principle is what counts.

2 Eco-innovation defined

2.1 Causal chains to performance

There are many possibilities for defining eco-innovation as a process and for developing indicators to show the position or progress regarding eco-innovation. The focus may be on eco-innovation as a scientific and research activity; as an R&D activity resulting in knowledge and patents on processes and products; as an institutional framework in the firm creating eco-innovation, etc. The problem with all these justifiable approaches to eco-innovation is that they are not easily linked to the intended outcome of the multitude of interlinked processes involved, ultimately leading to a higher welfare and a better environmental quality for society. The number of patents focussing on environmental improvements may be a good indicator of the volume of eco-innovation research being funded and carried out. Rising environmental investments also may be indicative of a move towards a more ecological orientation in society. A rising number of ISO14001 environmental management certified firms may indicate the good intentions of the firms involved. These positive developments in the three exemplary indicators may at the same time take place in a stagnating economy with a deteriorating environment. Good intentions are not yet activities and the activities based on good intentions may be ineffective or not effective enough for overall sustainable development of society. Conversely, eco-innovation may develop for purely technical or economic reasons. Coal gasification may evolve to be a key technology in reducing CO_2 emissions, though it surely has not been developing for that reason. Its high energy-to-electricity conversion ratio and the option of flexibly co-producing other products like synthesis gas, H_2, and ethanol or methanol have driven first developments. The fact that the gaseous waste outflow is nearly pure CO_2 makes it most fit for carbon capture and sequestration, at a relatively low price. If carbon sequestration is the way to go, this technology clearly has good environmental papers, in a scenario where fossil energy sources remain dominant and CO_2 emissions are to be reduced by such end-of-pipe measures. It is not the intention which counts in eco-innovation but the result.

The result cannot directly be seen in the technology innovation taking place. Technologies are defined here in the broad sense of covering techniques, the knowledge and organisation to handle techniques, and the knowledge and organisation to have the techniques functioning in their broader economic and regulatory surroundings. The technology as such cannot be planted in the economy as if functioning independently from its surroundings. Others use it and react to it, unavoidably influencing both economic and environmental performance resulting. Cars with increased fuel efficiency, as in innovative hybrid drives, have played a distinct role in moving towards heavier cars, as these have become less expensive in use. The fastest accelerating two-tonnes SUV now is one with a hybrid drive. Placing technologies in their socio-economic context is an essential step in specifying their eco-innovation contribution. On the other hand, there are developments in society which do not alter technologies but do lead to economic growth with environmental improvements. Car sharing techniques have developed, as social-legal-administrative constructs. Substantial increases in its share may greatly enhance economic and environmental performance of person transport. The technologies and organisation involved have been around for quite some time: Cars, mobile phones and identification keys. Both for technology embodied innovation and social based innovation the result cannot be seen directly by looking at the activity. A first step is comparison with activities with a similar function, as is done in environmental LCA, combined with Life Cycle Costing to catch the economic aspect. Environmental improvement is measured by comparing the LCA outcomes of the old and the new alternative, while decreasing cost for the same function indicates a welfare rise. However, the cost decrease implies an income effect, leading to spending on other items, according to the marginal propensity to consume. This may nullify the initial environmental improvement, or worse. The reasoning being set up to catch such "rebound" effects till now are quite incidental. The ultimate criterion is how all such mechanisms work out combined, at the level of society as a whole. Also, the LCA comparison which lies at the basis of this analysis is only possible if the functionality remains the same. When new and multiple functionalities are involved, the comparative LCA score cannot easily be established. Then the contribution to the more abstract entity of value creation or economic welfare may be established and linked to environmental quality, ultimately at the societal level only. So, the question of definition of eco-innovation may be turned around, focussing at economic growth and rising environmental quality, as the core elements we want to catch in eco-innovation. Eco-innovation at macro level cannot be influenced as such. It is the result of myriads of processes and decisions regarding micro level eco-innovations, together creating the result.

The challenge is how to define the most relevant pathways toward macro level sustainability results. *Ex post* analysis on which causal chain(s) have shown to be effective for a specific innovation or eco-innovation may not necessarily result in a helpful prescription of what should be done to support the development of eco-innovations in the future. Specific innovation processes, even if having a high potential benefit from an environmental as well as from an economic perspective, may stop or have long breaks for various unpredictable reasons. One does not easily see the failures, and explaining why something did ***not*** happen is not easy and not easily generalisable. Although it is important to distinguish successful innovation process of the past and possible further processes of eco-innovations to receive a better understanding of eco-innovations, the main focus should be on drivers and factors of influence which support or stop eco-innovations in general differentiated as to different stages in the innovation processes involved. To recognize the (potential) relevance of these driving factors it is helpful to discuss the cause-and-effect chains which they may be embedded in. Causal chains on performance thus become a core tool of analysis to discuss different drivers and hurdles of eco-innovation processes.

The first conclusion here is that, as the ultimate criterion is how society develops, the basic definition of eco-innovation is at the level of society. Derived from the base definition, there may be more partial units and mechanisms which should be analysed in terms of relevant criteria, as involving drivers and other variables, leading to ***predictive performance indicators***. The reference for the base definition is society, in terms of both its economic functioning and its environmental functioning. A first approach to causal chains is in terms of the drivers of innovation processes as knowledge development; next as technology development; as market development; as market reactions, like rebound effects; and finally as to macro level performance resulting. Such a framework will be worked out in more detail

2.2 Innovation and eco-innovation defined

In defining a complex phenomenon like eco-innovation it is good to go back to some basics in terminology, and link it to the central scientific domains involved. Firstly, innovation is any change in a product, a technology, or an activity, as empirical categories. Products here comprise both goods and services, services being products with a limited goods aspect, like public transport. Secondly, innovation is used as a normative concept, as a change 'in the right direction'. Innovation then is: Better performing products and technologies, improving the activities based on them. The normative content taken broadly can be filled in as an improvement in society, increasing welfare. Main elements involved in welfare include the economic, environmental and social performance of society, covering the three main pillars of sustainability[3]. This normative concept of innovation implies tradability between different aspects. A better social performance and environmental quality may supersede a loss in market based economic welfare, and vice versa. How exactly this trade-off is made depends on social preferences, customarily discussed in a welfare theoretical realm.

Innovation in general is a change in economic activities that improves their performance. In the context of sustainable development (SD), this means an improvement in terms of the three dimensions of sustainability combined. Though the innovation concept clearly can be linked

[3] Technically, the welfare function involved will usually be of the Bergson-Samuelson type, which apart from individual welfare also covers some collective elements like income distribution. The social welfare function may be defined broader (see Sen 1970) so as to include purely collective considerations like social stability, justice and ecosystem quality.

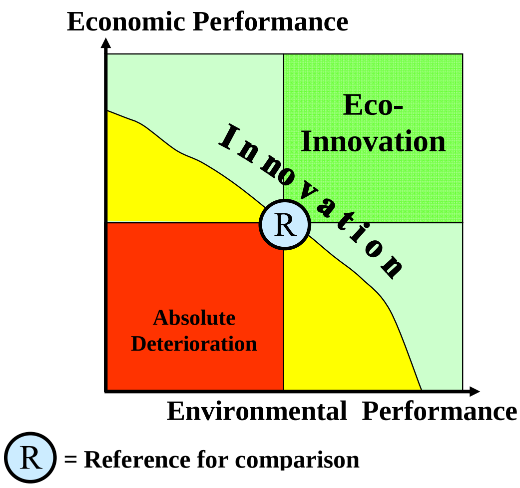
to the three pillars of sustainability, we focus on the economic and environmental aspect of sustainable development. This leads to the following base definitions.

Innovation ***is a change in economic activities that improves the overall performance of society across the economic, (social) and environmental dimensions of sustainable development.***

Eco-innovation ***is a change in economic activities that improves both the economic performance and the environmental performance of society.***

Eco-innovation hence is a subclass of innovation. Innovations not being eco-innovations, are characterized by environmental improvements with economic deterioration or economic improvements with environmental deterioration. They may have a positive overall according to some combinatory metric across these dimensions, for example a large improvement of the environmental performance which compensates the deterioration in environmental terms, see the curved line. Above this line, the light blue-green surfaces, there may be a contribution to weak sustainability. Under this line, the yellow surface, there is no overall innovation, only either economic or environmental improvement, at too high environmental or economic cost respectively.
When a change in economic practices is both economically and environmentally negative, there is an absolute deterioration, the red surface. In this case the development is neither an innovation nor an eco-innovation, and worse.

Figure 2.1 Eco-innovation as a subclass of innovation.



With weak sustainability compensating mechanisms may indicate an overall improvement even though there is an environmental deterioration (the upper blue-green field to the left of Figure 2.1). Such a weak sustainability improvement would count as an innovation but not as an eco-innovation. An eco-innovation is only given if no trade-off is necessary that is when both dimensions improve, the economic performance and the environmental performance. This definition avoids the discussion on normative issues concerning the trade-off between the environmental and the economic dimension. Such measures are difficult enough already, especially regarding environmental performance. Eco-efficiency analysis may be a guide on eco-innovation processes at several stages. Without improved micro level eco-efficiency of specific technologies, macro level improvements are hardly possible (except maybe by structural change due to trade based innovation, see section below). However, as micro level improvements will be damped down by mechanisms like rebound effects and income effects, their contribution at a macro level may not be high enough to lead to eco-innovation.

Eco-innovation thus defined in no way is dependent on intentions, though of course good intentions may be instrumental. Nor is eco-innovation linked to a specifiable part of the economy, like primarily involving environmental technologies. Nor is centred around recycling activities, or around products with a long life time, or with those using less materials. Such characteristics may constitute strategies for finding eco-innovative solutions. However, if recycling improves the environment but is much more expensive as compared to primary production, it cannot contribute to eco-innovation at all. In special situations, not only the economic performance may be worse but also the environmental performance of recycling may be worse than primary production, as may be the case with paper recycling in sparsely populated areas. If a long life time product functions in a rapidly developing technology, the older apparatus may be too polluting and expensive in use because of high energy requirements and toxic emissions, as compared to newer ones, which may have enhanced user quality as well. This may now be the case with mobile phones and computers. So there are no easy product characteristics to indicate eco-innovation, as contributing to improved welfare and environmental quality.

Eco-innovation as defined here may not even involve new high tech products and production processes. The improved labour productivity in the US in the last decade has been based on organisational changes, or trade based innovations (den Butter 2006). The lower cost of wholesale and retail in the Wal-Mart stores, as compared to the smaller towns based shops, has been a major factor in this essential parameter (Eröcal 2005). The environmental performance of the retail activities probably has been positive as well from a comparative point of view with small scale distribution. However, as US citizens now have to drive around nine kilometres on average to the nearest supermarket, the overall welfare and environmental performance of the US may not be so positive, let alone the social performance. However, the use of low cost labour in such stores is based on a larger share of lowly educated persons, bringing up the wage rate in the lower sections of the labour market but bringing down average labour productivity per hour[4]. A similar development but in most EU countries less extensive has been induced by the growth of megastores in Europe. This example indicates the difficulty in establishing innovation, as the ultimate welfare effects are not covered by market considerations alone, and for establishing eco-innovation, as the induced traffic and further income effects may well lead to a deteriorating environmental performance overall in society.

More generally, the role of technical inventions is quantitatively limited in economic growth and environmental improvement. Econometric analysis shows how shifts in supply chains may play a dominant role in economic growth, with data on environmental performance again lacking. For the Netherlands there has been a pronounced shift in the last half century from research and development based economic growth to such *trade induced* economic growth, see den Butter (2006), who indicates that this pattern is not restricted to the Netherlands. A long term survey by Edgerton (2007) shows the essential role of ***old*** technologies in long term economic growth, with for example key roles for old fashioned shipping and other transport and low tech sweatshops in current globalisation induced high growth. He refers to the focus on new technologies as 'technohype'. This position seems untenable in the long run, at least

[4] This low income in terms of inequality of income distribution is not caused by Wal-Mart and IKEA, but is caused by lack of demand for lower educated labour types. Wal-Mart and IKEA help to reduce the inequality by offering jobs for the lowly educated. See Tinbergen 1975 on the race between economic growth determining the volume and nature of labour demand, and improved education determining the volume and nature of labour supply, together determining income distribution.

on first notice, as new technologies clearly play a role in economic development. However, the answer to this objection is that technology diffusion has no national boundaries in the long run. Eco-innovation at a national level can be based on free riding on the collectively developing global knowledge base to a substantial extent, taking care of its profitable dissemination regardless of where the new ideas and technologies originate. Even if protected by patent rights, production and use of technologies requiring a licence on the patents can take place in any country in the world, with consumption resulting in different global regions again. Mechanisms related to increased market share of already existing eco-efficient products, as diffusion, are essential for eco-innovation. This diffusion has more relation to cultural and institutional mechanisms than to specific research and development activities.

Going to actual performance improvement as the basis for defining eco-innovation has a conceptual peculiarity: it is the ***dynamic performance*** which has to be measured or indicated. How to set up this dynamic analysis is by no means self-evident, as there are widely differing time frames involved. From basic research through R&D to market introduction and broad market diffusion a period of several decades may be involved. Environmental interventions activate a new time series of events in the environment, such mechanisms establishing environmental quality levels at later stages. Global warming emissions exert their influence on climate for a long period of time, methane for decades and carbon dioxide for centuries. The climate consequences build up slowly and in turn have further environmental effects, which partly are irreversible. Decreases in biodiversity may last for up to millions of years. Somehow, the overall environmental performance has to be measured in its main constituent dynamic aspects. That is a substantial task in the specification of the environmental indicator, see section 5.2 below. The economic performance is to be specified in the same framework, but without the time lags involved in environmental mechanisms. These may cover long periods. Climate changing emissions, for example, may exert their influence over centuries, with effects like sea level rise lagging up to a century as well. By reducing the environmental part to environmental interventions, the time frames of economic and environmental performance can be synchronised. This requires a shift in the analysis from environmental quality to environmental impacts, as environmental interventions, which may be handy but conceptually problematic. Even so, the dynamic performance requires the specification of this performance at several periods in time, if not continuously.

2.3 Eco-innovation and sustainable development

Eco-innovation has been defined in terms economic and environmental performance of society, covering two of its three pillars, which allows for the use of eco-efficiency as a tool for analysis. There is more to sustainability however than performance. Sustainability is a normative concept stating a principle for intergenerational justice and - the social aspect here left out of account - for social justice now. There has been a vast debate on how to make the intergenerational justice concept practicable. Two schools developed, that of weak and of strong sustainability. ***Weak sustainability*** states that future generations have their just share if their overall welfare options increase, as total capital available to them, covering man-made and natural capital together. This position implies a trade-off between economy and environment, where economic growth can compensate for environmental deterioration, see Pearce and Atkinson (1993). ***Strong sustainability*** states that we should leave future generations at least as well off in terms of both man-made capital and natural capital. This position is closely linked to the goal of decoupling economic growth from environmental pressure, or more strongly stated, of combining growth with increasing environmental quality. An early survey on this subject is in Neumayer (1989, updated 2003).

The problem of measurement has been substantial. There is a long history of analysis of optimal use of depletable resources, starting in the Thirties with Hotelling (1931). There are some recent studies on the depletion of biotic resources (see Ayres et al 1999) and there is considerable effort to include the measurement of (loss of) natural capital and its productivity in the input-output framework of national accounting, see Dietz & Neumayer (2007) for a survey. For weak sustainability, the combined measurement of market based welfare and environment based welfare is required, in a neo-classical framework. The advocates for using even non-satisfactory neo-classical measurement, like Pearce, state that in decision making this at least leads to some reckoning with the environment. The Stern Report may be seen as a successful example for this position, by stating that the costs of non-policy are higher than the costs of policy, using some neo-classical framework for quantification. The political influence of this report has been substantial, which hardly would have been the case if costs and benefits had been specified in disparate and incomparable terms. However, political expediency is not a foundation. The opposite position is taken by economists from the ecological economy school. Faucheux et al (1997) state: "Irremediable uncertainties in model specification and empirical measurement mean that the neoclassical theory is not robust for defining or estimating indicators for sustainability."

How to deal with this unsatisfactory state of affairs? One unexpected way out of the problem is to shift to strong sustainability, not for reasons of principle but for practical reasons. Though measurement of environmental quality then still is required, this measurement can be on a different foundation than that of neo-classical economics. Next to the neo-classical quantification based on individual willingness-to-pay (or to-accept) and revealed private preferences, there then are other measures on the environment, as based on revealed collective preferences or stated collective preferences, see Huppes and Ishikawa (2005; 2007b) for a survey. This shift in focus does not solve the problem of aggregation but allows for a more flexible treatment of the evaluation of overall environmental quality. In general, dynamic quantification of environmental effects is extremely difficult at endpoint level of environmental quality, production possibilities and human health. The modelling at midpoint level, like climate change and acidification is easier but leaves the uncertainties and evaluation problems to a later stage. One example of evaluation based on public preferences has been developed in the Netherlands where in a covenant between the Dutch central government and the oil and gas producing firms it was stated that implementation of the policy goals could be with the most efficient means. The trade-offs between different environmental aspects then are to be specified. This was done in a workshop with all ministries involved, the main oil industries, and specialists on environmental problem analysis, see Huppes et al (2007). Such practical solutions seem the most promising road ahead for arriving at reasoned evaluations, and allowing for a sensitivity analysis on the specific evaluation methods used. In the framework set up by the definition of eco-innovation as presented above, the bright green area is that of strong sustainability and absolute decoupling. The line between weak improvements and weak deteriorations is based on an evaluation of environmental effects in a *numeraire* which can be linked to monetary specification of market based welfare. This may be filled in in a neo-classical way, but may also be based on other methods of evaluation.

2.4 Eco-innovation and eco-efficiency

There is a connection, but not a direct one, between eco-innovation and eco-efficiency. Both concepts relate to sustainability measurement but in a different way: *eco-efficiency offering a static measurement, possibly in a comparative static way, while eco-innovation gives a dynamic view.* The static measurement of economic and environmental performance in one period can be caught in the eco-efficiency score of that period: the impacts on environmental impacts and the economic welfare of that period can be expressed as a ratio, for example as

GDP per unit of environmental impact, comparable to value added per unit of environmental impact as advocated by the World Business Council on Sustainable Development (see WBCSD 1992 and Schaltegger & Sturm 1989; 1990). There are several methods for quantification of the eco-efficiency ratio, see table 2.1

Table 2.1 Four basic variants of eco-efficiency (Source: Huppes & Ishikawa 2007a)

	product or production prime	*environmental improvement prime*
economy divided by environment	production/consumption value per unit of environmental impact: **1 environmental productivity**	cost per unit of environmental improvement: **3 environmental improvement cost**
environment divided by economy	environmental impact per unit of production/consumption value or: **2 environmental intensity**	environmental improvement per unit of cost: **4 environmental cost-effectiveness**

The interesting feature of eco-efficiency is that it can be applied both at the micro, meso and macro level of analysis. If eco-efficiency at the meso level of sector improves, while total demand remains the same, the environmental performance of society improves by necessity. The critics of eco-efficiency are partially right in stating the it is not eco-efficiency that counts but *eco-effectiveness* (see McDonough & Braungart 2002 for a strong statement). Eco-effectiveness results by linking eco-efficiency to the volumes involved. Their cradle-to-cradle strategy is inspiring, focusing on big jumps instead of piecemeal improvement. However, also big jumps can be analysed from the point of view of value creation and (remaining) environmental impact, that implies: also in terms of eco-efficiency and eco-innovation.
Improving eco-efficiency while increasing economic performance may still not be enough to constitute eco-innovation. A ***strong enough eco-efficiency improvement*** is a requirement for an eco-innovation, as a developments into the dark green area at the top right in Figure 2.1 (see e.g. Ilinitch & Schaltegger 1995; Schaltegger 2000; Schaltegger & Burritt 2000; 2005).

For effective eco-innovation, as absolute decoupling, this eco-efficiency score should be improving in time. Then economic growth may be combined with increasing environmental quality, by lowering environmental impacts at the same time. The simple arithmetic for the macro level is that the percentage improvement in eco-efficiency should be higher than that of economic growth to arrive at an effective increase in environmental quality, how ever measured.

3 Conceptual framework for eco-innovation: a field model

3.1 Linking society and environment

Having set macro level societal eco-innovation as the basic definition for eco-innovation, there is a substantial task resulting, in reasoning backwards from this ultimate eco-innovation performance to the development in specific activities leading to it. The actual modelling may be difficult, in a fundamental way even impossible as several processes are not causally determined but based on creativity and free will. We will not develop a detailed model here but will indicate a main modelling structure in which different mechanisms have their place. This structure is the conceptual framework in which in a next step main mechanisms relevant for eco-innovation can be placed, still not based on specific models. Finally, the eco-innovation indicators can then be linked to these main mechanisms.

At its most general level, this structure involves a two layered model see figure 3.1, with the blue symbolic level of society linked to the green physical level of the environment through economic activities, especially consumption and production. These activities on the one hand have a symbolic aspect as in terms of value delivered by a production process, ultimately derived from consumption value. On the other hand they have a physical aspect as in terms of material resources entering production, and their transformations into materials and useful energy, and the environmental interventions involved as in terms of emissions, with their impact on biodiversity, health and the life support functions of the environment. How exactly the physical relations with the environment may be specified will be worked out in detail in chapter 5.2. Though complex, such relations with the environment are conceptually simple as compared to the social mechanisms involved in eco-innovation, which lack a physical foundation. The social relations involved have numerous feedback loops, see figure 3.2.

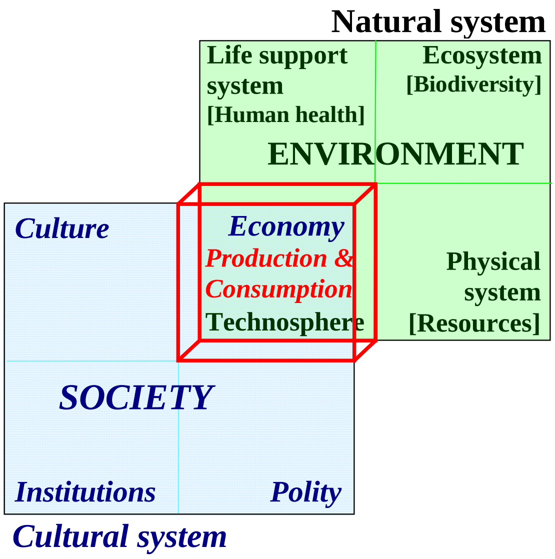


Figure 3.1 The physical and the cultural levels of environment and society.

3.2 Structuring the social system

Next to the physical aspects of production, consumption and waste handling and ecological processes, there is the level of social processes. These first involve economic processes linked to the technosphere, based on preferences, markets and organisations like firms. In turn, these are guided by more general institutions, like ownership and liability rules, and cultural characteristics. These cultural mechanisms cover both knowledge and values. Both, the economy, the institutions and the cultural system have their own internal and their interrelated dynamics. The study of society as a system has come up at the end of the eighteenth century, with views on society as an organism coming up in the nineteenth century. However, the systems analysis in which the current social sciences can be placed is a product of the Forties and Fifties of the last century, connected to names like Talcott Parsons in a more static version, to Amitai Etzioni in more social action dynamic version, and later in the Sixties and Seventies to management sciences, as developed by their students like for example by Niklas Luhmann and Renate Maintz. Society consists of main elements which have an internal structure and external relations, to the other elements of society. Various terminologies have developed, which seem to converge to four basic categories: Culture, Institutions, Economy and Polity (or also: Politics, with Policy resulting in a more specific sense).

In large, complex modern societies, these four main elements or functions have been differentiated into separate organisations, each one with its own culture, smaller scale institutions, and an economy, with a material aspect to keep the organisation functioning. Though clearly not the last word in development in the social sciences, there seems to be no other framework with a general applicability than this one. The framework and terminology are broadly used, also by historians of economics and technology like North, Freeman, Louça, Edgerton and Mokyr, see next chapter.
The framework can be used in a simple way, for a start. Culture exerts its influence on the economy, as by setting values on what is allowable in terms of advertising, while the economy influences culture as through lifting taboos on sexuality by explicit advertising.
Similarly, culture is the driving force for changes in the polity, by indicating directions for societal development and establishing the values society adheres to.

Institutions, involving norms and ensembles of norms and roles, as organisations, form the stable structure guiding many developments. Liability rules defining the characteristics of ownership are essential elements in economic development. Internalisation of external effects in market prices, as through systems of emissions taxes, would create incentives for a very different economic development than is taking place now, where the prime incentive is directed virtually only at private consumer satisfaction. Even if the consumer, as a citizen, values the environment highly, he has only a very limited option to act in this way in his buying behaviour, due to limited knowledge and due to the collective good nature of environmental quality. If he acts alone, his costs are high but virtually without effects on the environment, that is the prisoners' dilemma. Rules on disclosure of environmental performance, as an institution, could solve the information problem to some extent, but not the prisoners' dilemma as connected to collective goods.

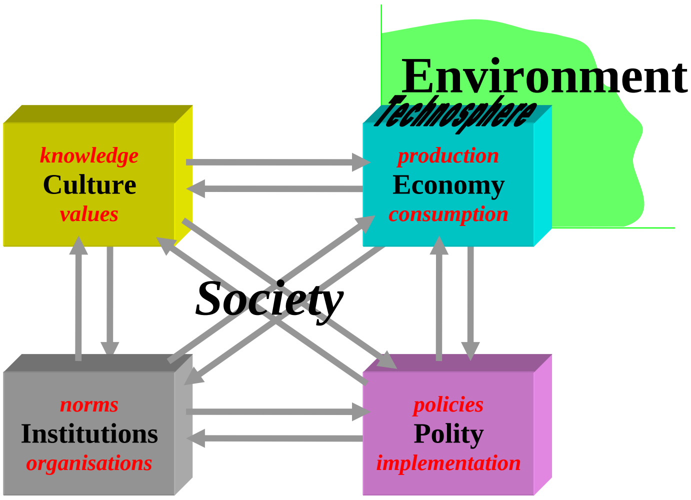


Figure 3.2
Relations between the elements of the social system

The dynamics of the system, hence also eco-innovations, result from internal developments in each of the four domains, but at the highest level of society from the interactions between the main domains. Each of the domains can directly influence any of the others, leading to twelve connection arrows. Dynamics may involve a cascade of relations. In the cultural system, economic theory indicated that collective goods are not created, or are destroyed, by markets which do not reflect these collective goods in their prices. This has led to an influence of Culture on Polity, with principles for policies like the polluter pays principle (now also part of the new sustainable development strategy). Next, this has led to a number of emission taxes as on SOx in Japan, which have been conducive to the development of efficient desulfurisation techniques, an influence of Polity on Culture, which, together with the direct incentive of the emission tax, has lead to the broad application of desulfurisation techniques in the Economy. This highest level of the framework helps to give perspective to dynamic reasoning, as without this overview one may easily select too partial mechanisms. When thinking about the effectiveness of policies, the broader relations may easily be forgotten. Subsidies to develop and implement specific environmental technologies in the market, for example, may be highly effective. From the broader systems perspective, they run counter to the institutionalised polluter pays principle, diminishing the incentives to reckon with effects of activities on public goods. Waiting till the subsidy comes, and till then letting things get worse, may become the more advantageous behaviour. The diffuse overall effect, difficult to quantify, might be more important than the specific environmental advantages created by the subsidy.

The overall systems perspective with twelve lines of influence, leads to a rich spectrum of possible relations if chains of influence between the main system domains are envisaged. For a three-step mechanism, there already are well over a thousand options. These are superimposed on the autonomous momentum in culture, economy, institutions and polity. There are several perspectives allowing for some simplification. From a long term perspective, for example, it is cultural developments which guide policies, help create institutions and lead to economic developments, as Mokyr emphasises. However, we are not socio-economic historians but scientists supporting the development of policy. The overall responsibility for corrections in the system lies with the polity, deciding on goals and means, with decisions and implementations. Politics can exert influence on specific economic activities directly, or the influence can be indirect through cultural and institutional mechanisms. Our focus here is not so much on developing empirical models in general but on routes along which public policy may enhance eco-innovation. Hence, for example, how developments in environmental quality and economic performance lead to policy, the *response* feedback loop in the DPS(I)R[5] scheme, is not as stake here; this study is part of that response, of Luhmann's *autopoiesis*.
So, from a policy perspective, we look at unidirectional causality here. We, as society, may wait for cultural and economic developments to produce eco-innovation autonomously, which might be the case in the long run.
Or the polity takes its role as the practical driver of the system, itself driven ultimately by cultural developments within the institutional framework of democracy.
So, without denying the basic influence of culture in societal development, in the analysis for eco-innovation indicators it is policy here which may change the drivers, through cultural mechanism as in guiding education and research, through

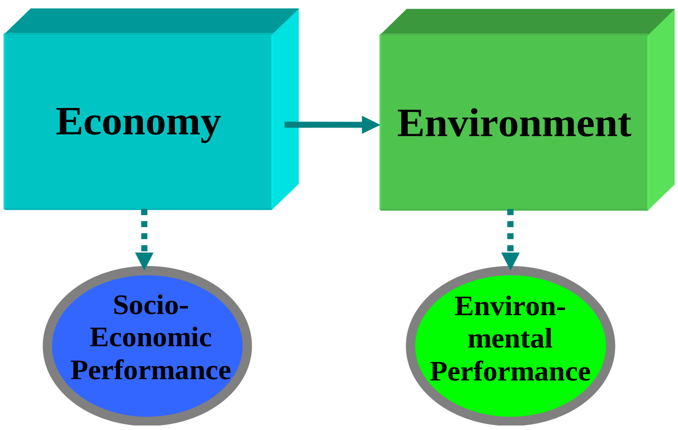


Figure 3.3 Performance based on the functioning of the economy with impact on the environment.

[5] Driving forces – Pressures – State (– Impacts) – Responses

institutional mechanisms, as in developing environmental liability rules and rules for EU wide research cooperation, and in enhancing funding of research as in expanding EU RTD funding and pressing national states to take similar measures. And of course public policy can influence economic activities directly, by building infrastructures, giving subsidies, developing complex sets of environmental requirements on activities, etc. From the policy perspective, specification of goals and means is an essential starting point. For eco-innovation, these goals are economic performance and environmental performance, as depicted in figure 3.3. The blocks indicate processes, while the ovals depict the characteristics in which the goals are framed. In modelling terms, in this context, the policies are the instrument variables, the relations within economy and environment involve intermediate variables and the performance criteria are the goal variables.

3.3 The full eco-innovation chain: From knowledge to sustainability

A recent survey of neo-Schumpeterian theories on innovation dynamics and economic growth (Hirooka 2006) distinguishes between stages in development of innovation and economic growth. These stages involve:
technology trajectory, covering science, invention, discovery and core technologies, as clusters
development trajectory, leading to specific installations and products
diffusion trajectory, with quantitative development of related markets.

It is at the diffusion trajectory that speeding up of economic growth takes place. The clusters of technologies reach the diffusion stage in linked blocks, as may lead to the Kondratiev and other cycles in economic development. The general structure of technology development is that there is a range of scientific developments which converges around a number of related technologies, starting, speeding up and then coming to saturation. With some delay, a similar process starts in terms of more specific possibly marketed technologies and products, the development trajectory, which also starts some lead activities, then a bandwagon effect, and then saturation. Finally, the actual market introduction follows, again with some lead entrepreneurs starting up the market, then a fast growth period, and then market saturation with a slow-down of growth. The empirical analysis of cases indicates that, for major developments, the time horizon typically involves a few decades for each of the trajectories, with some overlap in time between the trajectories. Overall duration from scientific development to market saturation is from a few decades up to a century, or even longer.

This approach is focused on innovation in general, not on eco-innovation, and it is partial in the sense that several mechanisms supporting and guiding growth are left out of account, such as trade-based innovation, see below.

The shift from innovation to eco-innovation requires the shift towards performance as followed here, which brings in the broader considerations on further factors or drivers to improved performance. The partiality thus showing has two angles. The broader framework indicates more complex embedding mechanisms for scientific and technological development, in terms of institutions and culture of society at large, but also new mechanisms which seemingly can work without involving technological development. The major example studied is on trade innovation.

As has been shown convincingly, it is not just technical implementation of innovation which drives progress, nor is it just the organisation of innovation processes in the firm which is essential also for dissemination, but also the capacity to specialise and create economies of scale which lower costs and increase competitiveness. This last process may take a substantial share in growth of total factor productivity, depending on the economic structure of the country involved (Butter & Wit, 2006: 15; Amable 2000: 413-5). For the Netherlands they indicate that in the last decades this factor has become the major one in productivity growth, while in other economies it is substantial and has been rising. Butter and Wit conclude that the Lisbon strategy should not only refer to R&D related growth but as much also to what they call *trade innovation*, as processes of outsourcing and off-shoring in supply chains, changing the quantitative roles of already existing technologies, and in the process of course also involving new technologies. As Edgerton (2006) has shown, many of the high growth successes of the twentieth century were based on technologies that had been around for decades and more.

What is the role of individual firms in the trajectories as described by Hirooka, and in the additional mechanisms like that of trade innovation, and in embedding mechanisms resulting from institutional change and cultural development?

The role of the firm is a quite limited one in the technology trajectory. With exceptions in a few larger firms, basic research has been funded and organised publicly, in universities and specialised research organisations. In the development trajectory, firms play a more important role but mostly not a dominant one. Smaller firms, supported by risk and profit seeking investors play a role, often making losses for the major part of their existence. If the technologies and products then start in niche markets and get into accelerated growth, the losses may be recovered, or new firms may step in. It is especially in this third trajectory, of diffusion, that the creativity in firms plays a central role in innovation and eco-innovation.
With the empirical role of the firm clear, the question on drivers of the process can come back again. What is driving what in the science-invention-innovation-growth trajectory, now including the added environmental aspects? We first indicate in a bit more detail the development of technology knowledge and then will come back to the routes along which policy may enhance the drivers for eco-innovation.

3.4 Technology knowledge distributed in organisations

The knowledge aspect in eco-innovation is spread out in the development process over several organisations, and within organisations over different knowledge owners. In most of these, the route to successful development is a mixture of top down planning, bottom up market reactions, from a larger perspective horizontal knowledge exchange and evolutionary processes of adaptation and selection. The interesting thing to note is that in the development process ultimately leading to successful eco-innovation and sustainability, there always is mix of drivers and incentives operant related to the four subsystems of society. The emergence of Microsoft in the Eighties is at the interplay of long standing research and education in which Microsoft did not play a role, as a cultural phenomenon; of hardware development leading to the affordable PC for mass production by IBM, an economic phenomenon; the development of protection of intellectual property rights in the US, an institutional phenomenon; and the splitting up of IBM by the American government (started by president Johnson) leading to its withdrawal from software development, a mixed policy and institutional phenomenon. Even in this exceptional case where a risk taking entrepreneur from the start has become the leading firm in the mature market, the knowledge involved was not developed by Microsoft, nor owned by Microsoft. The edge in the market made it the most profitable firm in the world, quite surely realising innovation on a larger scale than any firm before. Combining existing information has been its expertise, with technology knowledge playing a limited role. The entrepreneurial capacity is clearly of central importance in eco-innovation, but not the creation of specific technology knowledge by the firm itself. IBM has had a number of Nobel prize laureates for work based on its profits but not leading to its profits. The IBM PC department now is Chinese owned. Microsoft decided to spend not on science but on charity.

So, focussing on more narrow technology knowledge which surely is required, the next question is how this is being developed. It is not the R&D in firms, the main spending category of Microsoft, but the development of coherent clusters of technologies in the technology and development trajectories. A substantial amount of technology knowledge is developed in universities and specialised research institutes. The German Fraunhofer Institute is a well known example, but there are similar organisations in most countries. Currently, countries try to divert their research budgets into an R&D direction. This shift in research direction may be detrimental if not guided by as yet unavailable wisdom, as institutions of higher education and research do not have the adequate knowledge for market oriented development, and basic research is diminishing. R&D in research organisations is probably less effective than R&D in firms. Even if advantageous in the short run, which is possible at least incidentally, the long term effect might be the drying up of advances in basic science.

For the moment the conclusion is that in different stages of knowledge development the four main subsystems in society all are involved, with a prime focus on public organisations in the first stages of the knowledge developing process and of market knowledge in the later stages. How more basic research leaves the realm of science and moves into the realm of business knowledge is a central question, with insight and knowledge indicators for that process a priority.

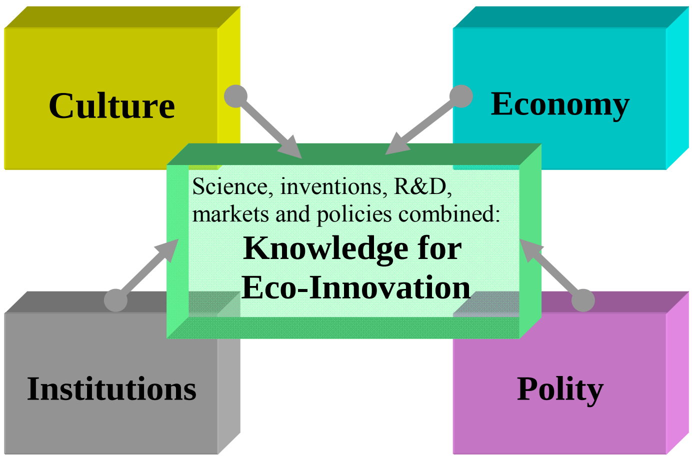


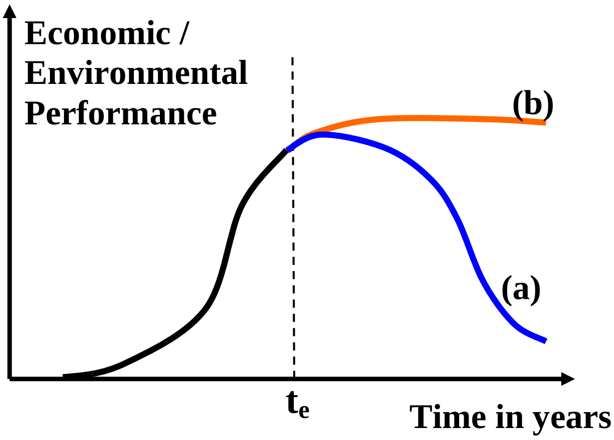
Figure 3.4. Knowledge for eco-innovation as created

Summarising, the technology knowledge for eco-innovation is part of this broader technology knowledge, with roots in science, in institutions and public policy and for later stages in firms. The growth of this knowledge from an environmental perspective, in formulating, financing, guiding and executing research and development activities, now is mainly lacking. There are some developments towards sustainability analysis of new technologies, including eco-efficiency analysis, but especially guidance toward sustainability in the earlier stages of knowledge development is lacking.

3.5 Technology knowledge, build-up in time

The time ranges involved in eco-innovation processes are substantial. Not only may current impacts on the environment have a delay up to several centuries, and major effects typically taking several decades to show, but also the adjustment of processes in society takes its time. Apart from decision making and effectuating of policies, the different stages in the build-up of knowledge take their time. Usually, the general scientific background of new developments may have taken place about a century ago. For example, early 20th century relativity theory and quantum theory still lead to new developments in technology. Also, when the step from science to operational technology has been made, the time to broad market effects and environmental consequences may be substantial. How can we get a rough estimation of the time frames involved? One way is to look at the large chunks in the main lines of economic growth. The Kondratiev cycles for long term economic growth last for fifty to sixty years, the most widely accepted cycle being the one starting at the end of the 19th century driven by the innovation clusters in transport, the car and the truck, and in electricity production, for distributed light and power. The drivers behind these developments, to be reflected in predictive indicators for eco-innovation, surely came well before, but also on the road. What might we expect from an ETS system with high induced costs for emissions, say 60€ per tonne of CO_2equivalent? What are the effects of 20% renewables required in the year 2020? What are the effects of environmental liability? What are the effects of better cross country communication lines for eco-innovation? Predictable price permit costs for emissions will start to have effects already on the relatively short notice of five to ten years, while boosting and redirecting research will typically lead to changes in a timeframe of thirty to fifty years. Would it be possible to systematically link indicators to such a time frame? In doing so, we should at least consider two basic forms of dynamics in effect curves. One gets started and then ebbs away (a) like patents in a certain technology domain, or a certain percentage of renewables in energy supply. The other gets started and then remains operant for a long time (b), like internalisation of environmental external effects in environmental policy instruments like the ETS.

Figure 3.5.1. Time to effective influence on eco-innovation performance, t_e.



When taking more specific clusters of technological development, empirical analysis becomes more convincing. Schumpeter (1942) postulates that economic development can be ascribed to innovation. Hirooka (2006) demonstrates this with a range of empirical evidence. He shows that an innovation consists of three trajectories:

- the technology trajectory;
- the development trajectory;
- the diffusion trajectory.

The technology trajectory refers to the development of the fundamental science and technologies. The development trajectory refers to the development of products that are based on this fundamental knowledge. The diffusion trajectory refers to market formation and diffusion in these markets of the products that have been developed. Hirooka shows that all three trajectories follow a non-linear, logistic path which results in the s-curves shown in Figure 3.4.

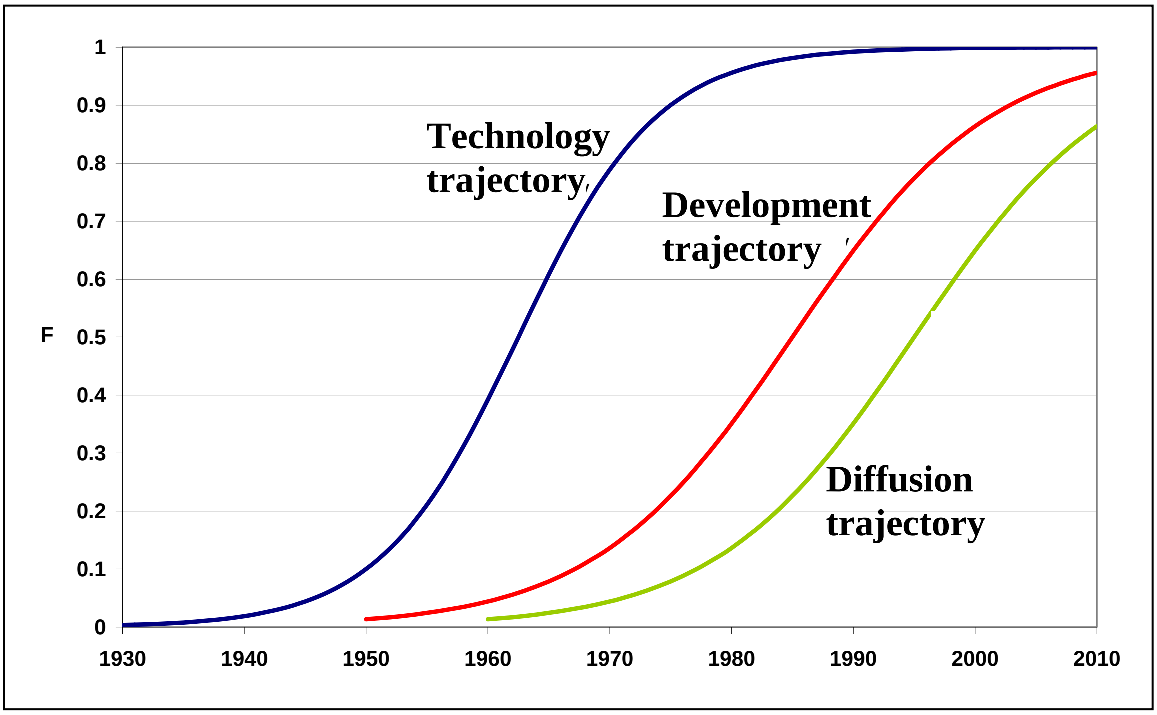


Figure 3.4. The three trajectories in innovation according to Hirooka (2006). Roughly based on the data for the *Innovation paradigm of electronics* (figure 7.3 in Hirooka 2006)

The empirical data in Table 3.1 shows that the two time lags involved between the three development stages is rather constant over a century. It shows that practical development based on developed principles takes around three decades and market diffusion a bit over a decade.

Table 3.1. A survey of time lags between the three trajectories at T=0.5 (based on Hirooka, 2006).

	Trajectories				
	Technology	Development		Diffusion	
	T=0.5	T=0.5	Time lag (year)	T=0.5	Time lag (year)
Synthetic dyestuffs	1845	1880	35	1893	13
Biotechnologies	1960	1993	33	2004	11
Electronics	1960	1986	26	1994	8
Computers	1943	1977	34	1989	12
ISDN	1969	1992	23	2003	11
Multimedia	1974	2002	28	2013	11

Hirooka delivers empirical evidence for a causal relation between the diffusion of clusters of innovations and the Kondratiev business cycles[6]. This is clear support of the postulate of Schumpeter. Hirooka also analyses the role of the institutional component of innovation. He shows that timely general government interventions were critical to the successful development of the electronics industry in Asian countries (specifically Japan).

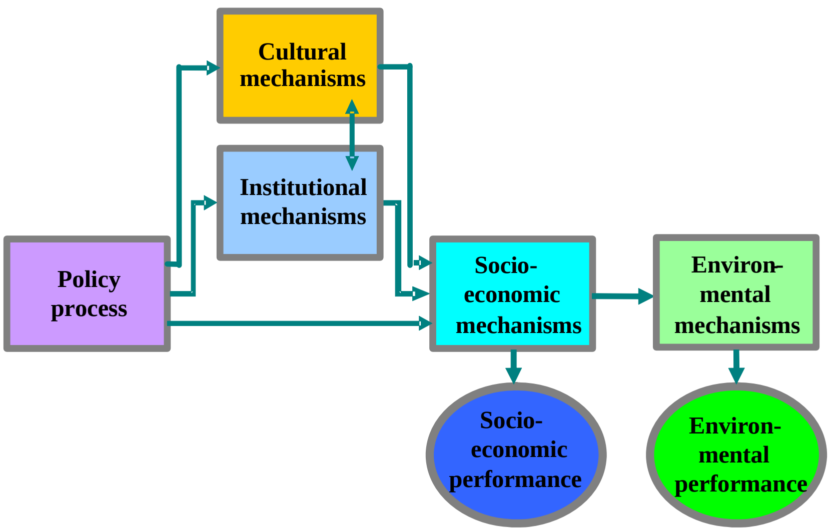
[6] Kondratiev business cycles (or waves) are regular, sinus wave like cycles in the modern world economy. The cycles consist of alternating periods between high sectoral growth and periods of slower growth. The average length of the cycle is fifty to sixty years. (e.g. Freeman & Louça 2001).

3.6 Filling in main causal chains from a policy perspective

Based on the conceptual causal framework, it is possible to group activities and developments systematically, and to indicate how these activities and developments relate to the ultimate eco-innovation performance of society, in principle. Even if such relations with ultimate performance cannot be quantified fully or partially, their interpretation as in terms of mechanisms involved *on the road to improved performance* may become better founded.

Let us see now how this general structure might be filled in. The reasoning goes backward, from performance to policies. The starting point is the economic and environmental performance, where economic performance may include a number of social variables like, at a macro level, employment and income distribution, hence *socio*-economic. The performance may refer to an expected future, but it is performance. The performance results from economic activities, as production and consumption, including public consumption and including the investments required for production, and including all waste management. The economy can be viewed from the main organisations involved, that is producers, including waste managers, and consumers. This view first connects to the micro level of activities, where new technologies are introduced and used, where some firms grow and others do not, and where obsolete firms and technologies disappear from the market. How these micro activities relate to the macro level performance is not self-evident. The growth of firms can be derived from their balance sheets. If they pushed a competitor out of business, or if their growth was based on some element of vertical integration, the overall effect on society is not so easy to see, and surely not from the firm's accounts. Similarly, the environmental performance may improve due to shifts in production structure, which are unavoidable in innovation and eco-innovation. Economic growth as such can be measured at an aggregate level only, because such shifts can be reckoned with in aggregations and because additional corrections can be executed. One tricky subject in establishing innovation is to correct for price changes. It is conceptually difficult to speak of constant prices if essentially new products, including services, are coming on the market. Even for products in a steady development stage like personal computers, the increase in memory and computing power is partly counteracted as by increased complexity of programmes. In analysing eco-innovation it therefore is essential to distinguish between the micro level 'where the real things happen', and the also very real meso and ultimately macro level, where outcomes may be quite different from singled out micro developments, not only in terms of economic growth and decoupling. These three levels of analysis will be subject of different mechanisms and hence different eco-innovation indicators.

Figure 3.5. Main causal mechanisms from a policy perspective only.



All three levels of the economy are influenced by the outside world, by the institutions, culture and polity of society. From a policy perspective, there is not only the option to influence the economy directly, as through the Porter type environmental shock therapy inducing change, but also indirectly, by policies focused at changes in culture and institutions. Unemployment may be structurally high due to high levels of social security payment, which decreases economic performance in terms of GDP but increases performance in terms of GDP per worker or per working hour. Reducing unemployment by institutional changes may foster growth but hardly lead to environmental improvements, hence not to eco-innovation. Such institutional mechanisms abound.

Starting at eco-innovation performance, there are several lines which here start at politics. The other lines as in figure 3.2 are left out of account in this reasoning. Figure 3.5 therefore should not be interpreted as meaning that the prime causality for performance lies with politics, but that in reasoning backward from performance to options of policy to change performance, several causal routes can be distinguished.

To further clarify this point, the feedback mechanisms from performance are indicated in figure 3.6. The interrelations between the systems may be direct, as when environmental deterioration due to climate change makes agriculture more difficult in warm and arid areas. There is one level of this feedback which deserves specific attention, feedback based on the insight not only in terms of actual mechanisms but also based on ***expected*** performance. This steering mechanism is based on insight, and has been worked out in the DPSIR scheme mentioned before. This scheme has been developed by the OECD for their work on environmental polices and reporting. It was also used in the CSD (Commission on Sustainable Development) set of indicators of sustainable development (second revised version 2007). It has also been used by the US Interagency Working Group on Sustainable Development Indicators. In an extended form – Driving Forces-Pressures-State-Impact-Responses – it is used by the EEA and Eurostat to help structure environmental statistics. It has proven useful for supporting analysis and for organising data. It is, however, a loose framework with no facilities for linking data, modelling etc., as is for example the case in a national accounting framework. If the feedback could be improved in "automatic" cultural and institutional mechanisms, such societal characteristics would be a major indicator for eco-innovation. Usually, responses by the polity more *ad hoc*, focussing at specific technologies and products like bioethanol for car transport.

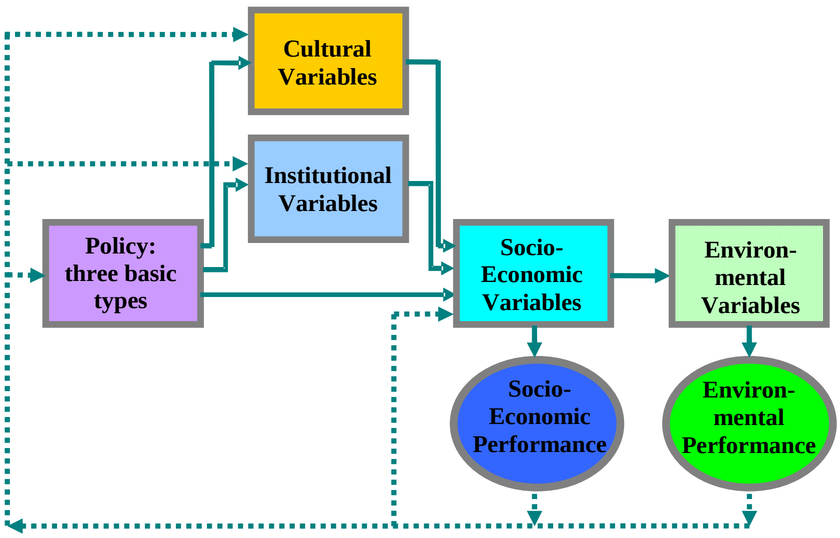


Figure 3.6. The Driving Forces-Pressure-State-(Impact-) Response (DPS(I)R) analytical framework. Response in dotted lines.

3.7 Potential eco-innovation

Ultimate performance being based on many mechanisms, circumstances and unforeseeable conditions, the predictive value of specific parameters will always be limited. The framework for analysis will to some extent remain a framework even if efforts for substantial improvement were successful. Putting scientific scrutiny to work would almost certainly lead to the notion that "we don't know". It is hard to believe however that anything goes, that it does not matter which direction we take in developing values and knowledge, creating institutions, and fostering technologies. How can we come around this dilemma? One way is to depict the potential of technologies, in a certain setting, for example according to their fitting in attractive or less attractive scenarios from a sustainability point of view. A hydrogen producing solar cell may fit in well into a low emission and low cost energy system, if the components of such a system would be designed from abundant materials and investment cost per kWh could be low. The same type of reasoning can be set up for fusion power, also optimising its functioning. The analysis of potentials, not for two technologies but for ranges of technologies, then could form a basis for selecting funding, of course provided the proposed research has high quality. Such scenarios based evaluation of potentials could be highly illuminating on the potential of different technologies. Of course, the Sterling engine drama may still repeat itself, the better option remaining the potentially better option forever. Therefore, the bet should never be on one technology. But agreed wisdom on potentials would be highly useful in directing research and technology development. Such analysis of potentials would be a key issue in evaluating the sustainability of technologies.

3.8 Proxy indicators

In actuality, it often is difficult to arrive at data which can be placed in the causal chains involved towards eco-innovation. For keeping the finger on the pulse, other variables might then be measured to indicate expected future performance, based on their being caused by instead of causing relevant but more difficult to measure variables. An example is the number of patents with an environmental aspect involved, clearly related to eco-innovation. This score may be indicative of knowledge development, as a dependent variable, while having limited causative effects towards eco-innovation performance. In specific instances such a patent may even be a hindrance in the application of the knowledge it is based on, as has been shown in many cases, especially if the patent is held by smaller firms or individuals who are not capable to do the R&D and market development involved in practical implementation of the technology. So the first most basic grouping of indicators for improved economic and environmental performance is in being causative, or in being statistically indicative only, that is in predictive indicators, and in proxy indicators. The predictive indicators can further be grouped according to their place in the main causal chains, as related to economic activities in production and consumption; to cultural and to institutional mechanisms shaping these; and to policies, either directly impacting the economy or indirectly shaping future performance through cultural and institutional mechanisms.

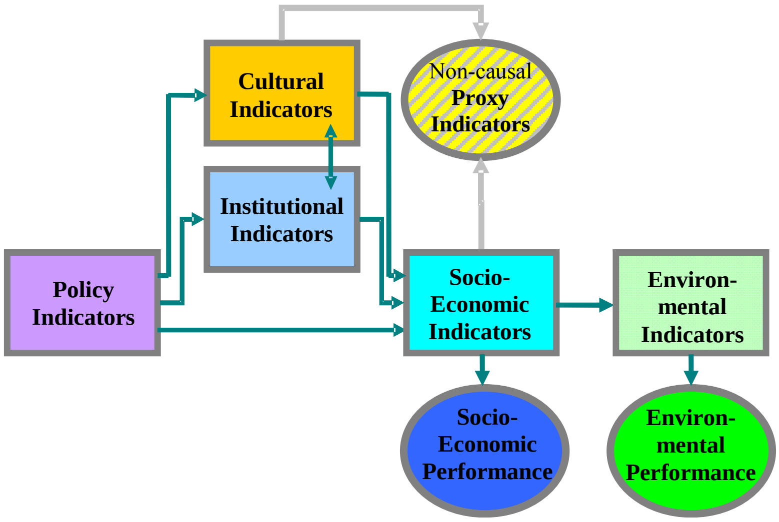


Figure 3.7. Main groups of indicators for eco-innovation performance.

4 Typology of eco-innovation: indicators grouped in causal chains

4.1 From innovation indicators to eco-innovation indicators?

Adding the environment component to innovation indicators might seem a straightforward solution. However, this is not easily done. Let us take a few examples at a macro level in the economy, closest to where eco-innovation performance can be measured see table 4.1. Neither of these innovation indicators can be transformed by some addition into eco-innovation indicators. These economic innovation oriented indicators would have to be transformed by adding some environmental aspect, or similar environmental indicators would have to be developed independently. Adding the qualification 'environmental' or eco-innovative seems easy, but is hardly possible in practice. A few options will be investigated.

Table 4.1 Some macro level indicators for innovation from the European Innovation Scoreboard

OUTPUT – Intellectual property	OUTPUT – Applications
- EPO/USPTO patents per million population - Patents per million population - Triadic patent families per million population - New trademarks per million population - New designs per million population	- Employment in high-tech services (% of total workforce) - Exports of high technology products as a share of total exports - Sales of new-to-market products (% of total turnover) - Sales of new-to-firm not new-to-market products (% of total turnover) - Employment in medium-high and high-tech manufacturing (% of total workforce)

4.2 Filling in main groups of indicators

There is substantial difficulty in identifying eco-innovation "in the chain" due to the complexity of the dynamic processes involved. This complexity refers to social processes and interrelated decision making procedures, to lack of specification on what factors contribute to eco-innovation; and to the long time frames involved. To reduce complexity, we have defined eco-innovation in terms of the combined improvement of economic welfare and environmental performance. This definition may be linked to absolute sustainability, as absolute improvement of environmental quality, or reduction of negative environmental interventions, combined with economic growth. Or it may be defined as *relative sustainability,* that is a reduction of environmental stress per unit of economic welfare lower than the rate of economic growth. Both economic welfare and environmental quality and performance are to be specified to give empirical content to the concept. This specification will be detailed later in this paper. With these macro-level anchor points established, we can reason backwards to the processes involved in environment and society, and how these may be influenced by policies, using the simplified causal framework as developed. Based on the causalities involved operant causes can be defined as indicators of the ultimate eco-innovation performance, see figure 4.2 below. Thus specifying eco-innovation indicators in the chain allows for their empirical specification, as predictors of later actual performance on the one hand, and as potential subjects of direct or indirect eco-innovation policies on the other.

However, before establishing causal linkages, two related problems are to be investigated in some more detail: The time frames involved and the level of aggregation in what the indicators refer to. The time frames involved may be extremely long, even without involving institutional and cultural mechanisms. Let us take two undisputed examples of brilliant technological ideas. Both these new technologies depended heavily on scientific developments taking place at the time. One, from 1962, is the ***Josephson junction*** (Josephson 1974). This technology may ultimately help develop quantum computers foreseen to develop by 2050, and then will help boost the IT sector, like transistors did before. A still longer time frame is involved in the ***Sterling engine***, named after Robert Sterling who patented an improved design in 1816. Many have spent their fortune on its commercial development, since this engine not only had a substantially higher energy efficiency than the steam engines of the time. It also has a higher energy efficiency than current Otto or Diesel motors, as it can work with much lower differences in temperature. The first commercial applications have started in recent years, at a small scale only, after nearly two centuries of development. These examples show that at a detailed level of specific technologies, the long time path leads to myriads of interrelated events which eventually prove the new technology to be part of an eco-innovative development, or not. The predictive value of indicators at a micro level of technology ideas, or even technical principles, is difficult to establish. Hardly ever is there a single chain of events from idea, to discovery, to technical principle, to further research on mechanisms, to development and possible patenting, to prototype, and then to market introduction, to learning curves and further market penetration, and then finally to mature market growth and final saturation. At the same time, the causality of eco-innovation resides at this micro level of specific technologies and products in specific markets, with their environmental interventions resulting from the activities involved. These activities with their direct interventions sum up to society's welfare and to the total of society's environmental interventions. Environmental quality may follow even later, as many mechanisms like climate change and health effects take years, to decades and sometimes even centuries to materialise. We may be able to measure the development of biodiversity. It will be extremely difficult however to translate this backward to detrimental and to mitigating factors or activities, let alone to policies having had an influence on these. With the caveats on timeframes and complexities in mind, let us now look at what is possible in terms of translating back to causative factors, which then serve as predictive indicators for eco-innovation.

4.3 Specifying the unit of analysis

Going backwards in the causal chains in eco-innovation, we first are in the realm of specific technologies in or close to their operation in markets. Can we analyse products, product systems, firms, cradle-to-gate systems? All have their problems. Let us take an example of how broad to define a product system. The new variant considered, and applied already, looks bad on first sight, not eco-innovation but double deterioration. Adding 230 Volts plugs in a train is bad for environmental performance of the train and it increases costs. However, it makes professional travellers shift from plane to train. This broader view, not necessarily involving any rebound mechanism, seems much more relevant. This is a nice example of where product LCA/LCCs lose their usefulness and a higher systems level of analysis is required, to show how ultimately societal performance may be influenced.

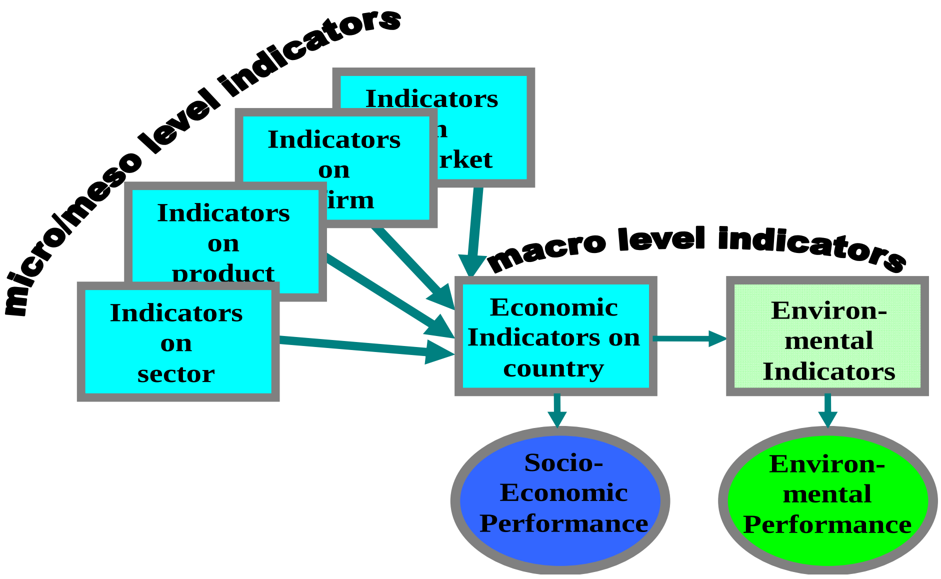


Figure 4.1. Performance indicators in the economy at macro, meso and micro level.

4.4 Measuring performance, directly and indirectly

At the boundary between economy and environment, directly measuring the development of performance is possible at a micro level only. Real information on performance always is at that micro level. Any economic activity in society has a value added, or a consumer surplus realised, and it has a number of direct environmental interventions. There is a base level of each activity which may be recorded, or measured in a more indirect way. Electricity production from coal at a certain site and period of time has its value added and it has its direct environmental interventions. The transport of coal from Australia to Europe also has its value added over a certain period of time and it has its environmental interventions. This is the basic building blocks we have for measuring economic and environmental performance at a certain moment, and for measuring changes therein, as in terms of eco-innovation. However, the units of activities involved are small and extremely numerous and do not link to decision levels. In LCA, the lowest level of combined economic and environmental data is called the ***unit process***. In practice measurement of such basic activities is done either by statistical means, assuming that there are homogeneous populations to draw cases from. Often measurement is more indirect, based on some modelling. Truck driving, for example, is measured in environmental terms based on truck samples with tests based on typical driving performance; with the amounts driven based on diesel/petrol use and consumption characteristics; and economic data on truck transport based on very different sources again. If measured directly or indirectly with some limited modelling involved, this basic level of activities is where real knowledge on economic and environmental performance resides. Though efforts to improve on these base data are increasing, see table 4.2, the lack of micro level recording seems the most basic bottleneck in establishing economic and environmental performance in time, as the basis for actual measurement of eco-innovation performance.

Table 4.2. Some data sources for environmental information based on EU rule making

- NAMEA (National Accounting Matrix Including Environmental Accounts)
- EPER (European Pollutant Emission Register)
- EMEP/Corinair (European Monitoring and Evaluation Program)
- UNFCCC/IPCC (United Nations Framework Convention on Climate Change Greenhouse Gas Inventory Data)
- GAINS (Greenhouse Gas and Air pollution Interactions and Synergies)
- RAINS (Regional Air Pollution Information and Simulation)
- PRTR (National Pollutant Release and Transfer Registers
- EEA transboundary emission collection, combining EMEP and UNFCC
- WasteBase (European Topic Centre on Resources and Waste management)

One basic feature of this data level, if adequately set up, is that the sum total of all micro activities in a year can be aggregated by straightforward addition into the totals for society, in terms of national income, GDP, total consumption, final demand, etc., at the economic side, and as totals of environmental interventions at the environmental side[7]. The micro-macro link does not pose any fundamental problems; it “just” is a matter of data and adding up. The causes for the performance in one year are complex and multiple and spread out in time. The effects of environmental interventions, as pressures, in one year on the environmental quality resulting are complex and multiple and spread out in time. This level of basic activities and their direct environmental interventions is the one and only switch point where economic and environmental aspects of reality are more or less unequivocally linked.

Statistical offices may improve substantially in the production of time series for economic and environmental performance of activities in production and consumption, as a basis for establishing eco-innovation at all levels in society.

Related to such basic data, there are two ways to arrive at more meaningful units, by making relevant aggregates of economic activities and by going backwards in the causal chains involved. Aggregation of activities may focus on their function, for example as the value of consumption and as environmental interventions generated in that consumption directly, and then also indirectly, covering the production and waste management activities required. Conceptually, there are the usual problems of relating consumer prices to welfare, the domain ranging from welfare economics to the study of happiness, and questions on how to link consumption to specific production activities, as is on the agenda in the realm of LCA, see some remarks below. What is clear is that the sum total of all activities in a year with their direct environmental interventions, corresponds to total consumption plus investments in that

[7] Possibly in a spatial configuration. This adds another layer of complexity which we will not go into here.

year and all environmental interventions in that year. Whatever ways of linking into further aggregates may be useful; the only real data are at this detailed level of activities. They feed into more aggregate data types like totals for product groups, or for sectors, like in NAMEAs. The prime sources used relate to activities of installations, firms and public and private consumers, linked by the flows of products between them. This is the hard level of analysis, at the boundary where physical activities and their societal meaning still constitute two sides of the same coin.

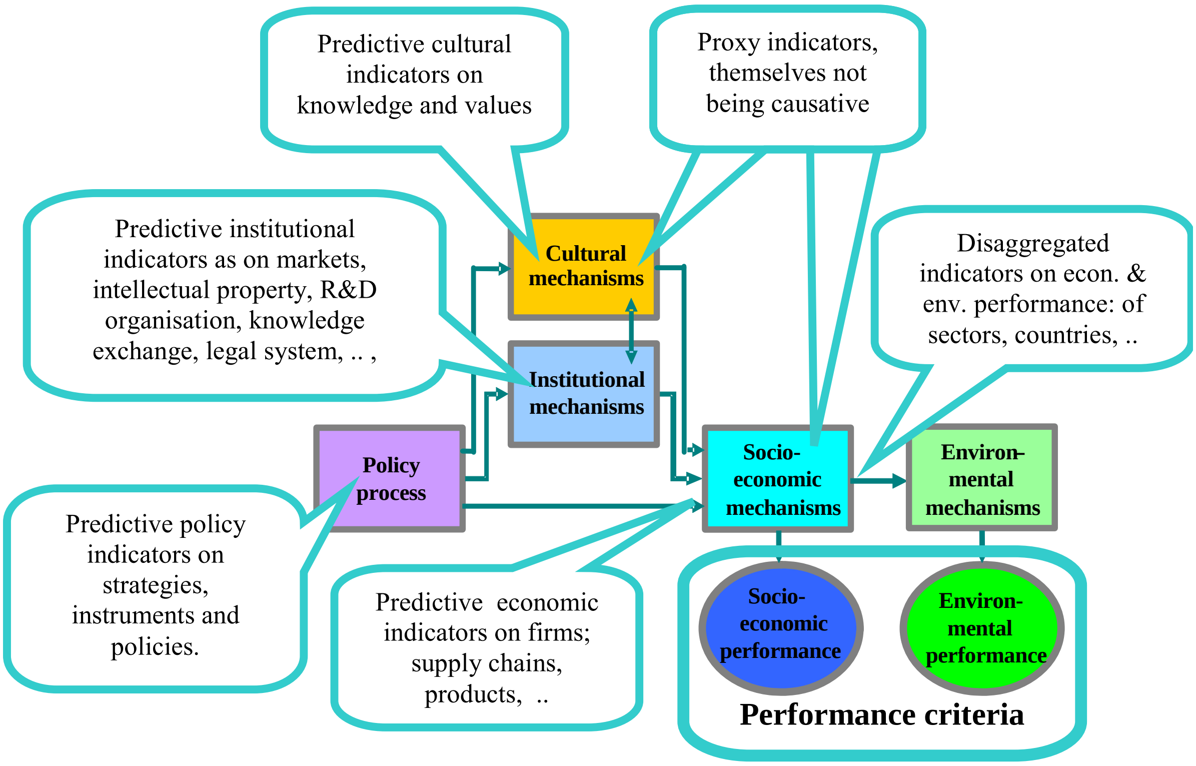
> ***Whatever may be possible further up in causal chains, the basic knowledge on eco-innovation in society resides at this micro level. Undoubtedly, without adequate measurement of indicators here, as detailed time series, the upstream indicators may hang in the air, as beliefs without historical foundation.***

It also is at this level that relevant aggregates can be formed, where performance can be measured still quite directly. Obvious units are products, firms and sectors. Many innovations are embodied in products. As is clear with the emission free car, which runs on electricity, it is not the product as such but the sum total of activities related to its functionality which are to be accounted for. The product is to be approached from a life cycle point of view. All problems of LCA apply, as in allocation and the time horizons involved in production processes[8]. Some aspects of eco-innovation can be measured at this level, as the economic and environmental performance of products like electric lights, electricity and coating systems. For firms the performance may take a slightly different angle, reckoning with their combined economic and environmental performance, measured as their value added and direct environmental impacts. For a fuller picture of their impacts, the performance in their chains of supply and demand may be taken into account, moving towards an LCA-type of analysis. The interesting thing about firms is that on the one hand their performance can be measured relatively directly, while on the other hand firms constitute the organisations in which a main part of innovation takes place.

The aggregate level of analysis may differ in its spatial and time extensions. It is possible to add up activities over a year, in a region, a country or the EU. However, the boundaries to functional analysis are unclear in a globalising world. Products and firms span the world. Sectors, as additions of specific types of activities may be defined at a country level, but their interrelations as in input-output analysis cover the world. Also the time frame of aggregates other than additions over regions and time will hardly refer to one time period. Supply of firms and upstream activities for products precede the activity in the firm and the use of the product. Also causative factors for improved eco-innovation by necessity precede it in time. Market diffusion may take years, after market introduction and after prototype development and after the knowledge and ideas were created leading to the prototype.

[8] The truck to transport the iron ore, which was used to make the steel for the furnace construction of the steel maker which produced the steel for your beer can will have been horse drawn, for some of the steel in the can.

Figure 4.2. Predictive indicators, main groupings.



With the entities and units to measure specified, and with the basic economic and environmental variables to measure well established, the eco-innovation performance is a matter of consistently measuring in time. It is the dynamic performance which is to be established through measurement.

Only if the performance measurement in time series is there, the derived predictive indicators can receive a firm foundation. Only on the basis of empirical information may such derived indicators be corroborated. Without this empirical analysis, it is not possible to make any statements on validity, reliability, uncertainty of whatever measure of quality one wants to use.

Some improvements in basic data gathering are taking place, at the aggregate level. ESA95 and increasingly more valuable NAMEA data are coming up, but not necessarily based on better basic data. The transformation methods are systematised and improved. This also holds for larger data base projects like the EIPRO project and the ongoing EXIOPOL project.

With these caveats in mind, we will now proceed to the detailed specification of derived predictive indicators, in the next chapter.

5 Eco-innovation indicators detailed

Within each main grouping of predictive indicators, several domains and options for indicator specification exist. For example, environmental indicators can be placed at several places along the empirical causal chains involved, and may be integrated into overall scores using different methods for aggregation. These aggregated environmental indicators may easily be corrupted if they are not consistently developed. Climate changing emissions change the climate, which in turn has substantial consequences on biodiversity. Putting climate impact (as GWP score) and biodiversity in the same list of indicators to be aggregated cannot lead to a consistent outcome any more, as the GWP score partly determines the biodiversity score. Arriving at mutually independent indicators, at that level in the causal chains, is essential for transparent analysis of eco-innovation, and for eco-efficiency and more generally sustainability analysis as well.

A few choices have been made here on where to place activities in the framework. For example, knowledge development, not yet being applied enough to be Research & Development, is placed at the knowledge part of cultural development, regardless of whether it is based in firms, in public bodies or in research organisations, and disregarding the funding basis.

The format for filling in the indicators sections follows a similar pattern. First a survey of indicators is given, next, their place in causal chains is specified more precisely in the framework as developed, and finally a first evaluation as to usefulness and measurability is made.

5.1 Economic performance of activities

Eco-innovation is defined in this project as a change in economic activity that delivers enhanced economic and environmental performance. One major challenge of measuring eco-innovation is developing economic and environmental measures which are compatible, i.e. the economic and environmental components of eco-innovation must relate to the same activity. This section discusses and suggests indicators of improved economic performance.

The purpose of economic activity is to deliver functionalities that meet human needs and wants at a cost consumers (which may be individuals or businesses) are prepared to pay. In Figure 5.1 the functionalities are delivered by processes and products (including services) produced by firms, which may be classified as belonging to economic sectors, and which have supply chains consisting of firms which may belong to different sectors. The sectors will belong to a national economy.

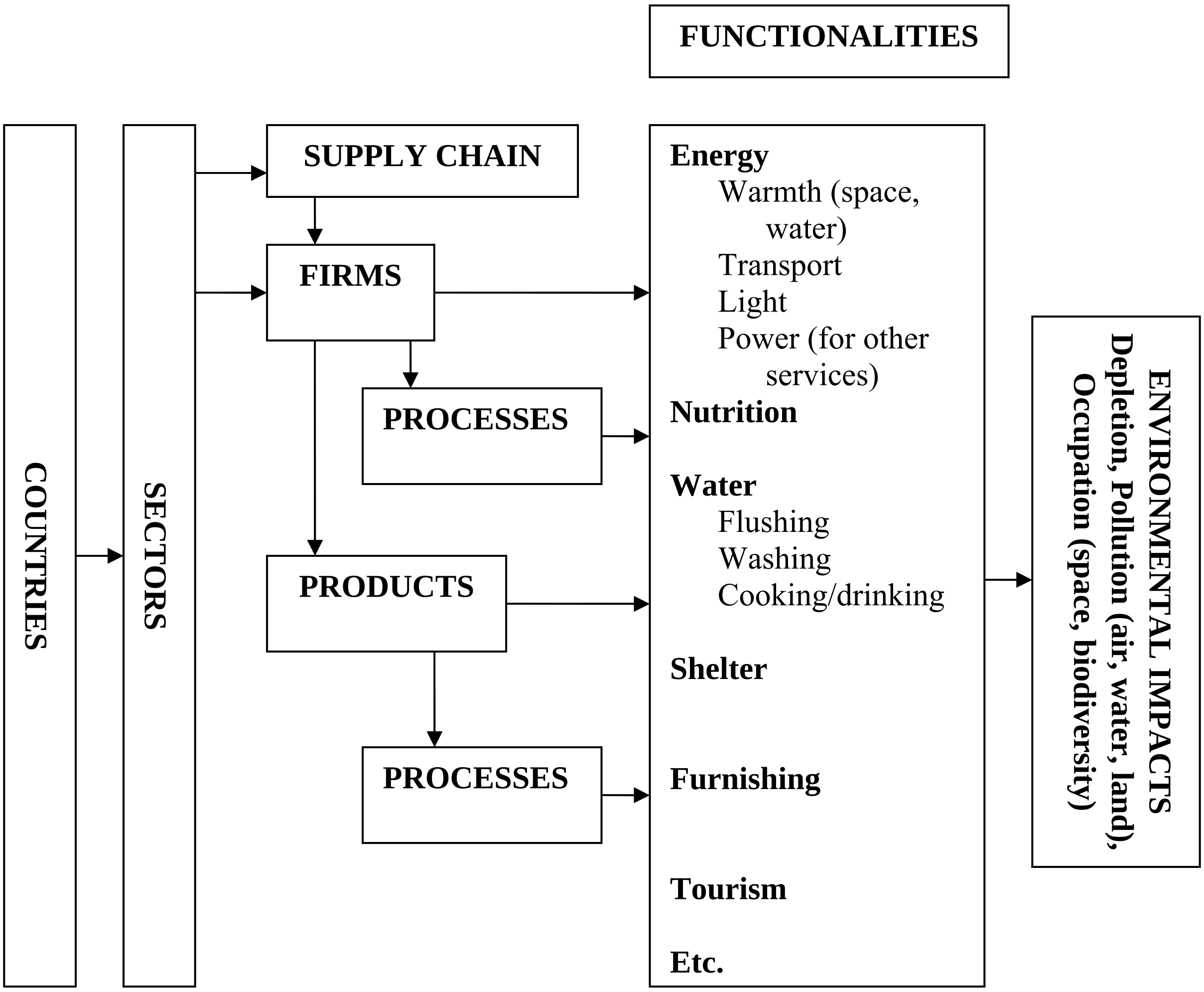


Figure 5.1: The Process of Delivery of Economic Functionality

There are many aspects of this process that can be measured to determine economic performance. Output measures of economic performance such as GDP and growth in GDP at the national level or value added at the firm level, are obvious and well developed measures of economic performance. However, in measuring innovation or eco-innovation we are interested in more than just economic performance in terms of the quantity of economic activity – we want to consider the quality or functionality of the economic activity as well.

Thought about in this way the most basic measure of improved economic performance for products and processes is therefore one which can show that greater functionality or output is being delivered for the same cost, or the same functionality or output is being delivered for reduced cost.

The focus on functionality requires a bottom-up assessment based on measurement at the micro level of products, processes and services and can be conducted looking at either consumption or production.

On the consumption side the basic measure is "Functionality/Cost", where functionality may be measured in a wide variety of different ways, depending on the product or process under consideration. For example, in the case of transport, the unit of functionality may be (vehicle-km), and the cost to the owner will be the life-cycle cost of acquiring, operating and disposing of the vehicle over the period of ownership.

It should be borne in mind that many products have multiple functionalities, so that in comparing the functionalities of different products, one must be careful to compare like with like. For example, cars have many functionalities apart from the delivery of (vehicle-km) (an obvious one is conferring status, or making a social statement), so that it is important when comparing products like cars that they are as similar as possible in terms of other functionalities. The 'eco-innovative product or process' will then be one which delivers cheaper functionality and improves environmental performance.

Each product will have at least one function and given the number of products and services available there are an almost unlimited number of functionality/cost measures that could be derived (given the availability of data). Given the number of possibilities selection of a representative range of measures reflecting key aspects of consumption is likely to be required to make the task manageable and provide useful indicators for policy-makers working in the area of eco-innovation.

Products and processes are produced or operated by firms, and it is therefore also of interest to measure the economic performance of firms. This is likely to focus on measures of production rather than consumption, although firms may be interested in the consumption performance of their products, particularly if this is a factor the final consumer consider important in choosing whether or not to buy a particular product. Clearly a firm may have different products and processes, delivering different functionalities, so a complete view of its performance will require some aggregation across these different outputs. Normally this aggregate is expressed in money terms, so that measures of a firm's performance will often be some measure of economic (money) output compared with economic inputs (e.g. value added, profitability, labour productivity), sometimes compared with other firms (e.g. market share). The 'eco-innovative firm' will then be one which improves its economic performance while also improving its environmental performance.

Further indicators may be added which give some idea of the 'drivers' of eco-innovation at work in the firm (e.g. management commitment/training, in-house research) or in corporate innovation networks, or of the environmental performance of the firm's supply chain, especially if the firm concerned is large enough to be able to influence this. On the other hand, to compute the 'economic performance' of a supply chain is mostly impossible in practice, unless sales or value added are considered to be sufficiently good indicators. As one moves away from measures related to specific products, services or processes, the ability to assess improved functionality/cost measures becomes more difficult. The traditionally measured economic performance indicators on the firm level like sales, profitability, and other measures are mostly not related to functions but to products, production plants or a firm as a whole and thus difficult to transform to the function unit under analysis. Furthermore, these indicators are often, but not necessarily always, related to innovative or eco-innovative activities in the firm, sector, region, or nation. Nevertheless, on the firm level itself it is often possible to find proxies or to make rough calculations to compare different products or services which fulfil a certain function.

Firms are conventionally grouped into economic sectors, obviously introducing a higher level of aggregation. Many of the measures of sectoral economic performance are the same as for firms and will consist of an aggregate, or average, of the sectors' firms' performance. And then sectors are aggregated into national economic statistics.

Time and Eco-innovation

One critical issue in the consideration of economic performance is time. Time affects whether an activity can be considered an eco-innovation. Economies are inherently dynamic, and the consideration of the timescale will be crucially important to a judgement as to whether or not economic performance has improved. Many new technologies, and new firms, are not economically profitable to begin with (i.e. they deliver lower functionality per unit cost than incumbents). In general this is not different between conventional innovations and eco-innovations. There is always a risk in investment that it will not pay off, and different investments pay off, when they do, over different periods of time. In any evaluation of economic (as well as environmental) performance, the timescale over which the evaluation has been conducted should therefore be made explicit.

An example may be renewable energy, and the 'feed-in' tariffs which a number of countries have introduced to promote it. At present most such energy is not economically competitive (i.e. it is more expensive per kWh delivered than a non-renewable alternative). That is why it needs the subsidy, as for example a feed-in tariff. In the short term, therefore, it does not deliver enhanced economic performance and therefore, despite its enhanced environmental performance, it is not an eco-innovation in current market terms, as the term is used here. If, using some welfare function, a value may be given to environmental effects, the outcome could still be an innovation, the light blue green surface in figure 2.1. However, this situation may change as through learning processes induced by this non-eco-innovative market introduction. Mass deployment of renewable energy technologies as through feed-in tariffs may engender learning by doing or economies of scale, reducing unit costs. This has already happened to such an extent with wind power that onshore wind turbines in the best sites are now competitive with other means of generation. Also the costs of competing options may rise, like through a price rise of fossil fuels; the introduction of CO_2-emissions trading and taxes, etc. Both developments have taken place in the last couple of years. Other countries may decide to also deploy these technologies, generating export markets with further decreasing unit cost. All these developments are likely to take time. Provided that economic performance is computed over that time, it may well be that a new technology which in the short term was an economic cost actually turns out to deliver enhanced economic performance, and therefore to be an eco-innovation (provided that it improved environmental performance as well).

For any product or process which delivers improved environmental performance, there are therefore three possibilities:

- It immediately delivers improved economic performance as well (e.g. compact fluorescent light bulbs, some home insulation), in which case it is unequivocally an eco-innovation
- It does not deliver immediately improved economic performance, in which case it is only a *potential* eco-innovation which
  - Becomes an actual eco-innovation when its economic performance improves and it is widely taken up (a process which may take decades or even centuries)
  - Never becomes an eco-innovation because its economic performance never improves adequately

Eco-innovation and the impact of the boundary of analysis

The boundary within which economic performance is considered is also a relevant consideration. If the boundary of the calculation of 'economic performance' is just those businesses, clearly the economic performance picture will be positive for them, but less so for the activities pressed out of the subsidized markets, and diffusely pressed out of spending on

totally different items. For example, for the producers of renewable energy it may result in highly profitable businesses. In a short term macro-economic view the feed-tariff is currently a net economic cost for the German economy as a whole because the energy produced is more expensive than non-renewable energy. Taking a broader and more long-term macro-economic perspective, further effects like the creation of a large number of jobs in structurally weak regions and the development of an increasingly internationally competitive industry may constitute further reasons for government support (infant industry support). Such effect mechanisms then would have to be taken into account systematically when making comparisons between options for eco-innovation.
Another example relates to the market boundary being considered. Many markets are highly imperfect and exhibit market failures, not only in respect of environmental impacts. An economic activity may be highly successful in market terms (i.e. deliver a certain functionality at low cost, and result in profitable businesses), but generate environmental costs which actually exceed the market benefits, using some trade-off value between these magnitudes. Similarly, an environmentally preferable activity may seem to be uneconomic in market terms, but actually be socially desirable because of the environmental benefits it delivers. It is obviously important that analysis takes the full picture (all the market and external costs and benefits) into account, but because of uncertainties in the monetary valuation of external costs and benefits it may not be possible to say definitively whether they change the picture as revealed by markets, corrected for taxes and subsidies or not, and corrected for deviations from ideal perfect competition or not.

This project has decided to define innovation, and eco-innovation, in terms of the delivery of net market benefits. Because of the existence of market failures like environmental externalities, this does NOT mean that if an environmentally preferable technology (like renewable energy technology) is not an eco-innovation over a particular timescale that it is socially undesirable. For example, it may well be that, because of their reduction in carbon emissions, renewable energy technologies are highly desirable socially, even if at present they are not eco-innovations (though over time they may become so, as discussed above). Based on this broader evaluation, society may chose to go for lower economic performance and a higher environmental performance, violating either the Lisbon or the Gothenburg objectives.

To conclude, eco-innovations are always socially desirable (because they are win-win). Environmental improvements that are not eco-innovations *may* be socially desirable in the short term, if the social judgement is that the environmental benefit outweighs the economic cost, and may become eco-innovations in the future. And, of course, innovations (improvements in economic performance) that damage the environment may be socially undesirable if that damage is greater than the economic benefit.

5.1.1 Economic indicators for performance measurement of eco-innovation

The discussion above indicates some significant challenges in developing the range of indicators this project is interested in. However, simple economic aggregates are available and can be used to reveal the quantity of economic activity. Less easy is the assessment of the functionality delivered by that economic activity: assessment of both product functionality and total life cycle costs are not simple tasks. Below we collate the measures that we consider relevant to measurement of economic performance and which may be used as part of constructed eco-innovation performance indictors.

Approaches to measuring economic performance

There are a wide range of options for measuring economic performance. For example:

1. Mainstream economic performance data at micro, meso and macro levels - eg firm and national accounts.
2. Alternative measures of economic performance with a focus on economic value – eg measures of shareholder value, Economic Value Added (EVA).
3. Alternative measures of economic performance with environmental and/or sustainability focus - eg ISEW, GPI, HDI etc.
4. Welfare beyond economic welfare – eg well-being and happiness.

We are interested in the indicators and data collected for measures in 1. While the objective of economic activity may be to understand whether increased levels of welfare are being created it would unduly complicate an already complex task to add this dimension into our considerations on eco-innovation. We are also excluding measures that correct mainstream economic measures for unaccounted environmental impacts as eco-innovation should be based on independent economic and environmental measures.

Where do we want to measure economic performance?

Economic performance can be measured at three main levels: micro, meso and macro and within these measurements could focus on the following:

- **Micro**: firm, individual, household, product, service, function, need

- **Meso**: sector, supply chain, region, product system/service system, infrastructures (eg transport, energy, communications, water), some firms (depending on size, eg perhaps trans-national firms)

- **Macro**: economy-wide: nation, economic blocks, global

There is an assumed flow of data from the micro level upwards to meso and macro. Measures. available at the micro level are therefore discussed first and this is followed by discussion of meso and macro levels.

Measuring economic performance at the micro level

Firms

Neely (2002) distinguishes three broad approaches to business performance measurement. These three approaches are:

1. Accounting perspective – e.g. sales, profit, value added, number of employees,
2. Marketing perspective – e.g. unit market share; percentage sales from new products; number of new product launches; desirable output per unit of output
3. Operations perspective – e.g. performance measurement frameworks such as the balanced scorecard, the performance prism and alternative approaches such as activity-based costing and shareholder value analysis.

Most of these measures are not or do not all result in direct economic output performance measures, although they are intended to assist management in adding economic value by firms. However, they are useful in thinking about how the economic performance of a firm can be measured and may also be relevant in assessing levels of innovation or eco-innovation.

The first approach includes direct measures of economic output performance. The second reveals performance that is likely to be related with output performance, whereas the second and third would seem to be of more relevance to the development of predictive indicators.

The third approach may be worth considering as a means of capturing the range of factors that need to be addressed to stimulate eco-innovation. This would be on the basis that if eco-innovation requires multiple enabling factors to be present then multiple indicators, in the form of scorecards or similar approaches, or a set of indicators related to different stages of innovation processes may be required to establish whether these enabling factors are present.

The overarching goal of eco-innovation for firms should be to create the improved eco-efficiency required for eco-innovation. Eco-efficiency impacts (like e.g. improved corporate and national competitiveness through greener products) are a result of outcomes (e.g. greener products dominating the market) and outputs (e.g. more greener products) which in turn are created or caused by processes (e.g. successful eco-innovation processes and management as well as successful marketing of the innovative green products) which require inputs (e.g. knowledge, manpower, capital). The endpoint of measurement is ultimately output because impacts and outcomes are often either assumed on basis of output or because they are difficult to measure.

Measures of economic performance within firms: Output measures

1. Production Output/Sales/Income/Revenue/Market share

Measured by financial value, weight/volume, or units sold in a specified time period.

- Total production output of the firm or for individual product streams or services

The data to calculate these basic indicators of technical and economic performance is mostly provided by management accounting and production information systems in the firm. They are proxis of the targeted economic success and important indicators to show whether a production process has been successfully established for mass production (production output), whether the firm has established an infrastructure and believes in market demand (production output and sales), whether it has been accepted by the market (income and revenue) and whether it is competitive and a market success (revenue and market share).

2. Value Added

Value of outputs minus value of inputs in a specified time period

- Total value added created by the firm or with a product/service

Value added provides information about the economic value a firm could create with its activities or with a product, service, etc. Value added informs about the economic value created for the totality of a large variety of stakeholders (like employees, government, shareholders, etc.) of the firm. It therefore represents the direct contribution of a firm to the economic performance of a region or nation. Most accounting systems provide the information or can be developed to create the necessary information for the firm as a whole. However, this indicator is often hard to measure for products and services because most corporate accounting systems do not necessarily support the calculation for a particular product or service.

3. Profit

In general profit is defined as the difference between sales price and the costs of manufacturing the product or service. However, profit is often a fuzzy term, because different definitions exist like accounting profit, economic profit, gross profit, net profit after tax, operating profit, etc. The question which profitability figure should be used depends on the sector, (national or international) accounting regulations, firm culture and tradition, etc. Furthermore, the best profitability figure depends very much on the context and goal for which the information is used. E.g. even in accounting very different profitability figures are used, like return on investment (for investment decisions), return on net assets (for profitability considerations of production processes and plants), contribution margins (for the assessment of products), etc. Thus, profitability figures to measure eco-innovations must relate to the kind of innovation analysed (e.g. whether it is a product, a service, a production process, etc.) and have to be defined very clearly and made transparent in order to create information value to readers. Profit is often replaced or complemented as an indicator by cash-flow based indicators like shareholder value

4. Years of sustained growth, duration of value creation and shareholder value

Not very useful as an input to any constructed ratio indicator for the early stages of an innovation. However, for shareholder value considerations this indicator may be of interest at later stages of the innovation process to measure the economic profitability when changing from a niche to the mass market and for the development in the mass market. Duration of value growth is one of the key value drivers of the shareholder value and thus considered in its calculation. The main problem with this indicator is that it is mainly useful for ex ante estimations and dependent on many assumptions which often cannot be compared or measured on a large scale. Shareholder value is based on the expectation of future case-inflows and cash-outflows as well as costs of financing, value growth duration and the weighted average cost of capital. As an indicator, shareholder value is fairly difficult to calculate for a large number of firms and long time periods and has little linking points to macro-economic measures.

Measures 1-3 above can be used with a denominator, for example, number of employees, capital deployed, R&D expenditure, or number of staff engaged in R&D, to allow comparisons to be made between different firms' **productivity**, for example, labour or capital productivity. Alternatively, **growth** in measures 1-3, and related productivity measures, can be measured by increases in production output, sales, value added or profit in a specified period. The use of value added mirrors GDP at a macro level, either measured in market prices or factor cost[9].

Production output would seem to focus on size rather than value although year-on-year growth could possibly be useful. However, year-on-year growth can be down to many factors which may not be related to innovation. Price, sales (price times production output) and profit would seem to be more functions of the market and how competitive it is, although the degree of innovation will be reflected in the price a product receives. Value added focuses more on what the firm does internally to create value, although one aspect of it will be determined by the price a firm's outputs receives.

[9] The measure in *factor cost* differs from the more prevalent *market price* measure found in the income and expenditure accounts by its exclusion of taxes on production (formerly called indirect taxes) and the inclusion of subsidies. While the *market price* measure represents the value of GDP as paid for by final consumers, the *factor cost* measure, more appropriately in the case of industrial production, takes the point of view of producers.

Measures of economic performance within firms: Input measures

The necessary input to create eco-innovations may be very different depending on the market dynamics, the industry sector, technological developments and political regimes. However, people, knowledge, and financial capital are always necessary inputs. Important input measures driving eco-innovations can for instance be:

- Number of employees
- Capital expenditure/operational expenditure CAPEX/OPEX
- R&D expenditure
- Number, or percentage, of staff engaged in R&D or product/system development

The measurement of firms' economic inputs mainly seems relevant as denominators to the economic output indicators - to give measures of productivity – although denominators will not always be needed. As a difference to conventional innovations specific knowledge on environmental impacts and eco-efficiency are additionally important. Even if the initial intention and idea which started the innovation process was not related to eco-efficiency, it is necessary to have a certain basic knowledge about eco-efficiency in order to assess the eco-efficiency relevance of the innovation, once it is established in the market. Furthermore, many eco-efficiency innovations which are driven by corporate actors are related to higher service components and organizational change than traditional innovations. Information and knowledge thus play an important role in many eco-innovation processes.

Inter-firm economic measures

A key corporate driver for eco-innovations is to increase competitiveness. The relative market position of an eco-innovation furthermore indicates how it is accepted by customers, how well it is established in networks and how much it influences the market dynamics. Important indicators are thus:

- Market position of firm (and development of market position) – ranking and direction based on any measure of economic performance e.g. economic value added, turnover, etc. and possible denominators of employees, capital etc. Also qualitative measures of customer satisfaction.
- Market share (proportion) (and dvelopment) – value, number, weight/volume
- Involvement in partnerships/networks – measured by amount or resources expended (time or money) in joint workingEtc.

Inter-firm measures link the micro to the meso scale as they are dependent on having some understanding of which firms comprise a sector or product/service grouping. The measures incorporate output economic performance but not all are not of use as numerators in eco-innovation performance indicators, for example, environmental performance divided by market position is not a meaningful ratio. In this case rather the market share or the growth of market share can be a meaningful denominator if related to the reduced environmental impacts compared to the conventional products which dominated the market before the introduction of the eco-efficiency innovation.

Investment and shareholder value measures of performance

The value of investments, financial market indicators and the shareholder value are measures that investors (e.g. shareholders) and media often use to evaluate the economic performance of firms. For example:

- Share price
- Price to earnings ratio
- Market Capitalisation: 'A high market capitalisation to the value added ratio in its sector indicates that financial markets rate the firm's prospects highly. DTI (2007)

- Economic Value Added (EVA)
- Etc.

A large body of literature exists on measures of firm performance used by investors, accountants, and corporate finance departments. On the first spot these indicators might provide plenty of ideas and data to examine further which of the indicators could be of interest (for an overview see e.g. Neely 2002; Rappaport 1987). However, because of its completely different focus, characterized by an accounting and financial market view, it is mostly difficult to derive meaningful relationships of performance to innovation, let alone eco-innovation from this literature. Given that the conventional accounting and corporate finance measures do not provide better insights into innovation and eco-innovation related value added or overall economic performance then simpler measures may be worth exploring further.

In practical terms the options for firm level measures of economic performance of eco-innovations may be limited as the World Business Council on Sustainable Development (WBCSD 2006, p.16) indicates:

> 'Only a small number of [value] indicators fit the three criteria necessary for them to be generally applicable to all firms: concerned with a global business value or environmental issue, relevant to virtually all businesses and having an agreed measurement method and definition. While there are many issues and associated indicators, most fail to meet at least one of these three criteria.'

The WBSCD roughly considers two aspects to be the only generally applicable measures of product service value:

- Quantity of goods/services produced or provided to customers or
- Net sales

Additional indicators of economic value 'could become generally applicable if current efforts to develop global agreement on measurement methods are successful. According to the WBCSD these measures include:

- Gross Margin (Net Sales - Cost of Goods Sold)
- Value Added (Net Sales - Costs of Goods Purchased)
- Income / Earnings / Profits
- Share Value
- Liabilities (e.g. Insurance Costs)
- Reserves / Provisions
- Investments and Write-offs
- Costs (e.g. Cost of Goods Sold, Production, Energy, Materials, Waste Disposal, Pollution Control)

However, given the need for the WBCSD indicators to be globally applicable this may place undue constraints on the selection of possible indicators. At the European level there would seem to be agreement on how indicators such as value added are reported.

Indicators for Products

The WBSCD (2000, p. 31) suggests the following potential indicators of product/service value under the heading of function. However, it highlights that these are highly specific to the end user and the product service concerned which raises issues about general indicators of product economic performance

- Product Performance (e.g. laundry loads washed, number of diapers used in a baby's life time)
- Services Delivered (e.g. standard banking transactions)
- Agricultural Yield (e.g. bushels harvested)
- Agricultural Effectiveness (e.g. hectares treated)
- Product Durability/Lifetime (e.g. vehicle miles travelled)
- Transport Capacity (e.g. ton-kilometres, passenger-kilometres)

The introduction to this section suggests the development of economic measures for products and areas of consumption based on functionality/cost. While conceptually this is simple, measurement raises a number of practical issues which require further work:

"For the economic part of the eco-efficiency ratio, there are three basic approaches available, all based on life-cycle costing: market cost related values, as in management accounting and budget analysis; cost benefit analysis, for the market related cost and benefits; and a steady state type of cost, conceptually best linked to steady state models for environmental analysis such as LCA. Establishing the economic score raise no fundamental problems, but several practical ones, for example, as related to discount rates and to mechanisms to take into account the analysis." (Huppes and Ishikawa 2007a, p. 32)

Further work will be needed to develop such measures that consider the availability of consistent cost/functionality data and the product categories that could most usefully be used to be representative of broader eco-innovation trends.

Indicators of household economic activity

The economic performance of households is a complement to that of firms and is important to examine as it reveals information on consumption rather than production activities. Data on household income and expenditure by category is available giving quantity of economic activity, For some activities data on functionality may be available, for example, household expenditure on vehicles and annual household mileage allowing an aggregate functionality/cost measure to be constructed for this activity. However, for other important consumption categories such as food and drink, housing, and clothing this would not be possible, or at least would not be easy to do.

Macro/meso measures of economic performance

The options for macro and meso indicators of performance are similar in what they measure but, obviously, differ in the level or unit at which they are measured. They will be formed from aggregations of micro level data.

A wide range of data is collected at the meso and macro levels. For example, the UK Treasury breaks down their tabulation of recent economic data into following headings[10]:

- Output/demand

[10] See http://www.hm-treasury.gov.uk/media/3/9/a3web150607.pdf for further details.

- Labour market
- Investment
- Productivity
- Inflation
- Balance of payments/trade
- Public Finances
- Financial.

Production; income/use of income; and capital formation (accumulation) are the main headings in the European System of Accounts (ESA95). These are combined with balance sheets to describe the stocks of assets and liabilities at the beginning and end of an accounting period. There is a significant issue to be addressed in the dealing with the divergent accounting and innovation cycles.

At the **meso** level the following could be used as economic performance measures and/or components of a constructed eco-innovation performance measure:

- Gross value added by region
- Gross value added by sector

Use growth in gross value added for a year-on-year indicator, or used with a denominator of population/ employees to give sectoral/regional labour productivity measure allowing comparison between sectors/regions within a specific time period.

- Market share of business sectors in EU/international markets

There are lots of potential sectors to collect data for but an indicator could be constructed for some key economic sectors which are representative of consumption/production as a whole, for example, vehicle manufacture or chemicals.

The indicator could measure within a sector how it is changing, or measure change between sectors (how different sectors are performing relative to one another). It would also be useful to get measures that indicate broad structural changes in sectors by size, in terms of value added, volume/weight or units product/service sold. For example, for renewables vs nuclear vs coal/gas fired power stations or organic vs intensive agriculture.

At the **macro** level the following could be used as economic performance measures and/or components of a constructed eco-innovation performance measure:

- GDP growth
- GDP per capita
- Labour productivity – GDP/employees, GDP/hours worked
- Total factor productivity

Summary of most useful Economic Performance Indicators

Micro

Value Added
Value of outputs minus value of inputs in a specified time period
Total value added for firm (or by individual product, but hard to measure as need to separate out inputs contributing to product)

Production Output/Sales/Income
Measured by financial value, weight/volume, or units sold in a specified time period.
Measure total output by firm (or by individual product streams).

Use with a denominator, for example, number of employees, capital, R&D expenditure, or number of staff engaged in R&D, to allow comparisons to be made between different firms in terms of **productivity**, for example, labour or capital productivity. Alternatively, year-on-year **growth**, and related **productivity growth** measures, for time series measurement. The use of value added mirrors GDP at macro level.

Market share of eco-innovation or eco-innovative firm

Meso

- Gross value added by region
- Gross value added by sector

Measure growth for year-on-year indicator
Use denominator of population (or employees) to allow productivity comparison between regions and sectors within a specific time period

Market share of key sectors (eg car industry in different member states)

Macro

- GDP

Measure growth for year-on-year indicator
Use denominators of population or employees to allow productivity comparison between countries within a specific time period.

The above economic indicators of performance are well developed. Further work is needed to develop measures of functionality/cost which is beyond the scope of this work. Any further work in this area should also consider how the economic aspects of functionality/cost can be combined with environmental performance to give an eco-innovation indicator, either for individual products or for functional consumption categories.

5.2 Environmental performance of activities

5.2.1 General Framework of Environmental Indicators

As defined in this document eco-innovations are characterised by enhancing both economic as environmental performance. In order to determine if the environmental performance is enhanced indicators are needed for the environmental performance. The usual way to describe the path from economic activity to environmental effects is the cause-effect chain. The so-called DPSIR chain is one that is often used in State of the Environment reporting (UNEP/GRID-Arendal, 2002). The different letters in DPSIR stand for, see Figure 5.2:

- Driving Forces: Socio-economic and socio-cultural forces driving human activities which increase or mitigate pressures on the environment
- Pressures: Stresses that human activities place on the environment
- State of the Environment: the condition of the environment
- Impacts: effects of environmental degradation
- Responses: responses by society to the environmental situation

Below an example of a DPSIR chain is given.

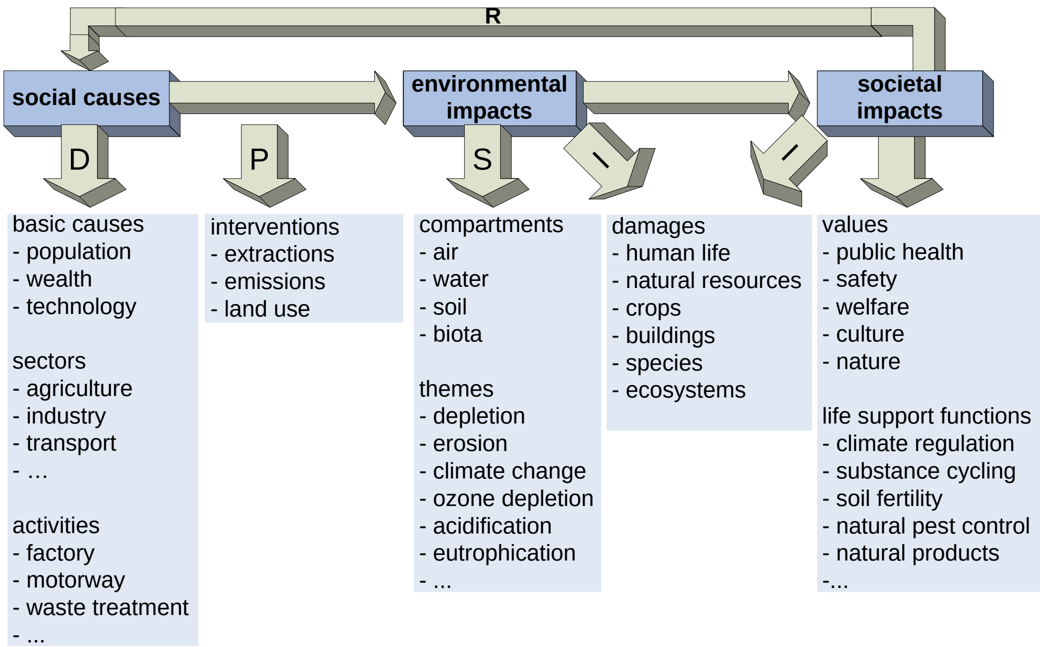


Figure 5.2 Driving forces, Pressures, States and Impacts as taken from the DPSIR framework.

Within the framework of the development of standardisation of the methodology of Life Cycle Impact Assessments (LCIA) an important effort has been made to create a set of environmental indicators for product systems (Udo de Haes et al., 2002). The structure, which fits nicely within the DPSIR framework, consists of the following elements:

- environmental interventions (Pressures): "the physical elements that cross the border between the product system and the environment" (Udo de Haes et al., 1999). This includes extraction of natural resources and the emissions of substances and other physical elements like radiation and noise. They also include physical changes to the environment like cutting down trees, shooting animals, lowering the ground water table, surface mining etc.

- midpoints (State): all elements in an environmental mechanism that fall between the environmental interventions and the end-points e.g. concentration of substances in surface water, temperature of the atmosphere, sea-level, pH of surface water etc.
- endpoints (Impacts): those elements of an environmental mechanism that are themselves of value to society e.g. elements of nature like forests and coral reefs and physical aspects of human health such as lifetime and bodily functions .
- areas of protection: a class of endpoints that deserve protection. In ISO 14042, three classes are used: 'human health', 'natural environment' and 'natural resources'.

Within the LCA two types of Environmental Indicator are used: midpoint based and endpoint based. Bare et al. (2000) argue that both have their specific strong and weak points:

- midpoint indicators are relatively certain but are less environmentally relevant because they focus on variables that generally are far removed from their endpoints that matter for society.
- endpoint indicators give results that are expressed in very relevant terms but are relatively (to extremely) uncertain.

In this work we choose to use midpoint indicators for three reasons: first of all environmental problems like climate change, acidification, photochemical smog formation etc are all defined on a midpoint level. Secondly although midpoint indicators are further removed from their endpoints they are much more frequently used in a policy context in order to reduce the uncertainties. Thirdly, since there is already quite some uncertainty in indicators on the midpoint level it is preferable not increase these uncertainties by using endpoint indicators.
An important issue with the determination of environmental indicators is the fact that for emission related problems the location of the emission has a strong influence on the impact. For stratospheric ozone depletion and climate change the location of the emission is only of minor importance. However, for all other emission-related problems the location is a crucial factor. For example the impact of an emission in an area in which there is already a high deposition of acidifying substances is much higher than when the same emission would occur in an area where deposition levels are very low. Therefore, next to generic indicators, site-specific indicators have been developed for these problems. These can of course only be used if the location of the emission is specified.

In the paragraphs below a description is given of the environmental problems and indicators that could be used to assess the environmental impact of innovations. The text is based on Udo de Haes et al. 2002.

5.2.2 Abiotic Resource Depletion

Abiotic Resource Depletion is defined as the depletion of environmental stocks of useful materials. Udo de Haes et al., 2002 distinguish three types of abiotic resources:

- ***deposits*** or stocks that are irreversibly depletable such as fossil fuels and mineral deposits
- ***funds*** that are temporarily or locally depletable such as peat and nutrients from soil minerals

- ***flows,*** non-depletable but with a limited availability at a certain time such as fresh water precipitation and solar radiation.

In Udo de Haes et al 2002 fossil energy and mineral deposits are grouped as irreversible depletable deposits or stocks. However, the results of the use of these two types of resources is very different. When iron ore (iron oxide) is taken from the Earth's crust it is refined to produce iron (the oxygen is removed via a reduction process) and this pure iron is used for example to produce ships. This means that iron is still available for future use. Actually it is available in a more refined and useful form than the iron ore itself. This is very different for fossil fuels. Only a small part of the fossil fuels is used to produce other more refined materials like plastics (<3%). The majority is of course used only to extract the embedded chemical energy to drive our production processes, transport and household equipment. In this process the energy is dispersed as waste heat. So while it is possible to put minerals to other uses even after products are made from them this is not true for fossil fuels that are used as source of energy. Therefore we have chosen in this study to treat fossil fuels and mineral resources separately. Similar to Global Warming Potentials (defined by the IPCC) Abiotic Depletion Potentials have been determined for depletion of different mineral and fossil resources. There are different sets available but we chose the set that has been defined by Guinée et al., 2002. The abiotic depletion impact related to a specific eco-innovation can be calculated with the equation below:

$$ADP = \Sigma_i (m_i \times ADP_i)$$

where m_i is the mass of mineral i, ADP_i is the abiotic depletion potential of mineral i.

5.2.3 Land use

Land use as an environmental problem is defined here as the economic use of land which makes it unavailable or less available for nature. Once the activity ends the land area can be returned to nature, therefore by nature land use should be measured not only by the area which is occupied but also by the time this area is used. This results in the following formula to calculate increase of land competition:

increase of land competition = a x t

In which a is the land area that is occupied (m^2) and t is the time this area will be occupied (yr).

5.2.4 Climate change

Climate Change is defined as the anthropogenic enhancement of the greenhouse effect. The mechanism that causes this effect is called 'radiative forcing'. An increased radiative forcing is caused by the increase of greenhouse gases in the atmosphere. On a midpoint level the impacts of climate change range from changes in weather & precipitation patterns, sea-level rise, increased number of extreme weather events etc. The most important substances that contribute to climate change are: CO_2 , CH_4 , N2O and synthetic volatile chemicals like Fluor containing alkanes and sulfurhexafluoride. The indicator that is commonly used for Climate Change is the so-called Global Warming Potential (GWP). GWP values have been calculated for most substances that increase the radiative forcing of the atmosphere. Lists of GWP are published by the International Panel on Climate Change (IPCC) which has been established by the WMO and the UNEP. The global warming potential impact related to a specific eco-innovation can be calculated with the equation below:

$$GWP = \Sigma_i (m_i \times GWP_i)$$

where m_i is the mass of greenhouse gas i, GWP_i is the global warming potential of greenhouse gas i. GWPs exist for different time horizons, the default value for the time horizon that is normally used is 100 years.

5.2.5 Stratospheric ozone depletion

Stratospheric ozone depletion is defined as the degradation of the ozone in the stratosphere caused by anthropogenic emissions. The so-called ozone layer in the stratosphere protects life of Earth from short wave UV radiation from the sun. On a midpoint level the effects consist of the degradation of ozone in the stratosphere, the increasing amount of UV radiation reaching the surface of the earth etc. The most important substances that play a role in stratospheric ozone depletion are: NOx (when emitted at high altitudes), volatile chlorine and/or bromine- containing persistent chemicals. The indicator that is commonly used is the so-called Ozone Depletion Potential (ODP). ODP values have been calculated for most substances that contribute to stratospheric ozone depletion. Lists of ODPs have been published by the WMO. The calculation of the ozone depletion potential impact related to a specific eco-innovation can be calculated with the equation below:

$$ODP = \Sigma_i (m_i \times ODP_i)$$

where m_i is the mass of ozone depleting gas i, ODP_i is the ozone depletion potential of ozone depleting gas i.

5.2.6 Photo-oxidant Formation

Photo-oxidant formation is defined as the increased production of photo-oxidants (ozone and peroxylacetyl nitrate) in the lower troposphere caused by anthropogenic emissions. The presence of increased photo-oxidants presents itself in the form of photochemical smog also known as Los Angeles smog. Most important anthropogenic emissions that play a role in the formation of photo-oxidants are Volatile Organic Compounds (VOCs), NOx, and CO. There are two indicators that are commonly used to express the total contribution of a product or process to photo-oxidant formation: MIR and POCP. The first originates from a North American context and the second from a European context. In this study we chose to use POCP as an indicator for photo-oxidant formation since it is not clear if the North American MIR can be applied to the European situation. A list of POCP values has been published by Derwent and Jenkins (1991). A modified and more complete list was published in 2002 by Guinée et al, 2002.

The calculation of the photo-oxidant formation potential impact related to a specific eco-innovation can be calculated with the equation below:

$$POCP = \Sigma_i (m_i \times POCP_i)$$

where m_i is the mass of photo-oxidant forming gas i, $POCP_i$ is the photo-oxidant forming potential of photo-oxidant forming gas i.

5.2.7 Acidification

Acidification is defined as the increase in acidity of water and soil caused by anthropogenic emissions. The common mechanism is the deposition of anions that are removed by leaching or biochemical processes, leaving excess hydrogen ions in the system. Most important anthropogenic emissions that increase the acidity of water and soil are NOx, SO_2, and NH_3 . Other substances that can contribute to acidification are HCl, HF, H_3PO_4, HNO_3, H_2SO_4, SO_3 and H_2S. The site-generic acidification potentials of these substances have been published in different lists with only minor differences (e.g. Wenzel et al., 1998 and Guinée et al.,2002) . We propose to use the list that was published by Guinée et al., 2002.

The calculation of the acidification potential impact related to a specific eco-innovation can be calculated with the equation below:

$$AP = \Sigma_i (m_i \times AP_i)$$

where m_i is the mass of acidifying emission i, AP_i is the acidification potential of acidifying gas i.

5.2.8 Terrestrial Eutrophication

Terrestrial Eutrophication is defined here in line with Udo de Haes et al. 2002 as the adverse effects of excess nutrients on plant functioning and on species composition in natural or semi natural terrestrial ecosystems. The use of nitrate and phosphate fertilizers and the emissions of NOx from the burning of fossil fuels adds huge amounts of these nutrients to natural and semi-natural areas. The increased availability nitrogen and phosphorus favours the growth of some species while others will lose out. Thereby the structure and stability of ecosystems can be damaged and biodiversity is often reduced. The relevant emissions are ammonia and NOx emitted to air. Though phosphorus is an important nutrient in the eutrophication of rivers and lakes its importance for terrestrial ecosystems is minor, because under natural conditions their growth is rarely limited by phosphorus (Chardon, 2000).

The calculation of the terrestrial eutrophication potential impact related to a specific eco-innovation can be calculated with the equation below:

$$TEP = \Sigma_i (m_i \times EP_i)$$

where m_i is the mass of eutrophying emission i, EP_i is the eutrophication potential of eutrophying gas i.

5.2.9 Aquatic Eutrophication

Aquatic Eutrophication is defined here in line with Udo de Haes et al. 2002 as nutrient enrichment of the aquatic environment. Emissions of nutrients can lead to water that is dominated by phytoplankton. This makes water more turbid which in turn has several negative effects on water ecosystems. First of all the amount of sunlight that reaches the water bottom will be reduced and thereby submerged plant life will be reduced as well. Furthermore, the increased turbidity will be a big disadvantage for predators that depend on their eyes to find prey and the water will be dominated by zooplankton eating fish. Zooplankton eats phytoplankton which means that the reduction in zooplankton further increases the domination of phytoplankton. When the excess of phytoplankton dies the decomposition of these species will cause an increase in oxygen use. This means that oxygen levels in the water will go down and fish will die. (Kristensen and Hansen, 1994). Most important substances for aquatic eutrophication are phosphorus and nitrogen compounds. Since the decomposition of organic material also causes oxygen demand emissions of these compounds measured as COD and BOD are often handled together with nutrients.

The calculation of the aquatic eutrophication potential impact related to a specific eco-innovation can be calculated with the equation below:

$$AEP = \Sigma_i (m_i \times EP_i)$$

where m_i is the mass of eutrophying emission i, EP_i is the eutrophication potential of eutrophying emission i.

5.2.10 Human Toxicity

Human Toxicity is defined here in line with Guinée et al. 2002. It covers the impacts on human health of toxic substances present in the environment. In general three things are important to determine the impacts of a toxic compound: the fate of the substance in the environment (based on e.g. degradation rates, vapour pressure, solubility) once it is emitted, the exposure of humans to this substance and the toxicity of the substance which determines the toxic impact it will have once a human being is exposed to it. Although the discussion on the characterisation of human health is not settled yet a major standardisation effort has been done by the UNEP-SETAC Life Cycle Initiative (http://lcinitiative.unep.fr/) to come up with a 'recommended' model for determining the Human Toxicity Potential for substances. This so-called USEtox model uses a multi-media model to determine the fate of a substance, a human exposure model and human effect factors. By combining these three models human toxicity potentials are calculated. At the time of writing the human toxicity potentials from the USEtox model have not yet been published. In the mean time we choose to use the Human Toxicity Potentials as defined by Guinée et al., 2002. These are similarly based on a multi-media model for fate, a human exposure model and human effect factors.

The calculation of the human toxicity potential impact related to a specific eco-innovation can be calculated with the equation below:

$$HTP = \Sigma_i (m_i \times HTP_i)$$

where m_i is the mass of toxic emission i, HTP_i is the human toxicity potential of toxic substance i.

5.2.11 Ecotoxicity

Guinée et al. 2002 defines ecotoxicity as covering the impacts of toxic substances on aquatic, terrestrial and sediment ecosystem. They calculate ecotoxicity potentials for freshwater ecosystems, marine ecosystems, freshwater sediments and terrestrial ecosystems. The marine ecotoxicity is under strong debate and we choose not to use marine ecotoxicity potentials. The freshwater sediment ecotoxicity is derived more or less directly from fresh water ecotoxicity and we choose not to use those as well. As with human toxicity, three things are important to determine the impacts of a ecotoxic compound: the fate of the substance in the environment (based on e.g. degradation rates, vapour pressure, solubility) once it is emitted, the exposure of biota to this substance and the toxicity of the substance which determines the toxic impact it will have once biota are exposed to it. Although the discussion on the characterisation of ecosystem impacts is not settled yet a major standardisation effort has been done by the

UNEP-SETAC Life Cycle Initiative (http://lcinitiative.unep.fr/) to come up with a 'recommended' model for determining the Freshwater Toxicity Potential for substances. As with Human Toxicity, this USEtox model uses a multi-media model to determine the fate of a substance, an ecosystem exposure model and ecosystem effect factors. By combining these three models freshwater toxicity potentials are calculated. At the time of writing the freshwater toxicity potentials from the USEtox model have not yet been published. In the mean time we choose to use the Freshwater aquatic Toxicity Potentials, and Terrestrial Ecotoxicity Potential as defined by Guinée et al., 2002. These are similarly based on a multi-media model for fate, an exposure model and effect factors.

The calculation of the Freshwater aquatic ecotoxicity potential impact related to a specific eco-innovation can be calculated with the equation below:

$$FAETP = \Sigma_i (m_i \text{ x } FAETP_i)$$

where m_i is the mass of toxic emission i, $FAETP_i$ is the freshwater ecotoxicity potential of toxic substance i.

The calculation of the Terrestrial ecotoxicity potential impact related a specific eco-innovation can be calculated with the equation below:

$$TETP = \Sigma_i (m_i \text{ x } TETP_i)$$

where m_i is the mass of toxic emission i, $TETP_i$ is the terrestrial ecotoxicity potential of toxic substance i.

5.3 Eco-innovation indicators for Firms: Determining appropriate eco-innovation indicators and proxies from a business perspective

What needs to be done next is the identification of the appropriate eco-innovation indicators, proxies and drivers within the eco-innovation framework presented earlier. Indicators, proxies and drivers should be derived in a structured and well-regulated process. Therefore, the different classifications of eco-innovation (see chapter 2) need to be analysed within their various contextual dimensions. Hereby the (eco-) innovation life-cycle should be regarded as meso trajectory interacting with agents, structures, components, and processes at micro- and macro- levels of society. Of interest are what triggers and what indicates eco-innovations throughout the interacting processes between the various stages of the eco-innovation life cycle and the processes taking place at micro and macro level. Furthermore, after having identified eco-innovations, their eco-efficiency should be determined according to the eco-efficiency ratio (in its most general form: value added/environmental impact added, or specified as a certain economic performance indicator/certain related environmental performance indicator) and eco-efficiency portfolio matrix provided in chapter 5.3.2 (for a more detailed discussion of the eco-efficiency matrix on the firm level see e.g. Schaltegger and Sturm 1992; Ilinitch and Schaltegger 1995; Schaltegger and Burritt 2000). This is to benchmark various eco-innovations into relatively strong and weak eco-innovations and therefore being able to identify the relatively best eco-innovations available in the market as described in chapter 5.3.3. Here it is important to grasp the systemic nature of eco-innovations being embedded into the micro and macro features of their societal context, which again is embedded and dependent on ecological resources. Strong eco-innovations show high economic performance and are decoupled from environmental depletion. They constitute or contribute to a path of strong eco-efficiency and strong sustainable development (see e.g. Schaltegger 2000; Schaltegger et al. 2006).

Innovation processes with a focal firm driving or managing the process can be more or less closed or open (Chesbrough 2006). Today ever more corporate driven innovations processes are open. Although no empirical research has been conducted on the openness or closedness of eco-innovation processes, it can be assumed that the general trend to more open innovation processes is also true for eco-innovations.

The more open an innovation process is the more the development of eco-innovations is not a task of a single individual or firm but the result of many different stakeholders and actors contributing to various steps and stages of eco-innovation process. It is therefore necessary to consider how stakeholders can be involved in an efficient and effective manner into the innovation process. Measurement of eco-innovation progress and eco-efficiency thus should inform and support the key stakeholders involved. A special focus of indicator development and use must lie on the information needs of those agents who drive, support or block processes of eco-innovation. This includes micro-level agents such as entrepreneurs, intrapreneurs (entrepreneurs in the firm) and interpreneurs (entrepreneurs of networks driving and organizing the performance of the network) but also macro-level agents such as governments and NGOs among others. Especially the relations and interactions between those agents within and between the different contextual dimensions of our society should be investigated in order to find out what influence they have on the development of eco-innovations and how they are reciprocally influencing each other and are influenced by proceeding eco-innovation development.

5.3.1 Satisfying specific stakeholder needs

Having described the eco-innovation context from a broader perspective, the focus is now on what determines eco-innovations from the business perspective. The broader the level of activity at which eco-innovation is taking place, the more complex the management of these activities due to an increasing number of actors involved, which in turn makes the analysis of the activities related to eco-innovations more complex (Schaltegger & Dyllick 2002; Schaltegger et al. 2003). Eco-innovation indicators can be regarded as condensed information for decision making (Olsthoorn et al. 2000). By simplifying a complex reality they help to communicate relevant aspects or complex interrelations between different aspects of the organisational environment. Indicators supply information, they identify key factors or driving forces, they support monitoring the impact of certain activities or policy responses, they may be used as a powerful tool to raise public awareness and they help to identify trends and progress of activities over time (EEA 1999; EEA 2005). The purpose of eco-innovation indicators is to inform stakeholders about environmental performance vis-à-vis economic performance of activities related to eco-innovations. Aiming at the derivation of appropriate eco-innovation indicators and proxies, the innovative product, product group or other functional unit as well as the system boundaries and the time frame for measurement have to be defined. Moreover, one should bear in mind that indicators need to serve internal and external stakeholders' differing information needs with differing degrees of detail.

"Of critical importance is that eco-efficiency indicators must be unambiguously defined in such a way that the economic and environmental dimensions measured reflect and are focused on the activities of concern to specific stakeholders (...). Divisional management may, for example, need to focus on the economic and environmental impacts of strategic business units or sites. Middle and lower levels of management focus on product groups, product units, sites and production steps. As indicators are used to guide management control and strategic planning activities, indicators must be defined with care and must take the specific circumstances of a firm into account" (Schaltegger & Burritt, 2000, 363ff.).

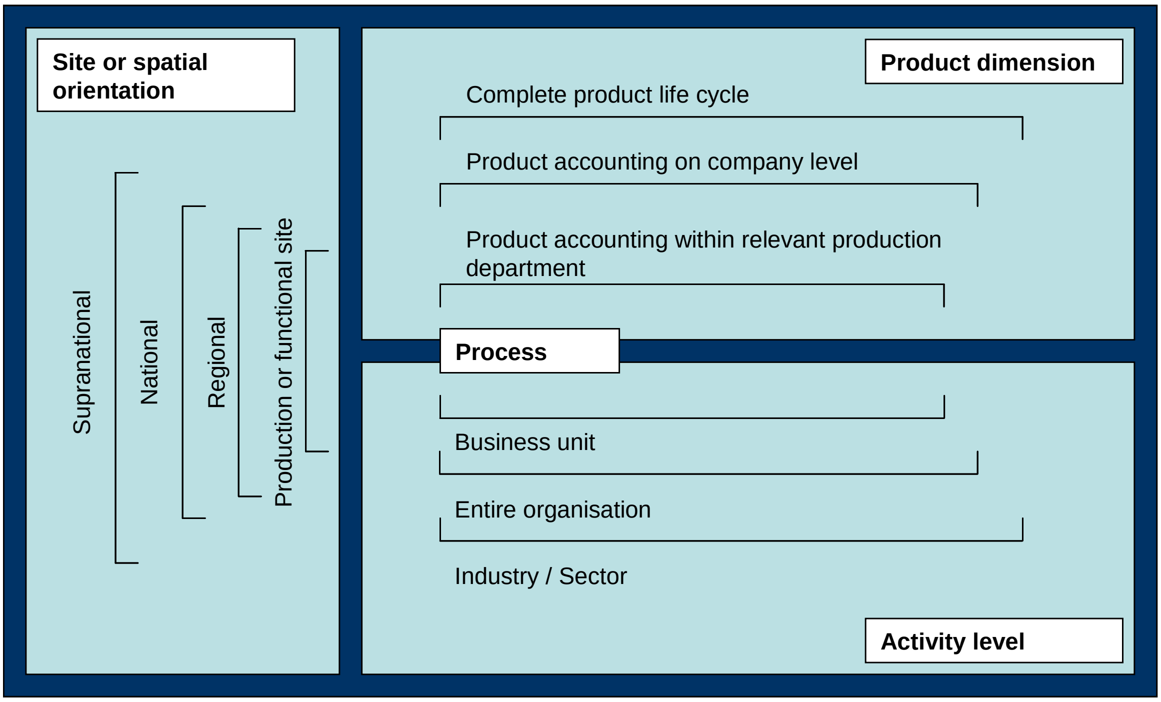


Figure 5.3 Possible aggregation levels for different innovative products, product groups or other functional units (adapted from Schaltegger &Sturm 1992, 147)

Depending on the stakeholder's main interest, the eco-innovation indicators need to be related to their level of concern. That is why the economic as well as the ecological performance indicators defined for eco-innovations' eco-efficiency analysis need to distinguish between different aggregation and activity levels (see Figure 5.3, and also figures 4.1 and 4.2 in a more general sense).

If we are, e.g., dealing with an innovative process, its eco-efficiency could be analysed for the business unit where the innovative process is taking place (micro-perspective). If the eco-innovation business is related, e.g., changing the management system of an entire organisation, then top management might be interested in an indicator assessing the innovation's annual eco-efficiency performance with regard to the entire organisation (micro-perspective). A production manager might be interested in what eco-efficiency indicator can be attributed to his product throughout the supply chain taking into account the eco-efficiency of the product's entire life-cycle (meso-perspective). If the eco-innovation is of a functional nature the analysis level could be on the functional service or industry level (meso-perspective). Government as stakeholder might be interested in the eco-innovation's impact on society as a whole (macro-perspective). With regard to the level of analysis it is important to take into consideration that environmental and economic data must be consistent, i.e., "[i]f an enterprise expands its eco-efficiency reporting to include the life-cycle of its products and services, it has to ensure that, if the environmental item includes activities up- and/or downstream, the financial item used as a reference figure also covers these activities" (UNCTAD 2003, 12). In order to determine appropriate eco-innovation indicators, eco-efficiency ratios that provide an insight into the decoupling of eco-innovations' environmental pressure from economic performance need to be identified. Hence, the appropriate Economic Value Added (EVA) and Environmental Impact Added (EIA) indicators of the eco-efficiency ratio for eco-innovations depending on the stakeholder needs need to be defined. Derivation of eco-efficiency indicators takes place according to the eco-efficiency path procedure (see Figure 5.4).

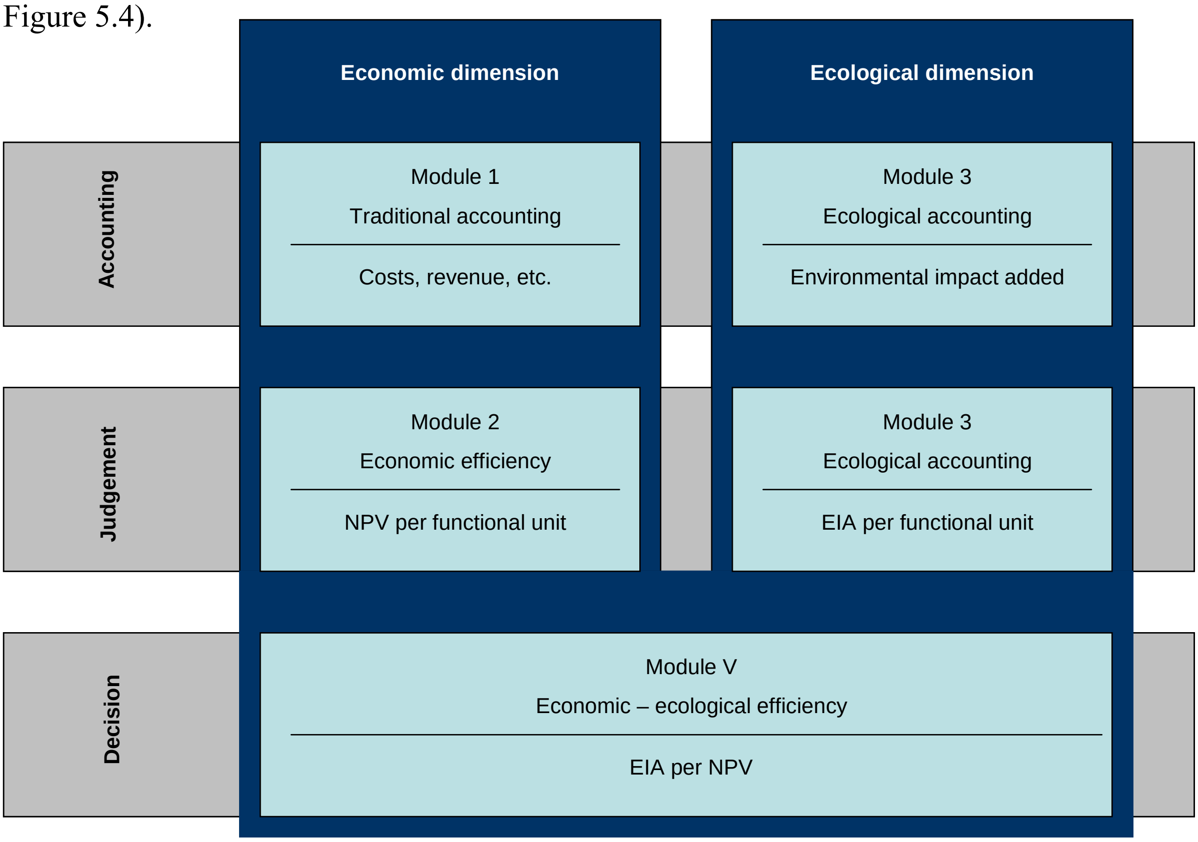


Figure 5.4 The eco-efficiency path procedure (adapted from Schaltegger & Burritt 2000, 359; Schaltegger & Sturm 1992, 2007)

With different stakeholder groups asking for different information, a list of exemplary eco-efficiency indicators could look as follows:

Stakeholder group	Example of eco-efficiency indicator	Focus
Shareholders	SHV / NPEIA	Assessment of financial investment into innovative firm
Government, top management	VA / EIA	Assessment of eco-innovation impacts on society as a whole
Government, top management	(corporate taxes) / EIA	Assessment of impacts relevant for the government and the tax agency
Top managment	Income / EIA	Assessment of annual performance
Site management	ROCE / EIA	Assessment of site
Project management	NPV / NPEIA	Assessment of capital investment project
Divisional management	CM / EIA	Assessment of innovative product group
Product management	CM / EIA	Assessment of innovative product

CM = contribution margin; EIA = environmental impact added; NPEIA = net present environmental impact added;
NPV = net present value; ROCE = return on capital employed; SHV = shareholder value; VA = value added

Table 5.1 Examples of eco-efficiency indicators (Burritt & Schaltegger 2000, 364)

The selection of appropriate environmental performance indicators, economic performance indicators as well as eco-efficiency indicators should be determined separately for every eco-innovation product, product group, and other innovative function depending on the addressed stakeholder's information needs and the activity or aggregation level the indicator is referring to.

5.3.2 The role of the firm in different stages of eco-innovation processes

After having discussed some general key issues (like the explicit consideration of the information needs of the addressees and stakeholders involved in the innovation process, the match of the scope of economic and environmental indicators to calculate eco-efficiency, etc.) of deriving and defining eco-innovation indicators from the perspective of a firm this section discusses on a more concrete level possible indicators for different stages of eco-innovation processes.

Figure 5.5 distinguishes four core stages which summarize a set of possible open or closed innovation processes. Any eco-innovation will involve ideas, prototypes, a niche market introduction or development and a mass market diffusion. The necessary main processes can be called idea generation, prototype development, niche market introduction and mass market diffusion.

For every stage different stakeholders or key players and different drivers will play an important role to support a successful development. Whereas the eco-efficiency effect is still a potential effect in the idea and prototype stage it materialises ever more with the introduction into the market and diffusion. The eco-efficiency effects are of more predictive nature in the first two stages and more real world related in the last two stages. As a consequence, the eco-innovation indicators have to be distinguished for each stage.

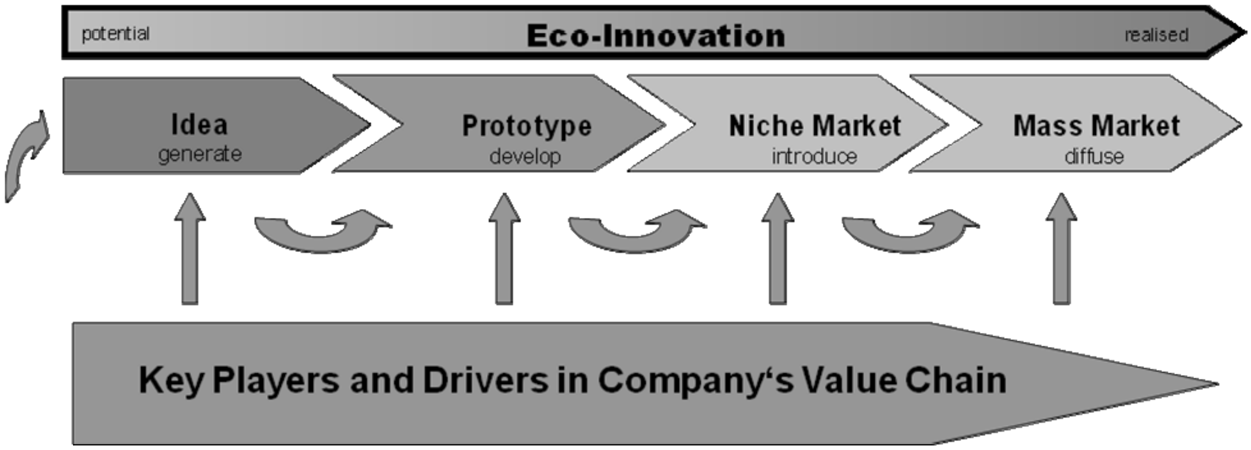


Figure 5.5: Stages of eco-innovation processes

An innovation's eco-efficiency ratio in each stage of the innovation process can be regarded as significant indicator for its benchmark position as eco-innovation. From a corporate and management perspective a distinction between lagging and leading indicators is useful. *Lagging indicators* represent impacts, outcomes or output whereas *leading indicators* are related to factors driving the impact, outcome or output performance (for a general discussion of lagging and leading indicators and their use in the corporate context see Kaplan and Norton 1992; 2001; for a discussion in the context of corporate sustainability management see Schaltegger and Dyllick 2002).

Figure 5.6 illustrates possible lagging indicators related to the four stages of eco-innovation processes as distinguished:

- For the idea generating stage: potential eco-efficiency effect of patented idea
- For the prototype stage: potential eco-efficiency effect of prototypes measured in prototype testing
- For the niche market stage: actual efficiency effect of products in use, considering production and consumption as well as disposal, etc. First measures based on new indicator and measurement approaches being tested.
- For the mass market stage: actual efficiency effect of products in use, considering production and consumption as well as disposal, etc. on a large scale. Precise measures and established measurement systems in place.

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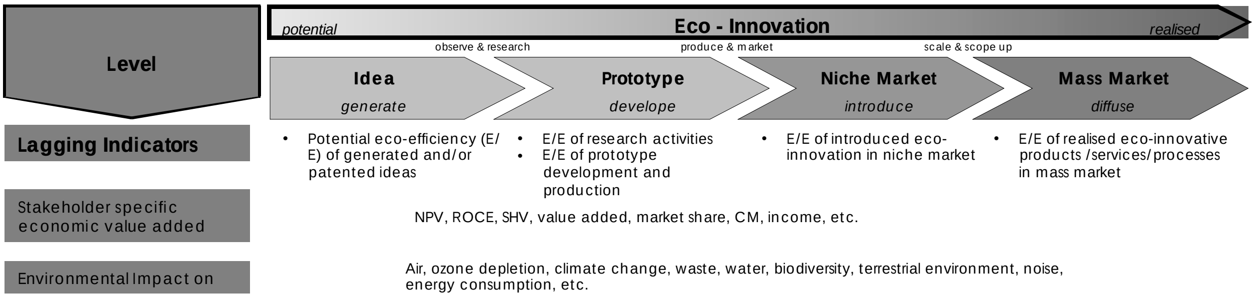

Figure 5.6: Lagging indicators of eco-efficiency for different stages of eco-innovation

For each stage the key actors and drivers can be identified. The following general lists are rather collections of possible issues and have to be specified in each case depending on the product, service, process, function of customer need and addresses involved.

Idea generating stage

Key actors in the idea generation stage are for example:

- Internal key players:
- Marketing research,
- Knowledge Management, Top Management
- Environmental and sustainability Management
- Etc.

Among the main *drivers* for eco-innovation in the idea stage are:

- Sustainability integrated into core strategy
- Existance and number of stakeholder dialogues
- Networks & clusters
- Inhouse excellence initiatives
- Participation in eco-fairs
- Participation in sustainability events
- Incentives & reduced risk to innovate
- Competitive pressure
- Sustainability part of firm culture
- Proactive support by top management
- Proactive stakeholder strategy
- Etc.

Activities which support the idea generating stage and thus can be considered as early drivers or leading indicators:

- Awareness raising for sustainability issues
- Fostering stakeholder involvement and open innovation strategies
- Adapting tax policy (environmentally related taxes)
- Supporting utilisation of renewable resources
- Increasing taxing on depletion of scarce resources

- Providing incentives for eco-innovations
- Supporting ecopreneurs, especially SMEs
- Fostering top-runner strategies (subsidies, prizes)
- Etc.

Prototype development stage

Key actors in the prototype development stage are for example:

- R&D Department
- Top Management
- Financial Department
- Procurement /
- Supply Management
- Etc.

Among the main *drivers* for eco-innovation in the prototype development stage are:

- Inclusion of env. concerns in R&D
- Policy to avoid toxic materials
- Minimization of resource use and materials
- Accountabiilty for environmental management
- Making use of LCA principles
- Sufficient budget for R&D investments
- Good supply chain management
- Participation in excellence inititatives / prizes

Activities which support the prototype development stage and thus can be considered as early drivers or leading indicators:

- Supporting networks between firms, universities & other research institutes
- Subsidizing R&D activities with focus on sustainability issues (eco-design)
- Adapting tax policy (environmentally related taxes)
- Supporting utilisation of renewable resources
- Increasing taxing on depletion of scarce resources
- Providing incentives for eco-innovations
- Supporting ecopreneurs, especially SMEs
- Fostering top-runner strategies (subsidies, prizes)

Niche market introduction stage

Key actors in the niche market introduction stage are for example:

- Bioneers and ecopreneurs (Schaltegger 2002)
- Marketing & Sales
- Logistics / Distribution
- Sustainable reporting
- Etc.

Among the main *drivers* of eco-innovation in the niche market introduction stage are:

- Convincing market launch
- Successful market introduction and marketing strategy
- Good reputation / credibility

- Good logistics / distribution system
- Cooperative / alliance strategy
- Attracting investors
- Good timing and placing
- Etc.

Activities which support the niche market introduction stage and thus can be considered as early drivers or leading indicators:

- Compensating small market share (subsidies)
- Supporting sustainable transport / distribution policies
- Adapting tax policy (environmentally related taxes)
- Providing incentives for eco-innovations
- Supporting ecopreneurs, especially SMEs
- Fostering top-runner strategies (subsidies, prizes)
- Etc.

Mass market establishment stage

Key actors in the mass market establishment stage are for example:

- Ecopreneurs
- Marketing & Sales
- Logistics / Distribution
- Sustainability Management
- Etc.

Among the main *drivers* of eco-innovation in the mass market establishment stage are:

- Successful marketing strategy
- Good reputation / credibility
- Good logistics / distribution system
- Firm‘s ranking in indices
- Etc.

Activities which support the mass market establishment stage and thus can be considered as early drivers or leading indicators:

- Supporting sustainable transport / distribution policies
- Adapting tax policy (environmentally related taxes)
- Providing incentives for eco-innovations
- Supporting ecopreneurs, especially SMEs
- Fostering top-runner strategies (subsidies, prizes)
- Etc.

For each innovation stage, both, economic and environmental issues have to be combined in a matching way to determine the optimal eco-innovation indictors. Starting with the definition of lagging indicators, the key actors, drivers and leading indicators can be developed on basis of cause-and-effect chains. The linking of lagging and leading indicators, and of actors with desired impacts, outcomes and output supports a better understanding of the innovation processes and what factors can be supported and influenced on a corporate, societal and political level in order to spur eco-innovation.

5.3.3 Integrating environmental and economic performance indicators

Due to a great diversity of applications, industries and stakeholders many diverse and diverging approaches determining environmental performance, economic performance and innovation activities are existing (e.g. see ISO 14031, EEA-CSI, OECD key environmental indicators, OECD decoupling indicators, SETAC, EMAS, ACCA, GRI, WBCSD, CIS). Olsthoorn et al. (2001) mention that information needs of many different stakeholders should be served by normalised and, in a separate step, aggregated or standardised sets of indicators. In order to conduct an eco-efficiency analysis of eco-innovations, it is wise not to create an entirely new set of indicators to be added to the already existing ideas. Rather a set of environmental performance indicators should be chosen from those already existing sets. Indicators suggested by the ISO 14000 series could serve as reference here. Applied to innovative products and innovative functions, environmental performance analysis of eco-innovations could be executed with ISO 14031 indicators as basis. ISO 14031 provides for a set of environmental performance indicators that are suitable for the assessment of the environmental performance of operations related to eco-innovations (operational performance indicators OPI). These OPIs could be used to fill the environmental performance dimension of the eco-efficiency equation.

Furthermore, the appropriate economic performance indicators for eco-efficiency assessment need to be identified. Here, it is important to stick to the same system boundary used for an eco-innovation's environmental performance determination. If, for example, we decide to analyse an eco-innovation from a life-cycle perspective, a life-cycle perspective should be applied for the derivation of environmental as well as economic performance indicators. Recently, efforts have been made to integrate life cycle costing (LCC) into eco-efficiency analysis (Kicherer et al. 2007; Norris 2001). Given that Life Cycle Assessment of environmental performance and LCC differ in purpose and approach (see Table 5.2), it needs to be ensured that the applied "(...) ecological and economical figures are derived from the same starting point, i.e. cover the same scope and are comparable" (Kicherer et al. 2007, 2) for instance with regard to system boundaries and time scale.

Tool/Method	LCA	LCC
Purpose	Compare relative environmental performance of alternative product systems for meeting the same end-use function, from a broad, societal perspective	Determine cost-effectiveness of alternative investments and business decisions, from the perspective of an economic decision maker such as a manufacturing firm or a consumer
Activities which are considered part of the 'Life Cycle'	All processes causally connected to the physical life cycle of the product; including the entire pre-usage supply chain; use and the processes supplying use; end-of-life and the processes supplying end-of-life steps	Activities causing direct costs or benefits to the decision maker during the economic life of the investment, as a result of the investment
Flows considered	Pollutants, resources, and inter-process flows of materials and energy	Cost and benefit monetary flows directly impacting decision maker
Units for tracking flows	Primarily mass and energy; occasionally volume, other physical units	Monetary units (e.g., dollars, euro, etc.)
Time treatment and scope	The timing of processes and their release or consumption flows is traditionally ignored; impact assessment may address a fixed time window of impacts (e.g., 100-year time horizon for assessing global warming potentials) but future impacts are generally not discounted	Timing is critical. Present valuing (discounting) of costs and benefits. Specific time horizon scope is adopted, and any costs or benefits occurring outside that scope are ignored

Table 5.2 How LCA and LCC differ in purpose and approach (Norris 2001, 118)

An LCA of the environmental performance of operations related to eco-innovations should include OPIs that cover the following categories (CEN 1999):

- Input categories:

    Materials, energy, services supporting the organisation's operation

- Physical facilities and equipment used

- Output categories:

    Products, services provided by the organisation, wastes, emissions

Every stage of the innovation life-cycle should be assessed according to the input used, physical facilities and equipment used and output used. The environmental performance indicators derived through the assessment of the eco-innovation life-cycle then should be correlated with the costs occurring throughout the eco-innovation life-cycle. That way an eco-efficiency ratio with regard to an innovation's operational performance can be derived. Kicherer et al. (2007) suggest that for the relation between environmental impact derived from LCA analysis and economic costs derived from LCC analysis a normalisation procedure as described in ISO 14042 should be applied. By means of a normalisation procedure comparability can be ensured, complexity reduced and thus decision-making simplified. Being able to link LCA with LCC figures of innovative products and processes allows for the determination of their eco-efficiency, i.e. the ratio of environmental impact unit (derived from LCA) per monetary unit earned (derived from LCC) and therefore makes them comparable to benchmarks. Furthermore, the normalised costs of an eco-innovation calculated by means of financial life cycle costing can be set into relation to the gross domestic product of a considered region, which then shows the magnitude the eco-innovation in question contributes to the GDP of that certain region (Kicherer et al. 2007). However, it has to be noticed that LCA is confronted with major drawbacks, such as the high costs to carry out an all-embracing LCA including all pre- and post-steps of all suppliers, suppliers of suppliers, distributors, customers and activities of disposal involved. Here, "the uncertainty and lack of precision of inventory data increase with the distance from the information collector (the firm)" (Schaltegger 1997, 4). Furthermore, the aggregation of environmental information with different spatial impact is problematic since "...aggregated local emissions do not provide any valuable information as they do not tell anything about the potential or even actual environmental impacts. One kilogram of mercury emitted on one hour at one place may kill many people, but the same amount emitted over a year at a hundred places may be without considerable impact. (...) Ecologically it therefore does not make any sense to aggregate interventions with local impacts that occur in different ecosystems. Such a life cycle perspective does not impede, but it rather creates, ecological sub-optimization!" (Schaltegger 1997, 4f.).

5.3.4 Environmental condition indicators as impact reference

Moreover, ISO 14031 suggests to have a set of environmental condition indicators (ECIs) that can give information about an eco-innovation's actual impact or potential impact on the surrounding environment (CEN 1999). In order to analyse the determination of a certain eco-innovation's contribution to the regional, national or global environmental conditions, e.g. of the ozone layer, air pollution, biodiversity, energy consumption, the core set of environmental indicators developed by the EEA (2005) could be used as reference environmental condition indicators (ECIs). This information should be integrated into the EIA side of the eco-efficiency equation. So far the European Union's work on indicator derivation has resulted in a core set of indicators[11]. The European Environment Agency (EEA) has selected a core set of 37 environmental indicators from a much larger set on the basis of the following criteria (EEA 2005):

- policy relevance,
- progress towards targets,

[11] see http://themes.eea.europa.eu/IMS/CSI

- availability and routinely collected data,
- spatial coverage,
- temporal coverage,
- national scale and representativeness of data,
- understandability of indicators,
- methodologically well founded,
- EU priority policy issues.

EEA stresses that the selected set of indicators is policy relevant and stable, however not static and therefore still subject to further future development. The indicators cover six environmental themes:

1) air pollution and ozone depletion,
2) climate change,
3) waste,
4) water,
5) biodiversity and
6) terrestrial environment.

Furthermore, four sectors are covered:

7) agriculture,
8) energy,
9) transport and
10) fisheries.

Though it is good to have such an already established set of reference indicators that can be used by all kind of different stakeholders with differing information needs, this set does not yet sufficiently cover all aspects to be considered and therefore is open to further indicator development (EEA 2005). EEA mentions that more research needs to be done on indicators covering other relevant priorities, such as chemicals, noise, industry, consumption, material flows (EEA 2005). Taking into account the above mentioned obstacles of data aggregation, it has to be taken into account that "only those interventions which impact the same ecosystems are considered, aggregated and assessed" (Schaltegger 1997, 5) giving privilege to decentralised and site-specific collection, recording and auditing of data, which in turn results in higher quality assessment.

5.4 Predictive institutional indicators for eco-innovation

Institutional or structural factors guide the actions of economic actors. It is '…clear that the development of technologies cannot be considered in isolation from the institutional settings that provide the rules of the game for firms, consumers and regulators.' (Foxon, 2003, p. 3).

This section explores the possible indicators of eco-innovation that could be derived from an examination of the institutional factors that affect eco-innovation. The section first gives our understanding of the meaning of the term institutions and then outlines a range of possible indicators in this area. The most promising of these indicators in terms of data availability, practicality of collection and construction of the indicators are summarised at the end of the section.

What do we mean by institutions?

Institutions are the framework of structures, mechanisms and norms within which economic, cultural and policy activity takes place and which influence how such activity takes place. There is a dynamic relationship between the activities taking place within the categories of institutions, culture, economy and policy. Institutions are shaped by interactions with and between the activities in the categories of culture, economy and politics. Equally well institutions influence the other categories.

Institutions can be legally defined: the organisations, structures and processes that control and shape cultural, economic and policy activities. They include political structures and processes, the rules governing economic transactions, environmental regulation (in its broad sense of all legally enforceable environmental instruments) and the planning system.

Alternatively, institutions need not be legally defined. They can be the attitudes, norms or accepted ways of doing things which while not legally defined still affect the way in which cultural, economic and political activity is conducted. These range from the trivial to more important, for example, the wearing of formal business attire and expected standards of courtesy and honesty. Legally defined institutions are likely to have attributes that are easier to measure than non-legally defined ones.

The sanctions for breaching the legally defined structures and processes of institutions are clear, or at least subject to legal determination. In the case of norms it is less clear. There is a range of possible behaviours around the norm which are likely to be underpinned by a legal minimum standard. Breaching norms may result in sanctions from other organisations/individuals, such as the removal of co-operation or dissolution of working relationships, or, alternatively, a more positive response that may actually create value for the organisations concerned.

The boundary between institutions and other categories, such as culture, economy, policy, is blurred. Individual policy measures fall into the policy category. However, as packages of measures develop they would seem to move towards creating an institutional framework. Alternatively, groups of policy instruments linked by an underlying principle (e.g. polluter pays or internalisation of external environmental effects) or approach (e.g. market based or command and control) could be put under the category institutions. Another useful distinction that could be made is that the mass of policies actually in place fall under institutions, but those under development and review by government fall under policy.

What are the most important institutional and structural factors relevant to eco-innovation?

The performance of institutions can be measured in many ways but what we are interested in is measuring the impact of institutions on eco-innovation.

Section 2 has distinguished between innovation and eco-innovation. Lamers (2007) suggests the following further differences:

- Technical innovation is market driven and reflects the needs of the consumers (computers, mobiles)
  - Eco-innovation is also additionally policy driven:
  - Policy sets standards and targets
  - Policy required to invest in clean air, water, carbon dioxide reduction
- Banks and investors are used to assessing technical and market risks.
  - For eco-innovation additional political risks have to be included.

So eco-innovation adds to the range of factors a firm has to consider in the process of developing its goods and services beyond whether an activity is financially viable and legally compliant. Assessing whether a firm's products meet environmental criteria and regulatory requirements complicates product/service development and may actually be beyond the capabilities of some firms. Assessment is likely to require use of non-economic assessment methodologies and also may be at odds (or at least may be perceived to be) with business and consumer preferences.

To develop predictive institutional indicators for eco-innovation it is necessary first to consider, 'what institutions affect eco-innovation?' and secondly, 'how can the impact of institutions be measured?'.

There is a range of different types of institution including for example:

- Political – formal societal decision-making processes
- Economic –governance of economic interactions and market formation
- Legal – development and upholding of law
- Environmental – regulation of interactions with the environment
- Planning – control of land use and spatial aspects of society
- Educational – organisations such as schools and universities but also curricula and education and the economic objectives guiding them
- Knowledge – management of knowledge development and distribution and protection of intellectual property rights.

All of these institutions will affect eco-innovation in some way. The task is to measure this impact and also identify drivers that are linked to eco-innovation rather than just innovation.

This project has identified five main elements that are of institutional importance to eco-innovation. Other than environmental regulation these are all factors that are typically considered to be important to innovation more generally. The five factors are:

1. Markets
2. Environmental Regulation
3. Intellectual Property Rights
4. Basic research and research & development: organisation and volume
5. Pre-competitive knowledge exchange and networks

Each of these five factors is discussed below and suggestions are made for possible indicators. The final part of this section gives a summary and recommendations for the most promising indicators.

5.4.1 Markets

1. Market indicator for innovation (not just eco-innovation)

The existence of well functioning markets may be an important spur for both innovation and eco-innovation. As such a measure of the health or functionality of markets is likely to be one aspect of an institutional indicator related to innovation and eco-innovation. This measure needs to capture some of the main aspects required of a functioning economic market such as upholding of market rules, supportive macroeconomic conditions, etc. Further measures will be needed to reflect how the market encourages or discourages eco-innovation.

The **Capital Access Index** (CAI) compiled by the Milken Institute may be one candidate for and indicator of the general health of the market. The CAI, 'ranks countries around the world in terms of the financial infrastructures that support entrepreneurial activity by providing access to capital. We look at such factors as macroeconomic environments, financial and banking institutions, the development of the equity and bond markets, and alternative capital sources. Because a firm's access to capital allows it to implement innovative ideas and contribute to technological advancement, job creation, and quality of life, the index is a tool for measuring how countries can act to reduce more fully their financing barriers.' (Barth, 2006, p.1).

Alternatively, or additionally, elements of the **Global Competitiveness Index** (GCI) produced annually by (World Economic Forum, 2006) may be useful measures of market health. The 2007/8 GCI specifies 12 pillars of global competitiveness:

Overall Global Competitiveness Index
Subindex A: Basic requirements
- 1st pillar: Institutions
- 2nd pillar: Infrastructure
- 3rd pillar: Macroeconomic stability
- 4th pillar: Health and primary education

Subindex B: Efficiency enhancers
- 5th pillar: Higher education and training
- 6th pillar: Goods market efficiency
- 7th pillar: Labor market efficiency
- 8th pillar: Financial market sophistication
- 9th pillar: Technological readiness
- 10th pillar: Market size

Subindex C: Innovation and sophistication factors
- 11th pillar: Business sophistication
- 12th pillar: Innovation

Either single elements or the overall composite index could be used for a number of the institutional elements we are interested in.

However, care should be taken in using GCI or other similar indicators constructed from a mixture of hard and soft sources as OECD (2004) notes, 'As an illustration, Gregoir and Maurel (2003) have analysed the robustness of the World Economic Forum (WEF) classification. They show that a totally different ranking could emerge among countries only by weighting the data used by the WEF differently on the basis of econometric results.' More details of CAI and GCI are given in the Annex.

Market indicators for eco-innovation (beyond innovation)

1. Investment in eco-innovation/green enterprises/green technology

Indicators:

- Total value of investments in eco-innovation, and as a proportion of total investment (broken down by investor type).

- Number and value of environment-focused investment funds (especially environmental technology focused) and venture capital operations in absolute terms and relative to non-green funds.

The indicators require a clear definition between eco-innovation and a distinction between it and green, ethical, or sustainable investment more generally (the difference between two suggested indicators above). A methodology would also be required to deal with flows of investment across international boundaries. Investment could be measured according to its source and destination, and by investor type e.g. government, private.

- Elements of relevance from the Environmental Sustainability Index (ESI):
    1. ESI Dow Jones Sustainability Group Index (DJSGI) and
    2. ECOVAL variables

The Environmental Sustainability Index (ESI) gives the following definition for DJSGI: 'Ratio of the market capitalization of the firms included in the 2005 Dow Jones Sustainability Index to the market capitalization of the firms eligible for inclusion in the Dow Jones Sustainability Index' (p317, Appendix C, Esty, 2005) and indicates also the availability of data for the indicator in countries covered by ESI.

The logic of using DJSGI in ESI is given as, 'The Dow Jones Sustainability Group Index tracks a group of firms that have been rated as the top 10% in terms of sustainability. Firms that are already in the Dow Jones Global Index are eligible to enter the Sustainability Group Index. Countries in which a higher percentage of eligible firms meet the requirements have a private sector that is contributing more strongly to environmental sustainability.' (p. 317, Appendix C, Esty, 2005).

The ESI ECOVAL indicator measures the average Innovest EcoValue rating of firms headquartered in a country. The EcoValue indicator is a measure of environmental performance at the firm level.

These indicators raise the question as to whether the firms used in these measures are representative of the broader economy. However, even if they are not they may cover a significant proportion of major and influential firms that are indicative of performance of the national economy. The relationship of these indicators to eco-innovation needs to be further explored, and whether the aspects of the indicator that measure environmental performance can be separated from broader sustainability issues. The **FTSE4Good** list of firms could be used in a similar way. However, an issue with all these data sets is the cost of gaining access to them.

2. Access to capital for eco-innovation.

The Capital Access Index (CAI) and Global Competitiveness Indicator (GCI), as discussed above, include measures for access to capital for all purposes. It may be possible to modify the measure of ease of access to capital to be more relevant to eco-innovation.

The 2001 Capital Access Index (CAI) looks at the relationship between access to capital and the Environmental Sustainability Index (ESI) (Yago et al 2001) and demonstrates a statistically significant link between CAI and both ESI and private sector responsiveness. 'Interestingly, one of the factors that seems to enable environmentally sustainable growth as measured by the ESI is the capacity of the private sector to develop green-friendly production techniques…The conditions of transparency and access that sustain capital flows are intertwined with environmentally sustainable development …'. (pp 32-33, Yago et al 2001). However, this seems to be a short piece of analysis that identifies the link but doesn't further explore the relationship and the existence of causal links.

3. Enhanced capital allowances (ECAs) for environmental technologies

Enhanced capital allowances can be used both as a measure of the amount of a particular (eligible) eco-innovative technology being adopted, and also as a driver to increase uptake of eco-innovative technologies. The effectiveness of both of these will be related to the range, definition and subject of ECAs. To be an effective measure of eco-innovation ECAs would need to be available to a wide range of eco-innovative technologies. They can be applied to specific named products or generic product categories which meet certain standards of environmental performance. Defined in the latter way they can be used to bring products to market which are not yet viable. An issue that arises for European cross-country comparison is the extent of ECAs and the consistency of the range of technologies that are covered by them across Europe.

Indicator:

- Existence, range and take up of ECAs.

4. Environmental standards for products and services

The existence, stringency and likely future development of product standards, whether for reasons of environmental performance, health or safety, are likely to be important factors affecting the degree of innovation in a market. Measuring the number of environmental standards in place would seem to be the most basic approach to judging this but overlooks how challenging the standards are relative to existing practice and what is technically possible. Even if challenging and progressively tightening standards are in place some measure of how well enforced these are is needed to gauge whether the standard is likely to be a meaningful incentive to innovation.

Indicators:

- Number of products/services on sale with environmental standards in place.

- Proportion of products/services on sale covered by environmental standards.

- Stringency (e.g. progressive tightening of standards) and institutional arrangements for enforcement.

Future work is necessary to find ways of capturing the stringency (or otherwise) of environmental standards. For example, standards may be in place but they may not be very challenging or have any requirement to improve. Ideally it is desirable to capture the difference between future standards, technical possibilities and current achievements. One possibility would be to measure the number of future product standards, enshrined in legislation or formal agreements, which go (significantly) beyond current performance. A significant enabler of the UK Climate Change Levy Agreements was the background research done in advance of their negotiation on the possibilities for cost-effective energy efficiency measures across a wide range of sectors. Also the European Commission project looking at the possibilities for product improvement, IMPRO, may be useful in this regard[12].

Indicator:

- Number of prosecutions/warnings for breaches of product standards.

Regulations will only incentivise innovation it is believed that they will be enforced, and the penalties give a significant incentive to comply. This is not always the case. For example, the enforcement of the Essential Requirements of the Packaging Regulations has been poor. In the UK only a handful of prosecutions have been made since introduction of Essential Requirements in spite of evidence of breaches.

5. Reporting requirements and public disclosure on environmental performance.
Environmental reporting is a driver of environmental performance and learning within firms whether it is compulsory or voluntarily. For example, compulsory reporting requirements of varying degrees of stringency exist in Denmark, the Netherlands, Norway, Sweden, France and UK. No compulsory requirements are in place in Central or Eastern Europe (ACCA, 2004). There are the also the IPPC requirements on reporting (which may be a possible source of data on eco-innovation performance). ACCA (2004) provides information on the status on non-financial reporting, globally and across Europe based on data collected by CorporateRegister.com.

Indicators:

- The existence of legal requirements to report on environmental performance in key areas such as carbon emissions and waste generation.
- Voluntary measures taken by firms to report on environmental performance in key areas such as carbon emissions, emissions, and waste generation.

[12] The second stage of the European Commission project Identifying products with the greatest potential for environmental improvement IMPRO (environmental IMprovement of PROducts) was intended to identify possible ways in which life-cycle environmental impacts can be reduced for some of the products that are among those with the greatest environmental impacts. The analysis first considered improvement potentials that are technically feasible. Following this, the associated socio-economic impacts were to be considered and analysed. The first three groups of products that are among those with the greatest environmental impacts currently analysed are: passenger cars, meat products and housing. The final results of the IMPRO project were expected by the end of 2007. Further information on the IMPRO project, available from http://susproc.jrc.es/pages/r4.htm and http://ec.europa.eu/environment/ipp/identifying.htm.

6. Availability of environmental specialists

The availability of environmental specialists is likely to influence the progress of eco-innovation and as such is a relevant institutional measure for eco-innovation. The number of environmental specialists could be used as a measure but requires an assessment of what constitutes an environmental specialist. More useful than the number of environmental specialists would be a measure which reflects the availability of appropriately qualified environmental specialists. This would need to reflect, not just the number of specialists, but the supply of specialists relative to the demand for their skills. An obvious point at which to measure this indicator is at the completion of degree level courses in terms of numbers of new graduates and postgraduates in environmentally related areas. However, this doesn't indicate that they will go on to work in related areas and a measure of active specialists would be useful. But the diversity of roles and situations in which environmental specialists are likely to be required makes data collection and indicator construction problematic. The indicators could focus on science and technology in terms of developing eco-innovations, or the more entrepreneurial skills associated with exploitation, or a mixture of both. Choosing a number of representative disciplines related to eco-innovation may be appropriate rather than the compilation of comprehensive data on all relevant skills and expertise.

Indicators:

- Number of different types of key specialists actively involved in eco-innovation – e.g. engineers (and subtypes), designers, managers, etc within firm or external consultants.
- Supply and demand – through a Community Innovation Survey question on whether firms can source sufficient eco-innovation specialists.
- New graduates and postgraduates in key environmental disciplines – measure number of environment-related masters' course graduates.
- Global Competitiveness Index (2006/7) 9th Pillar: Innovation 9.05 Availability of scientists and engineers (see Annex).

Data is available on graduates in science and technology through the Eurostat (Human Resources in Science and technology (HRST) database[13] but further data on disciplinary breakdown is needed to make this a useful indicator of eco-innovation.

The collaborative project between UNESCO's Institute for Statistics (UIS) and Eurostat on Careers of Doctorate Holders (CDH) may improve data in this area, particularly in going beyond graduates' first destinations, but it appears that it will only provide data on the generic situation of graduates rather than breakdowns by area of expertise. The project aims at developing a regular and internationally comparable production system of indicators on the careers and mobility of doctorate holders. 'A first metadata and data collection was launched in Autumn 2005, which provided a first set of results for seven countries: Argentina, Australia, Canada, Germany, Portugal, Switzerland and the United States. These first results shed light on the main demographic, educational, labour market and mobility patterns of doctoral graduates. They also mark some progress in the understanding of both the measurement issues and patterns of international mobility, notably by the use of qualitative indicators such as the intentions or reasons for mobility.' (Eurostat (2007) While this work will develop knowledge in understanding the careers of doctorate holders it will obviously be a while before data is available with European coverage.

7. Share of market for domestically-produced environmentally preferable goods

[13] See http://europa.eu.int/estatref/info/sdds/en/hrst/hrst_st_sm.htm for details of database.

A measure of the market share of domestically-produced environmentally preferable goods in particular markets (e.g. organic food, renewable energy, rail/road passenger km) and the trend in these measures would provide a clear indicator of whether the overall conditions exist for eco-innovative products to make it to market. It would also provide a useful measure of overall success of eco-innovation activities. However, the trends would be dependent on a wide range of factors throughout the innovation process. Indicators covered might include:

- Organic food to conventional food (value and/or tonnage)
- Renewable to conventional energy
- Road to rail passenger km
- Road to rail freight kms.

Data from the PRODCOM database available from Eurostat may be able to provide data on some of these areas in terms of value or volume and could be a base from which to build these selected indicators. In summary, 'PRODCOM is a system for the collection and dissemination of statistics on the production of goods in the EU-27. Information provided in PRODCOM includes data for the value and volume of production in the Member States that has been sold by their producers in a particular reference year. Commodities are specified in the PRODCOM list, which includes around 4 500 products, updated on an annual basis' (p.18, Eurostat, 2007)[14].

5.4.2 Environmental regulation and internalisation of environmental effects

1. Quality of environmental regulatory regime

A well designed and implemented regulatory regime should penalise firms and individuals that breach regulations, reward those who are compliant or exceed current requirements and assist by raising awareness of regulatory requirements and the means to meet them. A poor system of environmental regulation will reduce the willingness of firms to eco-innovate for a number of reasons. Firms who are trying to innovate may be economically undermined by firms whose poor performance or compliance is likely to result in reduced costs; the areas in which eco-innovation is considered desirable may not be made clear by the regulatory system; or the system may be unresponsive to the entry to new technologies and processes.

The aspects of a regulatory regime that might be desirable to measure might include the proportionality of regulatory actions, responsiveness to new developments (policy and science), clarity of requirements, transparency, predictability, and stability over time amongst others. The range of aspects that could be measured suggests that a single measure of regulatory quality is inappropriate and this is supported by Radaelli and De Francesco (2004) "It would be wrong to look for 'the' measure of regulatory quality. Not only does quality mean different things in the light of different principles and the preferences of different stakeholders, it is also extremely difficult to capture it by dint of a single measure. No matter what the quality of aggregation is, it is usually very difficult to deduce or infer from ambitious indexes of quality what needs to be done to further improve regulatory quality. The consequence is that we recommend systems of indicators rather than individual indexes. Complex measures – we argue – should be considered as one component of a system of indicators that also includes simple measures." The paper suggests three possible systems to assess regulatory quality which are consistent with Lisbon objectives. The first is a simple

[14] See http://europa.eu.int/estatref/info/sdds/en/europrom/europrom_base.htm

macro *ex ante* system, the second a more complex *ex post* system and the third one based on a sophisticated quality assurance system intended to provide 'a bridge between measurement of regulatory quality and the systematic evaluation of better regulation.'
The OECD has investigated Regulatory Quality Indicators[15] and states:
"Indicators of regulatory quality tell us something about the performance and quality of regulations. The primary focus of this project is on the process that produces regulations: carried out in the right way, it can help bring about regulations of high quality, which again can have a positive influence on economic performance. The regulatory process consists of three elements that have an influence on the countries' capacities to assure high quality regulations: regulatory policies, regulatory tools and regulatory institutions. All of these elements contribute to countries' capacities to assure high quality regulations."
The OECD was invited to participate in work by the European Commission on Regulatory Quality Indicators. The project aimed at developing a set of regulatory quality indicators, and launch a survey to map country performance. The final report [See Radaelli and De Francesco, 2004] is now available.
The measures from the above work focus on the economic aspects and impacts of regulation rather than the environmental impacts of the regulatory system. In the absence of better measures the following are proposed as potential measures of the quality of environmental regulatory regimes:

- Number of prosecutions for breaches of environmental regulations by regulator(s).
- Value of fines (total and average) imposed for breaches of environmental regulations
- Levels of environmental taxation in absolute terms, and as a proportion of total tax revenues and GDP.

From a quick investigation data for the first two measures do not seem to be available on an EU wide basis. The European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL) may be the organisation to clarify this point.[16] Data are collected in, for example, the UK where a National Enforcement Database exists. It has not been possible to investigate whether other member states hold this or similar data, and it is not clear if the UK database is in the public domain. However, summary details for successful prosecutions are given on the Environment Agency website: 'successful prosecutions against firms in 2006 totalled over £3.5 million in fines that averaged £11,800 per business (compared to a total of £2.7 million and an average £8,600 in 2005). We successfully prosecuted 380 individuals; including 29 firm directors in 2006. Six directors were fined £5,000 or more and five received other penalties, including two custodial sentences totalling 14 months'.[17]

For the third suggested measure data is available but there are the issues of whether green taxes revenues should diminish if they are the taxes are effective and it also not really a regulatory measure. However, the level of green taxes may possibly be a proxy of overall level of environmental regulatory activity.

2. Extending systems of producer liability, producer responsibility and polluter pays

[15] See http://www.oecd.org/document/3/0,3343,en_2649_34141_34061123_1_1_1_1,00.html#Regulatory_Quality
[16] See http://ec.europa.eu/environment/impel/index.htm
[17] See http://www.environment-agency.gov.uk/yourenv/eff/1190084/pollution/296030/296054/?version=1&lang=_e

Extending producer liability, producer responsibility and polluter pays are about extending the reach of the regulatory system beyond point sources of pollution and creating mechanisms that encourage producers to adopt responsibility for the impacts of their products and services across the life cycle.

Extended liability involves increasing the liability of firms for the unintended impacts of their activities/products, for example, making firms landfilling waste liable for impacts from the landfill even after site is closed.

In terms of financial risk, producer responsibility is less onerous than extended liability as the impacts of products are easier to predict than the extended liability impacts but it still can place requirements for producer to address impacts of product across the life cycle and beyond the point of purchase.

Some potential indicators for extended liability and producer responsibility:

- Number of extended liability arrangements in place, forthcoming or proposed
- Proportion of firms and sectors with extended liability arrangements in place, forthcoming or proposed
- Number of extended producer responsibility arrangements in place, forthcoming or proposed
- Proportion of firms and sectors with extended producer responsibility arrangements place, forthcoming or proposed.

Any indicator needs to define how to treat the different aspects of producer responsibility, which may include:

- Take back requirements at end of life,
- extended free guarantees/maintenance agreements given by producer/retailer,
- eco-labelling,
- performance targets,
- eco-design requirements.
- measures to reduce the impact of a product in use – direct e.g. improved product standard or indirect e.g. cost recovery, such as, for example, paying for the removal of nutrients or pharmaceuticals from water supply.

Some of these measures are more effective than others but also the type of producer responsibility measure used will vary according to nature of product.

5.4.3 Intellectual property rights (IPR)

This institutional factor is concerned not with the output of intellectual property from the economy but with the systems that protect those who generate intellectual property and allow its exploitation. The inability to protect intellectual property is often considered a significant disincentive to innovation of all types. However, systems of IPR also need to allow diffusion and incentivise others to use that intellectual property, provided of course they acknowledge the IP's owner appropriately, whether financially or otherwise. A compromise needs to be struck, 'between the negative aspects of monopoly that they involve and the good of technological progress they can encourage' (Pitkethly, 1999). These comments apply to innovation generally not just eco-innovation.

As with other institutions the elements that are important with regard to a system of Intellectual Property Rights are its existence and the quality of the system.

1. Quality of systems of intellectual property rights

As with indicators intended to reflect the quality of other regulatory systems there is an issue here of how to develop simple metrics that adequately reflect complex systems. Qualitative approaches which survey the views of those using the system will give a greater level of detail but are costly to complete. Quantitative approaches may not give as a clear a picture but data collection is easier.

Potential measures reflecting the quality of patent system include:

- Cost of obtaining patents
- Speed of granting patents once they have been submitted
- Number of pending applications for patents[18]
- Access to the patent system, i.e. cost of application as a barrier - measured by distribution of applicant organisations' size in terms of staff and turnover (although this may reflect true relative outputs of innovations of different size firms)
- Effectiveness of checking for prior patents.

The PCT Union's (international Patent Co-operation Treaty Union) International Search and Preliminary Examination Guidelines, which were established by the International Bureau of the World Intellectual Property Office (WIPO), has a chapter on the adoption and implementation of quality management systems by the International Authorities (WIPO, 2004). These were initially intended as a guide to the development of internal quality assurance but it appears that there are moves to standardise certain aspects of this which would result in comparable indicators for different patent granting organisations that are members of the PCT Union (WIPO 2005).

2. Enforcement of systems of intellectual property rights

- Existence of effective systems for challenging breaches of IPR
- Number of challenges and/or number of successful and failed challenges. Numbers of this kind may not be very meaningful – it is not clear whether an effective system would have many or few challenges, or more or less successful vs. failed challenges
- Cost of mounting an IPR challenge.

3. Patent licensing

Patent licensing activity is indicative not only of an effective IPR system but also the translation of IP into products and services that are likely to reach the market.

- Number and value of patents licensed to third parties
- Number and value of environmental patents licensed to third parties
- Institutional activities to promote take-up (licensing, development) of environmentally beneficial inventions.

[18] See http://www.wipo.int/ipstats/en/statistics/patents/patent_report_2007.html#P673_38549 for data on this indicator

Overall measure for IPR

The above aspects could be combined into a measure of overall budgets of patent offices and split between registering, enforcing and licensing activities for all and specifically environmental activities. Similar approaches could be used for other IP systems, including trademarks, copyright, and community designs.

5.4.4 Basic research and research & development: organisation and volume

The European Innovation Scorecard[19] (EIS) has a number of measures of innovation in terms of R&D and basic research:

EIS INPUT – KNOWLEDGE CREATION

2.1 Public R&D expenditures (% of GDP) EUROSTAT, OECD
2.2 Business R&D expenditures (% of GDP) EUROSTAT, OECD
2.3 Share of medium-high-tech and high-tech R&D (% of manufacturing R&D expenditures) EUROSTAT, OECD
2.4 Share of enterprises receiving public funding for innovation EUROSTAT (CIS4)

EIS OUTPUT – INTELLECTUAL PROPERTY

5.1 EPO patents per million population EUROSTAT
5.2 USPTO patents per million population EUROSTAT, OECD
5.3 Triadic[20] patent families per million population EUROSTAT, OECD
5.4 New community trademarks per million population OHIM
5.5 New community designs per million population OHIM

The EIS measures innovation generally rather than eco-innovation. De Vries (2007) indicates that **environmental innovations** can be measured within overall patent data and gives example of how environmental regulation on SO_2 was reflected in patent data. He cites the strengths of patents as including: they are an output measure of innovation (if not economic performance) compared to the other major measure of innovation activity – R&D – which is an input measure; they are widely available and combine detail with coverage; and can be broken down into different technological areas. An important source of data on patents is WIPO (2007).

5.4.5 Pre-competitive knowledge exchange and networks

Many sources indicate the importance of activities involving co-operation and networking to the delivery of innovation. Foxon (2003) in his overview of innovation theory discusses some of these, for example, OECD studies (OECD 1999, 2002) that identify several broad trends that are combining to change the conditions for successful innovation including:

- *Growing importance of linkages and interactions between the science base and the business sector:* the importance of feedbacks from the development, production and use stages to scientific research has been highlighted above;

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[19] See Appendix for full set of measures used in European Innovation Scorecard.

[20] A triadic patent is a patent for the same invention that is filed at the European, Japanese and American patent offices.

- *Increasing need for firms to engage in networking and collaboration:* this is particularly as a consequence of importance for good business practice of the growth and diversity of knowledge-intensive services. Networking and collaboration may result in *clusters* of innovative firms and other private and public knowledge-based organisations as key local or regional drivers of growth and employment;

A practical example of action by a government to promote networking and information flow is Environment Canada's Corporate Environmental Innovation (CEI) (Moffat and Auer (2006)), the approach of which is based on:

- Generating and sharing knowledge and information
- Linking sustainable development to business value
- Developing tools and the capacity for cultivating innovative corporations.

Indicators:

- Number of networks in existence to promote eco-innovation.
- Number of firms involved in networks to promote eco-innovation
- Existence and number of sector clusters
- Pre-competitive knowledge exchange and networks – number and turnover of firms involved in environmentally beneficial knowledge exchange networks.

The Community Innovation Survey (CIS) collects data on the percentage of innovation-active firms reporting co-operation arrangements on technological innovation activities with other organizations. Broadening the relevant CIS questions to address eco-innovation would be one possible way of getting better data on this.

5.4.6 Summary of possible predictive institutional indicators of eco-innovation to use and develop

Markets

Indicator number	Objective	Indicator	Comments
1	To measure the overall health/functionality of market (as a pre-requisite for eco-innovation to occur).	a. Capital Access Index: use overall index or sub-components, e.g. 'macro-economic environment' or 'institutional environment'. b. World Economic Forum Global Competitiveness Index and/or 'pillars' that contribute to it, e.g. 'Pillar 1 Institutions'.	Indexes available and annual time series with global coverage including EU 27. Issue of sensitivity of final index to weightings used in its construction.
2	To measure the degree to which the market encourages eco-innovation	a. Number and value (absolute and relative to all investment) of environment-focused investment funds. b. Availability of venture capital for eco-innovation.	Need to define what constitutes a green investment and how this relates to eco-innovation. Can Eurostat venture capital data be broken down to reflect eco-innovation investment?
3	To measure the respon-	Elements of Environmental Sus-	Data available from ESI for one

	siveness of the market to eco-innovation.	tainability Indicator: a. Dow Jones Sustainability Group Index (DJSGI). b. ECOVAL (the average Innovest EcoValue rating of firms headquartered in a country.	year but not as a time series. See p317-318, Appendix C, Esty (2005). Presumably data available for other years from Innovest for EcoValue, Dow Jones, but at a cost.
4	To measure the existence of compulsory environmental reporting requirements as an indicator of the significance of environmental performance in the market.	Existence of compulsory public reporting of environmental performance.	Based on assumption that public reporting drives environmental performance.
5	To measure degree of importance businesses attach to environmental performance.	Percentage of firms reporting voluntarily on environmental performance (and in key areas such as carbon emissions, emissions, and waste generation.	Data available to 2004 (at least) from ACCA (2004) with and further years potentially from CorporateRegister.com
6	To measure availability and demand for environmental specialists	a. Number of new graduates and postgraduates in environmental disciplines. b. Demand for environmental specialists.	Use existing databases of graduate disciplines, e.g. Eurostat HRST database, but issue of level of detail and need to define range of relevant disciplines Collect data through surveys of business managers – or add a question to CIS survey? For example, are there sufficient environmental specialists available for your firm to employ?
7	To measure the changing market share of a representative range of environmentally preferable goods and services	Share of market for domestically-produced, environmentally preferable goods and services..	Use Eurostat PRODCOM database as basis for value and volume of goods in key generic categories?

Environmental regulation and other pressures for internalisation of environmental effects

8	To measure the quality of the system of environmental regulation (as a factor reducing undercutting of eco-innovative activities).	a. Number of prosecutions for breaches of environmental regulations. b. Value of fines (total and average) imposed for breaches of environmental regulations.	Is data available across Europe? Available in UK but may not be in public domain.

Intellectual property rights (IPR)

9	To measure the quality of systems of intellec-	a. Number of pending applications for patents.	‘a’ available from WIPO. Data for others from European

	tual property rights - protecting and licensing IP.	b. Number and value of patents licensed to third parties. c. Number and value of environmental patents licensed to third parties.	Patents Office?

Basic research and research & development: organisation and volume

10	To measure the degree of organisation of basic research and R&D, in general, and in relation to eco-innovation.	Use existing European Innovation Scorecard measures (EIS): **Input – Knowledge Creation** 2.1 Public R&D expenditures (% of GDP) 2.2 Business R&D expenditures (% of GDP) 2.3 Share of medium-high-tech and high-tech R&D (% of manufacturing R&D expenditures) 2.4 Share of enterprises receiving public funding for innovation. **Output – Intellectual Property** 5.1 EPO patents per million pop. 5.2 USPTO patents per million population 5.3 Triadic patent families per million population 5.4 New community trademarks per million population 5.5 New community designs per million population.	Need to modify/use alternatives to get measures related to eco-innovation. WIPO (2007) gives data on numbers of patents by 30 different technical fields for years 2000-2004 including Environmental technologies (see page 23, WIPO, 2007).

Pre-competitive knowledge exchange and networks

11	To measure the amount of networking activity which encourages eco-innovative outcomes.	a. Number of mechanisms (e.g. networks) to transfer eco-innovation insights between research community, business and government. b. Number of people involved in eco-innovation knowledge transfer networks. c. Number and turnover of firms involved in eco-innovation knowledge transfer networks.	For example, numbers of bodies such as ETAP, CIP (Competitiveness and Innovation Framework Programme) and number of firms/ people involved. CIS has information on the percentage of innovation-active firms reporting co-operation arrangements on technological innovation activities with other organizations. Could these CIS questions be broadened to address eco-innovation? Inno-Policy Trendchart approach could also be extended to eco-innovation.

5.5 Predictive cultural indicators for eco-innovation

Definition of cultural mechanisms

For the purpose of this project cultural mechanisms are defined as:

- The socially transmitted values, attitudes, and behaviours of people, firms and groups in society,
- Knowledge and understanding in society - but not the institutions of knowledge and understanding - that they are formed in.

Cultural mechanisms are fundamentally important to innovation as they affect the nature of interactions between individuals, organisations and institutions and the understandings of innovation these groups have.

Cultural mechanisms affect eco-innovation in the same way as they affect innovation. However, cultural mechanisms are a fundamental factor affecting both the degree of importance individuals and institutions attach to environmental issues and also their willingness or ability to act on these concerns.

The aspects that could be measured to get an insight into the cultural mechanisms affecting eco-innovation are likely to require an emphasis on qualitative rather than quantitative approaches.

James (2005) considers that there is a long way to go in understanding cultural mechanisms and how they may impact on innovation, let alone eco-innovation, and how the impact of these mechanisms might be measured:

> "Indeed, it is now difficult to explain the continuing competitive advantage of certain industrial clusters over others if their cultural conventions, rules of behaviour and explicit accord are not taken into account. ... While there is growing consensus that culture plays an important role in shaping the conditions conducive to innovation, the precise impact of regional culture on the competitive performance of firms in innovative regional economies has yet to be fully specified, let alone measured. ... As long as culture remains inadequately conceptualized, theorized, and empirically verified within the regional learning and innovation literature, it will continue to be viewed by many as a 'dustbin category', at best brought in as an ad hoc bolt on to orthodox economic policy analyses; at worst, it will be sidelined completely."

Ernst (2001) comes to a similar view:

> "In short, it can be summarized that innovation research lacks a profound empirical study to date which analyses the relationship between organizational culture and innovative performance on the firm level based on a theoretically derived and valid measurement scale for organizational culture."

However, more positively Dorabjee et al. (1998) report on "a pilot study carried out to investigate methods for determining corporate culture in the pharmaceutical industry and its effect on innovation and development of new medicines. The results showed that it is possible to use a questionnaire-based approach for this type of investigation to demonstrate cultural differences between firms and between departments. Furthermore, the results could be related to factors most suited to fast development and to innovation."

These quotes focus on the organisational and business cultures that are conducive to innovation and indicate some confusion as to whether there is a common understanding of how cultural mechanisms affect innovation. There is also a broader set of cultural mechanisms that will impact on individual and institutional values, attitudes and behaviours in respect of the environment and eco-innovation, and these need to be considered.

This project has identified four main cultural aspects that are of importance to eco-innovation. These are:

1. Knowledge of eco-innovation performance
2. Insight into the factors conducive to eco-innovation
3. Values conducive to economic innovation
4. Values conducive to eco-innovation

Each of these factors is discussed below and suggestions are made for possible indicators. The final part of this section then gives a summary and recommendations for the most promising indicators.

5.5.1 Knowledge of eco-innovation performance

This aspect is intended to reflect whether there is progress, and awareness of progress, on eco-innovation, first, through measures of progress of eco-innovation (their coverage, quality and gaps within them) and second, the uptake of indicators of eco-innovation and by whom they are being used.

Given the status of data in this area, the indicator is likely to need to be largely based on a qualitative approach to reviewing progress, i.e. surveys of whether indicators are being used, rather than the collection of quantitative data that indicates actual progress on eco-innovation. Extending the scope of Pro Inno Europe's[21] approach to measurement and characterisation, as used in Inno-Policy Trendchart and Inno-Metrics, would be one way to collect data in the area of eco-innovation at the national and regional level. "The INNO-Policy TrendChart describes and analyses major innovation policy trends at national and regional levels across Europe in an independent way…A policy monitoring network tracks developments in innovation policy measures in 39 countries. The information collected by this network is used to run and maintain an inventory of innovation policy information and policy measures, and also feeds into annual country reports and an annual European Innovation Progress Report."[22]

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[21] PRO INNO Europe is an initiative of Directorate General Enterprise and Industry which aims to become the focal point for innovation policy analysis, learning and development in Europe. See http://www.proinno-europe.eu/ for more info.
[22] Quote taken from Pro Inno Europe website: Inno-trend http://www.proinno-europe.eu/index.cfm?fuseaction=page.display&topicID=52&parentID=52

Questions could also be added to the Community Innovation Survey to gain information on whether firms use eco-innovation indicators.

However, some quantified indicators could be derived from the survey suggested above:

- Member states with national eco-innovation performance indicators in development,
- Member states with national eco-innovation performance indicators in use,
- Regions with eco-innovation performance indicators in development,
- Regions with eco-innovation performance indicators in use,
- Firms with eco-innovation performance indicators in development.
- Firms with eco-innovation performance indicators in use.

Depending on the degree of coverage and consistency of measures revealed in collating the above measures, other more quantitative measures could perhaps be developed.

5.5.2 Insight into factors conducive to eco-innovation

The objective here is to measure the level of understanding of the factors that result in eco-innovation. While it may be possible to assess this through various types of review process it is not something that translates easily into an indicator. Questions that would need to be addressed include:

- Where is insight on eco-innovation to be found? Possibilities include academic literature, the knowledge and practices of individuals/organisations, or policy analysts in government.
- How should the existence of an ‘insight’ and numbers of insights be assessed?
- If an ‘insight’ can be identified, how can its quality be assessed? This is likely to be subjective. Academic and business literature contains numerous insights into innovation but these of varying quality and limited use.
- How to measure progress on developing insight over time? This might be approached by the dominance, acceptance and use of particular concepts, approaches and theories by different bodies responsible for innovation; by assessing the number and usefulness of new theories developed. Citations for particular works could be counted.

Assessing these points could be done through ongoing process of detailed research and review but the outputs do not lend themselves to being captured in a simple indicator.

The quantity of research into eco-innovation processes could be used as a proxy for understanding of eco-innovation, assuming that the quantity of research is related to level of insight. The quantity of research could be measured either as an input or output:

- Output: number of papers/reports/conferences on eco-innovation processes,
- Input: numbers of researchers/research bodies working on eco-innovation processes,
- Input: research budgets at EU, national and regional level for eco-innovation

- Existence of mechanisms (networks) to transfer insights between research, business and government.

A further and critical issue is that some means is needed to identify the research that is related to eco-innovation. Given the breadth if disciplines that contribute to eco-innovation research this could be difficult. However, bibliometrics based on relevant key words related to eco-innovation could be used. This would not require the detailed analysis of research content that a full review process would require but does require some consideration of whether identified papers are relevant to eco-innovation.

Alternatively, the existence and number of knowledge transfer mechanisms could be used as a proxy for eco-innovation insights. These would use two of the indicators suggested for the institutional indicator of pre-competitive knowledge transfer.

5.5.3 Values conducive to economic innovation

Martins and Terblanche (2003) have assessed the values that seem to be conducive to innovation:

"Post-industrial organisations today are knowledge-based organisations and their success and survival depend on creativity, innovation, discovery and inventiveness. An effective reaction to these demands leads not only to changes, in individuals and their behaviour, but also to innovative changes in organisations to ensure their existence (Read, 1996) ... Organisational culture appears to have an influence on the degree to which creativity and innovation are stimulated in an organisation. ... Based on a literature study it was found that there is little agreement on the type of organisational culture needed to improve creativity and innovation. There also seems to be a paradox in the sense that organisational culture can stimulate or hinder creativity and innovation (Glor, 1997; Tushman and O'Reilly, 1997). Several researchers (Ahmed, 1998; Filipczak, 1997; Judge *et al.*, 1997; Nўstrom, 1990; O'Reilly, 1989; Pinchot and Pinchot, 1996; Tesluk *et al.*, 1997) have worked on identifying values, norms and assumptions involved in promoting and implementing creativity and innovation. Very few empirical studies, and especially quantitative research, seem to have been done to support the findings of researchers, but several values, norms and beliefs have been identified by researchers such as Judge *et al.* (1997), Nўstrom (1990) and O'Reilly (1989) in their empirical research."

The Climate for Innovation Questionnaire (CIQ)[23], examines the organisational environment, in the context of creativity and innovation and has the following dimensions:

- Challenge/involvement
- Freedom
- Trust
- Idea time
- Play/humour
- Conflicts
- Idea support
- Debates
- Risk taking

[23] 'Originating from the University of Lund in Sweden (Ekvall, 1996), but further developed by the Creative Problem Solving Group, Buffalo, USA (Lauer, 1996)' Dorabjee (1998). Also see http://www.innovationclimatequestionnaire.com/

For each of these dimensions a series of questions is asked. The dimensions are based on previous work examining the factors conducive to innovativeness and creativity in organisations.

Beugelsdijk (2007), which contains a useful literature review of entrepreneurial traits and how they relate to innovation performance, demonstrates a link between entrepreneurial culture, innovativeness and economic growth: ‘In this paper, we empirically study the relationship between entrepreneurial culture and economic growth. Based on a micro based comparison of entrepreneurs and non-entrepreneurs, we develop a measure reflecting entrepreneurial attitude at the regional level. We subsequently relate this newly developed variable, ‘entrepreneurial culture,’ to innovativeness and economic growth in 54 European regions. Extensive robustness analysis suggests that differences in economic growth in Europe can be explained by differences in entrepreneurial culture, albeit mostly in an indirect way.’

The European Innovation Scoreboard (EIS) (2006) indicators under the heading of Input – Innovation & Entrepreneurship are relevant in this area and have the significant advantage that they are already collected.

3.1 SMEs innovating in-house (% of all SMEs)
3.2 Innovative SMEs co-operating with others (% of all SMEs)
3.3 Innovation expenditures (% of total turnover)
3.4 Early-stage venture capital (% of GDP)
3.5 ICT expenditures (% of GDP)
3.6 SMEs using organisational innovation (% of all SMEs).

From this brief sampling of a much broader literature on organisational culture and innovation there are measures and approaches which are intended to reveal cultural mechanisms that affect innovation at the firm level. However, a number of possibly interesting approaches used are based on qualitative approaches which are resource intensive to compile on a wider geographical or temporal basis. Further work is also needed to consider the link with broader societal values and economic innovation.

The literature on the organisational values that are conducive to economic innovation is unclear. However, approaches such as the Climate for Innovation Questionnaire have been used to measure these values at a firm level. These approaches are based on empirical studies of a larger number of firms but these approaches are used commercially and data underlying them may not be in the public domain making them unsuitable for publicly available European Indicators.

Alternatively, the results of a firm having values conducive to economic innovation can be measured, for example, in terms of the innovation inputs this results in. Some of the European Innovation Scoreboard indicators can be used to measure values in this way. However, while innovation inputs may be indicative of the presence of values conducive to economic innovation they do not reveal what these values are or how these can be encouraged.

5.5.4 Values conducive to eco-innovation

In addition to the broader factors important for innovation what are the values held by individuals and expressed by organisations which are of relevance to eco-innovation? That is, aside from economic or legal requirements and drivers, what are the factors that mean eco-innovation is likely to be considered important by individuals and institutions? These factors can be revealed through qualitative research on public opinions and values or through measurement of proxies that are likely to be related to these.

Qualitative research can be conducted using polls, focus groups or deliberative approaches, although these are time and resource intensive. Issues that could be explored in this way include:

- Degree and trend of environmental concern expressed by individuals, households, businesses, government, educational institutions, media. Not only as a single issue but also relative to other issues – economy, health, education, crime etc.
- Degree and trend of understanding of environmental problems shown by individuals, firms etc.
- Degree and trend of responsibility for creation and solving of problems acknowledged by firms, individuals etc.
- Public awareness of environmental impacts of everyday actions.
- Trends in individual environmentally beneficial actions (e.g. turning off lights/appliances, recycling/reusing).
- Willingness of individuals/organisations to experiment with new environmental-related approaches/products.
- Trust/belief in institutions such as government, experts, on environmental issues.

There is a wealth of data on questions such as these collected by firms, governments and research institutes. However, consistency between research, variability of opinions over time and in response to new developments, and the large impact of the way questions are framed, all mean care is needed in transferring the conclusions to areas they were not explicitly intended to inform.

The main source of data is opinion polling data, with numerous relevant polls conducted, but there is an issue around compatibility, coverage and time series for data. Also opinion polls focus on attitudes to environment rather than eco-innovation. And of course there may be other values that are conducive to eco-innovation, for example, a desire to be market leader in a developing sector. These need to be explored through further research. Other approaches can give insights, for example, deliberative work, but these are unlikely to provide affordable cross-Europe, time series data. Another alternative is to use proxy measures approach that assume pro-environmental/eco-innovation values are expressed through, for example, membership of environmental groups, or green purchasing/procurement. These may be easier to gather data on.

The European Values Survey[24] would be one source of data on cultural mechanisms especially as it goes beyond a focus on organisational or business culture. However, while there is a time series for this date, the 'waves' of data collection are rather infrequent to make it a useful indicator for policy.

The European Commission's Eurobarometer survey of public opinion in the European Union[25] is also a promising source of data in terms of the questions it asks about attitudes to the environment and in particular the protection of the environment and the role of EU in environmental protection, in its standard twice yearly survey.

[24] See http://www.europeanvalues.nl or http://spitswww.uvt.nl/fsw/evs/index2.htm for details
[25] See http://ec.europa.eu/public_opinion/index_en.htm for further details.

Alternatively, the following proxy measures may be easier to measure, but give less direct insight into the values conducive to eco-innovation:

- Membership of (environmental) NGOs – but while a relationship between this and interest in the environment (or other issues) may be expected, the relationship to eco-innovation may be less conclusive.
- Participation of institutions/processes to jointly explore environmental problems, develop shared agreement on responses and allocate responsibility for action – e.g. Dutch model of cross-sectoral policy development (this seems as much a cultural as an institutional mechanism)
- Purchasing habits of individuals and organisations as one reflection of values and attitudes:
  - Individuals/households
    - Value of eco-innovative products bought annually by households and nationally
    - Proportion of household budgets spent on eco-innovative products annually
    - Individuals/households possessing particular technologies and take up trends of these products
  - Public procurement – existence of green procurement policies and value of green procurement as total value and relative to all procurement
  - Private procurement – existence of green procurement policies and value of green procurement as total value and relative to all procurement
- Environmental Sustainability Index indicator of relevance - IUCN (The World Conservation Union) member organizations per million population. IUCN is the oldest international environmental membership organization, currently with more than 1000 members (governmental and NGO) worldwide, including the most significant environmental NGOs in each.
- GCI elements of relevance
  - Pillar B. Private Institutions, 1. Corporate ethics, 1.12 Ethical behaviour of firms
- Environmentally engaged content in primary school curricula.

5.5.5 Summary of possible predictive cultural indicators of eco-innovation to use and develop

Knowledge on eco-innovation performance

Objective: to understand if we are making progress on eco-innovation?

Indicator number	Objective	Indicator	Comments
1.	To measure progress at EU and member state level on development of eco-innovation indicators through existence and coverage of measures of eco-innovation.	a. Number of member states with national eco-innovation performance indicators in development. b. Number of member states with national eco-innovation performance indicators in use. c. Number of regions with eco-innovation performance indicators in development.	Extend scope of Pro Inno Europe's approach to measurement and characterisation, as used in Inno-Policy Trendchart and Inno-Metrics, to eco-innovation for member states and regions. Also by consideration of material from ETAP, ETAP National Action Plans and National Innovation Strategies. See Inno-view survey by

		d. Number of regions with eco-innovation performance indicators in use.	Cunningham (2007), as an example, but only covers measures of innovation, not eco-innovation.
2.	To understand whether firms are using measures of eco-innovation.	a. Number of firms with eco-innovation performance indicators in development. b. Number of firms with eco-innovation performance indicators in use.	Not available – add to Community Innovation Survey questionnaire? Importance of positive response is the indication that firms are interested in eco-innovation rather than the level of performance any indicator might reveal. Depending on number of firms using eco-innovation indicators it may provide a useful source of data for performance assessment.

Insight into factors conducive to eco-innovation

Objective: to measure the level of understanding of the factors that result in eco-innovation.

Indicator number	Objective	Indicator	Comments
3.	To measure quantity of research inputs on eco-innovation as a proxy for the level of understanding of eco-innovation processes.	Quantity of research (value, number of researchers/research institutes) active in areas of eco-innovation.	Currently not available. May be possible to create from existing data on research activities. But would require assumptions about the areas of research that are relevant to eco-innovation. Available from Commission, ETAP, or member states?
4.	To measure quantity of research outputs on eco-innovation as a proxy for level of understanding of eco-innovation processes.	Number of a. journal papers b. reports c. conferences on eco-innovation.	Construct through bibliometric analysis.
5.	To measure existence of knowledge transfer mechanisms as a proxy for understanding of eco-innovation processes.	a. Number of mechanisms (e.g. networks) to transfer eco-innovation insights between research, business and government. b. Number of people involved in eco-innovation knowledge transfer networks.	For example, numbers of bodies such as ETAP, CIP (Competitiveness and Innovation Framework Programme) and number of firms/ people involved. Derive from CIS survey of Inno-Policy Trendchart. (NB Indicators here are same as first two indicators proposed for institutional indicator of pre-competitive knowledge transfer.)

Values conducive to economic innovation

Objective of indicator: To understand the degree to which values conducive to economic innovation are present.

Indicator number	Objective	Indicator	Comments
6.	Measurement of presence of values conducive to innovation in EU firms.	Presence of values related to innovation in firms.	Measure through Climate for Innovation methodology, or similar approaches, and build a representative sample across Europe. Not currently collected on an EU-wide basis or as a time series indicator. Approach used commercially for internal use by firms and considered in academic literature. The indicator would focus on identifying the presence of values in firms that may be conducive to innovation outputs, rather than firms' actual innovation outputs.
7.	Measurement of values conducive to innovation. (Use European Innovation Scoreboard (EIS) (2006) indicators: Input – Innovation & Entrepreneurship).	SMEs innovating in-house (% of all SMEs).	Already collected - EIS 3.1 EUROSTAT (CIS4)
8.	As 7	Innovative SMEs co-operating with others (% of all SMEs).	Already collected - EIS 3.2 EUROSTAT (CIS4)
9.	As 7	Innovation expenditures (% of total turnover).	Already collected - EIS 3.3 EUROSTAT (CIS4)
10.	As 7	Early-stage venture capital (% of GDP).	Already collected - (EIS 3.4) EUROSTAT (CIS4)
11.	As 7	ICT expenditures (% of GDP).	Already collected - EIS 3.5 EUROSTAT (CIS4)
12.	As 7	SMEs using organisational innovation (% of all SMEs).	Already collected - EIS 3.6 EUROSTAT (CIS4)

Values conducive to eco-innovation

Objective of indicator: To measure the value–based or cultural factors that mean eco-innovation is likely to be considered important by individuals and institutions (apart from economic or legal requirements).

Indicator number	Objective	Indicator	Comments
13.	Insight into values that are likely to be	Presence of values related to eco-innovation in firms.	Requires qualitative survey data collected across EU and link to

	conducive to eco-innovation.		measure of eco-innovation. Existing survey data may give insights, for example, Eurobarometer . At UK level Defra survey of public attitudes to environment in England is a comprehensive survey with time series data. Make eco-innovation a focus for a future Innobarometer survey.
14.	Insight into values that are likely to be conducive to eco-innovation through the proxy of the number of individuals who are members of pro-environment groups.	a. Membership of (env.) NGOs – but while relationship between interest in environment (or other issues) may be expected, the relationship to eco-innovation may be less conclusive. b. IUCN.	Both proxy measures based on assumption of link between pro-environmental membership and eco-interest/action on eco-innovation Environmental Sustainability Index Indicator
15.	Insight into values that are likely to be conducive to eco-innovation through measurement of purchases of (indicative) eco-innovative products and services.	a. Value of eco-innovative products bought annually by household and nation. b. Proportion of household budget spent on eco-innovative products annually. c. Take-up rate of specific eco-innovative products.	How to categorise eco-innovative products? How to pick representative selection of eco-innovative product(s)/service(s)?
16.	Insight into values that are likely to be conducive to eco-innovation through proxy of levels of green public procurement.	a. Existence of green procurement policies. b. Value of green procurement as total value and relative to all procurement.	Source from Eurostat, ETAP?

5.6 Predictive policy indicators for Eco-innovation

Policy at whatever level it is formed, be it firm, region, Member State, or EU, obviously, has the potential to be a significant driver of many outcomes sought by society, including eco-innovation. However, whether or not policy contributes to or achieves desired outcomes and which types and combinations of policy instruments are more effective in delivering particular outcomes is a trickier question to answer, as the following quotes indicate:

> '…it has to be admitted that the innovation literature is still at the level of providing a conceptual approach rather than a detailed theory which would specify causal relations between different system components. However, we would argue that the insights provided could still prove useful to actors and players involved in low carbon innovation.' Foxon (p.45, 2003).

‘No general statements can be made about the kind of policy instruments that are best suited to support the development and diffusion of environmental technology.’ Oosterhuis (p vi, 2006).

The relationship between policy drivers and outcomes of innovation is not deterministic. Investment in R&D, or the presence of other drivers of innovation will not lead to guaranteed innovation outputs. However, firms and countries that do invest in the inputs to innovation are more likely, but not guaranteed, to be ones that have the most innovative outputs in quantity or quality.

The lack of clarity on the aspects of policy that are likely to be drivers of eco-innovation creates a problem for the development of predictive indicators in this area. We are therefore suggesting three broad types of policy indicators of eco-innovation that are not dependent on specific models of eco-innovation and policy impact:

1. The significance accorded to eco-innovation at the strategic policy level.
2. The quantity of eco-innovation policy activity.
3. The quality of eco-innovation policy processes.

These overlap to a degree and are discussed in more detail below. However, an important recommendation in this area is to develop the evidence base on eco-innovation policies so that in future better predictive policy indicators can be implemented.

1. The significance accorded to eco-innovation at strategic level

Firms, regions, and countries that have explicit eco-innovation policies at a strategic level and which attach a high level of significance to meeting these objectives are more likely to have greater eco-innovative outputs.

Indicator 1 – Number of member states with eco-innovation objectives reflected in headline strategic policy objectives.

For example, eco-innovation objectives reflected not just in environmental policy but also other key policy areas such fiscal, industrial and/or R&D policy.

Indicator 2 – Number of member states with national (cross-)governmental eco-innovation targets in place.

Indicator 3 – Number of member states with ‘meaningful’ eco-innovation strategies in place.

This indicator may be derived through assessment of, for example, the existence of strategic policy statements, targets, active policy work, reports on progress, budget allocations, delivery agencies allocated responsibility, and progress against ETAP roadmaps.

2. The quantity of eco-innovation policy activity

Indicator 4 - Number of eco-innovation policies in place in each member state.

There is the issue of how to define an eco-innovation policy and also quantity may not necessarily be indicative of quality. The Inno-Policy TrendChart approach and definitions may be useful here as a basis to develop further.

Indicator 5 - Resources assigned to eco-innovation policy.

A simple concept, which could be measured in terms of financial or staff resources, but might be a hard measure to get data for, and there could be an issue of consistency across member states if it was collected.

3. The quality of eco-innovation policy process

The basis of this approach would be to assess whether eco-innovation policy performs well against tests of good policy making, rather than trying to assess whether the content of policy is likely to be effective in driving eco-innovation.

Focusing on the quality of the policy process, which should be related to quality of policy outcomes, removes the need to assess the quality of individual policies in terms of their likely impacts on eco-innovation, which requires empirical derivation of relationships and/or assumptions about the conceptual mechanism of innovation.

Some elements of good quality policy making are given in Box 1, as suggested by the UK Government's Cabinet Office (there are other relevant works covering similar ground), which could be used as the basis of assessment criteria.

Box 1 – Some key aspects of good quality policy making

From Professional Policy Making – Core Competencies (Cabinet Office, 1999)

- **Forward looking –** takes a long term view, based on statistical trends and informed predictions, of the likely impact of policy
- **Outward looking –** takes account of factors in the national, European and international situation and communicates policy effectively
- **Innovative and creative –** questions established ways of dealing with things and encourages new ideas; open to comments and suggestions of others
- **Using evidence –** uses best available evidence from a wide range of sources and involves key stakeholders at an early stage
- **Inclusive –** takes account of the impact on the needs of all those directly or indirectly affected by the policy
- **Joined up –** looks beyond institutional boundaries to the Government's strategic objectives; establishes the ethical and legal base for policy
- **Evaluates –** builds systematic evaluation of early outcomes into the policy process
- **Reviews –** keeps established policy under review to ensure it continues to deal with the problems it was designed to tackle, taking account of associated effects elsewhere
- **Learns lessons** – learns from experience of what works and what doesn't.

There are many options for criteria that could be used to assess the quality of the eco-innovation policy process. For example:

- Presence of eco-innovation targets
- Stringency of eco-innovation targets compared to existing targets/achievements (percentage improvement/number of years to meet target)
- Eco-innovation agreements with key firms
- Existence of sanctions for failure to meet targets
- Stakeholder awareness of policies and responsibilities that flow from them
- Qualitative surveys on policy 'competencies' in Box 1 with stakeholders.
- Proportion of environmental taxes in overall tax revenues
- Supplier obligations or other ways of promoting take-up of cost-effective household energy efficiency.
- Creation of new environmental industries (ratio of turnover of new industries to public/consumer expenditures [e.g. from feed-in tariff] to promote them).

Extending the approach of Inno-Policy TrendChart [26] which tracks developments in innovation policy measures throughout Europe would be one way of collecting this sort of information. Inno-Policy TrendChart provides useful information on innovation policy but has nothing to say on eco-innovation or sustainable development.

Box 2 - Inno-Policy TrendChart

"The INNO-Policy TrendChart tracks developments in innovation policy measures throughout Europe. An innovation policy measure is defined as any activity that mobilises:

- Resources (financial, human, organisational) through innovation orientated programmes and projects;
- Information (road-mapping, technology diffusion activities, coordination) which is geared towards innovation activities;
- Institutional processes (legal acts, regulatory rules) designed to explicitly influence the environment for innovation.

At the same time, it must achieve public policy objectives in the area of innovation:

- With a percentage of (national) public funding;
- On a continuing basis (usually not a one-off 'event');
- Where the target group or eligible participants include enterprises.

The overview table 5.3gives an indication of the number of policy measures per country and category and provides a quick one-click access to all measures in one country in a particular category." [27]

Table 1 gives an example of how the sort of information collated by this approach is reported.

Table 5.3: Approach to appraisal of innovation policy making processes used in European Innovation Progress Report 2006

Tool for policy making/co-ordination	Criteria Ranking *, **, ***

[26] This is one aspect of the Pro Inno Europe initiative of DG Enterprise and Industry. See http://www.proinno-europe.eu/trendchart for further details.
[27] From further details and the overview table see http://www.proinno-europe.eu/index.cfm?fuseaction=page.display&topicID=262&parentID=52

Strategic policy making (national strategies, white papers, etc.): prevalence of evidence based and open consultation procedures	* Almost no background discussion, studies and stakeholder participation ** At least some attempt to these activities are systematically pursued *** All of the above items are systematically taken into consideration
Existence of co-ordination mechanisms (high-level councils, inter-ministerial committees, etc.)	* No mechanisms for co-ordination ** Few, rather fragmented and bilateral co-ordination processes *** Well organised coherent system of policy co-ordination
Systematic review process for innovation policy	* Almost no policy documents and hence little assessment ** A few, ad hoc reviews *** Systematic policy review
Design and implementation of innovation policy measures	* Very centralised/closed system for designing and implementing policy ** Consultation and partnerships exist mainly on an ad hoc basis *** Systematic interaction with all stakeholders
Taken from first two columns of Exhibit 39: Appraisal of policy making processes in the TrendChart countries (CEC, 2006)	

If the above approach were to be developed in relation to eco-innovation, the tools/criteria ranking would need to be developed further to include more specific questions in relation to eco-innovation and perhaps questions focused on the Lisbon agenda, for example, are economic policy and the approach to eco-innovation aligned and ideally integrated?

Systematically gathering information on eco-innovation in this manner would improve the knowledge base on eco-innovation policies. This would enable evaluation of the identified policies both against the quantitative measures of eco-innovation performance proposed in this project, and also through rigorous policy evaluations of the measures identified as being in place in individual countries. An improved understanding of the impact of eco-innovation policy packages would enable better predictive policy indicators to be developed in the future.

This systematic approach to developing the evidence base on eco-innovation policy is a significant task but one that is likely to be necessary to understand eco-innovation better. However, it would appear that the existing INNO-Policy TrendChart system could be relatively easily extended as a first step in this direction.

6 Operational measurement of indicators

6.1 Eco-innovation quantified with available data

We define eco-innovation as the combined improvement of economic and environmental performance of society. The eco-innovation of countries can be measured in terms of the change in economic and environmental performance. The aim of eco-innovation should be an absolute decoupling of economic and environmental performance. Time series on economic development are well established; while a similar time series on not too small set of environmental parameters has recently been developed, much broader than the ESA95 based time series which are available at Eurostat for some countries only, and with a limited time coverage. We pick out the scores for global warming as an example here, see figure 6.1.

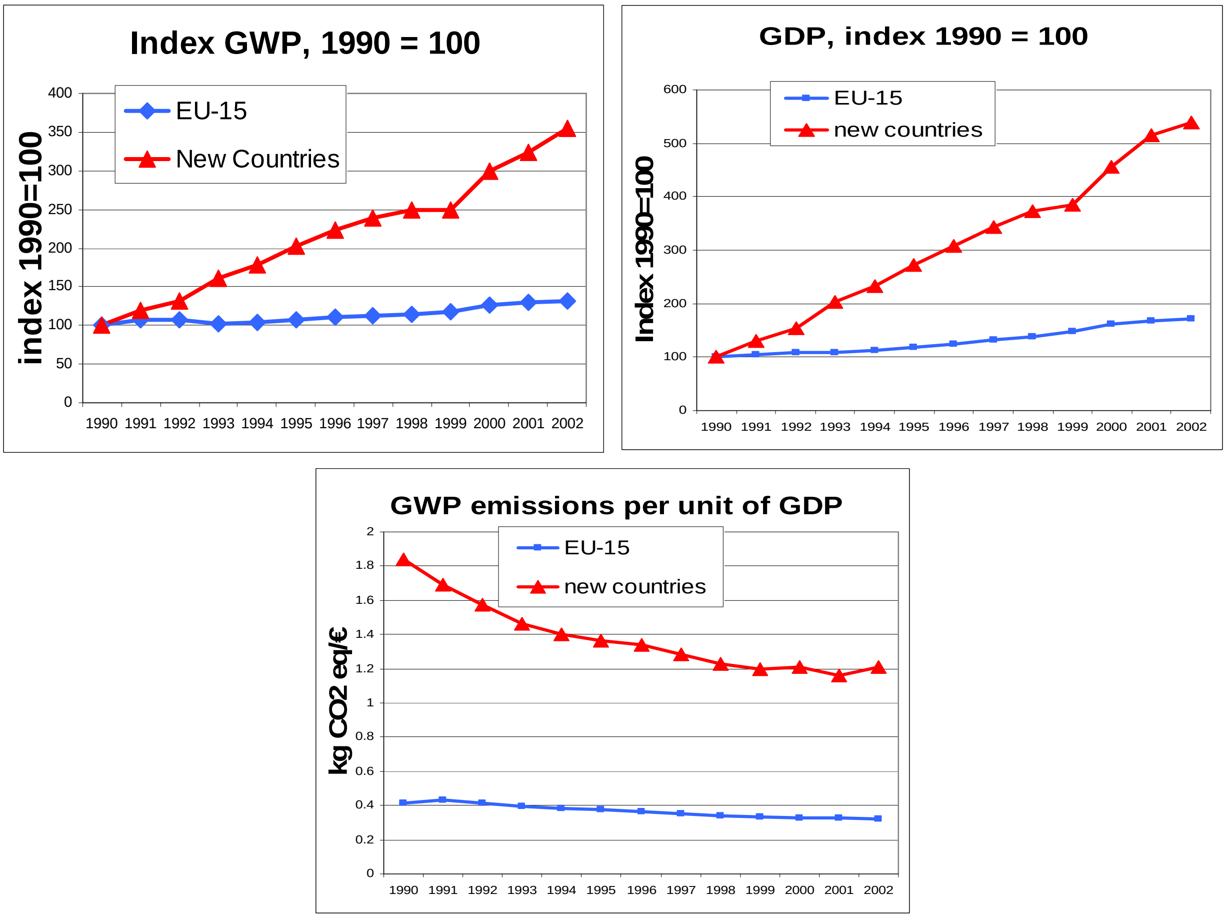

Figure 6.1 Economic growth, environmental impact and eco-efficiency of EU15 and New Countries, 1990-2002.

The interesting outcome first is how the new EU countries improved their combined economic environmental performance dramatically when they entered the institutional framework of the EU. Their eco-efficiency scores improved substantially, though not as fast as their enormous economic growth. The absolute amount of environmental impact went up substantially still. The institutional realignment created a clear example of fast decoupling, though still only the weak and not the absolute decoupling. Secondly, for the Old Countries, the eco-innovation performance was not impressive at all. For some years the improvement per unit of GDP, that is the improvement in eco-efficiency at a country level, compensated for growth and in other years it did not. Overall effects on environmental quality remain as negative as a decade ago, being somewhere at the boundary between absolute and relative decoupling. The challenge to really move towards eco-innovation still is there, as the environmental intensity of production in many areas remains too high.

6.2 Improved measurement for eco-innovations quantification and target setting

In chapter 5, an attempt has been made to specify the most reasonable and feasible predictive indicators. The problems involved in actual measurement of the eco-innovation indicators remain substantial. One of the central problems is that for covering the innovation aspect of eco-innovation, a dynamic time series analysis is required. As discussions at Eurostat have shown, the room for systematic improvement of data provision is limited. There are a few survey type data sources, where maybe one or two questions on eco-innovation could be entered. Also the statistics on patents are available only in a form relevant to some extent (with theoretical caveats) for innovation analysis. The content analysis which would form the basis for establishing the eco-innovation potential cannot now be made. Already the current exercise on innovation analysis, with source material made anonymous seemingly for privacy reasons, is very restricted in its options.

Only for the direct measurement of performance a framework is available, with basic data increasingly being measured adequately in more EU countries, with more relevant detail on environmental variables and improved quality of economic data. The current practice that for environmental data different samples are used than for economic data remains a curious historical lapsus. Especially at the level of aggregation to sectors, improvements are taking place and will take place at improved pace with the introduction of the new version of NACE, version 2. This new European sector classification system has been set up in close cooperation with the US and has been accepted by the UN as the universal new classification system.

Improving the predictive value of derived indicators remains a matter of better modelling, to improve the scientific insights in what may drive our society in the direction of sustainability. A coordinated programme based on conceptual agreement on an appropriate framework combined with the ecological aspect of sustainability could give substantial new insights in the course of some larger research projects.

For the moment, the best predictors of eco-innovation reside close to the performance level: activities with a high (= good) score on eco-efficiency have the potential to contribute to eco-innovation and decoupling within the course of a few years. Results of this analysis could give guidance to the policy process for improved eco-innovation in a much broader way than predictive indicators may give. Single indicators can catch a limited part of reality only, while the consensus is forming that a concerted group of policy actions could hold the best cards for improvement.

What comes out of the analysis here is that the policies developed, however exactly, will function very differently as far as time frames are involved. Only substantial changes in market condition, in price levels, can exert a substantial influence on performance within a limited number of years. All major groups of variables possibly conducive to eco-innovation exert their influence over decades, and longer. There seems to be a convergence between economic historians and economists that institutional rules are the dominant background for long term changes in the economy as are required for eco-innovation and absolute decoupling.

In such an open situation, the setting of targets at the level of predictive cultural, institutional and policy indicators for eco-innovation seems to be of limited value. Only the setting of targets in the economy seems promising, like a minimum level of eco-efficiency for having policy support in expanding the introduction of the technologies and products involved. This would require a more standardised method of analysis and a better method for integration of environmental aspects in a single environmental score on performance. Explicit policy choices are required for this evaluation subject.

7 Research on eco-innovation

7.1 Eco-innovation research: Introduction

Challenges ahead concern environmental quality, economic welfare and social amenity and stability, both from a short term and long term intergenerational perspective. Economic activities play a key role for all three aspects of sustainability. The dynamics of the economy are to be geared towards these three goal domains. The central goals of this research programme are to improve insight in the:

1. Actual sustainability functioning of society, especially regarding its dynamics.
2. Processes involved in eco-innovation for sustainability.
3. Ways and means in which society may improve its sustainability performance, as eco-innovation.

The viewpoints partly are general, from a global point of view, but also concern the special position of the EU, with competitiveness in a globalising economy as a key factor, also for social aspects of sustainability. The European goals have been extensively worked out in the renewed Sustainable Development Strategy, building on the Lisbon and Gothenburg Agendas and on further international declarations and agreements.

7.2 Eco-innovation in a globalising knowledge economy

The context the research is to deal with the new situation the economy is moving into. This move can be characterised as a multilayered shift. The first shift concerns the mechanisms of economic growth. Improved production processes, investment in capital goods and cheaper and better products were the keys to improved performance, covered by the large body of economic theory of the last two centuries. Optimisation under the typical market conditions of full competition forms a core element, based on full ownership of capital goods and products. The shift here is towards a knowledge economy, with new characteristics. Capital goods play a lesser role, investments are investments in knowledge. Knowledge as a good has totally different characteristics from traditional goods. Firstly, use of knowledge is non-rival, which means that the use of it by one person leaves the full product available for a next user. An operating system is an example, where large market shares even improve the product, as it becomes a standard. Secondly, knowledge has a limited excludability, which means that the product easily moves from the original possessor to other persons and organisations. Most knowledge can easily copied. The cost of creating the knowledge may be high, as with operating systems and medicines, while the use of the knowledge constitutes a minor cost outlay. Traditional economic theory would go for marginal cost pricing for optimisation. In the new knowledge based economy, marginal cost pricing leads inevitably to losses. Some level of monopoly is required to keep up profits, as incentives for private development of knowledge. Increasing returns to scale are a basic characteristic of the new economy.

The second shift is that towards globalisation. Traditional economic ideas on drivers for international trade go back to Ricardo, with nations specialising in activities in which they are relatively good, by natural endowments or by the special capacities of its population. This factor still is there, especially regarding the capacities of the labour force, but now is superseded by the mechanisms of the knowledge based economy. Knowledge created can be used with little additional cost for each additional user. Earning back your investment in knowledge creation, and making a profit, means: Going for the global market. If you leave out one continent, you loose a part of the pie you created.

The third shift is towards specialisation in production. The knowledge base of production requires ever more specialised knowledge on production. Few firms, globally, are able to improve on specialised waste water treatment services, or on chip making installations, or on low input civil engineering design, usually not more than a few. These firms are specialised in the integration of deeper specialised knowledge, both public and proprietary, in dynamic markets. Layered development of physical installations and products becomes a rule, with not one actor being responsible for innovation and eco-innovation, but clusters linked by markets, by vertical integration in firms, by contracts, and by social and information networks required to activate this integration of specialised knowledge for the production of goods and services.

The fourth shift concerns the way environmental considerations are implemented in the market. The environmental policy went through the stages of end-of-pipe measures, performance standards, market incentives, product regulations and consumption changes. The globalisation taking place makes it increasingly difficult to regulate specific activities and products. The knowledge created in one place is pushing towards global application, while also the physical basis of production increasingly is based on global concentration of production. A typical electronic product like a mobile phone has design cost as a major cost factor. The physical production of the nearly global product is based on international specialisation with half the world involved somewhere in the production and assemblage of components of the capital goods and products. National restrictive environmental regulation mostly does not stand a chance. Global standardisation of environmental performance, as effectively created by the EU several times, is one way out, a challenge for policy. More generally, the entries into sustainability policy will shift from regulation of specific products to regulation of activities in general. In the domain of energy and climate policy, the ETS (European Trading System) is a general applicable instrument, influencing all myriad decisions in society towards reduced carbon dioxide emissions, also abroad. This dynamic influence not only is on firms and consumers in production and consumption, but also on research and research & development, with knowledge institutes and inventors, and in education. More specific policies, like those on biofuels, cannot have such a diffuse and broad effect.

7.3 Societal challenges to be met

In the new context of the globalising knowledge economy the challenges of society relate to finding its place dynamically, dealing with the actual challenges of today. Climate change, for example, should be dealt with not only in a piecemeal way but also through radical innovation, including radical changes in consumption patterns. Also, improving Europe will not be enough, as climate change is global; Europe constitutes only a part of the world; and European consumption, in a physical sense, increasingly involves globalising chains of production processes. Mobile phones, even if *Made in EU* substantially originate abroad in a physical and a knowledge sense.

Focussing on short term improvement in performance may be conflicting with long term solutions. Protecting knowledge property so as to increase the monopolistic power of firms implementing knowledge may lead to market gains on the short term but to inflexibility on the long term as monopolies will use all means to protect their monopoly effectively. US policy has virtually abandoned anti-monopolistic actions, with Europe challenges monopolies as in the case of the Windows operating system. Profits in the US are extremely high as a share in national income, with undesirable social effects resulting. Europe may prevent these effects, but possible at the cost of reduced competitiveness and growth, in the short and medium term at least. Integration of environmental considerations at this strategy level is an as yet unresolved subject. How to deal with these conflicting elements in strategic policy issues is a main challenge.

The urgency of climate change has made this the focus of much policy development. However, there are many more soft and hard constraints in sustainable development. Growth increasingly nears the physical limits of the earth, in absolute terms or as dynamic problem. This is not only the case with fossil and fissile energy resources but more generally for supply of minerals, like most metals, and of biotic resources, like wood and fish. Also, the pollution problems may shift in location and nature, but mostly are increasing at a global level, including ozone formation due to photo-oxidant formation (POCP), fine dust creation with contaminants attached to the particles, and widespread reduction of biodiversity due to combined effect routes, including shifts in nature and quality of land use.

Next to the environmental challenges, the economic challenges are pressing, due to the ease with which firms may act globally, with other industrialised and industrialising countries easily taking in knowledge digitally, by exchanges in education and by hiring specialised personnel.

In the social domain, here focused on the economy, similar challenges are ahead. In competition, lowly educated personnel competes with similarly educated persons in developing countries, forcing salaries to those in developing countries. Specialists can sell their capacities in a global market, driving up their prices in skewed markets. Increasing income inequality results with pressures leading to inflation. Pressures on taxing, also for reasons of competitiveness, put pressures on public spending on education and general research.

Putting the brakes on the globalisation developments, to create the fortress Europe, has become impossible and would lead to incredible economic, environmental and social losses in the long run. However, finding a strategic place is essential to remain ahead in the world. Eco-innovation is one central domain of reflection and action, leading to a way out in a sustainable direction.

7.4 Research challenges detailed

The research challenges now can be stated more precisely, referring back to the general research goals in the introduction. We distinguish four domains of research, to be approached in an integrative manner.

7.4.1 Knowledge on sustainability performance.

Contrary to expectations, the knowledge on sustainable performance is limited. We don't know overall performance; we lack the normative integration of different aspects in a sustainability framework; we don't know what is contributing to better performance, and what is detracting from that. Detailed insight in how we are doing, dynamically in time, requires a substantial amount of research. The insights resulting not only regard specific technologies but include knowledge on shifts in sector performance, shifts in sector structure and shifts in consumption structure, and a range of boundary conditions of a physical, economic, social and political nature. Together these can give the tendency for developments in short and medium term performance of society. This research has to build on data, which are as yet sparsely and incoherently available, so should involve bodies involved in data gathering, from the new more theoretically advanced viewpoints. The integration and transformation of data into knowledge is closely related to scientific positions. Main stream economist may go for integration ***beyond GDP***, while ecological economist may refrain from integrating environmental aspects into few scores, let alone a singly one in monetary units. Basic data can be constructed open to several of such interpretations.

7.4.2 Linking micro performance to macro performance

Secondly, there is big gap between the innovation performance at a micro level, where drivers are operant, and the sustainability performance of society, at a macro level. For example, improved biorefinery technologies may well contribute to disastrous deterioration of biodiversity, through steeply increasing volumes of biomass harvested for energy and materials purposes. Similarly, the growth effect of cost reduction in household apparatus production may lead to larger energy use due to the income effect resulting in more air travel, one of the consumption items with a high income elasticity of demand. Framing micro-level improvements, from research, R&D, to niche market and mass diffusion, in their macro level functioning in society is a main scientific challenge. This subject relates very much to the sustainability assessment of technologies, but is broader as also purely behavioural and structural developments are included, like market development, education and consumption preferences.

7.4.3 Innovation processes detailed in time

Thirdly, there is the vast domain of research on the processes related to innovation, how they function in different organisations and how the speed of innovation and eco-innovation can be increased in the processes involved. There is a focus on knowledge creation and diffusion and a focus on how firms can organise and implement the eco-innovation process. The process either involves individual firms, or groups, like pre-competitive exchange organisations or supply chains. Also subjects like industrial transformation fall in this domain.

7.4.4 Guiding sustainable development

Fourthly, there is the developing subject of how to analyse and organise the overall sustainability dynamics of society. How does the institutional framework function, including IPR (intellectual property rights) rules and litigation aspects, how does the cultural domain develop, covering both knowledge and values, and which role do public policies play in the dynamics of the economy? These questions then are mirrored in how policies might be improved and developed, especially regarding the institutions which guide knowledge development in general and economic activities in particular. This subject requires the broadest integration of empirical and normative knowledge.

Together, these four main lines of research on eco-innovation for sustainability constitute an integrated domain of research. The competitiveness of Europe will depend on how this analysis is brought up, as a continuous process. The actions of Europe will diffuse out to improved sustainability development of the world.

7.5 Research programming requirements

Research programming refers back to disciplines involved, from both a multi- and interdisciplinary perspective and a transdisciplinary perspective related to applications in several domains, ranging from an SME market perspective to an EU strategic policy perspective. This means that research on eco-innovation for sustainability will not easily fit into the normal research platforms, which are discipline or domain specific. This challenge in research organisation requires active coordination between research funding organisations, especially for the more basic research aspects.

One clear focus will have to go through the Framework Programmes of the EU, requiring a structuring step so as to link the research on eco-innovation into the overall framework programme. There is a hierarchy involved here, as much of the applied research in the framework programme already is focused at innovation and eco-innovation, both in terms of content, like the nano-technology subjects, and in terms of creation of institutions, as in collaborative networks for knowledge exchange in Europe. Uptake of explicit eco-innovation research in the framework programme can be through detailing calls to the relevant level of specific research projects, or through a more open formulation of broader issues in this conceptually still open subject.

8 Discussion and conclusions on eco-innovation indicators

These conclusions are identical to the ones in the executive summary.

- The proof of the pudding is in the eating: The basic indicators for eco-innovation refer to eco-innovation performance of society directly. This performance is at the macro level, as the sum of myriad micro level activities.
- Linking micro level eco-innovation performance to macro level performance is not a self-evident step, as indirect effects of a rebound nature are to be considered and a adequate reference for comparison is to be made. Micro-economic indicators are most relevant for the monitoring of eco-innovation development if they can be associated with improved eco-efficiency performance.
- Derived indicators for eco-innovation are relevant for monitoring and for policy only if they are predictive for later performance.
- In the causal chains involved, factors conducive to eco-innovation can apply in the economy directly. The may reside in the cultural domain as in terms of development of eco-innovation knowledge and values. They may be in the institutions of society guiding both cultural and economic development. Or they may be in terms of policies directed at institutional development, cultural development or economic development towards eco-innovation.
- The nature of the economy is shifting, with cost of knowledge development becoming a main factor. This means that decreasing cost become a rule with full competition increasingly being replaced by monopolistic competition.
- Rules on intellectual ownership are essential in creating incentives for knowledge development on the one hand and for avoiding undue monopolistic profits on the other hand. Consistent sets of
- Time scales involved in major mechanisms in innovation are substantial: three decades from science to new technology and one decade from new technology to mature markets
- Private firms play a key role in the market implementation of technologies especially in the final stage of their development where performance becomes visible.
- The current set of predictive indicators is fuzzy, as quantified modelling of major mechanisms is lacking. This situation can be improved but major uncertainties on the potential of technologies will remain.
- The most practical indicators chosen by us mostly cannot be quantified systematically for the EU. This was the outcome of substantial discussions at Eurostat. For most indicators, more incidental project based data generation seems the best option.
- Current theory on innovation and our data on eco-innovation performance of EU countries suggest an extreme influence of institutional factors on changes in eco-innovation performance of countries. This shows especially in the eco-innovation development in the New Countries as compared to the Old countries after European institutions became implemented there.
- Short term policy considerations on eco-innovation are best focussed at institutional adaptations creating market activities and changed behaviour of firms and consumers. The short term incentives and drivers, if consistent and stable, also work on medium and long term eco-innovation development.
- Additionally, medium term considerations are best focussed at pre-competitive research programmes with high eco-innovation potential. Criteria for the assessment of the eco-innovation potential of technologies are to be actively developed.

- Additionally long term policy considerations are best supported by substantial basic free-and-open internationally oriented research, with some sustainability guidance in funding using the same framework but more cautiously as for the sustainability assessment of pre-competitive technologies.
- Setting up a consistent set of eco-innovation oriented institutions is a substantial task, both in an intellectual and in a policy development sense. The currently developing European Carbon Trading System is a major example of institutional development for eco-innovation. Catching such developments in indicators seems hard if possible at all; it is the development as such which counts.
- Promotion of bio-ethanol and biodiesel as direct interventions in the economy by both the EU and the US, would not count as eco-innovation because they are costly in terms of economic performance and may well have an even negative environmental performance at a macro level. Eco-innovation guidance and incentives, in stead of the direct interventions in the economy, seem more basic for effective eco-innovation policies.
- Current operational indicators have a limited predictive value and hence a limited policy relevance. This state of affairs may be improved upon. However, for many policy and monitoring purposes, "indicators in a framework", that is models, might be more relevant.
- A conceptual framework for long term modelling and scenario development is to be actively further developed, to align research and research & development programmes to some extent towards eco-innovation, and to allow for more reasoned long term indicator and policies development.

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List of tables and figures

List of tables

List of figures

Annexes

Annex 1 Report on the ECODRIVE Workshop on Eco-Innovation, Brussels 3-4 September 2007

1. Introduction and Workshop Goals

1.1 Project Description

The Gothenburg and Lisbon goals require high productivity growth with absolute decoupling of environmental impacts, at a macro level, realised basically through the process of eco-innovation at a micro and meso level. Eco-innovation indicators are to measure progress, both the economic performance, as in terms of cost reduction and enhanced functionality, and the environmental performance, as by reduced emissions and resource depletion and other environmental improvements.

Actual improvement is at a micro level, involving technologies, including their upstream systems (cradle-to-gate); goods and services, as product systems covering their life cycle; and innovative behaviours, both by producers and consumers. As most incentives and improvements work through firms and sectors, performance measurement at meso-level is essential as well. This project distinguishes three types of eco-innovation indicators. First is the actual economic and environmental performance. Second are indirect proxy indicators on expected actual performance. Third are the indirect indicators capturing the factors conducive to eco-innovation, as drivers, ranging from having an eco-innovation manager to the internalisation of externalities in prices.

The ECODRIVE project intends to:

- Further detail the conceptual basis and typology of eco-innovation
- Set out the methodology for eco-innovation indicators selection
- Structure the indirect indicators field with a focus on the most powerful predictive factors
- Indicate most relevant drivers for application in policy and management
- Give an exemplary application of the indicators of all types
- Indicate efforts to improve the data availability for eco-innovation indicators
- Specify research for improving insight into positive and negative factors on eco-innovation.

1.2 The Workshop

A brainstorm session with public and private sector stakeholders in order to further develop and validate the approach so far applied by ECODRIVE was hold on 3rd and 4th September 2007 in Brussels.

The workshop consisted of four thematic units:

First, a general introduction about the eco-innovation topic was given.

Second, an outline of the research having been done on eco-innovation within the MEI project and ECODRIVE project was given followed by a discussion on the relation between ECODRIVE and MEI.

The third part of the workshop gave insights into the operationalisation of eco-innovation indicators.

Finally, panel members from the European Commission and other institutes involved in indicator development and sustainability research reflected on the workshop and the research carried out within ECODRIVE.

1.3 Executive Summary

ECODRIVE's attempt to come up with indicators for eco-innovation should be regarded as an essential part of the EU's Environmental Technologies Action Plan (ETAP), which is still in need for improved data and information about eco-innovation throughout Europe in order to be able to identify trends in this field. Throughout the workshop it became clear that it is of utmost importance that the indicators developed within ECODRIVE as well as its affiliate and complementary project MEI are applicable to the environmental and financial as well as innovation indicators having already been developed and used, e.g., by EUROSTAT or the OECD. In the end not an entirely new data set should be created but one that can be combined and integrated with already existing ones, which is essential for the identification of trends over a long term. In order to reduce complexity, a clear definition of the eco-innovation term is needed. Another important aspect is that the indicators to be developed are stakeholder oriented, reduce complexity, are manageable and are supportive to already existing eco-innovation projects within the EU and OECD respectively. Furthermore, the indicators should be well founded without being derived from a too complex causal chain and they should allow for benchmarking of different eco-innovations. Special attention should be paid to indicators for system innovation, since system innovations can be regarded as those having the biggest impact on the sustainability of economy, state, society and environment. Finally, the set of developed eco-innovation indicators should be supportive to the delivery of strategic knowledge on eco-innovation which will help the EU to gain sustainable competitiveness within this field. Within this context it is important to emphasise the link between eco-innovation indicators and EU policy targets. The indicators should serve policy makers as guidelines on where future policy targets should be directed at.

2. Workshop Agenda

Day One: ***3 September 2007***

10.00-10.30 Registration and coffee

Chair: Gjalt Huppes

10.30-10.45 Opening
10.45-11.00 Introduction by (Ian Clark, DG Environment)
11.00-11.15 Introduction by Andrea Tilche (DG Research)

11.15-12.45 Keynote speakers on Eco-Innovation general approaches

- 11.15-11.45 Economic History and Policy: Frans Berkhout (VU Amsterdam)
- 11.45-12.15 EEA: Orsola Mautone (EEA)
- 12.15-12.45 INNOVA programme: Sebastian Gallehr / Viola Peter

12.45-13.45 Lunch

Chair: Michele Galatola

13.45-14.45 Presentations from the MEI project

- 13.45-14.05 Conclusions from the first 2 MEI workshops – René Kemp
- 14.05-14.25 Indirect measurement of eco-innovation based on firm environmental performance data – Sergio Larreina
- 14.25-14.45 Data use in economic models of eco-innovation and data needs – Klaus Rennings

14.45-15.45 Presentations from the ECODRIVE project

- 14.45-15.05 The role of Eco-Innovation – Paul Ekins
- 15.05-15.25 Philosophy of Eco-Efficiency for Eco-Innovation – Stefan Schaltegger
- 15.25-15.45 Analytical background – Gjalt Huppes
- *15.45-16.15 Tea break*

16.15-18.00 Discussion relation ECODRIVE & MEI

- 16.15-17.00 Discussion relation MEI / Ecodrive
- 17.00-18.00 General discussion
- 18.00 Closing

Day Two: 4 September 2007

09.00-12.15 Indicators for Eco-Innovation made operational

- 09.00–09.15 Opening (Paul Ekins)

Format of presentations: For each set of indicators, there will be a short presentation from the ECODRIVE team with discussion on how the most relevant indicators could be made operational in statistical practice of firms and other organizations, and statistical bureaus.

Chair: Ben Shaw

09.15-09.45 Environmental Performance Indicators : René Kleijn
09.45-10.15 Economic Performance Indicators: Paul Ekins

10.15-10.45 Coffee break

Chair: Rene Kleijn

10.45-11.15 Derived Business related indicators: Stefan Schaltegger / Marianne Esders
11.15-11.45 Derived Cultural and Institutional indicators: Ben Shaw
11.45-12.15 Derived Policy indicators and Drivers: Ben Shaw

12.15-13.15 Lunch

13.15-16.00 Integration: practical indicators for the main framework

Panel members will reflect (<5 min) on the workshop:
DG Environment DIR.-G3: Jakub Wejchert
DG Environment DIR.-G3 (ETAP): Maciej Szymanowicz
DG Enterprise Dir.-Industrial & Emission Control: Achim Boenke
Vrije Universiteit, Amsterdam : Frans Berkhout
UNEP: Matthew Bentley
Roskilde University, Department of Environmental Social and Spatial Change (ENSPAC): Peter Calow

16.00-16.15 Closing and summary of workshop: Stefan Schaltegger

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4. Eco-Innovation in the light of ECODRIVE and MEI - Day One Part I

4.1 Chair Opening: Gjalt Huppes (CLM)

After a short workshop introduction, the chair presented a comparison of the EU countries' performance on global warming.

4.2 General Introduction to ETAP – Ian Clark (DG Environment)

Ian Clark gave an introduction to the EU's Environmental Technologies Action Plan (ETAP) http://ec.europa.eu/environment/etap/index_en.htm. It was explained how ETAP came into existence and what are the reasons behind ETAP. Furthermore, the increasing support of EU Members was mentioned and it was stressed that there is potential to open up markets towards increased action on the demand side of eco-innovations towards increasing investments and increasing attention towards the synergies between policies and eco-innovation progress. Additionally, the existence of data gaps was mentioned (e.g. with regard to trade efforts in eco-industries). It was concluded that there is a need for improved information about eco-innovation to be able to analyse trends.

4.3 Measuring Eco-Innovation: A Step Towards Lisbon and Gothenburg – Andrea Tilche (DG Research)

Andrea Tilche gave a presentation on measuring eco-innovation: A step towards Lisbon and Gothenburg. It was mentioned that the EU wants to increase R&D expenditure in % of GDP, which at the moment is too low (navigating around 2%) compared with R&D expenditures of Japan (3,15% of GDP) and the US (2,59% of GDP). It was stressed that this is only a supply side measure and that prospective focus should increasingly lie on centres of excellence. Furthermore, the objective of reaching eco-innovation was described as decoupling of economic activity (GDP) and environmental impact ("indicators"). The following EU policies and initiatives are regarded as drivers for eco-innovation stimulating economic growth and job creation, etc.:

- Lisbon Agenda
- ETAP
- Stern Report
- German Ecological Industrial Policy Initiative
- IPPC Report
- Lead Market Initiative

- Greening of Industrial Policies
- Green Public Procurement
- Revision of EMAS and Eco-Label Regulations
- Sustainable Consumption and Production Action Plan (SCP)

The diffusion of environmental innovation is understood according to Jänicke's (2000) concept describing the relations between policy induced diffusion and technology induced diffusion. ETTAR (focus on training needs, methods and activities), FUNDETEC (focus on funding schemes for eco-innovation), MEI and ECODRIVE were mentioned as those EU projects directing towards eco-innovation. It was concluded that

a) a mix of different actions on the demand as well as the supply side are needed,
b) there is a need for indicators on the three pillars of sustainability
c) there is a need for indicators that help to better orient policies, funding mechanisms and related demand side measures.

4.4 Economic History and Policy – Frans Berkhout (VU Amsterdam)

During the presentation Frans Berkhout mentioned that he is sceptical about how to define what actually accounts for an eco-innovation. According to him there are all kinds of production processes influenced by environmental policies, which does not simultaneously make them to eco-innovation. Environmental innovations are not specific but hard to identify. It was mentioned that the relation between technology and the environment can be regarded as a double edged sword. In this context the knowledge and technology resulting in:

- Information effects
- Efficiency and mitigation effects
- Structural effects

One possible instrument is the satellite SMOS. It was mentioned that all industries are developing towards increased resource efficiency and eco-efficiency due to the fact that pollution control is improving and that decarbonisation is increasing. Berkhout mentioned the stabilisation triangle needs to be filled with seven wedges (renewable electricity and fuels, energy efficiency and conservation, fuel switch, nuclear fission, forests and soils, and CO2 capture and storage). Various technologies are already available in order to allow for improvements towards eco-efficiency. Technology is the most important factor to deliberate from environmental impacts. According to Berkhout the issue is decoupling. Innovation theory should be taken as basis to identify the developments towards eco-innovation. There are three forms of innovation: product, process and system innovations, which can be either incremental or radical. When thinking about innovation, accumulation and path dependency have to be taken into account. When linking innovation to environmental performance there are three main points to be considered:

1) Resource productivity is fundamental to process industries
2) Most markets for goods and services increase consumption of resources, that is why policy must mainly be concerned with the direction of innovation
3) Eco-innovation of processes and products is increasingly oriented towards systems innovation (long term goal).

The focus should increasingly lie on supporting system innovations. The institutional context needs to be changed to achieve system innovation. Furthermore, it was mentioned, that also lock-in is regarded as hindering innovation, it is needed for stability reasons leading towards a decrease of people's risk aversion and therefore to increase in risky efforts to create something new. A final point made by the audience was that liberation is needed to open up processes enabling new markets.

4.5 EEA thoughts about Eco-Innovation – Orsola Mautone (EEA)

Orsola Mautone presented the European Environment Agency's ideas about the role of the institutional and cultural context for furthering eco-innovation and especially of two factors: environmental tax reform (ETR) and pension funds. The issue raised was how those two factors can boost eco-innovation. The EEA briefly presented the activities it is running on these issues. It was mentioned that regarding ETR there is a shift away from taxing good resources towards taxing bad resources. In this context eco-innovation is regarded as one potentiality. The aim is directed towards a long-term substantial change. So far 6-7% of tax income comes from environmental taxes. It is important to take up a broader framework approach and not only sporadic actions. Investment in eco-innovation is regarded as opportunity to solve the issue of economy shrinking in Europe due to expected ageing in the upcoming decades. This opportunity should be grasped before others steal the leading role. The fact that Europe is ageing raises another issue, that of pension funds. The consequence is a switch from public pension systems to private pension systems or combined systems. Thereby the nature of investments is crucial. The main question is, whether there should be eco-investments into pension funds. This issue is included in ideas of ETAP, UNEP FI (responsible investments in public pension funds), Eurosif (venture capital for sustainability) and individual member states' long term vision strategies. Other eco-innovation actions mentioned are ENEA, which is connected to cohesion policy (assessment of future impact of eco-innovation projects (from 2000-2006) and the EU green chemistry prize, which is planned to be set up. From an institutional and cultural perspective Mautone stressed to make use of the market and not leave it to the market. Markets look for continuity, therefore a stable environmental policy is crucial. An example mentioned was insurance firms including environmental concerns into their rating systems. The EEA interest lies with indicators as tool to influence governments / political decision makers. It was concluded that a definition of eco-innovation is important in order to be able to define eco-funds and eco-investments.

4.6 Eco-Innovation Indicators under Europe INNOVA's "Innovation Watch": Viola Peter

Viola Peter from Europe-INNOVA gave a presentation on INNOVA's initiatives regarding eco-innovation indicators. INNOVA, which is a DG Enterprise FP6 initiative lasting until 2008, is a sector based approach focusing on innovation networking in Europe. Thereby, eco-innovation is regarded as one main point of focus. It was mentioned that the focus from a definition of eco-industry has changed towards a focus on defining eco-innovation. Viola Peter raised the issue that so far information can only be found on environmental performance indicators or on financial performance indicators, however, not on eco-innovation indicators. Therefore, a definition for eco-innovation is needed. It was mentioned that patents can only serve as proxy to identify innovation champions with regard to certain environmental technologies but not regarding industries. Possible indicators for eco-innovation could be new products, new to market products, personnel training efforts, cooperation and networking efforts, external knowledge acquisition and sharing efforts, especially with regard to public R&D institutes, industry, and other knowledge sources. INNOVA's future emphasis will lie on identification of eco-innovation potentials in nine selected sectors, the definition of potentials with IPC classes and the identification of inventors, firms and countries related to eco-innovation. INNOVA regards patents still as main indicator towards eco-innovation research, although there might be drawbacks coming from this approach.

5. Eco-Innovation in the light of ECODRIVE and MEI - Day One Part II

5.1 Chair: Michele Galatola (DG Research)

The next section of the workshop was chaired by Michele Galatola (DG Research). He gave a short introduction to the MEI project and expressed the EU's interest in the relations between MEI and ECODRIVE. He expressed that the projects should not be regarded as identical projects due to their similar research fields, however, that they should be regarded as complementary. Both projects apply different definitions of eco-innovation. Whereas MEI applies an environmental focus, ECODRIVE applies and environmental and economic focus. Within ECODRIVE the emphasis rather lies on what conditions are necessary to promote a win-win solution. Furthermore, a question about the projects perspective was raised: Who should benefit from the research, i.e., who is the main target group: business or society?

5.2 Conclusions from the first 2 MEI workshops- René Kemp (MEI)

MEI is an FP6-Project involving several collaborating institutions, e.g. Eurostat, EEA, etc. It was stressed that the term eco-innovation can be conceptualised in differing ways. Furthermore, it was mentioned that eco-innovation is on a path towards gaining increasing attention from nations, cities, the Commission, business and finance. However, consumers were described as not yet paying so much attention to environmental aspects and eco-innovations. Eco-innovation was described as having the potential to make Europe more competitive and sustainable. The MEI project objectives are conceptual clarification and to meet the methodological challenges or developing eco-innovation indicators. Therefore, MEI organised five workshops. Regarding the working definition of eco-innovation, it was stressed that MEI is not looking at aims or motivations behind eco-innovations merely at the results and effects with special emphasis on environmental improvements, life-cycle focus, and novelty to firms or users. It was mentioned that the majority of innovations nowadays show some form of environmental benefit. MEI classifies eco-innovation into four classes:

a) Environmental technologies
b) Organisational innovation (for the environment)
c) Product and service innovations
d) Green system innovations

Possible eco-innovation indicators mentioned were budget and expenditure on R&D, total innovation expenditure and environmental impact of innovation activities.

5.3 Indirect Measurement of Eco-Innovation Based on Firm Environmental Performance Data – Sergio Larreina (LEIA)

During this presentation it was stressed that retrieving and analysing existent information is the method to go towards eco-innovation. One important aspect is benchmarking, i.e., the comparison of information. Problems that might occur are with regard to information are the amount of information, scattered information, false or even non-existent information. A possible solution might be to do a survey.

5.4 Data Use in Economic Models of Eco-Innovation and Data needs – Sebastian Voigt (ZEW)

The focus of this presentation lay on data sources and needs for endogenous technological change in economic models. Technological progress has been a highly active research field in recent years. In particular, efforts to endogenize technological change have been a major subject for scholars. With regard to economic climate change modelling, this approach opens new perspectives for handling prospective issues concerning mitigation policies and emission reductions. In this respect, three principal sources of endogenous technological change are discussed in the relevant literature: investment in research and development, knowledge spillover and learning-by-doing. A difficulty for the calibration and estimation of certain parameters is the availability of corresponding data. First, many modellers base their calibration on assumptions, the foundations of which are often not very transparent. Second, a lot of data originates from a variety of sources due to the absence of a unitary data source regarding the main elements of technical progress. However, there are databases which may be pertinent for models of endogenous technological change. Data could for instance come from

NSF or BEA (USA)

IEA, OECD (ANBERD)

Eurostat (GERD; BERD, NACE)

EU KLEMS.

The advantage of Eurostat is that it is probably the database most appropriate to apply to environmental innovations. However, application of the mentioned data sets is rare in the existing modelling approaches. Furthermore, on the disaggregated level the data quality differs broadly from country to country. In order to represent knowledge capital, it is necessary to expose proxies like investments in information and communications technologies. It was mentioned that the ZEW tries to classify energy-related and environmental investments in research and development. Furthermore, the presenter stressed that data provision by developing countries as well as transparency regarding underlying data sources and assumptions in models need to be improved. Questions for future research are: How can distinctions be identified? How to integrate Eurostat data? How to integrate the very important energy related sectors? How to integrate the database into models? How to further standardise the data collection processes in Europe?

5.5 The Role of Eco-Innovation – Paul Ekins

According to Paul Ekins (ECODRIVE) eco-innovation is currently of great interest to European policy makers because it seeks to combine two substantive social priorities

- Competitiveness, growth, employment (Lisbon agenda)
- Environmental threats, quality (Gothenburg, SDS, 6EAP)

Historical experience since the industrial revolution is overwhelmingly of trade-off of environment for economic performance. This has come to be perceived as unsustainable, in the sense of entailing an unacceptable threat of economic and social disruption. However, it is also perceived as unacceptable for the trade off to work the other way round – EU policymakers and publics are currently not even prepared to accept reduced (let alone a negative) rate of economic growth.

In this context, to fulfil policy makers' expectations eco-innovation must deliver both improved economic performance (output, welfare, employment, exports; taking into account both time period and scale – country, sector, firm, process, product); and improved environmental performance (over the life-cycle and relevant time-periods, taking into account multiple dimensions and rebound effects).

There are a number of theories as to how innovation takes place, its signs, how its pace or direction can be changed and the obstacles/barriers to innovation. These include theories of:

- Technology push/market pull (Foxon/Carbon Trust)
- Alignment/co-evolution of social sub-systems (Freeman & Louca):
  - Science, technology (inc. infrastructure) – R&D, education
  - Economics – supply (firms, public sector), demand (firms, public sector, individuals)
  - Politics – policy
  - Culture – purpose/identity/meaning leading to lifestyles, value systems, fashion

- Propositional and prescriptive knowledge (Mokyr)
- Technological transitions/multi-level system change/niches, regimes, landscapes (Geels)
- Different kinds of innovation
  - Technological, organisational, business-related, social (Hauschildt)
  - Product & process, organisational, institutional (Horbach)

ECODRIVE would draw on these theories in deriving its measures of eco-innovation, to include indicators of innovation performance, innovation processes, and innovation drivers. Innovation processes involved the co-evolution of social sub-systems, and could be organisational (e.g. related to the public sector), business-related (e.g. a firm's management or accounting system, social (related to civil society), or institutional (related to legal, financial, policy frameworks). Innovation drivers were the social forces that can bring about or change the direction of innovation. They are complex and entail multiple interactions and feedback between changes in values/preferences, external circumstances and events, which may lead to changes in lifestyles, social concerns, which may lead to changes in personal, organisational and institutional objectives and behaviour and changes in policy. ECODRIVE would be analysing the drivers specifically from a policy perspective.

5.6 Philosophy of Eco-Efficiency for Eco-Innovation – Stefan Schaltegger

In his presentation on the philosophy of eco-efficiency for eco-innovation, Stefan Schaltegger (ECODRIVE) stressed that indicators need to be stakeholder- or addressee-specific. Eco-efficiency indicators for eco-innovation can support the measurement of eco-innovations competitiveness and therefore make them benchmarkable. Eco-efficiency, which is a ration of economic value added (EVA) by environmental impact added (EIA) show the eco-innovators where improvement is needed. Within this context it is important that the environmental and economic indicators relate to each other. A product innovation perspective leads to incremental innovations which does not question the product itself. A functional innovation perspective questions the product and strives towards improvement though functional or service innovations or increasing product-service combinations. A need perspective directs innovations towards the user's desire. Innovations should not be regarded as linear, however, as a process of innovation. Appropriate drivers enhance the steps from one to the next innovation stage, i.e., they are enabling factors that push an eco-innovation towards its establishment (e.g. inside the firm / process) or mass-market dissemination (product/service). It is important that the level of detail applies to the aggregation level, i.e., it needs to be clear who is the addressee and what is the use of the information the indicator is supposed to deliver. During the presentation the EEA representatives raised the issue that the eco-efficiency perspective might be a too narrow approach towards eco-innovation indicator development. Furthermore the EEA raised the issue of subsidies. As an example the wind power industry in Denmark, which is still in a period of receiving subsidies. Can this industry be regarded as an eco-innovation from an eco-efficiency perspective? According to the ECODRIVE project team, the subsidised wind power industry should be labelled a weak eco-efficiency. Issues like the just mentioned one stress the importance of system boundary and perspective definition. That is due to the fact that the eco-efficiency of one eco-innovation can differ on the micro and the macro level of determination. Furthermore, it was mentioned that the eco-efficiency evaluation can only be executed in the realised stage. In the beginning stage there is the need for somebody who is convinced that the innovative idea will become a success (entrepreneur). In the beginning stages you can only predict the potential eco-efficiency of an eco-innovation. Profitability will only be realised after some time has gone by, which does not exclude subsidised innovative products or processes from becoming profitable eco-innovation in the future.

5.7 Analytical Background – Gjalt Huppes

The analytical background in ECODRIVE relates to how expected future performance can be indicated by most relevant drivers. There is one fundamental problem in this respect, which is that the future is not determined but can only be envisioned based on feasible and to some extent probable mechanisms. Though with a certain softness, some main lines on mechanisms can be sketched, finally linking to a policy perspective. The analytical background links to social science categorisations with a systems perspective, distinguishing between the economy at a macro level, where the ultimate eco-innovation performance can be measured, and predictive factors, determining the future eco-innovation performance in society. Factors within the economy are closest to the future, either as structural development, or as micro-level developments, especially in firms, which may exert their influence on eco-innovation of society already at short notice. Next, the three other components of the social system, culture, institutions and policy, exert their influence on economic and environmental performance. These are reflected in cultural factor and indicators, comprising knowledge and values; institutional factors and indicators, structuring culture but especially creating the mechanism for economic development, and increasingly environmental development of society; and policy factors and indicators. These policies can act directly on the economy, on the cultural system, as involving knowledge development on specific technologies, and policies changing institutions, like new rules on environmental reporting and environmental liability. On the long term, the institutional factors seem dominant.

5.8 Discussion: Relation between ECODRIVE & MEI

The discussion round's chair stressed that MEI and ECODRIVE are complementary. He raised the issue that there are differing definitions of eco-innovation in the two projects, which might become problematic when eco-innovation indicators are to be operationalied. Furthermore, DG Research would like to know how far the two project are from actual operationalisation of eco-innovation indicators, proxies and drivers. The MEI project announced that their approach is close to existing indicators. They looked at existent indicators with regard to patents, survey and output indicators. They want to further go into the methods to be used when applying those indicators and identify the problems of those already existent indicators. Therefore an indicator analysis is conducted. Furthermore, indicators need to be combined and reference to literature about innovation trajectories needs to be included. Additionally, there should be a reference to the OECD framework of national systems of innovation. Also the idea of innovation networks and clusters of innovation (Porter) should be taken into account.

When discussing whether bio-fuels are an eco-innovation or not ECODRIVE members mentioned that both projects should not focus on intention but on performance. Whereas MEI focuses on environmental performance, ECODRIVE takes environmental improvement innovations and looks at their economic performance.
The question was raised how policy can be informed by eco-innovation indicators on what policy steps to take.

Klaus Rennings (MEI) mentioned the methodological differences between MEI and ECODRIVE. According to him MEI follows an innovation theory approach. The existing database should be extended to environmental issues, which is regarded as quite complicated since the necessary environmental data is still missing. On the other hand the ECODRIVE project looks rather at ecological performance in combination with eco-efficiency analysis and life-cycle analysis. This was regarded as a very specific perception of eco-innovation and it was questioned whether it would be a fruitful idea to combine both projects.

Frans Berkhout (VU Amsterdam) stressed that attention should be paid to referring to innovation theory when assessing how innovation should be measured. He mentioned that within innovation literature researchers have been careful on how to measure economic performance of innovation. Indicators should capture the quite complicated link between environmental performance, investment and economic performance. Traditional innovation theorists so far have had trouble to make the causal links between innovation performance and environmental performance as well as between investments in innovation and environmental performance.

ECODRIVE mentioned that there needs to be a distinction between incremental innovators and disruptive innovators for eco-innovation indicators. Another challenge is to cope with the political heat between the different definitions of eco-innovation. According to ECODRIVE it is important to realise that a definition of eco-innovation needs to relate to economic performance (see Lisbon Agenda goals) and not only to environmental performance. Therefore the link between environmental and economic performance of eco-innovation must be found.

David Gee (EEA) mentioned that there has been a long hard struggle to incorporate the economic dimension. However, the intellectual ground is increasingly directing towards including sustainability concepts into their activities. Europe now has the opportunity to come up with an ecological revolution to be sold to growing countries such as China, India and Brazil.

According to Paul Ekins (ECODRIVE) the ecological revolution idea is based on win-win potential for the future. Therefore, it is important to include the long-term perspective.

Klaus Rennings (MEI) mentioned that issues of competitiveness and employment have been included into eco-innovation research for ten years. However, innovation is a different concept than competitiveness and employment. Therefore, the concepts should be analysed separately. It should not be presupposed that there is improvement in employment rates and competition, however, it should be looked at what are the effects of eco-innovation on employment and economic performance.

Closing of Workshop Day One.

6. Indicators for eco-innovation made operational – Day Two Part I

6.1 Opening – Paul Ekins

The session was opened by summarising Day One's main point and by stressing that whereas MEI mainly looks at improving environmental performance EC's interest lies in measuring environmental performance and economic performance. Furthermore it was mentioned that there might be difficulties with regard to time, aggregation levels and understanding about whether improved eco-innovation performance is taking place.

6.2 Environmental Performance Indicators – René Klein

Environmental performance indicators should be derived from indicators that are already available in literature. Indicators to measure environmental performance should follow the DPSIR Chain approach:

- Driving forces
- Pressures
- States
- Impacts
- Responses by society to environmental situation that occurs

Furthermore, the LCIA Framework by Udo de Haes et al. (2002) provides for a framework for indicators on environmental intervention, midpoint state, an endpoint impacts. ECODRIVE will focus on midpoint state indicators.

Rene Kemp (MEI) raised the question on how to deal with variation and uncertainties, e.g. in climate change. How to incorporate those variations and uncertainties into the GWP measurements?

David Gee (EEA) questioned whether eco-innovations always have to lead to reduction of environmental pressure on macro level. It was concluded that one has to always take into consideration the aggregation level one is referring to. The macro level surely has to be taken into account, however, one cannot always tell the macro level effects of an micro-level eco-innovation.

Klaus Rennings (MEI) mentioned that it is quite difficult to make an LCA for complex products and Rene Kemp raised the question how LCA deals with rebound effects. It was concluded that rebound effects are not taken into account in an LCA. However, EIPRO takes into account rebound effects. In the input output model one can specify the expenditures; LCA is progressing towards considering loops that represent those input output relations.

Paul Ekins (ECODRIVE) mentioned that conceptually it would be optimal to have a fully linked economic and environmental model. Researchers in the UK are developing macro-economic models that are oriented towards that direction.

David Gee (EEA) wondered why the ECODRIVE model neglects impact indicators. This is a problem for innovation analysis because large scale indicators come from impacts. Paul Ekins mentioned that impact consideration depends on time scale because the impacts can only be measured after a long term has passed by.

6.3 Economic Performance Indicators – Paul Ekins

There should be economic and environmental performance improvement when talking about eco-innovation.

David Gee (EEA) wondered what happens if the functionality you concentrated on is not the right one, e.g., what if people do not want mobility from transport but access. It was responded that one can concentrate on different functionalities. Change in functionality does not reduce GDP but just changes the purpose money is spent on. The car industry might suffer, however other industries (tourism) gain. That is why you need a macro focus and cannot just look at the car industry level.

Peter Calow (Roskilde University) mentioned that in a macro-economic context politicians will go for indicators regarding products, firms, industry and put emphasis on those in terms of policy development. He wondered how ECODRIVE is going to put in the cautions that should be associated with those reductionist measures in order to help the political process. Paul Ekins responded that most politicians are interested in indicators at aggregate levels, e.g., at sectoral levels. It has to be ensured that there are new dynamic sectors coming up. If other sectors are declining, this has to be taken into account. Indicators need to be represented sufficiently at all levels, to show that what effects on the micro level are not necessarily the same effects on the macro level. Micro level impacts are not just simply transferable into macro level impacts.

DG Enterprise raised the issues of investment and investment cycle. Where should they be located? Furthermore Klaus Rennings wondered about how to link the innovation activity and the economic performance? Which existing databases are going to be used? What kind of new data needs to be created? Paul Ekins (ECODRIVE) responded that national accounts (economy) IPRO database (products) are to be used. Klaus Rennings mentioned that there should be more emphasis on linking of innovation activities to existing data that can measure their performance. Achim Boenke (DG Enterprise) mentioned that the issue is that of timing with regard to how to transform the innovative idea into a eco-innovative product actually spread on the market.

Chair: René Klein

6.4 Derived Business Related Indicators – Marianne Esders

Regarding this presentation on business related eco-innovation indicators, proxies and drivers Achim Boenke (DG Enterprise) and Klaus Rennings mentioned that the presented indicators should be linked to already existing indicators, e.g., those developed by the chemical technology platforms, Eurostat, CORDIS.

6.5 Derived Cultural and Institutional Indicators – Ben Shaw

Regarding this presentation René Kemp (MEI) mentioned that there needs to be more structure and indicators need to be linked to firm, sector, government, and society spheres. Rennings stressed that awareness indicators, public awareness and environmental consciousness of people is statistically analysed in Germany. These statistics show that there is high environmental consciousness, which, however, is not reflected in the environmental behaviour of people. The gap between the awareness and behaviour needs to be explained.

Stefan Schaltegger (ECODRIVE) stressed that eco-innovation development needs entrepreneurs (see German eco-innovative product "Bionade") and good firm-policy relations. Eco-innovation is also dependent on the relations between firms and policy. The nature of these relations is dependent on national culture. Whereas in some countries there is always conflict, in others there is cooperation. A crucial question here could be about how you could create situations in which politicians and firm managers collaborate and therefore create the needed basis for eco-innovation progress. With regard to institutions, the general climate for innovation is also relevant for eco-innovation. Indicators that are used to measure the general climate of innovation can be used to measure eco-innovation. It should be made use of existing literature.

6.6 Derived Policy Indicators – Ben Shaw

Regarding this presentation on derived policy indicators Paul Ekins (ECODRIVE) emphasised the fact that the link between environmental policy and environmental improvement is not easily provable. There are so many contextual factors that you cannot explicitly identify the general high level conclusions. Klaus Rennings stressed that causal chains can be assessed ex post however, you cannot transfer one success from one country to the next, since you do not know whether it will have the same results. David Gee (EEA) pointed out that making use of past experience is better than doing nothing. It is better to make a few mistakes than to remain inactive.

Rene Kemp (MEI) mentioned that literature shows that the best approach of policy to stimulate eco-innovation is one where eco-innovation incentives are combined with a political targeting approach.

David Gee (EEA) mentioned that a complex reality can only be dealt with b coming up with complex solutions. DG Environment pointed out that the more complex a situation is the more complex is the measurement. Therefore a set of measurements needs to be combined. Gjalt Huppes (ECODRIVE) opposed by mentioning that it is impossible to combine the measurements for millions of products. DG Environment stressed that not just individual measurements are important but how these measurements can work together. David Gee (EEA) responded that one has to go upstream along the main indicators you are interested in. One should target at some products and then upstream towards industry conclusions.

Klaus Rennings (MEI) pointed out that there is no individual innovation indicator that could help to identify the right policy decisions. Typically best practices are collected, top runners are studied, and then it is looked at how this can be transferred or scaled up to the European level. If implementing new instruments, one can make use of existent economic models, (emission trading system's influence on economy).

DG Environment pointed out that ETAP looks at what national policies seem to do well. Effectiveness of policies is based on surveys of what actually works. The interaction between policies and the actual outcomes is what DG Environment actually is interested in.

Rene Kemp (MEI) mentioned that work by Martin Jäneke and Rennings on patents on innovation might be useful.

MEI and ECODRIVE agreed on the three defined policy dimensions. Furthermore, mapping of innovation activities has a long tradition and should be used as reference (see OECD mapping).

Finally, there was a discussion about the mega-store issue. Their US development was market driven. In Europe this did not work out due to quality-of-life and environmental issues as for example driven by public policy in the UK.

7. Integration: Practical indicators for the main framework - Day Two Part II

7.1 Panel Member Reflections

Frans Berkhout (VU Amsterdam)

1. Indicators are communicative devices intended to bundle information.

   It is important to consider for whom the indicators are made, i.e., to recognize the audience. Two possible audiences to recognise are managers and policy makers. Different sorts of audiences require different sorts of information.
2. Indicators need to be well founded. Usually indicators are rather proxies. When inventing an indicator the causal link has to be clear. Given the incredible complexity between innovation investments and outputs and the relation to environmental performance, it is important to not have a too long and complex causal chain.
3. Operationalisation: Proposed indicators need to be reportable. They should be based on already available data. Otherwise a new data collecting system needs to be created. Panels and trends can only be developed if you use already available data.
4. Groups of indicators: Several indicators are needed however not too many. There should be families of indicators that can provide a signal. They need not to tell you everything. Be rather minimalist with the number of indicators you create. You should focus on the target of your indicators. It is important to clarify whether you are trying to control or influence an innovation system. Usually the aim is to influence, therefore the indicators should be directed towards that direction.

7.1.2 Maciej Szymanowicz (DG Environment)

It is important to bear in mind the goal of the project research. ECODRIVE work needs to provide indicators. For the time being a lot of EU institutions are interested in the outcome of the project. There is a possibility that the work should be continued after the outcome of these projects are provided.

7.1.3 Matthew Bentley (UNEP)

1) Definition: The definition of eco-innovation needs to be clear. The terminology confusion needs to be cleared up.
2) Social aspects should be included in the eco-innovation concept.
3) A too broad definition of eco-innovation will lead to too complex outcomes.

4) Eco-innovation is a subjective concept. It might be regarded differently in different countries. MEI and ECODRIVE should work even more closely together.
5) Research should be continued in a follow up project. There is a need to carry on the work done so far.
6) Indicators: They should be drawn on sets that already exist. UNEP is willing to work together with the ECODRIVE team on further development of indicators.
7) It is important to consider how the ideas can be transferred to developing countries. It should be considered whether there are any other international issues with regard to developing countries. In this context the social aspects play a crucial role.
8) Indicators: Do not limit yourself to indicators that are already existent. It's good to have new indicators that might bring new insights. Maybe a "wish list" of indicators can be helpful for inclusion if there is no dataset available yet.

7.1.4. Achim Boenke (DG Enterprise)

1) The emphasis should be on a shift from traditional technology push towards an market demand approach.
2) A weighting factor for environmental performance indicators is crucial and a focus point for environmental performance indicators should be developed.
3) For economic performance indicators, the issue of investment by firms and the cycle of investment are of crucial importance. The economic issue plays a very strong role in a long term perspective. An end-of pipe improvement approach is not sufficient.
4) With regard to policy indicators it should be thought about what is the right mix of different approaches to be used. There is not THE right answer. Therefore the focus should lie on a mix of policy instruments.
5) It should be thought about how ECODRIVE indicators could facilitate other European Commission projects, e.g., projects focusing on making lead markets more innovation friendly.
6) Other issues: communication of results. We have to strike a balance between accurate and comparable indicators and on the other side the regulatory practicality. Long-term comparability is needed. Furthermore, the indicators must be acceptable and applicable in an international context, because we are not working in an isolated EU context.

7.2 Discussion Round

7.2.1 European firms' profiling with regard to eco-innovation

René Kemp (MEI) raised the issue, whether European firms are serious about profiling themselves as eco-innovative.

Achim Boenke (DG Enterprise) responded that various reports are coming out from many firms (sustainability reports). This is a sign that firms have increasingly put sustainability at their heart. Furthermore, e.g., the chemical industry follows sustainability programs like the Responsible Care program. However, it should not be forget that the first aim of firms is to be profitable. If one product is replaced by another product that is more environmentally friendly, it still needs to pay off.

A second aspect is energy. Firms focus on energy reduction leading to cost reduction and being more competitive on the market. There is the chance for a win-win situation. Large firms are dragging the smaller ones with them. However, SMEs do not only react at larger firms, they act by themselves, too. Finally, sustainable behaviour improves the image of firms.

Maciej Szymanowicz (DG Environment) mentioned the Life Environment Project: A call for proposals usually leads to many responses. This is a sign that there is interest. Furthermore, investments in clean technologies is increasing. ETAP and the CIP project go into that direction, too.

7.2.2 Definition of the eco-innovation concept

Stefan Schaltegger (ECODRIVE) mentions that the chemical industry is an example where efficiency gains are an important issue. Here you have process innovations, however, also product innovations. It is important to have an eco-innovation term that links economic and environmental performance. There is the need for a common understanding. He suggests to distinguish between environmental innovations (environmental improvement), eco-efficiency innovations, eco-innovations (strong eco-efficiency innovations), and sustainability innovations.

Paul Ekins (ECODRIVE) mentions that not all green activities can be called eco-innovations.

Stefan Schaltegger (ECODRIVE) mentions that not every eco-innovation is introduced in industry. There is enormous potential but it is not always put into practice. It is important to be aware that the existence of the potential will actually lead to implementation. Therefore, policy makers have to look at these cases and need to support the dissemination of these potentials.

7.2.3 Export of eco-innovations

Eco-innovativeness of export is an issue to be considered. Which impact does export of eco-innovations have on Europe and on importing countries?

Gjalt Huppes (ECODRIVE) mentions the importance of acceptance of environmental indicators in an international context.

Achim Boenke (DG Enterprise) stresses that international acceptance leads towards ensuring exchange and comparability of information in order to understand the other parties and to exchange information and share tools.

Frédéric Morand (Eco-Innovation) points at technologies transfer. According to him the success of technology transfer is questionable. There are many wrong assumptions. It has a history of failures. An example is the food industry: Food shipping across the world is not eco-efficient. There needs to be a benchmark or criteria here that is based on eco-efficiency basis.

Achim Boenke (DG Enterprise) responds that bio based products are from renewable resources: South America Palm Tree issue. There need to be norms and standards to be followed so that the European industry is not made responsible for the activities going on in South America (cutting of rainforests). There are norms and standards developed, however they are on a voluntary basis, which makes monitoring and control difficult.

Frans Berkhout (VU Amsterdam) points back to the issue of technology transfer.
He mentioned the case that an old-fashioned production technology is transferred to a developing country. From the exporting country the technology is not regarded as an eco-innovation, however, in the developing country the transferred technology might be regarded as eco-innovation, because there it might lead to environmental and economic improvement.

Paul Ekins (ECODRIVE) stresses that in the ECODRIVE context we are talking about export of environmentally beneficial technologies. He puts forward the question how it is possible to verify that exported technologies actually will lead to environmental benefits in the importing countries.

Frédéric Morand (Eco-Innovation) stresses that there is a need to check that everything that is exported is not doing any environmental harm to the importing country.

René Kemp (MEI) mentions that you need to distinguish between eco-innovative technologies. End-of-pipe of technologies might not be the best solution to importing developing countries. There is a need for research on checking what is going on in developing countries importing technologies from Europe

7.2.4 Length of causal chains for indicators

Gjalt Huppes (ECODRIVE) emphasises that causal chains should not be too long. However, indicators should enable analysis of long causal chains, e.g., by means of a range of indicators. Therefore, there should be both, long causal chain indicators and short causal chain indicators.

Frans Berkhout (VU Amsterdam) stresses that too long causal chains are not functional. If there is too much distance there will be too much uncertainty. Indicators shouldn't be too far away from your object of interest.

David Gee (EEA) refers to the midpoint indicators approach earlier presented by (ECODRIVE). Impact realisation and therefore impact indicators are necessary to analyse the actual effect or benefit an eco-innovation has. There is the need for early warning impact indicators for policy making. These should be distinguished from eco-innovation impact indicators. There needs to be a focus on early intelligence since early impact indicators will show the direction of innovation, which then leads to appropriate policy response.

7.2.5 Distinction between innovation and change in performance

René Kemp (MEI) mentions that there needs to be clarification on how to relate innovation to changes in economic and environmental performance. How to distinguish between what is an innovation and what is merely a change in performance?

Gjalt Huppes (ECODRIVE) stresses that you need to provide for technology specifications. Then you can make scenarios for similar functions and products.

Stefan Schaltegger (ECODRIVE) emphasises that one needs to distinguish between improvement, invention and innovation. Ex ante on the micro level it is difficult to measure the economic and environmental effect of innovations. Ex post you can measure this effect. Does it make sense to distinguish between improvement and innovation? A firm innovation might not be useful to the industry. EU interest rather lies in innovations new to the industry in order to improve competitiveness of the EU.

Jakub Wejchert (DG Environment) mentions that ETAP aims at ensuring that you can bring about a change. It does not only focus on things that are new. The important question is: How can you move from a niche to a mainstream? In some cases you could consider whether an organisational change (new business model) is needed in order to enable the acceptance of an innovation. We want to make sure that a novel invention will not stay in the niche market. ETAP was set up with a broad range of actions, however, most recently ETAP gains an emphasis on the demand side to overcome the problem that there are so many potential technologies out there without being diffused into the market. Emphasis now changes to demand side: How does greening procurement relate to technology take up?

Paul Ekins (ECODRIVE) mentions that there is the need for an innovative culture that speeds up the take-up of innovative technologies.

René Kemp (MEI) points at learning-by-doing effects which are quite important for the use of innovations.

Jakub Wejchert (DG Environment) emphasises that there is a need for indicators on system innovations.

Achim Boenke (DG Enterprise) stresses that one should not confuse innovations with inventions. Market demand is an important issue for innovation. There are two ends of the market to be considered, the bottom end of the market and upper end of the market.

7.2.6 Policy impacts

Klaus Rennings (MEI) mentions that an interesting field to be researched is on policy impacts: What are the impacts of new policy instruments?

Stefan Schaltegger (ECODRIVE) suggests that a mix of policies should not be regarded just at one point of time but over a longer scale of time.

7.2.7 Market failure and competitiveness

Stefan Schaltegger (ECODRIVE) mentions that firm strategies to influence regulation towards avoiding marketing failure is not openly communicated, otherwise the firm immediately loses its competitiveness with regard to that strategy.

7.2.8 Lead market concept

Klaus Rennings (MEI) mentions that the concept of environmental lead markets lets you go beyond what other countries do. If other countries follow, the lead market can proceed.

7.2.9 The EU's conception that eco-innovation will lead to competitiveness

Paul Ekins (ECODRIVE) poses the question how strong the EU's conception is that eco-innovations will actually lead to comparative advantage.

Jakub Wejchert (DG Environment) responded that it is increasing. The idea is increasingly entering the mind-set of EU officials. Greening of industrial policy (including restructuring / greening of industry) is supposed to be highly influenced by development towards eco-innovativeness. The idea of a green and sustainable industry including sustainable consumption is entering into high-level EU thinking.

Achim Boenke (DG Enterprise) mentioned that sustainable industrial policy is prepared, which shows the EU's actual direction towards sustainability. Furthermore, the European Commission promotes eco-innovation. Europe should move forward along this line. However, the industries need the political support. Otherwise, industry will just shift their industrial arena from Europe to foreign countries.

Jakub Wejchert (DG Environment) adds that the size of the European eco-industry is a third in world share. Growth rates in eco-innovation industries are predicted to be quite strong. Therefore, the eco-innovation area is identified as potential area for competitive advantage.

The eco-innovation arena is regarded as important answer to societal and environmental issues and as means to capitalise economic potential.

7.2.10 Eco-innovation indicators' end users

According to Matthew Bentley (UNEP) it needs to be made absolutely clear who are the end users of the developed eco-innovation indicator: either policy makers or business.

7.2.11 Project Outlook

Jakub Wejchert (DG Environment) stressed the following points to be considered for further developments within the ECODRIVE project:

1) Can you help us suggest what kind of indicators we could use or further build on?
2) What are the kind of system types of indicators that need to be looked at in the future?
3) What combinations of indicators need to be considered?
4) What policy mixes are needed?
5) What is the relationship between indicators and policy targets? Which indicators are useful to set the targets?
6) If you cannot define concrete indicators, what guidelines would you suggest?

There should be policy support as outcome of ECODRIVE.

7.3 Workshop Summary and Closing – Stefan Schaltegger

The goal of the ECODRIVE and MEI projects is the development of an eco-innovation indicator framework. However, it has to be considered that the projects are too short to allow for coming up with a big set of data. Therefore, the goal of both projects should be to develop a consistent framework and to link the two frameworks, if possible. The overarching goal is to support the EU policy process aiming at improving competitiveness of industries and therefore the EU by increased consideration of environmental issues. MEI and ECODRIVE are complementary. There should be a follow up project to bring both projects closer together.

Jakub Wejchert (DG Environment) mentions that there is the plan to set up a strategic eco-innovation intelligence network. This might be an interesting opportunity for the parties already involved in the eco-innovation projects. The objective of the strategic eco-innovation intelligence network is to deliver strategic knowledge on eco-innovation.

Stefan Schaltegger (ECODRIVE) concludes that many issues have been addressed in the workshop. The goal now is to focus on specific aspects. Different levels of analysis, approaches, addressees need to be structured. Furthermore, the EU's feedback on what is most important to the EU should be taken into consideration.

Finally Maciej Szymanowicz (DG Environment) points out that ECODRIVE will have to indicate the possibility to combine indicators with already existing data.

Annex 2 Indexes on innovation, competitiveness and sustainability: details

This appendix contains details of and links for further information on the following:

- Environment Canada's Corporate Environmental Innovation (CEI)
- Milken Institute Capital Access Index
- European Innovation Scoreboard
- World Economic Forum Global Competitiveness Index (GCI)
- Environmental Sustainability Index

Environment Canada's Corporate Environmental Innovation (CEI)

From Moffat and Auer (2006):

CEI therefore focuses on three areas of engagement to support business leadership, each of which is described in this paper:

- Knowledge and information - making sustainability information available and relevant: CEI's knowledge and information initiatives focus on helping to ensure that markets and consumers have useful, accessible and timely information on corporate environmental performance.
- Linking sustainable development to business value: CEI's work in this area is focused on bringing together the financial sector, corporations and other stakeholders to identify, develop and support the link between corporate environmental and financial performance and to make this link more relevant to business and financial sector audiences.
- Tools and capacity-cultivating innovative corporations: CEI's engagement in this area is focused on supporting Canadian firms' awareness of and access to the tools, research and information they require to maximize the competitive and innovation benefits of environmental leadership.

Milken Institute Capital Access Index

The details below are taken from Appendix A, Barth et al. (2006), which gives details of a methodology for measuring access to capital, involving the assembly of some apparently fairly complex measures.

"There are seven subcomponents[to the CAI]: macroeconomic environment (ME), institutional environment (IE), financial and banking institutions (FI), equity market development (EM), bond market development (BM), alternative sources of capital (AC), and international access (IA).

"The macroeconomic environment captures the extent to which a country's macroeconomic environment is favourable to the running and financing of a business. Macroeconomic variables include low and stable inflation and interest rates, low tax rates, and a level of financial sophistication compared to international norms.

“The institutional environment (IE) reflects the extent to which a country has the institutions needed to support and enhance business financing activities. That includes enforceable property rights, an efficient judicial system, efficient bankruptcy procedures, and a low corruption environment.

“The subcomponent financial and banking institutions (FI) measures the level of involvement of deposit-taking institutions in financing businesses. Some variables included in FI are the level of private sector credit extended by deposit taking institutions, the soundness of financial institutions, the ease of access to bank loans, and the efficiency of the banking system. Equity market development (EM) reflects the extent to which financing of business operations is important for a given country. Some of the EM variables include: stock market capitalization to GDP, the liquidity of the stock market, and changes in the number of listings.

“Bond market development (BM) captures the importance of bond financing of business operations. Some variables include the size of private and public bonds to GDP and the securitized asset issuance to GDP.

“Alternative sources of capital (AC) measures a country’s use of such financing pools as venture capital, private placements, and credit cards.

“International access (IA) measures the level of foreign capital available to businesses in a particular country and includes variables such as the volatility of exchange rates, international reserve holdings, portfolio and FDI capital inflows and outflows, and sovereign ratings.

“To calculate the various scores, first the non-surveyed or missing variables in FI, EM, BM, AC and IA subcomponents are assigned a score of zero. This reflects the fact that the industry or sector in question is either missing or so small that its effect on capital access is immaterial.

“In some countries, non-survey variables are missing due to slow data reporting; still, the industry exists as evidenced from prior years’ data. In these cases, the prior year’s values are used for the current year rather than assigning a zero or missing value.
Second, the variables are ranked by every decile according to the directional relationship to capital access. The resulting scores of 1 to 10 are then assigned for countries ranking lowest to highest in terms of capital access. The score for each sub-category is calculated by a simple average of the variables, but only if the data in the category is greater or equal to fifty percent of the total variables in that category.

“Third, the Capital Access Index is calculated using the weighted average of the seven subcategories. The first two subcategories, ME and IE, are weighted 25 percent each. The other five subcomponents, FI, EM, BM, AC, and IA, each are weighted as 10 percent of the final CAI score.

“Theoretically, the scores can range from zero to 10. However, because every country has some kind of macroeconomic and institutional structure, the minimum for each of these two categories is one; therefore the lowest possible score can only be 0.5.”

European Innovation Scoreboard

The *European Innovation Scoreboard* (MERIT/JRC, 2006) uses the following indicators of innovation:

EIS 2006 INDICATORS

INPUT – INNOVATION DRIVERS

1.1 S&E graduates per 1000 population aged 20-29 EUROSTAT
1.2 Population with tertiary education per 100 population aged 25-64 EUROSTAT, OECD
1.3 Broadband penetration rate (number of broadband lines per 100 population) EUROSTAT
1.4 Participation in life-long learning per 100 population aged 25-64 EUROSTAT
1.5 Youth education attainment level (% of population aged 20-24 having completed at least upper secondary education) EUROSTAT

INPUT – KNOWLEDGE CREATION
2.1 Public R&D expenditures (% of GDP) EUROSTAT, OECD
2.2 Business R&D expenditures (% of GDP) EUROSTAT, OECD
2.3 Share of medium-high-tech and high-tech R&D (% of manufacturing R&D expenditures) EUROSTAT, OECD
2.4 Share of enterprises receiving public funding for innovation EUROSTAT (CIS4)

INPUT – INNOVATION & ENTREPRENEURSHIP
3.1 SMEs innovating in-house (% of all SMEs) EUROSTAT (CIS3)
3.2 Innovative SMEs co-operating with others (% of all SMEs) EUROSTAT (CIS4)
3.3 Innovation expenditures (% of total turnover) EUROSTAT (CIS4)
3.4 Early-stage venture capital (% of GDP) EUROSTAT
3.5 ICT expenditures (% of GDP) EUROSTAT
3.6 SMEs using organisational innovation (% of all SMEs) EUROSTAT (CIS4)

OUTPUT – APPLICATIONS
4.1 Employment in high-tech services (% of total workforce) EUROSTAT
4.2 Exports of high technology products as a share of total exports EUROSTAT
4.3 Sales of new-to-market products (% of total turnover) EUROSTAT (CIS4)
4.4 Sales of new-to-firm products (% of total turnover) EUROSTAT (CIS4)
4.5 Employment in medium-high and high-tech manufacturing (% of total workforce) EUROSTAT

OUTPUT – INTELLECTUAL PROPERTY
5.1 EPO patents per million population EUROSTAT
5.2 USPTO patents per million population EUROSTAT, OECD
5.3 Triadic patent families per million population EUROSTAT, OECD
5.4 New community trademarks per million population OHIM
5.5 New community designs per million population OHIM

Also states (p10)

‘2.2. Five key dimensions of innovation performance
Innovation is a non-linear process. The 25 EIS innovation indicators have been classified into five dimensions to better capture the various aspects of the innovation process. *Innovation drivers* measure the structural conditions required for innovation potential, *Knowledge*

creation measures the investments in R&D activities, *Innovation & entrepreneurship* measures the efforts towards innovation at the firm level, *Applications* measures the performance expressed in terms of labour and business activities and their value added in innovative sectors, and *Intellectual property* measures the achieved results in terms of successful know-how.'

The first five Scorecard measures are intended to measure the structural conditions required for innovation potential – indicators 1.1-1.5. These are input measures and do not seem to reflect the broader institutional structures that may affect whether innovation happens or not, whereas the other indicators do include some significant institutional/structural measures.

World Economic Forum Global Competitiveness Index (GCI)

Composition of index below – taken from http://www.weforum.org/pdf/Global_Competitiveness_Reports/Reports/gcr_2006/composition.pdf which also gives details of how the GCI is constructed. Data for the index is drawn from the Executive Opinion Survey, which captures the perceptions of over 11,000 business leaders worldwide and is combined with other hard data sets. Commentary on the nine pillars of the index is contained in *The Global Competitiveness Index: Identifying the Key Elements of Sustainable Growth* (Chapter 1, World Economic Forum, 2006) available at http://www.weforum.org/fweblive/groups/public/documents/wef_member_pdf/gcr_0607_1_1_gcindexes.pdf.

Composition elements of GCI

1st Pillar: Institutions

A. Public institutions

1. Property rights
1.01 Property rights

2. Ethics and corruption
1.02 Diversion of publics funds
1.03 Public trust of politicians

3. Undue influence
1.04 Judicial independence
1.05 Favoritism in decisions of government officials

4. Government inefficiency (red tape, bureaucracy and waste)
1.06 Wastefulness of government spending
1.07 Burden of government regulation

5. Security
1.08 Business costs of terrorism
1.09 Reliability of police services
1.10 Business costs of crime and violence
1.11 Organized crime

B. Private institutions

1. Corporate ethics
1.12 Ethical behavior of firms

2. Accountability
1.13 Efficacy of corporate boards
1.14 Protection of minority shareholders' interests
1.15 Strength of auditing and accounting standards

2nd Pillar: Infrastructure

2.01 Overall infrastructure quality
2.02 Railroad infrastructure development
2.03 Quality of port infrastructure
2.04 Quality of air transport infrastructure
2.05 Quality of electricity supply
2.06 Telephone lines (hard data)

3rd Pillar: Macroeconomy

3.01 Government surplus/deficit (hard data)
3.02 National savings rate (hard data)
3.03 Inflation (hard data)
3.04 Interest rate spread (hard data)
3.05 Government debt (hard data)
3.06 Real effective exchange rate (hard data)

4th Pillar: Health and primary education

A. Health
4.01 Medium-term business impact of malaria
4.02 Medium-term business impact of tuberculosis
4.03 Medium-term business impact of HIV/AIDS
4.04 Infant mortality (hard data)
4.05 Life expectancy (hard data)
4.06 Tuberculosis prevalence (hard data)
4.07 Malaria prevalence (hard data)
4.08 HIV prevalence (hard data)

B. Primary education

4.09 Primary enrolment (hard data)

5th Pillar: Higher education and training

A. Quantity of education
5.01 Secondary enrolment ratio (hard data)
5.02 Tertiary enrolment ratio (hard data)

B. Quality of education
5.03 Quality of the educational system
5.04 Quality of math and science education
5.05 Quality of management schools

C. On-the-job training
5.06 Local availability of specialized research and training services
5.07 Extent of staff training

6th Pillar: Market efficiency

A. Good markets: Distortions, competition, and size

1. Distortions
6.01 Agricultural policy costs
6.02 Efficiency of legal framework
6.03 Extent and effect of taxation
6.04 Number of procedures required to start a business (hard data)
6.05 Time required to start a business (hard data)

2. Competition
6.06 Intensity of local competition
6.07 Effectiveness of antitrust policy
6.08 Imports (hard data)
6.09 Prevalence of trade barriers
6.10 Foreign ownership restrictions

3. Size
0.00 GDP – exports + imports (hard data)
6.11 Exports (hard data)

B. Labor markets: Flexibility and efficiency

1. Flexibility
6.12 Hiring and firing practices
6.13 Flexibility of wage determination
6.14 Cooperation in labor-employer relations

2. Efficiency
6.15 Reliance on professional management
6.16 Pay and productivity
6.17 Brain drain
6.18 Private sector employment of women

C. Financial markets: Sophistication and openness
6.19 Financial market sophistication
6.20 Ease of access to loans
6.21 Venture capital availability
6.22 Soundness of banks
6.23 Local equity market access

7th Pillar: Technological readiness

7.01 Technological readiness
7.02 Firm-level technology absorption
7.03 Laws relating to ICT
7.04 FDI and technology transfer
7.05 Cellular telephones (hard data)
7.06 Internet users (hard data)
7.07 Personal computers (hard data)

8th Pillar: Business sophistication

A. Networks and supporting industries
8.01 Local supplier quantity
8.02 Local supplier quality

B. Sophistication of firms' operations and strategy
8.03 Production process sophistication
8.04 Extent of marketing
8.05 Control of international distribution
8.06 Willingness to delegate authority
8.07 Nature of competitive advantage
8.08 Value-chain presence

9th Pillar: Innovation

9.01 Quality of scientific research institutions
9.02 Firm spending on research and development
9.03 University/industry research collaboration
9.04 Government procurement of advanced technology products
9.05 Availability of scientists and engineers
9.06 Utility patents (hard data)
9.07 Intellectual property protection
9.08 Capacity for innovation

Environmental Sustainability Index

Table C.1 below is taken from the Appendix C of Esty (2005). The Appendix also has the following information on each of the variables listed in the table:

- The variable number.
- The variable code.
- The reference year (MRYA = Most Recent Year Available for the stated range).
- The variable description.
- The units in which the variable is measured.
- The primary data source.
- The logic for including the variable in the ESI.
- The methodology used to produce the variable, including any additional processing of the data beyond that of the data providers.
- The observed mean and median values for all countries.
- The observed minimum (min) and maximum (max) values for all countries.
- The 2.5 and 97.5 percentile cut-off values. In calculating the ESI, extreme values that fell outside the ranges of these values are truncated.
- The table with the original and imputed data. Note that where data for a given variable were imputed, the estimated values are shown in brackets.

Table C.1: Variables sorted alphabetically by variable code

Page	Variable Code	Variable Description	Indicator Description
281	ACEXC	Acidification exceedance from anthropogenic sulfur deposition	Reducing Ecosystem Stress
309	AGENDA21	Local Agenda 21 initiatives per million people	Environmental Governance
295	AGSUB	Agricultural subsidies	Natural Resource Management
267	ANTH10	Percentage of total land area (including inland waters) having very low anthropogenic impact	Land
268	ANTH40	Percentage of total land area (including inland waters) having very high anthropogenic impact	Land
287	BODWAT	Industrial organic water pollutant (BOD) emissions per available freshwater	Reducing Water Stress
279	CARSKM	Vehicles in use per populated land area	Reducing Air Pollution
310	CIVLIB	Civil and Political Liberties	Environmental Governance
330	CO2GDP	Carbon emissions per million US dollars GDP	Greenhouse Gas Emissions
331	CO2PC	Carbon emissions per capita	Greenhouse Gas Emissions
275	COALKM	Coal consumption per populated land area	Reducing Air Pollution
311	CSDMIS	Percentage of variables missing from the CGSDI "Rio to Joburg Dashboard"	Environmental Governance
323	DAI	Digital Access Index	Science and Technology
301	DISCAS	Average number of deaths per million inhabitants from floods, tropical cyclones, and droughts	Reducing Environment-Related Natural Disaster Vulnerability
302	DISEXP	Environmental Hazard Exposure Index	Reducing Environment-Related Natural Disaster Vulnerability
296	DISINT	Death rate from intestinal infectious diseases	Environmental Health
297	DISRES	Child death rate from respiratory diseases	Environmental Health
317	DJSGI	Dow Jones Sustainability Group Index (DJSGI)	Private Sector Responsiveness
262	ECORISK	Percentage of country's territory in threatened ecoregions	Biodiversity
318	ECOVAL	Average Innovest EcoValue rating of firms headquarted in a country	Private Sector Responsiveness
284	EFPC	Ecological Footprint per capita	Reducing Waste & Consumption Pressures
327	EIONUM	Number of memberships in environmental intergovernmental organizations	Participation in International Collaborative Efforts
315	ENEFF	Energy efficiency	Eco-Efficiency
325	ENROL	Gross tertiary enrollment rate	Science and Technology
288	FERTHA	Fertilizer consumption per hectare of arable land	Reducing Water Stress
292	FORCERT	Percentage of total forest area that is certified for sustainable management	Natural Resource Management
280	FOREST	Annual average forest cover change rate from 1990 to 2000	Reducing Ecosystem Stress
328	FUNDING	Contribution to international and bilateral funding of environmental projects and development aid	Participation in International Collaborative Efforts

303	GASPR	Ratio of gasoline price to world average	Environmental Governance
305	GOVEFF	Government effectiveness	Environmental Governance
282	GR2050	Percentage change in projected population 2004-2050	Reducing Population Pressure
304	GRAFT	Corruption measure	Environmental Governance
274	GRDAVL	Internal groundwater availability per capita	Water Quantity
286	HAZWST	Generation of hazardous waste	Reducing Waste & Consumption Pressures
261	INDOOR	Indoor air pollution from solid fuel use	Air Quality
322	INNOV	Innovation Index	Science and Technology
294	IRRSAL	Salinized area due to irrigation as percentage of total arable land	Natural Resource Management
319	ISO14	Number of ISO 14001 certified firms per billion dollars GDP (PPP)	Private Sector Responsiveness
312	IUCN	IUCN member organizations per million population	Environmental Governance
313	KNWLDG	Knowledge creation in environmental science, technology, and policy	Environmental Governance
308	LAW	Rule of law	Environmental Governance
266	NBI	National Biodiversity Index	Biodiversity
258	NO2	Urban population weighted NO_2 concentration	Air Quality
276	NOXKM	Anthropogenic NO_x emissions per populated land area	Reducing Air Pollution
291	OVRFSH	Productivity overfishing	Natural Resource Management
329	PARTICIP	Participation in international environmental agreements	Participation in International Collaborative Efforts
324	PECR	Female primary education completion rate	Science and Technology
289	PESTHA	Pesticide consumption per hectare of arable land	Reducing Water Stress
333	POLEXP	Import of polluting goods and raw materials as percentage of total imports of goods and services	Reducing Transboundary Environmental Pressures
314	POLITY	Democracy measure	Environmental Governance
306	PRAREA	Percentage of total land area under protected status	Environmental Governance
265	PRTAMPH	Threatened amphibian species as percentage of known amphibian species in each country	Biodiversity
263	PRTBRD	Threatened bird species as percentage of known breeding bird species in each country	Biodiversity
264	PRTMAM	Threatened mammal species as percentage of known mammal species in each country	Biodiversity
285	RECYCLE	Waste recycling rates	Reducing Waste & Consumption Pressures
316	RENPC	Hydropower and renewable energy production as a percentage of total energy consumption	Eco-Efficiency
321	RESCARE	Participation in the Responsible Care Program of the Chemical Manufacturer's Association	Private Sector Responsiveness
326	RESEARCH	Number of researchers per million inhabitants	Science and Technology
259	SO2	Urban population weighted SO_2 concentration	Air Quality
332	SO2EXP	SO_2 Exports	Reducing Transboundary Environmental Pressures
277	SO2KM	Anthropogenic SO_2 emissions per populated land area	Reducing Air Pollution
283	TFR	Total Fertility Rate	Reducing Population Pressure
260	TSP	Urban population weighted TSP concentration	Air Quality
298	U5MORT	Children under five mortality rate per 1,000 live births	Environmental Health
299	UND_NO	Percentage of undernourished in total population	Basic Human Sustenance
278	VOCKM	Anthropogenic VOC emissions per populated land area	Reducing Air Pollution
273	WATAVL	Freshwater availability per capita	Water Quantity
290	WATSTR	Percentage of country under severe water stress	Reducing Water Stress
300	WATSUP	Percentage of population with access to improved drinking water source	Basic Human Sustenance
307	WEFGOV	World Economic Forum Survey on environmental governance	Environmental Governance
320	WEFPRI	World Economic Forum Survey on private sector environmental innovation	Private Sector Responsiveness
293	WEFSUB	World Economic Forum Survey on subsidies	Natural Resource Management
269	WQ_DO	Dissolved oxygen concentration	Water Quality
270	WQ_EC	Electrical conductivity	Water Quality
271	WQ_PH	Phosphorus concentration	Water Quality
272	WQ_SS	Suspended solids	Water Quality