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Realistic Eco-Efficiency Analysis

Why We Need Better Eco-Efficiency Analysis

From Technological Optimism to Realism

by Gjalt Huppes, CML

Eco-efficiency analysis relates two pillars of sustainability, the economic and the environmental one. There are several options for specifying eco-efficiency, as a partial or more encompassing concept. When using technology specification as the basis for eco-efficiency analysis, there is an inbuilt tendency towards unjustified optimism, as other societal mechanisms detract from the technology potential. A more systematic approach to modelling is required to arrive at a more realistic analysis, both lining the micro level analysis to the macro level sustainability consequences for society and reckoning with the relevant mechanism in society of economic, cultural, institutional and political nature. With more realistic modelling, more realistic requirements on the trade off between economy and environment at a micro level can be formulated. A substantial research programme is required for this purpose, with substantial efforts at standardisation. Work in the EU project CALCAS is addressing such research framing questions.

1 Introduction

The race between economic growth and environmental improvement is an open one. In some respects, the environment improves faster, as in terms of reduced toxic emissions. In other respects, economic growth is larger than environmental improvements per average unit of consumption, and hence the environment deteriorates. Main examples are global warming and land use shifts eating up nature areas. Together these constitute main factors for the fast reduction in biodiversity. Due to global interconnectedness of production processes, and as *low hanging fruits* have already been picked, measures for improving one environmental aspect impinge on other environmental aspects. Also, a fundamental sub-optimality is created by the lack of insight on the costs of overall environmental improvements.

Eco-efficiency analysis would give the insight in the relation between economic value creation and environmental quality. Though concepts have been developed (WBCSD 2000; Huppes, Ishikawa 2005), the analysis as a whole has not yet developed adequately for this task. Currently, the optimistic views of technologists show that all problems can easily be solved. For example, biofuels can solve the global warming problem. The micro-level analysis supporting this view, however, does not take into account the economic aspects involved in society at large, including the market mechanisms leading to conversion of nature area to agricultural lands as currently is taking place at a very high pace. If eco-efficiency analysis would develop more adequately, a more rational route to sustainability could be followed, reckoning with all relevant mechanisms in a reasonable way. Let us review the concept and the status of development of eco-efficiency research, and then come back on what is required for adequate development of analysis. One element highlighted will be how future actions might realistically be framed in models and scenarios. Of course, methods and models will never give the last and final answer. Without them, however, the right questions cannot even be framed, as empirical questions on relevant mechanisms and scenarios, and normatively on the relative importance of different environmental aspects vis-à-vis each other and against economic values, and mostly beyond eco-efficiency also relative to broader social values.

Let us start with clarifying the concepts involved. Eco-efficiency specifies the relation between economic value creation and the environmental effects caused in doing so (WBCSD 2000). The unit to which the concept may apply can vary. It often refers to one specific economic activity, like a production process, or to sets of activities as constituting a product system, supported by Life Cycle Analysis (LCA).[1] The concept can be applied still broader, to a firm, a sector (e.g. Dahlstrom, Ekins 2005), a region or country (e.g. Seppällä et al. 2005), or to the full world. Eco-efficiency analysis can support sustainable decision making by giving insight in the trade-offs as exist or are expected to be involved empirically, and by creating the option of specifying the minimum trade-offs which are required for sustainable development, covering the economic and environmental aspect. In supporting this eco-efficiency analysis, options for modelling economic, socio-cultural and institutional and regulatory mechanisms are to be taken into account, beyond the mere technological relations as now used in LCA. Decoupling is a related concept at the macro level, stating the environmental effectiveness of developments towards sustainability (McDonough, Braungart 2001), indicating that eco-efficiency has improved enough to compensate for economic growth. Without enough improvement in eco-efficiency, economic growth will lead to environmental deterioration; *"as you grow so shall you weep"* is a famous sentence by Mishan already in 1969 (Mishan 1969).

2 Background

The central subject in sustainability discourse is how to reconcile economic growth with environmental quality, also reckoning with social stability and equity aspects, especially distributional aspects. Eco-efficiency focuses on the relation between value created in economic activities and the environmental effects related to these, leaving several social aspects to a different discourse. The eco-efficiency concept came up around 1990 (Schaltegger, Sturm 1989), with broad use being induced through the World Business Council on Sustainable Development (WBCSD: http://www.wbcsd.org; especially Schmidheiny 1992). A related concept at a micro level is *marginal costs of emission reduction*, expressing the value lost in environmental improvement. Related concepts at an aggregate or macro level are *weak and strong sustainability* and *relative and absolute decoupling*, expressing the dynamics of economic development in relation to environmental effects (see Neumayer 2003).

The eco-efficiency concept can be used for measuring performance both at a micro level and a meso and macro level. From a business perspective, it allows to set targets for development of eco-efficiency of the firm (Reijnders 1998; DeSimone, Popoff 2000; Bleischwitz, Hennicke 2004; Seiler-Hausmann et al. 2004; Möller, Schaltegger 2005; Figge, Hahn 2005; Scholz, Wikke 2005). The ultimate criterion is in the effect on overall sustainable development of society, requiring a link from the micro to the macro level (Huppes, Ishikawa 2007). From a policy perspective, eco-efficiency analysis allows to align very different policies from the same sustainability perspective, like different domains of environmental policy, innovation policy and broader economic policy.

3 Normative concepts and definitions

Eco-efficiency may first be a measuring rod but it may also be defined normatively, as a goal, similar to sustainability and decoupling: "Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the earth's estimated carrying capacity." (WBCSD 2000, p. 6; original version 1992) Such normative goals may also be linked to strategies for moving into a more eco-efficient direction, like "reduce material intensity; reduce energy intensity; reduce dispersion of toxic substances; enhance recyclability; maximize use of renewables; extend product durability; increase service intensity" (WBCSD 2000, p. 15).

If such strategies indeed work out in terms of creating more eco-efficiency it requires a measuring rod. Eco-efficiency not only is used as a normative concept but also may be used in a quantitative way, as an empirical measuring rod. It then may measure performance, as actual performance. With it one can specify how the actual eco-efficiency performance is and how it is developing quantitatively. Or one may state normative objectives in a quantified way, similar to *absolute decoupling*, which also may denote an actual development, or a goal.

4 Quantified performance definitions

Eco-efficiency specifies the relation between economic value created and the environmental effects caused in doing so. Several similar options for definition exist (Huppes, Ishikawa 2005). The relation is expressed as a ratio, either as value per unit of environmental effects, that is *environmental productivity*, or as environmental effect per unit of value, that is *environmental intensity* of production and consumption. The information contained in these two variants is the same, the one being the inverse of the other. A more limited eco-efficiency concept focuses on cost only. Environmental improvement per unit of cost, that is *environmental cost-effectiveness,* very close to marginal cost of emission reduction. Again, the inverse can convey the same information, as *environmental improvement cost*.

Value based eco-efficiency concepts have the advantage that they can be applied to different scale levels. Total society, in terms of value creation and environmental impacts, is the sum of all activities creating value and having environmental impacts. The cost based versions of eco-efficiency can apply only at a micro level. For measuring the eco-efficiency ratio, the economic and the environmental performance both are to be expressed in one number. Several options exist for each, so in applications of eco-efficiency analysis a choice is required. A number of options is indicated.

5 Economic performance

A main distinction is between cost based and value based measures. When focusing on environmental improvements like add-on purification steps, the cost based performance is simpler to apply. For embodied environmental improvements, the value created in the market usually will be influenced as well. Then the broader value concept is to be used, which does not distinguish between motives for change. Ultimately, cost and value refer to the same phenomena, so there is no basic difference between cost and value based approaches. The relation is quite direct. Cost in economic theory terms is measured as proceeds forgone, as alternative cost. These proceeds reflect the value of what could have been produced, expressed in monetary terms.

From a business perspective, cost relate to purchases from other business and payments to the production factors labour and capital. These payments constitute the value added of the firm. When surveying the full production chain, the payments to other firms cover their purchases and their value added. Ultimately the selling price of a product to a consumer is equal to the value added in all activities required for that product in the chain. When products are competitively priced, their value added is covered in the market price. The value added includes the profits on the capital used in production.

When adding up all added values of all firms (including publicly owned ones) to the level of society, total value added in society results, as gross domestic product (GDP) at factor cost. Adding up all expenditures for final consumption, including public consumption, gives gross domestic product at market prices. In this second measure on GDP taxes and subsidies on products are included. A clear choice is to be made on including or excluding taxes when specifying value in money terms.

There are no basic problems in establishing cost and value on a yearly basis, though several options exist. However, when analyzing product systems or investment options, as based on life cycle analysis (LCA), life cycle costing (LCC) or cost-benefit analysis (CBA), costs refer to different years. Cost and value may then be discounted to a net present value, as in CBA and business oriented versions of LCC (Mishan 1971; Fisher 1971; Dasgupta, Pearce 1972; Dhillon 1989; Rebitzer, Seuring 2003; Huppes et al. 2004). Or they may be expressed as steady state cost, as in the LCA related type of LCC (Huppes et al. 2004). This type of micro level analysis concerning several years does not correspond to a macro level of GDP, as GDP data are not discounted. There is a vast literature on empirical and normative aspects in discounting (e.g. Mishan 1971; Kopp, Portney 1999; Portney, Weyant 1999).

There is a tendency in social accounting to correct market prices or value added with the welfare effects of the environmental externalities caused by the activities involved (Sen 1970). These external effects then are quantified in monetary terms. This integration precludes the specification of eco-efficiency, as numerator and denominator just are added up. Given the difference in underlying concepts of cost and value involved, this addition seems at best a last step, an optional one.

6 Environmental performance

Environmental effects of economic activities have their starting point in the environmental interventions involved, ranging from primary resources extraction to emissions, as mass flows, and also cover other influences (like land use, radiation, disturbances, etc.). These interventions in turn have further consequences in the environment (like climate change, acidification and toxic effects). Ultimately, these environmental mechanisms lead to effects on biodiversity, health, the life support system and availability of primary resources, as main foci of environmental concern. A survey is given by Udo de Haes et al. (2002).

When specifying eco-efficiency, the environmental performance can be based on specific interventions, specific environmental mechanisms or specific domains of environmental concern, or may cover all. All partial measures lead to a multitude of eco-efficiency scores (like for carbon dioxide emissions, methane emissions and iron extracted). In actual decision making these different eco-efficiency scores then all would have be taken into account, each one based on the same economic performance measure. It then may be more practical first to integrate the environmental aspects into one and have only one eco-efficiency score.

For the integration step, there are three basically different methods available, based on private preferences, on public preferences and on cost considerations. Private preference based methods are used by economists, stating what private persons express to be the value of environmental effects converting environmental effects into monetary value. Willingness-to-pay is the main concept here.[2] Public preferences on environmental impacts may be expressed directly in terms of weighting sets, as stated preferences. This seldom happens with NOGEPA-covenant[3] in the Netherlands as one main exception (Huppes et al. 2007). Indirect measures are based on the cost for realizing policy goals, or on the cost incurred in current environmental policies (e.g. Davidson et al. 2005; Kobayashi et al. 2005). The third method avoids the normative points of view of the other methods to some extent, by looking at current cost of reduction of environmental interventions or effects (Oka et al. 2007) or at inferior options for trade offs (Kuosmanen, Kortelainen 2005). More incidental approaches try to specify an overall score with a physical measure like embodied energy, or the land hypothetically required for binding emissions or preventing emissions through some technologies, with the Footprint as well known example (Wackernagel, Rees 1996).

Through either of these methods, different sets of environmental interventions can be translated into the corresponding overall environmental score, with easy practical applications (e.g. Lippiat, Boyles 2001; Itsubo, Inaba 2003). Of course, every person can have his private set of preferences and weights. There will never be society-wide agreement on any of these integration methods. However, by quantifying specific methods, a public discourse on relative importance of different environmental effects can better be founded.

7 Relation to sustainable development and eco-innovation

Eco-efficiency analysis is not a goal in itself. The ultimate goal is to contribute to the best combination of economic and environmental objectives, avoiding unnecessary cost and environmental damages, negatively, and positively indicating the requirements for sustainable development. Let us assume that the aim of sustainable development is set at absolute decoupling of economic growth and environmental impact, improving environmental quality.

We know that population growth and increasing affluence by technological development may well lead to long term global growth of GDP by two to three percent per year. Then the eco-efficiency of all activities in society is to improve by two to three percent per year on average at least, to be just at the boundary of absolute decoupling. In portfolio analysis of firms, it then is not enough to look at win-win options. Implementing such options may well imply a deteriorating environment. A too low eco-efficiency will lead to a too low eco-effectiveness at a societal macro level.

Many activities can hardly be improved environmentally, because their environmental impact is very low, as with some services, or because there are no viable alternative technologies available for yearly eco-efficiency improvement by two to three percent, as in steel production for some time to come. This implies that other activities have to increase their eco-efficiency even faster or that shifts towards relatively eco-efficient activities have to take place, through shifts in sector structure and consumptions structure. Establishing the eco-efficiency of such larger aggregates then is required for focused action.

8 What needs to be done

Technical and behavioural solutions to sustainability problems are widely available but do not materialise. Their technical analysis, as in Life Cycle Analysis, shows their technical potential for environmental improvement. This is an essential starting point for sustainable development analysis. Institutional, cultural and political realities guide activities into different and often adverse directions however, without easy solutions in current modelling, nor in current practice of policy guidance. Substantial cost of low-carbon energy, for example as induced by restrictive carbon trading, would ruin the energy intensive industries in the countries inducing these alone.

Within the EU, the Lisbon agenda indicates economic growth as the overriding objective, to pay for pensions and social security and to compete with other countries. The mechanisms created are real and not directly made compatible with sustainable development. Realistic modelling has to reckon with economic mechanisms directly related to the products and technologies analysed. Next, developments are to be placed in the broader economic framework of their functioning. Large scale use of corn based ethanol as a fuel leads to globally rising prices of corn and other staple foods. Income effects and cultural developments may substantially reduce improvements seemingly attractive at a technology level as studied in LCA. These often are named rebound effects. Increased lighting with high efficiency energy bulbs and heavier cars with increased fuel efficiency are examples.

The analytic framework for analysing environmental effects of economic activities is developing well, both at a micro level and increasingly linking the micro level with meso and macro level. A similar, fully connected, social and economic analytic framework is required for a realistic analysis of technical options. Current solar cells might meet our full energy needs. But they won't, not now at least. How do technical options fit in current institutional frameworks and in feasibly adapted frameworks? How do they relate to culture as a developing one? And which policies undermine or may support their introduction? A socio-economic systems analysis linked to life cycle systems analysis is dearly needed. Eco-efficient eco-innovation may then develop practically.

When developing and analysing roads towards a more sustainable society, technical and behavioural solutions may be found which "solve all problems". All energy may be produced from solar cells in a fraction of the deserts of the earth; houses and even glass houses may become energy producers instead of users of energy, and food consumers can substantially reduce their adverse effects on biodiversity by reducing meat consumption. Such optimism on technologies in production and consumption makes all environmental problems smelt and vanish like snow in the sun. With economic growth then unbounded the social problems of poverty would get solved in the same stroke. However, what we see is widespread destruction of tropical forests to accommodate for biomass based energy production; an explosion in the use of air conditioning; and ever heavier and faster cars more than compensating for increases in motor efficiency. In the rich countries, working hours could be reduced using a part of productivity increases for leisure time. Instead, there now is an urge to work more hours per week, per year and on a life time basis, with ever rising consumption as a consequence. There is a serious dilemma for framing analysis.

Without technological optimism, technical solutions will not be produced; without social optimism, social solutions will not come about; and without technical and social realism, solutions will not work for sustainability. The *central question for the research programme* proposed is how material technologies and social mechanisms can be developed which in combination may effectively lead us towards a more sustainable future. These domains are now disparate, as in Life Cycle Analysis and in Transition Studies. The answers require research along a number of well connected main lines.

1. A specification of sustainability goals in terms of environmental parameters and socio-economic parameters, as elements of the sustainability goal function at endpoint level; not at intermediate strategy level like 'reduced materials use'.
2. A technical linkage of individual activities in consumption and production to these sustainability goals at a micro level, under general assumptions for economic and social background mechanisms, as "LCA++".
3. A linkage to sustainability effects for *totals* in consumption and production at a meso and macro level, also based on simplified and partial socio-economic background mechanisms.
4. A specification of possible social developments at a country and global level in terms of 'institutional', 'cultural', and 'political developments', as general *social-technical scenarios*.
5. An evaluation procedure for new technologies reckoning with the realities in institutions, culture and politics as depicted in main social scenarios and in adjoining general technology scenarios.
6. An evaluation procedure for new policies and institutional arrangements, explicitly reckoning with cultural constraints and with the realities and scenarios for material technologies.

An example may indicate the problems to be solved by this trans-disciplinary research programme.

Biomass based energy may contribute to lower greenhouse gas emissions[4], lower resource depletion and increased energy supply security, as likely elements in the sustainability goals function of step 1. In step 2, the environmental analysis of such energy systems is available now, as in using advanced types of Life Cycle Assessment (LCA), with limited divergence between studies, but also with limited realism as to implementation options and broader consequences. How a substantial share of biomass in energy supply would work out, may be based on placing the intended volumes in the economic system, as in using combinations of LCA and environmentally extended input-output analysis, with simple assumptions on how markets and other institutions work, in step 3. The conceptual development is there, with standardisation (as in SNA 2002) and mathematics involved (Heijungs 2001; Heijungs, Suh 2002; Heijungs, Suh 2006). This analysis now is developing, but is not embedded in an overall framework. Such studies may indicate social and infrastructural bottlenecks.

In step 4, the systematic foundations are laid for the most relevant social scenarios, comprising mixes of policies and institutional and cultural developments. Specialised social research is to be recombined in one framework, actively linked to step 2 and 3. In step 5, the biomass-for-energy analysis is combined with the socio-technical scenario analysis, as the most complete sustainability analysis. The existing social scenario shows disastrous developments as in forest destruction for diesel oil and ethanol production, based on global market mechanisms with weak zoning laws in developing countries. Other social scenarios will show totally different results, but are relevant only if realistic, not just by assumption. Similar to technical design, social arrangements can be developed and evaluated from a sustainability viewpoint, in step 6, indicating how they can contribute to general sustainable technology development, and with a feedback to the scenarios of step 4. For biomass-for-energy, this might involve a departure from WTO rules and an international approach to effective nature conservation. Much of the research required is being described in the ongoing EU FP6 project CALCAS, running from 2006 to 2009.[5]

9 Summarising

A research programme is needed which can assess the sustainability of technologies and products and of the actions which may lead to their introduction in order to realistically evaluate their potential contribution to sustainability. Eco-efficiency thus better substantiated then can become one main way to help guide actions towards sustainability.

Notes

1) For an analytic approach in this context see Guinée et al. 2002.
2) See for a survey: DEFRA 2004.
3) NOGEPA is the acronym for “The Netherlands Oil and Gas Exploration and Production Association” (note of the editor)
4) But see Farrell et al. 2006 for exceptions in this case.
5) For *CALCAS* see http://www.calcasproject.net/.

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