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# Sustainability indicator development—Science or political negotiation?

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ABSTRACT

The efforts to develop sustainability indicators have strongly increased since the beginning of the 1990s, often led by intergovernmental processes. More recently, a number of sustainability indicator development processes have been initiated within large research projects that aim to design tools for sustainability assessments, funded by the European Union. The development of sustainability indicators provides a particular challenge to scientists, given the essentially normative dimension of the concept of "sustainability". Thus, we argue, the development of sustainability indicators is a process of both scientific "knowledge production" and of political "norm creation", and both components need to be properly acknowledged. Based on a respective theoretical framework and comparing five cases of sustainability indicator development processes (three science-led and two led by intergovernmental processes), we find that the political norm creation dimension is not fully and explicitly recognized in science-led processes. The paper concludes by discussing a number of implications for the design of sustainability indicator development processes, in particular with regard to participation and representation as well as adjustment of indicators over time.



## 1. Introduction

Since the publication of the Report "Our Common Future" (Brundtland Report) by the World Commission on Environment and Development in 1987 and the accomplishment of the United Nations Conference on Environment and Development (UNCED) in 1992, the concept of "sustainability" has been adopted as key political principle by most governments worldwide. In Chapter 40 of the Agenda 21, governments have in 1992 introduced the development of "sustainability indicators" as a key approach to provide a basis for sustainability-related decision-making processes (paragraph 40.6 of Agenda 21, see UNCED, 1992). At global level, the United Nations Commission on Sustainable Development (CSD) started work on the development of sustainability indicators soon after UNCED, presenting a first indicator set in 1995 (UNESC, 1995). Within the European Union (EU) "sustainable development" was introduced in 1997 as a core objective in its Article 2 of the Amsterdam Treaty and efforts to establish ways to measure progress through indicators were led by the European Environment Agency (EEA) and EUROSTAT, the statistical office of the European Union (EEA, 2005; European Commission, 2005a,b). In 2001, a specific EU Sustainable Development Indicator Task Force was founded that supported the further development of the indicators. Specific sectoral indicators have also been developed by a range of sector administrations at international, European and national levels. For instance in 1998, the Ministerial Conference on the Protection of Forests in Europe (MCPFE) adopted a set of indicators for sustainable forest management (MCPFE, 1998). Following the Cardiff process where the European Council urged "all relevant formations of the Council to establish their own strategies for giving effect to environmental integration and sustainable development within their respective policy areas" (EC,

*Abbreviations:* C&I, Criteria and Indicators; CSD, Commission on Sustainable Development; EEA, European Environment Agency; EFORWOOD, Sustainability Impact Assessment of the Forestry-Wood Chain; EU, European Union; INSEA, Integrated Sink Enhancement Assessment; MCPFE, Ministerial Conference on the Protection of Forests in Europe; OECD, Organisation for Economic Co-operation and Development; PLUREL, Peri-urban Land Use Relationships: Strategies and Sustainability Assessment; SD, Sustainable Development; SDI, Sustainable Development Indicators; SEAMLESS, System for Environmental and Agricultural Modelling, Linking European Science and Society; SENSOR, Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions; STS, Science Technology Studies; UNCED, United Nations Conference on Environment and Development.

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1998), the EEA led the development of the IRENA indicator set focusing on the integration of environmental aspects into agricultural policy and the TERM indicators into transport policies. Much of the work on sustainable development indicators was driven by political-administrative rationales, needs and bodies, and with the involvement of both political decision-makers as well as scientists.

With the adoption of the EU sustainable development strategy in 2001 and in the wake of the implementation of the results of the Johannesburg summit in 2002, the political notion of "sustainable development" as well as the political need to evaluate the impact of possible policy options on "sustainability" led also to the funding of a number of European projects tasked to further develop tools for sustainability impact assessments. Those included projects funded by the European Commission under the Sixth EU Framework Programme for Research and Technological Development: SENSOR (Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions), EFORWOOD (Sustainability Impact Assessment of the Forestry-Wood Chain), SEAMLESS (System for Environmental and Agricultural Modelling, Linking European Science and Society) and PLUREL (Peri-urban Land Use Relationships: Strategies and Sustainability Assessment). These are probably among the largest research- and science-driven efforts with regard to sustainability indicator development in Europe. Many sustainability impact assessments are using models based indicators. Unlike political-administrative processes these are science-driven, with scientific actors, mainly from natural science disciplines but also social sciences, that are at the core of the development process.

Generally, the above mentioned political-administrative and science-driven sustainability indicator development initiatives are driven by rather different rationales. While the latter ones develop indicators to use them in the context of ex ante sustainability impact assessments of alternative policies or scenarios based on modelling tools, indicator development processes driven by political-administrative bodies focus more on establishing measurement and monitoring tools on key sustainability dimensions. As such, they are not specifically designed for either ex ante or ex post impact assessments, and do not take specific needs of modelling tools into account. Irrespective of this difference, however, both types of initiatives need to balance the integration of knowledge and of societal norms in the indicator development process, which is the focus of the paper.

The role of sustainability indicators is to structure and communicate information about key issues and their trends considered relevant for sustainable development. Indicators have been defined by Ott (1978) as a way to "reduce a large quantity of data to its simplest form, retaining essential meaning for the questions that arebeing asked". However, we believe that indicators do more than describe current conditions or trends. They create an understanding and insight about how human and/or environmental systems operate; they suggest the nature and intensity of linkages among different components of the studied systems, and they offer a better understanding of how human actions affect different dimensions of sustainability (economy, environment, social issues). Indicators are consequently meant to support scientists, politicians, citizens, and decision-makers to monitor status and changes in key sustainability dimensions, and to more clearly foresee the consequences of action or inaction. The identification, measurement, and application of appropriate indicators remains among the major challenges facing policy-makers, bureaucrats, scientists, and citizens tasked with sustainability (McCool and Stankey, 2004).

The need to better understand and structure the indicator selection process has been underlined for some time (e.g. Niemeijer and de Groot, 2008; Cimorelli and Stahl, 2005; Niemeijer, 2002; Kelly and Harwell, 1988). Finding the right approach to representing a given issue through an indicator is important but sometimes difficult. Several authors have proposed approaches and conceptual ideas on how to structure the process for indicator development, especially for natural resource use and management indicators (Niemeijer and de Groot, 2008; Wilson et al., 2007; Donnelly et al., 2007; Hezri and Dovers, 2006; McCool and Stankey, 2004; Failing and Gregory, 2003; Reynolds et al., 2003). However, in our view, the fundamental challenge of sustainability indicator development is not primarily technical or at least not technical alone. It is political in at least two dimensions: Firstly, the concept of "sustainability" is per definition normative, reflected by the etymological roots of sustainability as a derivation from the Latin verb "sustenere" (= uphold). Secondly, in indicator development processes, decisions on indicators are taken by a usually rather limited number of persons, which are often experts in a specific area. These experts decide on the relative importance of an issue compared to a wide range of issues available, but usually need to arrive at a very limited number of indicators in total. Those who decide on what to "sustain" across a range of factors (ecological, economic, and social) are required to make normative decisions based on for example technical knowledge, but also on more or less explicit normative philosophical and political perceptions and intentions. It implies that those participating in the process are not only acting in their technical expert capacity, but also as "political citizens" taking normative decisions on what aspects to "uphold". The decision on "who participates" and "who decides" in indicator development processes is thus a crucial one, requiring both substantive expertise as well as balanced interest representation in a process that is essentially "norm-creating". The political aspects, for example the normative and value judgements involved, however, often tend to be neglected in the indicator development literature (for a similar argument see Turnhout et al., 2007, see also Cimorelli and Stahl, 2005). Hence, different ways of bridging the two processes have been suggested, such as using indicator frameworks to link signals (indicators) to policy (Gudmundsson, 2003).

To our mind the development of sustainability indicators is a process of both scientific "knowledge production" and of political "norm creation", and both components need to be properly acknowledged in the design of a process to develop sustainability indicators, in particular also in science-driven processes. It seems that in science-driven processes there is a certain tendency to ignore or underestimate the political "norm creation activity" by putting emphasis on the technocratic conception of expertise, and a separation of science and policy. This would help to explain why the science community has grappled without much success to develop a consistent non-normative theory on sustainability and its measurement through indicators. On the other hand the politically driven indicator development processes can easily 'hide' behind the knowledge creation activity, downplaying the norm-creating activity. Normative dimensions can thereby be hidden and, depending on which scientific constellation of experts involved, the indicator set becomes biased towards one or the other dimension of SD which lies in the interest of certain political actors.

In this paper we compare five sustainability indicator development processes with regard to the underlying design used and procedural approach employed: three science-driven processes and two governmental initiatives. The focus of the paper lies in particular on the approaches and experiences of the science-driven sustainability indicator development processes in the research projects EFORWOOD, SENSOR and SEAMLESS. We compare those to two government-led processes on sustainability indicator development (EU SDI, MCPFE C&I). Their respective indicator sets are widely used in sustainability reporting in Europe. Those cases should help us to get a grip on the question we are empirically interested in: *What is the role of political norm creation and knowledge production in the elaboration of SDI sets, both political and science-driven?*

The article proceeds in the next section with an outline of conceptual ideal-type approaches to sustainability indicator development. Thereafter, the methodical approach applied in this paper is presented. Chapter 4 introduces the five cases and analyses and compares the approaches followed within the indicator processes. Finally, we discuss our findings in the context of the initial hypothesis from which we departed and we outline implications for the design of sustainability indicator development processes.

## 2. Merging the scientific and the political context in sustainability indicator development: conceptual approaches

The process of developing sustainability indicators can be analysed with regard to how these processes take up and deal with the dimensions of knowledge production on the one hand and norm creation on the other. Both dimensions are integral components of sustainability indicator development processes due to the normative character of the concept of ‘‘sustainability’’ and the need to integrate knowledge on ecosystems and human–ecosystem interaction. The explicit or implicit design of an indicator development process determines how participating actors are selected, how they interact, and how decisions are taken. A comparison of the main ideal-type functions of a sustainability indicator development process shows, that the two main conceptual frames of such a process are following considerably different rationales (see Table 1). What varies is the degree to which these two frames are recognized in the indicator development process, and how these two relate to each other.

While the knowledge production frame is driven by the search for scientific, technical objective knowledge, the norm creation frame puts an emphasis on balancing norms, values and interests. Scientists both from natural and social sciences as well as experts (e.g. bureaucrats) act as ‘actors’ in the first frame (democratically) elected politicians and bureaucrats acting under their guidance, stakeholders and citizens in the second. Ideally scientists and experts look for the best available reflection of factual knowledge, while citizens, politicians or bureaucrats opt for the best possible reflection of norms, values by balancing respective interests. Theoretical and methodically sound approaches ideally guide scientific work, while democratic voting guides the work of the others. Finally, the knowledge production frame puts an emphasis on a ‘truthful’ representation of human system and ecosystem interactions, while the norm creation frame underscores the expression of democratically legitimized preferences on the values of nature as well as on a reconciliation of inter- and intra-generational equity as outcome.

Relevant policy studies literature focusing on the ‘‘knowledge’’ dimension comprise, amongst others, the knowledge transfer, knowledge utilization, learning, boundary, interactionist, or knowledge broker models. For instance, the ideal-type idea separating science and politics, underlying the ‘‘knowledge transfer’’ model in one particular strand of the science technology studies (STS) literature presumes that values and facts are clearly separated from each other (Pregernig, 2004; Hacking, 1999; Gieryn, 1999; Jasanoff, 1990; Hajer, 1995). In this ideal-type frame science is seen as the ‘‘place of (value-free) knowledge production’’, whereas politics is viewed as the ‘‘place of knowledge use’’, which is driven by values and power (Nowotny, 1994).

The implication of a dichotomous view on knowledge production and norm creation for sustainability indicator development would be a separation of scientific work on indicators from political influences, and a complete segregation of value judgements from scientific input. On a fundamental level, of course, this does not mirror reality as it is widely acknowledged that scientific knowledge embeds and is embedded in social practices, identities, norms and conventions (Jasanoff, 2005). There also exists a vast array of literature in the STS on the fuzzy frontiers of values and facts production, and on the co-production of natural and social knowledge and order (e.g. Jasanoff, 1987, 2005). The interrelation between (re)producing values in political systems and their interrelatedness with knowledge, including on the underlying natural systems is also in the focus of work on social systems, and in particular in work on system boundary construction (e.g. Gieryn, 1999; Waterton, 2005) as well as spanning (e.g. Pregernig, 2007).

Using a simple dichotomous conceptual frame of knowledge production and norm creation is nonetheless useful to analyse the similarities and differences of underlying conceptual approaches by scientific and policy-driven initiatives to develop sustainability indicator sets. This includes in particular science-driven initiatives which are mainly grounded in the natural sciences, such as for example ecological indicators, or sets based on complex ecosystem–human systems interaction frameworks (see e.g. Niemeijer and de Groot, 2008; Guldin and Heintz, 2007; The Heinz Center, 2002; OECD, 1993; EEA, 2005). These often seem to focus on the (major) task to assemble knowledge on key system components and their interrelatedness, and less on the normative underpinnings or implications.

With regard to sustainability indicator development McCool and Stankey (2004) argue that a clear division of roles of scientists and policy-makers is not realistic in its purest form and instead propose a functional division of roles between scientists and the public or policy-makers in the development process, while clearly underlining that these roles are interdependent and that the process needs to be iterative. Other approaches focus on the modalities of interaction between the scientists and policy-makers (Gibbons et al., 1994). Pülzl and Rametsteiner (forthcoming) for example applied a boundary spanning model where moderators link and act as brokers between scientists and policy-makers in

**Table 1**
Characteristics of the two main conceptual frames of sustainability indicator development processes.

| | Frame 1: Knowledge production | Frame 2: Norm creation |
|---|---|---|
| Background and input | Scientific and technical objective knowledge. | Norms, values and interest. |
| Actors | Scientists and experts. | (Democratically) elected politicians as representatives, bureaucrats, stakeholders, and citizens. |
| Ideal-type knowledge application | ‘Best available’ reflection of factual knowledge. | ‘Best possible’ reflection of societal norms, values and interest. |
| Ideal-type process | Scientific methods of disciplinary, inter-, multi- or trans-disciplinary science; Decisions on indicators based on their relative factual importance in human system–ecosystem interaction. | Democratic voting; decisions on indicators based on their relative value for society. |
| Outcomes | ‘Truthful’ representation of human system–ecosystem interaction. | Democratically legitimized preferences on values of nature, inter- and intra-generational equity. |

indicator development. Others, such as Donnelly et al. (2007) apply an expert-based multi-disciplinary approach for indicator selection. Turnhout et al. (2007) conceive of the indicator development as a "kind of joint knowledge production" between scientists and policy-makers.

While considerable more emphasis is so far put on the knowledge dimension, more and more scholars explicitly or implicitly underline the need to integrate different perspectives in sustainability indicator development, i.e. creating a closer interaction between frames 1 and 2. This is a consequence of at least three factors:

(a) the need to integrate different knowledge disciplines within one conceptual framework (at the most generic level: environmental, social and economic disciplines);
(b) the need to integrate the knowledge dimension and the normative dimension within one conceptual framework;
(c) the need to accommodate scientific comprehensiveness, accuracy, and practical feasibility (costs of implementation and technical-administrative feasibility).

With regard to (a) and (b) above, both the knowledge and norm creation have undergone important changes over the last decades, whereby the main locus of knowledge has diversified—from universities (knowledge production) and the state (norm production) to more diverse places e.g. the laboratory (Latour and Woolgar, 1979) and field of actors (Godin and Gingras, 2000). Policy analysis scholars (e.g. Rhodes, 1996; Pierre, 2000; Heritier, 2002; Hajer and Wagenaar, 2003; Knill and Lenschow, 2003; Mayntz, 2004; Pierre and Peters, 2005) describe this as a shift from "government" to "governance" as private and corporate actors, but also scientists and others partake in the policy process. In relation to the present issue, this has been interpreted as a change from the perception of sustainable development as a substantial concept defining ultimate aspirations, to a focus on procedural aspects, supporting pathways of change (ECSG, 2004), such as through sustainability impact assessment. In essence, what remains relevant for the analysis of different sustainability indicator development processes is the following: an acknowledgment of a diversity of participating actors selected across scientific disciplines and different (cross-sectoral) policy domains; policy-makers, and users ranging from government administrations and scientists to the public at large.

Given that it is fairly undisputed that "sustainable development" of societies is complex and that determining the most important aspects of the human system–ecosystem properties and interactions, including feedback dynamics, it is a formidably difficult task, it should not be surprising that the concept of "learning" is another characteristic element of sustainability indicator development processes. While knowledge generation can be considered a learning process per se, several explanations of policy change based on notions of learning have emerged in the policy science literature (see e.g. Bennett and Howlett, 1992). These include notions of "political-learning" developed by Heclo (1974), "policy-oriented learning" developed by Sabatier and Jenkins-Smith (1993), "lesson-drawing" analysed by Rose (1991), "government learning" identified by Etheredge (1981), "problem/instrumental learning" (Glasbergen, 1996) or "social learning" (Hall, 1993; SLG, 2001). During sustainability indicator development processes different types of learning occur, including social learning, problem and instrumental learning (Glasbergen, 1996). In our case we focus on "problem/instrumental learning", i.e. learning about the problems and instruments related to dealing with the issues in question, as this is one evident form of "learning" in sustainability indicator development processes.

The emphasis of this article with regard to sustainability indicator development processes, relates to (c), specifically, learning of actors involved in sustainability indicator development from practical testing and use of sustainability indicators. "Learning by testing" requires an *iterative* process with feedback loops during the sustainability indicator development, application, and further adjustment. Due to the normative nature of the concept of sustainable development and given the evolutionary character of interrelated human and ecosystems, this is not only to be understood as "optimization" process of testing and improving towards a stable optimum, but implies a continuous adjustment to emerging societal norms and priorities as well as knowledge about the physical system.

Summarizing the above, we hypothesize that the nature of sustainability indicators is to embed both knowledge and (political and social) norms. Consequently, the development of sustainability indicators is not a scientific task alone, but also involves political negotiation. This needs to be reflected in the design of the sustainability indicator development processes with regard to "who participates and decides" and how learning of participants is being enabled. The nature of sustainability indicators as concrete and condensed knowledge points and condensed "soft" norms on "what to uphold" also implies a periodical adjustment, not only because of increasing knowledge on complex systems, but in particular also because of changing social and political norms. This iterative element would likewise have to be visible in sustainability indicator development processes.

## 3. Assessing sustainability indicator development processes: the methodological approach

The empirical material analysed are documents of the five indicator processes (meeting minutes or protocols from meetings in the indicator development groups, stakeholder or user meetings, interim and final documents of the sustainability indicator sets), the professional backgrounds of the participants and the documentation of results (sustainability indicator sets). This approach does not allow precise assessment of all knowledge and normative backgrounds that went into the various development processes, but can act as a good proxy to compare the design of the indicator development process and main characteristics of the actual process. In addition, the authors were personally involved in a leading role in four of the five development processes analysed and could thus perform participant observation during all stages of the indicator development process.

In order to test the theoretical implications of the nature of sustainability indicators on the respective development process, a number of factors of analysis are derived based on the discussion in Chapter 2. The factors to delineate the underlying models of knowledge production and norm creation are shown in Table 2. The first three mainly address questions of participation, the last two appeal to the question of how different topical domains were merged and balanced, and in how far a learning takes place in indicator development processes.

Factor 1 will analyse in how far scientists and experts as well as politicians, and/or citizens or their "representatives", i.e. stakeholders or bureaucrats, were planned to be involved in the sustainability indicator development process, and in how far they have actually participated. Factor 2 will observe whether scientists and experts involved represent different fields of (ecological, economic, social) expertise. Factor 3 will study whether politicians and/or citizens of different policy domains were invited and did participate. For assessing factors 1–3, envisaged as well as actual participant lists were analysed. Workshop reports (e.g. stakeholder workshop reports) and other meeting documents were also used to identify actual participation.

**Table 2**
Assessment criteria for sustainability indicator development processes.

| Factor | Characteristic assessed (in the design and implementation of the indicator development process) | Model component |
|---|---|---|
| Participation | | |
| 1. Merging knowledge production and norm creation | Participation of scientists, experts, politicians, bureaucrats, stakeholders and citizens | Knowledge production and norm creation |
| 2. Merging different fields of knowledge | Participation of scientists and experts with ecological, economic and social expertise and their balance | Knowledge production |
| 3. Merging different policy domains (cross-sectors) | Participation of politicians or their representatives from different related policy domains | Norm creation |
| Decision-making and learning | | |
| 4. Selecting sustainability indicators based on existing and adjusting them to emerging scientific knowledge | Approaches to decide about inclusion or exclusion of indicators from different fields of knowledge; iterative revision also over the short term | Knowledge production |
| 5. Selecting sustainability indicators based on existing and adjusting them to changing social and political norms | Approaches to decide about inclusion or exclusion of indicators from different policy fields; iterative revision both short and longer term | Norm creation |

Factor 4 will consider whether and in how far explicit approaches, methods or rules were followed to select indicators across different fields of knowledge, i.e. by (democratic) voting (by consensus) as main decision mode for including or excluding certain indicators. It will also look at whether a learning process has been provided for and took place, i.e. did the indicator development process include iterative work phases, enable changes and readjustments of indicators after a first practical application (field test) and uptake emerging knowledge? Factor 5 will review how different societal values or political domains were included and balanced in the selection of indicators, i.e. have indicators been exposed to a larger public beyond the scientific community and have policy-makers and experts been involved? It will also look at whether provisions were made to allow for the adjustment to changing social and political norms. For assessing factors 4 and 5, documents guiding the design of the indicator processes as well as documents that described the processes (the actual approaches followed) are analysed. The latter include meeting minutes and sections of the (interim or final) documents containing text on the approach, e.g. in the methods section. Methods on the inclusion or exclusion of indicators (e.g. structured versus unstructured process) and design of the process (iterative versus static process) are derived from these documents.

## 4. Case studies: sustainability indicator development processes

Five indicator processes in Europe have been selected as case studies. They all aim at developing sustainability indicators but addressing different main subjects: forestry-wood chain, multi-functional land-use, forestry as well as sustainability more generally. Three are science-driven and two are government-led indicator processes that started out as a consequence of the UNCED Agenda 21 commitment taken up by countries (see Table 3).

EFORWOOD aims at developing a quantitative decision support tool for sustainability impact assessment of the European Forestry-Wood Chain and all its stages. One objective and expected deliverable was the development of indicators for the forestry-wood chain that reflect all aspects of sustainability from forests to consumption and waste recycling, and that address demands of a multiple user group including policy-makers and stakeholders.

**Table 3**
Sustainability indicator sets analysed in the paper.

| Case | Geographical scope | Initiative driven by |
|---|---|---|
| EFORWOOD | European Union | Science |
| SENSOR | European Union | Science |
| SEAMLESS | European Union | Science |
| MCPFE | Europe | Inter-governmental |
| EUROSTAT SDI | European Union | Inter-governmental |

SENSOR aims at developing science-based ex ante sustainability impact assessment tools to support decision-making on policies related to multifunctional land use in the European region. This includes development of an indicator framework and criteria for indicator selection ensuring a harmonised approach across the SENSOR project; indicators are meant to cover the environmental, social and economic dimensions of sustainable development.

SEAMLESS aims at developing a computerised integrated impact assessment tool making assessments, of the impacts of new agricultural and environmental policies using indicators covering the scales from field-farm to region, the EU, as well as some global interactions (Van Ittersum et al., 2008). The tool includes an indicator framework and criteria for indicator selection ensuring a harmonised approach covering the environmental, social and economic dimensions of sustainable development.

The MCPFE started work on developing sector-specific (forestry) sustainability indicators in late 1993, as a follow-up of the UNCED (1992) Agenda 21 commitment of countries. They developed a set of criteria and indicators for sustainable forest management during 1993–1994, endorsed the set at governmental level in 1998, and subsequently revised the set between 2001 and 2003.

The EU commitment to sustainable development at the 1992 Earth Summit resulted in a Strategy for Sustainable Development adopted in Gothenburg in 2001. Following this adoption the Statistical Programme Committee of the EU, led by EUROSTAT, agreed to set up a Task Force. Based on this work, the European Commission endorsed a set of indicators, which formed the basis for its first monitoring report (EUROSTAT, 2006). Thereafter, EUROSTAT in close cooperation with the Working Group on SDIs has undertaken a review of the sustainability indicator set during the years 2006 and 2007. The revised sustainability indicator set was then published in October 2007 (EU, 2007). However, those indicators sets are quite different from the ones discussed above as they are not sector-specific.

## 5. Results: sustainability indicator development processes

After the short introduction of the selected cases in Chapter 4 we analyse them according to the five factors of analysis stated in Table 2.

**Table 4**
Cases: merging knowledge and norm creation—participation.

| SI development process | (1) Merging knowledge and norm creation in the process through participation of both scientists and policy-makers and stakeholders |
|---|---|
| EFORWOOD | Yes in principle but scientists had a stronger role to play by design and in practice |
| SENSOR | Yes, but scientist had a stronger role to play by design and in practice |
| SEAMLESS | Yes, but scientist had a stronger role to play by design and practice |
| MCPFE C&I | Yes, with norm building dominating over knowledge creation |
| EUROSTAT SDI | Yes, knowledge creation mainly conducted by government representatives (SDI Task Force), based on policy framework. Political endorsement process of SDI by EU Commission |

Factor 1 (merging knowledge and norm creation) was assessed by looking at participation of actors that can be divided into two groups—those related to knowledge production (indicated by scientist involvement) and those representing societal and political norms and priorities (indicated by the involvement of policy-makers, citizens, stakeholders). The results show that in all sustainability indicator processes both groups were present, however, to different degrees, both in design and in practical implementation (see Table 4).

In EFORWOOD actors' involvement can be described as unbalanced. Being a research project, mostly scientists (about 95%) were involved in the indicator development process by design and in practice. Norm creation functions were designed to be brought in by stakeholders directly in the development process. In addition, further stakeholders, such as environmental interest groups and policy-makers, have been invited to take part in a so-called stakeholder workshop focusing on sustainability indicators (Gamborg, 2006). However, only a limited number of policy-makers took the opportunity to participate.

Within the SENSOR, the selection and development of indicators for the SIA Tool was dominated by scientists. Stakeholder activities involved EU officers and officials to discuss the impact assessment process, the respective guideline, their needs and the implications for the tools to be developed (Tabbush et al., 2008). The relationship to indicator selection was thus through the discussion on the indicator framework describing issues within which indicator development should take place, and which was based on the impact questions raised in the EU impact assessment guidelines.

The development of the SEAMLESS indicators has been initiated by scientists through combining the involved scientist expert knowledge. The indicator framework used assumes that the development of a policy is motivated by several ultimate goals in each of the three dimensions of sustainability (economic, environment, social). To achieve these ultimate goals both processes for achievement as well as means are needed (Alkan Olsson et al., in press). The sets of indicators developed by the scientists have continuously been discussed with policy-makers at different levels, mainly EU, national and regional level, to increase the match between the indicators that the policy experts deemed policy relevant and the capacity of the SEAMLESS assessment tool.

The process elaborating the MCPFE criteria and indicators for sustainable forest management involved, for the initial set of indicators, a Scientific Advisory Group which was led by a governmental representative. Being a government-led process, norm creation as well as operability of the SDI set in political practice was a main goal. Governmental representatives as well as stakeholder took an active part. Direct scientific input was mainly provided through federal (governmental) research institutions. The scientific community was, however, often only indirectly involved through various advisory roles to government representatives. The MCPFE only marginally involved explicit social knowledge into the elaboration process.

The process of elaborating the EU SDI, starting in 2001, was operationally led by EUROSTAT, in co-ordination with a Task Force, which consisted of administration officials from EUROSTAT and the European Commission as well as representatives of EU Member States, which often were experts from national statistical offices. The preliminary set of SDI was co-ordinated with a wide range of General Directorates within the Commission and Member States. The scientific input was mainly directly and indirectly provided through advisory roles to governmental representatives, while research institutions seemed to have been hardly involved.

Factor 2 (merging different fields of knowledge): the analysis shows a rather balanced picture across all five cases. The environmental and economic dimension of sustainability seems to be covered to a better extent than the social dimension (see Table 5).

In EFORWOOD, especially ecological expertise has been well covered by participants (scientists with special expertise in forestry and environmental science), while economic expertise was represented to a lesser degree (only very few economists took part); nearly no expertise (as judged by professional backgrounds) was explicitly covering the social dimension of sustainability.

In SENSOR expertise within all three domains was present. Economic modelling expertise in combination with environmental, landscape and land use expertise dominated over the social science expertise in terms of numbers, but the development of indicators within each sustainability dimension were undertaken by researchers with relevant background. Social scientists early raised the issue of how to include qualitative issues, which could not be modelled—especially dominant in the social domain. Considerable effort was used for development of quantifiable social dimension indicators, but eventually, several relevant issues could not be covered within the modelling framework (Farrington et al., 2008).

The development of the indicators in SEAMLESS has been done in a trans-disciplinary setting with an almost equal amount of economic and environmental scientists. However, as the major models of SEAMLESS are environmental and economic, there is a bias of indicators in these two fields and as a consequence there were substantially less social scientist involved.

In the MCPFE process, mainly the environmental dimension was covered through natural scientists with an expertise in forestry sciences and environmental sciences. To some extent economists took part in the process, but regarding the social dimension no documented explicit expertise could be ascertained.

For the EU SDI, which cover a broad range of issues across a broad range of policy domains structured into ten policy themes,

**Table 5**
Cases: merging different fields of knowledge—participation.

| SI development process | (2) Merging different fields of knowledge through participation of scientist from different scientific domains |
|---|---|
| EFORWOOD | Yes, but overwhelming ecological expertise, less on economic, and nearly none with regards to social issues, by design and in practice |
| SENSOR | Yes, but more competence in environment and economic aspects |
| SEAMLESS | Yes, but the social expertise were much smaller than the economic and environmental |
| MCPFE C&I | Yes, but more competence in environment and economic aspects |
| EUROSTAT SDI | Yes, but more competence in environment and economic aspects |

**Table 6**
Cases: merging different policy domains—participation.

| SI development process | (3) Merging different policy domains by involvement of respective policy-makers |
|---|---|
| EFORWOOD | Focus on two sectors (forestry, forest-based industry), limited recognition or participation of other policy domains (mostly environment) |
| SENSOR | Focus on land-use related sectors (agriculture, forestry, nature conservation, transport and infrastructure, energy and tourism) |
| SEAMLESS | Focus on one sector (agriculture), limited recognition or participation of other policy domains (mostly environment) |
| MCPFE C&I | Focus on one sector (forestry), limited recognition or participation of other policy domains (mostly environment) |
| EUROSTAT SDI | Cross-sector approach comprising a wide range of policy domains |

governmental officials from different units within EUROSTAT and the European Commissions related to these policy themes were involved, in addition to national governmental officials, particularly experts with an environment background. As far as it can be judged from participant lists of meetings there were comparatively fewer experts covering the social dimension.

Factor 3 (merging different policy domains): the analysis shows that the majority of initiatives cover different policy domains. However, most sets have a clear topical focus, and most of these focused initiatives did not put equal weight on involving other relevant policy domains beyond the environmental one (see Table 6).

In EFORWOOD the participation of policy-makers or stakeholders from relevant different policy domains was focused, by design, on the policy areas forestry and forest-based industry policy-makers. Other relevant sectors, such as agriculture and tourism, were not involved. In practice policy-makers and stakeholders participation from other than the sectors in focus was very limited.

The SENSOR project focuses on land use, and policies affecting land use. These are multiple (see Table 6) and the policy cases selected to be analysed in SENSOR involves bioenergy, various options of continuation of the CAP versus more promotion of the knowledge economy, biodiversity policies, the forest strategy and the European transportation policy. Consequently, the overall indicator set has been selected so as to respond to land use changes in general, and not to specific policy sectors. EU officials from different Directorate Generals (Environment, Regional Policy, Transport and Energy, Agriculture) were included in the interviews mentioned above, responding among other on the indicator framework and specific impact issues.

The SEAMLESS project is mainly focusing on the agricultural sector and on the effects on the agricultural sector on other sectors. Consequently, the main focus has been the interaction within the agricultural sector but also with the environmental sector such as conservation organisations and bureaucrats representing this area. Moreover as the agricultural agenda is changing with the transformation of the CAP the diversification of agriculture and the increasing importance of emerging issues has increased the interactions of the project as a whole with policy-makers from other sectors especially in the rural development, bio-fuel, and climate change contexts.

With regard to linking forestry with other policy domains, the MCPFE set has not been designed as a cross-sectoral set, and no explicit expertise was involved in the elaboration or revision of indicators to include wider land-use issues or further processing and consumption of forest products, or to make respective indicator sets compatible.

**Table 7**
Cases: selecting indicators and adjusting them to emerging knowledge.

| SI set | (5) Selecting sustainability indicators and adjusting them to emerging knowledge |
|---|---|
| EFORWOOD | Selection by consensus, adjustment in the course of the project |
| SENSOR | Selection by consensus, adjustment in the course of the project |
| SEAMLESS | Selection by consensus, adjustment in the course of the project |
| MCPFE C&I | Selection by consensus, adjustment through follow-up review and revision process |
| EUROSTAT SDI | Selection by consensus, adjustment through follow-up review and revision process |

In the EU-SDI Task Force members were mainly EU officials from different Directorates of EUROSTAT or the European Commission as well as representatives of EU Member States working in national statistical offices, or Ministries of Environment or environment related agencies. The subsequent SDI Working Group showed a similar composition, with considerably higher representation of Member States, compared to the initial phase of the SDI Task Force in 2002.

Factor 4 (selecting sustainability indicators based on existing and adjusting them to emerging scientific knowledge): the analysis shows that all processes were using a consensus principle in selecting sustainability indicators, and designed and implemented processes to allow for the uptake of new knowledge (see Table 7).

Within EFORWOOD selection of indicators was made by consensus, based on the principle that the number of economic, ecological and social indicators should be balanced. Both the development of indicators and their adjustment was designed as an iterative process with six rounds for comments. The resulting set was used for developing data collection protocols, collecting data and testing the impact assessment tools. In a second (adjustment) phase, experiences were systematically included for revising the set. The revised indicator set is planned to undergo a second round of testing in a different context before a third and final revision and adjustment of the set will be done. Knowledge build up has furthermore been facilitated by building the whole indicator development process upon existing SDI sets, in particular the EU SDI.

In the SENSOR project the development of an indicator framework departed in the impact issues reflected in the EU Impact Assessment Guidelines. A consultation within the project involving all partners on the relevance of the impact issues in relation to the SENSOR focus on multifunctional land use was carried out with the purpose of obtaining an adjusted framework. This resulted in an indicator framework, including key-questions, which guided the work on indicator development and selection (Frederiksen and Kristensen, 2008). These issues were further modified in the course of the project mainly due to operability aspects, where some indicators were abandoned due to lack of data or models (Bach et al., 2008). That is, the modification of the indicator system reflected whether it was actually possible to get the necessary information from the models. The model development and the indicator development and selection processes were run in parallel.

Due to the continuous contact with different type of scientists, stakeholders and policy-makers the SEAMLESS indicator set has been based on existing literature, and the indicators were continuously adjusted to emerging knowledge in relation to new scientific knowledge such as for example with the gross nutrient balance indicator discussed with the EEA. No voting was applied in selecting indicators. The scientific robustness of the indicators is to a large extent dependent on the robustness of the

**Table 8**
Cases: selecting and adjusting indicators to changing social and political norms.

| SI set | (6) Selecting and adjusting sustainability indicators to social and political norms |
|---|---|
| EFORWOOD | Initial selection based on political selection process of EU SDI and EU Sustainability Impact Assessment Guidelines, no adjustment within the lifetime of the 4-year project |
| SENSOR | Initial selection based on EU Sustainability Impact Assessment Guidelines, but a few indicators representing new issues, deemed relevant for multifunctional land use, were added and developed |
| SEAMLESS | The developed tool is generic to allow for adjustment, but no adjustment was planned within the lifetime of the project |
| MCPFE C&I | Yes, in the first revision a few indicators were added and others strengthened to better reflect emerging political norms |
| EUROSTAT SDI | Initial selection based on political (EU) strategy (mainly the EU Sustainable Development Strategy). The SDI set was adjusted to better reflect the revised EU SDS |

models which undergoes continuous testing and revisions throughout the lifespan of the project.

The MCPFE selected initial indicators on the basis of consensus on their respective scientific soundness, which was an explicit selection criterion. The MCPFE acknowledged that its sustainability indicator set needs adaptation over time, both to adapt to emerging knowledge and to changing social needs (MCPFE, 1998). Consequently, the first revision of indicators was conducted through a series of (mainly governmental) expert workshops during 2001–2003; the set of (quantitative) indicators expanded from 27 to 35. The new indicators reflected increased knowledge available on ecosystems (e.g. on deadwood, fragmentation), and of monitoring and reporting feasibility.

The EU sustainable development indicators were selected on the basis of consensus, building on a policy-driven framework for the indicators which was based on the existing priorities of the EU Sustainable Development Strategy (SDS) and the most relevant international commitments taken by the EU, whereby indicators were chosen according to the major policy commitments and objectives of the strategy and related EU strategies with a view to develop policy-relevant indicators that would serve a general follow-up of measures and actions taking place in the priority policy areas (EUROSTAT, 2006). Furthermore, it was agreed to follow the principle that indicators are, as far as possible, balanced across different dimensions. The Task Force applied an iterative selection process (ibid. 2006). In the subsequent follow-up work on reviewing and improving the SDI set by the SDI Working Group, a number of issues in topical areas have been taken up and further elaborated, including issues of data availability and data quality.

Factor 5 (selecting sustainability indicators based on existing and adjusting them to changing social and political norms): the analysis shows a large degree of divergence between cases (Table 8). This can be for different reasons, possibly the most important being that many of the sets are comparatively ‘‘new’’, while political and societal norms are often emerging slowly, over a number of years, or over a decade.

The indicator development process of EFORWOOD started on the basis of two documents reflecting political norms, the EU SDI (reflecting the EU Sustainable Development Strategy) and the EU Guidelines for Sustainability Impact Assessment. An iterative adjustment to emerging social or political norms and priorities has not been planned within the EFORWOOD project.

The selection of SENSOR indicators was based on decisions to use as far as possible existing indicators, and to ensure the end-user relevance by departing in the key-questions posed in the EU Impact Assessment Guidelines, as these are based on current EU policies and have already been subject to a political process (Frederiksen and Kristensen, 2008). The starting point for the indicator development and selection was thus based on political and social norms discussed prior to the project by policy-makers. A new indicator issue – landscape identity – was suggested based on the recent ratification of the Landscape Convention, and indicators matching this issue were developed (Bach et al., 2008).

In SEAMLESS new and emerging demands from policy-makers at different levels have been taken into consideration within the time span of the project. Moreover the tool is constructed in a generic way which enables the creation of new indicators either by extending to scope of included models or by adding new models. This is for example seen as a possibility to expand the number of social indicators which so far has been the weakest link in the project.

The MCPFE selected its initial indicators on the basis of longer-term political relevance, which is understood to reflect societal norms and priorities. It acknowledged early that its sustainability indicator set needs adaptation over time to adapt to changing social needs (MCPFE, 1998). Within the MCPFE the revision of indicators between 2001 and 2003 presents a reaction to shifting societal and political norms, e.g. to an increased emphasis on forest services, such as recreation or the importance to recognize the cultural and social values of forests in forest management.

The initial selection of the EU SDI was based on political norms and priorities, in particular those laid down in the EU Sustainable Development Strategy (EUROSTAT, 2006). A revision of the EU SDI aimed to enhance policy relevance by adjusting the SDI set as much as possible to the renewed EU SDS. It thus integrated emerging political norms. The revision was also utilized to integrate experiences made in the application of the first SDI set (statistical quality, monitoring and reporting effectiveness and efficiency).

## 6. Discussion and conclusion

The connection between (social science) knowledge and policy has been a longstanding debate in public policy (see e.g. Lynn, 1978). Sustainability indicators are at the same time a means to compile and structure knowledge and to express societal and political norms and priorities. While this dual role has been recognized by many scholars writing on the subject, it is less clear in how far this dual role has been recognized in the design and implementation of sustainability indicator development processes. The cases studied suggest that the socio-political dimension needs as much recognition and consideration in the design and implementation of a sustainability indicator development process as the knowledge or substance dimension. This seems not to be fully recognized yet. Secondly, science-led initiatives do also ‘‘vote’’ on the inclusion and exclusion of indictors or related subclasses; this voting procedure is not scientific in a positivist sense, but can be characterised as ‘political’. Thirdly, while in political processes most actors are representatives of democratically elected politicians, participation in science-led process is mostly restricted to ‘‘invited’’ experts (in their fields) and some policy-makers that are recognized experts in relevant issue areas and may thus not be representative.

The analysis of the cases shows that in practice all allowed a number of actors from both domains (science and policy) to participate in indicator development. However, science and policy-led processes had a different bias: in science-led processes there was, by design, a bias towards the knowledge production dimension, and less explicit recognition and inclusion of the normative political dimension in the indicator development process, particularly also with regard to participation, and thus representation issues. This is partly due to the research project character of these processes, which limits possibilities for allocating large budgets and time for such purposes. Anecdotal evidence also suggests that science-led processes (supposedly focusing more on knowledge creation than social or political norm building) find it more difficult to involve policy-makers in the development process than vice versa, and there are questions of how to get such indicator sets fully accepted and acknowledged as legitimate by policy-makers. Certain aspects such as e.g. the spatial scale (e.g. choice of NUTS3 region) may not be really chosen by scientists, but may be a predetermined and thus influences the development of the sustainability indicator set in a very specific way. This raises the question: what is better, a slightly more accurate but politically less relevant set, or a slightly less accurate but politically more relevant set? And, from that follows: what is the appropriate role of scientists in designing indicator sets: moderators, knowledge brokers, or leaders of development processes?

With regard to merging different knowledge areas, all processes have tried to follow the idea of balancing economic, ecological and social dimensions, but all processes were relatively weak regarding the participation of experts representing the social dimension. There is little indication that proper measures were undertaken to make sure that an envisaged balance is already reflected in the balanced involvement of respective expertise. None of the science-led processes seems to have devised strict science-based selection processes or rigorous formal rules to base decisions on exclusion or inclusion of indicators. Most processes have applied more or less long lists of general principles or selection criteria as "rules of thumb" to guide decisions, of which many are provided by the literature. Decisions on the inclusion or exclusion of indicators were usually consensus-based. Thus, in science-led processes, participants may decide on indicators outside their specific domain as informed citizens, i.e. in a political role, expressing societal norms, rather than in their scientific capacity. This indicates the central importance of representation and participation in the indicator development process, which needs to be properly designed at the outset.

Regarding the merging of different societal and political norms through the participation of representatives of these different domains, the main thematic focus of the indicator set determined participation, and thereby the resulting topical focus of the indicator sets. Topical focus and participation in turn is likely to influence the practical recognition and legitimacy of the sets. In other words, due to the normative nature of sustainability indicator sets, such sets are more likely recognized as legitimate by those actors who assume co-ownership, because they have been involved. The limits of participation of different policy domains intended or practically achieved in the development process put likely limits to recognition and use of the resulting set.

All cases studied implicitly or explicitly recognize that the indicator sets developed are interim results of a continuous improvement process, particularly with regard to integrating emerging knowledge. There are also many indications of a broad recognition of a learning process that took place during development. Science-led processes, contrary to government-led processes, have not explicitly provided for possible adaptation to changing social and political norms and priorities. This is partly due to the limited time span available in the context of the projects within which they were developed.

Are science-led sustainability development processes more accurate and comprehensive with regard to the knowledge they are able to embody in their indicator sets? Not necessarily, as government agency experts are also often technical experts with "scientist" standards, and not elected policy-makers. Neither do government-led sustainability development processes automatically achieve more policy relevance. It seems that this is only the case if such processes directly link indicators to concrete policy strategies and government commitments. One could assert that the higher the political "weight" of such commitments, the higher the political relevance (and use) of related indicator sets. This is at least what a recent comparison of EU SDI and EU structural indicators across EU Member States would imply (Pülzl et al., 2007). It found that, while objectives and structural indicators used in the EU Lisbon Process across Europe are closely aligned, EU and national SD strategies and related SDI, and – it seems – their actual use, are much more diverse.

As sustainability indicator development processes are per se normative, the normative value judgements have to be more explicitly acknowledged and given more weight by both scientists and policy-makers; new kinds of methodological choices regarding participation and representation need to guide development processes in order to achieve credibility and legitimacy within society. This may thus not be possible without a wider form of participation involving citizens or their representatives.

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