In-Stream

LINKING SUSTAINABILITY INDICATORS WITH POLICY MAKING

Results and Conclusion of IN-STREAM

25 September 2011

The research consortium is a multi disciplinary and international consortium of eight research organisations:

- Ecologic Institute, Berlin, Germany (Lead)
- University of Bath, Department of Economics, Bath, UK
- Fondazione Eni Enrico Mattei, Milan, Italy
- Charles University Environment Center, Prague, Czech Republic
- Institute for European Environmental Policy, London, UK
- Universität Stuttgart: Institut für Energiewirtschaft und Rationelle Energieanwendung, Stuttgart, Germany
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- Indicators should be used to support the integration of sustainability considerations across a wide range of policy areas. For instance, biodiversity and climate change related indicators can be useful for informing a wide range of policies, from budget allocations (e.g. EU Cohesion Funds) to environmental policies.

- As the concept of sustainability is complex and multifaceted; developing a “one size fits all” sustainability indicator for the assessment of any given policy is not possible. Sustainability measures and indicators have to reflect the preferences and value judgements of policy makers and the public, which depend on the policy issue in question and may change over time.

- Choosing the right indicator is therefore crucial in any step of the policy cycle. Policy makers need to understand the capacities of indicators to ensure that they are interpreted and used adequately. Qualitative assessments like the RACER or SWOT analysis used in IN-STREAM can provide that understanding.

- Building an efficient set of targets for multi objective policies requires a thorough understanding of the relationships among different indicators. Statistical techniques like correlation analysis or Principal Component Analysis can give a quick overview on those associations and help policy makers focus further analysis and policy making efforts.

- Composite indicators can be very effective tools in communicating overarching sustainability messages to non-experts, although subjectivity is intrinsic to the construction of such indicators. However, this subjectivity can provide an additional layer of information when composite indicators are used to make the underlying preference structure and value judgments more explicit and transparent.

- General equilibrium models allow estimating the often-claimed negative effects of climate change actions on competitiveness. They can also support policy makers determine compensations for the energy-intensive sector, as they highlight the potential tradeoffs between sector-based competitiveness measures and overall economic efficiency. Analyses of the regional employment impacts of climate change actions can show whether and how investments in renewable energy are displacing other investments. Additionally, they can estimate whether potential job losses can be compensated for by fostering an export industry that creates additional jobs.

- Policy makers setting ambitious biofuel targets to reduce GHG emissions can use models to determine whether the induced additional land conversion may offset much of the GHG emission reductions. The models also allow policy makers to take into account the potential impacts of those targets on food availability, risk of hunger and deforestation.

- Environmental indicators are very often only available as pressure indicators. Complementing those indicators with impact indicators, like health effects or biodiversity gains of emission reductions, supports policy makers in making the relevant tradeoffs within sustainability categories.

During the financial crisis the discussion on how to achieve and measure well-being has gained a new impetus. The ability and willingness of policy makers to take sustainability into account will be tested as they simultaneously deal with the economic and social impacts of the crisis and with rising global environmental challenges such as climate change. The most important aim of the IN-STREAM project was to support policy makers in this difficult task, by providing better indicators and better insights on how to use them in policies aimed at sustainability.

Therefore, the work of IN-STREAM focused on the links between mainstream indicators and sustainability measures, as well as on the links between the economic, social and environmental pillars of sustainability.

USE OF INDICATORS IN POLICY MAKING

The work of IN-STREAM has clearly shown that indicators should be used to support the integration of environmental considerations across a wide range of policy areas. For instance, biodiversity and climate change related indicators can inform a wide range of policies, from budget allocations (e.g. Cohesion Funds) to thematic environmental policies (e.g. air, water policies, etc.).

There is no "one size fits all" indicator that can be used across different policies. Rather than a single indicator family or composite index, the project's findings support a balanced use of a range of economic, environmental and social indicators across a wide range of policy areas, at different stages of the policy cycle. The choice of the right indicators and indicator sets can be crucial for the appropriate inclusion of sustainability concerns into policy making. For that purpose IN-STREAM has shown how to use qualitative assessments and statistical analysis of indicators to build a robust and effective indicator set.

The broad scope of the Beyond GDP agenda required a philosophy that embraced a wide range of methodologies and models. The quantitative work packages also applied different methods. The main methodologies and findings of the quantitative research can be summarised as follows:

COMPOSITE INDICATORS

It has long been debated whether sustainability should be measured by specific indicators for specific policies or by aggregate or composite indicators. On one hand, composite indicators can be very effective tools in communicating overarching sustainability messages to non-experts. On the other hand, the subjectivity which is intrinsic to the construction of these indices (such as on the choice of the indicators and their related weights, and on the aggregation procedure) have led to significant criticism. IN-STREAM used Computable General Equilibrium (CGE) models to gain further insights into this question.

In general, it is neither possible to summarise sustainability in just one figure, nor to rule subjectivity out, no matter how comprehensive, complex and innovative its generation process is. Nonetheless, as shown in the IN-STREAM analysis, composite indicators can be invaluable communication devices for making the preference structure and value judgments underpinning any given sustainability assessment more explicit. They can also offer the opportunity to investigate in depth how and if this assessment can change when those preferences and values change. This information can be very useful for policy decision makers and, in our view, can be even more important than the synthetic indicator provided.

TRADEOFFS IN SUSTAINABILITY POLICIES

The **effect of sustainability policies on economic competitiveness** is an important concern in many countries. The European Union committed to unilaterally achieving at least a 20 % reduction in its greenhouse gas emissions by 2020 compared to the 1990 level. IN-STREAM has investigated the implications of alternative EU emissions pricing strategies on economy-wide adjustment costs and competitiveness. In terms of conventional trade theory, the EU has a comparative advantage in the energy-intensive industries, which is decreased, but not abolished, even when relatively stringent emissions reduction targets and a uniform tax are applied. The results also suggest that differential emissions pricing schemes reduce overall economic efficiency and lead to a pending trade-off between sector-specific competitiveness concerns and broader economic considerations.

There are many studies which focus on the assessment of climate policies on a national and international level. Using an input output approach, IN-STREAM has examined the **impact on regional employment** of a program to increase the share of renewable energy carriers in electricity generation and the share of renewables in heat supply. These impacts are of particular interest for the state government of the German state of Baden-Wuerttemberg, where the manufacturing industries are particularly important as compared to the rest of Germany.

The results of the In-Stream project suggest that policy actions promoting renewable energy types do not necessarily create new jobs and additional turnover for the whole economy, since other investments might be displaced by investments in installations of renewable energy and the demand in other sectors might decrease. However, if the producers of the installations become internationally competitive and are able to export parts of their products to the rest of Germany and the world, these displacement effects can be attenuated and turnover and employment effects might be positive in total.

Biofuel targets and policies can reduce the GHG emissions of the global transport sector but initially this reduction can be more than offset by increased emissions from land-use change. The scenario assessment indicates that GHG emission reductions resulting from a higher biofuel consumption are counterbalanced by emissions from land use change in 2020, but lead to cumulative net GHG savings by 2030 compared to the Reference case, i.e., without an increase in biofuel consumption beyond the level of 2008.

Ambitious short-term biofuel targets can also jeopardize other social and environmental sustainability aspirations. The use of food crops for biofuels leads to higher agricultural prices that in turn increase the number of people at the risk of hunger compared to the Reference scenario, especially in the near term (2020). Deforestation is also projected to be higher in all biofuel scenarios to make room for biofuel crops.

VALUATION OF THE BENEFITS OF ENVIRONMENTAL ACTION

Policy makers have to make explicit or implicit tradeoffs as the reduction in the emission of one pollutant might be at the cost of an increase in another. Complementing pressure indicators with impact indicators can support policy makers in making these tradeoffs. This can be done using the impact pathway approach (IPA), which provides a logical and causal structure for the assessment of policies with a diverse set of impacts. The estimated impacts include damage and risk to human health, ecosystems, crops and materials. The IPA takes into account the non-linear relationships between pressures and effects as well as the dependency of the effects on time and site of the activities.

For many environmental impacts well-established indicators, e.g. DALYs (Disability Adjusted Life Years measuring health effects) or PDFs (Potentially Disappeared Fraction of species for ecosystem damage), exist which can be applied for cost-effectiveness calculations. These indicators can be further aggregated and compared across categories by transforming health and ecosystem damage into monetary values. The monetary valuation of damages using willingness-to-pay studies can consistently be applied in the assessment of costs and benefits of policy measures and technologies. Furthermore, these monetary values can then be integrated as a building block into more aggregated welfare indicators and used in impact assessments of policy proposals.

For climate change the impact pathway approach can also be used, i.e. damages and damage costs can be calculated either by agreeing on whether to use equity weighting or not or by using a distance to target approach. Having identified a sustainable emission scenario, the difference between the actual greenhouse gas emissions and the emissions of the sustainable path can be calculated.

CONCLUSION

The work of IN-STREAM linked mainstream indicators with sustainability measures, with the wider objective of linking sustainability measures and indicators more firmly into the policy making process. The project investigated the application of these tools, methodologies and examples in three different policy fields (Green Growth, Resource Efficiency and Biodiversity) and sought to support and improve the introduction of sustainability measures into policy making.

Some of the IN-STREAM results provide policy makers with important new indicators, measures and methodologies that aim to balance the inherent tradeoffs of policy making. Other parts of the analysis focus on advising policy makers on how to choose the right indicators and indicator set from a number of available sustainability indicators. Overall, the study suggests a range of opportunities for policy makers to take sustainability measures into account in all stages of the policy making process.

1.1 SUSTAINABILITY INDICATORS AND THEIR USE IN THE POLICY PROCESS

There is an increasing recognition of the need for policy to be driven not only by economic and financial motives, but also by wider sustainability concerns. In the pursuit of economic development, natural resources and environmental quality are degraded, undermining the foundations of socio-economic development over the long term.

Several initiatives aiming to stir policy making away from narrow economic motives have been carried out in the past decade. The European Union, inter alia, stated its commitment to integrating economic indicators with sustainability principles at the 'Beyond GDP' conference. Its related Communication (COM(2009) 433) formalised a system of 'environmental accounts', and the EU recently unveiled its Strategy 'Europe 2020: A strategy for smart, sustainable and inclusive growth' (EC, 2010), which aims to turn the EU into a smart, sustainable and inclusive economy. At Eurostat's 2011 conference, Environment Commissioner Potočnik stressed the need to develop indicators to monitor progress on green growth, green public procurement and eco-innovation, as well as to improve the measurement of natural capital and its eco-system services. Sustainability indicators are therefore emerging as crucial tools to inform policy making.

IN-STREAM seeks to link sustainability measures with mainstream economic indicators and aims to integrate those sustainability measures with policy making where sustainability concerns currently do not get the attention required.

Part of the IN-STREAM analysis was dedicated to exploring the policy needs and opportunities of an increased use of sustainability indicators for selected policy areas, and providing guidance on how these could be adopted at different phases of the policy development process.

An analysis across three broad topics (biodiversity, resource efficiency and green growth) and a number of related policy areas (biodiversity, agriculture, fishery, resource efficiency, climate change and cohesion policy) identified in which stages of the policy cycle indicators can be particularly useful, and what type of support they can provide to each step of policy development.

The policy cycle proved to be a useful approach for understanding and improving how sustainability indicators can support the policy making process. By breaking down policy development into clear, distinguishable stages, the decision making process becomes more understandable, allowing for useful comparisons and analyses of distinct stages and helping to identify weaknesses and opportunities in each step of the policy making process. This, complemented by the DPSIR model (Driver-Pressure-State-Impacts-Response), can also help clarify what type of indicators have been used so far and for what purpose, and how they should develop in the future.

The policy cycle approach also is helpful for understanding the key criteria which sustainability measures have to fulfil to be useful to policy makers. These key criteria differ substantially according to the phase of the policy cycle.

Problem identification: Indicators can support policy makers who would like to gain a clear overview of the nature and the scale of problems raised by stakeholders. To be useful in this policy phase, indicators have to be well-known and their importance recognised by the general public. Policy makers often need to make a case for action to the public, therefore it is crucial that the general public (including the media) recognises the relevance of the indicator used to justify action. Media analysis conducted during IN-STREAM has shown that most sustainability indicators are not well known to the public. This could be one reason why sustainability concerns do not always get the political attention they deserve.

Objective setting: There is increased pressure on policy makers to define quantitative objectives for any intended policy change. For example, policies aiming to halt biodiversity loss, halt ecosystem service losses and improve restoration of natural areas, as well as the new interest in green infrastructure, all require additional inputs in biodiversity indicators in order to appropriately define their objectives. In particular, the importance of ecosystem service indicators is increasingly recognised. These should be taken into account in several policy areas, besides biodiversity and nature related policies. To achieve this, policy makers need indicators that are available over time and for different countries, as comparisons across time and areas might support and justify the setting of ambitious, yet reasonable, targets.

The issue of ecological thresholds and tipping points is also of concern. Sustainability indicators have a key role to play, as they can inform about the proximity of such thresholds and the speed at which we are reaching them, and therefore help develop adequate policies to prevent trespassing them. The recognition of the over-exploitation of EU fisheries, for instance, underlines the importance of having good indicators to measure stock, determine sustainable yields, set targets and monitor progress, as well as to measure the performance of the Common Fisheries Policy. In this regard, internationally comparable data are particularly useful, as dangerous developments in a single country can be identified and acted upon.

Impact assessment: To increase public scrutiny of policy proposals some Member States and the European Commission have introduced obligatory quantitative policy assessments and/or impact assessments for policy proposals. On the one hand this quantitative focus can improve the transparency of assessments. On the other hand, it can reduce the attention paid to the costs and benefits of policies that are not easy to quantify, because within the framework of a quantitative assessment, qualitative assessments are often neglected. Such a lack of recognition can hurt sustainability; very often environmental damages and social impacts are more difficult to quantify because they are indirect and complex.

In order to carry out such assessments, the use of meaningful indicators that capture the environmental, social and economic dimensions of a given policy proposal is crucial to making informed decisions.

The impact assessments of several EU and national policies already take into account some sustainability indicators. Arguably, there is still a relatively strong emphasis on economic performance and administrative burdens, which may overshadow the measurement of environmental and social impacts. Additionally, there is currently a lack of harmonised guidance on the type of indicators to be used at different levels of the impact assessment. It will be therefore helpful to define a common set of useful indicators, which should ideally take into account the indicators already used at EU and Member State level and the data available.

The EU statistical office's development of 'environmental accounts', which build on the system of integrated environmental and economic accounting (SEEA), appears to be a step in the right direction towards measuring the potential impact of economic and social activity on the environment.

Appropriate assessments which make use of sustainability indicators can also have a significant impact on the allocation of future funding. For instance, the EU Cohesion Policy would particularly benefit from appropriate ex-ante and ex-post assessments of funding decisions. The Cohesion Policy's focus on economic development, particularly growth and jobs, has arguably granted more importance to the use of economic and employment indicators (e.g. GDP, competitiveness and jobs) at the expense of other sustainability indicators. Recently, it has been stressed that its effectiveness should be improved through, inter alia, more result-focused programming and increased emphasis on evaluation and indicators (EU Presidency, 2011).

Policy monitoring: When a policy is enacted, indicators are used to measure the success of the policy or strategy. For example, in order to monitor the achievement of the ambitious EU climate change targets, sustainability indicators have a crucial role to play, especially those measuring GHG emissions, energy intensity and the share of renewable energy consumption in total final energy consumption.

Overall, the IN-STREAM analysis reveals that there is currently a fair amount of indicators that focus on state and pressures, while fewer metrics are used for measuring impacts and responses. As a result, indicators seem to be used especially in the early phases of the policy cycle, e.g. for problem recognition and decisions on policy options. Our assessment suggests that there is scope to use them further, especially in the later stages of policy development. Monitoring and ex-post analyses should arguably be improved, both at EU and Member State level, in order to assess the effectiveness of policies. Sustainability indicators will be essential to make sure social and environmental considerations are duly taken into account.

The use of indicators in policy making is summarised in the following Figure.

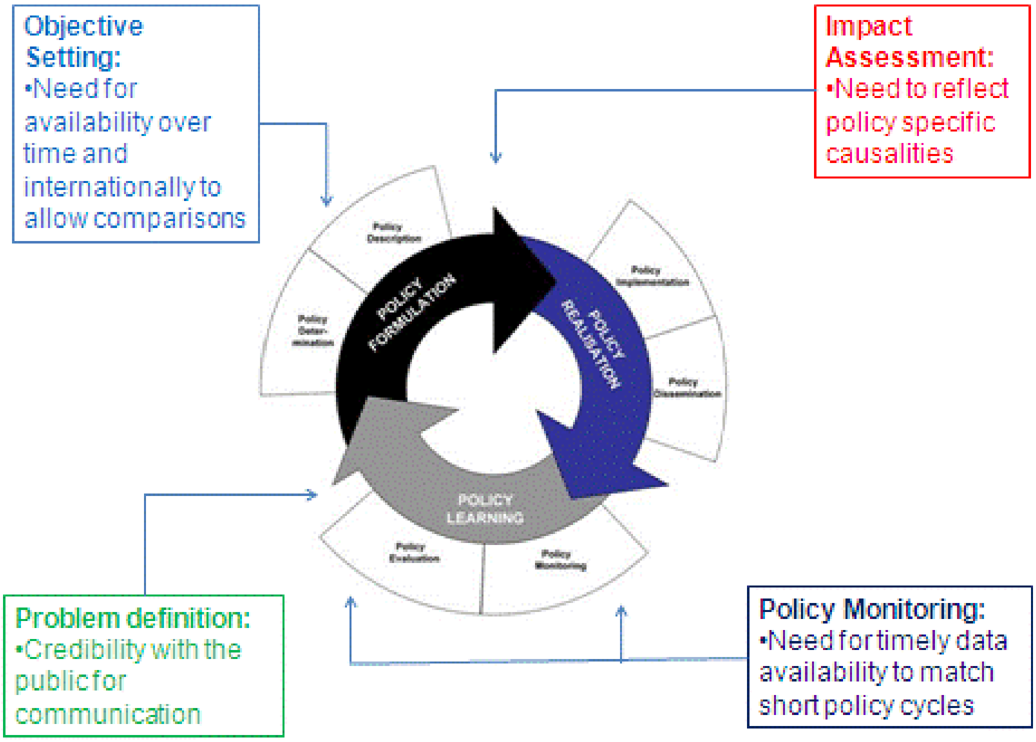

Figure 1: Indicators and the policy cycle

1.2 Key weaknesses of mainstream indicators in measuring sustainability

While on one hand it is crucial to make sustainability measures more attractive to use, on the other hand it is very important to understand exactly where widely-used mainstream economic indicators are failing to capture all dimensions of sustainability. The proponents of GDP very often claim that although the later does not measure social and environmental issues, increases in GDP are very often closely related to progress in environmental and social areas. A discussion of sustainability indicators begs for an account of the failures of GDP to be used as such a tool. To identify those failures, value judgements are very important as the definitions of well-being and sustainability obviously determine the right way to measure both concepts.

The discussion on the failures of GDP is nearly as old as GDP itself but in recent years the debate about the correct measurement of economic and personal welfare has received a substantial new impetus partly from the fall-out of the financial crisis. An important starting point was the Beyond GDP conference in the autumn of 2007 where over 650 participants came together to discuss how measures of progress, true wealth, and well-being can be improved and integrated into decision-making. The conference featured high-level speakers, like Hans-Gert Pöttering, President of the European Parliament, and José Manuel Barroso, President of the European Commission. Based on this success the Commission published the communication “GDP and Beyond Measuring Progress in a changing world” in August 2009[1], identifying a number of actions to be taken in the short and medium term.

In addition to these activities from the European Commission, in 2008 the French government assembled a high profile commission led by Joseph E. Stiglitz, Amartya Sen and Jean-Paul Fitoussi[2] which published important conclusions on the key failings to address in measuring economic, social and environmental welfare. Especially influential was the succinct summary of the key failings of

[1] GDP and Beyond Measuring Progress in a changing world, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0433:FIN:EN:PDF.
[2] Commission on the Measurement of Economic Performance and Social Progress, http://www.stiglitz-sen-fitoussi.fr/documents/rapport_anglais.pdf.

GDP as a welfare measure, which has become for many scientists a reference point to structure the broad Beyond GDP discussion.

The recommendations developed by the European Commission and the commission of the French government have now been taken up by many national and international organisations (EUROSTAT, the OECD, national statistical offices, several FP7 funded research projects to name but a few) and, currently, significant work is seeking to improve existing indicators and to create new indicators that better reflect all dimensions of sustainability. IN-STREAM sees itself as part of this broad undertaking, contributing to very specific problems in the measurement of economic, social and environmental welfare.

The discussion on improving the measurement of economic, environmental and social welfare is very wide but we would summarize the key challenges in the following points.

- Flow versus stock: As an indicator measuring financial flows the GDP neglects any changes to stocks. This means that changes to financial wealth are ignored as much as any changes to environmental or social capital.

- Environmental damages: Environmental damages or impacts are not reflected in GDP as far as they have no market prices. Accordingly, policies focused on GDP growth are likely to discount environmental costs of economic growth.

- Production versus consumption: As consumption is more closely related to well-being than production, a well-being indicator based on consumption levels would be superior to GDP.

- Income distribution: It is also criticized that GDP does not take income distribution into account assuming thereby that income produces the same amount of welfare however distributed.

- Social sustainability: Many commentators also demand the development of better indicators for social sustainability. Currently it is not possible to capture important dimensions of “social capital” like community cohesion, political voice or safety, which are known to influence well-being.

Even though there is a relatively broad consensus among commentators about these deficits, there is still no emerging consensus on whether all these extra dimensions of sustainability should be merged into one common sustainability indicator or whether a suite of indicators would be preferable. Frequently, policies that aim mainly at economic sustainability (e.g. cohesion policy aiming at regional economic growth) have significant environmental and social impacts that have to be reflected in policy decisions. Whether those policies would be better measured using composite indicators including all three dimensions of sustainability, or using a suite of indicators, is still controversially discussed.

Currently, there is a lack of understanding of how society can create well-being from economic and environmental resources and how these processes and institutions can become unsustainable over time. This reinforces the oversimplified view that sustainability is an environmental and economic issue. However, for society to be able to maintain well-being into the future, social functions must be monitored and encouraged. It is therefore important to pay attention to the indicators that demonstrate how society’s capacity to produce and distribute well-being is changing, such as crime rates, inequalities, youth unemployment, and social mobility.

The Beyond GDP Agenda is very wide and any project can only hope to take forward some parts of the agenda while necessarily neglecting others. IN-STREAM focused on addressing the following areas:

- **Dissemination:** The IN-STREAM team has worked on facilitating the use of sustainability measures by policy makers by analyzing the needs of policy makers, assessing the strengths and weaknesses of existing indicators and analysing statistical relationships between different indicators.

- **Aggregating and balancing of tradeoffs:** Additionally, the IN-STREAM team has developed a composite indicator of sustainability based on computerized general equilibrium models, with the key objective of showing the additional informational capacity which such an indicator can bring. Furthermore the team has modelled the impacts of environmental policies on competitiveness to show the tradeoffs and synergies between environmental, social and economic sustainability targets.

- **Environmental Damages:** Lastly, the research consortium has modelled and valued the costs and the benefits of environmental policies to human health and ecosystem preservation.

In order to ensure that the results are useful to policy makers, three policy fields or story lines were chosen as examples for potential applications of IN-STREAM results. For each policy field, one stakeholder workshop was conducted to understand the concerns and expectations of policy makers in the field and to discuss the IN-STREAM results with them.

1. Biodiversity: The COP convention in Nagoya in 2010 set an ambitious agenda for Biodiversity policy, and to achieve this, biodiversity indicators have to be more widely available and more widely used not only in biodiversity policies but also in other policies affecting biodiversity.

2. Green Growth and Green Innovation: The fallout from the financial crisis has sharpened the need to balance different objectives in policies aiming at green growth. Various international organisations have analysed how to measure success in multi-objective policies like green growth.

3. Resource Efficiency: One part of the green growth agenda which currently receives more attention is the resource efficiency agenda. One important precondition of success in reducing resource use in the EU will be to make progress in measuring resource use and the environmental impact of resource use. For this report, resource use was summarized under the green growth heading.

2.1 POLICY MONITORING WITH COMPOSITE INDICATORS

The possibility to develop synthetic measures of sustainability through aggregate or composite indicators is one of the most debated topics in sustainability literature. On the one hand indices simplify the complexity, and summarize the relationship among the variables. They also facilitate communication to decision makers. On the other hand any step in their construction – the choice of indicators to include, the "weights" to assign to each, the aggregation procedure – are prone to subjectivity, no matter the effort made. Therefore, many criticisms can be perfectly legitimate and correct.

Against this background, part of IN-STREAM's methodological quantitative research aimed to: (a) explore the potential/value added of composite indicators to monitor sustainability in business as usual and policy scenarios (b) investigate if and how economic modelling tools could support this analysis.

These issues have been addressed by applying a recursive-dynamic general equilibrium model for the world economic system (the Intertemporal Computable Equilibrium System (ICES) model) to a reference (no-policy) and an emission reduction scenario where the EU unilaterally cuts its GHG emissions by 20 % by 2020 with respect to levels of 1990. This can be considered the "climate-change component" of the Europe 2020 strategy. 23 sustainable development indicators belonging to the three pillars of sustainability (economic, environmental and social) have been extracted from the model output and compounded into an innovative sustainability index: the "FEEM" sustainability Index (FSI).

This exercise highlighted that the use of a composite indicator can be an invaluable communication/investigation device by making the preference structure and value judgments more transparent, including the relations between the different components of sustainability. It can also offer the opportunity to investigate in depth how and if this assessment can change when those preferences and values change. This information can be very interesting to policy and decision makers and particularly needed when complex policy implications are involved, like in the case of climate change policies. Rather than providing un-controversial and subjectivity-free unifying measures of sustainability, which is not possible no matter how comprehensive, complex and innovative composite indicators are, their correct use should be that of unfolding the complexity and explicating values. In this respect, transparency of construction of an index is its most important feature.

These properties are strengthened if composite indicators are used in combination with modelling approaches. On the one hand, the internal consistency of a mathematical structure allows "by construction" a coherent integration of different dimensions of sustainability inside an index. On the other hand, the possibility of conducting forward-looking simulations allows one to assess the implications for sustainability in different (BAU or policy) futures. That is,sustainability can be estimated ex ante and not only ex post. This can be appealing to a decision maker.

In this particular context, the use of CGE models presents two specific advantages: their large database makes it possible to calculate the indicators for several regions and sectors; their explicit modelling of market interactions and international trade is ideal for capturing how potential tradeoffs in sustainability originate and propagate through the economic system.

This said, the use of composite indicators and modelling approaches has to be considered just as a possible enrichment to the standard analysis of sustainability, particularly helpful for capturing quantitatively and explicitly the relations between a limited number of its very different parts. Indeed, the multifaceted nature of sustainability can be only partially encompassed by a model or an index, and the synthesis they provide suffers from all the limitations of the model and of the index themselves. For instance, when CGE are involved, limits are the full equilibrium view of the economic system, the assumed instantaneous often costless adjustments to that equilibrium, the crucial dependence of results on the calibration process, the simplified dynamics, the difficulty in dealing with non market values, and the "weak" representation of the environmental and social component. As such, models and indices should be considered support instruments within an ampler toolbox for a multi-criteria assessment.

More information on the "FEEM sustainability Index" is available at http://www.in-stream.eu/download/INSTREAM_FSI_final.pdf.

2.2 SETTING THE RIGHT TARGETS FOR MULTI-OBJECTIVE STRATEGIES – EUROPE 2020

Policy makers who set targets for multi-objective strategies like Europe 2020 have to solve an important dilemma. On the one hand they should not choose too many different targets as this will reduce communicability and accountability. On the other hand setting no targets for important parts of a large set of objectives could skew the attention and the effort of policy makers towards objectives with quantitative targets attached to them.

Policy makers can solve this dilemma if they have good information on the statistical relationships between different indicators. This will enable them to choose the lowest number of indicators which provide sufficient coverage of the objectives of the policy or strategy.

Correlation analysis or other statistical methodologies, which only require a limited analytical capacity, can support policy makers in this task. Analytical tools for statistical analysis include correlation analysis and advanced statistical techniques such as Principal Component Analysis (PCA) resulting in a variety of data patterns using scatter plots and bivariate correlation analysis, time series patterns, as well as PCA and Cluster Analysis (CA).

The methodology is very flexible and can be used to test all types of indicators and targets for multi objective strategies or policies. For example Europe 2020 has set 8 targets for 2020 aiming at environmental, social and economic sustainability:

- Increase the **employment rate** to 75 % of the 20–64 year old
- Increase **R&D spending** to 3 % of European GDP
- Reduce **Greenhouse emissions** by 20–30 %
- Increase the share of **renewable energy** production to 20 %
- Improve **energy efficiency** by 20 %
- Reduce school drop-out rates to below 10 %
  Increase the rate of 30–34 year old completing **third level education** to 40 %
- Reduce the number of people at **risk of poverty** by 20 million

Lessons can be learned from the analysis conducted by IN-STREAM on the choice of a set of indicators and on the interpretation of the indicator results.

GDP and Energy Efficiency: Correlation analysis between GDP and energy intensity (which is the inverse of energy efficiency) show that generally, energy intensity is negatively correlated with GDP growth meaning that energy intensity decreases (and energy efficiency increases) with rising GDP (as GDP is the denominator of energy efficiency). However, the differences among countries are significant. While in some countries the negative correlation is strong in others it is very weak. This can be used to identify countries with good practice (that have achieved some success in decoupling GDP growth from energy use) and focus countries (where no decoupling has been achieved and so policy actions would bring more significant rewards). It is worth noting that decoupling can occur for reasons unrelated to policy like the changing industrial structure of an economy. Statistical analysis should not replace more detailed analysis, but it can give a first indication where to look for good or bad examples. The results additionally can be used for the process of setting national targets. A time series analysis can also reveal whether the overall target is ambitious enough (or too ambitious) as the correlation can be used to calculate energy efficiency under different GDP growth scenarios.

Employment – unemployment rate: The Europe 2020 set of indicators does not include a very important social indicator: the unemployment rate. Obviously the employment rate is very much correlated with the unemployment rate but from a social point of view one might well argue that this does not suffice as labour markets could be very successful in creating jobs in general, nonetheless leaving some behind due to regional or skill imbalances. The analysis found that there was indeed a very strong negative correlation of employment rate and unemployment rate, and even more interestingly, that this negative correlation was even stronger between employment rate and the long term unemployment rate. In view of this strong correlation, the omission of the unemployment rate from the indicator set is not perceived as such a problem even from a social point of view.

At risk of poverty rates versus long term unemployment rates: To really understand the relationships of the economic variables and the social variables, it would be advisable to test the correlation between the long term unemployment rate and the risk of poverty rate. The time series analysis shows that many European countries have achieved serious drops in the rate of long term unemployment in the last decade (at least before the financial crisis set in). For many of those countries this has contributed to a drop in the risk of poverty rate, but for some countries the correlation was much weaker or even negative. This analysis delivers important messages to policy makers; in some countries the relationship might be weak because poverty is mainly concentrated in households outside the working age, or because low wages do not offer enough protection from poverty. This signalling can be used both for national target setting and for the formulation of specific policies aiming to achieve the Europe 2020 targets.

GDP and resource use: Another example of the signalling function of statistical analysis would be the relationship between GDP growth and resource use. Currently the Europe 2020 targets do not include a target on resource use, but such a target is expected to be adopted in the next year. Correlation analysis can be used to provide overview information for the negotiations of such a target. Generally, there is a strong positive correlation between resource use and GDP growth, but there are significant differences between nations. For example the scatter plot of ecological footprint and per capita GDP in Figure 2 shows that some countries with an ecological footprint of 4 reach per capita GDPs of more than $50,000 while other countries using as many resources, display a GDP of only $10,000 per capita. The plot also points out that for countries with an average per capita GDP nearing $20,000, some have an ecological footprint of 2 while others reach a footprint of nearly 6. These differences can both help set an ambitious agenda (as they show the values that other countries have achieved) and to nationalise these targets.

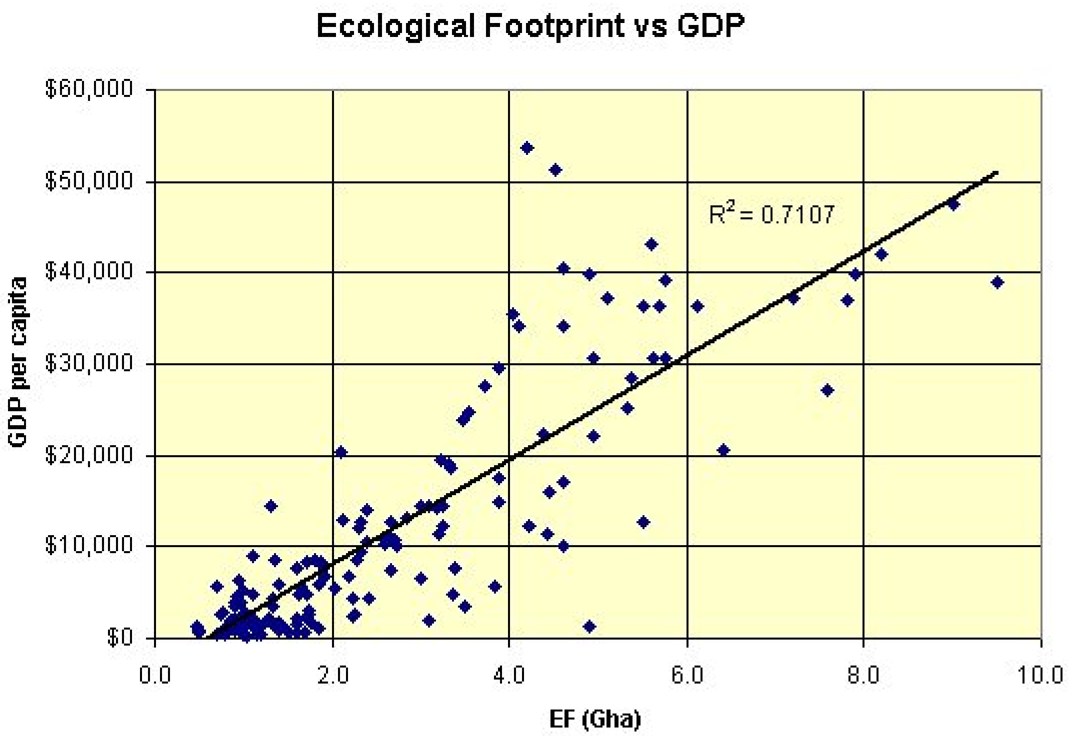

Figure 2: Scatter plot and regression line of per capita income and the Ecological Footprint.

This statistical analysis cannot replace an analysis of the causalities between the different variables as they only provide first indications where trade-offs and synergies between objectives can be found and where to look for good and bad examples. This being said, it becomes apparent that they are more appropriate in the first phases of policy making. The later stages such as impact assessments or evaluations will require a more refined set of tools. For example, they are useful tools that can help build a comprehensive and small set of quantitative targets for any policy. Relatively non-time consuming, they can be used even in policy processes with significant time pressure and can help to set more consistent and ambitious targets in multi objective policies.

More information on the statistical analysis of indicators is available at
http://www.in-stream.eu/download/WP3_Deliverable3.2_FINAL.pdf.

Even though not explicitly named a green growth strategy, the European Commission's Europe 2020 strategy has green growth at its heart. This strategy for smart, sustainable and inclusive growth aims to improve the European competitiveness, increase job creation and improve the innovation potential of the EU, while explicitly aiming to reduce the environmental impact of this growth by, for example, moving to a "low-carbon economy". In this respect, green growth is a very important subset of overall sustainability. While green growth aims to reconcile environmental and economic well-being, an overall view on sustainability would add the social dimension of sustainability to this assessment. Many commentators would even argue that social sustainability is also a necessary component of a green growth framework. Very often the three pillars of sustainability are closely connected. For example: job creation is crucial both for economic and social well-being, and a reduction in air emissions can be important both for environmental as for health reasons.

The question of how to measure progress towards green growth and how to balance the different objectives in the green growth agenda is also at the center othe OECD Green Growth Strategy as published in May 2011[3]. The strategy focuses on setting a policy and measurement framework for green growth but also discusses strategies to promote green growth. The strategy points out that it is necessary to adress social issues caused by green growth strategies like distributional impacts and labour market implications. Notwithstanding some commentators' reluctance to include these social issues into a green growth agenda, an acknolwedgement and mitigation of these social impacts is seen as crucial for the political success of green growth strategies. This focus on all three pilars of sustainability can also be observed in the choice of indicators, where social indicators feature heavily beside the economic and environmental indicators.

The IN-STREAM work summarized in this chapter is working according to the same agenda. The research conducted in IN-STREAM shows how the different objectives of green growth strategies can be monitored and reconciled by:

- evaluating indicators to choose the right indicator set;
- modelling impacts of environmental policies on competitiveness and job creation;
- valuing environmental benefits of policies in order to make them comparable with potential economic costs;
- estimating the impact of biofuel targets on land use;
- and assessing the distributional impacts of emission reduction policies.

[3] http://www.oecd.org/dataoecd/37/34/48224539.pdf

3.1 CHOOSING THE RIGHT INDICATORS WITH QUALITATIVE ASSESSMENTS

Green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies (OECD 2011). Therefore, a green growth strategy is centred on mutually reinforcing aspects of economic and environmental policy. It takes into account the value of natural capital and environmental pressures. Several EU and international agreements (the latest being Cancun (2011)) recognise the need to reduce emissions and provides the foundations for long-term global action.

Within this context, GHG emission (per capita/in levels) and energy intensity are commonly considered key structural indicators and are also part of the Europe 2020 indicator set. Accordingly, they have been considered particularly appropriate candidates (together with others, see IN-STREAM D2.2 and D4.1) to undergo a thorough qualitative analysis to provide both a practical application of qualitative procedures in indicator selection and to test the properties of the indicators themselves.

GHG emission reduction: GHG emissions are considered the most important structural indicator of climate change pressure, given their direct contribution to global warming, depending on specific heat absorptive capacity and lifetime in the atmosphere. According to Global Warming Potentials (GWP), different GHG emissions can be converted into CO2 equivalents and aggregated into a single figure. This composite indicator is thus able to summarize all the anthropogenic GHG covered, for instance, by the Kyoto Protocol from 1990 (base year) onwards. Several countries have used environmental indicators to monitor their progress towards international and national policy targets as required by UNFCCC since 1992 for countries listed in Annex I. Following the RACER analysis (see box at the end of the section), the GHG emission indicator is relevant and commonly accepted (has a strong link to the environmental component of sustainable development and is largely used in international and EU policies). Moreover, (EU Member) states can evaluate their progress towards meeting required reductions, track the timeliness, consistency and comparability of relevant policies and are encouraged to report the presence of implementation problems. Thus it is also credible (highly connected to its methodological and explanatory transparency) and easy (data are available, it is technically feasible and show complementarities with other indicators). Robustness is proven by statistical validation and its transparency.

Energy intensity and efficiency: Reducing energy consumption and eliminating energy wastage is an important objective pursued by the European Union and is the focus of the June 2011 "EU Energy Efficiency Directive MEMO/11/440, 22" (EU, 2011). Energy intensity is the indicator most often used as a proxy for developments in energy efficiency, but the two concepts are not exactly the same. The energy intensity indicator describes how much energy is needed to produce one monetary unit of value (GDP or value added or sectoral production etc.). Measuring energy/GDP allows one to capture in a synthetic way where there is a "decoupling" between final energy consumption and the economic performance of a country, sector or process. A shift towards "decoupling" is generally seen as indicating a relative decrease in pressures on the environment from energy production and consumption. Energy efficiency is a narrower and more technological related concept (OECD/IEA 2009). For a sector or a firm, increasing energy efficiency means a decrease in energy consumed per unit of goods or service produced ("technical energy efficiency"). For a country, energy efficiency measures the amount of energy consumed per unit of output produced (IDDRI 2011). The Climate Change and Energy Package (COM(2008)16, 17 and 19) includes a 20 % target in increasing energy efficiency. It is therefore an "absolute energy savings" target. Following the RACER analysis, the energy intensity indicator is relevant (has a strong link to sustainable development) and commonly accepted (it is partially used in EU policies). It is credible, easy and robust but it needs the support of other indicators for a better explanation of energy use.

The qualitative analysis is completed by a strength and weakness assessment (SWOT see box at the end of the section) of the two indicators. Notwithstanding their pros, (relevance, acceptance, credibility, relative easiness and robustness) they present some drawbacks.

Firstly, being pressure indicators, they do not reflect damages. GHG emissions for instance cannot per se capture effects of emission on human health. Or an increase in the "technical energy efficiency" does not always imply sustainable energy use as it can well be coupled with increased energy demand (rebound effect). For instance, the fact that the "rebound effect" might undermine the effectiveness of the energy package in achieving its objective has not been sufficiently acknowledged to date, resulting in a slight mismatch between the overall target set and the means to achieve it (IDDRI 2011).

Secondly, being often used "in aggregate" to summarize different information at the country level, they share part of the deficiencies of composite indicators. When GHG emissions are concerned for instance – given that each source has its specific carbon content, each sector a specific fuel mix and each country is more intensive in some sectors than others – a breakdown of the indicator into sector and fuel specific component can better help to tailor more effective policies.

Similarly, an energy intensity indicator at the country level is not informative on changes in energy mix and on developments of clean technologies.

The major conclusion of this analysis is that the choice of indicators surely needs to be based on criteria of relevance, acceptance, credibility, easiness and robustness. However, these are necessary but insufficient conditions to get the desired information on sustainability. On the one hand, the analysis and the indicator used should be carefully tailored to the policy investigation performed. On the other hand, even though the area of interest may seem very narrow and the indicators chosen very appropriate, it is often useful to complement the analysis with additional indicators to avoid misinterpretations.

More information on the qualitative assessment of sustainability indicators is available at http://www.in-stream.eu/download/D2.2_final.pdf.

ASSESSMENT METHODOLOGIES:

In the qualitative assessment of the selected indicators, the INSTREAM project applied two methodologies, RACER and SWOT, described below.

RACER evaluation framework has been developed by the European Commission[4], for assessing the value of scientific tools used in policy making processes. RACER is an acronym for:

→ **R**elevant = closely linked to the objectives to be reached

→ **A**ccepted = by staff, stakeholders, and other users

→ **C**redible = accessible to non experts, unambiguous and easy to interpret

→ **E**asy = feasible to monitor and collect data at reasonable cost

→ **R**obust = not easily manipulated

The INSTREAM project enriched the RACER approach with additional sub-criteria to tailor it to indicator analysis.

SWOT analysis is a tool usually applied to assessing an organization's, business' or program's ability to achieve a stated objective. It evaluates the internal and external factors that influence the probability of success of the objective[5]. Applied to indicator analysis, SWOT is an acronym for:

→ **S**trengths: Positive aspects of the indicator. The "core" strengths are the strongest aspects and main advantages of the indicator and the "important" strengths are those strengths that are highly significant but that may be shared with a host of other indicators.

→ **W**eaknesses: Negative aspects of the indicator. The "critical" weakness may preclude implementing the indicator at an EU level. The "important" weaknesses limit the usefulness of the indicator

→ **O**pportunities: Those aspects of the institutional, political, intellectual and technological environments that could help improve the indicator, lead to its successful adoption, or both.

→ **T**hreats: Those aspects of the institutional, political, intellectual and technological environments that could hinder the successful adoption of the indicator.

[4] The European Commission's Impact Assessment Guidelines (2005)

[5] SWOT analysis is credited to Albert Humphrey at Stanford University who used it for evaluating Fortune 500 companies in the 1960s and 1970s.

3.2 EMISSION REDUCTION POLICY AND COMPETITIVENESS

At the sixteenth United Nations Climate Change Conference in Cancún, the world community committed itself to the objective of limiting the rise in global average temperature to no more than 2° Celsius above pre-industrial levels in order to hedge against dangerous anthropogenic interference with the climate system. According to scientific knowledge compiled by the Intergovernmental Panel on Climate Change in its Fourth Assessment Report, this implies that over the next decades global greenhouse gas emissions must be halved from their 1990 emission levels. To date, however, prospects for a Post-Kyoto agreement covering all major emitting countries are bleak. Even in the case of a broader follow-up agreement to the Kyoto Protocol, it is much more likely that emission reduction targets will be quite unevenly spread across the signatory regions with OECD countries taking a lead role reflecting their historical responsibility and higher ability to pay.

One-sided commitments to ambitious emission reduction targets raise competitiveness and emission leakage concerns in all the major economies implementing or proposing unilateral responses to the threat of climate change. At the fore of climate policy discussions, competitiveness and leakage concerns refer in particular to the performance of energy-intensive and trade-exposed (EITE) industries. Obviously, unilateral emission pricing of domestic industries where emission-intensive inputs represent a significant share of direct and indirect costs will put these sectors at a disadvantage compared to competing firms in countries abroad which lack comparable regulation. The loss in competitiveness is to some extent associated with the potential for emission leakage, i.e., the change of emissions in non-abating regions as a reaction to the reduction of emissions in abating regions.

Leakage can arise when energy-intensive and trade-exposed industries in emission-constrained regions lose competitiveness, thereby increasing emission-intensive production in unconstrained regions (the trade channel). A second important leakage channel works through international energy markets (the energy channel): Emission constraints in larger open economies reduce the demand for fossil fuels, thereby depressing world energy prices which in turn lead to an increase in the level of energy demand in other regions. Competitiveness and leakage concerns have motivated claims for special treatment of energy intensive and trade-exposed sectors ranging from reduced emission prices or output-based emission allocation to border carbon adjustments.

A prime example of the competitiveness and leakage issues at stake in unilateral climate policy is provided by the European Union (EU) which considers itself as a leading force in the battle against anthropogenic climate change. During the Spring Summit in March 2007, the European Council agreed upon an ambitious climate policy with unilateral greenhouse gas emissions reductions in 2020 by at least 20 % compared to 1990 levels. But as described above this is only one of the targets of the Europe 2020 agenda, which also stipulates employment growth, social objectives and other environmental targets. The simultaneous pursuit of environmental and competitiveness objectives has led to the preferential treatment of EITE industries in EU climate policy. The aggregate EU emission reduction is divided between energy-intensive sectors – of which EITE industries are a subset – covered through an EU-wide emission trading system (the so-called EU ETS) and the remaining parts of the EU economy (without direct trade linkages). Mirroring competitiveness and leakage concerns, the emission reduction requirements for ETS sectors have been relatively lax compared to the reduction targets for non-ETS segments of the EU economy which effectively boils down to preferential emission pricing of EITE industries.

While the issue of competitiveness ranks high and has tangible implications for the design of unilateral emission regulations, the climate policy debate lacks a rigorous clarification of competitiveness notions and a comprehensive quantitative analysis of policy proposals that respond to competitiveness concerns of specific industries. In the assessment of unilateral EU climate policy, the bulk of competitiveness research is skewed towards a partial equilibrium perspective focusing on EITE industries that are directly affected by the EU ETS.

The sector-specific partial equilibrium framework allows for neither a comparison of competitiveness implications across different industries nor a simultaneous assessment of economy-wide performance in terms of an overarching welfare metric. General equilibrium analyses of EU climate policies based on multi-sector, multi-region computable general equilibrium (CGE) models emphasize the excess cost of emission abatement induced by emission market segmentation and overlapping regulatory measures rather than the competitiveness and leakage aspects.

In the IN-STREAM project, we analyzed alternative indicators that can be used to quantify specific aspects of competitiveness at the level of sectors and countries. We then used a computable general equilibrium model complemented with selected competitiveness indicators to facilitate the quantitative impact assessment of EU leadership in climate policy. Price discrimination in favour of EITE sectors may be warranted to preserve industrial competitiveness of these politically influential industries. From a broader economic perspective, however, the narrow focus on competitiveness concerns of EITE industries can be misleading. The sector-specific gains of preferential regulation in favour of these branches must be traded off against the additional burden imposed on other industries to meet an economy-wide emission reduction target. Beyond burden shifting between industries, differential emission pricing runs the risk of substantial excess costs in emission reduction as policy concedes (too) low carbon prices to EITE industries and thereby foregoes relatively cheap abatement options in these sectors. From the perspective of global cost-effectiveness, we find that differential emission pricing of EITE industries hardly reduces emission leakage since the latter is driven through robust international energy market responses to emission constraints. As a consequence, the scope for efficiency compared to uniform pricing is very limited. Only towards stringent emission reduction targets will a moderate price differentiation achieve sufficient gains from leakage reduction to offset the losses of diverging marginal abatement cost.

More information on emission reduction policy and competitiveness is available at

http://www.in-stream.eu/download/D6.1%20ZEW_Competitiveness%20final.pdf.

3.3 RENEWABLE ENERGY TARGETS AND EMPLOYMENT

Many studies focus on the assessment of climate policies on a national and international level. However, in countries with a federal system there may be different climate policies in place that, in the worst case, might counteract national policy actions. An example for this is a program by the state government of the German state of Baden-Wuerttemberg to increase the share of renewable energy carriers in electricity generation up to 20 by 2020. In the case of heat supply, the share of renewables shall be increased to 16 % by 2020.

The findings of a simulation within the IN-STREAM project (with the case of the region of Baden-Wuerttemberg in Germany as an illustrative example) suggest that regional policy actions (e.g. within a member state promoting renewable energy types) do not necessarily create new jobs and additional production for the whole economy. Instead, they induce a structural change of the economy since other investments might be crowded out by investments in installations of renewable energy and the demand in other sectors might decrease. However, if the producers of the installations are able to export parts of their products to the rest of Germany and to the rest of the world, these crowding out effects can be reduced and production and employment effects might be positive overall.

This project examined the regional impact of this program by using an input output approach. These impacts are of particular interest because in Baden-Wuerttemberg the manufacturing industries are more important than in the rest of Germany. Thus we analyzed the effects of the policy actions on production as well as employment in several sectors. We therefore constructed a regional input output table of Baden-Wuerttemberg and introduced seven renewable energy types in order to examine different paths for achieving the state government's targets.

We considered two scenarios with different methods for funding the construction and operation of renewable energy installations. In the first scenario, all the necessary investments are funded completely by internal sources. Hence, the scenario is driven by the assumption that these investments either crowd out investments in other industries of the regional economy or the investments are paid by the government, i.e. by taxes which are borne by all other industries and by the households. Therefore, the final demand of all other sectors decreases. In this scenario, we have a slight positive total production effect although in many sectors the production effect is negative. In addition, the total employment effect is negative since the more labour-intensive industries, in particular the manufacturing industries, are affected more heavily from the policy than the less labour-intensive industries.

The second scenario considers the case of a partly external funding by taking into account that the installations may be demanded from "abroad", i.e. the rest of Germany and the rest of the world. Therefore, investments in other industries are not completely crowded out in this scenario. In this scenario we also find positive production and employment effects for most industries besides the energy sector. Net production and employment effects for aggregate model sectors for this scenario are presented below.

Technically we chose an input output approach for our analysis since the data availability did not suffice to regionally disaggregate the underlying database of a computable general equilibrium (CGE) model. In an input output context the construction of a regional data source is less problematic. Furthermore, it completely serves the purposes of the tasks, i.e. the analysis of regional production, and employment effects can be represented within an input output approach with a similar accuracy as within a CGE framework. Also the sectoral disaggregation of the input output table is not inferior to that of most applied CGE models.

More information on regional labour market impacts of renewable energy targets is available at http://www.in-stream.eu/download/SVI_In-Stream%20D%206.3%20Regional%20indicators%20ZEW%20v2.pdf.

TABLE 1: NET PRODUCTION AND EMPLOYMENT EFFECTS INDUCED BY THE REGIONAL CLIMATE POLICY IN BADEN-WUERTTEMBERG UNTIL 2020, EXTERNAL FUNDING BY EXPORTING

SECTOR	ADDITIONAL PRODUCTION (MN €)	EMPLOYMENT EFFECTS (NO. OF JOBS)
Gross Employment effects of renewable energy sectors induced by the regional climate policy in Baden-Wuerttemberg until 2020		105.466
Net production and employment effects induced by the regional climate policy in Baden-Wuerttemberg until 2020, internal funding	2541.2	-34.812
Net production and employment effects induced by the regional climate policy in Baden-Wuerttemberg until 2020, external funding by exporting	6470.5	30.662

3.4 DISTRIBUTIVE IMPACTS OF EMISSION REDUCTION MEASURES (CUEC)

Adverse social and distributive impacts have often been considered the main obstacle to environmental regulation. It has been argued that energy taxation, as an example of emission reduction measures, would affect low income households more and may result in fuel-poverty. Although macro structural models, such as CGE type models, assess sectoral impact in detail, the distributive impacts on households are examined only broadly, most frequently through the impact on one household that represents the whole country or region.

One method of assessing distributive effects is to look at the budget shares of various household segments on regulated goods, or goods whose price will be affected by second-order effects. In our study we specifically examine expenditures of Czech households on energy and motor fuel, and find large differences in consumption patterns across household segments.Nobody demands energy or propellants per se, but energy demand is a derived demand that arises from the household's demand for the services supplied by electric appliances, the heating or the cooling systems, or by vehicles. As such, energy is not demanded directly; rather, it is used in a combination with other goods, typically capital goods, to produce the services we ultimately desire. Emissions can therefore be effectively reduced by policy measures targeting relevant durables. Distributive impacts will thus depend not only on pre-policy budget share, but also on whether a certain household possesses the durable or not. We identify several important socio-demographic and housing structural factors that determine the choice of having a private car in Czech households and based on the review of the OECD project on "Household Consumption and Environmental policy" we identify several household segments, which are more likely to possess electric durables and install energy efficient devices.

One can hardly expect household consumption to remain unchanged under a prospective policy's new conditions. Consequently, proper evaluation of distributional effects of policy should not ignore the behavioural responses of individuals on price and wealth changes connected to a policy. To consider the behavioural responses of the consumers, key parameters of household demand have to be plugged into any simulation or prediction model. Using a micro-simulation model for the Czech Republic, embedded with price and income elasticities, we predict the impact of several pricing policies on consumption, expenditures and welfare separately on several household segments.

We highlight that distributive impact assessment based on both household expenditures and the cost of living index can provide useful but different information for decision-makers. Changes in household expenditure patterns may inform a policy maker about the expected fiscal impact and environmental effect, and because the change in expenditures may determine investment in energy saving, the predictions of household energy expenses can serve as a useful indicator for the possible targeting of social mitigation measures and/or for considering a support measure in order to enhance energy saving installations within households. In comparison, the cost-of-living-based measures provide information about welfare loss or benefit induced by intended policy. Overall changes in welfare inform a policy maker about the economic efficiency and desirability of a proposed policy.

Providing predictions on both the expenditure patterns and welfare for several household segments separately is one way to address the distributive impacts. A second approach might rely on measuring indicators on equality. The Gini Index is the most well-known indicator to measure income inequalities before and after the implementation of policy. The Theil Index might be used to measure inequalities within and in between groups. Useful information also exists that can provide a measurement of distribution of tax payments, basically indicating whether taxes are paid evenly, or if there is regressivity or progressivity (eg: the Suits and the Jinonice Index).

Although, the indicators are very policy relevant, in most cases they represent a basic estimate of the true, but unknown, index and, as such, it is a function of the underlying distribution, which is unknown. In reality, we only observe a reasonably appropriate sample from that distribution, in light of which it makes sense to derive the underlying statistical distributions for testing and inference purposes. We document this problem on statistical inference of Gini and Suits indexes computed for the Czech Republic and find that only some changes in the indexes, but not all, are statistically significant.

3.5 ECONOMIC EFFECTS OF SUSTAINABILITY SCENARIOS IN LAND-USE AND AGRICULTURE

The IN-STREAM project has also assessed agricultural sustainability by exploring the linkages among economic and sustainable development aspirations in land-use, specifically in the area of biofuel production. The requirement of climate change mitigation has increased interest in land-based renewable energy sources. This requires an in-depth analysis of all components of sustainable development in a consistent framework: environmental, social and economic. The policy relevance of the quantified sustainability indicators is demonstrated by their suitability for formulating recommendations for environmentally sound agricultural and renewable energy policies.

For the analysis of the global agricultural system, a state-of-the-art ecological-economic modelling framework is applied. It has two major components: the FAO/IIASA Agro-ecological Zone (AEZ) model and the IIASA world food system (WFS) model. An initial baseline assessment provides the point of reference against which alternative biofuel scenarios are compared for assessing their impacts. This reference scenario assumes historical biofuel development until 2008 and thereafter keeps biofuel feedstock demand constant at the 2008 level. Biofuel scenarios explore the impact of different levels of biofuel demand and composition. The simulations were carried out on a yearly basis from 1990 to 2030.

Biofuel scenarios include an overall energy scenario with detailed elaboration of the regional and global use of transport fuels; pathways depicting the role of biofuels in the total use of transport fuels; as well as assumptions about the role and dynamics of second-generation biofuel production technologies and about the fraction of total biofuel production supplied by first-generation feedstocks (based on conventional agricultural crops such as maize, sugar cane, cassava, oilseeds, palm oil, etc.).

The primary intended outcome of the biofuel scenarios is to reduce GHG, mainly CO_2, emissions from the global transport sector. Therefore a net reduction of GHGs of the whole lifecycle of biofuel production and consumption, including land use change effects, is imperative for accelerated biofuel deployment. This is reflected in the sustainability criteria being established for biofuel use. Land conversion and changed land management practices to produce biofuel feedstocks (direct land use change) and displacing agricultural activities to other areas and causing land use change somewhere else (indirect land use changes) due to regional development induced by biofuel initiatives can lead to both carbon losses or gains in the biospheric carbon stock. Of particular concern for greenhouse gas impacts is conversion of carbon-rich habitats such as forests, natural grassland, or wetlands to cultivated land.

Figure 3 highlights the cumulated net GHG savings in the biofuel scenarios WEO-2009 and EU-V1 to EU-V3 relative to the REF. The net GHG balance of a biofuel scenario (shown in blue, bar "Net GHG balance") is determined by the GHG savings achieved from biofuel replacement of gasoline and

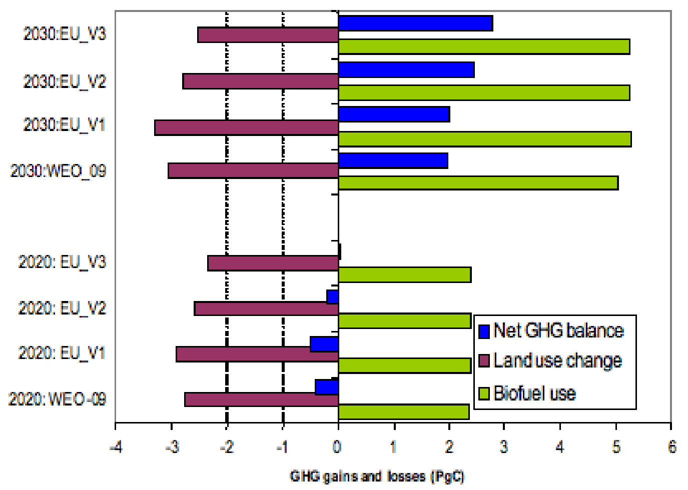

Figure 3[6]: Cumulative net GHG savings of biofuel scenarios

diesel (Bar "Biofuel use") minus the GHG emissions caused by direct and indirect land use changes (Bar "Land use change").

Carbon losses from vegetation and soils due to land use changes (deforestation and grassland conversion) occur mainly at the time of land conversion. In contrast GHG savings resulting from the replacement of fossil fuels with biofuels accumulate only gradually over time. For the biofuel

[6] Source: IIASA World Food System scenario simulations, June 2010

scenarios net GHG balances only become positive after 2020. By 2030 the amount of second-generation biofuels increases GHG savings via biofuel use while at the same time only a little additional land use conversion is required. The additional net greenhouse gas savings from the assumed biofuel use for the period 2020–2030 amounts to roughly 3 Pg[7] CO_2 emissions, while there are hardly any emissions due to additional land cover conversion, resulting in a net accumulated production by 2030 of 2–3 Pg[8] CO_2 emissions.

The biofuel scenarios have important implications for the social dimension of sustainability. Equity and access to food and energy are important concerns in sustainable development. According to the Reference scenario without additional biofuel targets, the number of people at the risk of hunger declines gradually over the coming decades, reaching 807 million people in 2030 and 720 million in 2030. This positive trend is undercut by the introduction of ambitious biofuel targets. Demand for cereals is projected to increase in all biofuel scenarios and, despite expanding arable land to satisfy this demand, cereal prices will increase as well. Higher prices will worsen the access to and affordability of food for the poor.

Figure 4 shows that the number of people at risk of hunger will increase relative to the REF scenario under all biofuel scenarios in all regions of the world. This increase is larger in 2020 than in 2030 because adjustments on the production side (land conversion, capacity expansion, etc.) take time; therefore achieving the 2020 biofuel targets implies diversion of food crops and increasing prices. With more time for production adjustments and for improvements in second-generation biofuel technologies, the pressure on crop prices in general, and on cereal prices in particular, is smaller in 2030, leading to lower but still significant increases in the number of people at the risk of hunger.

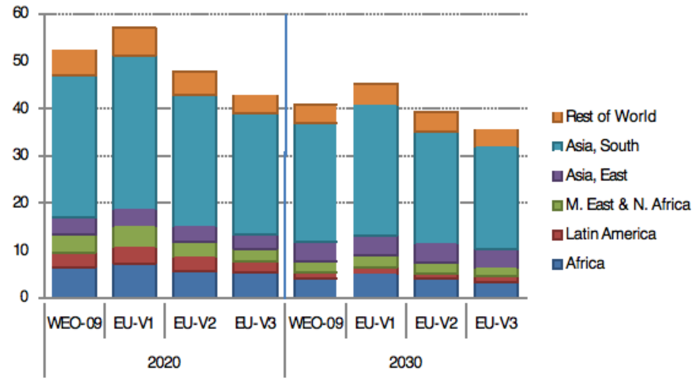

Figure 4[9]: Additional people at risk of hunger

The conclusion from the selected results of the biofuel scenarios above is that economic and sustainability chara cteristics of the global agricultural system are resulting from a complex set of cause-effect relationships. Their assessment requires an in-depth representation of the natural resource base (land, climate, agronomic features) and the socio-economic processes involved in their utilization. This globally The two main implications are that sustainability targets in one region can negatively affect prospects for sustainable development in other regions, and that sustainability improvements in one domain (e.g., GHG emissions reduction) can degrade sustainability characteristics in other domains (e.g., equity and hunger, deforestation). Analysts need to assess these linkages thoroughly so that policy makers can make informed judgments about the benefits and costs of the policy options available to them.

More information on biofuel and land use changes is available at

http://www.in-stream.eu/download/Deliverable_6.4.pdf.

[7, 8] 10^{15} grams of carbon or billion tons of carbons

[9] Source: IIASA World Food System scenario simulations, June 2010

3.6 CLIMATE CHANGE – ASSESSMENT OF GREENHOUSE GAS EMISSIONS

Climate change and its impacts should be accounted for in future political decisions. A possible general measure to reduce climate change impacts is the internationally agreed upon 2 °C target. Reaching this target will entail considerable costs to the economy, which policy makers will need to justify to the general public. The following assessments can be used to estimate the benefits of reaching these emission targets, and to compare these benefits against the costs.

GHG emissions: By observing greenhouse gas emissions, it is possible to compare the actual emissions expressed in CO_2-equivalents with a modelled sustainable emission path that resulting in the 2°C target. The model not only includes the dominant CO_2 emissions and other GHGs, but also includes as a novel feature the non-GHGs Black Carbon (BC), organic carbon (OC) and SO_2. A possible deviance between the sustainable future path (e.g. Europe's contribution to the 2 °C target) and the actual path (in the future) can be depicted. Here, energy-related emissions modelled with the TIMES model are presented; the REF scenario represents a business-as-usual emission path.

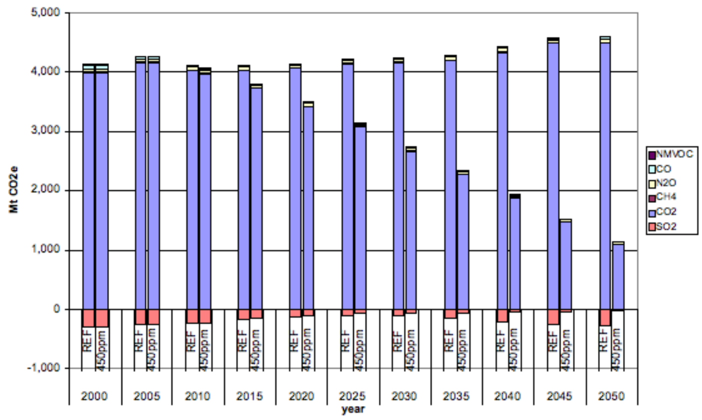

Figure 5[10]: Emission path EU29 (only energy-related)

Costs distance to target: The distance to target can also be expressed as costs. The difference between the Annual System Costs of the two scenarios thus expresses the avoidance costs for meeting the climate change target. The avoidance costs are relatively minor for the first 15 years of the policy but increase sharply in the later stages.

Total damage costs: The benefits of the avoidance of emissions are the avoided total damage costs of emissions related to climate change. These can be expressed by multiplying the emitted tons of carbon with the damage cost per ton of carbon. Marginal damage costs of climate change are assessed with integrated assessment models. Figure 6 shows the range of total damage costs calculated with the FUND[11] model.

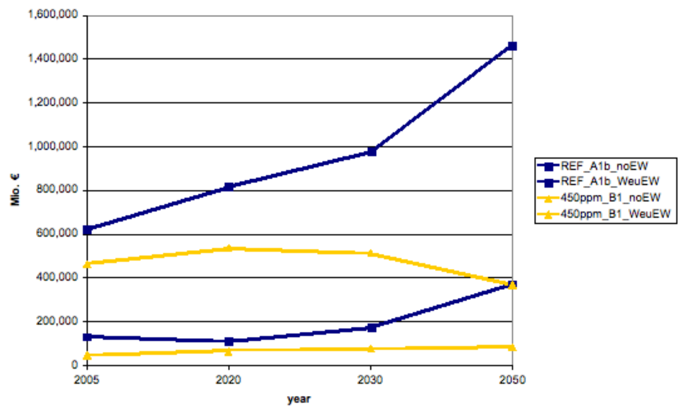

Figure 6: Total damage costs of EU29 GHG emissions

An extra feature is that avoided damages can be compared with avoidance costs (annual system costs shown above). Figure 7 shows the avoided damages if the target emission path is achieved. The green line represents values which are European equity weighted (WeuEW)[12] and are thus an upper bound, the blue line are avoided damages without equity weighting (noEW) which represents a lower bound. The yellow line is the difference of the annual system costs per year.

[10] Source: TIMES model within HEIMTSA Common Case Study

[11] www.fund-model.org

[12] If no equity weighting is applied, all damages worldwide are accounted for in actual values. Problems occur when comparing avoidance costs for measures e.g. in Europe with the "relatively" low damages that can be saved by that in poorer countries worldwide, due to lower monetary value of affected assets like destroyed homes. Equity weighting removes this bias and weights the global damages with the average income of the region where the measures should/can take place. Europe doesn't have high damages due to climate change but is a big emitter of GHGs. Equity weighting is thus used to show what the damages would be if they happened to us. In economic assessment EW is mostly used as sensitivity analysis to account for differences in regional welfare.

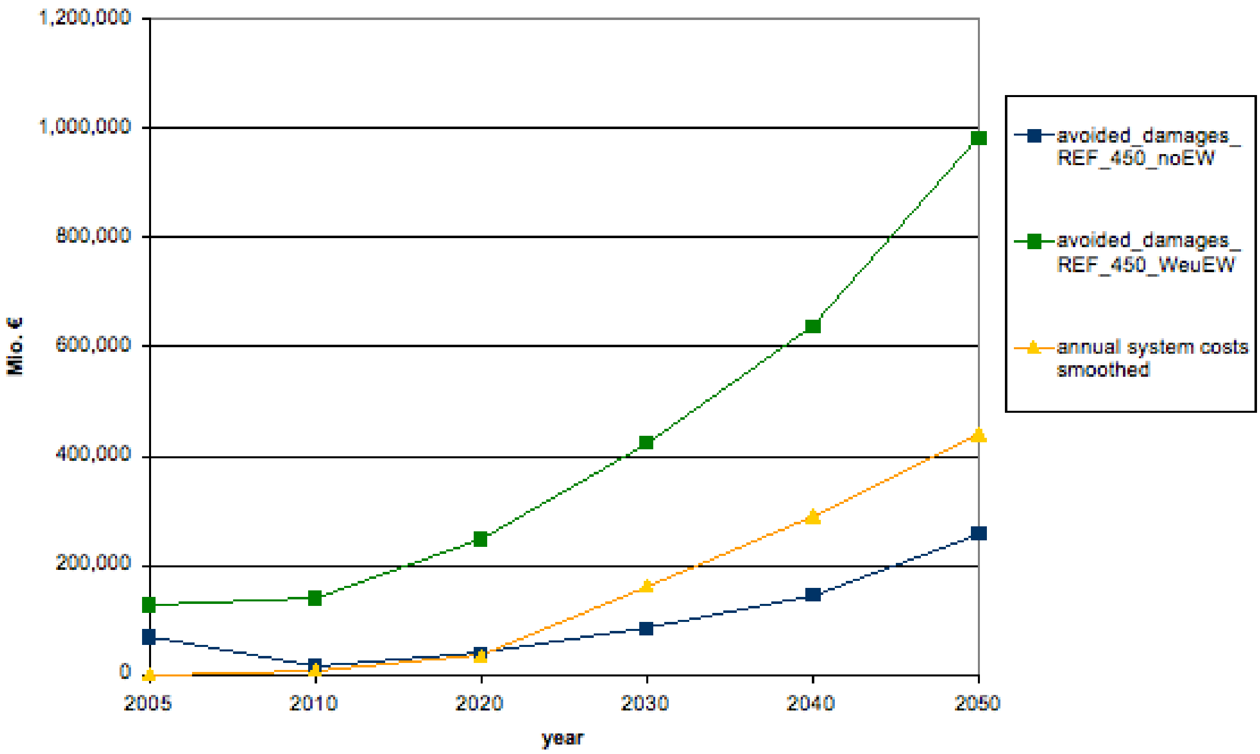

Figure 7: Avoided damages and avoidance costs EU29

CONCLUSION

The indicator "GHG emissions" is easy to calculate and only minor errors occur. A new aspect is the incorporation of non-GHGs like black carbon (BC), organic carbon (OC), non-methane volatile organic compounds (NMVOC), sulphur dioxide (SO_2) and carbon monoxide (CO). Two weaknesses of the approach are that, firstly, only a relative comparison to the previous year is possible and that, secondly, there is uncertainty regarding the sustainability of the target path.

With the "distance to target", a sustainable path is visible, but the path has to be calculated by a model, and the 2 °C target is placed and not deviated from research results. The indicator "costs of distance to target" is comparable to other indicators and an aggregation is possible.

The comparison of the avoidance cost of emissions and the avoided damage costs of these emission reductions can give insights into the economic impacts of emission reduction policies. This will help policy makers justify the costs of emission avoidance. Forecasts on innovation have been included in the estimates of costs and benefits, but significant uncertainties remain, as innovation is difficult to predict.

The overall avoidance costs exceed the avoided damage costs if the results are not equity weighted. This result corresponds nicely with the well known fact that many costs of climate change caused by European emissions will not fall on European countries, but on other (mostly poorer) countries outside Europe. A disadvantage of the methodology is that not all damages are included, as they are either not assessable or not yet known.

More information is available at
http://www.in-stream.eu/download/IN-STREAM_deliverable-5%201_110727_FINAL.pdf.

3.7 POLICY CONCLUSIONS FROM SENSITIVITY ANALYSIS

Simulation exercises in economics, like in other model based sciences (as done in IN-STREAM), depend on the choice of the basic parameters of the model. While these themselves should be well founded on underlying assumptions, only a thorough sensitivity analysis can establish the robustness of the deductions (or alternatively show weaknesses of the approach). In such an exercise, the modeller analyses the measure of variation of key output variables of the model with respect to a sensible variation of input variables. In the case of IN-STREAM, we did a sensitivity analysis for the simulations on economy-wide and sectoral competitiveness indicators (see section 3.3), and on the composite sustainability indicator (see section 2.1).

The results on competitiveness confirm the validity of the results of the IN-STREAM project, with the exception of one indicator, the Relative Trade Balance (RTB) index, which is very sensitive to the underlying assumptions. Across the robust indicators, there are also important differences: while the economy wide Terms of Trade are largely unaffected by the sensitivity analysis, the magnitude of the sectoral indicators apparently depends on that choice.

Regarding the composite sustainability indicators, the construction and use of these indicators raise criticisms and debate. The reason for this is that any step of the process - the choice of indicators to include, the choice of “weights” to assign to each, the aggregation procedure - are subjectivity prone, no matter the effort made. When this is the case, many criticisms can be perfectly legitimate and correct.

As shown by the present exercise, it must be accepted that, notwithstanding the technical feasibility, it is neither possible to un-controversially summarize sustainability in just one figure, nor to rule out the subjectivity of composite indicators. In fact, we have shown that the country ranking proposed by the complex FEEM-Sustainability-Index demonstrates a rather good degree of robustness, especially concerning the positions at the top and at the bottom. Nonetheless, this robustness is far from offering full objectivity and invariance.

Regardless, there are very good reasons in favour of the use of composite indicators. As shown by IN-STREAM research, they can be invaluable communication devices to make the preference structure and value judgments more transparent, originating a given synthetic sustainability assessment. They can also offer the opportunity for an in depth investigation of if and how such an assessment can change when those preferences and values change. In this respect, sensitivity analyses, coupled with the transparency of construction, are key features to apply to composite indicators. All the information gathered can then be of significant interest to policy makers, and can be potentially more important than the synthesis provided.

As a policy conclusion, the IN-STREAM project demonstrated that the robustness and sensitivity of indicators are important criteria for decision makers to examine.

More information on sensitivity analysis of IN-STREAM models is available at

http://www.in-stream.eu/download/D6.6a_sensitivity_%20FSI.pdf and http://www.in-stream.eu/download/D6.6b_Sensitivity_ZEW.pdf.

Biodiversity – the variety of ecosystems, species and genes – is an essential part of the world's 'natural capital', and its conservation and restoration is thus a key environmental priority for the EU. The Economics of Ecosystems and Biodiversity initiative (TEEB, 2010) highlights the link between biodiversity, the health of ecosystems and the often overlooked important goods and services, and the related value that these provide. The TEEB for National Policy-Making[13] (TEEB, 2011), emphasising the need for correct metrics, calls for suitable indicators and accounting frameworks to measure our natural capital, and highlights urgent steps to allow the formation of a solid evidence base for informed policy decisions.

While it is a very complex task to measure all different aspects of biodiversity, over recent years an increasing number of indicators have been developed due to the need to provide manageable information on biodiversity and ecosystem health, pressures leading to its loss and potential impacts on human well-being to policy makers. A recent indicator-based assessment by the European Commission[14] revealed that, whilst some progress had been made, the state and trends of Europe's biodiversity are still a serious cause for concern, with a wide number of ecosystems and ecosystem service flows having degraded in recent years. For instance, some biodiversity-rich areas like grasslands and wetlands are declining, and up to 25 per cent of European animal species, including mammals, amphibians, reptiles, birds and butterflies face the risk of extinction.

The development of indicators has been mainly driven by several key biodiversity policies. This includes the implementation of the Birds and Habitats Directives and the related Natura 2000 network, which are legal cornerstones of EU biodiversity policy. In addition, indicators were adopted to monitor and communicate progress against the global and European commitment to either significantly reducing or halting biodiversity loss by 2010, as well as related actions set out in the Strategic Plan adopted by Parties to the Convention on Biological Diversity (CBD) in 2002 and the EU Biodiversity Action Plan (BAP) in 2006. The targets were not met and it has been highlighted that, inter alia, a major failure of the EU BAP was related to the lack of appropriate indicators and baselines to measure progress[15].

After the 2010 target was not achieved, new global and European missions, visions and targets were agreed upon in order to achieve the halt of biodiversity and ecosystem services loss, and restore them as far as possible by 2020. At the European level it resulted in the adoption of the new EU biodiversity strategy, which proposes a range of new initiatives that will arguably require a set of indicators to assess their future efficiency. New objectives on losses of ecosystem service and improving restoration, as well as the new interest in green infrastructure, clearly require the development of additional indicators, particularly on ecosystem services. Similarly, the new CBD Strategic Plan (Aichi targets 2011–2020) has initiated discussions on the further development of the basket of indicators applied to measure progress towards the previous plan.

Additional efforts are particularly needed to streamline biodiversity considerations into broader EU and national policies. Evaluations[16, 17] at both the global and European level recognized the insufficient integration of biodiversity into wider policies, strategies and programmes as one of the main reasons for failing to meet the initial targets. Numerous EU policies - for example, the Common Agricultural Policy, Common Fisheries Policy, Cohesion Policy, trade and development policies - have an impact on biodiversity or can benefit from (and sometimes even rely on) ecosystem goods and services. Indicators are essential to ensure that policy makers in other fields take possible impacts on biodiversity into account, recognise its value and quantify the efficiency/effectiveness of integration into different policy areas.

Overall, it is apparent that the importance of biodiversity and healthy ecosystems for human

[13] Chapter 3: Strengthening indicators and accounting systems for natural capital: http://www.teebweb.org/LinkClick.aspx?fileticket=J3_lcRRutGw%3d&tabid=1019&language=en-US

[14] European Commission (2010) Monitoring the impact of EU biodiversity policy, http://ec.europa.eu/environment/nature/info/pubs/docs/biodiversityindicators_factsheet.pdf

[15] Herkenrath, P, Fournier, N, Gantioler, S, Good, S and Mees, C (2010) Assessment of the EU Biodiversity Action Plan as a tool for implementing biodiversity policy. June 2010. European Commission Biodiversity Knowledge Base. Service contract nr 09/543261/B2.

[16] European Commission (2010) The 2010 assessment of implementing the EU Biodiversity Action Plan. Communication from the Commission, COM(2010)548 final.

[17] CBD - Secretariat of the Convention on Biological Diversity (2010) Global Biodiversity Outlook 3.Montréal, 94 pages.

well-being and long term prosperity is increasingly being recognised. The latest developments in EU biodiversity policy, the recent CBD Conference of the Parties (COP) meeting in Nagoya and the strong attention received by TEEB in the EU and globally make the development of adequate means of measurement a very crucial and timely topic.

4.1 CHOOSING THE RIGHT INDICATOR FOR MONITORING THE EU BIODIVERSITY STRATEGY

The level of complexity in measuring the different components of biological diversity – species, genetic and ecosystem diversity – poses considerable challenges regarding the construction of policy-relevant biodiversity indicators. It is difficult to derive an indicator that reliably covers all facets of biodiversity simultaneously, and allows for addressing all different challenges in measurement (e.g., reports on a limited number of well studied species from a much larger whole that remains largely unknown). For example, the Red List Index mainly addresses species at risk of extinction, whereas losses of more common species are not captured. In addition, very species-rich taxonomic groups, such as insects, are only poorly covered compared with other groups, such as mammals and birds. Recent efforts have therefore been concentrated on developing and agreeing upon a basket of indicators that complement each other and jointly capture biodiversity's multiple dimensions and potential interactions.

A first set of CBD indicators was adopted in 2004, during the 7th Conference of the Parties to the CBD. The EU followed suit, setting in motion a process for streamlining European biodiversity indicators (SEBI) in 2005, to be linked to the global framework and consisting of an initial set of 26 indicators. The conceptual basis of both baskets thus, to a large extent, followed the content of the CBD and aimed at capturing status and trends of biodiversity, key threats and the sustainable use of its different components.

Amongst the indicators that underwent a qualitative analysis in the IN-STREAM project, the Common Bird Index, Red List index, Favourable Conservation Status (FCS) and Marine Trophic index are all included in the SEBI set of indicators used to monitor biodiversity trends and progress towards EU biodiversity conservation targets. Although it is the principal measure of performance of the Habitats Directive, the FCS indicator has not fully integrated core sets of indicators for policy areas impacting and/or relying on biodiversity, including agriculture, fisheries or cohesion policy. Its long time lag in capturing the impact of policy implementation on biodiversity is raised as one of the main reasons for the failed integration. On the other hand, the Common Bird index is applied as a key indicator for agricultural policy, being perceived as more amendable to change. The Red List index and Marine Trophic index are also used in the context of annual assessments of EU fisheries policy.

However, the examples above also illustrate that so far only a few biodiversity indicators have entered other policy areas. As mentioned above, the insufficient integration of biodiversity concerns continues to be one of the main reasons for failing to meet the target of halting biodiversity loss. This might be linked to a number of limitations that have been identified in relation to the existing indicator framework and need to be addressed. These include, inter alia, the poor representativeness of state indicators, and the limited information captured in the indicators of sustainable use (which do not fully reflect the extent to which fisheries, forests and agricultural ecosystems are sustainably managed). The development of streamlined sets of biodiversity indicators to be integrated into other policy areas could help to support further mainstream biodiversity policy.

Furthermore, the SEBI indicators provide only a limited picture of policy responses to address biodiversity loss and the impact of such responses. The targets and actions of the EU Biodiversity Action Plan largely addressed the implementation of relevant responses, rather than the achievement of a specific status or reduction of impacts. In this regard it markedly differs from the SEBI indicators, which put a stronger emphasis on status and key threats. To inform the selection and design of new policies, indicators should reflect not only where we stand with regard to the targets set, but also why we have met or missed certain targets. Response indicators are essential in this regard. While it is not always feasible to capture multiple dimensions of policy responses into a quantifiable indicator, the development of standardised reporting and analysis could support the application of qualitative indicators of response.

The post-2010 biodiversity policy also marks a shift in emphasis towards ecosystem services and the importance of biodiversity for human well-being. The increased focus on ecosystem services demands suitable indicators to estimate trends in their provision and to provide a more complete picture of ecosystem resilience. It is assumed that the linkage between ecosystem services, biodiversity and resilience is strongest where all the diversity of ecosystem services is captured. However, such indicators are a relatively new tool, currently available for only a fraction of the wide array of services derived from ecosystems[18, 19]. There is a need, on the one hand, to address current gaps through further development of ecosystem services indicators and, on the other, to better integrate the indicators developed by the scientific community into biodiversity policy-making, in order to increase our understanding of the true value of nature.

More information on qualitative assessments of indicators is available at

http://www.in-stream.eu/download/D2.2_final.pdf.

[18] Layke, C (2009) Measuring Nature's Benefits: A Preliminary Roadmap for Improving Ecosystem Service Indicators. WRI Working Paper, World Resources Institute, Washington DC.

[19] Anton, C, Young, J, Harrison, P A, Musche, M, Bela, G, Feld, C K, Harrington, R, Haslett, J R, Pataki, G, Rounsevell, M D A, Skourtos, M, Sousa, J P, Sykes, MT, Tinch, R, Vandewalle, M, Watt, A and Settele, J (2010) Research needs for incorporating the ecosystem service approach into EU biodiversity conservation policy. Biodiversity Conservation, No 19(10), pp2979-2994.

4.2 SUSTAINABILITY INDICATORS FOR HEALTH AND ECOSYSTEM IMPACTS

Estimation of health and ecosystem impacts allows policy makers to assess the sustainability performance of environmental policies. One major result of the IN-STREAM project is the support for a range of different economic, ecologic and social indicators to analyse different developments with respect to achieving sustainability. Therefore, an assessment of policy measures and technologies requires integration among these three pillars of sustainability. With respect to environmental (and partly social) indicators for measuring sustainable development, the estimation of impacts on human health and ecosystems are the most prominent. Furthermore, the monetary valuation of these damages allows for cost-benefit and cost-effectiveness analysis of policies and technologies and help decision makers to identify (environmental) policy options.

Pressure indicators (e.g. emissions of pollutants) or state indicators (e.g. concentration of pollutants) are often used as environmental indicators. However, these indicators have several disadvantages, e.g. they do not give an indication about the degree of sustainability reached. Only a comparison with values of past years or other countries is possible. Furthermore, there are numerous pollutants and there is no criterion on which to make choices. In addition, no aggregation (to reduce the number of indicators) and no comparison with indicators of other categories are possible. Thus, the focus on pressure and state indicators does not provide a reliable guidance for policy makers with respect to the identification and development of policy measures for emission reduction. Instead, pressure indicators should be transformed into impact indicators.

The transformation of pressure and state indicators into impact indicators can be done using the impact pathway approach (IPA). The estimated impacts include damage and risk to human health, ecosystems, crops and materials. The IPA takes into account the non-linear relationships between pressures and effects and the dependency on time and site of the activities.

The IPA was developed in the ExternE project series of the European Commission[20]. The impacts of different pollutants are highly dependent on the site of emission and the affected population. Thus the assessment starts with an analysis of the site specific characteristics of the emitting source (height of emission releases, urban or rural source of emissions). Complex models for chemical transportation and transformation as well as studies of impacts of changes in concentrations of pollutants, e.g. epidemiological studies, relate the changes in emissions to impacts on human health and ecosystems. In a final step, these impacts are expressed in monetary terms in order to compare the different impact categories. These impact categories consist of damages to human health, buildings and materials, crop yields and biodiversity. The latest update of the IPA and all its components has been achieved in the recently finished EU-funded NEEDS[21] and HEIMTSA[22] projects.

Health impacts can be aggregated to DALYs (disability adjusted life years). DALYs include the reduction in life expectancy, measured in years of life lost (YOLL) and the reduction in the quality of life due to health impacts measured in years lived with disabilities (YLD). For ecosystem damages, the aggregated impacts can be expressed in PDFs (potentially disappeared fraction of species). PDFs indicate the changes in the number of species in a certain area.

In the original report of the IN-STREAM project (Deliverable 5.1.) 14 different airborne pollutants, including so-called classical air pollutants (NO_x, SO_2, NH_3, NMVOC and particulate matter), heavy metals (As, Cd, Hg, Se) and other pollutants (CO, Benzo(a)pyrene, PAH), have been identified as being relevant for the development of an indicator for human health impacts for the EU-27. For these pollutants, damage factors in terms of mortality and morbidity impacts per tonne of emission have been applied.

For the assessment of ecosystem damages, only three air pollutants have been identified as being relevant for the analysis: NH_3, SO_2 and NO_x. For these pollutants, the impacts on ecosystems in form of biodiversity losses due to acidification and eutrophication were estimated.

20 ExternE: Externalities of Energy, http://www.externe.info

21 NEEDS: New Energy Externalities Development for Sustainability; http://www.needs-project.org/

22 HEIMTSA: Health and Environment Integrated Methodology and Toolbox for Scenario Assessment; http://www.heimtsa.eu/

The estimated damage factors for human health and ecosystems have been applied to two emission scenarios which have been developed in the EU-funded HEIMTSA project. The objective of the project was to assess the impacts on human health caused by climate policy measures. Within this project a business as usual (BAU) scenario without further climate change policies after 2012, and a scenario including these policy measures (e.g. the EU energy and climate package for 2020) have been estimated. The scenarios were built for the years 2020, 2030 and 2050. The following two figures show the results of the exercise presenting the impacts on human health and the ecosystem for the most important substances. The increase in health impacts in the climate policy scenario for 2020 and 2030 relates to the chosen policy measures to decrease GHG emissions. One prominent measure in this context is the promotion of the use of biomass in domestic heating. This leads to a reduction in CO_2 emissions but increases emissions of particulate matter (especially PM2.5), causing negative health impacts. In 2050, technological change and additional policy measures are expected to reduce GHG emissions and health impacts simultaneously compared to the BAU case.

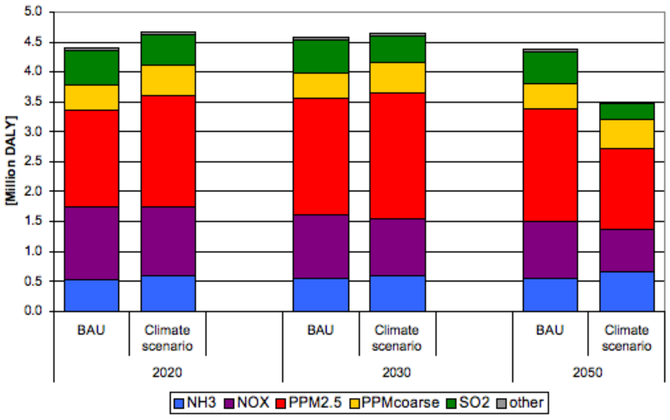

Figure 8: Human health impacts for climate change policy measures in EU-27

The effects for biodiversity caused by the policy measures mentioned above are comparable to those for human health for the years 2020 and 2030. However, in contrast to the resulting benefits to human health in 2050, the impacts on biodiversity still remain higher for biodiversity. For all

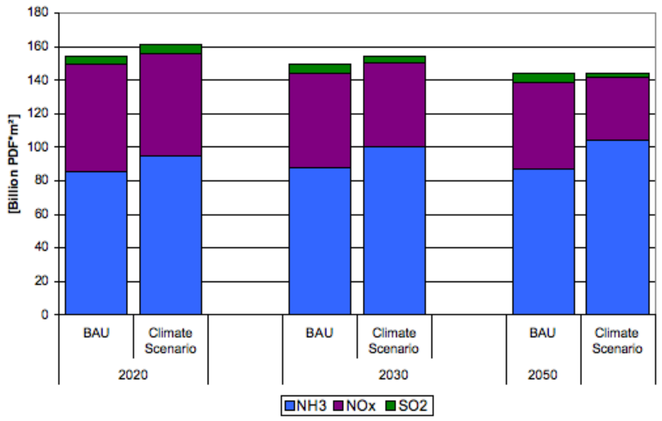

Figure 9: Ecosystem impacts climate change policy measures in EU-27

three years of the assessment, the higher biodiversity losses in the climate scenario are related to higher emissions of NH_3 in this scenario. As NH_3 mostly results from agricultural processes, the increase in emissions is related to the applied policy measures for this sector, e.g. changes in diets, changes in fertilisation processes, etc.

CONCLUSIONS

The assessment of air pollution requires transforming the existing pressure indicators into impact indicators for different air pollutants, as only then can comparisons among these pollutants be made and an aggregation of the pollutants with respect to different impact categories, e.g. human health or ecosystems, becomes feasible. The study provides an introduction into the methodology applied for these impact assessments, i.e. the impact pathway approach, and presents an exemplary application of damage factors for health and ecosystem damages for future emission scenarios.

The estimation of impact indicators provides a useful tool to decision makers when it comes to quantifying the ecological effects of different policies and technologies. In addition, the monetary valuation of the impacts allows for cost-benefit analysis of the policies and technologies. Thus, the quantification of impacts to human health and ecosystems for past and future years serves as an indicator for measuring development with respect to the ecological issues of sustainability.

More information on the valuation of ecosystem services and health impact is available at

http://www.in-stream.eu/download/IN-STREAM_deliverable-5%201_110727_FINAL.pdf.