In-Stream

Integration of mainstream economic indicators with sustainable development objectives

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Table of Contents

Key Messages of IN-STREAM 5

Executive Summary 6

1 Introduction – Beyond GDP and IN-STREAM 9

2 Qualitative Research in IN-STREAM 12

2.1 Introduction - the qualitative work of IN-STREAM 12

2.2 Assessment of Indicators 12

2.2.1 IN-STREAM Indicator selection 12

2.2.2 Evaluation methodology: RACER and SWOT 14

2.2.3 Conclusions 16

2.3 Assessment of Policies 17

2.3.1 Methodology used for the assessment 17

2.3.2 Key results and conclusions 19

2.4 Social sustainability indicators 20

3 Quantitative Research in IN-STREAM 24

3.1 Introduction 24

3.2 Statistical analysis of sustainability indicators 28

3.2.1 Objectives and methodology 28

3.2.2 Major findings 29

3.3 Competitiveness and output impacts of mitigation policies 32

3.4 Regional employment impacts of renewable energy policies 34

3.5 Greenhouse gas emissions impacts of mitigation policies 35

3.6 Distributional implications of mitigation policies in the Czech Republic 42

3.6.1 Objectives and methodology 42

3.6.2 Major findings 42

3.7 Decomposition analysis of air pollutants in the Czech Republic 44

3.7.1 Objectives and methodology 44

3.7.2 Major findings 46

3.8 Land and agriculture impacts of biofuel policies 48

3.8.1 Objectives and methodology 48

3.8.2 Major findings 48

3.9 Health and ecosystem impacts of mitigation policies 53

3.9.1 Methodological background 53

3.9.2 The aggregation of health and ecosystem impacts into indicators for sustainability 56

3.9.3 Development of a sustainability indicator for health and ecosystem impacts 58

3.9.4 Major findings 59

3.10 Comparison of informative capacity of aggregated sustainability index with disaggregated indicators 61

4 Engagement and dissemination 66

4.1 Identifying needs and opportunities for better communicating the importance of indicators 66

4.2 Stakeholder workshops and final conference 67

4.3 Dissemination work of IN-STREAM 69

5 Conclusions 73

Key Messages of IN-STREAM

- 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.

Executive Summary

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.

Another important aspect related to climate change policies is their **equity implication**. By increasing the price of fossil fuels, they may hit more severely lower income households, exert a regressive effect, and therefore weaken the social pillar of sustainability. IN-STREAM test this in the Czech Republic. It is shown that overall a regressive effect of emission reduction program is present, but it is quite small. An appropriate program of revenue recycling can mitigate this adverse effect, nonetheless if revenues are used to lower labor costs, pensioners will still remain to be negatively affected compared to other household segments. This emphasises the need of a careful design of the fiscal instrument.

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 Introduction – Beyond GDP and IN-STREAM

As IN-STREAM is linking mainstream indicators with sustainability measures it was crucial for the project to understand where exactly 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 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.

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[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 .

- 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.

This dissemination oriented work was also used to link the quantitative and qualitative work packages. As the project itself, the following report does develop first the results of the qualitative research conducted before the results of the quantitative research are summarized. Nonetheless the two working blocks were conducted interlinked with each other as each working block provided important inputs into the other.

The qualitative work identified and assessed the indicators, which were used in the quantitative models. Additionally, the qualitative analysis identified the potential applications of the quantitative modelling results.

On the other hand the quantitative modelling results were used to understand and quantify the trade-offs and synergies between different dimensions of sustainability, which policy makers have to balance. This important understanding fed back into the qualitative analysis where the usefulness and robustness of sustainability indicators to identify those trade-offs was assessed.

2 Qualitative Research in IN-STREAM

2.1 Introduction - the qualitative work of IN-STREAM

The IN-STREAM project included a qualitative analysis of key sustainability indicators (under WP2) and their role in policy making (WP7).

In particular, WP 2 aimed to develop and test a methodology that could assess indicators with respect to their analytical robustness and their political relevance. Two existing methodologies for indicator assessment (RACER and SWOT) were further developed to increase their relevance for policies with significant impact on sustainability. Overall 17 indicators of different groups such as economic indicators and accounting frameworks, subjective wellbeing indicators, biodiversity indicators and resource efficiency indicators.

WP 7 focused on ‘institutional engagement and policy implications. It aimed to explore the policy needs and opportunities of an increased use of sustainability indicators for selected policy areas, and investigated how indicators are currently portrayed by the media. It also provided guidance on how indicators could be further adopted at different phases of policy development.

The work also brought together the findings from the quantitative and qualitative analysis to provide a better understanding of how the two approaches can support each other, and draw lessons for future indicators use.

2.2 Assessment of Indicators

2.2.1 IN-STREAM Indicator selection

The Lisbon Strategy sets ambitious goals for the EU: it increases its international competitiveness, expands employment opportunities and enhances the economic prospects and human wellbeing of Europeans. These commitments have been flanked since 2010 by the Europe 2020 Sustainable Development Strategy (EU-SDS), which aims at sustainable and inclusive growth, encompassing all three pillars of a sustainable development: economic, social and environmental. But if political strategies in principle address all dimensions of sustainability, the public discussion is still almost exclusively dominated by mainstream economic indicators, above all GDP. In fact, according to the Stiglitz Commission (Stiglitz et al. 2009): “There is therefore a critical need in Europe for indicators and measurement systems that—working in conjunction with and complementing mainstream economic indicators—provide a useful measure of progress toward economic success, human wellbeing, environmental protection and, thereby, long-term sustainability.”

In this context, IN-STREAM analyses qualitatively and quantitatively the feasibility and opportunities of linking mainstream economic indicators with key wellbeing and sustainability indicators, also highlighting synergies and trade-offs implicit in Europe‘s simultaneous pursuit of economic growth, social inclusion and environmental sustainability.

In the vast number of sustainability indicators regularly published by intergovernmental, international and national institutions, the IN-STREAM project decided to focus on a limited set of indicators selected against the backdrop of the Lisbon Strategy and the Sustainable Development Strategy. Each of them was chosen for its potential to add value to a policy assessment simply based on economic indicators and applying the "selection filters" listed in table 1[3].

Table 1: IN-STREAM Selection filters

1. Relevance to EU policy – each indicator/approach should be relevant to the EU policy needs of the EU, especially those of the Lisbon Agenda, the renewed Sustainable Development Strategy (SDS), or (to a lesser extent) the Maastricht criteria.
2. Bridging of sustainable development/economic divide – each indicator/approach should be relevant to the effort to bridge economic and SD issues. A single-issue indicator can still be relevant to bridging if it could be used within a compound indicator, indicator set or index.
3. Feasibility of analysis – each indicator/approach and the related research questions should match the capabilities of the IN-STREAM project partners, and the work required must stay within the budgets of the work packages. For the quantitative analysis, this includes the ability to incorporate indicators/approaches in the models used by the project team.
4. Progress beyond the state-of-the-art: The analysis is expected to yield insights into the relationships between economic performance and socio-environmental indicators that go beyond the current state of knowledge while avoiding duplication of past research.
5. Little overlap with other efforts – duplication of other current research projects should be avoided and attention paid to generating synergies among projects.

Then, their informative performances and properties were analysed quantitatively and/or qualitatively.

Against this background a total of 16 qualitative evaluations were carried out, including three economic indicators and accounting frameworks, one basket of economic indicators, three subjective wellbeing indicators and frameworks, five biodiversity indicators, three resource efficiency indicators (substantially overlapping with the EU-SDS indicators for climate policy) and a basket of resource indicators as listed in table 2.

[3] Filters and criteria for IN-STREAM indicators selection were defined in an internal "Scoping Paper on Indicator Selection" (Best et al., 2009)

Table 2: IN-STREAM indicators for the qualitative assessment

Economic Indicators and accounting frameworks	GDP Adjusted Net Savings (ANS) System of Integrated Environmental and Economic Accounting (SEEA) Basket of Economic Indicator
Subjective wellbeing indicators and frameworks	Happy Planet Index (HPI) National Accounts of Wellbeing (NAW) Human Development Index (HDI)
Biodiversity indicators	Red List Index Pan European Common Bird Monitoring Scheme (PECBMS) Index Potentially Disappeared Fraction (PDF) Favourable Conservation Status (of habitats and species) The Marine Trophic Index (MTI)
Resource efficiency indicators	Energy Intensity GHG emissions Waste indicators Basket of resource indicators

The selection reflects interest in different typologies of indicators—individual, sets, headline, composite, and aggregate indicators, stock and flow—different pillars of sustainability, and the possibility to connect to the quantitative assessment performed by IN-STREAM.

2.2.2 Evaluation methodology: RACER and SWOT

The 16 indicators listed in table 2 have been tested through two methodologies: RACER and SWOT analyses (Table 3). The European Commission's Impact Assessment Guidelines (European Commission, 2005) specify the so-called RACER criteria for useful indicators. It is an evaluation framework developed for assessing the value of scientific tools for use in policy making. The IN-STREAM project developed additional sub-criteria that aim at making the meaning of each RACER criterion more explicit, tailor it to the specific objectives of IN-STREAM, and bring to the fore the more nuanced differences among the selected indicators.

SWOT is a tool for assessing an organization's, business' or program's ability to achieve a stated objective[4]. It evaluates the internal and external factors that influence the probability of success of the objective.

Table 3: RACER and SWOT

RACER analysis	SWOT analysis
Relevant = 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	**S**trengths = positive aspects grouped as 'core' or 'important' **W**eaknesses = negative aspects grouped as 'core' or 'important' **O**pportunities = aspects that could help to improve the indicator **T**hreats = aspects that could hinder the successful adoption of the indicator

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

The detailed RACER analysis conducted within IN-STREAM WP2 highlighted the following insights.

→ **R**elevant: All the selected indicators have a strong link to sustainable development and are related to EU policies or directives. The selected indicators are connected to the definition of sustainability, even though not all of them have a specific target for sustainability. Therefore, all of them are relevant in capturing the essence of the problem and in measuring events in a comparable way across Member States. In particular, the larger part of the selected indicators attempts to fill specific gaps of GDP in measuring sustainability, such as the ANS, the SEEA-2003, the HPI, GHG emission and Waste indicators; the latter ones are related to the environment pressure dimension.

→ **A**ccepted: Most of the indicators have a medium to high level of stakeholder acceptance except for the HPI and the NAW, which measure a subjective evaluation of wellbeing, and are therefore not widely accepted as mainstream, but they found audience among wellbeing researchers as contributors to measuring subjective wellbeing linked with economic and environmental goals. Among biodiversity the PDF indicator is not widely accepted because it is more regionally specific, and among the resource indicators the energy intensity indicator is used because is more a proxy of energy efficiency and less explanatory.

→ **C**redible: Credibility of those indicators is highly connected to their methodological and explanatory transparency. All of the selected indicators are transparent in methodology and measures and unambiguous in their definition and messages.

→ **E**asy: Data availability, technical feasibility and complementarities with other indicators are the key elements that define an indicator as easy to use and understand. Only a few indicators can be considered incomplete in terms of data availability, such as ANS, SEEA-2003 and the Red list index, because they are dependent on a vast amount of underlying data or are very data intensive, and therefore are not available for all countries.

→ **R**obust: Robustness is one of the most important criteria because it includes statistical validation and therefore the reliability of the indicator. It also embraces the completeness of the information given and its level of responsiveness to policy intervention. Transparency has a high level in all indicators, with completeness from medium to high. The biodiversity indicators have a lower level in completeness because they need to be combined to other in order to detect biodiversity pressure.

The SWOT methodology stressed the following:

Economic indicators and accounting frameworks: Both the ANS and the SEEA-2003 attempt to fill specific gaps of the GDP in measuring weak sustainability. They are relevant, transparent and complete, and, as such, are used to measure sustainability. The ANS focuses on addressing the negligence of stock movements of GDP and it allows inclusion of changes in stock (physical, environmental and human capital stock). The SEEA-2003 is a refined and robust environmental accounting system that can be used to add the environmental dimension to economic indicators. Nonetheless, both indicators face significant challenges in their application; environmental pressures cannot easily be integrated into an accounting system because valuations of pressures are not robust enough (or do not have a common acceptance/consensus). The same is true of some social dimensions of sustainability. Therefore their use is still limited to few, albeit important cases.

Wellbeing indicators: There is widespread consensus to move beyond GDP as a measure of wellbeing. The selected wellbeing indicators are strongly linked to sustainability, are robust measures of human wellbeing and are able to combine environmental and social dimensions. But in fact, they are scarcely used and accepted by stakeholders. Their major limitation is the unclear relationship between social and economic welfare and happiness or wellbeing. The data sources have a good quality but low availability and they also suffer from time lags and small geographical coverage.

Biodiversity indicators: The proposed aggregated indicators are very important in giving a more general overview of trends in the field of biodiversity. Nonetheless the necessary aggregation processes require judgements on the relative weights of different components and wade into subjectivity. For instance indicators tracking the conservation status of species are very useful in concentrating on species in danger, but they have the inherent disadvantage that any changes within a group (a species getting less endangered or the population of a species dropping close to endangerment) are not taken into account. These indicators are reliable and transparent but they have a lower level in completeness because they need to be combined to each other in order to detect biodiversity pressure.

Resource efficiency indicators: The analysed resource efficiency / pollution indicators add another important environmental dimension to sustainability assessments. They all provide good measure of the efficiency performance of an economic system, and in this sense they are relevant and accepted. They are also credible, relatively easy and robust. Nonetheless environmental pressures can increase in an unsustainable way even if efficiency rises. Moreover the proposed indicators do not reflect the environmental damages, but pressures. Under these respects they miss part of their ability to capture the environmental dimension of sustainability.

2.2.3 Conclusions

There is widespread consensus on the usefulness of indicators going beyond the economic dimension and of aggregate indicators. However, there are strong resistances in their widespread use.

Part of the difficulty is in practical methodological computation problems. Data deficiency, burdensome collection and the impossibility of performing meaningful comparison across countries are objective barriers to their use. Nonetheless, the major hurdle to their acceptance and then implementation is represented by the subjectivity and/or lack of common consensus on the subjective judgments embedded in the indicators themselves. This is particularly evident for aggregate indicators in which subjectivity in the weighting procedure is unavoidable, even at very low levels of aggregation, like in the case of biodiversity indicators, or even more, when wellbeing is concerned.

In fact, the strongest appeal of mainstream economic indicators is that they are considered to provide unambiguous, objective and shared information.

It has finally to be considered that the “added value” of an indicator is strongly dependent on the policy field or problem for which is it used, but also on the policy cycle, as different stages in the policy cycle require different types of indicators or measurements.

For more information please see http://www.in-stream.eu/download/D2.2_final.pdf .

2.3 Assessment of Policies

The aim of the work carried out under WP7 of the IN-STREAM project was to explore the policy needs and opportunities of an increased use of sustainability indicators for selected policy areas, and provide guidance on how these could be adopted at different phases of policy development. The key objectives were to:

- Assess to which extent different indicators (in particular the IN-STREAM indicators used throughout the project) are currently used in policy-making
- Investigate the scope for further use of sustainability indicators across the policy-cycle of a number of selected policy areas, chosen in the light of current policy priorities.
- Understand how sustainability indicators have been taken up by the media so far, and highlight the potential for improving their communicability
- Identify needs for additional indicators, barriers to further uptake and suggestions as to how the current gap in the use of indicators in policy making can be bridged.
- Provide some useful policy recommendations to further stimulate the use of sustainability indicators in policy making

For these purposes, a policy cycle approach was chosen to identify the current and potential use of indicators within given policy areas.

2.3.1 Methodology used for the assessment

The analysis followed four key steps, which are here summarised.

Step 1: Establish a list of **key environmental policy areas** which require a range of different indicators to assess progress towards sustainability: biodiversity, agriculture, fishery, resource efficiency, climate change and cohesion policy. To facilitate understanding, they were grouped into the three IN-STREAM storylines: green growth, resource efficiency and biodiversity. The full list of EU policies and legislation taken into account is shown in the table below.

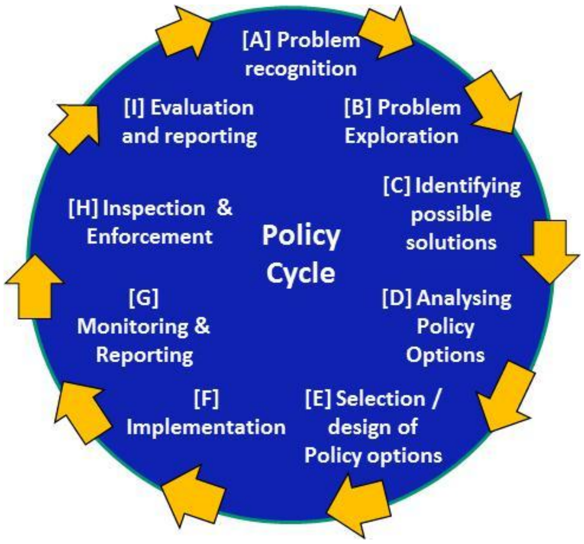
Table 4: Storylines and associated policy areas selected for the analysis

Storylines	Policy areas	Selected EU policies
Biodiversity	**Biodiversity**	• Habitats Directive • Birds Directive • Biodiversity Action Plan (BAP) • EU Biodiversity Strategy to 2020
	Agriculture	• Common Agricultural Policy (CAP), Pillar I • CAP Pillar II: European Agricultural Fund for Rural Development (EAFRD) and 2007-2013 Rural Development Programmes (RDP) • Others, e.g. 2007 Council Regulation on organic production and labelling of org. products
	Fisheries	• Common Fisheries Policy (CFP) • Integrated Maritime Policy • Marine Strategy Framework Directive • Green Paper on the reform of the CFP
Green growth	**Cohesion Policy**	• Community Strategic Guidelines on Cohesion 2007-2013
	Climate Change	• EC Communication 20/20 by 2020; 20-20-20 climate and energy package • Energy Efficiency Directive • Renewable Energy Directive
	Energy efficiency	• Energy Performance of Buildings Directive • Energy Efficiency Action Plan • Energy Using Products (EUP) Directive
Resource Efficiency	**Resource efficiency**	• Thematic Strategy for the Sustainable Use of Natural Resources • Raw Materials Strategy • Resource Efficiency Roadmap 2050 • Sustainable Consumption and Production • Sustainable Industrial Policy Action Plan • Ecodesign Directive • Others: Water Framework Directive (WFD), CAP, CFP, Biodiversity policy, Energy policy, etc.

Step 2: **Select a range of indicators** to be taken into account in the analysis. These built on the 16 IN-STREAM indicators used in the course of the qualitative analysis (see chapter 2.2 above), as well as on other indicators identified through a desk study and with the help of stakeholders. This was not intended to be an exhaustive list, but an example of how certain indicators can be helpful in policy making

Step 3: Develop a framework to link different sustainability indicators to the various steps in the **policy-cycle** of the selected policy areas. For this purpose, tailored policy cycles were identified for each policy area under analysis. An example is shown in the figure below.

Figure 1 The policy cycle



Step 4: **Consultations** with policy-makers and experts on the selected policy-areas allowed the integration of a desk based research with different information on how indicators are currently used, how they should be used in the future, and on key gaps and opportunities. A questionnaire was developed to gather information, and interviews were carried out in person or over the phone.

2.3.2 Key results and conclusions

The policy analysis undertaken highlighted a number of important considerations and recommendations, which are summarised below.

It is apparent that there are currently a fair amount of **indicators that focus on state and pressures, while fewer are measuring impacts and responses**. As a result, indicators seems to be used especially in the early phases of the policy cycle, e.g. for problem recognition and decisions on policy options. There is the scope to use indicators further, especially in the later stages of policy development.

The use of 'environmental accounts' is increasingly important for integrating environmental considerations into policy decisions. Frameworks like the **Natural Capital Accounts** and the **System of Economic and Environmental Accounts (SEEA)** have a lot of potential and should be further supported by European, national and local institutions and statistical offices.

The objectives of halting biodiversity loss, along with the new aim of halting ecosystem service losses, improving restoration of natural areas and the new interest in green infrastructure, each require additional inputs in biodiversity indicators. In particular, the importance of **ecosystem service indicators** is increasingly recognised. These should be taken into account in several policy areas, not only biodiversity and nature related policies.

The issue of **ecological thresholds and tipping points** is of particular 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 to develop adequate policies to prevent exceeding them them.

The recognition of the **over-exploitation of EU fisheries** 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 **agricultural policy**, the importance of **public goods** aspects merits additional efforts at developing both biodiversity and ecosystem service indicators, to ensure that wider public goods can be duly taken into account in decisions, funding, investments and instrument design, implementation, monitoring and evaluation.

It is of foremost importance to reduce the environmental impacts related to **resource consumption**. To do so, resource efficiency indicators and targets should be set. Introducing adequate indicators in sectoral policies will be crucial for target setting and monitoring of resource use by specific sectors of the economy and/or products, especially those with the largest environmental impacts (e.g. housing, food and drink, and mobility).

In order to monitor the achievement of the ambitious EU **climate change** targets, sustainability indicators have a crucial role to play, especially regarding GHG emissions, energy intensity and the share of renewable energy consumption in total final energy consumption. Cross-policy impacts, especially with regard to biodiversity policy, should also be taken into account.

The development of a coherent and robust system of sustainability indicators, suited to account both for outcomes and results, is critical in the context of **Cohesion Policy**. Indicators should be embedded at the level of policy, programme and project. This will require additional administrative capacities and technical support systems to guarantee the availability, collection, analysis and presentation of adequate data.

There is clearly a gap between the importance of sustainability indicators that are most used or needed by policy makers and the information passed on to the general public by the media. While in general the **communicability** of sustainability indicators and the awareness around their importance should be improved, it may also be necessary to choose different indicators for analysis and for communication. This can ensure that the most robust indicators are used to inform policy choice, and at the same time that the importance of sustainability criteria is fully appreciated by the public.

For more information please see Deliverable 7.2 and Deliverable 7.4 on http://www.in-stream.eu/docs.html .

2.4 Social sustainability indicators

A key starting point for much sustainability research was the Brundtland Report (World Bank, 1987[5]) which identified different aspects or pillars of sustainability—economic, environmental, social and institutional. However, the majority of the research following the Report has focused on environmental and economic sustainability. Where research or policy has included social aspects of sustainability, they have tended to be included on a limited conceptual foundation, or more as indicators of social desirability than social sustainability. The objectives of the research in IN-STREAM were to provide a robust set of social sustainability indicators that, if possible, could work with the other quantitative indicators in a modelling framework. Also, IN-STREAM was interested in how measures of subjective wellbeing may be integrated into wider sustainability research and quantitative research in particular.

However, the current situation is that there is little useful research that could contribute to the advanced modelling with which the rest of the IN-STREAM quantitative work streams were involved. That is, where 'social' indicators existed that could be integrated into the quantitative models, there was limited foundation for these indicators as sustainability indicators.

It is important at this point to note that social sustainability is different from social desirability, that is, ideological concerns about what makes society 'good' or valued have to be separated from what makes society sustainable. Whilst there is clearly some overlap, there are a number of other factors that must be clarified, for example, some things that may improve wellbeing now could cause a long-term decline in wellbeing, such as rapid social change.

We use a definition of social sustainability as *the extent to which social functions enable the individual or set of individuals in question to maintain non-decreasing wellbeing into the future.*

This definition means that the indicators for social sustainability have to be able to give information about the likely path of future wellbeing, or the ability of society to 'generate' wellbeing from various inputs. It also requires understanding about social wellbeing.

The state of the art in this field is limited, particularly social sustainability concepts and indicators. There is little research from sociologists on conceptual understanding. The field of social wellbeing is more advanced and certainly growing in stature. However it still raises controversy. The IN-STREAM research therefore is relatively foundational, exploring contested concepts and drawing together preliminary conclusions in order to advise policy makers and stakeholders, and to provide a basis for future academic research.

Methodological approach

The approach taken was to undertake a literature review of current understandings of social sustainability, particularly from sociological literature, and of wellbeing. These were then used to develop a usable definition that in turn was used to suggest a small number of

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[5] *World Bank (1987): Our Common Future. Report of the World Commission on Environment and Development. Available online at http://www.un-documents.net/wced-ocf.htm*

indicators for social sustainability. These are compared with indicators suggested by the literature and to those in use.

Based on the definition above, arrived at after a literature review and conceptual discussion, the research looked into two areas: indicators for wellbeing and indicators that may show how social functions may generate or decrease social wellbeing.

Perhaps the simplest and most direct way of measuring wellbeing is to ask people to indicate their current general wellbeing. This is known as subjective wellbeing (SWB) and despite being criticized for its simplicity and potential lack of comparability across languages and cultures, it has shown a large degree of robustness to counter these criticisms. Data has been collected on the topic around Europe and wider for a substantial period, allowing for a decent dataset. However, there are deeper conceptual criticisms, such as how hedonic 'treadmills' may adjust wellbeing over time (Fleurbay 2008[6]), also that SWB does not capture aspects of wellbeing that may be important such as what types of happiness/wellbeing are increasing or decreasing, or inequalities. Happy life years (HLY) have combined SWB with the life expectancy of a country to create an indicator intended to be more (conceptually) comparable to GDP in that they both measure a *quantity* of something. Veenhofen (1996[7]) developed this indicator and in subsequent research has shown it to be an interesting indicator, but one that has not gained much ground politically. This may be because it is a slow-moving statistic and thus difficult for politicians to use or adjust.

There are indicators developed to measure quality of life (QoL) as a proxy for wellbeing, with the assumption that we can measure more objectively the factors that go towards wellbeing even if we cannot know for sure how individuals will process these into wellbeing. The UN's Human Development Index (HDI) takes a simple, equally weighted index of income, health and education, and is very influential and widespread despite, or perhaps because of, its simplicity. The Economist magazine's Quality of Life Index used a wider range of inputs and a more complex weighting system to combine SWB with objective wellbeing.

There were few stand-alone social sustainability indicators found in the literature. Littig and Griessler (2005[8]) suggest around 20 topics under three themes—basic needs, social justice and social cohesion—but do not give specific indicators for these. Some of these topics have obvious or established indicators that could be assigned (such as individual income, which could be indicated by GDP per capita), but others are more vague (such as friendship or solidarity). Another criticism of these indicators is that there is a danger of this list moving from social sustainability to social desirability.

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[6] *Fleurbay, M. (2008): Beyond GDP: Is there any progress in the measurement of individual wellbeing and social welfare? Available online at http://www.stiglitz-sen-fitoussi.fr/documents/Beyond_GDP.pdf*

[7] *Veenhofen, R. (1996): Happy Life-Expectancy: A comprehensive measure of quality-of-life in nations. Social Indicators Research 39:1-58.*

[8] *Littig, B., E. Griessler (2005): Social sustainability: A catchword between political pragmatism and social theory. International Journal of Sustainable Development 8(1/2)*

Given the definition above, a number of indicators were suggested that would help monitor social sustainability. These were:

Crime Rates

A rise in the rate of certain types of crime (such as burglary) suggests that society is becoming less sustainable for a number of reasons. Firstly, because more people are losing out by becoming victims of crime, a straightforward fall in welfare. Secondly, it suggests that the key institutions of justice and law are being held in less esteem, with consequences for people's trust in them to convert inputs into wellbeing in the future. Thirdly, it suggests that more individuals are willing to break social (as well as legal) barriers to crime, and are less able to empathise with fellow individuals, hence are more willing to steal from them.

Corruption

A high level (or rise in) corruption suggests that institutions do not trust in themselves, but rather that individuals within institutions hold the ability to make things happen. Changes in corruption levels can be a sustainability indicator, since it is expected that trust in institutions is needed for efficient creation of wellbeing. The relationship may be U-shaped, since at very low levels of institutional trust, corruption is needed to make anything happen, and so a corrupt institution may be better than none at all.

Long-term Unemployment

Unemployment can indicate social sustainability, since high levels of long-term unemployment are symptomatic of inefficient structures, at an economic but also social level. As well as the innate disutility of unemployment—shown to be a key factor in reducing SWB—it is likely that long-term unemployment diminishes the ability of society to create wellbeing in the future.

At a less precise level, the following are suggested as areas in which indicators could be found to show changes in future wellbeing. These are *Social fragmentation*, *Social mobility*, *Exploitation,* and *Identity.*

Overall, IN-STREAM has found that there is very limited existing research into social sustainability indicators and so presents a relatively foundational approach. Concepts and definitions were explored, and the conclusions were less about quantitative relationships and more about suggesting directions for future research. In particular, it is important that future approaches to social sustainability take the concept seriously.

3 Quantitative Research in IN-STREAM

3.1 Introduction

The quantitative research performed within IN-STREAM employs advanced statistical and modeling methodologies to support the general project aim: understanding and assessing the synergies and redundancies between mainstream economic indicators and key well-being and sustainability indicators. This approach has two specific objectives. The first, more operational, is to quantitatively test these relationships as well as assess the strengths and weaknesses of a selected set of key sustainability indicators, including composite indicators. The second, more methodological, aims to highlight the potential of different statistical and modelling techniques, to investigate the field of sustainability and derive concrete guidelines on indicator use.

To ensure the quantitative analysis is both informative and manageable, it focuses on a limited set of sustainability indicators and on four themes: competitiveness, employment and unemployment, health and biodiversity, and food security. The selected indicators and themes were chosen based on clear EU policy relevance, with an explicit reference to the lists set by the Lisbon Strategy and the EU Sustainable Development Strategy. In addition, the indicators were selected based on their coverage of all the different pillars of sustainability, as well as compatibility with the measurement capability of modeling tools and quantitative approaches available within the IN-STREAM quantitative research team.

The capacity of these indicators to measure sustainability has been tested with different analytical approaches, but in a common background scenario: an EU unilateral climate change policy reflecting the EU's medium-term (the "20-20-20 climate and energy package") and long-term (stabilization of temperature increase at 2°C within the century) goals.

In the first step, statistical techniques were applied to highlight relationships (although not necessarily causality) between and within mainstream economic indicators and sustainable development indicators (section 3.2). This exercise clearly indicated that GDP is more or less directly linked not only to many economic sustainability indicators, such as employment and unemployment, but also to some well known "beyond GDP indices", such as the Ecological Footprint and the Environmental Sustainability Index (ESI). Therefore, to some extent, the use of GDP can be helpful as a proxy for the behaviour of other indicators and indices when they could not be observed, measured or modelled. Nonetheless, sometimes (for instance in the case of ESI) this link can be very weak, confirming the inadequacy of GDP to satisfactorily capture the environmental (and particularly the social) aspects of sustainability. These shortcomings are particularly concerning in the assessment of sustainability policies. In this case, a more comprehensive perspective should be applied both in terms of the indicators and of the investigation criteria used.

The statistical analysis of sustainability indicators is followed with a macroeconomic assessment conducted with a Computable General Equilibrium approach (section 3.3). The case of the EU climate change mitigation policy, which aims to stabilize the increase in temperature below 2°C within the century, is particularly enlightening.

Disregarding environmental benefits, EU GDP is negatively affected by the EU climate change mitigation policy (-0.3% vs. 0.5% in 2020 in a no-policy case). Additional concerns for

EU policy makers include the potential adverse impacts on competitiveness of a unilateral EU climate change policy. The problem in assessing these impacts is that the very concept of competitiveness is somewhat ambiguous – there are many alternative meanings and conceptions, presenting significant challenges. IN-STREAM's proposed solution is to focus on a narrow set of competitiveness indicators that represent emerging consensus in the most recent literature in the field: Terms of Trade (ToT), Relative World Trade Shares (RWS), Revealed Comparative Advantage (RCA), and Relative Trade Balance (RTB).

A first reassuring message from the analysis is that all the chosen indicators agree qualitatively. The policy reduces competitiveness of energy intensive sectors (EITS) in the EU. In fact, a moderate intervention of price differentiation favouring these sectors could improve competitiveness and also lower the overall cost of the policy. Moreover, gains from reduced leakage and improved terms of trade in non-abating regions are sufficient to offset the increase in additional direct abatement cost within the EU. Nonetheless, the possibility to modify the policy in this way is limited, as a stronger preferential treatment for EITS imposes an additional burden on other sectors with a net negative impact.

The fact that quantitative results vary widely is less reassuring. Indeed, depending on the indicator chosen, the negative impact expected on EITS competitiveness can be moderate or very large (competitiveness losses range from 3.9% to 100% compared to the business as usual (BAU) case). In this case, a sensitivity analysis can ameliorate some of these issues. A sensitivity analysis tests the robustness of results, applying changes in modelling assumptions in order to assess potential variations in indicator performance. It is shown that out of the 4 selected indicators, 3 are quite robust. More specifically, RTB is the most sensitive to the initial assumptions, showing the highest losses. By removing it, competitiveness losses across different indicators vary between the 4% and the 9%, a much narrower and more informative range. Thus, the key takeaway is that sensitivity tests are a powerful tool in the indicator selection process.

CGE models, with their explicit representation of inter-industry and inter-country trade of factors, goods and services, present advantages in capturing some features of economic sustainability at the sectoral, national, and international level. Nonetheless, they are ill suited to address many other important dimensions of sustainability.

One issue is the lack of sub-national specificity in the different dimensions of CGE models, such as geography and income level. In this case, other approaches can and must be used. IN-STREAM applied two methodologies to address this aspect: regional input/output analysis to capture sub-national economic impacts of mitigation policies and a distributional indicator-based analysis to address equity implications.

IN-STREAM demonstrated the potential of regional input/output analysis by investigating the employment effects of the renewable energy program by the government of the German state of Baden-Wuerttemberg for 2020 (section 3.4). The analysis demonstrates that supporting renewable energy does not necessarily create additional jobs, but instead induces a structural change of the economy where some sectors increase production and employment and others shrink. The possibility to have net employment gains crucially depends on the ability of regional producers to sell products to the rest of Germany and in the international market. This points to an important caveat in sustainability assessment: distributional implications are relevant not only from a social perspective, but also geographically. Accordingly, a desirable property of sustainability indicators is the possibility to perform sub-national assessments.

Distributional analysis focused on the implementation of the 2003/96/EC Directive on energy taxation in the Czech Republic (section 3.6). It tackled yearly energy expenditures and welfare as a percentage of total household expenditures for ten income-based segments, six of the segments additionally defined by availability of heaters (i.e. if certain energy types are used at all), and by geographical characteristics. Although the analysis showed an adverse distributional effect, it was very small. Moreover, an appropriate revenue redistribution program could mitigate this. However, care should be placed in the design. For instance, if revenues are used to lower labour costs, pensioners would still be negatively affected compared to other household segments. The researchers also propose the construction of an inequality index similar in interpretation to the Gini index. This is particularly interesting, as it can convey clear information even in cases where pairwise comparison, a common technique (often applied, for instance, in health studies), does not provide robust results.

A third analytical approach, the decomposition technique (section 3.7), was applied to analyze the effect of the entry of the Czech Republic in 1997 into the EU law on emission reductions. By "decomposing effects", this methodology offers useful and policy-relevant information on the different determinants of the effectiveness of a given policy. It thus acts as a useful complement to policy analyses employing broader modeling exercises. Specifically, three components were identified: the *fuel intensity effect,* measuring the change in consumption of each type of fuel used in the production per unit of economic output; the *fuel mix effect,* measuring how the composition of various types of fuels used affects emission levels; and the *emission coefficient effect,* capturing how effectively fuels are used in terms of air pollutants (i.e., the change in end-of-pipe type technology). The legislation was quite effective: it motivated firms to improve environmental efficiency, particularly end-of-pipe technology, and decreased the amount of emissions during the period of 1995-1999 by using fuel more efficiently. The emission intensity effect (specifically, the emission coefficient effect) was the main contributor to this outcome. In the case of particulate matter, the fuel mix effect was mostly negative until 2000, which suggests a move toward environmentally friendly fuels. After 2000, the end of the regulation period, the emission level of the pollutants remained more or less stable.

With their top-down nature, another weakness of CGE models is that they necessarily simplify many complex cause-effect relationships characterizing real world dynamics. For instance, this is the case (to stick to the economic dimension of sustainability) of agricultural systems. Assessing sustainability in this field requires coupling the socio-economic processes with an in-depth representation of the natural resource base (land, climate, and agronomic features).

IN-STREAM (section 3.8) applied this bottom-up approach coupling the FAO/IIASA Agro-ecological Zone (AEZ) model and the IIASA World Food System (WFS) model to investigate the implications of different medium-term targets for biofuel development in the transport sector (increasing the amount of total renewable transport fuels by 13-21 Mtoe in 2020 and 16-25 Mtoe in 2030). The inclusion of detailed land use and food demand dynamics can completely change the overall impacts of the policy.

Compared to the Reference scenario, where biofuel consumption remains at 2008 levels, the assessment indicates that biofuel targets could help avoid more than 2 PgC by 2020 and more than 5 PgC by 2030 from transport. Yet these GHG improvements are counterbalanced by increased emissions from subsequent land use changes. In 2020, total emissions actually increase and in 2030 net savings are reduced from 40%-60%. Global agricultural value-added also increases (by up to 2.3% in 2030 relative to the Reference case). The downside of these improvements is that the use of food crops for biofuels leads to significantly higher agricultural prices, that in turn increase the number of people at risk of hunger by 40 to 60 million in 2020 and 35 to 45 million in 2030, depending on the biofuel scenario. An additional 4 to 6 million hectares are projected to be deforested to make room for biofuel crops across the various biofuel scenarios.

A more general limit of economic models relates to environmental sustainability analyses. These analyses hardly go beyond the simple impacts on GHG emissions, although this is certainly an important environmental and economic policy indicator (section 3.5). Indeed, trade off within the environmental domain of sustainability can be detected even when, as in the case examined, GHG emissions decline. Topical examples include health and ecosystem impacts of non CO_2 pollutants (section 3.9). These have been analyzed with a bottom-up model, allowing consideration of different emission sources, pollutants, impact categories, environmental media, as well as geographical (from national to global) and spatial (different elevations) scales, in an integrated framework.

Within this framework, different pollutants are initially selected by screening their damaging potential in monetary terms on health, biodiversity loss, and climate change. For the 18 non-GHG pollutants identified, damage coefficients are applied, translating the related emissions into Disability Adjusted Life Years (DALY) and Potentially Disappeared Fraction of Species (PDFS). Finally, trends in the two indicators are contrasted in the reference scenario and in the climate change policy scenarios. .

Two results are of paramount policy interest. First, the temperature stabilization policy reduces the negative impacts of non-CO_2 emissions on health by roughly 20%; however, the policy has only a marginal influence on biodiversity losses. Moreover, when present, the positive effects are long-term. Until 2030, both health impacts and biodiversity losses are higher in the policy scenario. Health results are driven especially by 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, causing negative health impacts. Only after 2030, technological change and additional policy measures reduce GHG emissions and health impacts simultaneously compared to the BAU case. The higher biodiversity losses are related to higher emissions of NH3 in agriculture driven by CO_2 reducing changes in diets (consumption of less red and more white meat), changes in fertilization processes, etc. The important message is thus that moving from pressure indicators, like GHG emissions, to impact indicators, like DALY or PDFS, can offer better support in policy decision making.

A legitimate question is whether it is possible to come to a final comprehensive conclusion regarding the overall sustainability implication of a given policy, in view of this contrasting information. In the sustainability literature, one possibility is offered by the construction of sustainability indices or composite indicators.

Part of IN-STREAM's quantitative research explored the potential of composite indicators to provide synthetic measures of sustainability and deliver additional information compared to "simple" GDP (section 3.10). This has been done by extracting a composite indicator from a CGE model and measuring its informational properties in the context of the proposed EU mitigation policy scenario.

The exercise demonstrated that a composite indicator, if properly constructed, is suitable to provide a synthetic measure of sustainability and convey many interesting policy insights, going beyond the informative capacity of GDP.

Nonetheless, abstracting from the specific case, this synthesis cannot summarize all the different aspects of sustainability, nor is it subjectivity-free. Selection, weighting, and aggregation of indicators to build the index are unavoidably prone to subjectivity. Nonetheless, there are good reasons in favour of the use of composite indicators. As shown by IN-STREAM research, if transparent, they can be invaluable communication devices to show the preference structure and value judgments originating from a given synthetic sustainability assessment. They can also offer the opportunity to investigate in depth if and how this assessment can change when those preferences and values change. Yet again, sensitivity tests reveal their importance. This information can be valuable for policy decision makers and are potentially as (if not more) important as the synthesis provided.

As a concluding remark, IN-STREAM's quantitative research also demonstrated that sustainability analysis can greatly benefit from the use of quantitative modelling frameworks (bottom-up and top-down). Consistent and controlled mathematical structures are particularly useful to gain insights and measure synergies and conflicts between the different components of sustainability. Moreover, model projections can provide important information regarding possible conflicts and bottlenecks in sustainability – valuable information for a decision maker.

Nevertheless, the multifaceted nature of sustainability requires the integrated use of different modelling tools, as none of them, used independently, can address all complexities. Moreover, models themselves are subject to specific limitations; therefore they should act as support, and not replacement, of other investigation methodologies.

3.2 Statistical analysis of sustainability indicators

3.2.1 Objectives and methodology

The main objective of the statistical analysis is to relate identified sustainability measures to widely used metrics of economic performance, in order to gain a better understanding of the linkages, especially synergies and trade-offs, between sustainability goals and mainstream economic performance benchmarks. There are two specific objectives:

- Examine past research on how changes in SD indicators relate to changes in GDP, employment, and competitiveness.

- Establish and validate quantitative linkages between SD indicators and mainstream macro and sectoral indicators.

The analytical tools for the statistical analysis include correlation analysis and advanced statistical techniques such as Principal Component Analysis (PCA). Accordingly, the analysis resulted in a variety of data patterns using scatter plots and bivariate correlation analysis, time series patterns, as well as PCA and Cluster Analysis (CA) to identify similarities among the countries included in the database with respect to the selected indicators. Due to the large number of indicators, some of which are not generally part of macro-economic performance assessment, we selected indicators for this analysis that are widely known and reported on, and for which the economic literature has formulated linkages to other metrics of human welfare and environmental sustainability. By applying this approach we were able to underpin the purely empirical analysis with contextual information, allowing a more informed and nuanced interpretation of the data.

3.2.2 Major findings

a) Relationships between IN-Stream indicators

We find some interesting associations between the employment rate and other variables (see Figure 2). There seems to be a relatively strong negative correlation between the employment rate (as defined above) and the unemployment rate (the fraction of those who would like to work but cannot find a job). This indicates that the higher the employment ratio is, the lower the share of people who are unemployed, implying that more employment creates more jobs and refuting the argument that there is a limited number of jobs in the economy and that early retirement would help the young generation to find employment. This negative correlation is even stronger between the employment rate and the long-term unemployment rate. Finally, the employment rate tends to correlate negatively and rather strongly with government debt, although there are a few special cases, mostly due to historical reasons.

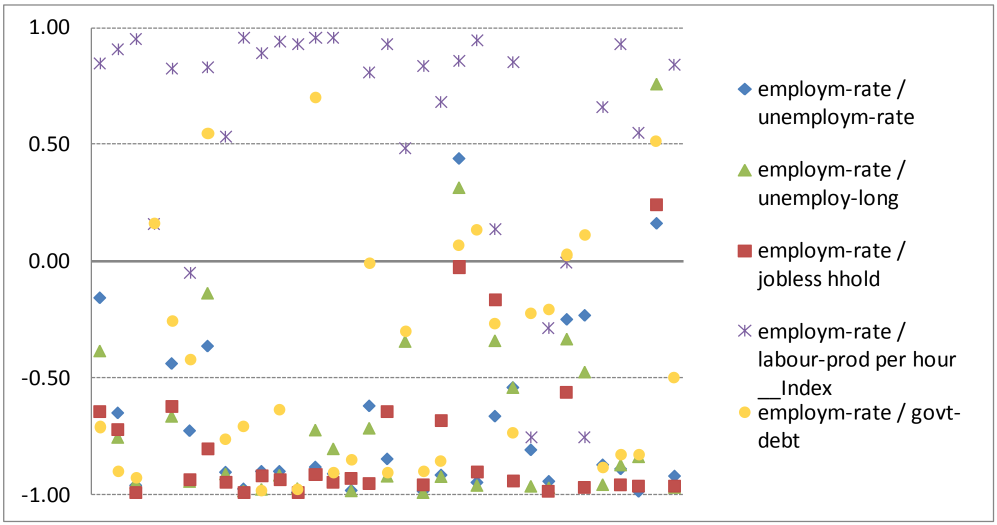


Figure 2: Correlation values for selected European countries: employment rate vs. unemployment rate, long-term unemployment, jobless households, labor productivity, and government debt

b) Links between IN-STREAM and “beyond-GDP” indicators

We also performed extensive correlation analyses between the IN-STREAM indicators and selected ”beyond GDP” indexes and their components, as well as between ”beyond GDP” indices. This analysis also covered sustainability indices from other sources. An important result stems from exploring the relationships between GDP per capita and the Environmental Sustainability Index (ESI) and the Stress component of ESI. The stress component includes a range of social and environmental factors of sustainability, ranging from total fertility rates to emissions of various pollutants and use of natural resources (Figure 3). The suggestion that richer societies are more concerned about and more willing to spend money on improving some elements of social and environmental sustainability is confirmed by the somewhat scattered yet overall positive correlation between GDP and ESI. Interestingly the association between GDP and the STRESS component of ESI is more diverse across countries and is negative for the full sample of the EU27+ countries included here.

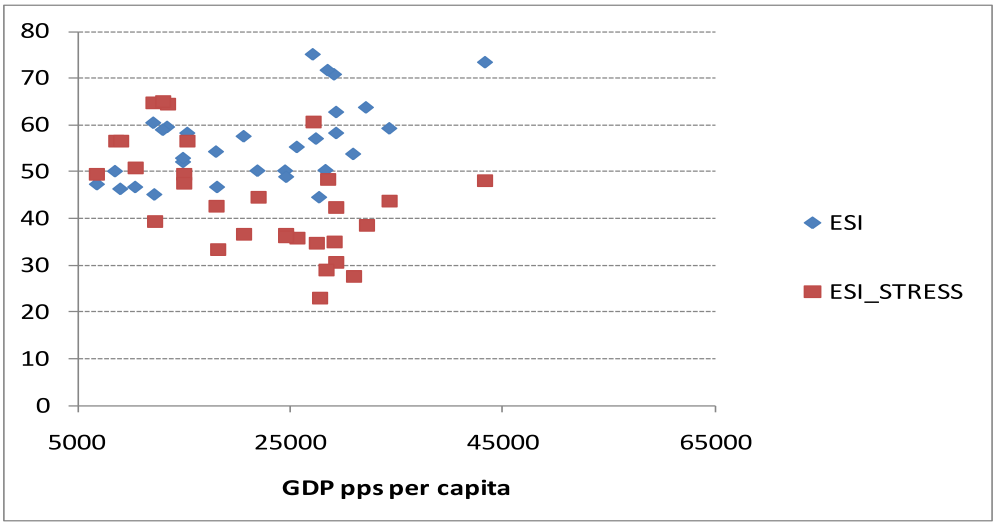


Figure 3: Correlation of GDP per capita with ESI (r=0.55) and with its Stress component (r= -0.53)

The relationship between the so-called main-stream and the “beyond GDP” indicators show that despite its recognized and often criticized deficiencies, GDP is an important component of many “beyond GDP” indicators. GDP influences the values of the “beyond GDP” indicators and indexes directly (by direct inclusion as a component of an index) or indirectly (as a driver behind the processes represented by some of the components included in an index). These relationships confirm both common and less common expectations: many social and some environmental indicators/indices correlate with GDP, at least to some extent. This also means that using GDP as a proxy for indicators that are not directly observed, measured or modelled could shed light on approximate values of those indicators. Nonetheless, such exercises require caution and rigorous testing in the geographical, social, and economic context in which they are intended for application.

c) Scatterplot analysis

Selected statistical techniques are used to search for links between macro-economic benchmarks of economic performance and performance in the social and environmental dimensions. This includes examining some major questions on the linkages between economic growth and environmental health and sustainability, such as:

Can economic growth be achieved through more efficient use of natural resources?

What are the relationships of economic growth and consumption levels (e.g., ecological footprint, environmental performance)?

We find that the Ecological Footprint is strongly negatively associated with per capita GDP (R2=0.71), as shown in Figure 4. The more affluent a nation becomes, the greater its natural resource requirements in order to provide the goods and services it consumes. Neither the EPI nor the EF associations with income shown here provide new insights, but we included them nonetheless because they are important reminders that economic growth has different impacts on the environment and requires a comprehensive strategy to harness the benefits while minimizing the negative impacts.

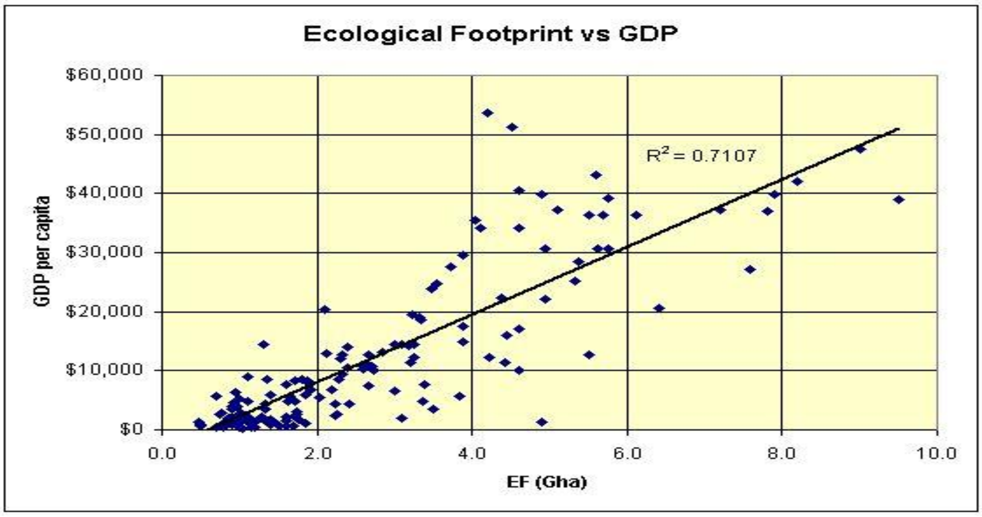


Figure 4: Scatterplot and regression line of per capita income and the Ecological Footprint.

d) Principal component analysis

We adopted Principal Component Analysis (PCA) to reduce dimensionality in high-dimensional datasets and search for underlying latent concepts such as competitiveness, intelligence, and environmental conscience. The results do not deliver strong evidence for the existence of latent constructs, but do show that the indicators are not entirely independent of each other. When we consider the proportion of variance explained by the principal components, we find that the explained amount of variation declines markedly after the fifth principal component. The main principal components that emerge from the PCA contain some interesting groups of indicators, shown in Table 5 for the first four components.

Table 5: The principal components and indicators loading most strongly on them.

1st component	2nd component	3rd component	4th component
Unemployment	Debt	Government expenditures	Household consumption
Youth unemployment	Exports	Government spending on education	Final consumption
GDP growth	Total Trade	Tertiary enrolment	
Fixed capital formation	Trade in services	CO_2 emissions per capita	
CO_2 emissions per GDP	ANS	GDP per capita	
	Current account balance	Energy intensity of GDP	

For more information please see http://www.in-stream.eu/download/WP3_Deliverable3.2_FINAL.pdf .

3.3 Competitiveness and output impacts of mitigation policies

This section demonstrates the extent and the limits to which competitiveness concepts at the sectoral and economy-wide level can introduce an 'operational element' into the current discussions on EU leadership in GHG emissions reduction. In dealing with competeveness, it advocates the use of computable general equilibrium (CGE) models as an appropriate methodological tool, and complements the existing body of literature in the following manner:

Firstly, competitiveness is not a subject category per se, neither in economic theory in general, nor in normative economics in particular. This explains why a plethora of alternative notions exists. This research reviews a large literature body and derives the competitiveness notion which is interpreted as a consensus view instead of further underscoring the insurmountable differences between alternative definitions. This approach is able to deal with the complexity, and overcome the ambiguity, of the term "competitiveness" in a pragmatic and efficient way.

Secondly, acknowledging a major methodological challenge with regards to the operationalisation of the concept of competitiveness for a quantitative policy analysis, this study comes up with an array of indicators that are commensurate with the proposed notion of competitiveness. It is then demonstrated how the various indicators at the sectoral and the economy-wide level can be operationalised within a multi-sector, multi-region computable general equilibrium framework and tests the consistency of alternative indicator specifications. In particular, according to the most recent literature in the field, the focus is put on: Terms of Trade (ToT), Relative World Trade Shares (RWS), Revealed Comparative Advantage (RCA), Relative Trade Balance (RTB)[9]. We argue that by introducing these types of indicators into our framework, we establish the desirable property of any measure of RCA

[9] ToT compares the ratio of a country's overall exports with the ratio of country's overall imports in all sectors, RWS compares the ratio of a country's exports in a certain sector to the world's exports in this sector with the ratio of country's overall exports to the world's exports in all sectors. For a particular region and sector, RCA compares the ratio of exports by a specific sector to its imports with the ratio of exports to imports across all sectors of the region. Finally RTB compares the trade balance (exports minus imports) for a product to the total trade (exports plus imports) of that product

to reflect equilibrium trade flows and minimize any bias in this measure that might occur due to nominal exchange rate impacts and inflation shocks.

Thirdly, by analyzing a sequence of unilateral carbon pricing policies with elements of tax differentiation in favour of energy-intensive industries, this study reveals the trade-offs to be faced when competitiveness is prioritized by policy makers. In particular, based on quantitative simulations with a large scale computable-general equilibrium model of global trade and energy, we show that the sector-specific gains of preferential regulation in favour of EITE 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, our results highlight the scope for substantial excess cost in emission reduction at the regional level, as policy grants lower carbon prices to EITE industries and thereby forego relatively cheap abatement options in these sectors. From the perspective of global cost-effectiveness, however, preferential emission pricing for domestic energy-intensive and trade-exposed sectors can reduce leakage and thereby lower the overall cost of cutting global emissions as compared to uniform emission pricing.

Figure 5 demonstrates that moderate carbon price differentiation (up to factor 2 in favour of EITE industries) slightly reduces losses in global real consumption compared with a simple rule of uniform emission pricing. Gains from reduced leakage and improved terms of trade in non-abating regions are sufficient in magnitude to offset the increase in additional direct abatement cost for the case that Europe pursues climate policy with some degree of preferential treatment in favour of EITE industries.

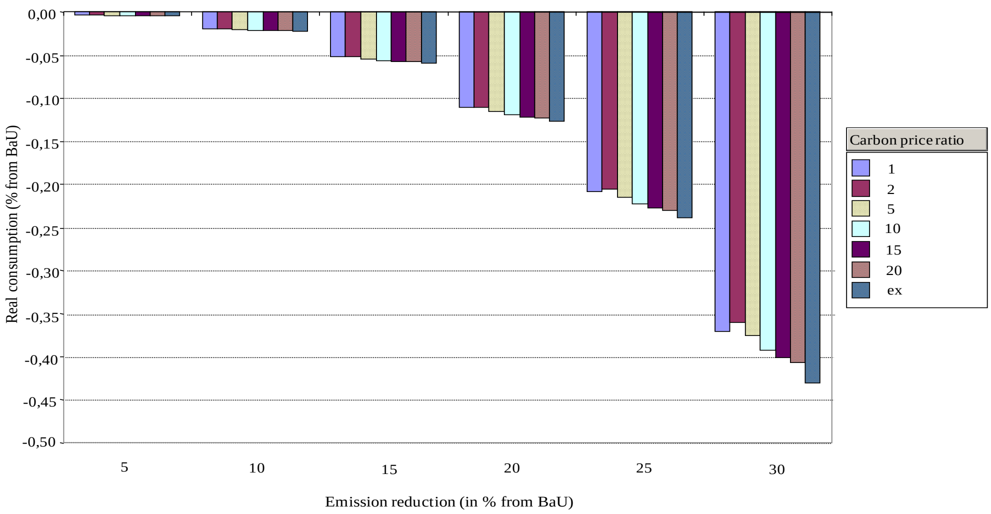


Figure 5: Changes in global real consumption (% change from BaU)

Fourthly, we go beyond a purely descriptive assessment of competitiveness through an explicit link to the normative concept of welfare. It is shown that explicit analytical and numerical linkages between competitiveness and welfare can be established when the former is measured as changes in economy-wide terms of trade. The decomposition procedure reveals the extent to which welfare implications change as a result of the impact of carbon abatement on terms of trade. In contrast, the linkages to welfare cannot be established when competitiveness is measured by revealed comparative advantage indicators. This is due to the fact that constant RCA indicator values within the given framework might be consistent with different levels of welfare and terms of trade.

Paul Krugman has condemned the obsession with competitiveness as “both wrong and dangerous”. Our assessment of competitiveness issues in unilateral climate policy is somewhat more differentiated. The notion of competitiveness at the sectoral level should not be mixed up with the broader issue of structural change towards a low-carbon economy. The commitment to reduce emissions in a cost-effective manner shifts comparative advantage towards emission-intensive industries which makes the loss in competitiveness of emission-intensive branches rather a desired feature than a feared outcome of rational climate policy. The competitiveness concerns of emission-intensive and trade-exposed industries are legitimate to the extent that competing firms abroad face an undue comparative advantage because of a lack of comparable regulation. However, second-best responses to the problem of emission leakage must be carefully assessed. Despite the potential pitfalls of price differentiation at the regional level, our findings lower concerns on these pricing strategies when global cost-effectiveness is taken into consideration: The moderate non-uniform emission pricing which is erected to protect energy-intensive industries in the EU will barely hurt global real consumption, while it will, to some extent, enhance environmental effectiveness of unilateral actions.

Simulation exercises in economics, as in other model based sciences (e.g. those done in IN-STREAM), depend on the choice of 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 the weaknesses of the approach). In such an exercise, the modeller analyzes 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.

The results confirm the validity of the results of the IN-STREAM project with 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.

For more information please see

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

3.4 Regional employment impacts of renewable energy policies

There are many studies which 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 which, in the worst case, might counteract the 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 to 20 % until 2020. In the case of heat supply the share of renewables shall be increased to 16 % by 2020. In this task of the project we examined the regional impact of the mentioned program by using an input output approach. These impacts are of particular interest, as in Baden-Wuerttemberg the manufacturing industries are highly important when compared to the rest of Germany. Thus we analyzed the effects of the policy actions on production, as well as on the employment of several sectors. We subsequently constructed a regional input output table of Baden-Wuerttemberg and introduced seven renewable energy types in order to examine different paths to achieve the state government's targets. Since the data availability did not suffice to regionally disaggregate the underlying database of a computable general equilibrium (CGE) model, we chose an input output approach for our analysis. 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.

We consider two scenarios which differ in the way of what sources fund the investments in 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 manufacturing sectors, 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. We also find positive production and employment effects for most industries besides the energy sector.

Our findings suggest that policy actions promoting renewable energy types do not necessarily create new jobs and additional production for the whole economy. Rather, they induce a structural change of the economy since other investments might be crowded out by investments in installations to be used for renewable energy sources 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 the rest of the world, these crowding out effects can be attenuated and production and employment effects might be positive in total.

For more information please see http://www.in-stream.eu/download/SVI_In-Stream%20D%206.3%20Regional%20indicators%20ZEW%20v2.pdf .

3.5 Greenhouse gas emissions impacts of mitigation policies

Climate change and its impacts should be accounted for in future political decisions. As the IPCC showed in 2007, a concentration of 450 ppm CO2e would most likely lead to global warming of 2 °C above the pre-industrial level. The 2 °C target is internationally accepted and partly agreed on, e. g. in 2010 at the COP16 in Cancun. Several indicators exist which are able to monitor the accomplishment of the target and some express this in costs.

Greenhouse gases (GHG) differ in their warming influence on the global climate system due to their different radiative properties and lifetimes in the atmosphere. To illustrate GHGs as only one quantity, they are often declared in CO2-equivalents (CO2e). This is achieved by using global warming potentials (GWP) (Table 6). The GWP depends on the chosen time frame, as the gases have different residence time in atmosphere. Current works aim at identifying the GWPs for non-GHGs like SO2 (sulphur dioxide), BC (black carbon), OC (organic carbon), VOC (volatile organic compounds) and CO (carbon monoxide).

Table 6: Global warming potentials (GWPs for non-GHG substances preliminary rough estimates)

Gas	GWP 100 years (Range)
CO2	1
CH4	25 (16 – 34)
N2O	298
SF6	22800
SO2	-40 (-24 – -56)
BC	680 (190 – 2240)
OC	-69 (-35 – -104)
VOC	3.4 (2 – 7)
CO	1.9 (1 – 3)
NOx	~0

Sources: IPCC, 2007; http://cdiac.ornl.gov/pns/current_ghg.html; Amann et al., 2010, Amann, 2011; http://www.stanford.edu/group/efmh/jacobson/0710LetHouseBC%201.pdf

Costs of climate change

There are different approaches to expressing the costs of climate change. Usually, damages should be monetized by assessing the damage costs. It is thereby necessary to be able to assess damages due to climate change. As this is not possible, e. g. because of unexpected or hereto unknown damages, the alternative is to assess abatement costs. Marginal abatement costs express how much the last ton of carbon abated costs to reach a given target.

Abatement costs

Recommendations for abatement costs are based on the values of the meta-study of (Kuik et al. 2009) for a 450 ppm CO2e-target. A stabilization target of 450 ppm CO2e equals the worldwide aspired 2 °C-target.

The abatement costs lie at 225 €/t CO2e (128-396 €/t CO2e) in 2050. By interpolating the given values with 5 % ,which considers the market interest rate, one gains the values in Table 7. Thus in 2010 a central value of 32 €/t CO2e (18-56 €/t CO2e) follows.

Table 7: Abatement costs for 450 ppm target in €/t CO2 - interpolated with 5 %

	2010	2020	2025	2030	2040	2050
lower value	18	30	38	48	79	128
central value	32	52	66	85	138	225
upper value	56	92	117	149	243	396

Table 8 shows the abatement costs for a target of 550 ppm, which leads to a global warming of about 3 °C. The abatement costs thus lie at 83 €/t CO2e (49-134 €/t CO2e) in 2050 and at 12 €/t CO2e (7-19 €/t CO2e) in 2010.

Table 8: Abatement costs for 550 ppm target in €/t CO2 - interpolated with 5 %

	2010	2020	2025	2030	2040	2050
lower value	7	11	15	19	30	49
central value	12	19	25	31	51	83
upper value	19	31	40	51	82	134

Damage costs

The recommended values for damage costs of carbon dioxide stem from the model FUND. Scientifically consented is the choice of a discount rate of 1 % PRTP and averaging with 1 % trimmed. As a lower value we recommend the value for damage costs without equity weighting, and as upper value the value which is equity weighted for a European average. All values are discounted to the year of emission.

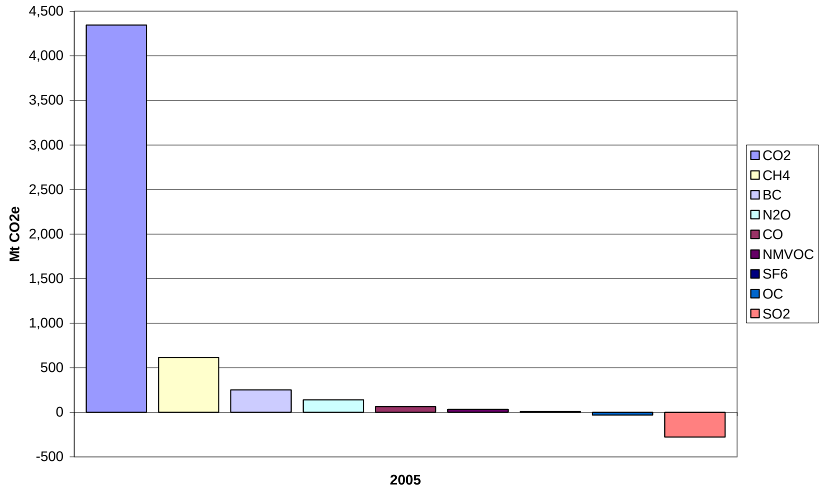
Table 9: Recommendation marginal damage costs in €2010/t CO2 in relation to scenario

A1b		2010	2020	2030	2050
lower value	NoEW_1%_Av1%	14.60	22.88	34.60	70.60
upper value	WeuEW_1%_Av1%	140.64	169.84	197.92	276.29
B1		**2010**	**2020**	**2030**	**2050**
lower value	NoEW_1%_Av1%	10.63	15.39	21.55	41.85
upper value	WeuEW_1%_Av1%	105.82	128.14	147.01	189.83

Indicators

GHG emissions: When observing greenhouse gas emissions, it is possible to compare the actual emissions expressed in CO2-equivalents with a modelled sustainable emission path that leads to reaching the 2°C target.

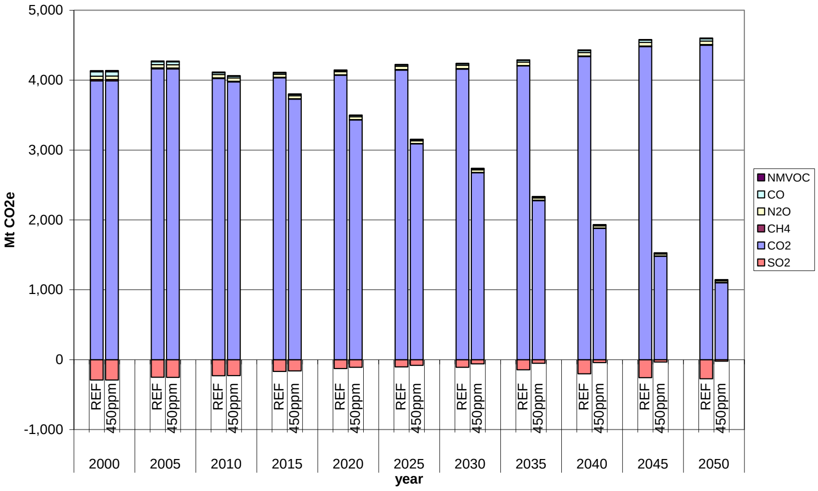
By using the GWPs shown above, all emissions known to be related to the greenhouse effect can be displayed in CO2e. The following figure shows the emissions in 2005 in CO2e. The great influence of CO2 emissions is visible as well as the cooling effect of SO2. A new feature is the depiction of the non-GHGs BC, OC and SO2. Air quality restrictions which limit the emissions of OC and SO2 will thus affect global warming.



Source: HEIMTSA Common Case Study, UNFCCC, http://gains.iiasa.ac.at

Figure 6: GHG emissions 2005 in EU29 in CO2e

Distance to target: 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 TIMES are presented; the REF scenario represents a business-as-usual emission path.



Source: TIMES model within HEIMTSA Common Case Study

Figure 7: Emission path EU29 (only energy-related)

An alternative and easier way of applying the indicator would be to calculate the cumulated deviance every year. The problem with this approach is the negligence of the point of avoidance.

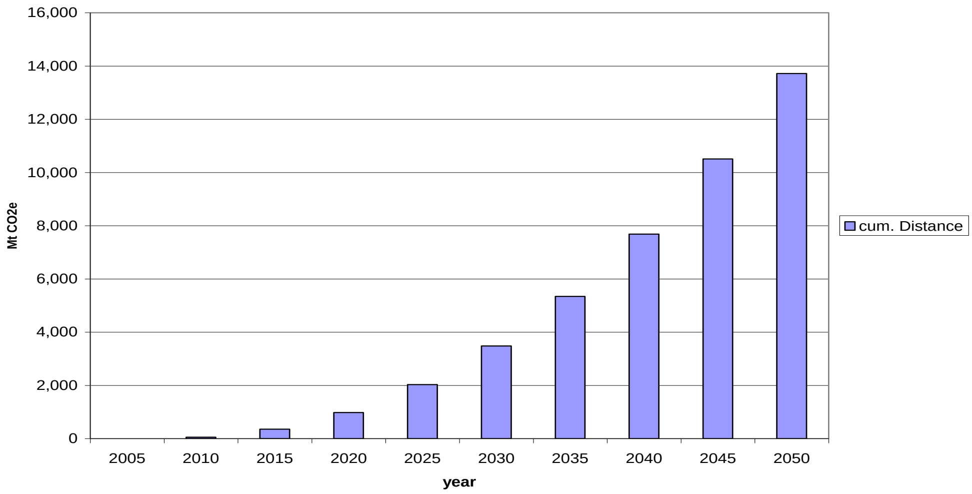


Figure 8: Cumulated distance to target emissions EU29

Costs distance to target: The distance to the target can also be expressed as costs. The difference between the Annual System Costs of the two scenarios thus expresses the avoidance costs to meet the climate change target.

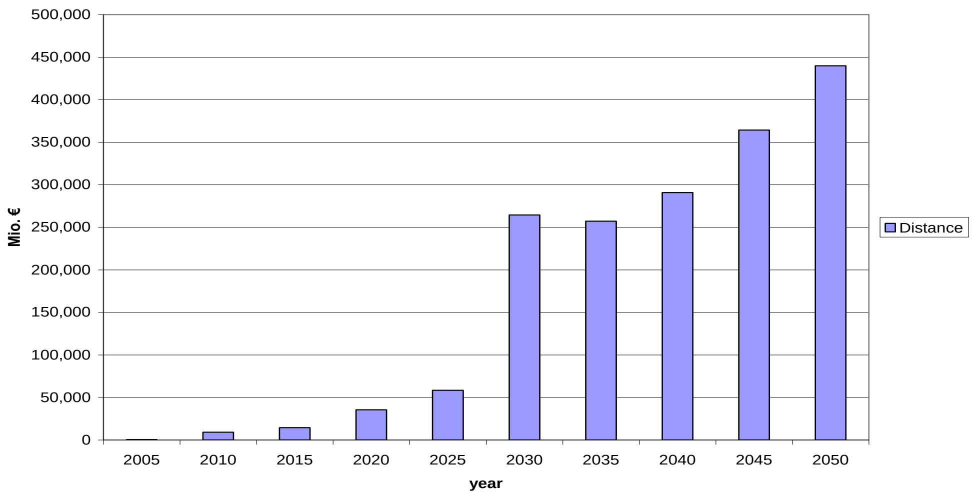


Figure 9: Distance of Annual System Costs (TIMES)

Total damage costs: Finally, the total damage costs of emissions related to climate change can be expressed by multiplying the emitted tons of carbon by the damage cost per ton of carbon. Marginal damage costs of climate change are assessed with integrated assessment models. Figure 10 shows the range of total damage costs calculated with the FUND[10] model.

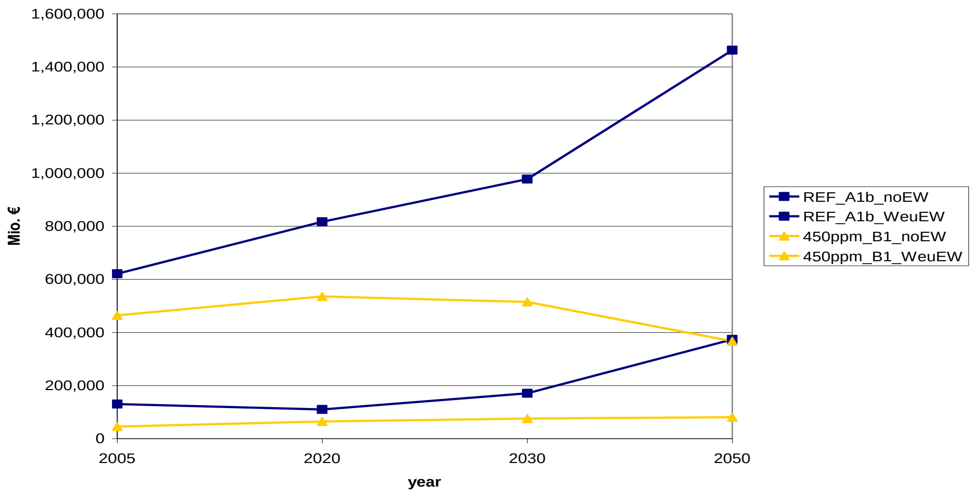


Figure 10: Total damage costs of EU29 GHG emissions

The example uses the marginal damage costs of SRES A1B for the REF scenario, and the marginal damage costs of SRES B1 for the 450 ppm scenario to illustrate a possible range of damage costs, which are an approximation of the real values.

An extra feature is that avoided damages can be compared with avoidance costs (annual system costs shown above).

Figure 11 shows the avoided damages if the target emission path is achieved. The green line represents values which are European equity weighted (WeuEW) and are thus an upper

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[10] www.fund-model.org

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.

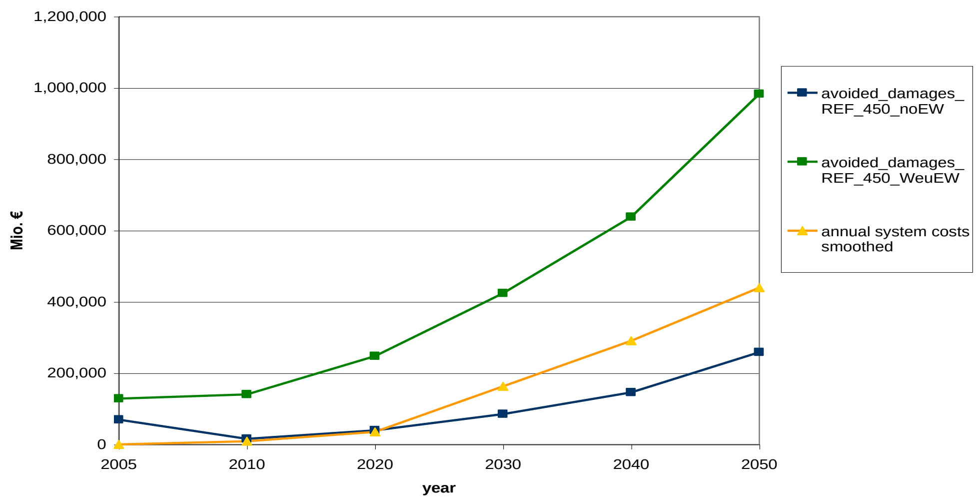


Figure 11: Avoided damages and avoidance costs EU29

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 (SO2), and carbon monoxide (CO). Points of concern are that only a relative comparison to the previous year is possible and that it is uncertain whether the target path is really sustainable.

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 aggregation is possible. Unfortunately, the costs depend on assumptions; therefore, it is difficult to determine the innovation potential.

The indicator "Total damage costs" is similar to the costs of distance to target. It is an aggregate measure for damages and accounts for a worldwide emissions path. A disadvantage is that perhaps not all damages are included and that the decision of whether to apply equity weighting is made politically.

All indicators have strengths and weaknesses and thus should and could be further developed.

For more information please see http://www.in-stream.eu/download/IN-STREAM_deliverable-5%201_110727_FINAL.pdf .

3.6 Distributional implications of mitigation policies in the Czech Republic

3.6.1 Objectives and methodology

The distributional effects of environmental regulations are still subject to debate. In principle, the examination of the distributional aspects of regulation requires analyzing the distribution of financial benefits as well as of environmental benefits generated by the given policy.

Although a large number of studies analyze the distribution of financial effects, the data can still be hard to interpret, as the overall effects depend in part on what consumer's responsiveness is assumed to be in simulations (including elasticities of demand), how any revenues collected from taxes are used (the revenue-recycling effect), and whether general equilibrium effects are considered (the tax-interaction effect). A simple but quite frequently used approach for analyzing the distributive aspects is based on an examination of expenditure patterns of and/or tax payments paid by various household segments such as income deciles or segments defined by social status or size of residence. It is, however, hard to imagine that a household will consume as much after policy implementation as beforehand, and therefore proper modelling requires the inclusion of price responsiveness, i.e., elasticities of demand. However, price effects on other factors and goods might be only analyzed using a combined Input-Output analysis with a demand / expenditure system or in a general equilibrium framework (either soft-linked micro-simulation model and macro model or by hard-linking the Integrated-microsimulation-CGE modelling by disaggregating one representative household into several classes). This last type of analysis has however only been utilized rarely and in few policy domains due to detailed data requirements and large computation effort.

In this project, we examine specific expenditure patterns of several household segments and then utilize a microsimulation model to predict the effects on energy expenditures and consumption, welfare and tax payments; we then analyze the distributional effect using inequality indexes.

3.6.2 Major findings

Table 10 reports the average effect of implementation of the 2003/96/EC Directive on energy taxation in the Czech Republic on energy expenditures and welfare as a percentage of total household expenditures per year for ten income deciles, six segments defined by availability of heaters (i.e., whether certain energy types are used at all), and a household of pensioners living in residence with less or more than 20,000 inhabitants. It is shown that overall the effect is very small; revenue recycling can mitigate adverse effects, but if revenues are used to lower labour costs pensioners will still be negatively affected compared to other household segments.

Table 10: Distributional effect of implementation of the 2003/96/EC Directive in the Czech Republic (in percent of total expenditures)

	Effect on energy expenditures				Welfare impact			
	No recycling	SSC	PIT (lowest rate)	PIT (tax credit)	No recycling	SSC	PIT (lowest rate)	PIT (tax credit)
1st decile	0.07%	0.09%	0.09%	0.09%	-0.22%	-0.04%	0.04%	0.02%
2nd decile	0.09%	0.10%	0.10%	0.10%	-0.23%	-0.04%	0.01%	-0.01%
3rd decile	0.11%	0.12%	0.12%	0.12%	-0.20%	-0.04%	-0.02%	-0.03%
4th decile	0.07%	0.08%	0.08%	0.08%	-0.26%	-0.12%	-0.11%	-0.11%
5th decile	0.09%	0.09%	0.09%	0.09%	-0.23%	-0.07%	-0.07%	-0.06%
6th decile	0.10%	0.11%	0.11%	0.11%	-0.20%	-0.04%	-0.03%	-0.03%
7th decile	0.06%	0.07%	0.07%	0.07%	-0.21%	0.00%	0.00%	0.01%
8th decile	0.07%	0.08%	0.08%	0.08%	-0.18%	0.05%	0.04%	0.05%
9th decile	0.06%	0.07%	0.07%	0.07%	-0.17%	0.09%	0.06%	0.07%
10th decile	0.05%	0.06%	0.06%	0.06%	-0.12%	0.13%	0.05%	0.06%
Only Electricity	0.05%	0.07%	0.07%	0.07%	-0.11%	0.10%	0.11%	0.11%
ELE+cookGAS	-0.25%	-0.24%	-0.24%	-0.24%	-0.27%	-0.14%	-0.12%	-0.09%
HEAT+cookELE	-0.03%	-0.02%	-0.02%	-0.02%	-0.05%	0.15%	0.15%	0.15%
HEAT+cookGAS	0.24%	0.25%	0.25%	0.25%	-0.07%	0.14%	0.13%	0.13%
GAS	-0.13%	-0.12%	-0.12%	-0.12%	-0.34%	-0.14%	-0.14%	-0.14%
SOLID	0.38%	0.39%	0.40%	0.40%	-0.37%	-0.18%	-0.16%	-0.16%
retired city20k-	0.05%	0.05%	0.05%	0.05%	-0.28%	-0.27%	-0.28%	-0.28%
retired city20k+	0.12%	0.12%	0.12%	0.12%	-0.19%	-0.18%	-0.19%	-0.19%
Weighted average	**0.07%**	**0.08%**	**0.08%**	**0.08%**	**-0.19%**	**0.01%**	**0.01%**	**0.01%**

Issues of inequality with respect to the environment have been tackled by researchers for several decades with a broad variety of approaches and research topics ranging from the siting of hazardous waste facilities to participation in decision making about environmental issues. In our study, we focused on the inequality in perceived air quality in several cities in the Czech Republic using a methodology developed in health studies. Our paper identifies limitations of the of pairwise comparison method of distribution spreads and finds that, even in cases where such analysis does not provide unambiguous results, an index of inequality suited for categorical data can be computed. The interpretation of such an index is similar to the interpretation of other inequality indexes such as the Gini index, i.e., the index reports values on a scale of 0 that indicates perfect equality to 1 that indicates perfect inequality.

We document our approach here (Table 11) for one of the variables used in the study, specifically the question of whether air quality in your neighborhood can be described as very good (1), quite good (2), quite bad (3), or very bad (4). If we use only categorical values, we find that the median citizen in most of the Czech cities perceives air quality quite bad, except citizens in Pilsen and Ostrava—the two industrial cities in our sample—who perceive air quality as very bad. However, the inequality analysis reveals higher overall disparities in answers from Prague and Ostrava. Meanwhile, it finds that the answers of respondents from rest of the Czech Republic and from Liberec are more tightly grouped around prevailing answers. So, while the median respond is same in Ostrava and Pilsen, the responses regarding air quality perception are distributed among inhabitants in Ostrava less evenly than among the population of Pilsen.

Table 11: Air quality perception in the Czech cities: an application of inequality index for ordered data

	Brno	Liberec	Ostrava	Pilsen	Prague	Other cities
Median value of the responses	2	2	3	3	2	2
Inequality indicator	0.362	0.279	0.438	0.365	0.422	0.280

3.7 Decomposition analysis of air pollutants in the Czech Republic

3.7.1 Objectives and methodology

A decomposition analysis differs from an econometric analysis, which aims to estimate a reduced form of the relationship between a dependent variable and covariates. A decomposition analysis aims to explain the channel through which certain factors affect a variable. The index decomposition analysis (IDA) relies on index theory and may be based on either the Laspeyres or Divisia index method. The Laspeyres index is easier to understand, but it may generate large residuals, and when the absolute contributions of each of the factors are relatively large, part of the emissions can remain unexplained. The Divisia index-based method overcomes this problem in that it generates no or only negligible residuals.

IN-STREAM carried out the index decomposition analysis using the Divisia index-based method to examine change in air pollutants and the degree of their contribution to environmental degradation. Specifically, we analyze the emissions levels of various pollutants such as SO2, CO, NOx, VOC, and PM in the Czech Republic during the period 1995 – 2007. We carry out the decomposition in several degrees of detail. At first, we decompose emissions levels of pollutants from 1997 to2007 in the Czech Republic into 3 factors: scale effect, composition effect, and emission intensity effect: the scale effect measures how economic growth as a whole affects air pollutant emissions, the composition effect reports how the change in economic structure has an effect on the pollution level, and the emission intensity effect calculates how environmentally efficient firms are relative to economic output.

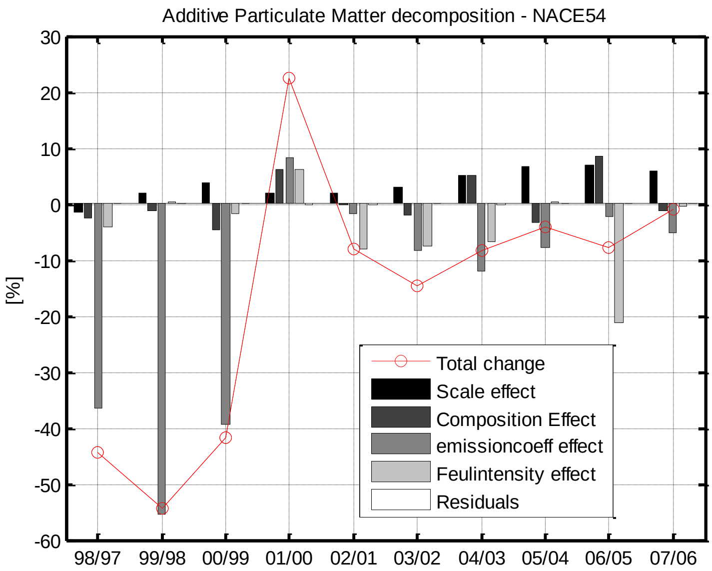


Figure 12: 4-factor decomposition of air emission in the Czech Republic, Divisia Index 1997-2007

In the existing literature, the emission coefficient is usually time invariant, based on a theoretical value coming from chemistry. In our dataset, the amount of pollutants released by a particular type of fuel is reported, and we may thus benefit from richer variation in our data for facilities as well as a longer time horizon. This enables us to conduct a 5-factor decomposition analysis. Using our detailed data, the emission intensity is further decomposed into a fuel intensity effect and an emission coefficient effect in the 4-factor decomposition, whereas it is decomposed even further into fuel intensity, an emission coefficient, and a fuel mix effect in the 5-factor analysis. The finer decomposition then provides useful and policy relevant information because the fuel intensity effect measures the change in consumption of each type of fuel used in the production per unit of economic output, the fuel mix effect measures how the composition of various types of fuels used affects emissions levels, and the emission coefficient effect captures how effectively fuels are used in terms of air pollutants, i.e., it captures the change in end-of-pipe technology.

Table 12: 5-factor decomposition of air emission aggregated over period in the Czech Republic

	PM	SO_2	NOX	CO
1995-2007				
Total change	**-93.1%**	**-82.1%**	**-28.7%**	**-69.2%**
Scale effect	2.4%	1.0%	-3.4%	5.8%
Composition effect	-9.2%	-17.5%	-21.8%	-18.0%
Fuel Intensity	-9.7%	9.3%	12.5%	4.5%
Fuel Mix	-9.0%	-3.6%	-2.7%	-21.4%
Emission Coefficient	-67.6%	-71.3%	-13.2%	-40.1%
1995-2000				
Total change	**-92.6%**	**-81.2%**	**-30.3%**	**-65.1%**
Scale effect	1.5%	0.4%	-0.9%	3.0%
Composition effect	-9.7%	-20.5%	-15.7%	-18.5%
Fuel Intensity	-8.0%	15.3%	5.0%	4.3%
Fuel Mix	-9.0%	-1.8%	-1.4%	-10.7%
Emission Coefficient	-67.3%	-74.6%	-17.4%	-43.1%
2001-2007				
Total change	**-6.6%**	**-4.8%**	**2.4%**	**-11.6%**
Scale effect	1.8%	1.1%	0.8%	2.0%
Composition effect	0.4%	4.9%	3.2%	-2.4%
Fuel Intensity	-3.6%	-10.8%	-2.6%	0.7%
Fuel Mix	-0.6%	-3.6%	0.5%	-7.5%
Emission Coefficient	-4.6%	3.6%	0.5%	-4.5%

Our decompositions are undertaken also at various level of disaggregation of the Czech economy in order to examine how the results might be affected if one applied various sector resolutions to the decomposition analysis. In a last step, we focus more on time aggregation. At first, we aggregate the 4-factor decomposition results as based on year-by-year changes for three distinct time periods to examine a trend in driving forces of air emission changes: a) during the period when firms were obligated to fulfill strict requirements on emissions limits (1997-2000), b) during the period when the efforts of government and enterprises was determined by implementation of EU acquis communitaire (2000-2004) and c) during the period when enterprises had to do their best to become competitive in the EU market (2004-2007). Last, we analyze cumulative changes in emissions over the entire period as well as over two periods before and after 2000, i.e., when the strict emission requirements had to be fulfilled by large emitters.

3.7.2 Major findings

The first finding of our research is that the law reflecting the EU requirements, which came into force and were implemented in 1997 in the Czech Republic and required large sources to meet emissions limits by the end of 1998, was quite effective: it motivated firms to improve environmental efficiency, especially end-of-pipe technology, and to decrease their emissions during the period 1995-1999 by using fuel more efficiently. Second, we find that the main contributor to this decrease was the emission intensity effect (specifically, the emission coefficient effect), which is consistent with other studies from developed or transition countries. Furthermore, the composition factor was one of the strongest among our five analyzed factors and contributed to overall emissions reductions by 10% to 20% from 1995 to 2000. The fuel mix effect was mostly negative in the case of particulate matter until 2000, which suggests firms changed their inputs to use more environmentally friendly fuels. After 2000, after the regulation period, the emissions levels of the pollutants stay more or less stable. Finally changes in the structure of the economy in the Czech Republic actually contributed temporarily to increases in emissions levels; this is inconsistent with the predictions of the EKC hypothesis. As the country develops, the structure of the economy should move from "dirtier" towards "cleaner" and thus exhibit a downward-sloping emissions pathway.

In the second task, we aim to derive the marginal abatement costs (MAC) of airborne emissions, which are usually based on engineering studies or come from shadow prices estimated by CGE models. While the former approaches lack economic theory and overestimate MACs, the latter rely on a top-down approach that does not allow us to derive the MACs for detailed sectors or segments. The only theoretically sound option is based on a cost function or distance function. This approach has not been applied very often, and there is no study using firm-level data in transition countries. We cover this gap and estimate shadow prices of classic airborne pollutants in the Czech energy sector and analyze the main drivers of MACs. Employing a parameterized Input Distance Function, we estimate the median shadow prices for the power sector to be €8,374, €1,198, €2,805, €6,051, and €8,549 per ton of PM, SO2, NOx, CO, and VOC, respectively. Our results are lower than the values estimated from sector-level data for the Czech Republic [Salnykov & Zelenyuk, 2006] but slightly higher than the estimates from the GEM-E3 model [Pye, et al., 2008] and in the range of MAC derived by the GAINS model.11 Then, we decompose shadow prices estimates and test the hypotheses that the marginal abatement costs decline over time and rise with declining emissions levels and/or a declining emissions rate. Most results indicate that the MACs for the Czech power firms rise over time and cannot reject the hypotheses that MACs rise with declining emission level and rise with declining emission rate—at least for NOx and CO.

[11] Salnykov, L. M., Zelenyuk, V. P. (2006): Parametric estimation of environmental efficiencies and shadow prices of environmental pollutants: cross-country approach. EERC working paper. 2006.

Pye, S., et al. (2008): Analysis of the Costs and Benefits of Proposed Revisions to the National Emission Ceilings Directive - NEC CBA Report3. National Emission Ceilings for 2020 based on the 2008 Climate & Energy Package. s.l. : AEA Energy & Environment, 2008. European Commission DG Environment C.5. ED48763 – R3 Issue 2 (Final report).

3.8 Land and agriculture impacts of biofuel policies

3.8.1 Objectives and methodology

The main objective of the IN-STREAM study on agricultural sustainability is to explore 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. The goal is to assess the implications of alternative biofuel strategies for the agricultural sector's ability to provide a wide range of goods and services, including food, feed, fibre, and bio-energy crops, while at the same time fostering the long-term sustainable use of land and water resources.

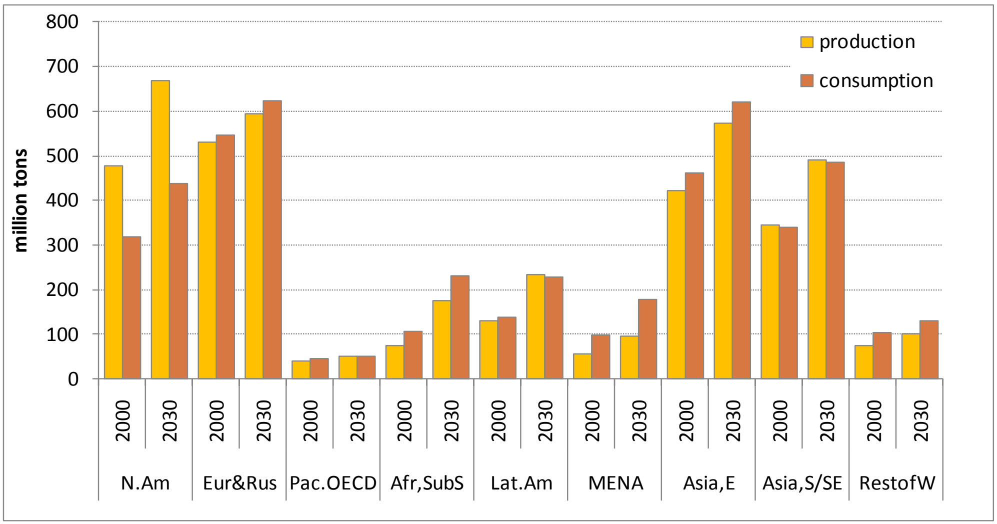
An improved understanding of the energy-food security-environment linkages requires a spatially detailed assessment of alternative land use and rural development options and strategies. For the analysis of the global agricultural system, a state-of-the-art ecological-economic modelling framework is applied. It has two major components: the FAO/IIASA Agro-ecological Zone (AEZ) model and the IIASA world food system (WFS) model. The two main models, adapted and expanded for resource use and by-product generation of biofuel production, are the instruments for scenario evaluation to assess the impacts of alternative biofuel deployment and determine pathways on food and agriculture at the national, regional, and global levels. In addition, a rule-based downscaling methodology is applied to allocate the results of the world food system simulations to the spatial grid of the resource database for the analysis and quantification of environmental implications. An initial baseline assessment provides the point of reference to 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.

3.8.2 Major findings

Baseline

The primary role of the reference scenario (REF) is to serve as a "neutral" point of departure against which various biofuel scenarios can be compared in order to assess the impacts of biofuel expansion. In the long run, the increase of demand for agricultural products is largely driven by population and economic growth, both of which grow more quickly in developing than in developed countries. According to the most recent UN population projections, world population growth is projected to continue at about 1%/year over the next two decades, with most of the increase occurring in developing countries. Growth of the global economy in the REF is projected to continue at 2.9% annually up to 2020, slowing somewhat to the annual rate of 2.6% in the 2020s. The growth rate in developing countries is estimated to be three times as high (at the rate of 5.8% and 4.7% up to 2020 and in the 2020s, respectively) as in the developed world (1.9% and 1.4% in the same time periods). The climate change scenario is derived from the HadCM3 results based on the IPCC SRES A2 emissions pathway.

As a result of population and economic growth, cereal demand continues to grow, and production increases from 2.1 billion tons in 2000 to 2.7 billion tons in 2020 and to nearly 3.0 billion tons in 2030. Figure 13 shows the regional patterns of cereal production and consumption in the REF scenario.



Source: IIASA World Food System reference scenario (REF) simulations, June 2010.

Figure 13: Total cereal production and consumption, Scenario REF

As the share of developing countries in global consumption increases from 55% in 2000 to 60% in 2030 and production increases are not large enough to compensate increased demand, net imports of cereals by developing countries grow over time from 120 million tons in 2000 to about 188 million tons in 2030. North America is by far the largest net exporter of cereals with about a third of production being exported to the world market. Increasing global demand triggers modest increases in world market prices of most agricultural commodity groups (see Table 13).

Table 13: Agricultural prices as simulated in scenario REF

Commodity group	Price Index (1990=100)		
	2000	2020	2030
Crops	92	93	97
Cereals	94	104	108
Other crops	91	88	92
Livestock products	102	105	108
Agriculture	95	97	100
Wheat	88	116	119
Rice	97	95	99
Coarse grains	97	104	109
Bovine & ovine meat	107	106	110
Dairy products	97	104	109
Other meat	102	106	109
Protein feed	108	115	121
Other food	90	87	91
Non-food crops	80	76	82

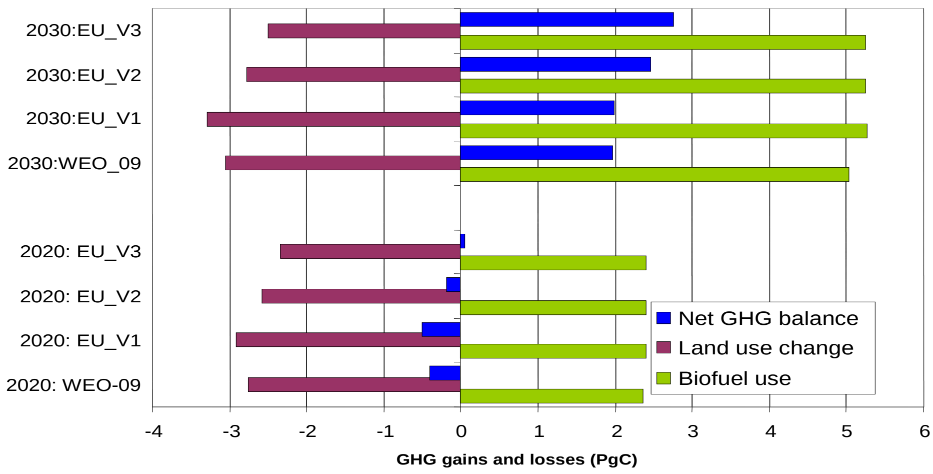
Source: IIASA World Food System reference scenario (REF) simulations, June 2010.

Biofuel scenarios and their implications

Biofuel scenarios include three main components: (i) an overall energy scenario with a detailed elaboration of the regional and global use of transport fuels; (ii) pathways depicting the role of biofuels in the total use of transport fuels; and (iii) 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 CO2, emissions from the global transport sector. Therefore, a net reduction of GHGs throughout 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. The emissions implications of land use changes are widely debated when previously unused or differently used land is converted to produce biofuel feedstocks. 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 14 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 with the blue bar "Net GHG balance") is determined by the GHG savings achieved from biofuel replacement of gasoline and diesel (Bar "Biofuel use") minus the GHG emissions caused by direct and indirect land use changes (Bar "Land use change").



Source: IIASA World Food System reference scenario simulations, June 2010.

Figure 14: Cumulative net GHG savings of biofuel scenarios

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 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 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 CO2 emissions since there are hardly emissions due to additional land cover conversion resulting in a net accumulated production by 2030 of 2-3 Pg CO2 emissions.

Biofuel development is expected to lead to increasing and diversifying agricultural production. To what extent will the additional production of crops developed on arable land as feedstocks for biofuels production increase the value added of the agriculture sector? Changes relative to the REF scenario are shown in Table 14.

Table 14: Impacts of biofuel expansion scenarios on agricultural value added

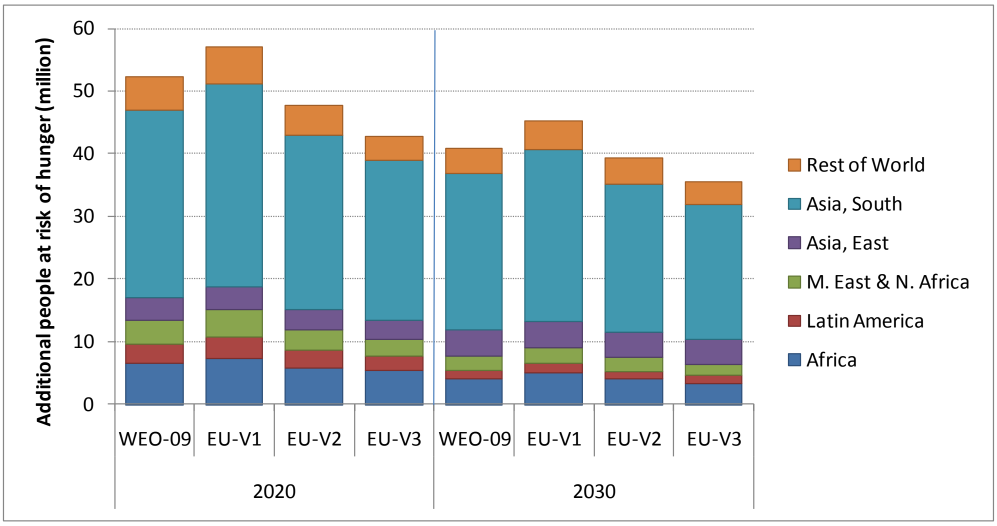
	Change in Agricultural Value Added relative to reference scenario REF (%)							
	WEO-2009		EU-V1		EU-V2		EU-V3	
	2020	2030	2020	2030	2020	2030	2020	2030
Developed	2.5	3.5	2.6	3.7	2.3	3.3	2.3	3.0
Developing	1.0	1.5	1.1	1.6	0.9	1.4	0.8	1.3
World	1.5	2.1	1.6	2.3	1.4	2.0	1.2	1.8

Source: IIASA World Food System reference scenario (REF) simulations, June 2010.

Agricultural value added increases for all biofuels scenarios at the global and regional levels. Increase rates for the world are between 1.2 and 2.3%, depending on the biofuel scenario and time. There is a noticeable regional disparity: agricultural value added increases more in the developed than in the developing world. Thus, under the assumed policy setting, the agricultural sector in developed countries benefits more than in developing countries in terms of percentage gains relative to the baseline scenario. The highest gains are projected for North America with an additional 6% gain in agricultural value added relative to scenario REF.

According to the reference scenario, the number of people at risk of hunger declines gradually over the coming decades, reaching 807 million people in 2030 and 720 million in 2030. This positive trend is reversed 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 15 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. The 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 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 risk of hunger.



Source: IIASA World Food System reference scenario simulations, June 2010.

Figure 15: Additional people at risk of hunger

The regional distribution of the additional people at risk of hunger shows that South Asia and Africa will suffer most in 2020. By 2030, the number of hungry people will be lower in almost equal proportions across the world regions. The only exception is East Asia, where the number of undernourished people will increase compared to 2020. This indicates the relative scarcity of additional arable land and the lower potential for second-generation biofuels in this region.

The conclusion from the selected results of the biofuel scenarios above is that economic and sustainability characteristics of the global agricultural system result 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 connected system involves remote causations in which policies pursued in one region or country affect the conditions (commodity trade and prices) in other regions. 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 policymakers can make informed decisions about the benefits and costs of the available policy options.

For more information please see http://www.in-stream.eu/download/Deliverable_6.4.pdf .

3.9 Health and ecosystem impacts of mitigation policies

The ongoing discussion on improving the observation of an economy's sustainable development, e.g. the European Commissions debate on "Beyond-GDP" measures, highlights the importance of an assessment of impacts on human health and ecosystems caused by economic activities. Within IN-STREAM, the analysis of ecologic, and to a certain extend social, indicators focussed on the assessment of impacts on human health and losses of biodiversity in terms of reductions in the quality of life and the number of species inhabitant in a certain area. These indicators are of great use for the assessment of sustainability of different countries.

3.9.1 Methodological background

The estimation of environmental impacts follows the impact pathway approach (IPA) to transform pressure and state indicators into impact indicators. The estimated impacts include damages and risks to human health, ecosystems, crops, and materials. The IPA represents a bottom-up approach that was developed in the ExternE project series of the European Commission (European Commission, 2005). [12] The IPA starts with an analysis of the site-specific characteristics of the emitting source and links changes in emissions to changes in concentrations. This linkage is based on existing source-receptor matrices (SRM, see Tarrasón (2008)) and multi-media models, e.g., the EMEP models for air pollutants. The changes in concentrations are then related to changes in exposure and the resulting impacts via concentration-response functions (CRF). The impacts resulting from these changes can then be valued in monetary terms in order to allow for a comparison across different damage categories. An update of the IPA and all its components has been completed in the EU-funded NEEDS[13] and HEIMTSA[14] projects.

[12] ExternE: Externalities of Energy, http://www.externe.info

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

[14] HEIMTSA: Health and Environment Integrated Methodology and Toolbox for S**cenario** A**s**sessment; http://www.heimtsa.eu/

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. It is especially the spatial characteristics of the emitting sources that lead to substantial differences in the impacts, i.e., emissions from urban transport activities in comparison with emissions from a high stack power plant in a rural area. Furthermore, a difference in the effects also occurs for emissions in summer and winter due to different background concentration levels and chemical transformation processes. In order to account for these important site-specific factors, an approach of differentiating the emissions of different economic sectors has been developed.

The main features of the IPA are the following:

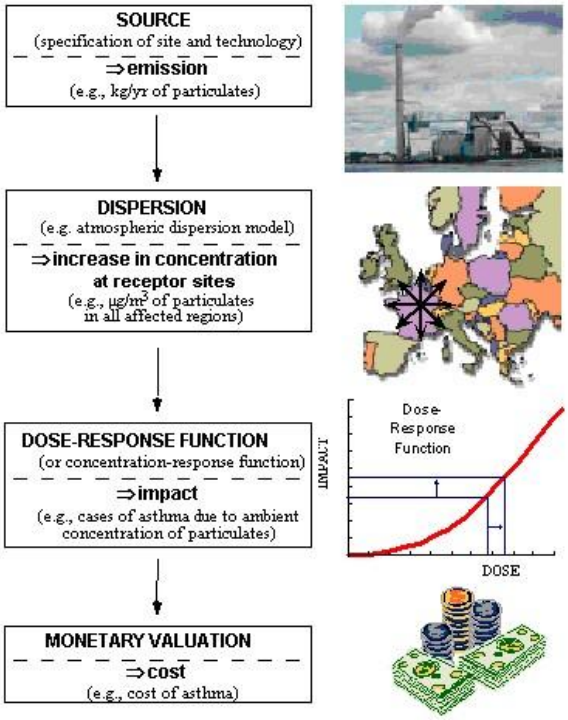
- All alternatives that pose a higher health risk on individuals or exceed sustainability targets, e.g., health impacts that occur with higher probability, are excluded in advance. Weighting is only possible for small individual risks and reversible ecosystem damage.
- Assessment of impacts is needed at all spatial levels, i.e., local, regional, hemispheric, and global levels. The relative importance of larger scale impacts is increasing as emissions from far away countries, e.g., China, can influence the concentration level at the European scale. Thus, an assessment of the emissions on a global scale becomes more important also for European policy making.
- Life cycle impacts, i.e., construction and dismantling, provision of fuels, and waste treatment and disposal, should be taken into account in order to assess the total impacts that arise from emissions of a certain technology. The assessment of life cycle impacts is especially relevant when comparing renewable energy generation technologies, as most of these tend to have very low emissions from the operation of the technology but emission vary in the upstream processes.

The monetary valuation of impacts is based on the (measured) preferences of the affected well-informed population, i.e., the willingness to pay (WTP) for the avoidance of a certain risk. The WTP of affected individuals can be measured by using contingent valuation surveys. For the monetary valuation of damages to crops and materials, market prices can be applied. The monetary valuation allows for aggregation and comparisons across impact categories. These monetary values are a building block for setting up aggregated welfare indicators.

There are a number of issues that are not included in the integrated assessment approach of the IPA. These are:

- Effects that are not considered as externalities as there are markets in which these effects are covered, e.g., effects on employment are not considered within the integrated assessment as the labor market covers these effects. The same applies for the depletion of non-renewable resources (market for resources) and changes in research and development expenditures (sunk costs).
- Effects where no data or methods are yet available for the assessment. This leads to an exclusion of an assessment of risk aversion, especially so-called Damocles risks with very low probabilities and very high damage risks, e.g., the risk of a nuclear accident, terrorism, or nuclear proliferation.

- Visual intrusion or annoyance, as there is a large variability in the stated preferences of individuals which makes a benefit transfer very difficult.
- The precautionary principle which asks for the inclusion of all potentially hazardous substances. This is not feasible due to a lack of information about the substances to which this refers and which effects these substances cause.



Source: European Commission (2005), p. 2

Figure 16: The impact pathway approach

A tool for integrated impact assessments is the EcoSense model[15], an integrated computer system developed within the ExternE project series with latest updates in the EU-project NEEDS and HEIMTSA. The EcoSense model is based on the impact pathway approach. The model allows for an estimation of average monetary damage factors per country for all pollutants in order to estimate “external costs per kg (or per kWh)” on a country-specific level, including LCA data. It helps to overcome the problem of a lack of site-specific input data, and it avoids costly sophisticated dispersion model runs. A detailed description of the model can be found in Preiss and Klotz (2007) and Preiss et al. (2008).

To analyze the environmental performance of policies and technologies, an integrated impact assessment is required. This approach is defined by a multidisciplinary process

[15] For more information on the EcoSense model, visit http://ecosenseweb.ier.uni-stuttgart.de.

that synthesizes knowledge across scientific disciplines with the purpose of providing all relevant information to decision makers in order to decision making. The integration aspect of this approach refers to the consideration of different emissions sources, e.g., transport, energy conversion, agriculture, etc., and a range of different pollutants and impact categories. Furthermore, different environmental media as well as different scales (from local to global) need to be taken into account. The EcoSense model can be used as a tool for integrated impact assessments because it includes a number of airborne pollutants, heavy metals, GHGs, and radionuclides for the assessment of impacts on human health, biodiversity, crops, and materials. Furthermore, the model provides results for different European countries on a local, regional, and hemispheric scale.

3.9.2 The aggregation of health and ecosystem impacts into indicators for sustainability

Health impacts can be aggregated to DALYs (disability adjusted life years), which 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). This indicator assigns a value between 0 and 1 for each year, with a score of 1 for death and a score of 0 for perfect health. In contrast to the concept of DALY developed by the World Health Organisation (WHO), no weighing of health impacts according to the age of the affected individuals and no discounting of future health impacts are included in these estimations. In the EU-funded project NEEDS, the monetary value of a DALY has been estimated at €[16]40,000 (Desaigues et al., 2011).

For ecosystem damages, the aggregated impacts can be expressed in pdfs (potentially disappeared fraction of species). The original IN-STREAM project report (Deliverable 5.1) provides a detailed overview of different endpoints for ecosystem impacts and shows that a pdf is estimated by the ratio between the number of target plant species present in an occupied or converted land use type and the average number of species in the reference area type. As this ratio is subtracted from 1, a pdf of 0 represents a case where the level of biodiversity is at its maximum. On the other hand, a pdf of 1 means that no species are present in the assessed land use type, i.e., in the case of complete sealing of the area. In the EU-funded project NEEDS, the value of a pdf has been estimated at 0.47$€_{2000}$ (Kuik et al., 2008).

Within the original study of the IN-STREAM project (Deliverable 5.1), an approach is presented and applied that allows for the identification of a number of pollutants that can be considered more relevant for the assessment than others. This approach is similar to a study associated with the EU-funded EXIOPOL project[17] that has been carried out by Müller et al. (2009). Within this section, the total emissions for the EU-27 have been estimated using production data from the Eurostat dataset PRODCOM and emission

[16] In 2000 prices.

[17] EXIOPOL: A new environmental accounting framework using externality data and input-output tools for policy analysis; http://www.feem-project.net/exiopol/

factors from the ecoinvent2.0[18] database (Frischknecht et al., 2007). Damage factors from the LCA datasets EcoIndicator99 (Goedkoop and Spriensma, 2001), IMPACT2002+ (Jolliet et al., 2003), and ReCiPe (Goedkoop et al., 2009) have been applied to these emissions to estimated the damages for the endpoint categories human health, ecosystem quality, and climate change (in $kg_{eq}CO_2$). Based on the monetary valuation of these endpoint categories using values derived in the EU-funded NEEDS project, the total monetized damages were estimated and the pollutants ranked by their impacts. For human health and ecosystem damages, these values are presented in the section above. The valuation of GHG emissions is based on a value of 21 $€_{2000}$ for a tonne of CO_2 derived in Preiss et al. (2008). This screening procedure resulted in a list of 18 relevant pollutants. This list of pollutants is presented in Table 15 below.

Table 15: Final result of the screening process for relevant substances

Pollutants	Human health impacts	Biodiversity losses	Climate change
Ammonia	X	X	
Arsenic	X		
Benzo(a)pyrene	X		
Cadmium	X		
Carbon dioxide			X
Carbon monoxide			X
Dinitrogen monoxide			X
Dioxins	X		
Mercury	X		
Methane	X		X
Nitrogen oxides	X	X	
NMVOC	X		
PAH, polycyclic aromatic hydrocarbons	X		
Particulates, < 2.5 um	X		
Particulates, > 2.5 um, and < 10um	X		
Selenium	X		
Sulfur dioxide	X	X	
Sulfur hexafluoride			X

[18] Further information and reports for EcoInvent can be found at www.ecoinvent.org

3.9.3 Development of a sustainability indicator for health and ecosystem impacts

For the above-presented 18 pollutants, damage factors in terms of DALY, including mortality and morbidity impacts, per tonne of emissions based on results of the NEEDS project and from the LCA databases IMPACT2002+, EcoIndicator99, and ReCiPe have been applied. These damage factors per tonne of emissions have been estimated for two scenarios. First, the factors have been derived for a situation of unknown spatial characteristics of the emitting sources. Thus, the original results of NEEDS (Preiss et al., 2008) and an average damage factor for the three LCA databases has been recommended to be applied in a situation where no further information on the emitting sources is available. Second, spatial characteristics with respect to emission height and affected population density for a number of economic sectors have been provided based on work carried out in the ongoing EXIOPOL project (Müller et al., 2010). This spatial characterization of emitting sources is especially relevant for the assessment of emissions of primary particulate matter as these substances have the highest impacts on human health and the resulting damages are highly dependent on the affected number of individuals. The following table shows the applied damage factors for human health and the differentiation between levels of stack height and population densities.

Table 16: Damage factors for human health including spatial characteristics of emission source

Relevant Pollutants	Damage factors in YOLL-eq./kg			
	ground level (0-3m)	low level (3-20m)	medium level (20-100m)	high level (>100m)
Ammonia (NH_3)	2.65E-04	2.65E-04	2.65E-04	2.65E-04
Arsenic (As)	1.92E-02	1.92E-02	1.92E-02	1.92E-02
Benzo[a]pyrene ($C_{20}H_{20}$)	3.18E-01	3.18E-01	3.18E-01	3.18E-01
Cadmium (Cd)	5.81E-03	5.81E-03	5.81E-03	5.81E-03
Dioxins	9.25E+02	9.25E+02	9.25E+02	9.25E+02
Mercury (Hg)	2.00E-01	2.00E-01	2.00E-01	2.00E-01
Methane (CH_4)	4.53E-08	4.53E-08	4.53E-08	4.53E-08
Nitrogen oxides (NO_X)	1.71E-04	1.71E-04	1.61E-04	1.20E-04
NMVOC	1.07E-05	1.07E-05	1.07E-05	1.07E-05
PAH, polycyclic aromatic hydrocarbons	8.95E-04	8.95E-04	8.95E-04	8.95E-04
$PPM_{2.5}$, low pop. Density	1.69E-03	6.99E-04	6.99E-04	3.51E-04
$PPM_{2.5}$, high pop. Density	9.49E-03	1.52E-03	7.20E-04	3.51E-04
PPM_{coarse}, low pop. Density	4.95E-04	9.88E-05	9.88E-05	3.65E-05
PPM_{coarse}, high pop. Density	2.71E-03	3.83E-04	1.23E-04	3.65E-05
Selenium (Se)	2.56E-03	2.56E-03	2.56E-03	2.56E-03
Sulfur dioxide (SO_2)	2.02E-04	2.02E-04	1.76E-04	1.62E-04

For the relevant pollutants for ecosystem impacts, damage factors in form of biodiversity losses were estimated. In contrast to the damage factors for human health impacts, no differentiation between spatial characteristics of the emitting sources has been feasible. The estimated damage factors for ecosystem damages are:

SO_X: 1.73 PDF*m^2* year per kg deposition

NO_X: 9.52 PDF*m^2* year per kg deposition

NH_3: 25.94 PDF*m^2* year per kg deposition

3.9.4 Major findings

The estimated damage factors for human health (DALY/t) and ecosystems (pdf/t) have been applied to emissions scenarios that have been developed in the EU-funded HEIMTSA project. The objective of the projects was to assess the impacts on human health caused by policy measures targeting a decrease in GHG emissions by about 70% in 2050 compared to 1990, in order to remain within the Kyoto targets of a global warming by not more than 2°C. Within this project a business as usual (BAU) scenario without further climate change policies after 2012 and a scenario including these policy measures for the years 2020, 2030 and 2050 has been estimated based on different energy, transport and agricultural models.

The following figures show the results of the exercise presenting the DALYs and the pdfs for the most important substances for the years 2020, 2030 and 2050. From the tables it can be seen that damages to human health in the climate scenario are higher than in the BAU case for 2020 and 2030. This effect results from 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 which leads to a reduction in CO2 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. The assessment of health impacts needs to be taken into account when assessing the performance of the policy measures.

The effects for biodiversity caused by these policy measures are comparable 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 when comparing the BAU and the climate scenario cases. For all three years of the assessment the higher biodiversity losses in the climate scenario are related to higher emissions of NH3 in this scenario. As NH3 mostly results in agricultural processes, the increase in the emissions is related to the applied policy measures for this sector, e.g. changes in diets, consumption of less red and more white meat, changes in fertilisation processes, etc. While these measures lead to reductions in GHG emissions, the impacts on biodiversity need to be taken into account when analyzing the performance of the policy measures.

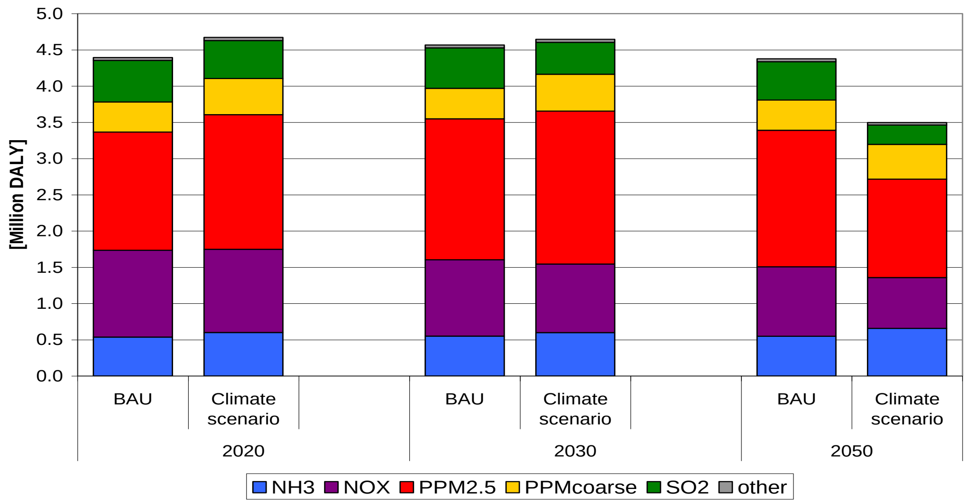


Figure 17: Human health impacts for climate change policy measures in EU-27

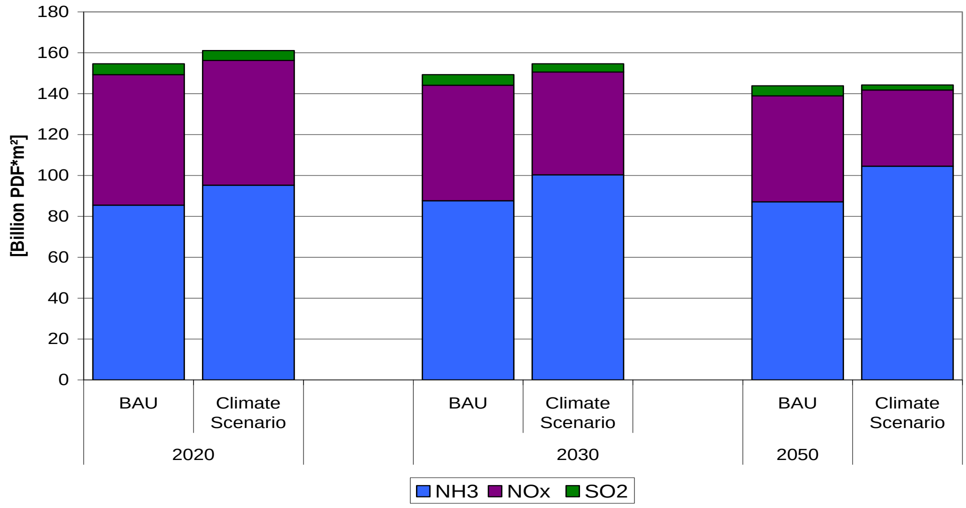


Figure18: Ecosystem impacts climate change policy measures in EU-27

Both estimations show the necessity of integrated impact assessments, including the impacts on human health and ecosystems, for the analysis of the performance of different policy measures. Furthermore, the monetary valuation of these damages allows for cost-benefit and cost-effectiveness analysis of the policies and helps decision makers to define the best policy option. In addition, the integration of health and ecosystem impacts into the political decision making process leads to an overall reduction in these impacts and helps policy makers to reach a sustainable development path. However, there is need for further research with respect to integrated assessments as well as the development of sustainability indicators. As presented, the indicators for human health and ecosystem impacts cover a limited list of pollutants identified as being relevant. For future assessments of these impacts it might be necessary to extend this list of pollutants and study damage factors for new pollutants.

For more information please see http://www.in-stream.eu/download/IN-STREAM_deliverable-5%201_110727_FINAL.pdf .

3.10 Comparison of informative capacity of aggregated sustainability index with disaggregated indicators

Sustainability literature offers one particular feature that presents interesting opportunities for policy evaluations: the possibility to develop aggregated measures of sustainability. By compounding the different dimensions of sustainable development, indices have several positive aspects: they allow summarizing the relationship among the variables, facilitate communication to decision makers, and may serve as a basis for “early warning” (UN, 1995). Well-known examples of aggregate sustainability indices include the Human Development Index, the Environmental Sustainability Index, the Environmental Performance Index, the Ecological Footprint, the Index of Sustainable Economic Welfare and the Genuine Savings.

However few issues like the construction and use of composite and aggregate sustainability indicators raise criticisms and debate. The reason is that any step of the process—the choice of indicators to include, the “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.

Against this background part of IN-STREAM's methodological quantitative research aimed to: (a) explore the potential of composite indicators to provide synthetic measures of sustainability and deliver additional information compared to those conveyed by the "simple" GDP and (b) investigate if and how economic modeling tools could support this analysis.

These issues have been addressed using a recursive-dynamic general equilibrium model for the world economic system (the Intertemporal Computable Equilibrium System (ICES) model). The model represents 40 countries/regions and 17 industries, and its simulation period is 2010-2020. With this tool a reference and emission reduction scenarios, in which the EU unilaterally cuts its GHG emissions by 20% with respect to 1990 in 2020, have been analyzed. 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) (Figure 19).

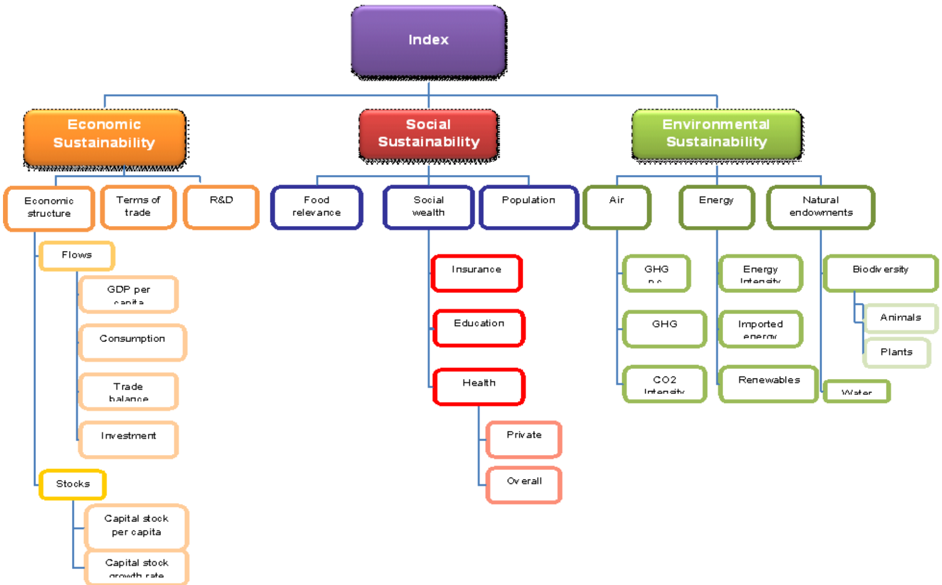


Figure 19. The structure of the FSI

The major novelties in the approach followed regard firstly the weighting and aggregation procedures in building the FSI. These take into account possible complementarity or substitutability of performances among different indicators, thus they are not simply "additive". Weights have been elicited interviewing experts in focus groups—secondly, the use of model projections. On the one hand this allows the assessment of the implications for sustainability in different countries in different *futures*. That is: sustainability can be estimated *ex ante* and not only *ex post*. On the other hand, the internal consistency of the model allows "by construction" a coherent integration of the different dimensions of sustainability inside the composite index. This will also encompass all feedbacks and interconnections among economic systems.

With this exercise it has been possible to show that, *subjected to given experts' opinions* (see Tables 17a and 17b):

Table 17a: Contribution of single indicators to the FSI according to experts' opinion

Indicator	Contribution
Food relevance	12.22%
Population	9.72%
R&D	9.21%
Water	8.26%
Terms of trade	5.67%
Energy intensity	4.91%
Renewables	4.26%
Education	4.18%
Imported energy	3.93%
CO2 intensity	3.83%
Plants	3.55%
GHG intensity	3.32%
Capital stock per capita	3.23%
Animals	3.21%
Overall health	3.08%
GHG per capita	3.07%
GDP p.c.	2.69%
Insurance	2.47%
Consumption	2.29%
Capital stock growth rate	2.15%
Investment	1.91%
Private health	1.66%
Relative trade balance	1.18%
Sum	100%

Note: different colors correspond to the three areas of sustainability: economic (yellow), social (purple), environmental (green)

Table 17b: FSI and GDP per capita country ranking in 2010

		FSI	change in ranking	GDP pc		
1	SWE	0.684	=	1.000	SWE	1
2	CHE	0.633	-2	1.000	DNK	2
3	AUT	0.629	-4	1.000	USA	3
4	FIN	0.620	-4	0.979	CHE	4
5	GBR	0.583	-1	0.978	BNLX	5
6	FRA	0.575	-7	0.962	GBR	6
7	DNK	0.561	5	0.912	AUT	7
8	CAN	0.560	-1	0.896	FIN	8
9	JPN	0.557	-5	0.884	CAN	9
10	GER	0.549	-2	0.794	AUS	10
11	NOR	0.520	-8	0.752	ITA	11
12	ITA	0.509	1	0.747	GER	12
13	NZL	0.492	-3	0.743	FRA	13
14	ESP	0.479	-1	0.738	JPN	14
15	BNLX	0.470	10	0.613	ESP	15
16	RUS	0.467	-7	0.601	NZL	16
17	Baltic	0.443	-4	0.539	PRT	17
18	RoEU	0.440	-2	0.535	GCM	18
19	PRT	0.438	2	0.425	NOR	19
20	ARG	0.394	-4	0.394	RoEU	20
21	USA	0.390	18	0.376	Baltic	21
22	RoE	0.376	-11	0.370	POL	22
23	MEX	0.371	-4	0.363	RUS	23
24	ZAF	0.362	-1	0.355	ARG	24
25	BRA	0.354	-4	0.326	ZAF	25
26	SEA	0.349	-6	0.289	TUR	26
27	GCM	0.340	9	0.285	MEX	27
28	AUS	0.332	18	0.278	BUL	28
29	IDN	0.318	-9	0.267	BRA	29
30	RoAsia	0.316	-7	0.232	MEast	30
31	POL	0.314	9	0.191	RoLA	31
32	BUL	0.294	4	0.175	SEA	32
33	RoLA	0.283	2	0.174	RoE	33
34	FSU	0.274	=	0.158	FSU	34
35	TUR	0.267	9	0.145	CHN	35
36	CHN	0.257	1	0.143	NorthAfr	36
37	MEast	0.231	7	0.122	RoAsia	37
38	RoAfrica	0.212	-2	0.086	IDN	38
39	NorthAfr	0.159	3	0.080	IND	39
40	IND	0.144	1	0.000	RoAfrica	40

There is a group of countries composed by more developed economic systems (but not by all of them), where economic, environmental and social sustainability move together. There is another group of countries, mostly, but not necessarily only, developing countries, where at least one dimension of sustainability diverges from the other. This seems to partly support an “environmental Kuznets curve” (EKC) idea: when a given level of economic development is reached, good economic, environmental and social performances could not be in opposition, but below that level the contrast can be stronger.

The first group of countries is also that of the top-performers, while the second performs lower in terms of FSI. This expresses clearly the idea of sustainability replicated by the composite sustainability indicator: the different dimensions of sustainability are complements; therefore a bad performance in any of them greatly lowers the final score.

A direct consequence of this is that one “dominant” (or at least clearly dominant) sustainability component cannot be identified over the other. Thus none of them singularly taken is able to summarize all the informative content of the FSI. This applies particularly to GDP. Its country ranking is very different from that of the FSI. The case of USA is striking. They rank first as per capita GDP, but the FSI places them 21st due to their relatively high GHG emissions per capita and energy intensity (Table 1b).

The EU pursuit of an improvement in environmental sustainability, represented by the implementation of a unilateral 20% emission reduction policy, apparently does not originate conflicts across the different sustainability dimensions within the EU. This is potential good news for policy makers. Indeed all three sustainability pillars improve. However, the EU policy can trigger potential conflicts with sustainability, especially environmental and social, in the non EU countries. Both are induced by the well-known phenomenon of carbon leakages, which on the one hand foster the economic performance of carbon intensive sectors in non-EU countries, and on the other worsen their environmental performance and drain resources from health and education investment.

The following general conclusions can then be drawn:

Sustainability can be analyzed with a consistent quantitative modeling framework, and this methodology is particularly useful to get insights on, and measure the relations between its different components. Moreover, inter-temporal modeling exercises can provide important informative support to anticipate possible trends in sustainability and its components in given (business as usual or policy) scenarios. This can be appealing to a decision maker.

In this 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 modeling of market interactions and international trade is ideal for capturing how potential tradeoffs in sustainability originates and propagates through the economic system. A CGE approach presents also specific limitations that should not be hidden. The majors 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 to deal with non market values. This said, the use of a modelling approach is a useful enrichment to the standard analysis of sustainability, particularly important to capture quantitatively and explicitly the relations between very different domains. As such it can be a powerful communication device. Nonetheless, due to the multifaceted nature of sustainability, it must not be considered the “only” or the “best” approach to analyzing sustainability, but an additional instrument in an ampler toolbox.

It is also clear that, notwithstanding the technical feasibility, it is not possible to un-controversially summarize sustainability in just one figure or for subjectivity to be ruled out of composite indicators. And this applies no matter how comprehensive, complex and innovative their generation process is. Nonetheless, there are very good reasons in favor of the use of composite indicators. As shown by IN-STREAM research, they can be invaluable communication devices to elucidate the preference structure and value judgments originating a given, synthetic sustainability assessment. They can also offer the opportunity to investigate in depth if and how this assessment can change when those preferences and values change. This information can be very interesting for policy decision makers and, potentially, is as, if not more important than the synthesis provided.

For more information please see http://www.in-stream.eu/download/D6.6a_sensitivity_%20FSI.pdf .

4 Engagement and dissemination

4.1 Identifying needs and opportunities for better communicating the importance of indicators

Any successful move towards a new or reformed set of indicators for policy making depends on, inter alia, whether such metrics are perceived as useful and pertinent by the general public. Indicators that the press and the public can easily identify with and understand (e.g. GDP, unemployment rates, inflation etc.) are arguably more readily picked up by policy makers.

In the context of WP7, an analysis was conducted on selected media and indicators to provide a better understanding of which and how sustainability indicators have been most reported on, and what is needed to improve their communicability.

The methodology adopted for this analysis covered a limited number of sources (14 newspapers) and indicators (19), and therefore aimed to provide illustrative examples rather than an exhaustive statistical analysis. Nevertheless, significant trends stand out even from this limited analysis.

Overall, there still appears to be a disproportionate coverage focusing on more traditional mainstream indicators, like GDP, and overlooking sustainability indicators. What is more, when alternative indicators are taken up by the media, they are often not the most significant ones at policy level. The media tend to prefer indicators that are easy to understand and that people can more easily relate to, or indicators that are already strongly publicised by their creators.

Among the sustainability indicators analysed, the most popular ones appear to be those measuring a combination of economic and social factors (e.g. HDI, GNH). Forthe media analysed, these indicators received far more attention over time than pressure or status indicators linked to specific environmental matters, like biodiversity. In some cases, this appears to be related to the reputation of the source (e.g. the United Nations for the HDI), as well as the 'popularity' of the issue measured (e.g. 'happiness' is a topic that people can easily relate too). Other indicators, for example the water and ecological footprints, are generally very popular thanks to their ability to quicklyconvey a complex metric (e.g. ecological impacts measured in terms of 'planets' used) and the intensive marketing and/or awareness campaigns conducted by NGOs.

In general, there seems to be a more prominent focus on indicators measuring social and economic factors at the expense of those measuring the pressures on and status of biodiversity. This lack of attention from the media can be in stark contrast, in some cases, with decision-making actors. For example, the Common Bird Index, a headline indicator in the Sustainable Development Strategy, is widely known and discussed in the wider policy community, however, in the last 20 years, it has never been mentioned in the selected media sources.

Sustainability indicators as a whole are, seemingly, rarely referred to as alternatives to GDP by the media when measuring or discussing progress. A cursory research shows a vast difference in popularity between the two sets of indicators. Nonetheless, the limitations of GDP in measuring true progress have been extensively covered by the print media.

Discussions on such a topic, and on sustainability indicators in general, have tended to cluster around specific events, such as domestic or international political developments, the regular publication of statistical or qualitative reports on sustainable development, and the creation of a new indicator.

There is clearly a disconnect between the sustainability indicators that are most used or needed by policy makers and the information passed on to the general public. There is therefore a need to improve the communicability of some key indicators, for instance by translating their result into more understandable messages and increasing public interest though more frequent awareness raising campaigns.

On the other hand, some indicators may be simply too complex to be easily communicated. For instance, an indicator like the Human Appropriation of Net Primary Production (HANPP) can be extremely informative for policy making (e.g. for agriculture policy and resource efficiency), but too technical to be communicated to the general public. Other indicators, like the Ecological Footprint, can be considered less robust by the scientific community, but widely taken up by the media for their clear message. Similarly, an accurate indicator like the Marine Trophic Index (MTI) can be difficult to appreciate by the public, while a more simple measure of 'fish catch' would be easily communicated. This does not mean that some indicators are better than others, but rather that indicators can have different functions. While some may be more suitable for policy and research, others would be more appropriate to communicate a message to the outside world.

It is therefore important that the right indicators are used for the right purpose. There is sometime a trade-off between meaningfulness and clarity that should be taken into account in policy making. While in general the communicability of sustainability indicators and the awareness around their importance should be improved, it may also be necessary to choose different indicators for analysis and for communication. This can ensure that the most robust indicators are used to inform policy choice, and at the same time that the importance of sustainability criteria is fully appreciated by the public.

4.2 Stakeholder workshops and final conference

In the context of the IN-STREAM project, three workshops were organised in the course of 2011 to disseminate and discuss preliminary results with relevant stakeholders in different European cities. Each of the events was structured around one of the three storylines developed for the project: biodiversity, resource efficiency and green growth.

The key aims of these events were to:

- Introduce the IN-STREAM project and its objectives;
- Present useful findings and approaches of interest for policy makers, indicators users and researchers;
- Share views and experiences on how sustainability indicators have been used and should be used in the future for policy making; and

- Contribute to the sharing of information and increased use of sustainability indicators.

The first workshop focused on the use of sustainability indicators for biodiversity policy, and took place in Brussels on the 8th and 9th of February 2011. It was carried out jointly with a workshop on footprint indicators organised in the context of the OPEN:EU (One Planet Economy Europe) FP7 project.

The second workshop centred on the use of sustainability indicators for resource efficiency policy, and took place in Prague on the 7th of April 2011.

The third workshop focused on the use of sustainability indicators for green growth, and took place in Berlin in July 2011.

Overall, the workshops' participants showed a real interest in the issues investigated by the project. There was a general consent that the IN-STREAM analysis of the use of indicators in various policy areas and at different phases of the policy cycle yielded valuable insights. The work approach, structured around the three storylines, was also appreciated.

It was noted that the policy areas investigated are closely interlinked with each other. The linkages and commonalities between them makes a whole range of issues very relevant across all the three storylines (e.g. land-use), pointing to the need for sustainability indicators to account for cross-policy impacts.

Across all the storylines, strong advocacy for the development of indicators supporting a life-cycle perspective emerged. It was also stressed that indicators should help provide insights into the pressures of human activities and consumption outside European boundaries. There was a large consensus that the use of policy-specific indicators (e.g. biodiversity indicators, climate change indicators etc.) should be streamlined across different policies to ensure a more holistic and integrated approach to environmental issues.

The importance of understanding the scale at which indicators can /should be used (national-regional-local) and the different stakeholders groups that would benefit from using them was highlighted.

It was noted that, given the wealth of indicators on offer, efforts should focus on identifying and assessing the indicators which are most promising and that can help improve how we 'measure to manage'. The choice of indicators, it was noted, should also be driven by a clear understanding of the questions they should help answer.

The role of environmental accounting frameworks such as the SEEA should also be given due attention, as they can support indicator development by making data available, and have therefore the potential for being a game changer in the 'Beyond GDP' process.

In this regard, the issues of data availability, timeliness and robustness of information were also mentioned several times in the course of the workshops. The case was made for further harmonisation and improvement of data collection methods in order to strengthen the use of indicators.

In the course of the workshops it was highlighted that the type of analysis the In-Stream engaged in is increasingly on demand, reflecting an rising interest in sustainability indicators and in their application to policy making. This follows from the recognition that today's environmental challenges are so broad that they require economy-wide solutions. The progressive mainstreaming of environmental policy into other policy areas transformssociety and the economy, a fact which increases the demand for orientation and macro-aggregate level analysis.

Further information on the events, including the power point presentations and full minutes, is available on the project website http://www.in-stream.eu/events.html.

For more information please see Deliverable 7.3 on http://www.in-stream.eu/docs.html .

4.3 Dissemination work of IN-STREAM

Additionally to the stakeholder events described above, IN-STREAM has used several channels for dissemination of its work and its results.

IN-STREAM website

The website has been updated regularly with the newest publications, announcements on stakeholder events, documentations of past events and a newsfeed. The website was also advertised in the presentations and newsletters described below. The project website featured a:

- **home page** with a general description of the project and the project partners and a newsfeed that regularly showed new developments in the politics and research of "Beyond GDP".
- A **Documents** page whereall deliverables of IN-STREAM and the workshop documentations were posted.
- An **events** page advertising IN-STREAM workshops including the internal workshops.
- Ad dedicated **conference** page that provided all details of the final conference including a facility to register online.

Newsletters

Overall three newsletters have been sent to over 500 recipients interested in the Beyond GDP process. The newsletters contained links to the most recent results of IN-STREAM and announcements of the stakeholder events. The newsletters were sent in January 2011, August 2011 and November 2011 and are available on the IN-STREAM website http://www.in-stream.eu/docs.html .

The workshops and the conference of IN-STREAM were also advertised in the newsletters of IEEP (http://www.ieep.eu/newsletter/autumn-2011/) and the Ecologic Institute.

Scientific Conferences

IN-STREAM project members have been presenting the results on various scientific conferences:

- Arnold, S (2011), *The Forgotten Dimension of Sustainability,* Public Lecture in the Global Futures Series, 7 April 2011, University of Bath.

- Arnold, S (2011), *Social Sustainability: Concepts and Indicators,* Departmental Seminar, Department of Economics, 26 January 2011, University of Bath. 2

- Arnold, S (2010), *Social Sustainability: Issues and Indicators,* Presented at the International Workshop on Sustainable Paradigms: From the definition to the operationalisation of sustainability indicators in policy making, May 2010, Venice.

- Arnold. S. (2009), *Indicators of Economic Success, Human Well-Being and Environmental Protection: The IN-STREAM Project,* Talk given at the Sustainable Consumption and Production Network (SCPnet) Networking Event (UK Environment Agency and Regional Development Agencies), 21 October 2009.

- Bosello, F. (2010), Presenting FEEM SI at the, "OECD Annual Meeting of Sustainable Development Experts (AMSDE)", 18 October 2010, Paris, France.

- Bosello, F. (2010), International Workshop on "Sustainable Paradigms from the definition to the operationalization of sustainability indicators in policy making", 24 May - 25 May 2010, Fondazione Eni Enrico Mattei, Venice, Italy.

- Bosello, F. (2010), Presenting FEEM SI - "Beyond GDP, Italy in the world sustainability ranking", University of Basilicata, Potenza, Italy, 4 March 2010.

- Bosello, F. (2010), Presenting FEEM SI - "Beyond GDP, Italy in the world sustainability ranking", Fondazione Eni Enrico Mattei, 18 December 2009, Venice, Italy

- Bosello, F. (2010), Presenting FEEM SI - "Beyond GDP, Italy in the world sustainability ranking", Fondazione Eni Enrico Mattei, 10 December 2009, Milan, Italy.

- Müller, W. (2011), Presentation of the IN-STREAM and EXIOPOL projects at the 6^{th} International Conference on Industrial Ecology organised by the International Society for Industrial Ecology (ISIE) at the University of California in Berkeley, California.

- Ščasný, M. (2011), Distributive impacts of emission reduction policies. Presentation at the Final IN-STREAM Conference: Beyond GDP - Sustainability Indicators for Policy Making, Brussels, 27/28th September 2011.

- Toth, F. (2010), FEEM workshop on 'Sustaianble Paradigms', 24-25 May 2010.

- Tsuchimoto, F., Ščasný, M. (2011), *Decomposition Analysis of Air Pollutant in the Czech Republic*, Paper presented at the 18th Annual Conference of the European association of Environmental And Resource Economists (EAERE), 29 June – 2 July 2011, Rome.

- Tsuchimoto, F. (2011), "The Statistical Decomposition Analysis of Local Air Pollutant in the Czech Republic". Seminar series Super Solidam Petram, 23 March 2011, Charles University in Prague, Czech Republic.

Scientific Publications

Additionally the IN-STREAM team published and prepared several scientific publications of IN-STREAM results.

Publications:

- Böhringer, Christoph und Victoria Alexeeva-Talebi (2011), *Unilateral Climate Policy and Competitiveness: The Implications of Differential Emission Pricing*, Oldenburger Diskussionspapiere, V-338-11, Carl von Ossietzky Universität Oldenburg.
- Cardin M., S. Giove, (2008), "Aggregation functions with non-monotonic measures", *Fuzzy Economic Review*, ISSN: 1136-0593, 13, 2, 3-15.
- Carraro C., F, Ciampalini, C. Cruciani, S. Giove, E. Lanzi, "Aggregation and Projection of Sustainability Indicators: a New Approach", Paper prepared for the OECD 3rd World Forum, 27-30 October 2009, Busan, Korea.
- Carraro, C., Cruciani, C., Lanzi, E., Parrado, R., (2011), "Nuovi orizzonti per lo sviluppo sostenibile", *Rivista Delle Politiche Sociali* N. 1, 2011.
- Cruciani C., E. Lanzi, Sustainability: the road not (yet) taken beyond GDP?, FEEM Policy Brief 2010.09
- Lanzi, E. e R. Parrado, 'Gli impegni di Cancún, gli impatti sulla sostenibilità', *Equilibri* 2011.01.
- Lanzi E., R. Parrado, "The hidden trade-off between climate policy and sustainability: an obstacle or a source of incentives to achieve an agreement?", FEEM Policy Brief 2010.08
- Ščasný, M., Tsuchimoto, F. (2011), Index-based Decomposition of SO2, NOx, CO and PM Emissions Stemming from Stationary Emission Sources in Czech Republic Over 1997-2007. In: Costantini, V., Mazzanti, M., Montini, A. (eds.), Advances in the Analysis of Hybrid Economic-Environmental National Accounts. Routledge, Series Routledge Studies in Ecological Economics, pp. 240. (*Published November 21st,* 2011; http://www.routledge.com/books/details/9780415594219/).
- Toth, F. (2011/12), Publication in the "Options magazine", IIASA.

Planned Scientific Publications:

- IEEP will be publishing a non-academic paper under the IEEP series 'Directions in European Environmental Policy (DEEP)' focusing on the current and potential use of sustainability indicators in policy makers, building on deliverable 7.4. The paper is in the process of being finalised and will be soon uploaded in IEEP's website. The team will aim to turn the DEEP paper into a paper/article for publication in an academic journal in the near future.
- The University of Stuttgart is preparing a paper on the spatial characterisation of sectors and the derivation of sector specific monetary damage factors.

Other dissemination events

The IN-STREAM team has also provided input into other dissemination events targeted at non-academic audiences:

- **Umweltbundesamt (Federal Office for Environmental Protection):** As part of a national German Workshop on Sustainability Indicators, the Ecologic Institute organised a dinner dialogue on the work of IN-STREAM. Klaus Rennings from the ZEW presented the IN-STREAM work on composite Indicators to members of the regional statistical offices and the national Environmental Protection organisations http://ecologic.eu/4268 .

- **American Voices Abroad:** Together with American Voices Abroad the Ecologic Institute organised a seminar on Beyond GDP indicators, presenting work done in IN-STREAM and comparing the European work with the US experiences. http://ecologic.eu/4266 .

5 Conclusions

The work of IN-STREAM focused on the links between mainstream economic indicators and sustainability measures and on the connection between the economic, social and environmental dimensions of sustainability. The final project aims were to test qualitatively and quantitatively strengths, weaknesses and redundancies of a selected set of key sustainability indicators and to propose qualitative and quantitative approaches to investigate the complex theme of sustainability. The outcome of this work would be to derive concrete guidelines for policy makers and practitioners in the field on indicator selection, use, and interpretation.

The first, and unsurprising, IN-STREAM research result is that sustainability, being a multifaceted concept, has to be investigated with different methodologies, different analytical tools and, most importantly, by gathering information from different indicators. In other words, developing "one size fits all" sustainability indicators or investigation approaches for sustainability assessment is unproductive. These require tailor made approachesfor each "pillar" of sustainability, each different aspects within each pillar, and each policy under scrutiny.

This is clearly demonstrated by the different quantitative analyses performed within IN-STREAM often stressing the weak correlation, if not the trade-off, between the economic dimension as measured by mainstream indicators (above all GDP) and the social and environmental ones. By the same token, similar contrasts potentially emerge between different economic, environmental, and social goals.

Specifically, IN-STREAM stressed how the EU climate change mitigation policy can conflict with economic goals: interestingly enough the economic variable most adversely impacted is not GDP (whose decline is limited), rather the competitiveness of energy intensive sectors. IN-STREAM also stressed that mitigation goals and the related implementation strategies can trade-off other environmental goals, at least in the short-medium term. This is for instance the case of biodiversity that can be threatened by the development of some GHG saving agricultural practices, or by unregulated biofuel development. The social dimension is also potentially at risk. For instance EU mitigation goals can foster the use of less carbon intensive, but more health-impacting fuels increasing mortality; they can increase food insecurity and the number of people at hunger risk outside the EU; or entail adverse distributional effect within a more regressive country.

These outcomes are not meant to convey an overly pessimistic message. On the contrary, they stress that a complex problem should be tackled by a panoply of instruments, to explicit synergies and trade-offs at stake. In particular IN-STREAM also showed that policies, if properly designed, can reduce, if not eliminate, undesired policy impacts.

This said, IN-STREAM directly addressed two very practical key questions :

- How to select the "right" indicators?
- How to interpret contrasting information?

Both issues have been tackled qualitatively and quantitatively.

IN-STREAM developed an improved version of the RACER (Relevance, Acceptability, Consistency, Easiness, Robustness) methodology for assessing the value of scientific tools for use in policy making, and of the SWOT (Strengths, Weaknesses, Opportunities and Threats) tool, originally applied for assessing an organization's, business' or program's ability to achieve a stated objective. Applying these tools to indicator selection, both proved to be very useful in focussing on the right indicator set. The potential of these methods is greatly increased when indicators are then related to the different phases of the policy cycle they have to support.

Under the quantitative point of view IN-STREAM pointed out that, standard correlation analysis can already provide a useful support in indicator selection. Showing when and by how much two indicators are linked helps to avoid unnecessary duplications in the indicator set. Robustness/sensitivity tests are another powerful methodology to select indicators especially when one sustainability aspect can be measured by many of them. When different options are at hand, it is reasonable to choose the one whose results are less influenced by changes in the initial conditions.

Concerning the interpretation issue, IN-STREAM demonstrated the usefulness of quantitative modelling framework, top-down or bottom-up. They can provide insights on the possible relations between different sustainability components, regional implications, potential trade-offs associated with the pursuit of certain policy objectives in a internally consistent, integrated and controlled environment. Moreover, very important under the policy view point, forward looking modelling exercises can provide important informative support to anticipate possible trends in sustainability. IN-STREAM also applied statistical decomposition techniques showing their ability to single-out the different component of the success (or failure) of a given policy. Finally IN-STREAM highlighted the informative support of composite indicators. In general, it is neither possible to summarise sustainability in one figure, nor to rule subjectivity out of them, no matter how comprehensive, complex and innovative their generation process is. Nonetheless, composite indicators can be important communication devices to make the preference structure and value judgments more explicit, underpinning any given sustainability assessment. They can also offer the opportunity to investigate in depth if and how 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.

To conclude, IN-STREAM also highlighted research gaps and line for future research.

Notwithstanding the large number of existing indicators, the role of biodiversity and ecosystem services in promoting sustainability, albeit recognized, is still not (or only partially) mainstreamed in sustainability policy analyses. Respect to this, indicators including thresholds and tipping points; shared view and metric on impact indicators (what happens to biodiversity?) and on response indicators (are policies successful to preserve improve biodiversity?) are needed.

A similar consideration holds for the interpersonal and spatial, social and equity dimension of sustainability. It is still underrepresented especially in quantitative sustainability assessments due to the objective difficulty to measure social capital. More research on this is thus needed.

Strictly related to this, the development of modeling tools for sustainability assessment and of robust/shared methodologies to compare their outcomes and the performances of different indicators, possibly emphasizing the role of impact rather than pressure indicators can be particularly useful.