Spatial-economic-ecological model for the assessment of sustainability policies of the Russian Federation

Project 213091

D4
Description of a set of the sustainability indicators coupled with the constructed model

Contract No.	SUST-RUS 213091
Workpackage	WP4 – Description of a set of the sustainability indicators coupled with the constructed model
Date of delivery	M18
Actual Date of Delivery	M18
Dissemination level	Public
Responsible	TML
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Status of the Document	Draft
Version	1.0

The research leading to these results has received funding from the European Community's Seventh Framework Program (FP7/2007-2013) under grant agreement No. 213091.

Table of contents

Figures

Tables

1. The SUST-RUS project

The objective of the SUST-RUS project is to develop and implement for Russia an integrated spatio-economic-ecological modelling approach, which represents the state-of-the-art in different areas of economic, transport, resource-use and environmental modelling, and can be used to assist policy makers in their choice of medium and long-term sustainability policies.

The purpose of this report is to introduce and develop a set of sustainability indicators associated with the model, which allows for quantification of social, economic and environmental effects of sustainability policies This will improve the use of the model as a tool to assess the effects of a set of important sustainability policy measures.

Sustainability means that the needs of the present generation should be met without compromising the ability of future generations to meet their own needs. The EU sets the following key objectives concerning sustainability[1]:

1. Environmental protection
2. Social equity and cohesion
3. Economic prosperity
4. Meeting international responsibilities

The SUST-RUS modelling approach is characterized by a balanced integration between social, economic and environmental policy objectives. Therefore, in this report we will uncover the appropriate indicators along these dimensions.

The SUST-RUS model will allow to tackle the following issues: rational use of available natural resources and land; differences in the economic development of Russian regions; efficient use of labour; environmental impacts of transportation, production and consumption activities distributed in space; analysis of inequality and poverty in the country; influence of international trade and delocalization of economic activities of the EU upon the Russian economic development.

2. Indicators for sustainability

2.1 Introduction

The concept of sustainability indicators

Indicators provide a different type of information than normal statistical data. A good indicator is a tool that expands the meaning of the attributes that composes it and can lead to better decisions and more effective actions by simplifying, clarifying and making information available to policy makers.

Traditionally indicators were used to measure economic development. As the notion of sustainable development expanded, it became apparent that indicators such as GDP failed to address issues inherent in the sustainability concept and therefore different measures had to be developed.

Sustainability indicators may be viewed as toolkits to guide policy makers when choosing among various policy options taking sustainable development into account. They ought to build the foundation for improved information and data collection, and enable a comparative and national (or regional) specific analysis of the state of and progress towards sustainable development.[2]

[1] EU-SDS: EU sustainable development strategy

[2] Spangenberg , J.H., Pfahl, S., Deller, K., 2002, Towards indicators for institutional sustainability: lessons from an analysis of Agenda 21, Ecological Indicators, 2, 2002, 61-77

Characteristics of an effective indicator

An indicator is a quantitative or qualitative measure derived from a series of observed facts that can reveal positions in a given area. When evaluated at regular intervals, an indicator can point out the directions of change across different units and through time. In the context of policy analysis, indicators are useful in identifying trends and drawing attention to particular issues. They can also be helpful in setting policy priorities and in benchmarking or monitoring performance.

Table 1: Properties of sustainability indicators

Scientific	Functional	Pragmatic
Measurable and quantifiable: they should adequately reflect the phenomenon intended to be measured	**Relevant**: for all stakeholders involved	**Understandable**: should be easily understood by stakeholders
Meaningful: appropriate to the needs of the user	**Leading**: so that they can provide information to act on	**Feasible**: measurable at reasonable effort and cost
Clear in value: distinct indication which direction is good and which is bad	**Possible to influence**: Indicators must measure parameters that may be modified	**Coverage of the different aspects of sustainability**: indicators address economic, environmental and social dimensions
Clear in content: measure in understandable units that make sense	**Comprehensive**: the indicator set should sufficiently describe all essential aspects under study	

Many indicators can be considered but this study selects indicators based on the following considerations:

- Assuring that indicators are representative
- Keeping the number of indicators at a reasonable level and striving for a certain balance in terms of number of indicators representing the various dimensions of sustainability
- Trying to avoid excessive overlapping
- Assuring practicability and feasibility; in particular having confidence that the indicators can be generated within the project.

Criteria and indicator set

Although the original definition by the Brundtland Commission from 1987 does not make such distinction3, sustainable development has later become perceived as a combination of three dimensions or "pillars", namely, the environmental, economic and social dimensions.

The different indicators are therefore classified following the three "pillars". We have economic, environmental and social indicators.

[3] Lehtonen, M., 2004, The environmental-social interface of sustainable development : capabilities, social capital, institutions. Ecological Economics. 49, 199-214

2.2 International experience with sustainability indicators

While indicators have been increasingly under study and the methods and data range has increased considerably over the years, there is no unifying framework or common indicator set which is universally accepted. Instead there have been several attempts at collecting indicators, often pushed by international organizations to provide at least a 'tool box' for common sustainability measures. Most notably the United Nations (UNCSD) has made a very comprehensive set of indicators which have a large acceptance within the international scientific community.

Since the term sustainable development gained major prominence in the 1987 (Brudtland), the EC has made considerable efforts to take up sustainability in many of its policies and 'act upon the right indicator'. The requirement for environmental considerations to be integrated into all Community policies was added in the 1992 Treaty on European Union (Maastricht Treaty) and reinforced in the 1997 Treaty of Amsterdam. The Cardiff European Council in June 1998 asked several Council formations to report on their steps towards integration of environmental concerns into their policies. This included a requirement to produce indicators to monitor progress. The first 'sphere of indicators' or dimensions mentioned only 4 priority goals: Climate change, Transport, Public health and Natural Resources (2002). The list continued to expand later on, extending the priority goals to 8 (2005) and finally 10 priority goals (2006) and mentioning several 'depths' or 'levels' of measures directed at several subgroups. Additionally, member states displayed a growing awareness of sustainability and started creating own frameworks of indicators, focused on elements of national importance, coinciding or at least touching on many of the 'common' aspects of sustainability studies.

The first full report on key 'sustainability indicators' of the OECD data from 1993 and since then the initial framework was updated regularly. In 1997, OECD developed a glossary of environment statistics. In 1998 the OECD launched the so-called sustainable development initiative, which culminated with a declaration from the OECD Ministerial Council and the publication of two reports on the OECD approach to sustainable development (OECD, 2001a, 2001b). The Council decided to extend the project by three years (2001–2004), which included a mandate to develop agreed indicators and incorporate these in OECD economic, social and environmental peer reviews. Sustainable development remains one of the five priority areas for the future work of the OECD, developing indicators is one of the key activities. One of the well known analytical frameworks, which was adapted by the OECD is the PSR framework (pressure-state-response) for economic (human) pressures on environment. The key indicators of the OECD are listed (by theme) in Table 3.

The World Bank has taken up similar efforts in developing sustainability indicators. However, the approach here was often more focused on the institutional side and on the specific social and environmental problems of developing countries. The indicators and frameworks used by the World Bank are in many ways close to the UNCSD indicators and experience of the OECD.

Table 2: Overview of international indicatory systems (adapted from INDI-Link project)

Organization	Activity scale	Headline set	Broader set	Framework	Criteria
United Nations division for Sustainable development (UNCSD)	Global	Core indicators as guideline for other countries (50)	98 SDI (larger set) allow for a more comprehensive set	SDI are placed in framework of themes and subthemes (15 themes)	SDI fulfill 3 criteria 1) relevance 2) critical 3) data readiness
OECD	OECD Member countries (30)	Core set of indicators (18)	Indicators for detailed environmental performance	Three themes: 1) environmental assets 2) economic assets 3) human capital	1) relevance 2) utility for users 3) analytical soundness 4) measurability
EU SDI	European Union Countries	10 Priority goals key indicators (14)	Level 2 and level 3 indicators with broader contextual framework	SDI are put in a framework of 10 priority goals linking to society, economy, government, environment, …	1) relevance for priority group (depending on level) 2) analytical traceability 3) measurability
World Bank	Large number of indicators along 3 dimensions	Economy, states and markets and global links			Indicators follow the principles of governing international statistical activities of the United Nations

OECD indicators in *Table 3* are specified by 'Assets' and 'Outcome' indicators. Environmental, Human and Economic capital is distinguished. The current outcome indicators are a mix of economic, social and quasi-environmental (for example urban air pollution) indicators. The 'depreciation' of human capital (unemployment ratio) and 'investment in human capital' (education expenditures) are very close to the 'current outcome' indicators 'employment to population' and 'education participation' rates. It is unclear if an indicator like the Gini coefficient is a social or economic indicator or health should be defined as ' human capital'.

Table 3: OECD key indicators

ENVIRONMENT ASSETS	Indicator(s)
Air Quality	GHG emissions NOX emissions
Water resources	Intensity of water use
Energy resources	Consumption of energy resource
Biodiversity	Size of protected area
ECONOMIC ASSETS	
Produced asset	Volume of net capital stock
R&D	Multi-factor productivity growth rate
Financial assets	Net foreign assets and current account balance
HUMAN CAPITAL	
Stock	Proportion of population with secondary/tertiary education
Investment in human capital	Education expenditure
Depreciation of human capital	Rate and level of unemployment
CURRENT OUTCOME	
Consumption	Household consumption
Income distribution	Gini coefficient
Health	Age expectancy at birth
	Urban air quality
Work status	Employment to population ratio
Education	Education participation rates

2.3 The search for sustainability indicators

2.3.1 Gross Domestic Product (GDP)

Until today, the Gross Domestic Product is used as the main indicator for economic vitality and wealth. It is the total market value of all final goods and services produced in a country in a given year, equal to total consumer, investment and government spendings, plus the value of exports, minus the value of imports. GDP is the crossing point of three sides of the economy: demand, production and income. It is important to take into account that GDP will measure the value of each product or service only once: the "final" value.

While internationally accepted and used in all relevant economic domains, its interpretation as a progress indicator is increasingly put into question by researchers, local communities, civil society, political authorities and international economic institutions (OECD, World Bank, European Union). While the link between GDP growth and welfare from low to medium levels of production has been proved, the real problems arise when comparing developed economies on the basis of GDP. This has been stated in the threshold hypothesis of Max-Neef (1995), stating that beyond a certain level of economic growth, there comes a point where welfare does not increase anymore and even can come to deteriorate. Therefore, growth in GDP should not be confused with growth in human welfare

In the context of sustainability this indicator is useful as a 'benchmark' indicator. It gives us information on the amount of production and the 'supply side' of the economy. It is a barometer for economic production, without any additional interpretation. In the context of economic modelling it is important to check the balance between factor incomes, value added and final demand.

The real question in a sustainability context, however, remains – how production is organized and which resources it employs?

A first important observation on GDP is that 'costs' and 'benefits' are counted together. The complete turnover of the economy is added together, not distinguishing the good from the bad… According to Stiglitz (2005) "No one would look at just a firm's revenues to assess how well it was doing. Far more relevant is the balance sheet, which shows assets and liabilities.

If countries "…strive to increase measured GDP, they may take actions which now, or in the future, may actually lower societal well-being. This is especially the case if our metrics do not take account of sustainability, if current consumption puts in jeopardy, for instance, future living standards. The most obvious cases involve depletion of resources and the degradation of the environment." (Stiglitz et al., 2009).

An important distinction to make is the types of goods produced. Should 'curative sectors' like recycling, waste cleaning, health services, law and order maintenance be quantified in the same way? This could lead to the perverse effect that pollution is actually counted as a benefit in GDP through higher health expenditures and waste cleaning. Even war and crime could be interpreted as motors of household and government expenditures. An illustration to this is provided by C. Cobb et al. (2007). A newspaper headline after the passing of hurricane Katrina and Rita through New Orleans, pointed at the enormous (more than expected) growth of GDP a few months later.

A relevant shortcoming in the case of the Russian economy is that GDP does not cover transactions in the informal economy. The real size of this informal economy is under dispute. The estimations of Byung-Yeon, Kimand, Youngho and Kang (2009) indicate it to be in the range from 12% - 38% of official GDP in the period 1992-1999 depending on the region of study.

A related but different topic is household work and volunteering. Many economic activities are supported by unpaid work often occurring within the household, communities and informal neighborhood efforts.

From a social point of view GDP is an insufficient measure as it does not take into account inequality in personal consumption and income. Neither does it take into account poverty.

As an environmental measure GDP has even more severe shortcomings as it does not take into account pollution damages, the cost of using non-renewable resources, loss of valuable lands used for agriculture or water logging and decreases in biodiversity. Actually GDP completely ignores natural resources other than those that are exploited and traded on the market. Under the GDP metric, complete devastation of natural resources may actually be a 'good' thing as it will fuel domestic production and lead to subsequent clean-up costs later on.

2.3.2 Alternative sustainability indicators

The previous paragraph clearly states that focusing only on maximizing production (GDP) is not a welfare improving or sustainable approach. A wide variety of other approaches were developed to construct new progress indicators. They were applied by different institutions including international organizations (World Bank, UNDP), statistical offices (Eurostat, Destatis), civil-society organizations and campanies and independent think-tanks (the New Economics Foundation, Redefining Progress).

The main three approaches were:

- Adjusting the original gross domestic product indicator to correct for its flaws
- Replacing gross domestic product by a totally new indicator
- Supplementing GDP by a set of economic, social and environmental indicators.

1) Adjusting GDP: Distinguishing goods and bads

Increasing specificity of GDP

One of the easiest adjustments in GDP is splitting up production of different sectors. In this way we can distinguish among agriculture, resources, industry, electricity, services of private firms, transport, government services to population, health sector, etc. The same distinction can be made at regional level.

ISEW and GPI

Several extensions to GDP were proposed, and the ISEW (Indicator for Sustainable Economic Welfare), GPI (Genuine Progress Indicator) and Genuine savings indices are the most notable.

The ISEW (Daly and Cobb, 1989) and GPI (Cobb et al., 1995) are very similar indicators. The basic idea of these indicators is to 'update' household/personal consumption expenditures into several categories, distinguishing 'good' and 'bad' expenditures, environmental damage, natural capital adjustments and inequality. All of these extra categories are valued in monetary terms. GPI essentially adds new data to the original ISEW indicator, including crime, divorce, loss in leisure and dome other topics. The amount of information taken into account by these indicators can be substantial and can include commuting costs, advertising costs, health expenditures, expenditures on consumer durables, informal economy, etc.

ISEW = Personal/household consumption expenditure - adjustment for income inequality + services from domestic labour costs of environmental degradation- defensive private expenditures + non-defensive public expenditures + economic adjustments - depreciation of natural capital.

GPI = Personal/household consumption expenditures + value of household work + value of volunteer contribution work - crime factor - environmental degradation factor (resource depletion, ozone depletion, pollution) - family breakdown factor- overextended worker stress factor - exploding consumer debt - inequality of distribution of wealth and income

While GPI has found its way to the public, it is questionable that it could be used as a policy instrument. The most important problem of ISEW/GPI indicators is the monetary value that is assihned to each additional category. The selection of criteria and the methods of assigning monetary values to them show a certain degree of arbitrariness, and have indeed changed over time and across studies. Other authors have questioned the mere possibility and merits of quantifying sustainability factors in a single (monetary) unit. Additionally, calculations of GPI rest on estimates and interpolations.

Green net national product

The unsustainable development leads to a net loss in capital, especially in natural resource capital and social capital. Green net national product indicator is similar to the NDP (net domestic product), but substracts the depreciation of natural capital from the index. According to Solow (1993), this is an estimate of Hicksian income, which shows the maximum we can consume in the present period without reducing future consumption possibilities. Hence this fits reasonably well with the notion of 'satisfaction of current needs, without compromising the possibilities of future generations'.

The original framework for the GNNP was developed by Hartwick (1990), who suggested deducting depreciation of all forms of natural capital (valued by the difference between price and marginal cost of providing natural capital) and changes in pollution, valued at marginal abatement costs. However, there exist many variations on the idea how the adjustments to natural capital should be calculated.

Genuine savings

Pearce and Atkinson (1993) proposed a measure of 'weak sustainability' which was an empirical application of the Hartwick rule: Genuine Savings (or adjusted savings). The indicator is used and developed by the World Bank. Basically it measures how much the country is investing in future consumption. Genuine savings measures net investments in physical, natural and human capital. It recalculates national savings by accounting for depreciation of production assets, depletion of natural resources, the value of global environmental pollution (including loss of welfare in the form of human sickness and health), and investments in human capital (spending on education is seen as saving rather than consumption as it increases human capital).

Genuine Savings is a forward-looking indicator, accounting for changes in capital stocks that will lead to future changes in income. As it takes into account human and natural capital it provides a more broad picture than traditional saving rates. The Genuine Savings approach can be usefully applied as a policy tool, e.g. to encourage resource-rich countries to invest their resource rents in other forms of capital in order to secure a sustainable path (Dietz and Neumayer, 2006). It also draws attention to investments in human capital and good governance.

The genuine savings indicator is a useful tool but is criticized on similar grounds as ISEW and GPI. The expression of natural and physical capital in monetary values and the perfect substitution which is assumed between these forms of capital is a mayor point of comments.

There are several additional ethical arguments against the definition of 'human' and 'natural' capital used by the World Bank.

Also due to the absence of data not all natural resources are taken into account, leaving a gap for interpretation problems.

2) Replacing GDP:

Ecological footprint (EF)

The Ecological Footprint is an accounting tool to measure how much nature a given group of population or country is using. It is measured in land units and is based on the assumption that each human activity uses resources and has waste flows which can be converted to a biologically productive area necessary to provide these functions (Wackernagel and Rees, 1996; Wackernagel et al, 1997). The interesting result is that since 1988 the humankind has been consuming more than the carrying capacity of the Earth.

The ecological footprint is a useful tool, but it is a rather indirect way for calculating sustainability. Consumption of resources is coupled with an amount of land use, which does not provide information on state of the economy or society. Ecological footprints tend to give low values for developing countries and high values for developed countries. This makes the indicator questionable for comparisons of human development.

However, this tool is useful for global monitoring of resource usage. Its contribution to the sustainability concept is based on the fact that it highlights the issue of equity between nations, between developing and developed societies. It has also raised awareness of the sustainability issues and demonstrated the human contribution to global changes.

Human Development Index (HDI)

The Human Development Index (HDI) is a composite index measuring the average achievements of a country in three basic dimensions of **human** development (UNDP, 2004): 1*) Life expectancy at birth*, 2) *Human capital*: adult literacy rate (with 2/3 weight) and the enrolment ratio (with 1/3 weight) 3) *Living standard*: GDP per capita adjusted to PPP. It is a performance indicator in the sense that the actual values are weighted against maximum and minimum target values on a 0 to 1 scale. Then it is calculated as a simple average of the 3 dimensions.

The HDI has proven its value in debates on internal disparities between countries and investments in human capital, however its focus on 'human' welfare makes it too anthropocentric to be used as a value for sustainability. It illustrates the social and economic dimensions, but fails almost entirely to take up environmental or ecological issues.

Happy Planet Index (HPI)

The Happy Planet Index, introduced in July 2006 by the New Economics Foundation and measured for 178 countries, is an index of human well-being and environmental impact. The indicator shows the ecological efficiency with which the well-being is delivered. It is based on two objective indicators, life expectancy and ecological footprint per capita, and one subjective indicator 'life satisfaction'. Multiplying longevity and the subjective life satisfaction, you get the 'degree to which people live long and happily in a certain country at a given time', also called Happy Life Years (HLY). This is divided by the Ecological Footprint (EF).

Environmental Sustainability Index (ESI)

The Environmental Sustainability Index (ESI) is a composite index tracking a diverse set of socioeconomic, environmental, and institutional indicators that characterize and influence environmental sustainability at the national scale. The ESI covers natural resource endowments, past and present pollution levels, environmental management efforts, contributions to protection of the global commons, and a society's capacity to improve its environmental performance over time. The ESI is based on 5 building blocks – environmental systems, reducing environmental stress, reducing human vulnerability, social and institutional capacity and global stewardship - comprising in total 21 underlying indicators (Esty et al.,2005)

The ESI covers an interesting range of indicators, but there is a complicated weighting process of components, which make it highly disputable.

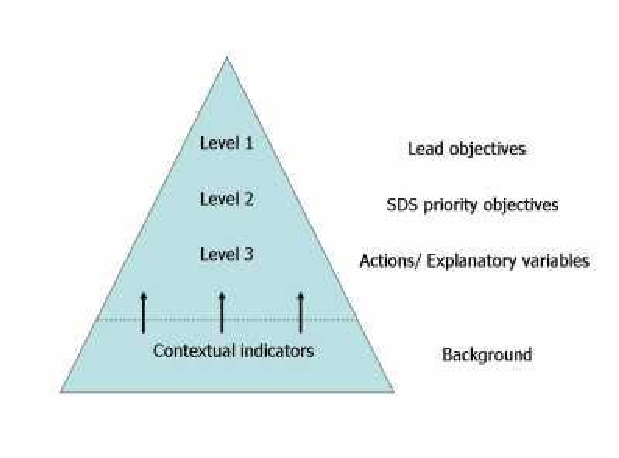
3) Supplementing GDP by a framework of indicators

EU Sustainable Development Strategy (SDS)

The SDI framework is based on ten themes, reflecting seven key challenges of the EU Sustainable Development Strategy (SDS), as well as the key objective of economic prosperity and guiding principles related to good governance. The themes follow a general trend from the economic, to the social, and then to the environmental and institutional dimensions. They are further divided into sub-themes to organise the set in a way that reflects the operational objectives and actions of the sustainable development strategy.

Based on the policy priorities of the SDS, a hierarchical theme framework was developed. For grouping the altogether about 155 SDIs, Eurostat has proposed a multi-layer system with 3 levels:

Figure 1: EU SDI framework



Level 1 (headline) indicators are to monitor the overall objectives of the SDS. These 12 robust and well-known indicators have a high communication value and are available for most EU member states for at least five years. These include for example GDP.

Level 2 indicators are related to the operational objectives of the SDS. These indicators are aimed at evaluation of the core policy areas and communication with the general public. They are robust and available for most EU member states for at least three years.

Level 3 indicators are related to actions outlined in the strategy or to other issues which are useful to analyzing the progress towards the SDS objectives. These indicators are aimed at further policy analysis and better understanding of the trends and complexity of issues associated with the theme or inter-linkages with other themes in the framework. They are intended for a more specialized audience.

Contextual indicators either do not monitor directly any of the strategy's objectives or they are not policy responsive. They provide valuable background information on the issues having direct relevance for sustainable development policies and are useful for the analysis.

Table 4: Headline indicators of EU SDI framework

Theme	Headline indicator(s) (first level)
Economic development	Growth in GDP per capita
Social inclusion	Risk of poverty
Public Health	Healthy life years
Global partnership	Official development assistance
Good Governance	Infringement cases Voter turnout Environment tax compared to labour tax
Demographic change	Employment rate of older workers
Climate and energy	Greenhouse gas emissions Consumption of renewables
Management of natural resources	Abundance of common birds Fish stocks
Sustainable transport	Energy consumption of transport relative to GDP
Sustainable consumption and production	Resource use relative to GDP (resource productivity)

Pressure-state-response model

The Pressure-state-response model (PSR) that has been proposed by OECD and the United Nations UNEP (Qian et al., 2001) shows the relationship between human activities, their environmental pressure and the government initiatives. The PSR approach is a causal one that covers causes and effects influencing a measurable state. In this sense, three categories of indicators are distinguished.

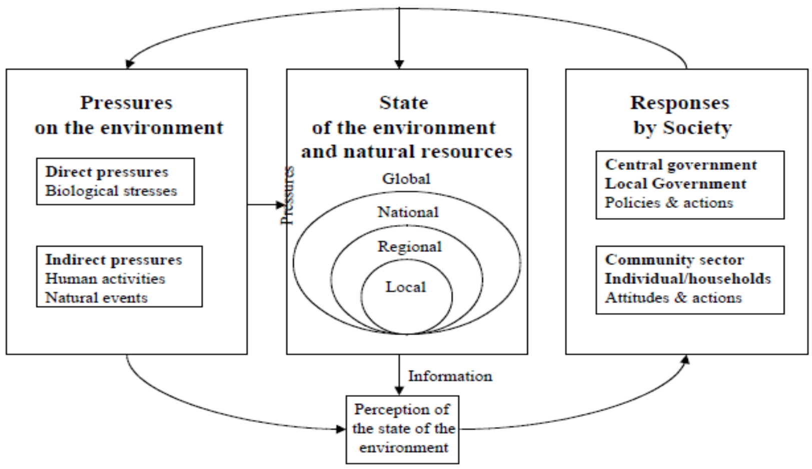
Indicators of environmental pressures (Pressure) describe on the damages originating from human activities, including quality and quantity of natural resources (emissions, mining of raw materials, fertilizer input).

Indicators of environmental conditions (State) are designed to describe the status quo of the environment and the quality and quantity of resources and their changes over time (e.g., forest area, protected areas).

Indicators of societal response (Response) show to which degree society is responding to environmental changes and concerns. This could be the number and kind of measures taken, the efforts of implementing or the effectiveness of those measures. Responses may range from public (e.g., legislation, taxation, promotion) to private sector activities (e.g., reduced consumption, recycling)

The PSR model has proven to be a logical, comprehensive tool to picture environmental issues from an anthropocentric perspective. Instead of observing a single phenomenon or problem a causal model of causes, impacts and effects on the environment are generated.

Figure 2: The PSR model

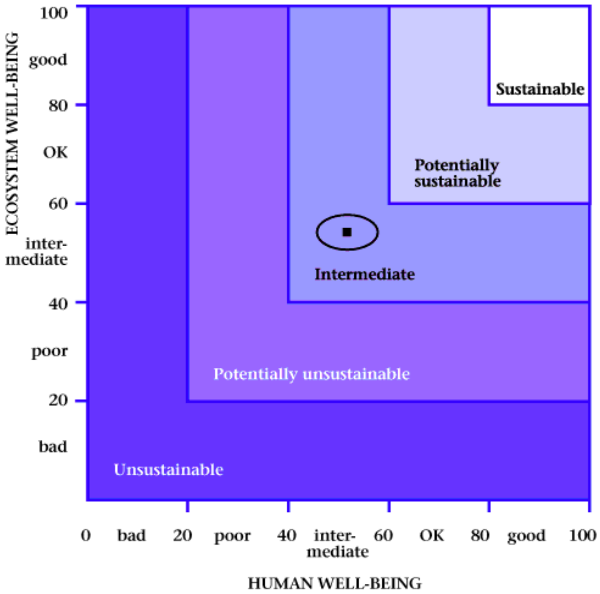


However, the PSR model has some weaknesses. The causal effects are simplified to linear relationships centered on human activities. Therefore it does not reflect the more complex relationships in ecosystems and in environment - economy interactions. The PSR model highlights environmental and economic relationships. The social component of indicators is not adequately covered.

Barometer of sustainability

The Barometer of Sustainability was developed in 1997 by Robert Prescott-Allen, in his book "The Well-being of Nations". It is the only performance scale designed to measure human and ecosystem wellbeing together without submerging one in the other. Its two axes—one for human wellbeing, the other for ecosystem wellbeing—enable socioeconomic and environmental indicators to be combined independently, keeping them separate to allow analysis of people-ecosystem interactions. Not aggregating these indicators enables showing the true situation of ecosystems and society.

Figure 3 Barometer of Sustainability



The indicators are valued on a point system determined by the researcher. There are 5 categories going from bad to good with points ranging from 0-20, 20-40, etc. A set of indicators are used for human wellbeing and for ecosystem wellbeing. The limits for the 'point' score are arbitrarily determined. The main use of the Barometer is to combine indicators enabling users to draw broad conclusions from an array of confusing and contradictory signals.

The main features of the barometer of sustainability are the following.

1. It integrates a flexible form of performance scaling. Each type of indicator can be integrated and a value can be attached to it.
2. The barometer explicitly states that human and biosphere health are equally important for a sustainable system. Progress in one dimension is impossible at the cost in the other. There is no trade-off between human well-being and ecosystem well-being.
3. The scaling is partially linear within certain boundaries. This makes comparability between extreme values possible.
4. The system is simple, no difficult computations are necessary to get from indicator to a scaling in the barometer of sustainability.

The Barometer approach -or the Well-being approach- is a promising one in the sense that it is easy to understand and to calculate and it gives an immediate tool to understand the interaction of ecosystem and human well-being. Moreover, it allows the interested parties to define their own criteria for sustainability and thus the overall process to be participative.

The main criticism of this approach is related to the possible subjectivity and 'ranking' of the indicators, which is 'ad random'. Questions arise on the scaling of the indicators, especially when countries are 'at the border' between scales. Also the assumption of no trade-off between human and ecosystem well-being can be criticized.

2.4 Summary

Indicators are an essential part of the results handling of any model and are a powerful tool for interpretation of results and policy making. The main problem is the specification of a particular indicator. There are hundreds of indicators that could potentially be used to measure sustainability. Deciding how many and which ones to use can be difficult.

As no clear alternatives are available, often GDP is used as a single measure of 'wealth and progress'. However from a sustainability point of view it is out of the question that this indicator is sufficient to measure the vast complexity of the economic, social and environmental dimensions of development. We have seen that it can even be counterproductive, as pollution and social problems may actually trigger a higher growth in GDP (however often temporal). There are a number of alternatives available to GDP, but there are large discussions on their acceptability and basis for policy development. Also it is questionable that all these indicators could be modeled based on the SUST-RUS methodology. Therefore our best option is to combine together indicators in economic, social and environmental spheres and to evaluate the overall progress to sustainability in different areas.

3. Creating a sustainability framework for SUST-RUS

3.1 Background of sustainable development in Russia

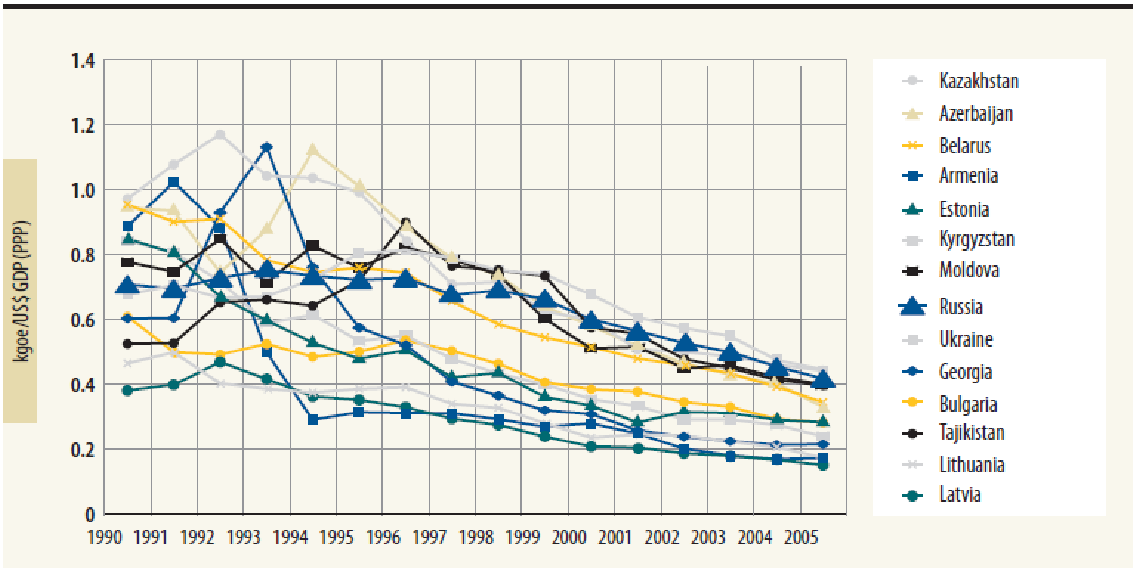
Energy and climate change issues

The process of economic transition to market economy in Russia was accompanied by a sharp decline in the gross domestic products (GDP) in the 1990s. Since the economic recovery (in the period 1999–2007), GHG emissions have been growing at a significantly slower pace than the economy. In 2007 GHG emissions in Russia totals to 2192,8 mln CO2 equivalent, or 108% to yearly emissions in 2000 and 66.1% in 1990. (Israel (ed), 2009). The diverging GDP and the GHG emission trends have been largely attributed to:

- shifts in the economic structure, in particular towards the non-energy intensive industries;
- shifts in the primary energy supply (increasing share of natural gas and nuclear energy);
- a decrease in population;
- an increase in energy efficiency due to new investments.

However, Russia's energy intensity has decreased over this time horizon much less than in most former Soviet Republics, at the annual rate of roughly 3.4% and 2.7%, respectively. The Baltic States, Belarus, Kazakhstan, Kyrgyzstan reduced energy intensity in the range of 5-8% per year during the last 15 years. Of the former Soviet Republics, Russia and Ukraine have become the most energy intensive economies in terms of energy intensity by the mid of 2000s (*Figure 4*).

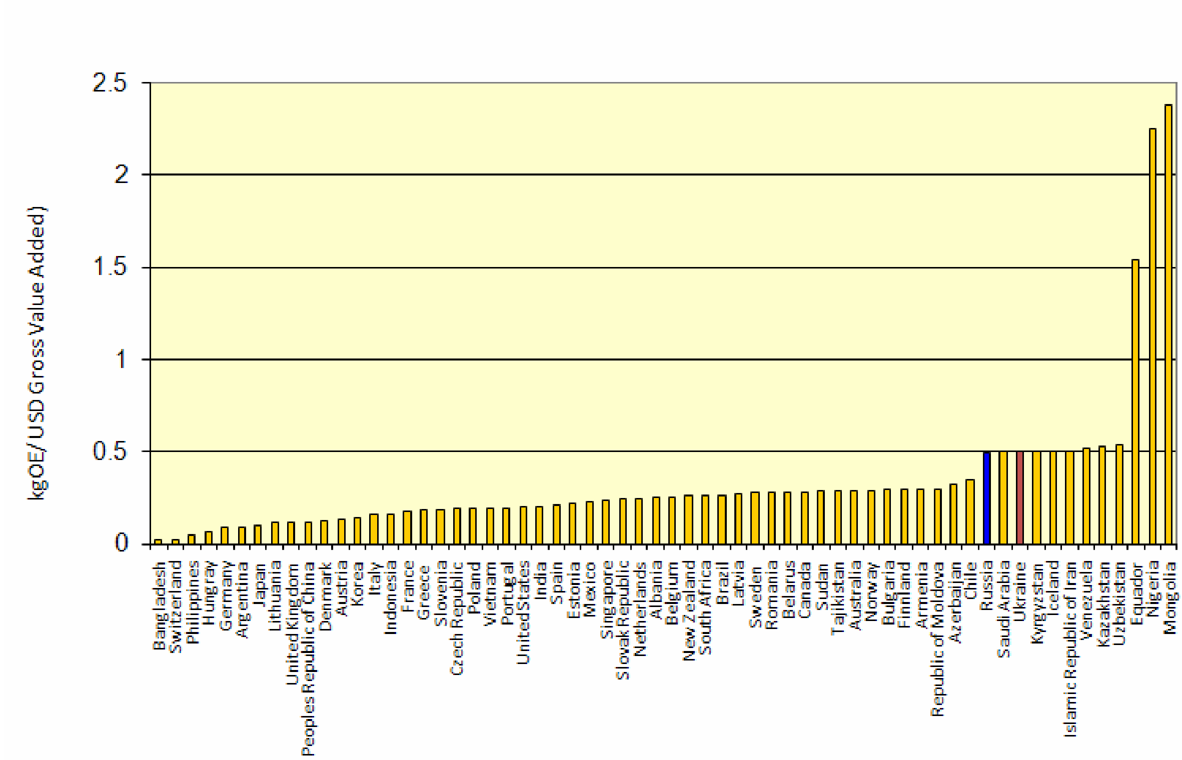
Figure 4 Energy intensities in GDP in former USSR countries



Source: Worldbank and IFC (2008)

Beyond the horizon of the current economic slowdown, one of the grand challenges which are faced by Russia is, therefore, to cope with the low energy efficiency and growing GHG emissions. Low energy intensity is endemic in every sector of economy, including residential sector and heavy industry. The latter has inherited an energy-inefficient and carbon-intensive production plants from the Soviet time and little has been achieved over the last two decades (*Figure 5*).

Figure 5 Comparison of Global Energy Intensities in Manufacturing Industries



Source: Worldbank and IFC (2008), modified

For example, energy efficiency of Russian steel producers is well below levels that have been already achieved internationally, in both developed and emerging countries. Energy intensity of Russian steel makers is twice as high as in France, Italy and Poland and roughly a quarter above the values in Czech Republic and Slovakia. In comparison to Chinese competitors, Russian producers are lagging well behind in pig iron production (20% above the average in China) and rolling production process (30% above the average in China). The poor energy efficiency performance can be translated into the disproportionately high level of CO2 emissions. Global energy-related CO2 emissions in the iron and steel sector were 1471 Mt CO2 in 2007, whereas Russia emitted 110 Mt CO2 (7.5%). Hence, Russia is currently contributing to the global emissions level at a high rate as to the global production level. Russian cement production is also relying on the obsolete plants, using primarily wet production method. In 2008, 16% of the total cement production was by means of the dry method. No progress has been achieved over the last 30 years in replacing this obsolete technology. In contrast, dry process method is used to produce 100% of clinker in Japan, 93% in South Korea, 92% in Europe, 82% in the United States, and 50% in India and China.

High prevalence of natural resources

The realization of the sustainable development goals plays an important role for Russia due to the fact the country signed the 1992 Rio Declaration. The significance of these goals also depends on the fact that Russian natural resource potential is considered as a world's natural sustainability provision. In reality, Russia still has 30% of the world wild nature resources (8 mill. hectares of the Russian territory). The Baikal Lake obtains 20% of world fresh water resources. Russia has 30% of world forest resources.

Russia holds the world's largest natural gas reserves, the second largest coal reserves, and the eighth largest oil reserves. Russia is also the world's largest exporter of natural gas, the second largest oil exporter and the third largest energy consumer.

However Russia is not rich enough in natural resources to ensure a lasting high living standard to its population. Russia ranks only 11th in terms of oil and gas reserves per capita (far behind countries in the Middle-East) and is in a need to diversify its economy towards commodity and service production.

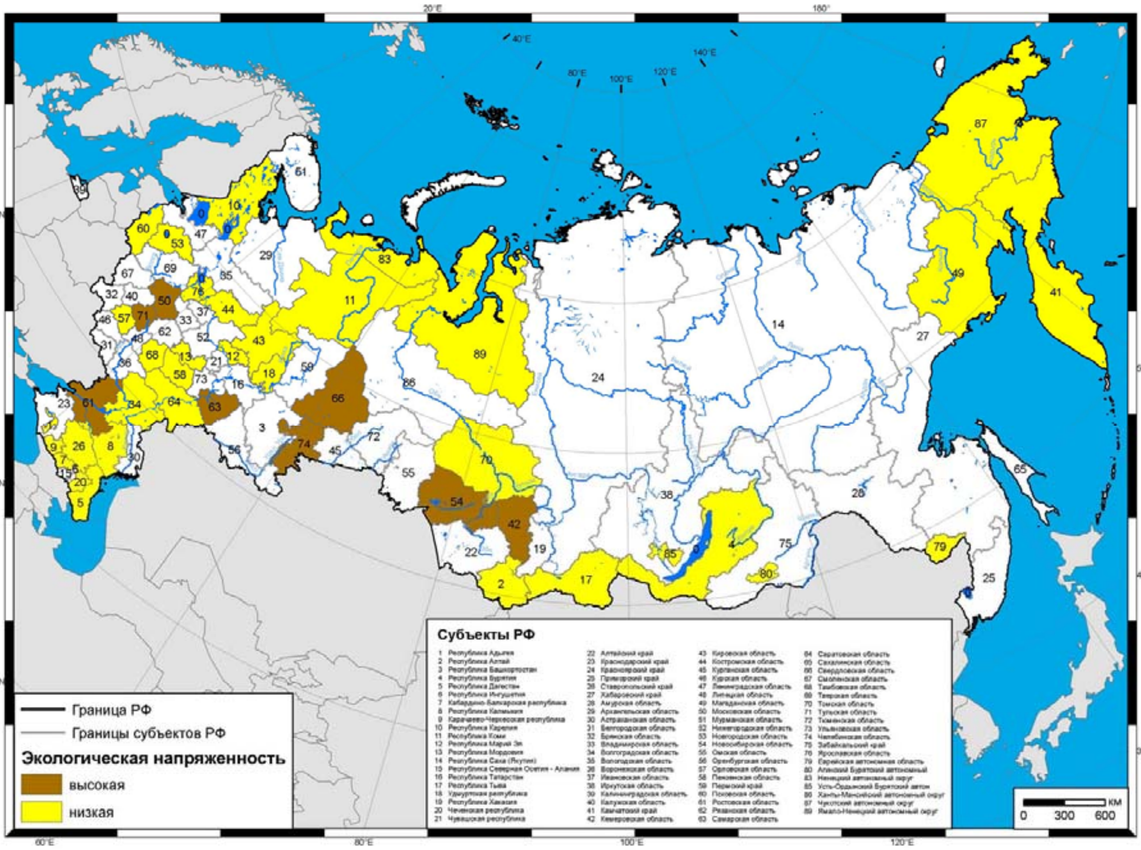
Pollution

Polluted land is a serious problem in the cities and manufacturing zones. Although, estimates of the degree of land pollution in terms of share of the Russian Federation differs from extreme 15% (Pachomova and Richter, 1998) to a more moderate 4%[4], all experts are certain that the problem of land pollution is critical in major Russian cities and industrial territories: Kemerov region, Moscow region (including the city of Moscow), Rostov region, Sverdlosk region, Tula region and Chelyabinsk region[5].

[4] Aggregate estimates of pollution in the Russian Federation for 2007, *Institute of Global Climate and Ecology,* *http://dynamic.igce.ru/complex/2007/*

[5] Ibid.

Figure 6 Degree of Aggregated Pollution of the Regions of the Russian Federation



Legend: Brown color – indicates high degree of pollution; yellow color – indicates low degree of pollution; White color – those regions were not monitored in 2007 and 2008.

Source: Institute of Global Climate and Ecology, Russian Academy of Science, Moscow (http://dynamic.igce.ru/complex/2008/).

Due to the economic depression in the nineties there was an essential decrease in the harmful pollution. It was the result of a decrease in production by 40%. In 1996 the harmful air pollution was decreased by 12,7% in comparison to 1992 (in 1997 the pollution situation was stabilized). However transport pollution rose after the depression. The quantity of the transport units doubled through the considered period. As a result 40 million Russians in 86 cities experience air pollution exceeding tenfold the "admissible limits" and more. (Pachomova and Richter, 1998)

Poor ambient air quality linked to acidifying emissions and ozone concentration is a further pressing environmental problem in Russia: air pollution levels exceed maximum allowable concentrations in major urban areas, while acidifying emissions lead to surface water acidification (e.g. in the border areas between Russia and Norway) and to heavy damages of forests (e.g. in Norilsk). The energy-related emissions of NO_x, SO_2, VOC and particulates are the main sources of air pollution. Today around 50% of total SO_2 emissions come from the five largest sources in the metallurgical industry. In future, SO_2 emissions from the power sector might even increase if natural gas is substituted by coal.

Unfavorable demographic situation

According to the World Population Data Sheet [WPDS 2004], the rate of population increase in Russia is the world's second lowest -0.6 percent after -0.8 percent in Ukraine. In addition, the WPDS projects population changes in Russia in 2004-2050 to be -17 percent (declining from 144 to 119 million). The only way for Russia to prevent an impending demographic crisis is to soften restraints on international and interregional migrations.

Informal economy and institutions in transition

The growth of the informal economy in transition countries and especially in the former Soviet Union republics has been particularly sharp. While measurements are hard to make, some current estimates range from 13% to 40% of the Russian GDP. The rise of the informal economy has gone hand in hand with rising unemployment figures, crime and general insecurity of institutions. The informal economy and formal sectors well co-exist and workers have been reported holding multiple jobs in both formal and informal sectors (Commander S , Tolstopiatenko A, 1997).

Progress in implementing sustainable development in Russia

Some steps to implement sustainable development goals in policy have been made. In 1994 the President of Russia signed a decree "On State strategy of the Russian Federation for environmental protection and sustainable development", where main features of these strategies were outlined. The latter means gradual reproduction of the natural ecosystems to the level of the guaranteeing stability of environment and future provision of sustainable favorable environmental development. Federal and regional authorities are responsible for the preparation of sustainable development programs.

In 1996 the State Concept on nature protection and sustainable development was adopted and published. This Concept was a result of a wide discussion among experts, officials and politicians. This Concept was a basis of a two year action plan on nature protection and sustainable development adopted in 1994.

The sustainable development strategy is yet to be created and ratified. According to a draft of the strategy[6] system of SD indicators is planned to be quite close to the UN CSD indicators. Thus, in the discussion of the appropriate indicator system for the SUST-RUS project we could use the UN system as a reference point of the Russian SD indicator system.

Improving energy efficiency, reducing GHG and acidifying emissions has been put on the top of political agenda recently. Russian government started introducing a mix of structural policies to limit the energy consumption and to reduce GHG emissions while favoring longer-term growth of an economy, and safeguarding competitiveness in the key industrial sectors. In June 2008, President Medvedev signed a decree aiming at reduction of energy intensity by 40% by 2020 compared with the 2007 levels. Climate Doctrine of the Russian Federation which has been approved in 2009 foresees further the reduction of natural gas use, limiting the burning of gas produced from oil wells, increasing the use of renewable energy in electricity production. Finally, Russia committed to reduce acidifying emissions in accordance with UNECE Convention on Long-Range Transboundary Air Pollution / The 1994 Oslo Protocol on Further Reduction of Sulphur Emissions.

[6] Shelekhov (Ed) (2002) Main Features of the Sustainable Development Strategy of the Russian Federation, Moscow, In Russian [Основные положения стратегии устойчивого развития России /Под ред. А.М. Шелехова. М., 2002. - 161 с. http://www-sbras.nsc.ru/win/sbras/bef/strat.html].

While putting it in the context of current environmental priorities and needs, the next chapter reviews the highly policy-relevant environmental indicator lists and explores the ways on how to implement the respective indicators into a quantitative framework of the SUST-RUS project. Appropriate indicators might assist Russian policy makers in their efforts to move from the current sectoral status-quo in terms of reducing energy-intensity, GH emissions and acidifying emissions.

3.2 CGE modelling and sustainability

Computable general equilibrium models (CGE) models have become a standard tool for applied analysis of measures in various policy domains including fiscal policy, trade policy and environmental policy (Böhringer 2004, Shoven and Whalley 1984, 1992, Piggot and Whalley 1985, Borges 1986, Pereira and Shoven 1988, Bergman 1990, Kehoe and Kehoe 1994, Klepper et al. 1995 and Bhattacharyya 1996). CGE models can incorporate several key sustainability indicators in a single micro-consistent framework, allowing for a systematic quantitative trade-off analysis between environmental quality, economic performance and income distribution. Furthermore, the CGE modeling approach provides an open framework for linkages to sector-specific models, important relationships to other disciplines adopting an integrated assessment approach or the incorporation of new economic research strings (Böhringer and Löschel, 2004).

Computable general equilibrium models are a class of economic models that are based on actual economic data (mostly national account data) to predict how the economy might react to policy changes, technological progress or other changes in the initial state of the model. These models have a strong foundation in micro-economic behavior and always represent economic agents separately. These agents are at least: consumers, government, firms and often include specific agents such as: investors, foreign sector(s), land owners, different household types, etc.

CGE models are nearly always calibrated on a yearly database of transactions between these agents, represented in an input-output table or a social accounting matrix. A set of exogenous parameters, mostly elasticities of substitution or price elasticities based on econometric research; determine how the economy will behave in out of equilibrium conditions.

While notable exceptions exist, most CGE models are calibrated on 1-year and are used in a comparative-static mode, where policies are checked as alternative scenarios against a fixed background. Dynamics have been included in CGE models and in this case partial adjustment exists in capital flows and/or trade balance of the country/region.

The core of a CGE model is the economic system and the transaction between the respective agents. However, CGE models are increasingly being used for assessment of more complex interactions between environment, ecology and social equity and their purely economic database is enriched with social and environmental data. Examples of these models are the GEM-E-3 model, Worldscan, EPPA, and many of their applications find their way to top level decision makers and academics. This makes the comparison of these models, their assumptions and results an interesting topic for study as well. C. Böhringer and A. Löschel (2008) conclude that operational CGE models used for energy-economy-environment (E3) analyses have a good coverage of central economic indicators. Environmental indicators such as energy-related emissions with direct links to economic activities are widely covered, whereas indicators with complex natural science background such as water stress or biodiversity loss are hardly represented. Social indicators stand out for very weak coverage, not at last because they are vaguely defined or incommensurable.

The often reported 'interrelatedness' between the economic, social and environmental sphere makes it harder to define the correct indicators within our model. Especially in CGE models that have their origin as a pure economic model, the distinction between social and economical may be hard to make. Therefore social can be redefined as equitable, with other words: the allocation of wealth, consumption and goods to different regions and niches in the population. The evaluation of policies in terms of equity is much more specified then those in terms of 'social' indicators. Also this broadens the interpretation of special allocation of industry, consumption, income within our model.

If we look at sustainable development from the economic rationale "allocation of scarce resources in the best possible way", the main problem with sustainability is the rational use of natural resources allocated in space and time. The scarce resources, such as minerals, water, land and ecosystem services thus need to be distributed in space within our model and be transported/traded with other regions and countries. The use of most of these resources depends upon the allocation of production and consumption activities. By incorporating the representation of geographically distributed consumption and production patterns into the modeling framework, it becomes possible to account for the use of natural resources in the economy as well as to assess the effects of sustainability policies upon different regions. One could also trace the differences in regional economic development and analyze regional inequality in the country.

The theoretical framework for multi-region and multi-industry for a core CGE model discussed in (A. Löschel and C. Böhringer, 2008) is similar to our plan for implementation of SUST-RUS. Primary factors of a region include regional value-added in terms of capital and labour, intermediates (materials), resources (such as land) and fuels (oil, coal, gas).

Production is captured by aggregate functions, where these factors are used, according to the baseline SAM matrix. Final demand is given as a CES composite which distinguishes commodities, energy and transport consumption. Consumers maximize utility, constrained by the regional factor income. Foreign sectors (imports/exports) are represented by the Armington substitution elasticity, where we assume that foreign and domestic goods are considered imperfect substitutes. Regions interact in terms of commodity and service trade, and are subject to government interventions in terms of taxation, distribution and legislation.

The power of such a model to incorporate environmental and equity relations increases dramatically when we have additional information. In the case of relation with the environment an approach can be taken to include a database of pollution by industry, abatement costs by industry, specify emission quotas, include specific taxes and subsidies, include estimates of health damages by type of pollution, etc. An additional database holding data on household level can increase the solution sphere of the model further, taking into account distributional aspects of income and possibly environmental effects.

Another important addition, usually made with respect to CGE models is a dynamic (partial adjustment) framework, often including parameters on technological change and capital accumulation.

3.3 Indicators in a CGE framework

Balance between data, variables and framework

The choice of indicators within a CGE model should be closely linked to the variables of the model. Therefore we have to link the interest of an indicator in terms of 'policy analysis' with the possibility of using the indicator in the proposed CGE modelling framework.

The basic set-up of the economic system in a CGE model depends on the amount of sectors and goods that are modelled explicitly. A more detailed system allows for more specific modelling of factors, intermediate output, energy inputs, industry concentration, household consumption, etc. but also creates additional problems in terms of deriving the right exogenous parameters such as elasticities of substitution, income elasticities, etc.

CGE modelling always involves choices, selecting the right framework and the right level of aggregation for the policies you would like to simulate.

Table 5: Overview of proposed sector/goods structure in SUST-RUS

Agriculture, hunting and forestry
Fishing
Mining and quarrying of energy producing materials (coal)
Mining and quarrying of energy producing materials (gas)
Mining and quarrying of energy producing materials (oil)
Mining and quarrying, except of energy producing materials
Food products, beverages and tobacco
Textiles and textile products
Leather and leather products
Wood and wood products
Pulp, paper and paper products; publishing and printing
Coke, refined petroleum products and nuclear fuel
Chemicals, chemical products and man-made fibres
Rubber and plastic products
Other non-metallic mineral products
Basic metals and fabricated metal products
Machinery and equipment n.e.c.
Electrical and optical equipment
Transport equipment
Manufacturing n.e.c.
Electricity, gas and water supply
Electricty distriubtion
Construction
Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
Hotels and restaurants
Transport, storage and communication
Financial intermediation
Real estate, renting and business activities
Education
Health and social work

Experience from the ISEEM model

The ISEEM model can be seen as a precursor to SUST-RUS. The aim of this model was similar: to create a flexible modelling framework that can handle the multiple dimensions of sustainability policy. This model was created for the Federal Science Policy Institute of Belgium (Belspo) and involved the Federal Planning Bureau, the University of Gent, the Facultés Saint-Louis and TML.

In the table below, the key sustainability indicators of the ISEEM model for Belgium are listed.

The indicators were chosen after a literature review and subsequent discussions between the project partners. The choice of indicators is characterized by:

- Division between social, economical and environmental indicators
- Focus on equity within the social indicators
- Environmental indicators are purely based on air pollution
- Focus on simple and easy way to interpret indicators
- Indicators can be distinguished on regional and national level according to interest

Table 6: indicators of the ISEEM model

ECONOMY	SOCIAL / EQUITY
GDP	Ratio high income / low incomes
Unemployment rate	Poverty gap
Consumption	Gini coefficient
Price index	
Tax revenues of government	
ENVIRONMENT	
GHG pollution	
NGHG pollution	
SOx pollution	
NOx pollution	

We can compare the list above with the list of indicators in Böhringer C. and Löschel A (2006), based on the EU structural indicators (2003).

Table 7: Comparing ISEEM and EU structural indicators

Indicator	ISEEM framework?	Extensions?
GDP per capita	Implemented	Regional GDP Sector GDP
Labour productivity	Implemented	Productivity by skill type
Employment rate	Implemented	Regional rate Employment by skill type
Employment rate of older workers	Not implemented	
Spending on human resource	Can be implemented	Expenditures on education
R&D expenditure	Can be implemented	Effect of R&D expenditures on productivity
IT expenditure	Can be implemented	
Financial market	Can be implemented	Foreign trade / trade balance
At-risk-of-poverty rate	Can be implemented	Poverty gap
Long term unemployment	Not implemented	Unemployment rate will be equal to 1-employment rate
Dispersion of unemployment rates	Implemented	
Greenhouse gas emissions	Implemented	Also other emission types Waste
Energy intensity of economy	Implemented	Energy intensity in terms of GDP
Volume of transport	Implemented	Trade margins Volume of transport in terms of GDP

3.4 Review of environmental indicators

We reviewed the most policy relevant lists of environmental indicators. We thereby focus on three highly policy-relevant environmental indicator lists – one developed by the United Nations Commission on Sustainable Development (UN, 2001) and two lists suggested by the European Commission (EC, 2003 and 2005a). We subsequently asses the feasibility of implementing selected environmental indicators into a CGE framework, grouping them into the following three categories: (i) environmental indicators which can be relatively easily implemented into a CGE model, (ii) environmental indicators which can be implemented within an extended CGE framework only and (iii) environmental indicators which cannot be covered by a CGE model. We conclude by suggesting a list of environmental indicators which can be used to assess the environmental dimension within a SUST-RUS modeling framework.

In this section, we focus on three highly policy-relevant environmental indicator lists – one developed by the United Nations Commission on Sustainable Development (UN, 2001) and two lists suggested by the European Commission (EC, 2003 and 2005a).The list established by the United Nations Commission on Sustainable Development (CSD) in 1992 categorizes 58 indicators in a framework of 15 themes and 38 sub-themes. 19 indicators are related to environment. Structural indicators in the EU (EU-SI) – 79 indicators in total and 18 related to environment – have been agreed upon by the European Council and the Commission in order to assess the progress made towards the Lisbon strategy goals. Finally, sustainable development indicators (EU SDIs), related to climate change and energy, sustainable consumption and production, sustainable transport, and natural resources, have been developed by the European Commission in order to measure progress towards the 2006 EU Sustainable Development Strategy (http://epp.EUROSTAT.ec.europa.eu).

We classified environmental indicators from these three lists into the following sub-theme groups:

- climate change
- energy
- renewable sources
- transport
- ozone layer depletion
- air quality
- agriculture
- forests
- desertification
- urbanization
- oceans, sees and costs
- resources use, waste, biodiversity and water resources.
-

Table 8 summarizes the feasibility of the implementation of the environmental indicators into a CGE framework alongside the sub-theme presented above as following: we highlight blue those indicators which can be relatively easily implemented into a CGE model, while yellow implies that environmental indicators can be implemented within an extended CGE framework only. All other indicators cannot be covered by a CGE model.

Table 8: Environmental indicators

	EU-SDI	EU-SI	UN CSD Indicators
Theme			
Climate Change	Emissions of GhG	010 Emissions of GhG	Emissions of GHG
	GHG emissions by sector (including sinks)		
	GHG emissions intensity of energy consumption		
	GHG emissions by transport mode		
Energy	Gross inland energy consumption by fuel	020 Energy intensity of the economy	Intensity of energy use – *Economic Indicator*
			Annual energy consumption per capita – *Economic Indicator*
	Combined heat and power generation	030 Combined heat and power generation	
	Implicit tax rate on energy	040 Implicit tax rate on energy	
	Final energy consumption by sector		
	Electricity consumption of households		
	Energy consumption by transport relative to GDP		
Renewable Sources	Electricity generated from renewable sources	050 Electricity generated from renewable sources	Share of consumption of renewable energy resources – *Economic Indicator*
	Share of renerwables in gross inland energy consumption		
	Share of biofules in fuel consumption of transport		
Transport	Volume of freight transport relative to GDP	060 Volume of freight transport relative to GDP	Distance travelled per capita by mode of transport – *Economic Indicator*
	Volume of passenger transport relative to GDP	070 Volume of passenger transport relative to GDP	
	Modal split of freight transport	080 Road share of inland freight transport	
	Modal split of passenger transport	090 Car share of inland passenger transport	
	Energy consumption by transport mode		
	Investment in transport infrastructure by mode		
	Motorisation rate of households		
	Average CO2 emissions per km from new passenger cars		
Ozone Layer Depletion	Emissions of ozone precursors by source sector / transport		Consumption of ozone depleting substances

Air Quality	Urban population exposure to air pollution by ozone	100 Urban population exposure to air pollution by ozone	
	110 Urban population exposure to air pollution by particulate matter	110 Urban population exposure to air pollution by particulate matter	
	Emissions of acidifying substances by source sector		Ambient concentration of air pollutants in urban areas
	Emissions of particulate matter by source sector / transport		

Table 9: Environmental indicators (continuation)

Agriculture			Arable and permanent crop land area
			Use of fertilizers
			Use of agricultural pesticides
Forests			Forest area as percent of land area
			Wood harvesting intensity
	Forest trees damaged by defoliation		
	Forest increment and fellings		
Dersertification			Land affected by desertification
Urbanization			Area of urban formal and informal settlements
Oceans, Seas and Coasts			Algae concentration in coastal waters
			Percent of total population living in coastal areas
	Fish catches taken from stocks outside of save biological limits	150 Fish catches from stocks outside of 'save biological limits'	Annual catch by major species
Resource Use, Waste, Biodiversity, Water Resources	Municipal waste generated	120 Municipal waste generated	Generation of industrial and municipal solid waste - *Economic Indicator*
	Municipal waste treatment, by type of treatment method	130 Municipal waste by type of treatment	Waste recycling and reuse - *Economic Indicator*
	Generation of harzardous waste, by economic activity		Generation of harzardous waste / management of radioactive waste - *Economic Indicators*
	Resource productivity	140 Resource productivity	Intensity of material use - *Economic Indicator*
			BOD in water bodies
			Concentration of faecal coloform in freshwater
	Sufficiency of sites designated under the EU	160 Sufficiency of sites designated under the EU	Abundance of selected key species

	Habitats directive	Habitats directive	
	Common bird index	170 Farmland bird index	
	Healthy life years and life expectancy at birth, by gender	180 Healthy life years at birth by gender	Life expectancy at birth - *Social Indicator*
	Index of production of toxic chemicals, by toxicity class		
	Population connected to urban waste water treatment with at least secondary treatment		

3.5 Creating an indicator framework for SUST-RUS

We propose to base our approach on the common "3 pillars methodology", where indicators are fitted to economic, environmental and social goals of sustainability. Our review of sustainability indicators in section 2.2 and the uses and critiques of GDP and alternative indicators for 'progress' has led us to use the approach of using multiple indicators to capture sustainability. This means that we see sustainability as the crossing point between several interlinked goals, expressed in terms of social welfare, economic production and preservation of the environment.

3.5.1 The economic dimension of sustainability

Production

We choose the GDP indicator as our main indicator for economic production. It is an indicator which fits perfectly within our understanding of economic modelling and is of key policy interest. However, we do not limit ourselves to output GDP as one single parameter. We choose to disaggregate the GDP at regional level and distinguish the contribution to GDP of different (aggregated) sectors. GDP can also be an element of other indicators. Examples are the intensity of trade compared to GDP (see foreign sector), energy consumption in terms of GDP, pollution in terms of GDP, etc.

Prices

In CGE modelling, prices are initially set at unity level. In the baseline, prices have no meaning. However, in simulations prices are endogenous and can convey interesting information on the behaviour of the model. Price increases in long term will decrease real income of households. Therefore, a change in price index is similar to 'inflation' in the real economy.

Foreign sector

The next key indicators are related to the international market. The SUST-RUS model will contain an elaborate model of the foreign sector. Trade balance is essential for long term stability of the economy. Building up large trade surpluses or deficits will lead to changes in the exchange rate. In SUST-RUS we can adapt the closure on foreign markets to allow for a change in trade balance, keeping the exchange rate fixed, or allow for a flexible exchange rate with a fixed trade balance. Fixing the exchange rate in short/mid term and adjusting trade balance by attracting or dumping foreign savings is a common assumption in CGE models.

Trade

The amount of imports and exports, compared to the size of the domestic or regional GDP is a common indicator for trade openness. This indicator may be useful when we look at policies that have as an essential goal to increase accessibility of a region to interregional and/or international markets. Trade openness is often associated with economic progress through increased competition and diffusion of technologies.

Trade balance

Trade balance is defined as net trade with foreigners: exports less imports. A trade deficit means that exports are insufficient to pay for imports and trade surplus is the opposite. The trade balance is a component of GDP. A simultaneous increase of both imports and exports by the same amount leaves unaltered the trade balance. Any difference in dynamics between exports and imports has an effect on trade balance

Government

Government income mostly depends on tax revenues; these in turn depend on economic activity. A new tax may increase government revenues, but decrease overall economic activity, leading to a reduction of revenues from other sources. When a federal and regional level government is modeled, transfers between governments and regions will be important for model equilibrium.

Investments

Investments and savings will in long term shape the country stock of capital and hence economic development. Domestic and Foreign Direct Investments can have opposite effect on regional development. Large amounts of FDI can quicken the pace of economic development, however in some cases there can arise uncertainty if benefits are mainly arising in the country or region of origin. Usual example of large foreign inflow of investments with limited permanent host country benefits is the mining projects.

Agglomeration and concentration

Agglomeration of activities has proved to be an important effect of the economies of scale and place and was one of the main reasons that increased the attention to regional and spatial economics in the previous decade. While agglomeration has proved to be an important aspect, there is no common index used to 'measure' agglomeration. One accepted index is the location coefficient, which basically divides the share of an industry's production (or employment) in the regional economy by the average share of this industry in national economy. A step further is to calculate a so called 'regional Herfindahl' index, which is the sum of the squared shares of an industry's production (or employment) in each region. A high value for this regional Herfindahl index points to a highly localized industry.

Table 10: Economic indicators

Theme	Indicator	Level	Unit	Formula
Economic production	GDP per capita	National Regional Industry/Services	Monetary	GDP / POP_r
Trade balance	Current account deficit/surplus	National	Monetary	$E - M = T$ E = *export* M = *import*
Trade openness	(Export + Import) / GDP	National Regional	Unitless	$\frac{(E+M)}{GDP}$
Public budget	Public deficit/surplus by GDP	National	Percentage	$\frac{PB}{GDP}$ PB = *public budget deficit/surplus*
Investments	Investment share in GDP(FDI)	National Regional	Monetary	$\frac{I_{foreign}}{GDP}$
Price level	Change in relative price compared to baseline	National average Regional average Goods (by type)	Percentage	$\frac{P \cdot (1+tc-sc)}{P^0 \cdot (1+tc^0-sc^0)}$ P = *price* tc = *tax* sc = *subsidies*
Government income	Tax revenues	National Regional	Monetary	TAXR *(endogenous model equation)*
Agglomeration and concentration	Herfindahl index for concentration Location coefficient	National Regional	Unitless	$HH_r = \sum_r (s_{i,r})^2$ $HH_i = \sum_i (s_{i,r})^2$ $s_{i,r}$ = *share of production of sector i, in region r* HH_i = *concentration of firms* HH_r = *concentration of regional production*
Integration within country economy	(Interregional export and import) / local production	By good Regional	Unitless	$\frac{\sum_i \left(\sum_{rr} XDDE_{i,r,rr} + \sum_{rr} XDDE_{i,rr,r} \right)}{\sum_i XD_{i,r}}$[7] $XDDE_{i,r,rr}$ = *interregional trade from region of origin r, to region of destination rr* $XD_{i,r}$ = *production of good i in region r*

[7] This is the aggregate index of economic integration (goods summed up), the index can (and will) also be calculated by good, in the case this is relevant.

3.5.2 The social dimension of sustainability

In fact the 'social' dimension of sustainability is not well defined, especially in the domain of CGE modelling. Economic parameters can be seen as essential components of the 'welfare' of the region and when the model contains only a limited amount of agents, social and economic indices will nearly be the same. Therefore if we speak about the 'social dimension' we should actually refer to the 'equity' dimension. Social tensions arise when the benefits of policy and development are unequally distributed among the population. While people are prone to accept a certain degree of inequality, high and rising inequality in incomes and consumption will always lead to social tension.

Poverty

Poverty is the impossibility to sustain one's most basic needs, due to a permanent income deficit. Poverty is the most basic 'social' indicator and also the most relevant for policy makers. While there are many kinds of poverty, incidence is most commonly related to low income. Therefore the first basic tool of analysis is to determine below which level of income we will assume that the household in question is 'poor'. In many cases this is set as a certain percentage of the mean or median income prevailing in the population. However, some 'absolute' poverty lines are also in use, for example the "1 dollar a day" line used by the World Bank. In Europe poverty lines defined at 40% or 50% of the mean income are in common use.

According to Amartya Sen, poverty has 3 dimensions: Incidence, Intensity and Inequality. Incidence is commonly referred to a percentage of population below poverty line. Intensity can be measure by comparing the mean income of the poor to the poverty line. Inequality is the inequality in income among the poor. Incidence and intensity fit best in the general equilibrium methodology as the definition of poverty is often not specified in enough detail to allow for distributional concerns within the poor household group. Currently we will only integrate the value of 'incidence and intensity' into the framework.

Unemployment

It is possible to argue that unemployment is not rather an economic than a social measure. However, unemployment has far reaching social effects that go much deeper than its basic 'inability to find work'. Unemployment is highly correlated with 'social indicators' that cannot be measured directly in an 'economic model'. Examples are: social seclusion, suicide, divorce, crime, political instability. If unemployment is a very local problem and labour mobility is low, regional development can be seriously slowed down.

Progressive taxation

Taxation is the main way for the government to gather income and to finance public goods. The moral rationale is that people which have a higher income earning ability and use public goods more intensively, should pay a higher share of their income in taxes. Implementation of a new tax can meet opposition when the after tax income of poor households will decrease relatively more than the after tax income of the high earners. Taxes on basic products can hurt poor households relatively more than richer households, even when products are taxed at a constant rate. A flexible index on tax concentration, such as the Kakwani index can evaluate if a tax is progressive or not and if some cut in the rate for poor household could be advisable.

Welfare

In economic theory, welfare and consumption are strongly linked. CGE models are based on microeconomic theory and therefore maximize consumer utility. In practice, money metric values of utility are used, such as the equivalent variation or compensating variation measure. Equivalent variation depicts the amount of money a consumer would pay ex-ante to avert a change in utility. Compensating variation depicts the amount of money that should be paid ex-post, for a consumer to reach the same utility. Both measures are valuable metrics of welfare for consumers, but give slightly different results. The reason for this is that equivalent variation uses the prices of the base case situation, while compensating variation the prices of the ex-post (simulated) alternative. In theory each set of prices can be used as a reference point (for example a weighted average of ex-ante and ex-post prices), in practice the equivalent variation measure has the best comparative result (as it is always compared to the base case situation and prices). Changes in equivalent variation can be summed up (as these are monetary valued) to country level. The result is a monetized 'social welfare' change, based on individual utilities. (cfr. Bergstrom-Samuelson social welfare function).

Inequality

Economic theory is strongly focused on the behaviour and income of individual agents. However the heterogeneity within a society, the ethical and moral preferences of agents may be to avoid large differences between individuals and income groups. A common technique used in welfare economics is the use of a 'inequality corrected' Bergstrom-Samuelson social welfare function. This is defined as an additive form of the money-metric changes in utility, with some degree of preference for society of inequality aversion. The Atkinson index is a measure for inequality, which is directly derived from this type of functions. An alternative to this index is the widely used Gini-index of inequality, which is used a lot in applied work.

Both of these indices are included in the table below, as we will define social welfare as the sum of equivalent variations. A modification to the basic welfare index can be made, summing up equivalent variations with a correction factor on inequality.

Table 11: Social indicators

Theme	Indicator	Level	Unit	Formula
Poverty	Amount of people defined as 'poor'	National Regional	Percentage of population	$\frac{n_{poor}}{\sum_r POP_r} = \frac{\sum_n 1 \; \lvert Y_n \leq PovLine}{\sum_r POP_r}$
Poverty	Mean income of 'poor' household compared to poverty line (Intensity)	National Regional	Value between 0 and 1	$Y_{poor} / PovLine$ $Y_{poor} = IncomePoor$ $PovLine = PovertyLine$
Inequality in income distribution	Gini index	National Regional	Value between	$G = \frac{1}{2\mu} \cdot \sum_i s_i \sum_j s_j \lvert Y_i - Y_j \rvert$ $\mu = MeanIncome$ $Y = Income$ $s_i = SharePopulation$

Inequality in income distribution	Atkinson index (ε as inequality aversion parameter)	National Regional	Value between 0 and 1	$A(\varepsilon) = 1 - \left[\sum_i s_i \left(\frac{EV_i}{\mu EV} \right)^{1-\varepsilon} \right]^{1/1-\varepsilon}$ s_i = *IncomeShare* *EV = EquivalentVariation*
Progressivity of tax system	Kakwani index (difference between concentration of tax payments and Gini index)	National Regional By good/service	Unitless	$\pi_k = C - G$ $C = \frac{1}{2\eta} \cdot \sum_i s_i \sum_j s_j \lvert TAX_i - TAX_j \rvert$ η = *MeanIncome* *TAX = TaxPaid* *si = SharePopulation* *C = ConcentrationCurve*
Income	Change in household disposable income	National Regional	Monetary value Change	$\left(\frac{CBUD}{CBUD^0} - 1 \right) \cdot 100$ *CBUD = Consumption Budget*
Unemployment	Unemployment rate	National Regional	Percentage	$\left(\frac{UNRATE}{UNRATE^0} - 1 \right) \cdot 100$ *UNRATE = Unemployment Rate*
Welfare	Utility based index : equivalent variation (EV)	National Regional	Monetary value Percentage of income	$\left(\frac{U_{new} - U_{old}}{PEV_{old}} \right) \cdot \frac{1}{ScalU} = EV$ *PEV = pricing index for utility* *ScalU = appropriate scaling index* *U = utility in new and old situation*
Welfare	Social welfare (Bergstrom-Samuelson welfare function)	National	Monetary value	$SWF = \sum_r EV_r$ *or (with inequality correction, cfr. Atkinson index):* $SWF = \sum_r \frac{(EV_r)^{1-\varepsilon}}{1-\varepsilon}$ [8] ε = *coefficient of inequality aversion*

[8] Note that if ε =0, the inequality corrected welfare function reduces to a sum of monetized utilities

3.5.3 The environmental dimension of sustainability

Climate change

Climate change is one of the main concerns for the coming century. Long term damage of carbon dioxide and other greenhouse gasses are considered high to very high and can cause severe damage to our ecosystem, however uncertainty on the extent and location of the damage make it hard to impose stringent criteria on global level. Emissions of greenhouse gasses are closely linked to the energy use within the economy and there exists a one to one link with fossil fuels use and carbon dioxide emission.

Air pollution

Greenhouse gasses are damaging the balance of the climate, but have in general little health impacts on short term. However, there exist an entire class of air pollutants with direct effect on human and biosphere health. These should be treated separately from greenhouse gasses. Damages of air pollution depends on concentration levels, however models often focus on emissions. This is because concentration is hard to measure and bound to complex and non-linear dynamics. Implementing a policy related to air pollution thus requires additional environmental research and advice.

Energy

All economic activity requires energy and efficient use of energy is a guarantee to sustained economic development. The use of energy is normally closely related to measures of air pollution, as combustion and air pollution are closely related. Technological changes may increase the efficiency of energy and decrease the output of emissions. Sustainable development has always focused on finding alternatives to fossil fuel use as a main energy source.

Waste

Waste is the unwanted materials left after consumption and production activities. In a perfect world all waste would be recycled and reused in valuable economic, social and environmental activities. However, in reality waste is one of the main source of pollutants and a considerable problem faced by developing and developed societies. Waste is similar to emissions, however waste has the property that it does not disappear in the air (unless it is combusted). Therefore waste management is a clear economic activity and waste can be modelled as a 'good' (or rather a 'bad') which can be traded and used as an input in activities. (recycling, waste storage or waste combustion). Non treatment of waste, unavoidably leads to pollution of land and water resources.

Table 12: Environmental indicators

Theme	Indicator(s)	Level	Unit	Formula
Climate change	GHG emissions by unit of GDP or by energy consumption	National Regional Industry	Monetary (damages) Tonnes	$\frac{\sum_{i,r} GHG_{i,r}}{GDP}$
Energy consumption	Gross inland energy consumption by fuel	National Regional Fuel type	Tonnes or value By GDP	$\frac{\sum_{i,r} OIL_{i,r}}{GDP}$ [9]
Energy	Electricity consumption by households	National Regional	KwH	$\frac{\sum_{i,r} ELEC_{i,r}}{\sum_{r} POP_r}$ POP_r = population
Energy	Final energy consumption	National Regional Sector	Tonnes By GDP	$\frac{\sum_{i,r} ENER_{i,r}}{\sum_{r} GDPR_r}$
Air pollution	Emission (damages) of several pollutants, including SOx, NOx, PM, etc.	National Regional Industry	Monetary (damages) Tonnes of pollutant	$\sum_{i,r} EMISSION_{type,i,r}$ (optional: multiply with $MONTVALUE_{type}$ [10])
(Waste)[11]	(Generated waste by industries)	National Regional Industry	Monetary(damages) Tonnes	N/A

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[9] Can be oil, gas or coal or other energy input… Division by GDP is optional, but will help scaling with other indicators

[10] Monetary value of emission by emission type (optional), monetary value proposed can be based on EXTERN-E

[11] Waste will only be modeled if the necessary data becomes available, it will not be taken up in the framework in this version.

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