# Sustainability perspectives: a new methodological approach for quantitative assessment

Carraro C., Campagnolo L., Eboli F., Lanzi E., Parrado R., Portale E.

**Abstract**

This paper proposes a new tool to assess sustainability and make the concept of sustainable development operational. It considers its multi-dimensional structure combining the information deriving from a selection of relevant sustainability indicators belonging to economic, social and environmental pillars.

The main novelties of this approach are the modelling framework, a recursive-dynamic computable general equilibrium used to calculate the trend of all indicators over time throughout the world, and the aggregation methodology to reconcile them in one aggregate index to measure overall sustainability. The former allows capturing the sector and regional interactions and higher-order effects driven by background assumptions on relevant variables to depict future scenarios. The latter makes it possible to compare sustainability performances, under alternative scenarios, across countries and over time.

Main results show that the current sustainability at world level differs from what the traditional measure of well-being, the GDP, depicts, highlighting the trade-offs among different components of sustainability. Moreover, in the next decade a slight decrease in world sustainability may occur, in spite of an expected increase in world domestic product. Finally, dedicated policies increase overall sustainability, showing that social and environmental benefits may be greater than the correlated economic costs.

***Keywords***: Sustainable Development, Sustainable Indicators, Computable General Equilibrium, Millennium Development Goals, Climate Change
***JEL Codes***: Q54, Q56, C68

This draft: December, 2012

## Introduction

Sustainable Development is amongst the top priorities within policy agendas worldwide. This concept implies not only increasing and spreading the well-being throughout the world, but also avoiding compromising the perspectives of future generations. This requires substantial changes in production processes and life-style as well as the compliance to the idea that global development does not coincide with economic growth.

The most recent evolutions of the sustainability debate refer to the analysis developed by the "Commission on the Measurement of Economic Performance and Social Progress" (lead by Stiglitz, Sen and Fitoussi in 2009). This tries to define more concretely the concept of sustainable development and to clarify the methodological approach in this field. The approaching "Rio+20" conference will summarize and assess the main achievements in sustainable development, providing further guidelines with main focus on green economy and the effective integration of sustainable development within all levels of institutional governance.

Despite more than 20 years of research in sustainability assessment and the construction of several different sustainability indices, none of the approaches has managed to replace the traditional measure of well-being: the Gross Domestic Product (GDP). The research is focused in expanding the sustainability dimensions considered, whereas the attempt to aggregate them are few and only concern specific areas rather than the sustainability as a whole. The utility of summarizing a wide range of indicators in a single measure to increase the awareness of policy makers' strategies is undeniable. Nevertheless, aggregating a set of indicators in a unique index has a number of shortcomings, such as the difficulty in establishing the correct weights and in finding comparable metrics for the various indicators.

This paper presents an original contribution in this field. It introduces a new measure of sustainability, the FEEM Sustainability Index (FEEM SI), which addresses the necessity of "going beyond GDP" within the assessment of well-being. It summarises and merges the information derived by a selection of relevant sustainability indicators chosen among the most reliable international sets and covering the traditional sustainability dimensions (economic, social and environmental). The evolution of indicators composing the FEEM SI is computed in a recursive-dynamic Computable General Equilibrium (CGE) model (ICES-SI). This allows the assessment of sustainability across different future policy scenarios and the comparison of the sustainability performance across countries and through time in a coherent framework. Further, the FEEM SI methodology introduces a novel aggregation methodology for the construction of the index, particularly suitable to capture trade-offs among all sustainability dimensions. These novel features make the FEEM SI an ideal tool for using the sustainability concept in an operative manner.

Building a sustainability index in a CGE framework is certainly an innovative approach in this field. The sustainable development concept encloses the well-being of future generations, therefore attributing a central role to the temporal dimension. An applied economic model allows projecting future scenarios and making policy simulations. In addition, the multi-dimensionality of sustainability usually makes it a hard task to highlight the interactions among indicators of different topics. CGE models are flexible in a way that they not only can incorporate several key sustainability indicators in a single micro-consistent framework, but also allow performing a trade-off analysis among different components of sustainability, especially useful in analysing the effects of a policy implementation (Böhringer and Löschel, 2006).

Main results show that the current sustainability at world level is quite different from what the traditional measure of well-being, the Gross Domestic Product, depicts, highlighting the trade-offs among different components of sustainability. Moreover, in the next decade a slight decrease in world sustainability may occur, in spite of an expected substantial increase in world domestic product. Finally, dedicated policies to some or all sustainability dimensions increase overall sustainability, showing that social and environmental benefits may be greater than the correlated economic costs.

The structure of the paper is as follows. After a review of the literature on Sustainable Development measures in section 1, section 2 briefly describes the indicators and methodology for the construction of the FEEM SI. Section 3 illustrates the assumptions for Baseline and Policy scenarios and compares the resulting sustainability paths. Section 4 draws main conclusions.

## 1. Sustainable Development measurements: an overview

Over the last two decades, there has been an ongoing debate on sustainability assessment and the limitations of GDP as unique measure of well-being and development. Sustainability is a dynamic concept, which brings together aspects intertwined in time and space. There are many alternative ways to describe Sustainable Development, but even a broadly used definition such as the one initially proposed by the Brundtland Commission[1] is often considered too elusive to provide clear methodological guidelines. Indeed, the multi-faceted nature of sustainability calls for a systemic approach combining economic and environmental aspects (growth and exploitation of resources) with social concerns (division of resources among countries/people) (Saltelli *et al.*, 2007).

Indicators[2] represent the main instrument to put sustainability theory in practice (Parris and Kates, 2003; Singh and Gupta, 2009) given their synthetic properties and the increasing use in policymaking and public communication. They are often organized in conceptual bundles, different in core values and sustainable development theories: issue- or theme-based frameworks, causal frameworks, capital and accounting frameworks, headline indicators, goal-oriented indicators and aggregate indices (UN, 2007; Pintér *et al.*, 2005).

Among them, **issue- or theme-based indicators** have a wide coverage of all sustainability components; they emphasise areas according to policy relevance and are very common since they are well suited to be linked to policy processes and targets. Sustainable development is typically divided in three (economic, environmental and social) or four pillars (economic, environmental, social and institutional); for each of them a set of indicators is defined, following a pyramidal structure from themes to sub-themes (Adelle and Pallemaerts, 2009).

Several international institutions deal with sustainable development through theme-based indicators: at the intergovernmental level, one of the most important players is the UN Commission on Sustainable Development (UN CSD), which has produced and revised a set of theme-based indicators to assess sustainable development.[3] OECD started in 1989 a framework to develop environmental indicators (Adelle and Pallemaerts, 2009) and in the OECD's second World Forum, in 2007 at Istanbul, launched the project on "Measuring the Progress of Societies". The project aims "to foster the development of sets of key economic, social and environmental indicators and their use to inform and promote evidence-based decision-making, within and across the public and private sector and civil society" (OECD, 2007). Although targeted to broader scope than sustainability, it is worth noting the important contribution of World Development Indicators (World Bank) that account 420 indicators covering 209 countries which also capture many

[1] WCED (1987) defines Sustainable Development as a "development that meets the need of the present generation without compromising the ability of future generations to meet their own needs".

[2] An indicator is a "quantitative or a qualitative measure derived from a series of observed facts that can reveal relative positions (e.g., relative position of a country) in a given area" (OECD, 2008). It should be exhaustive and concise, quantifying and aggregating data regarding to a specific aspect, enabling to assess change in time and giving insight on the reasons for change.

[3] This process, started in 1995, generated a set of indicators, first published in 1996. In the revised version of 2001, indicators are grouped into four pillars of sustainability – social, economic, environmental and institutional – each subdivided into themes, sub-themes and indicators. The third revision has been published on January 2007 and the 98 indicators are grouped into 15 themes and then divided into sub-themes.

dimensions of sustainable development. On the policy side, it is worth noting that European Union is committed to implement the European Union Sustainable Development Strategy (EU SDS).[4]

Sustainability indicators capture the complexity of the phenomenon and convey to policy makers important insights and directions. However, their actual effectiveness has been limited by the lack of a priority system among indicators (UN CSD 2006); current trends in sustainable development indicators show an increasing interest for the core sets of goal-oriented indicators and aggregate indices (Pintér *et al.*, 2005). The goal-oriented indicators link the choice of indicators with targets to improve their usefulness in comparing performance among countries, besides providing rankings. The Millennium Development Goals (MDGs) at international level or national or supra national established policy goals (EU Sustainable Development Strategy, Lisbon Strategy) are increasingly used for indicator selection and creation.[5]

Moreover, there are numerous attempts to move beyond the non-integrated indicators and consider different economy-nature-society dimensions in one indicator or index (Ness and Anderberg, 2007). A branch of literature focused on enriching existing indices with the inclusion of new components; for example, the Sustainable National Income (SNI) tries to include sustainable resource utilization in the national accounting system. Adjusted Net Saving corrects gross national savings with the estimate of capital depreciation, human capital investments, natural resources depletion and damages caused by pollution (Ness and Anderberg, 2007; Adelle and Pallemaerts, 2009)

There is also a flourishing literature focusing not only in improving current indices, but also in answering to the policy makers' need to have a synthetic tool for a wide collection of indicators: the **aggregate sustainability indicators or indices**.[6] These usually focus on specific area of sustainability. The Human Development Index (HDI - United Nations, 1990) assesses the ability of a country in attaining a healthy life, education and decent standard of living. The Wellbeing Index (WI - Prescott-Allen, 2001) is generated from two indices: the Human Wellbeing Index (HWI), including health, wealth, cultural and educational indicators, and the Environmental Wellbeing Index (EWI) centred on biodiversity and natural resources. The Environmental Sustainability Index (ESI, 2005) condenses 21 indicators covering six components of environmental sustainability (environmental systems, environmental stresses, human vulnerability to environmental stresses, societal capacity to respond to environmental challenges and global stewardship). The Environmental Performance Index (EPI) includes "25 performance indicators tracked across ten policy categories covering both environmental public health and ecosystem vitality" assessing the closeness of a country to environmental policy goals (Yale and Columbia Universities, 2010). A peculiar approach is the Ecological Footprint (Wackernagel and Rees, 1996), which accounts for the quantity of land necessary to sustain the annual individual consumption of goods, services, housing and transport. Another way of measuring sustainability is the use of monetary indexes; some examples of the monetary approach are the ISEW (Index of Sustainable Economic Welfare) from Daly and Cobb (1989); the Weak Sustainability Index from Pearce and Atkinson (1993); the so-called El Serafy approach (Yusuf *et al.*, 1989).

The aggregation of different indicators in an index does not see the favour of a portion of literature,

---

[4] The EU SDS is structured as a "hierarchical theme framework" composed by indicators ranging over ten themes. Eight are the so called "key challenges" (Sustainable Consumption and Production, Social Inclusion, Demographic Changes, Public Health, Climate Change and Energy, Sustainable Transport, Natural Resources, Global Partnership); in addition, the key objectives of economic prosperity and the leading principle of good governance are considered. Latest update in 2009 focused on "rapid shift to a low-carbon and low-input economy based on energy and resource-efficient technologies", "protection of biodiversity, water and other natural resources", "promoting social inclusion" and "Strengthening the international dimension of sustainable development and intensifying efforts to combat global poverty".

[5] Even institutions that normally adopt other approaches/models such as the World Bank (WB), the United Nations Development Program (UNDP) and the World Health Organization (WHO) have started to use the MDG indicators as a standard reference.

[6] An index is characterized by a set of indicators chosen to express as many characteristics and aspects as possible of a complex phenomenon (OECD, 2008). Aggregate indices have several positive aspects; presenting indicators in an aggregated way allows exploring the relationship among the variables, facilitates presentation of information to decision makers, and may serve as a basis for an early warning system (UN, 1995).

as it emerges from the Stiglitz *et al.* (2009), because it implies loss of information and implicit subjectivity. These are important objections and particular attention to the quality and the transparency of the aggregation methodologies is needed in order to guarantee consistency of assumptions and interpretability of the obtained ranking (Munda, 2004). On the other hand, the purpose of an aggregate index is undeniable: it attempts to summarise a too wide dashboard and to guide policy makers' assessment and action. In choosing this approach, it is important to follow a simple guideline: "Globally, all these composite indicators should probably be better regarded as invitations to look more closely at the various components that lie behind them" (Stiglitz *et al.*, 2009).

## 2. The FEEM Sustainability Index

The FEEM Sustainability Index[7] (FEEM SI) stems from this wide and heterogeneous literature on sustainable development measures. There are a number of factors making this index innovative within the research field on sustainability assessment.

First, the aggregate Index groups all sustainability dimensions simultaneously. Differently from the majority of aggregate indices, the FEEM SI intends to summarise the three main components of sustainability: economic, social and environmental. Figure 1 illustrates the structure of the FEEM SI and includes all indicators considered.[8] The leaves at the bottom of the decision tree are then gradually aggregated (from bottom to the top) in thematic indices. At the top node, the FEEM SI condenses economic, social and environmental dimensions.

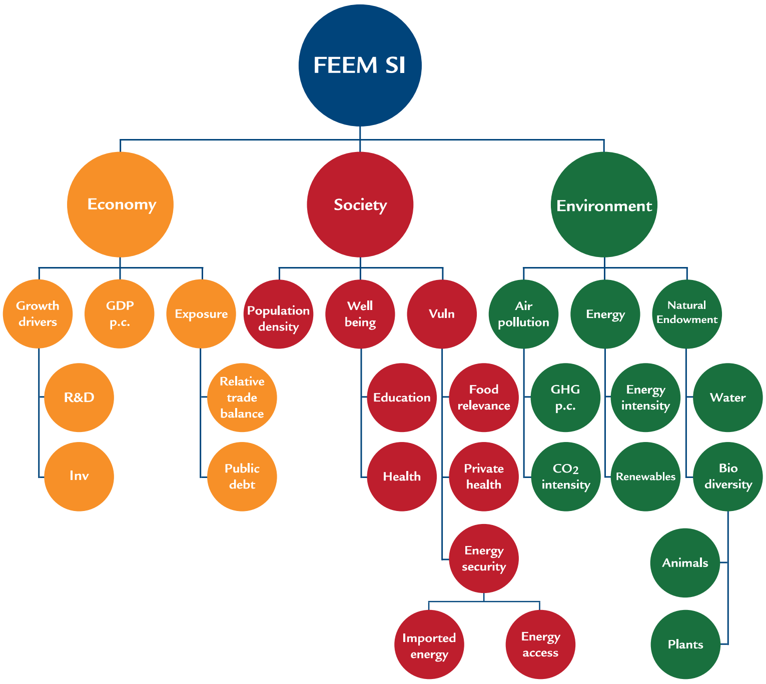



**Figure 1 - FEEM SI indicators' tree**

Another characteristic of the FEEM SI is the normalisation approach used to express all indicators through a common measurement scale:[9] an indicator-specific stepwise benchmarking function whose intermediate values are either established according to policy targets or observed trends. The

[7] Further description and extended results of FEEM SI project can be found in Carraro *et al.* (2011) and at: *www.feemsi.org*.
[8] A detailed description of indicator construction and sources is available in the Annex I.
[9] The normalization procedure converts indicator-specific unit measures to a common one in the range [0,1] and then allows full comparability among indicators.

upper and lower bounds of this function correspond to fully sustainable and unsustainable conditions, respectively. A finer tune on indicators values is guaranteed by the linearization of the benchmarking function.

As stated above, the indicators' aggregation procedure is a crucial point in determining the reliability and the credibility of an index. The FEEM SI adopts a complex double aggregation process. First, an experts' elicitation process via an *ad hoc* questionnaire produced a set of evaluations for each indicator and their combinations in each sub-node. A non-linear methodology (metric distance) combined diverging responses into a 'representative' set of weights used to compute a consensus measure. The second step was to combine normalised indicators' values and the weights created in the previous step. In this case, a non–linear aggregation methodology, the Choquet integral, is used. Following this approach, the FEEM SI optimizes the trade off between simplicity and effectiveness in representing preferences by focusing specifically on the interrelations across indicators. More details on both normalisation and aggregation methodology are in Carraro *et al.* (2011).

Two factors drove the choice of the above set of indicators. As a first step, a throughout analysis of the most reliable international databases (UN CSD, EU SDS, WDI) was carried out to select the most significant indicators for which quantitative data are available for the whole world at country scale. Then, a further refinement has been necessary in order to make possible their computation in the time-horizon under consideration (2004-2020) within the applied general equilibrium model used at this purpose. The rest of this section will explain at a deeper detail the main features of both model and database and their extensions to include as many indicators as possible in the CGE framework.

### *The ICES-SI model*

The FEEM SI builds on the recursive-dynamic general equilibrium model ICES-SI, an extended version of the ICES model.[10] The ICES model main scope is to assess the final welfare implication of climate change impacts and mitigation policies on world economies, as well as different trade and public-policy reforms in the vein of conventional CGE models. Its general equilibrium structure, in which all markets are interlinked, is capable to capture and highlight the production and consumption substitution processes in a socio-economic system as a response to shocks. In doing so, the final economic equilibrium obtained takes into account explicitly the "autonomous adaptation" of economic systems.

The economy representation is compliant with the usual CGE modelling: industries are cost-minimiser and present a nested production function in which primary factors and intermediates are combined to produce the final output. A representative household in each region receives income, defined as the service value of the national primary factors (natural resources, land, labour and capital). Demand for production factors and consumption goods can be satisfied either by domestic or foreign producers that are not perfectly substitutable according to the "Armington" assumption. The country representative households maximise their utility coming from the expenditure on aggregate household consumption, public consumption and savings under the budget constraint.

This way, ICES is capable to replicate, on the one hand, past and present patterns and, on the other hand, to project possible future development paths. This is the crucial reason why the present analysis uses such a model. Indeed, time projection is a concept neglected by the usual sustainability analysis due either to the absence of proper instruments or to the lack of faith in the possibility to predict the future behaviour of some indicators. A general equilibrium model offers the possibility to evaluate future trends of the indicators of the FEEM SI within a coherent and

[10] Eboli *et al.* (2010). See also http://www.feem-web.it/ices/ and the Annex II.

theoretically founded framework, which effectively works as a consistency grid for the indicators over time, keeping them meaningful with respect to one another.

The dynamic of the model is driven by two sources: one exogenous and the other endogenous. The first stems from exogenously imposed growth paths for some key variables - population, labour stock, labour productivity, and land productivity. The second concerns the process of capital accumulation, according to which capital stock is updated over time in order to take into account endogenous investment decisions. The model relies on a global trade database (GTAP-7) describing the world economic flows in the base year (2004).

In order to perform the analysis on sustainability, the ICES model has been extended adding new sectors and new exogenous variables. First, the sectoral detail has been enlarged to include or extrapolate some fundamental sectors for the construction of the sustainability indicators. Secondly, new variables have been included to enrich the model and to calculate the sustainability indicators related to them. For this purposes, changes have been made both to the database and to the model itself, leading to the improved ICES-SI model.

***Additional Sectors***

The GTAP-7 database (Narayanan and Walmsley, 2008) collects economic information in Input-Output Matrix format covering the global economic system. The original detail accounts for 57 sectors and 113 country/regions. The database provides details at country level if available; otherwise, more countries are grouped in one single macro-region. We aggregate the original 113 regions to 40, maintaining the world coverage.

As regards the sector specification, the final commodity aggregation for the ICES-SI includes 20 sectors, with a detailed disaggregation of energy and public services.[11] To perform the sustainability analysis we worked under two different directions. On the one hand, we reduced the number of sectors not relevant for the construction of sustainability indicators in larger sectors. On the other hand, we extracted several sub-sectors (Research and Development, Education, Private and Public Health and Renewable Energy Sources) from the original categorisation using the SplitCom facility (Horridge, 2008) and relying upon external data on trade flows, production and consumption of these sectors/commodities.

The *Research and Development* (R&D) sector is derived from the GTAP "Other Business Services" sector, which includes real estate activities, renting of various types of machineries, computer-related activities, R&D and other business activities. In order to isolate R&D, we used data on R&D expenditure as percentage of GDP in each country from the World Development Indicators (WDI) (World Bank, 2010). The share of R&D financed by Government, Firms, Foreign Investment and Other National was obtained from the OECD Main Science and Technology Indicators (OECD, 2010) and was used to attribute R&D to the different economic agents. The original sector residual, after the splitting procedure, was included in the "Market Services" sector. Since no data on international trade flows are available, it has been assumed that there are no direct imports and exports in R&D.[12]

A similar approach has been adopted to split the GTAP sector "Other Services (Government)" that includes services of public administration and defence, sewage and refuse disposal, activities of membership organizations and extra-territorial organization and bodies, education and health. Three new sectors have been extrapolated, namely *Education, Private Health and Public Health* using, for the former, data on overall expenditure in health and education from the WDI database (World

[11] Annex III describes the sectoral aggregation of the model in detail.
[12] This assumption complies with the fact that R&D is usually a domestic activity, as the government and firms would invest in R&D only to benefit their own country's productivity. In fact, even though firms employ foreign institutes for their research, they generally own the property rights of the inventions. Indirect R&D international trade is implicit in other commodities' trade.

Bank, 2010) and, for the others, the World Health Organization database (WHO, 2010). Regarding to imports, exports and agents' purchase of the commodities, we maintained the same proportions of the initial sector.

The GTAP sector "Electricity" includes electricity produced from every energy sources (both fossil and renewable). The sustainability analysis requires a higher technological detail; at the purpose, we separate from the original sector the *Renewable Energy Sources* (RES), namely wind, solar and hydro electricity. The residual of this procedure is included in the "Other Electricity" sector. The extrapolation of the RES sectors required two steps. First, we collect the physical energy production in Mtoe (Million tons of oil equivalent) from different energy vectors and for each GTAP-7 country/region, collected by the Extended Energy Balances.[13] Then, we assigned an economic value corresponding to the physical production (OECD/IEA, 2005; EC, 2008; Ragwitz *et al.*, 2007; GTZ, 2009; IEA country profiles[14]; REN21[15]) in each country. This information was useful to define the value of production for the new sector and to split it from the original one. Regarding imports, exports and agents' purchases of the commodity, the same proportions of the initial sector have been maintained for the new one.[16]

### *Additional variables*

Some of the indicators selected for the FEEM SI are related to variables not originally included in the GTAP-7 database, namely: use of water, biodiversity, access to electricity and inhabitable land. In fact, it has been necessary to include in the model external data relative to these variables: first adding the variables to the dataset and then linking them to the model. Linking new exogenous variables to pre-existing inter-connected endogenous variables allows simulating their future behaviour coherently with the endogenous path of ICES-SI over time.

The original GTAP-7 database includes a sector/commodity called "*Water*", but this only refers to water services infrastructures and does not really considers water availability and consumption. Therefore, additional variables have been added to the model in order to obtain a better indicator for water use. The Food and Agriculture Organization (FAO) provides the Aquastat database[17] that contains information on volumes of water consumption, which accounts for the total use of water in agriculture, industry and for private use and the total Renewable Water Resource (WTR). The latter is taken constant over time,[18] while water use in agriculture, industry and private sector has been linked respectively with demand of water services by agriculture, industry and households, this way changing endogenously in the model.

An index that quantifies the number of endangered species for both animals and plants over their total population in each country describes the *Biodiversity* loss. The data to construct these indicators has been obtained from the World Conservation Union (IUCN) Red List of Threatened Species Database. The number of endangered species has been linked to the model so that over time it is possible to detect whether the number of species in danger of extinction is increasing. Biodiversity loss can be related to multiple human activities, such as extension of agricultural fields, forestry abatement, fishing, hunting, industrial activities or pollution. As it was not possible to take account of all those factors, climate change and $CO_2$ concentration have been thought to be the most

---

[13] http://www.oecd-ilibrary.org/content/datacollection/enestats-data-en
[14] http://www.iea.org/country/index.asp
[15] http://www.ren21.net/
[16] The ICES-SI model reserves a particular treatment to energy commodities, which are included among value added factors and present a high degree of substitutability with capital. The explicit consideration of the RES sector implied some modelling changes: the new structure for the production function, consistent with the new database structure, incorporates a new nest to allow the inter-electricity substitution between RES and traditional electricity, whereas the electricity was previously considered as undistinguished irrespective of the source (see Annex II for further details).
[17] http://www.fao.org/nr/water/aquastat/main/index.stm
[18] In the time-horizon under consideration (2004-2020) this variable is not expected to change substantially.

significant variables to consider. According to a study by Thomas *et al.* (2004) relative to 1,103 animal and plant species in sample regions covering some 20% of the Earth surface, 15 to 37% of the species are at risk of extinction because of climate change scenarios at 2050. In order to proxy for climate change, the number of endangered species has been inversely linked to emissions of $CO_2$, i.e. higher emissions of carbon dioxide lead to an increase in the number of endangered species.

An additional variable, considering the share of population with *access to electricity***,** has been added to construct an energy access indicator. The source for the base year is the World Energy Outlook (IEA, 2010). As a Developing Country with unsatisfactory access to electricity reduces over time its GDP per capita gap with the OECD average level, it increases the possibility to afford population for basic needs, such as electricity; this relation determine the endogenous dynamic of this indicator within the ICES-SI model. The initial access to electricity converges slowly across time towards the universal coverage, but this is not even reached in the baseline scenario in some developing countries given the short time span.

Finally, we add the variable *available land* in each country (excluding deserts, ice-cover land and mountains) to define the population density indicator. The data source is the GTAP-7 land use database, relying upon FAO data.[19] There is no dynamic pattern imposed on this dataset: the available land remains constant through the time-horizon under consideration.

## 3. Projecting sustainability over time

The first question to address is how sustainability will change over time if the current growth and policy trends were to continue. To address this question we first present a reference scenario in which main macro-economic variables change according to current trends and without considering any explicit policy intervention to improve sustainability. The present level of sustainability throughout the world is then compared with the expected picture in 2020. These projections also serve as a reference scenario for policy simulations. The second question to address is in fact, how policies could affect sustainability trends. To study the effect of policies on sustainability, we study a policy scenario, which considers a set of policies addressing the different sustainability issues to assess changes in global sustainability.

### *3.1 Baseline scenario description*

The reference scenario reproduces historical data from 2004 to 2009 and then projected data up to 2020. The value added of the present baseline scenario is the replication of the financial crisis and its effect on future projections of economic growth and sustainability. Table 1 reports the main sources for both exogenous and endogenous dynamics.

Along with population and GDP trend, it is worth mentioning that energy sectors play a key-role in future sustainability. Apart from the relevance for economic development, energy production, being still mainly based on fossil fuels, affects the social (energy security) and environmental (climate change) dimensions. For this reason, one of the main drivers for future technological advancements in the energy system is the evolution of fossil fuels' prices and energy intensity.

[19] https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=1900

**Table 1 - Main variables and reference sources in the baseline scenario**

| Variable | Reference source |
|---|---|
| **Population** | UN World Population Prospect (2010 revision) – medium fertility variant |
| **Fossil fuel prices** | Eurelectric (2010) |
| **GDP** | 2005-2009 = WDI (World Bank, 2010)<br>2010-2020 = MMC_G10 scenario Med Pop - Medium Growth - Fast Convergence (Conv) developed within the RoSE project[20] + World Economic Outlook 2010 (IMF, 2010) for downscaling at country level |
| **Energy intensity** | 2005-2009 = IEA (2010)<br>2010-2020 = endogenous |
| **CO2 emissions** | 2005-2009 = IEA (2010)<br>2010-2020 = endogenous |
| **Public debt** | IMF (2010) |

### *3.2 Baseline scenario results*

The FEEM Sustainability Index is calculated for each country/macro-region in each year. Figure 2 illustrates the ranking for 2011.[21] Not surprisingly, developed countries/regions perform better than developing ones. Scandinavia, Central Europe and Canada show the highest values, since the high level of GDP per capita comes along with excellent performances in social and environmental pillars. Several highly advanced countries (USA, Germany, UK) are less sustainable especially because their energy mix is mainly based on fossil fuels and it implies a higher environmental impact. The central part of the ranking shows a quite heterogeneous composition comprising rich countries affected at huge extent by financial crisis (Italy, Spain) or low social performance (Japan, Korea) and countries with intermediate levels of economic development (Russia, Mexico, Turkey). Finally, the poorest areas in the world are at the bottom of the ranking, with China and India having the lowest scores.

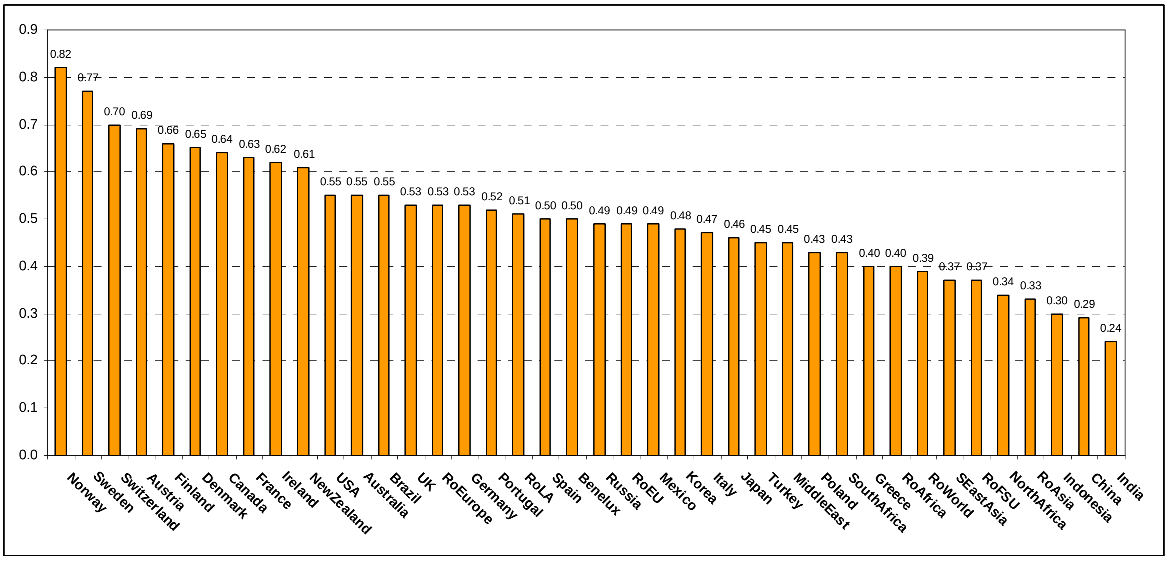



**Figure 2 - World Sustainability Ranking 2011**

Figure 3 compares the scores of each pillar (economic, social and environmental) and the aggregate index for the best and worst countries. The scores for the top-three countries are similarly high in the three main components of sustainability. Norway is at the top of the ranking, thanks to the high

[20] "RoSE - Roadmaps towards Sustainable Energy Futures: A Model-Based Assessment of Scenarios for Decarbonising the Energy System in the 21st Century". Project funded by Stiftung Mercator Foundation, Germany. It is worth noting that the above project is an initial attempt to develop new economic scenarios, replacing the SRES (Nakicenovic and Swart, 2000) previously adopted by IPCC – Intergovernmental Panel on Climate Change – for climate change analysis.
[21] Annex IV presents the 2011 ranking for each pillar and Sustainability maps.

scores in all components. Sweden performs a bit worse than Norway in all dimensions. Even though slightly better in economic terms, Switzerland scores at the third place because of the relative lower social sustainability (for instance with reference to population density, that is particularly low in Scandinavia).

Turning to the bottom-three countries,[22] the components are very unequally distributed and this makes clear the trade-offs at lower stage of economic development. Indonesia leads this special ranking due to the better environmental performance with respect to China, even though the latter has higher scores at economic and social level. India has a very low economic and social performance, even though on the environmental side it is superior to China.[23]

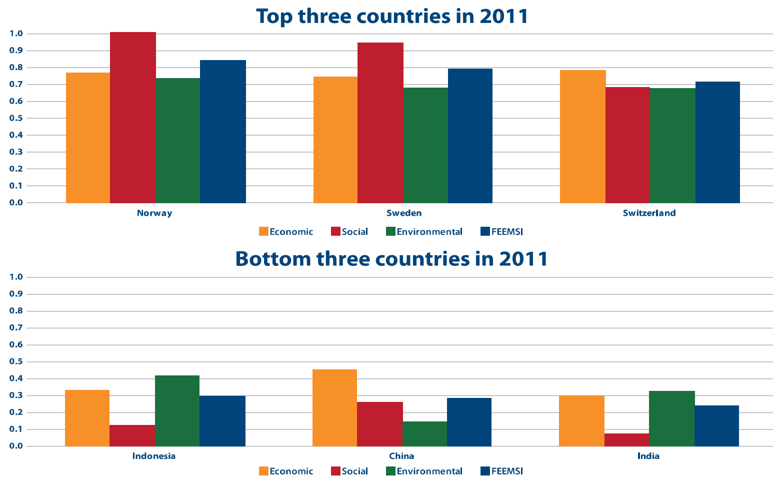



**Figure 3 - FEEM SI and sustainability pillars for the Top and Bottom Countries**

Cruciani *et al.* (2012) perform an in-depth analysis to check the robustness of the above ranking by building a linear convex combination of the weights assigned by 1000 *artificial experts* ranging between the two extreme real experts and then performing a Monte Carlo analysis. The dominance analysis, that is the probability that one country performs better than the follower similarly to the base case illustrated above, shows a robust ranking and marginal variability with respect to the picture presented here.

The main function of an aggregate sustainability index is to give a more complete picture on well-being with respect to what GDP does. Table 2 compares the FEEM SI ranking with the analogous for GDP p.c. A stronger relation between GDP p.c. and FEEM SI rankings characterizes the 10 bottom countries; a low GDP p.c. is normally associated to a low overall sustainability performance. Nevertheless, it is confirmed that the other indicators considered in the FEEM SI may skew the GDP p.c. ranking.

The richest country in the world in terms of GDP p.c., Norway, is also the most sustainable. However, USA, which has the second highest GDP p.c. in the world, is only at 11$^{th}$ position according to the FEEM SI ranking. This is due to one of the worst results in environmental sustainability not enough compensated by the good economic and social performance. Moreover, even though the GDP p.c. is high, public debt strongly penalizes the USA performance. Australia is another example of country that moves down substantially when comparing FEEM SI and GDP p.c., because of the relatively low sustainability of environmental dimensions. Conversely, Sweden, Finland and France have the reverse relationship (FEEM SI makes them better off than the GDP

[22] It is worth noting that many poor countries are grouped and appears performing better than those bottom-three. If taken separately, possibly other countries may perform worse. Unfortunately, data availability does not allow going at a deeper detail.
[23] Annex III presents the value and ranking of pillars for each country in 2011.

ranking). Looking at the very bottom of the ranking, India (38th according to GDP p.c.) becomes the worst performer (40th according to FEEM SI) because of its poor performance in social and environmental sustainability. Conversely, the poorest RoAfrica benefits from the relatively good environmental performance.

**Table 2 - GDP per capita and FEEM SI ranking in 2011**

| GDP pc ranking | Country | FEEM SI ranking | GDP pc ranking | Country | FEEM SI ranking |
|---|---|---|---|---|---|
| 1 | Norway | 1 | 21 | Portugal | 17 |
| 2 | USA | 11 | 22 | Poland | 29 |
| 3 | Switzerland | 3 | 23 | MiddleEast | 28 |
| 4 | Australia | 12 | 24 | RoEU | 22 |
| 5 | Austria | 4 | 25 | Russia | 21 |
| 6 | Ireland | 9 | 26 | Mexico | 23 |
| 7 | Denmark | 6 | 27 | RoEurope | 15 |
| 8 | Benelux | 20 | 28 | RoLA | 18 |
| 9 | Sweden | 2 | 29 | SouthAfrica | 30 |
| 10 | Canada | 7 | 30 | Brazil | 13 |
| 11 | Germany | 16 | 31 | Turkey | 27 |
| 12 | Finland | 5 | 32 | RoFSU | 35 |
| 13 | UK | 14 | 33 | Ro World | 33 |
| 14 | Japan | 26 | 34 | SEastAsia | 34 |
| 15 | France | 8 | 35 | NorthAfrica | 36 |
| 16 | Spain | 19 | 36 | Indonesia | 38 |
| 17 | Italy | 25 | 37 | China | 39 |
| 18 | Korea | 24 | 38 | India | 40 |
| 19 | NewZealand | 10 | 39 | RoAsia | 37 |
| 20 | Greece | 31 | 40 | RoAfrica | 32 |

We now move forward to consider the expected pattern of sustainability in the next future. Table 3 compares FEEM SI ranking and scores in 2011 and 2020. Most of countries/regions slightly increase their sustainability in the next ten years. Nevertheless, a few but important countries, among which USA, Russia and Brazil, show a decreasing trend in their own sustainability. This is due mainly to increasing public debt and environmental deterioration. As regards the variations in the sustainability ranking, Benelux (+7 positions), Germany (+5) and Italy (+3) benefit the highest advancements, while United States (-6) and Russia (-5) have the largest decrease.

## Table 3 - Sustainability ranking (2011 vs 2020)

| Rank 2011 | Country | FEEM SI 2011 | Δ Rank | FEEM SI 2020 | Country | Rank 2020 |
|---|---|---|---|---|---|---|
| 1 | Norway | 0.82 | = | 0.85 | Norway | 1 |
| 2 | Sweden | 0.77 | = | 0.81 | Sweden | 2 |
| 3 | Switzerland | 0.70 | **-1** | 0.74 | Austria | 3 |
| 4 | Austria | 0.69 | **1** | 0.70 | Switzerland | 4 |
| 5 | Finland | 0.66 | = | 0.68 | Finland | 5 |
| 6 | Denmark | 0.65 | = | 0.68 | Denmark | 6 |
| 7 | Canada | 0.64 | = | 0.67 | Canada | 7 |
| 8 | France | 0.63 | = | 0.65 | France | 8 |
| 9 | Ireland | 0.62 | **-1** | 0.63 | NewZealand | 9 |
| 10 | NewZealand | 0.61 | **1** | 0.62 | Ireland | 10 |
| 11 | USA | 0.55 | **-6** | 0.58 | Germany | 11 |
| 12 | Australia | 0.55 | = | 0.58 | Australia | 12 |
| 13 | Brazil | 0.55 | **-2** | 0.56 | Benelux | 13 |
| 14 | UK | 0.53 | = | 0.55 | UK | 14 |
| 15 | RoEurope | 0.53 | **-1** | 0.54 | Brazil | 15 |
| 16 | Germany | 0.53 | **5** | 0.54 | RoEurope | 16 |
| 17 | Portugal | 0.52 | **-2** | 0.53 | USA | 17 |
| 18 | RoLA | 0.51 | = | 0.53 | RoLA | 18 |
| 19 | Spain | 0.50 | **-2** | 0.53 | Portugal | 19 |
| 20 | Benelux | 0.50 | **7** | 0.51 | RoEU | 20 |

| Rank 2011 | Country | FEEM SI 2011 | Δ Rank | FEEM SI 2020 | Country | Rank 2020 |
|---|---|---|---|---|---|---|
| 21 | Russia | 0.49 | **-5** | 0.50 | Spain | 21 |
| 22 | RoEU | 0.49 | **2** | 0.50 | Italy | 22 |
| 23 | Mexico | 0.49 | **-2** | 0.49 | Korea | 23 |
| 24 | Korea | 0.48 | **1** | 0.49 | Japan | 24 |
| 25 | Italy | 0.47 | **3** | 0.48 | Mexico | 25 |
| 26 | Japan | 0.46 | **2** | 0.48 | Russia | 26 |
| 27 | Turkey | 0.45 | = | 0.48 | Turkey | 27 |
| 28 | MiddleEast | 0.45 | = | 0.47 | MiddleEast | 28 |
| 29 | Poland | 0.43 | = | 0.44 | Poland | 29 |
| 30 | SouthAfrica | 0.43 | = | 0.43 | SouthAfrica | 30 |
| 31 | Greece | 0.40 | = | 0.43 | Greece | 31 |
| 32 | RoAfrica | 0.40 | = | 0.40 | RoAfrica | 32 |
| 33 | RoWorld | 0.39 | = | 0.39 | RoWorld | 33 |
| 34 | SEastAsia | 0.37 | = | 0.36 | SEastAsia | 34 |
| 35 | RoFSU | 0.37 | = | 0.36 | RoFSU | 35 |
| 36 | NorthAfrica | 0.34 | = | 0.34 | NorthAfrica | 36 |
| 37 | RoAsia | 0.33 | = | 0.34 | RoAsia | 37 |
| 38 | Indonesia | 0.30 | **-1** | 0.32 | China | 38 |
| 39 | China | 0.29 | **1** | 0.32 | Indonesia | 39 |
| 40 | India | 0.24 | = | 0.29 | India | 40 |

Decomposing the analysis at level of single pillar and adding information on GDP evolution helps to understand the results in Table 3. Figure 4 presents the percentage variation in 2020 with respect to 2011 for the best ten performers (listed according to the 2011 ranking). These results illustrate that the sustainability of most countries increases. This increase is mostly driven by a positive change in the economic component, with the exception of Norway, France and New Zealand for which the environmental component has a larger variation. Social sustainability has a slower variation and decreases in a few countries (Norway, Austria and France). The only country whose sustainability is decreasing is Switzerland (-0.8%) due to a decline in the social (-0.6%) and environmental (-6%) dimensions – the latter caused by a marked deterioration in energy intensity – not compensated by the intensification in the economic pillar (4%) and in the GDP per capita (18.3%).

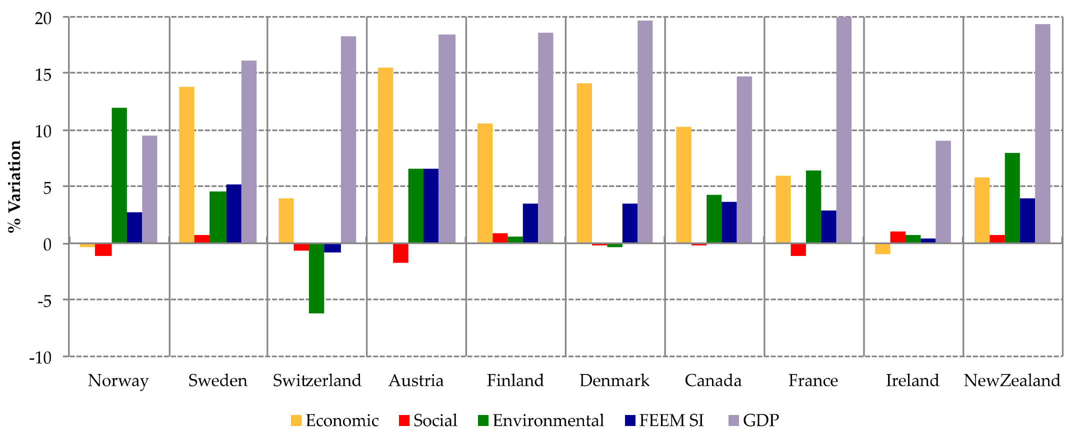



**Figure 4 - % variation of the best ten performers by dimension (2020 wrt 2011)**

Figure 5 shows the percentage variation for the worst ten performers in 2020 with respect to 2011 for each pillar, FEEM SI and GDP. Results highlight the expected trade-offs, in the initial stage of economic development, between the economic and social (all except Greece and RoFSU) or/and environmental (RoAfrica, RoFSU, Indonesia) pillars. The overall effect on sustainability is relatively small. It is worth noting the situation of RoFSU, whose GDP grows by some 80% but strong environmental deterioration produces a negative FEEM SI performance. FEEM SI value expansion is noteworthy for China (12.5%) and it is supported by a substantial change in all dimensions, namely 47% improvement in the environmental, 19% in the economic and a decreasing (-27%) in the social pillar. These variations make China able to raise one position in the ranking at expenses of Indonesia, where the environmental degradation partially counterbalances the greater improvement in the economic component. Finally, India presents a GDP per capita growth of 85.4%, which drives the economic pillar to a 50% increase over time.

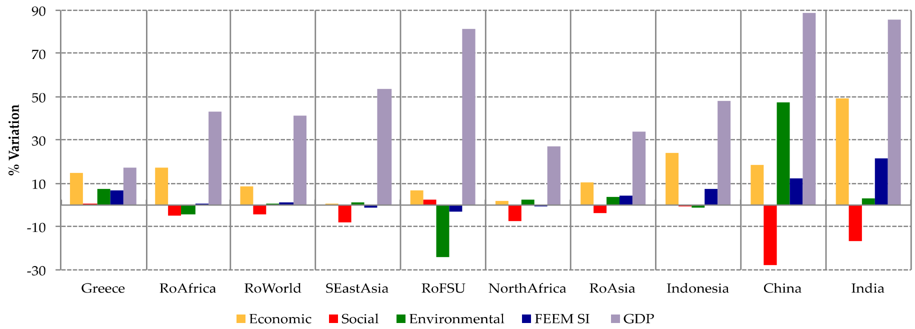



**Figure 5 - % variation of the worst ten performers by dimension (2020 wrt 2011)**

Looking at the world level, FEEM SI slightly decreases in the 2011-2020 period in spite of an increase of 20% in GDP p.c. This is strongly driven by the social deterioration that mainly, but not exclusively, affects the least developing countries. This is a clear signal of the wrong message delivered when considering GDP p.c. the only driver of well-being.

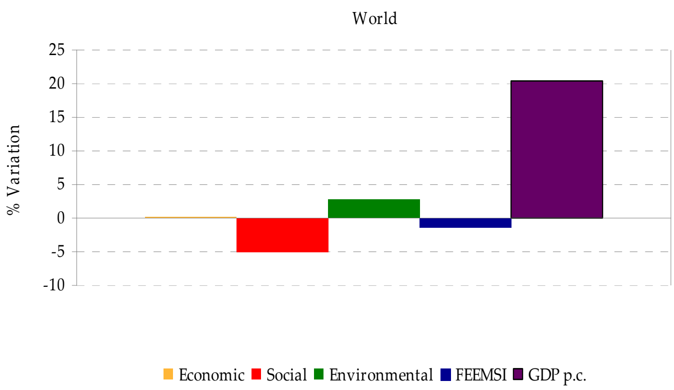



**Figure 6 - Percentage variation in aggregated regions by pillar (2020 w.r.t 2011)**

### *3.3 Policy Scenarios description*

One main insight from the previous section is that, in spite of a significant increase in global GDP p.c. in the next decade, global sustainability will slightly decline. It means that there is room for appropriate intervention to increase future sustainability. In order to assess how sustainability may be improved undertaking dedicated strategies, we propose and simulate three policy scenarios. We first performed an Environmental and a Social Policy separately, each considering selective interventions in related spheres. In addition, an all-inclusive scenario (Sustainable Development Policy) considers jointly the previous measures and, further, includes a subsidy on R&D, thus addressing all sustainability dimensions simultaneously.

The general equilibrium framework allows keeping track of variations worldwide even when policies involve directly either a single pillar or a subset of countries/regions. All policies take effect from 2010 to 2020. Each scenario is a combination of policies summarized in Figure 7 and described in Table 4.

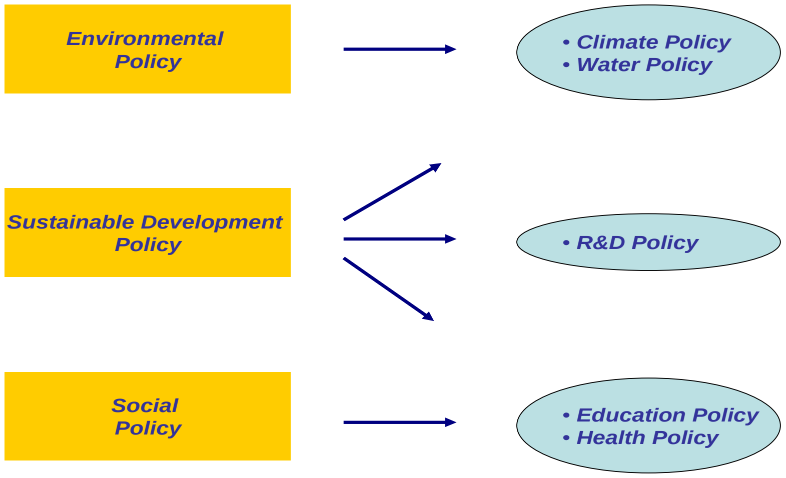



**Figure 7 – Overall Policy Design**

**Table 4 – Policy Scenario Characteristics**

| | |
|---|---|
| **Climate** | The climate policy considers the achievement in 2020 of the most ambitious reduction targets voluntarily declared by the most polluting countries in the last international negotiations in Copenhagen and Cancún (UNFCCC Conference of the Parties - COP15 and 16).[24] The Cancún Agreements confirmed the main conclusions already achieved in the Copenhagen Accord, officially recognizing the need to limit the increase of global temperature below 2 degrees. The climate policy fulfilment is put in practice by means of an international carbon emission trading system. China and India do not participate to the international trading scheme, achieving their own target on carbon intensity reduction unilaterally. |
| **Water** | This strategy aims at improving worldwide the efficiency of water use in all productive sectors. Water use efficiency throughout the world[25] increases uniformly by 20% from 2010 to 2020 with respect to the baseline scenario in which it is constant, by means of an exogenous shock imposed to the model. |
| **Education** | The second of the Millennium Development Goals (MDGs) (UN, 2011) points out the need of achieving universal primary education. The target consists in "*ensuring that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling*". While it is not possible to model directly these goals in a general equilibrium approach, we simulate the increase of investments in the education sector consistent with these goals. Glewwe *et al.* (2006) estimate the costs of meeting the MDG on education for some macro-areas of developing countries.[26] The interested regions are India, Indonesia, Rest of Asia, Brazil, Latin America, North Africa, Sub-Saharan Africa including South Africa and the Rest of the World. The intervention is modelled through a domestic subsidy to education sector provided by national governments. |

[24] http://unfccc.int/meetings/items/6240.php. It is worth noting that the most recent COP17 in Durban in December 2011 did not produced modifications of those targets.

[25] Indeed, policy targets for water efficiency are not that uniform in the world. The EU has no quantitative policy on water efficiency, and the International Water Management Institute (IWMI) though talking about an ideal 40% reduction in the use of water in agriculture, does not set particular targets. The only country with a water policy setting water efficiency targets is Australia, where the targets are in fact of 10% improvement in water efficiency.

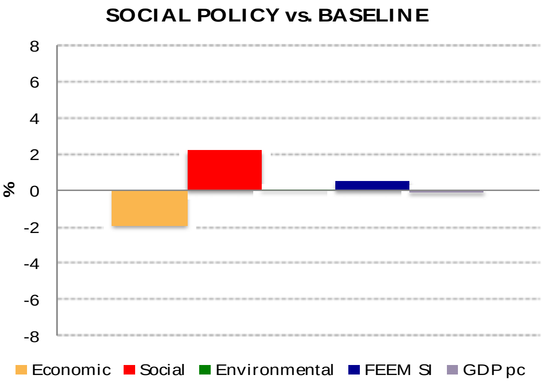
[26] Subsidies are taken from Table 8 (scenario 5), p. 23, in Glewwe *et al.* (2006).

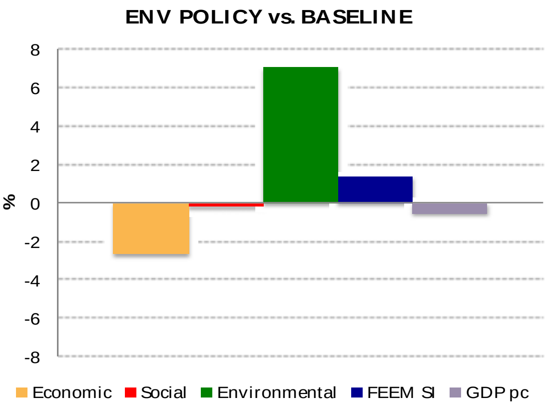
| | |
|---|---|
| **Health** | The fourth, the fifth and the sixth of the MDGs (UN, 2011) concern human health conditions in developing countries. They state the need of reducing, between 1990 and 2015, by two thirds the mortality rate of children under five (goal 4) and by three quarters the maternal mortality ratio, achieving universal access to reproductive health (goal 5). Moreover, HIV and malaria are the most dangerous diseases in Developing Countries: goal 6 promotes the reversion of the spread of these diseases by 2015 and the achievement, by 2010, of a universal access to treatment for HIV/AIDS for all those who need it. As for education policy, it is not feasible to model directly these goals in a CGE model but it is possible to simulate the increase in the financial resources to be invested in the public health sector to meet these goals. Subsidies have been calibrated according WHO targets (2001).[27] |
| **R&D** | In order to increase the technological advancements worldwide, we analyse a two-steps policy. First, an increasing subsidy on R&D in developed countries (up to 10% in 2020). Along with the subsidy, there is a technology transfer to developing countries simulated as a gradual 5% increase of industrial sectors' productivity, following Guellec and van Pottelsberghe de la Potterieet (2004).[28] In particular, productivity expands in the following sectors: food, energy intensive industries and (both RES and fossil-based) electricity. |

### *3.4 Policy Scenarios results*

This section aims to summarise the main outcomes due to the policy schemes previously described. The modelling framework allows capturing higher-order effects spread throughout the entire world since it brings to general re-adjustments in all markets driven by both global and sector- or country-specific policies. This is especially the case of social and environmental policies: the former applies to developing countries and public sectors, the latter mainly to developed countries and energy-intensive sectors (even though water efficiency measures are global).

Figure 8 represents the snapshot of percentage variations for sustainability dimensions and GDP p.c. in 2020 at world level in each policy scenario compared to the reference scenario. This clearly emphasizes how every sustainability component is affected by the policy action at the world level, revealing potential trade-offs. Including GDP p.c. gives interesting insights, as well. The cost of Social and Environmental policies considered separately in terms of a reduction in GDP p.c. clearly emerges, while in the case of SD policy GDP is higher than the baseline scenario since the benefits stimulated by R&D subsidies. Opposite to the improvement of social and environmental dimensions according to the correlated policy drivers, the economic pillar decreases in all cases, especially for the SD policy. This highlights the trade-off within the economic pillar, where an increase in subsidy implies a higher exposure because the increase in public debt.




---

[27] Page 170, Table A2.10: Annual Domestic Resource Mobilization ($US 2002) by Region.

[28] They estimate that the long-term elasticity of foreign R&D on productivity is in the range of 0.45- 0.5.

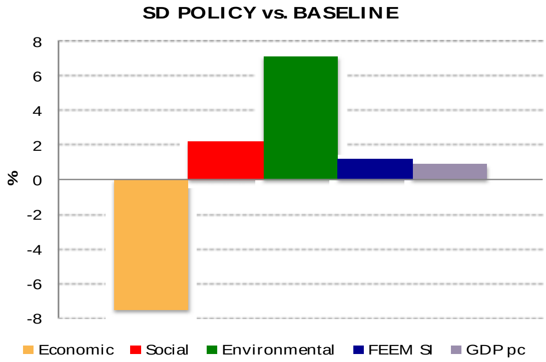



**Figure 8 - Policies' effect in 2020: World**

Looking more in detail at the impact on sustainability, in 2020 the strongest increase of the FEEM SI level with respect to the baseline scenario occurs with the Environmental Policy (1.36%). Even through the environmental dimension is similar in the two cases with a 7.04% gain in the Environmental Policy and 7.13% in the SD Policy, the performance of the economic pillars shows a minor decreasing in the Environmental Policy (-2.7%) compared to the SD Policy (-7.5%). The worse economic performance with the SD Policy stems from the increase of public debt implied by all intervention in the social sphere and the distortion in the economic system introduced to subsidise the R&D sector in Developed Countries. Nevertheless, while GDP p.c. drops of 0.54% in the Environmental Policy scenario, it increases of 0.85% when the SD Policy is implemented. In the latter case, it responds to the stimulus of R&D investment in the Advanced Economies and the resulting spill over in developing ones. Social Policy scenario presents the smallest gain in FEEM SI value (0.48%) due, as expected, to an improvement in the social pillar (2.17%), but at the expenses of a loss both in the economic pillar (-2.7%) and in GDP p.c. (-0.14%).

Even though the SD Policy negatively affects economic sustainability and is slightly lower then the Environmental Policy in terms of increased sustainability, it appears to be the most effective intervention at the global level. The mutual and consistent improvement in the social and environmental pillars boosts overall sustainability without raising the concerns that may occur if only the environmental sphere was considered.

For sake of brevity, we report the different impacts of policies on sustainability across several regional aggregates to see how the sustainability improvement spreads around the globe.[29] Figure 9 reports the EU27 performance on the top and Developed and Least Developed Countries (DC and LDC) ones on the bottom.

As regards the EU27, there is a considerable positive improvement in the environmental pillar in 2020 with both the SD and Environmental Policy, compared to the reference scenario. This improvement in environmental pillar is due to both the Climate Policy (-30% of GHG emission reduction in 2020 with respect to 1990) and the improvement of 10% on water efficiency. The environmental pillar increases slightly more (8.43%) with the SD Policy than the Environmental policy alone (8%). Nonetheless, the reduction of the economic pillars is higher in the SD Policy (-2.7%) than the Environmental Policy (-2.2%); therefore, the overall effect on sustainability (FEEM SI) is higher in the case of the Environmental Policy (1.13%) than the SD Policy (0.97%). The difference is mainly due to the subsidy on R&D that in the short-term increase the public expenditure and the aggregate debt, while presumably giving the economic return in a longer time-horizon.

[29] Annex V reports the change in FEEM SI value at the highest regional detail.

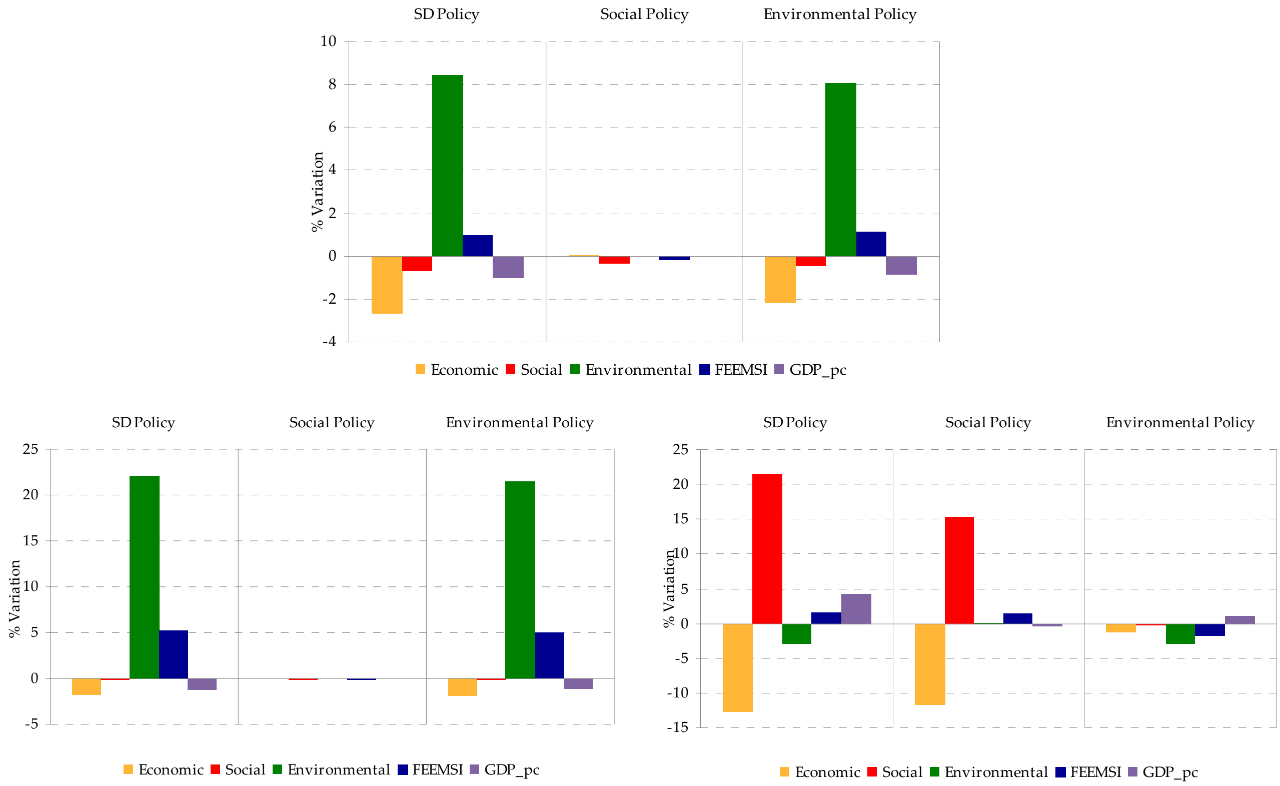



**Figure 9 - Policies' effect in 2020: EU27 (top), DC (bottom-left), LDC (bottom-right)**

The diverse effects induced by sustainability policies are clear when comparing DC and LDC. DC largely benefit from the Environmental Policy. In particular, there is a large improvement in the environmental dimension due to SD (22.1%) and Environmental Policy (21.5%): it leads to a marked increase in overall sustainability (respectively 5.2% and 5%) in spite of a slight decline in economic performance (respectively -1.8% and -2%) and GDP p.c. (-1.2% and -1.1%, respectively). Social pillar is unaffected since Social Policy does not concern DC.

On the other hand, LDC improve their sustainability supported by the MDGs stimulus. In the SD Policy, the social pillar improvement (21.5%) determines the overall positive performance of FEEM SI (1.7%), more than offsetting the reduced economic sustainability (-12.6%) driven by the increase in public debt necessary to subsidise the Education and Health expenditure. The Social Policy alone gives similar results, even though smaller in absolute terms. It is worth noting that in this case the impact on GDP p.c. is negative since there is no positive spill over induced by increased R&D in DC. Lastly, the Environmental Policy has a slightly negative effect on the FEEM SI (-1.8%) explained by a decrease of the economic (-1.3%) and environmental (-3%) dimensions, due to the environmental drawback of a higher competitiveness with respect to DC (environmental leakage).

## 4. Conclusions

The present study aims to introduce an innovative approach to the sustainability debate. Most policy-makers and stakeholders recognise the importance to modify the traditional idea of well-being, adding new attributes beyond the economic dimension. While many conclude on the opportunity to change this vision through qualitative approaches, there is increasing attention towards the quantitative measurement of sustainable development. This is challenging since it does not rely upon a single measure, as GDP for economic growth, but it involves a bundle of indicators, raising the issue on comparability among different measurement units and aggregation procedures of different components.

In this perspective, the value added of the FEEM SI analysis is projecting future world sustainability under different scenarios. This requires a consistent methodology in which interrelations among countries, sectors and sustainability components are well designed. To this purpose, we use a recursive-dynamic computable general equilibrium framework to design future scenarios, highlighting high-order effects to better understand the main drivers of future sustainability trends.

We highlight three sets of results. The first refers to the current level of sustainability across the world shows a quite heterogeneous situation. While advanced economies present an average level of sustainability, developing countries still have a significant gap. Looking in detail at the determinants of this result, it emerges that a high performance in each sustainability dimension is a necessary condition to reach the overall sustainability.

The baseline analysis from 2004-2020 reveals that even though all countries and macro-regions experiment economic growth in the post-crisis period, the FEEM SI slightly decreases at the world level. In other words, in spite of an increasing GDP per capita worldwide, the level of well being does not improve at the same pace, highlighting significant trade-offs among sustainability dimensions (mainly due to negative impact of growth on social component).

In addition, the paper illustrates the potential of FEEM SI in assessing the effects of policies on sustainability: a Social, an Environmental and a Composite Policy for Sustainable Development (SD). The Social Policy has a relevant effect on Developing Countries moving closer to the UN Millennium Development Goals. The Environmental Policy allows matching the climate targets at relatively low cost for Developed Countries, improving substantially the state of the environment. Finally, the SD Policy ensures a generalised increase in well-being worldwide that relies also upon the potential benefit for the overall society from increasing investment in Research and Development.

## References


Adelle C. and Pallemaerts M. (2009), *Sustainable Development Indicators – Overview of Relevant FP-funded Research and Identification of Further Needs*, European Communities, http://www.ieep.eu/assets/443/sdi_review.pdf

Boehringer C. and Loeschel A. (2006), "Computable General Equilibrium Models for Sustainability Impact Assessment: Status Quo and Prospects", *Ecological economics*, 60 (2006), 49-64.

Bosello F., Campagnolo L., Eboli F., Parrado R. and Portale E., (2011), "Extending energy portfolio with clean technologies in the ICES model", 14° Annual Conference on Global Economic Analysis – *GTAP* conference paper, https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3632

Burniaux J.-M. & Truong T.P. (2002), "GTAP-E: An energy environmental version of the GTAP model", *GTAP* Technical Paper n.16.

Carraro C., Campagnolo L., Cruciani C., Eboli F., Giove S., Lanzi E., Parrado R., Pinar M. and Portale E. (2011), *FEEM SI Methodological report 2011*, available on line at: http://www.feemsi.org/documents/FEEM%20SI%202011%20Methodological%20Report%202011.pdf

Council of the European Union (2006), *Renewed EU Sustainable Development Strategy (EU SDS)*, http://ec.europa.eu/research/sd/index_en.cfm?pg=renewed-sds

Council of the European Union (2009), 2009 *Review of the EU Sustainable Development Strategy (EU SDS)*, http://ec.europa.eu/environment/eussd/

Cruciani C., Giove S., Pinar M. and Sostero M. (2012), "Constructing the FEEM Sustainability Index: a Choquet-integral application", mimeo, submitted to 2012 *EAERE conference*.

Daly H.E. and Cobb J.J. (1989), *For the common good: redirecting the economy toward community, the environment and a sustainable future*. Beacon Press, Boston.

Eboli F., Parrado R. and Roson R., (2010), "Climate Change Feedback on Economic Growth: Explorations with a Dynamic General Equilibrium Model", *Environment and Development Economics*, Volume 15 (5), pp 515 -533.

European Commission (2000), "Green Paper - Towards a European strategy for the security of energy supply". Adopted on 29 November 2000 (*COM (2000) 769 final*).

European Commission (2005), "Sustainable Development Indicators to monitor the implementation of the EU Sustainable Development Strategy", Communication from Mr. Almunia to the Members of the Commission, (*SEC(2005) 161 final*).

European Commission (2008), "An EU energy security and solidarity action plan. Energy Sources, Production Costs and Performance of Technologies for Power Generation, Heating and Transport", *SEC(2008) 2872*.

European Commission (2009), "GDP and Beyond Measuring Progress in a Changing World", Communication from the Commission to the Council and the European Parliament, (*COM(2009) 433 final*).

European Commission (2010), *Draft White Paper on Transport. A Single Transport Area: Smart Mobility for People and Businesses Draft,* http://www.euractiv.com/en/transport/eus-new-transport-strategy-put-price-pollution-news-499273

European Environment Agency (2005), *EEA core set of indicators guide*, Technical Report No. 1.

Glewwe P., Zhao M. and Binder M. (2006), *Achieving Universal Basic and Secondary Education: how much will it cost?*, American Academy of arts and Sciences.

GTZ (2009), Energy-policy Framework Conditions for Electricity Markets and Renewable Energies, Eschborn, Germany

Guellec D. and van Pottelsberghe de la Potterieet B. (2004), *From R&D to Productivity Growth: Do the Institutional Settings and the Source of Funds of R&D Matter?*, CEB Working Paper N° 04/010, March 2004

Hertel T.W. (1997), *Global Trade Analysis: Modeling and applications*, Cambridge University Press, Cambridge.

Horridge M. (2008), *SplitCom: Programs to disaggregate a GTAP sector*, Centre of Policy Studies, Monash University, Melbourne, Australia.

Lee H. (2003), *The GTAP non-CO2 Emissions Data Base*, Center for Global Trade Analysis, Purdue University.

McKibbin W.J. and Wilcoxen P.J. (1998), "The Theoretical and Empirical Structure of the G-Cubed Model", *Economic Modelling*, 16(1), pp. 123-148.

Munda G. (2004), “Social Multi-criteria Evaluation (SMCE): Methodological Foundations and Operational Consequences”. *European Journal of Operational Research*, 158(3): 662-677

Narayanan B.G. and Walmsley T.L., (2008), *Global Trade, Assistance, and Production: The GTAP 7 Data Base*, Center for Global Trade Analysis, Purdue University.

Ness U.-P. and Anderberg O. (2007), “Categorizing Tools for Sustainability Assessment”, *Ecological Economics*, 60: 498–508.

OECD (1991), *Environmental Indicators: A preliminary set*, Paris.

OECD (1993), *OECD Core Set of Indicators for Environmental Performance Reviews: A Synthesis Report by the Group on the State of the Environment*, Paris.

OECD (2004), *Implementing sustainable development: key results 2001-2004*, Paris.

OECD (2007), *2nd World Forum on “Measuring and Fostering the Progress of Societies*, Istanbul..

OECD (2008), *Handbook on Constructing Composite Indicators: Methodology and User Guide*, http://www.oecd.org/dataoecd/37/42/42495745.pdf

OECD/IEA (2005), *Projected costs of generating electricity*, IEA, Paris.

Parris T.M. and Kates R.W. (2003), “Characterizing and Measuring Sustainable Development”, *Annual Review of Environment & Resources*, 28(1): 559-586

Pearce D.W. and Atkinson G.D., (1993) “Capital theory and the measurement of sustainable development: an indicator of ‘weak’ sustainability”, *Ecological Economics*, 8: 103-108

Prescott-Allen R. (2001), *The Wellbeing of Nations. A country-by-Country Index of Quality of Life and the Environment*, Island Press.

Ragwitz M. *et al.* (2007), *OPTRES: Assessment and optimisation of renewable support schemes in the European electricity market*, http://www.optres.fhg.de/OPTRES_FINAL_REPORT.pdf

Saltelli A, Jesinghaus J. and Munda G. (2007), *Well Being Stories, Beyond GDP Conference*, EU Parliament, Brussels 19-20 November 2007

Singh M. and Gupta D. (2009), “An overview of sustainability assessment methodologies”, *Ecological Indicators*, 9: 189–212.

Stiglitz J.E., Sen A. and Fitoussi J.-P. (2009), *Report by the Commission on the Measurement of Economic Performance and Social Progress*, http://www.stiglitz-sen-fitoussi.fr/documents/rapport_anglais.pdf

Thomas, C.D. *et al.* (2004), “Extinction risk from climate change”, *Nature* 427, 145-148.

UK Collaborative on Development Sciences (UKCDS, 2005), *Securing the future: UK Government sustainable development strategy*, http://www.ukcds.org.uk/publication-Securing_the_Future-75.html

UN (1992), Agenda 21, http://www.un.org/esa/dsd/agenda21/

UN (2010), *Goal 2 – Achieve Universal Primary Education*, fact sheet from UNITED NATIONS SUMMIT, 20-22 September 2010, New York, High-level Plenary Meeting of the General Assembly, http://www.un.org/millenniumgoals/pdf/MDG_FS_2_EN.pdf

UN (2011), *The Millennium Development Goals Report 2011*, http://www.un.org/millenniumgoals/11_MDG%20Report_EN.pdf

UN Commission on Sustainable Development (2006), *Global trends and status of indicators of sustainable development*, background paper No.2.

UN CSD (2005), *Indicators of sustainable development – CSD theme indicator framework*, UN Commission on Sustainable Development, NY, USA.

UN Development Programme (1990), Human Development Report, http:// www.undp.org

UN Economic and Social Affairs (2007), *Indicators of Sustainable Development: Guidelines and Methodologies*, October 2007; Third Edition.

UN Environment Programme (2003), *Global Environment Outlook*, http://www.unep.org/geo/geo3/english/

Wackernagel M. and Rees W.E. (1996), *Our Ecological Footprint: Reducing Human Impact on the Earth*, Gabriola Island, BC and Philadelphia, PA: New Society Publishers

WB (2010), *Addressing the Electricity Access Gap*, Background Paper for the World Bank Group Energy Sector Strategy, World Bank

WCED – World Commission on Environment and Development (1987), *Our Common Future*, Published as Annex to General Assembly document A/42/427, Development and International Co-operation: Environment August 2, 1987. Retrieved, 2007.11.14

WHO (2001), *Macroeconomics and Health: Investing in Health for Economic Development*, Report of the Commission on Macroeconomics and Health (2001).

Yale and Columbia Universities (2005), *2005 Environmental Sustainability Index*, Summary for policymakers retrieved at http://sedac.ciesin.columbia.edu/es/esi/

Yale and Columbia Universities (2010), *2010 Environmental Performance Index*, Summary for policymakers, retrieved at http://epi.yale.edu/

Yusuf J.A., El Serafy S. and Lutz E. (1989), *Environmental accounting for sustainable development*, UNEP World Bank Symposium, Washington D.C.

## Data Sources

Climate Analysis Indicators Tool (CAIT), version 3.0, Washington, DC: World Resources Institute, year 2005: http://cait.wri.org, http://earthtrends.wri.org.

Food and Agriculture Organization of the United Nations (FAO), Aquastat Database:
http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en

Food and Agriculture Organization of the United Nations (FAO), ResourceSTAT:
http://faostat.fao.org/site/377/default.aspx#ancor

FAO and IIASA (2000), Global Agro-Ecological Zones:
http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm

IEA (2010), World Energy Outlook:
http://www.worldenergyoutlook.org/database_electricity/electricity_access_database.htm

International Union for Conservation of Nature and Natural Resources (IUCN), Red List of Threatened Species: http://www.iucnredlist.org/.

OECD (2010), Main Science and Technology Indicators:
http://www.oecd.org/document/26/0,3343,en_2649_34451_1901082_1_1_1_1,00.html

REN 21, Renewable energy Policy Network for the 21st Century: http://www.ren21.net/

United Nations (2009), World Population Prospects: the 2008 Revision Population Database:
http://esa.un.org/unpp/index.asp?panel=2

World Bank (2010), World Development Indicators: http://data.worldbank.org/indicator

World Health Organization (2010): http://apps.who.int/ghodata/?vid=1901

# ANNEX I – THE INDICATORS' LIST

| DIM | NAME | EQUATION | LONG DESCRIPTION | LITERATURE |
|---|---|---|---|---|
| Economic | **R&D** | R&D Expenditure / GDP (%) | This indicator assumes a positive relationship between investment in R&D and growth, by maintaining that increased investment in R&D can bring more R&D output that will eventually lead to more innovation and increased productivity | EU SDS – UN CSD - WDI |
| | **Investment** | Net Investment / Capital Stock (%) | Investment is one of the main drivers of economic sustainability, allowing for capital accumulation, which boosts economic growth. This indicator is weighted considering the country specific capital stock. | EU SDS - UN CSD |
| | **GDP per capita** | GDP PPP / population | It is a measure of the per capita value of all market goods and services produced within a country. GDP p.c. is the typical indicator used to define the average well-being in a country. | EU SDS – UN CSD - WDI |
| | **Relative Trade Balance** | Trade Balance / Market Openness | The Relative Trade Balance measures the degree of a country's exposure in the global commodities markets. It considers the net export value and weights it with the country specific market openness (exports + imports). Relying relatively more upon exports is a signal of strong competitiveness. | - |
| | **Public Debt** | Government Debt / GDP (%) | Public Debt has an important role on the future perspective of a country's economy. It depends on current government choices on expenditure and taxation, and on previously accumulated debt. | WDI – UN CSD - IMF |
| Social | **Population Density** | Population / Country Surface | Population Density evaluates the population concentration in a specific country or macro-region (excluding uninhabitable areas). It represents the pressure on the available living space and resources for each individual. | UN CSD - WDI |
| | **Education** | Education Exp. / GDP (%) | Expenditure in Education constitutes an investment in human capital. The role of education in improving future economic conditions and enhancing mobility as well as gender equality is supported by several studies. | EU SDS – WDI |
| | **Health** | Total Health Exp. / GDP (%) | The generalised access to basic Health services is a major concern throughout the world. Monitoring the growth of expenditures in health by summing public and private expenditures allows to measure the degree of support on this issue. | WDI |
| | **Food Relevance** | Food Cons. / Private Exp. (%) | This indicator is used as a proxy for the poverty level. In fact, according to Engel's law, the higher the proportion of national income spent on food the lower the level of a country's welfare. | - |
| | **Energy Imported** | Energy Imported / Energy Cons. (%) | This is an indicator of energy security. The higher the Energy Dependence from abroad, the higher the risks deriving from changes in energy prices and political instability in energy-rich countries. | WDI |
| | **Energy Access** | Population with Access to Electricity / Total Population (%) | Access to Energy is important with reference to living conditions and future prospectives of well-being. This indicator considers the share of population having access to electricity. It allows capturing the intra country aspect of energy security, being more focused on distribution of energy resources than on availability at the country level. | IEO |
| | **Private Health** | Private Health Exp. / Total Health Exp. (%) | Monitoring the balance between public and private contribution to the health sector is essential for sustainability because it determines the availability of primary service to the whole society. The higher the share of Private Health expenditure, the lower the ability of poorer people to access to the health care. | WDI |
| Environmental | **GHG per capita** | Kyoto GHGs Emissions / Population | The Greenhouse Gases are considered as described in the Annex I of the Kyoto Protocol. Emission per capita is a measure of the burden that the society imposes on climate and environment. | EU SDS – UN CSD - WDI |
| | **$CO_2$ Intensity** | $CO_2$ Emissions / Total Primary Energy Cons. | This indicator is fundamental to monitor the improvement of the environmental performance of production and consumption activities, the latter playing a major role in the release of Carbon Dioxide into the atmosphere. | EU SDS – UN CSD - WDI |
| | **Energy Intensity** | Total Primary Energy Supply / GDP PPP | This indicator aims to assess the evolution of energy use efficiency. | EU SDS – UN CSD - WDI |
| | **Renewables** | Renewable Cons. / Total Primary Energy Cons. (%) | The gradual reduction of fossil fuel use is an important step towards security and sustainability of energy systems. The higher the share of green energy, the higher the environmental performance of the energy sectors. | EU SDS – UN CSD - WDI |
| | **Plants** | Endangered Species / Total Species (%) | This indicator represents an alarm signal of the general worsening of habitats. It provides a comparable measure of endangered Plant species throughout the world, by considering the number of endangered species over the number of total known species present in that country. | EU SDS – UN CSD - WDI |
| | **Animals** | Endangered Species / Total Species (%) | As in the previous indicator, it also represents an alarm signal of the general worsening of habitats. It is calculated in the same way but focusing on animal biodiversity. | EU SDS – UN CSD - WDI |
| | **Water** | Water Use / Total Available Water (%) | Human pressure on water, is an important indicator of resource pressure. It is estimated as water consumed in a country (for agriculture, industry and private uses) over the total renewable water resources available in that specific country. | UN CSD - WDI |

# ANNEX II – THE ICES MODEL

The Inter-temporal Computable Equilibrium System (ICES) model is a multi-regional recursively dynamic general equilibrium model based on the GTAP database, version 7 (Narayanan and Walmsley, 2008) and sharing the core structure of the GTAP-E model (Burniaux and Troung, 2002), which in turn is an extension of the basic GTAP model (Hertel, 1997). The calibration year is 2004 that constitutes also the beginning year for simulations. The model is recursively dynamic in the sense that each year of simulation is solved statically, but features of the period *t-1* are taken in account in period *t*.

The agents considered in each economy are *n* industries, a representative household and government. Industries are “typically” modelled through a representative cost-minimizing firm, taking input prices as given. In turn, output prices coincide with average production costs. Each firm is characterised by a general production functions, specified via a series of nested CES functions to consider both primary factors (Natural Resources, Land, Labour and the aggregate Capital&Energy) and intermediates.

Similarly to the GTAP-E production tree, the energy inputs are isolated from intermediates and are considered as primary production factors in a nested level of substitution with capital. The purpose of drawing such complex and nested production function is to have more degree of freedom in specifying elasticises of substitution among productive inputs. As described in Burniaux and Troung (2002), the main innovation of GTAP-E with respect to GTAP is moving away from the assumption of a Leontief relationship between the set of primary factors and the group of intermediates for commodity production. Based on strong empirical evidence, energy sources are no longer considered perfect complement of primary factors. Rather, they are at some extent substitutes of capital stock, through a Constant of Elasticity of Substitution (CES) function.

Moreover, this version of the ICES model improves the original energy sub-tree according to Bosello *et al.* (2011) through the introduction of several energy sources not originally explicit in both database (nuclear, biofuels, wind, solar, hydro) and model. As regards the database, it required the data collection on physical (International Extended Energy Balances) and monetary (OECD/IEA, 2005; EC, 2008; ISI, 2007; GTZ, 2009; IEA country profiles; REN21 website) data for each source and their . Moreover, the new model specification is as follows. Energy is produced using Electric and Non Electric commodities in the third level of the production function. The Non Electric commodity is produced using Nuclear and Non Nuclear commodities. The latter in turn is a combination of Coal or Other Fuels. Then, it is possible to choose between Oil&Gas and Non Oil&Gas aggregates: Oil&Gas is a composite of Oil and Gas, Non Oil&Gas includes Petroleum Products and Biofuels. As regards the Electric branch, it differentiates between Intermittent and Non Intermittent electricity. The former considers Solar and Wind power, the latter Hydropower and all Other Electricity typologies. Relevant intra-energy substitution elasticities come from previous literature on extended computable general equilibrium and integrated assessment models such as EPPA (Paltsev *et al.*, 2005), GTEM (Pant, 2007) and WITCH (Bosetti *et al.*, 2009).

In addition, it is worth to notice that domestic and foreign inputs are not perfect substitutes, according to the so-called “Armington assumption”, which accounts for - amongst others - product heterogeneity. In general, inputs grouped together are more easily substitutable among themselves than with other elements outside the nest. For example, imports can more easily be substituted in terms of foreign production source, rather than between domestic production and one specific foreign country of origin. Analogously, composite energy inputs are more substitutable with capital than with other factors.

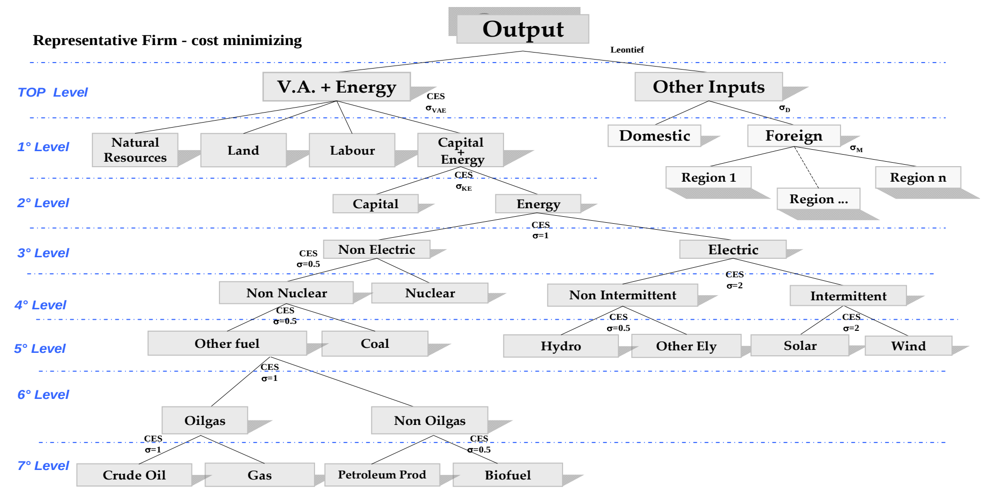



**Figure II.1 – The ICES nested production function**

Two industries are treated in a special way and are not related to any country, namely international transport and international investment. International transport is a world industry, which produces the transportation services associated with the movement of goods between origin and destination regions, thereby determining the cost margin between f.o.b. and c.i.f. prices. Transport services are produced by means of factors submitted by all countries, in variable proportions. In a similar way, a hypothetical world bank collects savings from all regions and allocates investments in order to equalise the current rates of return.

A representative household in each region receives income, defined as the service value of national primary factors (natural resources, land, labour, capital). Capital and labour are perfectly mobile domestically but immobile internationally. Land and natural resources, on the other hand, are industry-specific. This income is then used to finance three classes of expenditure: aggregate household consumption, public consumption and savings. The expenditure shares are generally fixed, which amounts to saying that the top-level utility function has a Cobb-Douglas specification.

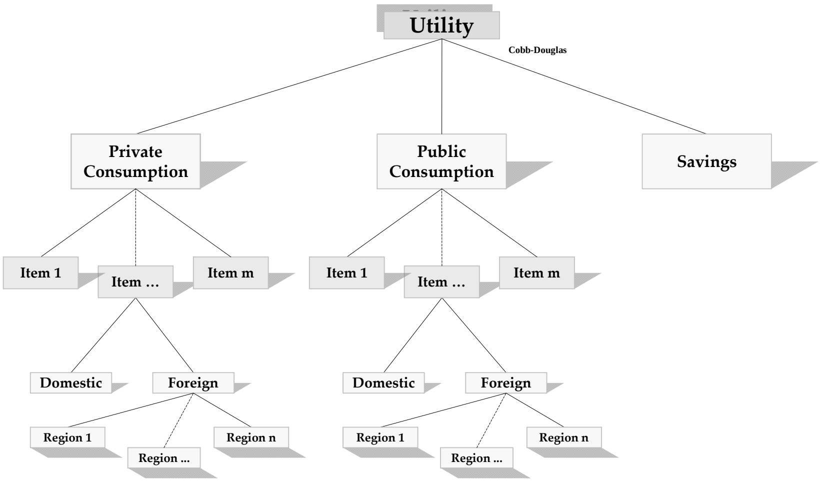



**Figure II.2 – The ICES consumption decisional tree**

Dynamics inside the ICES model are driven essentially by two different sources: one endogenous and one exogenous to the model. The first involves two components: one, the most important, is the capital and foreign debt evolution processes governed by endogenous investment decisions. The other concerns a peculiar treatment of the evolution of natural resources stock. On the other hand, there is a set of assumptions concerning the changes in some key economic - mainly supply-side - parameters and exogenous variables which are imposed to the model in order to reflect their possible evolution. These assumptions are made consistently with existing statistical sources, other modelling exercises and economic scenarios.

## ANNEX III – REGIONAL AND SECTORAL AGGREGATION

**Table III.1 - Sector detail**

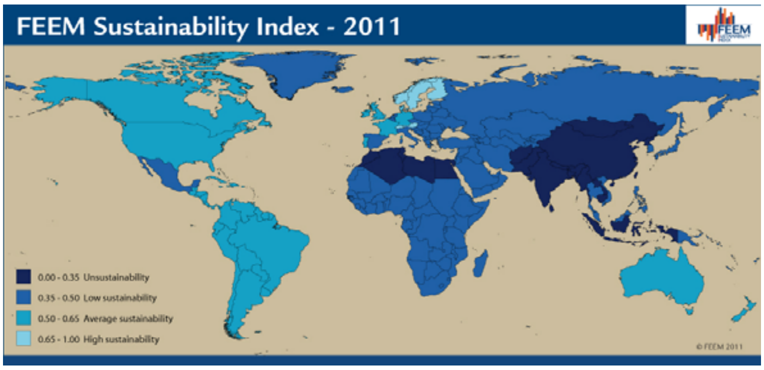
| No. | Sectors |
|---|---|
| 1 | Food |
| 2 | Forestry |
| 3 | Fishing |
| 4 | Coal |
| 5 | Oil |
| 6 | Gas |
| 7 | Pertoleum Products |
| 8 | Other Electricity |
| 9 | Renewables |
| 10 | Nuclear |
| 11 | Biofuels |
| 12 | Energy Intensive Industries |
| 13 | Other Industries |
| 14 | Water |
| 15 | Market Services |
| 16 | Public Services |
| 17 | R&D |
| 18 | Education |
| 19 | Private Health |
| 20 | Public Health |

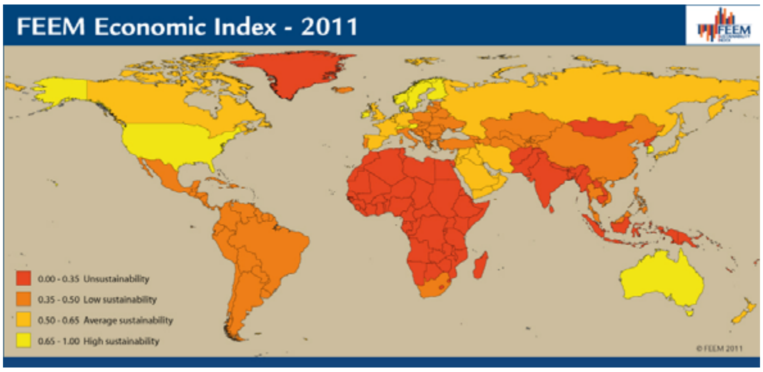
**Table III.2 - Regional aggregation**

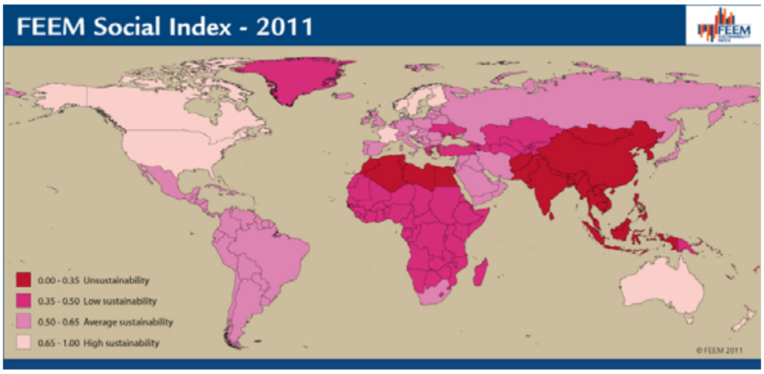
| No. | Macro-Regions | Countries |
|---|---|---|
| 1 | **Australia** | Australia |
| 2 | **NewZealand** | New Zealand |
| 3 | **Japan** | Japan |
| 4 | **Korea** | Korea |
| 5 | **China** | China, Hong Kong, Taiwan |
| 6 | **India** | Indonesia |
| 7 | **Indonesia** | India |
| 8 | **SEastAsia** | Malaysia, Philippines, Singapore, Thailand, Vietnam |
| 9 | **RoAsia** | Afghanistan, Bangladesh, Bhutan, Brunei Darassalam, Cambodia, Democratic Republic of Korea, Lao People's Democratic Republic, Macau, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Sri Lanka, Timor Leste |
| 10 | **USA** | USA |
| 11 | **Canada** | Canada |
| 12 | **Mexico** | Mexico |
| 13 | **Brazil** | Brazil |
| 14 | **RoLA** | Argentina, Bolivia, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Falkland Islands (Malvinas), French Guiana, Guyana, Suriname, Costa Rica, Guatemala, Nicaragua, Panama, Belize, El Salvador, Honduras, Saint Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos, Anguilla, Antigua & Barbuda, Aruba, Bahamas, Barbados, Cayman Islands, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Netherlands Antilles, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Virgin Islands (British), Virgin Islands (U.S.) |
| 15 | **Austria** | Austria |
| 16 | **Benelux** | Belgium, Luxembourg, Netherlands |
| 17 | **Denmark** | Denmark |
| 18 | **Finland** | Finland |
| 19 | **France** | France |
| 20 | **Germany** | Germany |
| 21 | **Greece** | Greece |
| 22 | **Ireland** | Ireland |
| 23 | **Italy** | Italy |
| 24 | **Poland** | Poland |
| 25 | **Portugal** | Portugal |
| 26 | **Spain** | Spain |
| 27 | **Sweden** | Sweden |
| 28 | **UK** | UK |
| 29 | **RoEU** | Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Malta, Slovakia, Slovenia, Bulgaria, Romania |
| 30 | **Switzerland** | Switzerland |
| 31 | **Norway** | Norway |
| 32 | **RoEurope** | Albania, Andorra, Bosnia and Herzegovina, Croatia, Faroe Islands, Gibraltar, Iceland, Liechtenstein, Macedonia, the former Yugoslav Republic of, Monaco, San Marino, Serbia and Montenegro |
| 33 | **Russia** | Russia |
| 34 | **RoFSU** | Belarus, Ukraine, Moldova, Republic of, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Armenia, Azerbaijan, Georgia |
| 35 | **Turkey** | Turkey |
| 36 | **MiddleEast** | Bahrain, Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Occupied Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen |
| 37 | **NorthAfrica** | Algeria, Egypt, Libyan Arab Jamahiriya, Morocco, Tunisia |
| 38 | **RoAfrica** | Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of the Congo, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mayotte, Mozambique, Niger, Nigeria, Reunion, Rwanda, Saint Helena, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe |
| 39 | **SouthAfrica** | SouthAfrica |
| 40 | **RoWorld** | American Samoa, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Micronesia, Federated States of, Nauru, New Caledonia, Norfolk Island, Northern Mariana Islands, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Island of Wallis and Futuna, Bermuda, Greenland, Saint Pierre and Miquelon |

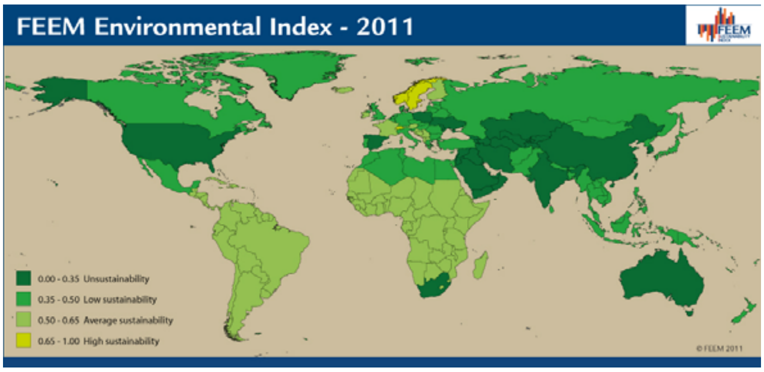
## ANNEX IV – Rankings and maps by dimension in 2011

| Country | Economic | Country | Social | Country | Environmental | Country | FEEMSI |
|---|---|---|---|---|---|---|---|
| Switzerland | 0.766 | Norway | 0.985 | Norway | 0.718 | Norway | 0.823 |
| Korea | 0.761 | Sweden | 0.922 | Sweden | 0.664 | Sweden | 0.774 |
| Norway | 0.752 | Canada | 0.845 | Switzerland | 0.661 | Switzerland | 0.700 |
| Australia | 0.737 | Denmark | 0.837 | RoEurope | 0.625 | Austria | 0.691 |
| Sweden | 0.728 | NewZealand | 0.829 | Austria | 0.623 | Finland | 0.661 |
| USA | 0.725 | Finland | 0.799 | Brazil | 0.597 | Denmark | 0.653 |
| Austria | 0.700 | USA | 0.790 | RoLA | 0.585 | Canada | 0.641 |
| Finland | 0.686 | France | 0.789 | Ireland | 0.528 | France | 0.630 |
| Ireland | 0.666 | Austria | 0.755 | RoAfrica | 0.523 | Ireland | 0.620 |
| Denmark | 0.663 | Australia | 0.734 | Finland | 0.512 | NewZealand | 0.609 |
| Germany | 0.617 | Ireland | 0.683 | France | 0.509 | USA | 0.554 |
| Benelux | 0.611 | Switzerland | 0.668 | Canada | 0.499 | Australia | 0.553 |
| NewZealand | 0.591 | Mexico | 0.656 | RoEU | 0.487 | Brazil | 0.546 |
| Russia | 0.586 | Portugal | 0.646 | RoAsia | 0.477 | UK | 0.531 |
| France | 0.584 | Germany | 0.618 | Denmark | 0.469 | RoEurope | 0.529 |
| Japan | 0.581 | SouthAfrica | 0.612 | UK | 0.451 | Germany | 0.525 |
| UK | 0.577 | Brazil | 0.603 | Portugal | 0.449 | Portugal | 0.522 |
| Spain | 0.575 | Spain | 0.597 | Turkey | 0.448 | RoLA | 0.512 |
| Canada | 0.566 | UK | 0.582 | Italy | 0.446 | Spain | 0.497 |
| MiddleEast | 0.558 | RoLA | 0.570 | RoWorld | 0.445 | Benelux | 0.495 |
| RoEU | 0.491 | Italy | 0.559 | SEastAsia | 0.440 | Russia | 0.493 |
| Poland | 0.463 | MiddleEast | 0.543 | Japan | 0.420 | RoEU | 0.493 |
| Portugal | 0.458 | Poland | 0.538 | Indonesia | 0.419 | Mexico | 0.492 |
| China | 0.455 | RoEurope | 0.519 | NewZealand | 0.411 | Korea | 0.477 |
| SouthAfrica | 0.454 | Russia | 0.511 | Greece | 0.402 | Italy | 0.472 |
| Brazil | 0.446 | RoEU | 0.499 | Benelux | 0.396 | Japan | 0.456 |
| Mexico | 0.435 | Turkey | 0.491 | Russia | 0.393 | Turkey | 0.453 |
| RoEurope | 0.433 | RoFSU | 0.482 | NorthAfrica | 0.385 | MiddleEast | 0.450 |
| Turkey | 0.417 | Benelux | 0.480 | Mexico | 0.374 | Poland | 0.430 |
| Italy | 0.404 | Greece | 0.439 | Germany | 0.372 | SouthAfrica | 0.426 |
| RoLA | 0.392 | RoWorld | 0.405 | Spain | 0.347 | Greece | 0.399 |
| SEastAsia | 0.390 | RoAfrica | 0.378 | India | 0.328 | RoAfrica | 0.398 |
| RoFSU | 0.386 | Japan | 0.351 | Korea | 0.312 | RoWorld | 0.385 |
| Greece | 0.354 | Korea | 0.330 | Poland | 0.304 | SEastAsia | 0.368 |
| NorthAfrica | 0.350 | NorthAfrica | 0.285 | MiddleEast | 0.283 | RoFSU | 0.367 |
| Indonesia | 0.331 | SEastAsia | 0.261 | Australia | 0.251 | NorthAfrica | 0.342 |
| RoWorld | 0.306 | China | 0.260 | RoFSU | 0.244 | RoAsia | 0.325 |
| India | 0.301 | RoAsia | 0.185 | SouthAfrica | 0.230 | Indonesia | 0.299 |
| RoAsia | 0.285 | Indonesia | 0.127 | USA | 0.210 | China | 0.287 |
| RoAfrica | 0.279 | India | 0.077 | China | 0.147 | India | 0.240 |


FEEM Sustainability Index - 2011
FEEM
0.00 - 0.35 Unsustainability
0.35 - 0.50 Low sustainability
0.50 - 0.65 Average sustainability
0.65 - 1.00 High sustainability
© FEEM 2011


FEEM Economic Index - 2011
FEEM
0.00 - 0.35 Unsustainability
0.35 - 0.50 Low sustainability
0.50 - 0.65 Average sustainability
0.65 - 1.00 High sustainability
© FEEM 2011


FEEM Social Index - 2011
FEEM
0.00 - 0.35 Unsustainability
0.35 - 0.50 Low sustainability
0.50 - 0.65 Average sustainability
0.65 - 1.00 High sustainability
© FEEM 2011


FEEM Environmental Index - 2011
FEEM
0.00 - 0.35 Unsustainability
0.35 - 0.50 Low sustainability
0.50 - 0.65 Average sustainability
0.65 - 1.00 High sustainability
© FEEM 2011

## ANNEX V - Sustainability ranking (2020: SD policy vs baseline)

| Rank Baseline | Country | FEEM SI Baseline | Δ Rank | FEEM SI SD | Country | Rank SD policy |
|---|---|---|---|---|---|---|
| 1 | Norway | 0.846 | = | 0.857 | Norway | 1 |
| 2 | Sweden | 0.814 | = | 0.827 | Sweden | 2 |
| 3 | Austria | 0.736 | = | 0.746 | Austria | 3 |
| 4 | Switzerland | 0.695 | -2 | 0.700 | Canada | 4 |
| 5 | Finland | 0.684 | = | 0.695 | Finland | 5 |
| 6 | Denmark | 0.676 | -1 | 0.690 | Switzerland | 6 |
| 7 | Canada | 0.665 | 3 | 0.688 | Denmark | 7 |
| 8 | France | 0.648 | -1 | 0.660 | NewZealand | 8 |
| 9 | NewZealand | 0.633 | 1 | 0.650 | France | 9 |
| 10 | Ireland | 0.622 | = | 0.628 | Ireland | 10 |
| 11 | Germany | 0.581 | -1 | 0.602 | Australia | 11 |
| 12 | Australia | 0.576 | 1 | 0.597 | Germany | 12 |
| 13 | Benelux | 0.558 | -2 | 0.581 | Brazil | 13 |
| 14 | UK | 0.547 | -2 | 0.577 | USA | 14 |
| 15 | Brazil | 0.544 | 2 | 0.558 | Benelux | 15 |
| 16 | RoEurope | 0.537 | -5 | 0.551 | UK | 16 |
| 17 | USA | 0.534 | 3 | 0.536 | RoEU | 17 |
| 18 | RoLA | 0.526 | -1 | 0.534 | Portugal | 18 |
| 19 | Portugal | 0.526 | 1 | 0.530 | RoLA | 19 |
| 20 | RoEU | 0.514 | 3 | 0.517 | Russia | 20 |

| Rank Baseline | Country | FEEM SI Baseline | Δ Rank | FEEM SI SD | Country | Rank SD policy |
|---|---|---|---|---|---|---|
| 21 | Spain | 0.500 | -3 | 0.516 | RoEurope | 21 |
| 22 | Italy | 0.499 | -1 | 0.510 | Mexico | 22 |
| 23 | Korea | 0.493 | -2 | 0.509 | Italy | 23 |
| 24 | Japan | 0.493 | -2 | 0.509 | Spain | 24 |
| 25 | Mexico | 0.483 | 3 | 0.507 | Korea | 25 |
| 26 | Russia | 0.481 | 6 | 0.506 | Japan | 26 |
| 27 | Turkey | 0.476 | -3 | 0.489 | SouthAfrica | 27 |
| 28 | MiddleEast | 0.465 | -1 | 0.474 | Poland | 28 |
| 29 | Poland | 0.437 | 1 | 0.464 | MiddleEast | 29 |
| 30 | SouthAfrica | 0.429 | 3 | 0.455 | Turkey | 30 |
| 31 | Greece | 0.426 | = | 0.437 | Greece | 31 |
| 32 | RoAfrica | 0.401 | = | 0.416 | RoAfrica | 32 |
| 33 | RoWorld | 0.390 | = | 0.375 | RoWorld | 33 |
| 34 | SEastAsia | 0.364 | = | 0.371 | SEastAsia | 34 |
| 35 | RoFSU | 0.356 | -3 | 0.354 | RoAsia | 35 |
| 36 | NorthAfrica | 0.342 | -1 | 0.354 | Indonesia | 36 |
| 37 | RoAsia | 0.339 | 2 | 0.345 | NorthAfrica | 37 |
| 38 | China | 0.323 | -1 | 0.323 | RoFSU | 38 |
| 39 | Indonesia | 0.321 | 3 | 0.318 | China | 39 |
| 40 | India | 0.291 | = | 0.304 | India | 40 |