This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

EU Framework Program for Research and Innovation actions (H2020 LCE-21-2015)

MEDEAS

MODELING THE RENEWABLE ENERGY TRANSITION IN EUROPE

Project Nr: 691287

Guiding European Policy toward a low-carbon economy. Modelling sustainable Energy system Development under Environmental And Socioeconomic constraints

Annex 8: Tasks 2.2.e.2- Environmental impacts indicators analysis

Version 2.0.0

Due date of deliverable: 31/12/2016 Actual submission date: 29/12/2016

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Document info sheet

Lead Beneficiary: ICM-CSIC

WP: WP2 Data collection

Task: 2.2.e.2

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Dissemination level : Public

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Scope of document

This document reports the environmental indices used to evaluate the human activities impact on the environment and the biosphere. This information aims to provide the modellers and data users with a guide of the main environmental indicators and their suitability for modelling purposes within the MEDEAS scope.

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List of abbreviations and acronyms

BII Biodiversity Intactness index

CF Carbon Footprint

DG Directorate General

CF Carbon Footprint

EEA European Environmental Agency

EF Ecological footprint

EDI Energy Development Index

EEA European Environmental Agency

GLASOD Global Assessment of Human-induced Soil Degradation

GDP Gross Domestic Product

GPI Genuine Progress Indicator

GHG Greenhouse Gases

GW Renewable power capacity

IPCC Intergovernmental Pannel on Climate Change (UN)

IEA International Energy Agency

NPP Terrestrial net primary (plant) production

OECD The Organisation for Economic Co-operation and Development

PB Planetary Boundaries

RET Renewable Energy Transition

RES Renewable Energy Sources

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SDGs Sustainable Development Goals

SEDI Sustainable Development Index

TPES Total Primary Energy Supply

TFC Total Final energy Consumption

UNSD United Nations Statistical Division

WF Water footprint

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Executive summary

Indicators have become a mainstream tool to help countries and policymakers to manage and evaluate different aspects. Environmental indicators are values that describe the state or conditions of the environment and its impact on human beings, ecosystems and materials, the pressures on the environment, the driving forces and the responses steering that system. The indicators here chosen will be mainly based on the MEDEAS model already existing modules (i.e. Economy, Energy, Materials, Land, Climate and Social) however new indicators for the construction of future modules will also be suggested. Due to the main objective of this subtask (environmental indicators), we focused on Energy, Climate and Land. However, we also report some indicators regarding Ecosystems and Water. A total of 120 indices have been explored under the ecosystem, climate, water, and energy areas. For each area we describe the main framework and the characterization for the selected indicators.

Ecosystem

Considering Planetary Boundaries (PB) as a framework, we selected 4 indicators to cover the main ecosystem aspects, that to date, better capture and summarize information and with open data sources: Terrestrial net primary (plant) production (NPP), Global Assessment of Human-induced Soil Degradation (GLASOD), Biodiversity Intactness index (BII), Ecological footprint (EF).

Climate

Besides the selected indicators selected in the Assessment Report AR5 IPCC reports (i.e. Greenhouse Gases (GHG) emission levels, atmospheric GHG concentration levels, changes in global temperature and sea-level rise, changes in regional climate variables, changes in the intensity or frequency of extreme events), we add the Carbon Footprint.

Water

We explored 20 indicators and we have considered here the water footprint indicator (WF) as a comprehensive measure of freshwater resources appropiation.

Energy

In this area there were two main sets of indicators that can be analysed: energy environmental impacts (mainly emissions) and energy efficiency indicators. We have selected three indicators

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that can give information of the ratio of electricity produced by renewables, the energy consumption per capita, and the amount of energy produced by Renewable Energy Sources (RES), thus the three indicators chosen are: Share of renewable energy in final energy consumption, Energy use (kg of oil equivalent per capita) and Renewable power capacity.

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Introduction

Indicators have become a mainstream tool to help countries in different areas: managing resources, evaluate pollution or economic costs/benefits of certain activities, evaluate Climate Change impacts, ecosystem damage/changes or even ecosystem services. In this regard, the number of environmental indicators has growth considerably as they become more popular and policymakers and environmental institutions rely more on them, as an assessment tool.

An environmental indicator id defined as (European Environmental Agency (EEA), http://glossary.eea.europa.eu/terminology/concept_html?term=environmental%20indicator): "A parameter or a value derived from parameters that describe the state of the environment and its impact on human beings, ecosystems and materials, the pressures on the environment, the driving forces and the responses steering that system. An indicator has gone through a selection and/or aggregation process to enable it to steer action." An alternative definition of environmental indicator is a number that has the "capacity to monitor and assess environmental conditions and trends so as to increase their accountability and to evaluate how well they are satisfying their domestic objectives and international commitments" (OECD, 2003).

There are different institutions producing environmental indicators. At global level OECD, United Nations Statistical Division and United Nations Economic Commission for Europe regularly publish environmental indicators for which internationally data is available for use in environmental reviews. In Europe there are also different EU-level bodies that produce environmental indicators. We can mention here three of the more important: European Environmental Agency, Eurostat and the Directorate-General (DG) for the Environment, with sectorial DGs of the European Commission as well as the Joint Research Centre making important contributions. Thus, there are abundant references about the different types and uses of environmental indicators. Regarding the types of environmental indicators, they can be classified differently depending on the source chosen. OECD (OECD, 2008, 2015) classifies them following the issues to be tracked: Climate change, Ozone layer depletion, Eutrophication, Acidification, Toxic contamination, Urban environmental quality, Biodiversity, Cultural landscapes, Waste, Water resources, Forest resources, Fish resources, Soil degradation (desertification, erosion), Material resources, Socio-economic, sectorial and general indicators.

Another classification is the one provided by the Eurostat (Eurostat, 2016). Eurostat gives 17 themes with different sub-themes (see table 1).

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Table 1 Eurostat types of environmental indicators following themes and sub-themes

Agriculture	Environmental impact of agriculture Food and crop production Water for agricultural use
Air	Air quality Atmospheric emission Ozone layer depletion
Chemicals	Environmentally harmful or toxic substances
Climate	Temperature Weather and climate-related effects
Energy	Alternative fuels Energy consumption Energy efficiency Energy production Renewable resources
Environmental economics	Environmental expenditure Environmental goods and services Environmental taxes
Environmental policy	Environmental awareness Environmental management and labelling systems
Fisheries	Aquaculture Fish stocks Fishing fleet
Forestry	Forest deterioration Wood resources
Natural areas, landscape, ecosystems	Habitat destruction and ecosystem degradation Land use Protected area Species distribution Species diversity Species phenology
Noise	Traffic noise Urban noise
Resources	Material flows
Soil	Soil water Contaminated area Erosion Nutrient content Organic matter

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Transport	Freight transport Passenger transport Transport cost Transportation infrastructure
Waste	e-Waste Hazardous waste Municipal waste Packaging waste Waste excluding major mineral waste Waste generation and management
Water	Freshwater pollution and physical properties Marine pollution and salt water physical properties Waste water treatment Water damage Water resources

Complementary to Eurostat themes the EEA gives also a classification of indicators in themes, which are slightly different from Eurostat, these are: Air pollution, Biodiversity, Climate, Energy, Transport, Water and other.

United Nations Statistical Division (UNSD) themes and indicator tables were selected based on the current demands for international environmental statistics and the availability of internationally comparable data. The main themes are: Air and Climate, Biodiversity, Energy and Minerals, Forests, Governance, Inland Water Resources, Land and Agriculture, Marine and Coastal Areas, Natural Disasters, Waste. Besides this classification, the United Nations supported a program called Sustainable Development Goals (SDGs) (Sustainable Development Goals, 2015, 2016, UNSD, 2015), which focus in the socio-economic aspects of environment more than strictly to track environmental changes or impacts of human action.

The approaches and methodologies applied to define environmental indicators can be classified in two categories: policy-based approaches and conceptual approaches (Eurostat, 2014). Here we will use both, taking into account that currently, there is already an intense debate on how to obtain useful indicators (Ritschelova, 2015). Besides the debate on the construction or selection of indicators, a framework recently considered very useful to frame and select environmental indicators is the Planetary Boundary (PB) concept (Steffen, 2015). The PB were introduced in 2009, and aimed to define the environmental limits within which humanity can safely operate. This approach has proved influential in global sustainability policy development.

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In this report we will follow Eurostat and EEA frameworks to select indicators, and we will also suggest some of them as key ones to be used in MEDEAS activities and model implementation. We chose Eurostat as a reference, not only for providing public available data for Europe, but also for being a reference institution at European level, which fits into the framework of action of MEDEAS objectives. We use then, ecological indicators in the context of climate change, and ecosystem impacts within the framework of the renewable energy transition (RET). We also will consider the framework provided by the PB. PB is aligned with MEDEAS aims because it tries to analyze the physical limits of the human activities and its impact on the environment from a general point of view. MEDEAS project is concerned about the physical limitations of the energy system, so the main issues pointed out by the PB help us on the selection of environmental indicators. The indicators chosen are considered at two levels Global and European.

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Methodology

Indicators are commonly combined to form a set, where each individual indicator provides one part of the picture. This is necessary because single indicators provide a powerful unbiased message easy to interpret regarding one specific dimension. However, such metrics present a narrow picture of the issue measured. This is why indicators are often referred as dashboards or scoreboards, and the component indicators are presented individually.

Indicators can also be combined to form indices (or composite indicators). Indices are developed by combining individual indicators into one measure, and are often used for multidimensional concepts, which cannot be captured using a single indicator. Complex issues such as human development are multidimensional in their very nature. Their assessment therefore requires a framework in which various elements can be captured. The component indicators of composite indices such as the Human Development Index have different units, which are converted or normalized prior to aggregation. Different methodological approaches to the compilation of composite indicators are reported in the Handbook on Constructing Composite Indicators (Nardo et al., 2008).

From all of the indicators suggested in the numerous references and reports, this document will choose some of them, based in two criteria: the suitability for modeling purposes within the MEDEAS model, and the public availability of the data.

To select the best suitable indicators for an impact assessment of the RET we used as a framework the main developed modules within the MEDEAS model. Such model modules are: Economy, Energy, Materials, Land, Climate and Social. Here, due to the main objective of this subtask (environmental indicators), we will focus on Energy, Climate and Land. However, we also report some indicators regarding Ecosystem and Water. Ecosystems are a key player in food security, which affects both, Economy and Social issues. Biosphere and the so-called ecosystem services directly affect atmospheric and ocean GHG (which, in turn, impact Earth's climate). In this sense, function and conservation of the ecosystems depends strongly of the water cycle, therefore water indicators are a key link between energy and ecosystem. Human management of water, land, and energy interacts with climate change and its impacts, to profoundly affect risks to the amount of carbon that can be stored in terrestrial ecosystems, the amount of water available for use by humans and ecosystems, and the viability of adaptation plans for cities or protected areas. Failure to manage land, water, and energy in a synergistic fashion can exacerbate climate change impacts

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globally (Searchinger et al., 2008; Wise et al., 2009; Lotze-Campen et al., 2010; Warren et al., 2011) producing emergent risks, which are also potential key risks.

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Results

A total of 120 indices have been explored under the ecosystem, climate, water, and energy areas (Annex 1). For each area we describe the main framework and the characterization for the selected indicators.

Ecosystem

This field is devoted to the relationship between living organisms inhabiting an ecosystem and its resources. We have explored up to 53 ecosystem indicators related to physiological rates of organisms, biodiversity, status of habitats and communities, cycle of elements such as Carbon or Nitrogen and Land use (Annex 1). Obviously, to assess and manage the antrophogenic use of the environment, biological information alone is not sufficient, economic, socio-cultural and ecological approaches must be included in the valuation of the ecosystem. (e.g. on Biodiversity indices - Laurila-Pant et al., 2015). Besides, our knowledge on the dynamics of ecosystems and functioning (e.g. populations size; distribution; thereat status, biodiversity) is still limited, and therefore difficut to evaluate the impacts on them. With this limitations, we selected 4 indicators to cover the main ecosystem aspects, that to date, better capture and summarize information. These 4 indicators are linked to the planetary boundaries rationale (Steffen et al., 2015) and have open data sources.

1. Terrestrial net primary (plant) production (NPP):

DEFINITION: The net primary production (NPP) is the rate of organic matter synthesized by photosynthesis by producers minus the rate of energy rate used for respiration and other damages. It refers to measurements of biomass and estimated NPP for terrestrial sites worldwide. NPP provides a measurable boundary for human consumption of Earth's biological resources (Running 2012).

PROS : Highly integrative. NPP is easily measurable on a global scale. NPP integrates aspects of five of the currently defined planetary boundaries (Steffen et al., 2015): land-use change, freshwater use, biodiversity loss, and global nitrogen and phosphorus cycles. It is also influenced directly by two others, climate change and chemical pollution.

CONS : Overall planetary totals low variability due to the small global variability of the key drivers (i.e. solar radiation: <0.001% from year to year; total global precipitation ca 2% each

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year). At regional level the variability might be large for example due to droughts, floods, heat and cold waves.

DATA : 82 NPP data sets are available online, covering the major world ecosystem types. Used to validate models of vegetation-soil-atmosphere interactions within the global carbon cycle and to calibrate remote sensing of vegetation worldwide.

https://daac.ornl.gov/cgi-bin/dataset_lister.pl?p=13

2. Global Assessment of Human-induced Soil Degradation (GLASOD)

DEFINITION: world map of human-induced soil degradation, using a expert-based approach. The status of soil degradation is presented in detail: extent, degree, rate and main causes of degradation.

PROS: Is a complementary measure to land-use, which is missing the antropogenic use. Close relationship between land-use and biodiversity (land-use and related pressures have reduced local terrestrial biodiversity).

CONS: small scale (not appropiate at national level), subjective scale and quantification, complex visualization

DATA: The type, extent, degree, rate and main causes of degradation are documented and can be downloaded.

http://www.isric.org/projects/global-assessment-human-induced-soil-degradation-glasod

For Land uses refer to the Report 2.2.e.4- Land uses due to the transition to a low-carbon economy. Responsible UVa.

3. Biodiversity Intactness index (BII):

DEFINITION: The BII index gives the average richness in a specific area impacted by a set of anthropogenic activities relative to their abundance in an intact ecosystem. See also Local Biodiversity Intactness Index-LBII (under construction: http://www.predicts.org.uk/)

PROS: The BII is an indicator of the overall state of biodiversity in a given area, synthesizing land use, ecosystem extent, species richness and population abundance data. It is sensitive to the drivers and changes in the populations of species that typify the process of

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biodiversity loss, and robust to typical variations in data quality. It is possible to estimate the value of BII for the past, and project it into the future under various situations (Newbold et al., 2016).

CONS: Sensitive only to longterm effects of habitat fragmentation, climate change or pollution (Scholes and Biggs 2005). Attention must be paid to the quantification of habitat degradation to provide reliable estimates of biodiversity loss.

DATA: Under construction: National Biodiversity indicators are under development after the Aichi Biodiversity Targets: https://www.bipindicators.net/

Also, Local Biodiversity Intactness Index: http://www.predicts.org.uk/

4. Ecological footprint (EF)

DEFINITION: The ecological footprint is a measure of human impact on earth's ecosystems (of resource use). It is the amount of environment required to produce the goods and services to support our lifestyles. EF is a “measure of how much area of biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices.”

PROS: is an ecological indicator of human impact. It integrates the link between humans and the ecosystem thoughout the use of resources. Is an ecological-economics tool.

CONS: EF is widely used, however there are severe criticism regarding internal contradictions due to the assumptions and simplifications used for its construction (Giampietro and Saltelli, 2014).

DATA: The EF measures for a particular population or activity how fast we consume resources and generate waste compared to how fast nature can absorb our waste and generate new resources. Two types of data: Biocapacity (biologically productive area available) and EF.

http://www.footprintnetwork.org/en/index.php/GFN/page/footprint_data_and_results/

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Climate

Here the main reference used is the AR5 IPCC reports (IPCC-WGII, 2014). Particularly, the suggested framework in Working Group II: Impacts, Adaptation and Vulnerability. In climate issues, indices and indicators are used as and assessment tool to measure impacts, so it is required to quantify the links between climate changes and impacts. IPCC explores different indicators: GHG emission levels, atmospheric GHG concentration levels, changes in global temperature and sea-level rise, changes in regional climate variables, changes in the intensity or frequency of extreme events. A main problem with indicators GHG emission and atmospheric GHG concentration levels are that the it is assumed that concentration levels will not be stabilized until the end of the 21st century (Wigley et al. 1996). The difficulties also are evident in climate variables and the intensity or frequency of extreme events. Thus, for each change in global or regional climate or extreme events, there is a range of levels of GHG concentrations that could cause such a change in climate.

While there are problems in choosing the temperature changes as a general indicator (mainly due to that changes in temperature are not proportional to changes in climate variables, extreme events nor GHG concentrations. It is used because the impact literature can be directly related to a change in global mean temperature and it is most feasible to relate changes in global mean temperature to GHG concentrations.

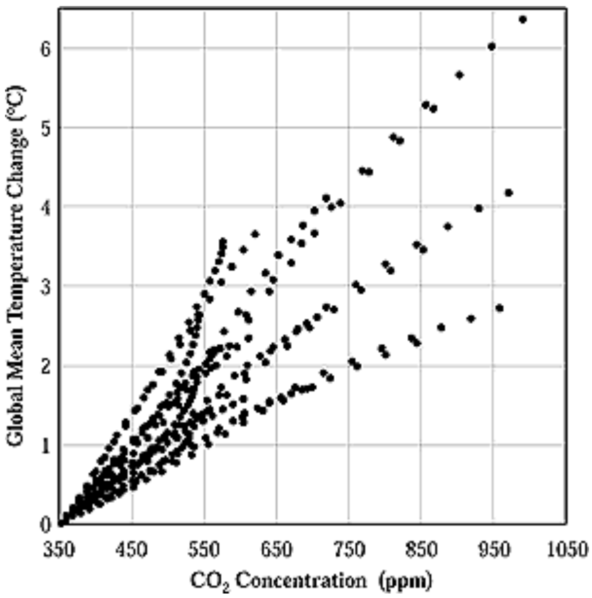

Figure 1 Global mean temperature change (from 1990) as a function of CO_2 concentration for SRES scenarios. For any given CO_2 level, uncertainties in temperature arise through several factors: other levels of GHG different of CO_2, uncertainties in climate sensitivity and changes in rates of radiative forcing.

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It should be pointed out that AR5-WII, 2014 does not address the effect of different rates of change in climate on vulnerability. Changes in extreme events such as more intense El Niño-Southern Oscillation events (Cai et al. 2014) could lead to more adverse impacts than a monotonic and gradual change in climate. Unfortunately, most of the impact literature has addressed only static or equilibrium changes in climate.

Thus to summarize, besides the selected indicators selected in the AR5 IPCC reports:

1. *GHG emission levels*, amount of Greehouse Gas released to the atmosphere per year. It is measured in million of metric tons of carbon dioxide equivalent.

2. *Atmospheric GHG concentration levels*, concentration of GHG at a certain time. It is measured in parts per million (ppm).

3. *Changes in global temperature and sea-level rise,* refers to the changes in the global mean surface temperature (Celsius degree per year) and mean sea level rise (Global Mean Sea Level in mm per year).

4. *Changes in regional climate variables*, they are related to changes in regional temperature, precipitation, solar radiation, relative humidity and air speed.

5. *Changes in the intensity or frequency of extreme events,* they can include heat waves, droughts, heavy downpours, floods, hurricanes and changes in other storms.

we add here the Carbon Footprint (Pandey et al., 2011; Barnett et al., 2013)

6. GHG emissions = Carbon Footprint (CF)

DEFINITION: The concept originates from the ecological footprint indicator (see above). CF is the amount of all GHGs (including Carbon) produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO_2). It is an indicator of unsustainable energy use.

PROS : Integrative. Includes carbon dioxide CO_2, Methane CH_4, Nitrous oxide N_2O, and other GHGs

CONS : lack of data availability for some countries; double counting; influenced by boundary conditions (include/exclude what emissions are to be counted) when calculating CF, this reduces the comparability of CF from different calculations

DATA : Data available at country and regional level, per capita. It can also be calculated at individual and organizational or activity level. http://data.worldbank.org/indicator/EN.ATM.CO2E.PC

http://edgar.jrc.ec.europa.eu/#

https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data#Gas

Water

Water is a key factor of interaction between human activities, ecosystems and natural resources. One of the main issues to consider is the water cycle as a whole and its role in the availability of freshwater for human uses (Huntington, 2006). Freshwater is also related to uses in agriculture and livestock, creating a circle around this resource that makes it especially interesting to quantify. The use of water by the energy sector, by thermo-electric power generation, hydropower, and geothermal energy, or biofuel production, can contribute to water stress in arid regions (Pittock, 2011). Some energy technologies (biofuels, hydropower, thermal power plants), transportation fuels and modes, and food products (from irrigated crops, in particular animal protein produced by feeding irrigated crops) require more water than others (Ackerman and Fisher, 2013). In irrigated agriculture, climate, crop choice, and yields determine water requirements per unit of produced crop, and in areas where water must be pumped or treated; energy must be provided (Gerten et al., 2011).

The links between energy-water-food are now a recent area of study (King and Carbajales-Dale, 2016). Identifying the “nexus” between energy, water and food production through the uses water and land and their impact in the agricultural sectors is a matter of growing interest not only by the scientific implications but also for the policy implications. The trade-offs between the limited global resources in the future regarding freshwater access and land use and energy production to deal with food security are an urgent subject to manage form international policies actions (Endo et al., 2015). A part of the water uses, the soil losses due to human action impact and related to global warming are affecting not only the arable land use and the water cycle but also the role of the soil as a carbon storage actor (Crowther et al. 2016). Thus, in this section, we explored 20 indicators (Annex 1) and we have considered here the water footprint indicator (WF) as a comprehensive measure of freshwater resources appropiation.

Water Footprint (WF)

DEFINITION: The WF measures the amount of freshwater resources are used and polluted. Is an indicator of freshwater use, of direct water of a consumer or producer and the indirect water use.

PROS: It is a multidimensional indicator, showing the volume of water consumption and pollution by source and by type of pollution. All components of the water footprint are specified geographically and temporally. Useful for the construction of Scenarios.

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CONS: It does not measure of the environmental impact of water consumption and pollution. The impact of water consumption and pollution depends on the vulnerability of the local water system and the number of water consumers and polluters that make use of the same system. It is must be complemented with other indicators (ie. Ecological and Carbon footprint). Simplification in the calculations might entail cascade errors.

DATA: It provides a numerical value of the water used or traded by individual, collective groups or product; type, location and time of water use. Data can be measured in cubic metres per tonne of production, per hectare of cropland, per unit of currency and in other functional units. Five datasets are included in the WF database: product water, national water, international virtual water flow, water scarcity and water pollution level.

http://waterfootprint.org/en/resources/water-footprint-statistics/

Fo all other water concepts please refer to the Report 2.2.e.5- Water uses due to the transition to a low-carbon economy. Responsible IIASA.

Energy

One of closer links between the use of resources and the human population is accounting for the energy needed to keep working the modern society. In this area there were two main sets of indicators that can be analysed: energy environmental impacts (mainly emissions) and energy efficiency indicators. A derived indicator set related also with the MEDEAS objectives is the exergy indicator.

OECD proposes a set of indicators regarding the energy environmental impacts main challenges. For OECD the main challenge is to decouple energy use and related air emissions from economic growth. Such decoupling will be achieved through improvements in energy efficiency and through the development and use of cleaner energy sources as RES, which is proposed to be implemented using a mix of instruments, including extended reliance on economic instruments. But there is necessary to trace the environmental performance, which can be assessed against domestic objectives such as energy efficiency targets, and targets concerning the share of renewable energy sources; and against international environmental commitments that have direct implications for domestic energy policies and strategies. In this sense OECD suggest two indicators: structure of the energy supply and the efficiency in the energy intensity in use, which is the energy cost per unit of GDP. Thus, the energy efficiency indicators are based mainly in tracking the energy intensity (OECD, 2015) related to the GDP of a country.

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Another indicator about the use of energy is the Exergy sustainabilty indicator (Gong, 2001) which is based on Life Cycle Exergy Analysis, a classical Life Cycle Analysis but using the exergy concept. Exergy can be used as an indicator of sustainability because it can account for future efficiency and provides a unitary measure to compare different materials and environmental performance of different industries. This indicator although very precise, lacks the simplicity and data publicly available to calculate it using a direct method.

Regarding SDGs a common used index (EEI-IEA 2014) is the Energy Development Index (EDI), which gives information about the energy access. EDI focuses on energy use (per capita energy and electricity use).

Table 2 Themes in the energy sustainability indicators (from Iddrisu, 2015).

Dimension	Indicator	Data required
Technical	Share of non-renewable energies in TPES Depletion coeff. Of local energy resources Overall system conversion efficiency	TPES total consumption on non-renewable energies Domestic production values of coal, oil, natural gas and solid fuels; Proved reserves of coal, oil, natural gas; Total forest area; Total land area TFC, TPES
Economic	1) Per capita consumption of commercial energies 2) Final energy intensity 3) Share of productive use of energy	1) Total commercial energy consumption; Population 2) TFC; GDP in Purchasing Power Parity 3) TFC; Residential Energy Consumption
Social	1) Per capita consumption of clean energies in the residential sector 2) Income inequality	1) Total Clean energy consumption in the residential sector; Population 2) Gini coefficient
Environmental	1) Share of “dirty fuels” in residential energyconsumption 2) Carbon intensity	1) Total consumption of coal, peat, crude oil, solid fuels; 2) TPES; Total CO_2 emissions from fuel combustion
Institutional	Overall Self Sufficiency	TPES; Indigenous production

However, EDI does not account for energy sustainability: self-sufficiency, rate of substitution of finite resources by renewables and environmental burden (García-Álvarez, 2016, deLlano-Paz, 2016).

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Besides the OECD indicators there are other different indicators reported which are more sustainability oriented. These are the energy indicators for the SDGs, recently (Iddrisu, 2015) has been suggested a multi-dimensional indicator SEDI: Sustainable Energy Development Index which is compatible with Human Development Index and Energy Development Index, but providing a more understandable view of the energy sustainability. SEDI considers five dimensions of sustainability: technical, economic, social, environmental and institutional and integrates them in one index (see table 1). The problem with this new indicator is that, currently, there is not publicly available data to obtain an historical database of it.

In Europe, EEA, report as energy indicators: Final energy consumption by sector, Total primary energy intensity, Primary energy consumption by fuel, Renewable primary energy consumption, Renewable electricity consumption, Efficiency of conventional thermal electricity generation, Final energy consumption intensity, Share of renewable energy in final energy consumption, Overview of the European energy system, Progress on energy efficiency in Europe, Overview of the electricity production an use in Europe. Some of them are of interest and aligned with the MEDEAS model design and Partially Aggregated Variables.

After considering the different indices linking energy production/consumption and environmental impacts in the framework of RET, we have selected three indicators that can give information of the ratio of electricity produced by renewables, the energy consumption per capita, and the amount of energy produced by RES, thus the three indicators chosen are: Share of renewable energy in final energy consumption, Energy use (kg of oil equivalent per capita) and renewable power capacity.

1. Share of renewable energy

DEFINITION: is the amount of renewable energy consumed for electricity, heating and cooling, and transport in the EU member states with actual and normalised hydro- and wind-power generation, and expressed as share against gross final energy consumption. The units of this indicator are ktoe (Kilo tonnes of Oil equivalent). This indicator is developed to track the evolution of the Europe 2020 strategy for renewable energy in the EU.

PROS: It is an indicator that is very much aligned with the main objective of MEDEAS project, which is the RET. It will give useful information about the progress and evolution of the RES in the market through energy use. It can assess the rate of change of the energy mix and so, the CO_2 emissions reduction and reduces primary energy production (some RES

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have a 100 % transformation efficiency, which improves the conversion efficiency of the system).

CONS: The indicator measures the relative consumption of energy from renewable sources in total energy consumption for a particular country. The share of renewable energy could increase even if the actual energy consumption from renewable sources falls. Similarly, the share could fall despite an increase in energy consumption from renewable sources. CO_2 emissions depend not on the share of renewables but on the total amount of energy consumed from fossil sources. Attaining the 2020 target for the share of renewable energy does not necessarily imply that CO_2 emissions from energy consumption will fall. Electricity consumption within the national territory includes imports of electricity from neighbouring countries. It also excludes the electricity produced nationally but exported abroad.

DATA: there are two main sources of data for the two geographical levels required. For global data it can be used the World Bank database or the IEA database. For EU there are Eurostat and the European Environment Agency databases.

2. Energy use (kg of oil equivalent per capita)

DEFINITION: refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport (IEA, 2016).

PROS: It includes energy from combustible renewables and waste - solid biomass and animal products, gas and liquid from biomass, and industrial and municipal waste. Biomass is any plant used directly as fuel or converted into fuel, heat, or electricity. So it accounts for all sources of primary energy and gives an approximation of the total energy consumed per capita in mtoe.

CONS: The statistics is made by country so breaks in time series due to lack of data in some countries are unavoidable. The conversion in Oil equivalent forces to make conversion efficiency assumptions, these are: thermal efficiency of 33 % for converting nuclear electricity into oil equivalents and 100 % efficiency for converting hydroelectric power to oil equivalent.

DATA: there are two main sources of data for the two geographical levels required. For global data it can be used the World Bank database or the IEA database. For EU there are Eurostat and the European Environment Agency databases.

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3. Renewable power capacity (GW)

DEFINITION: is the maximum net generating capacity of power plants and other installations that use renewable energy sources to produce electricity. For most countries and technologies, the data reflects the capacity installed and connected (IRENA, 2016).

PROS: It gives a measure of the installed power capacity per country, region and global for RES. Thus the power capacity can track the total amount of maximum electricity produced by RES per year.

CONS: As the other statistics by country, it has also lack of data in some countries. The maximum capacity does not account for intermittency problems that RES have and so for the necessary energy storage and grid management issues. Thus the indicator does not account for the necessary changes and transformations of the electric grid needed when a large-scale deployment of the RES will be implemented.

DATA: there are two main sources of data for the two geographical levels required. For global data it can be used the World Bank database or the IEA database. For EU there are Eurostat and the European Environment Agency databases.

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Conclusions

In this report we have explored a total of 120 indicators using different sources. Based on the MEDEAS model, we have selected four areas to classify the environmental indicators. The selected areas are: Ecosystem, Climate, Water and Energy. For each area of study a set of indicators has been chosen. The indicators selected have the common characteristics of having public available historical data, which can be found in international environmental organisations such as Eurostat, World Bank or European Environmental Agency. The main conclusion regarding environmental indicators is that, despite the amount of available indicators and their popularity for management purposes, there is a lack of agreement within the scientific community about the uselfuness of some indicators (or sets of them) to capture the complexity of the phenomena they aim to represent. Besides, here we suggest the most representative in the areas selected, compatible with the modelling purposes, as a first step to consider for inclusion within the MEDEAS model.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

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Appendix 1

Indicator	References
ECOSYSTEM	
Agri-environment indicators	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17964
Agricultural land (% of land area/km2)	International Bank for Reconstruction and Development/The World Bank, 2016. World Development Indicators. Highlights: featuring the sustainable development goals, WDI 2016
Agriculture: area under management practices potentially supporting biodiversity	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Agrophenology	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17965
Aquaculture: effluent water quality from finfish farms	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Arable land (hectares/%of land area/hectares per person)	International Bank for Reconstruction and Development/The World Bank, 2016. World Development Indicators. Highlights: featuring the sustainable development goals, WDI 2016
Behaviour patterns	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Biodiversity hotspots	Hudson, L.N., Newbold, T., Contu, et al.., 2014. The PREDICTS database: A global database of how local terrestrial biodiversity responds to human impacts. Ecol. Evol. 4, 4701–4735. doi:10.1002/ece3.1303
Biodiversity indexes (Margalef index, Shannon-Wienner index , Jaccard index, Simpson index, Richness, Abundance, Equitability)	Gamito, S., 2010. Caution is needed when applying Margalef diversity index. Ecol. Indic. 10, 550–551_Keylock, C.J., 2005. Simpson diversity and the Shannon-Wiener index as special cases of a generalized entropy. Oikos._Newbold, T., Hudson, L.N., Arnell, A.P., Contu, S., Palma, A. De, Ferrier, S., Hill, S.L.L., Hoskins, A.J., Lysenko, I., Phillips, H.R.P., Burton, V.J., Chng, C.W.T., Emerson, S., Gao, D., Pask-hale, G., Hutton, J., Jung, M., Sanchez-ortiz, K., Simmons, B.I., Whitmee, S., Zhang, H., 2016. Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. Science (80-.). 353, 288–291._Scholes, R.J., Biggs, R., 2005. A biodiversity intactness index. Nature 434, 45–49. doi:10.1038/nature03289_Hudson, L.N., Newbold, T., Contu, et al.., 2014. The PREDICTS database: A global database of how local terrestrial biodiversity responds to human impacts. Ecol. Evol. 4, 4701–4735. doi:10.1002/ece3.1303_
Biodiversity intactness index (BII)	Scholes, R.J., Biggs, R., 2005. A biodiversity intactness index. Nature 434, 45–49. doi:10.1038/nature03289

Biogeochemical flows (P Global: P flow from freshwater systems into the ocean. P Regional: P flow from fertilizers to erodible soils. N Global: Industrial and intentional biological fixation of N)	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9629
Biologic C bomb	Sitch, S., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K., Venevsky, S., 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Glob. Chang. Biol. 9, 161–185. doi:10.1046/j.1365-2486.2003.00569.x
Coverage of the ecosystem	Hudson, L.N., Newbold, T., Contu, et al.., 2014. The PREDICTS database: A global database of how local terrestrial biodiversity responds to human impacts. Ecol. Evol. 4, 4701–4735. doi:10.1002/ece3.1303
Ecological footprint	Rees, W.E., Wackernagel, M., 2013. The Shoe Fits, but the Footprint is Larger than Earth. PLoS Biol. 11, 1–3. doi:10.1371/journal.pbio.1001701
Ecology associations	Ellis, E.C., Kaplan, J.O., Fuller, D.Q., Vavrus, S., Klein Goldewijk, K., Verburg, P.H., 2013. Used planet: a global history. Proc. Natl. Acad. Sci. U. S. A. 110, 7978–85.
Ecosystem goods and services	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Ecosystem successions	Ellis, E.C., Kaplan, J.O., Fuller, D.Q., Vavrus, S., Klein Goldewijk, K., Verburg, P.H., 2013. Used planet: a global history. Proc. Natl. Acad. Sci. U. S. A. 110, 7978–85.
Elements cycle (Carbon, Nitrogren, Phosphorus, Iron)	Sitch, S., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K., Venevsky, S., 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Glob. Chang. Biol. 9, 161–185. doi:10.1046/j.1365-2486.2003.00569.x_Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9629_Wang, T., Müller, D.B., Graedel, T.E., 2007. Forging the anthropogenic iron cycle. Environ. Sci. Technol. 41, 5120–5129. doi:10.1021/es062761t
Extinction rate	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9629
Fertilizer consumption (kilograms per hectare of arable land)	Steffen, W., Persson, Å., Deutsch, L., Zalasiewicz, J., Williams, M., Richardson, K., Crumley, C., Crutzen, P., Folke, C., Gordon, L., Molina, M., Ramanathan, V., Rockström, J., Scheffer, M., Schellnhuber, H.J., Svedin, U., 2011. The anthropocene: From global change to planetary stewardship. Ambio 40, 739–761.

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	doi:10.1007/s13280-011-0185-x
Fire disturbance	Sitch, S., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K., Venevsky, S., 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Glob. Chang. Biol. 9, 161–185. doi:10.1046/j.1365-2486.2003.00569.x
Fisheries: European commercial fish stocks	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Food production index	International Bank for Reconstruction and Development/The World Bank, 2016. World Development Indicators. Highlights: featuring the sustainable development goals, WDI 2016
Forested land (Growth, turnover, % of original forest cover, deforestation, reforestation and deadwood)	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9629
Genetic diversity	Secretaría del Convenio sobre la Diversidad Biológica (2014), 2014. Perspectiva Mundial sobre la Diversidad Biológica 4. Montreal.
Growing season for agricultural crops	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17966
Habitat corridors	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Habitat fragmentation	Secretaría del Convenio sobre la Diversidad Biológica (2014), 2014. Perspectiva Mundial sobre la Diversidad Biológica 4. Montreal.
Human appropriation of net primary production in earth's terrestrial ecosystems	Haberl, H., Erb, K.H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W., Fischer-Kowalski, M., 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. Proc. Natl. Acad. Sci. U. S. A. 104, 12942–7. doi:10.1073/pnas.0704243104
Invasive alien species	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Irrigation water requirement	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17967
Land area where elevation is below 5 meters (% of total area)	International Bank for Reconstruction and Development/The World Bank, 2016. World Development Indicators. Highlights: featuring the sustainable development goals, WDI 2016

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Land use (Land use and land use intensity classes)	Hudson, L.N., Newbold, T., Contu, et al.., 2014. The PREDICTS database: A global database of how local terrestrial biodiversity responds to human impacts. Ecol. Evol. 4, 4701–4735. doi:10.1002/ece3.1303
Life history cycles	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Migration paths	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Natural resources (Renewal and depletion)	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17967
Net Ecosystem Exchange	Sitch, S., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K., Venevsky, S., 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Glob. Chang. Biol. 9, 161–185. doi:10.1046/j.1365-2486.2003.00569.x
Plants metabolism (Leaf respiration, canopy transpiration, leaf area index (LAI), photosynthesis activity, Chlorophyll)	Sitch, S., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K., Venevsky, S., 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Glob. Chang. Biol. 9, 161–185. doi:10.1046/j.1365-2486.2003.00569.x
Primary and secondary vegetation	Hudson, L.N., Newbold, T., Contu, et al.., 2014. The PREDICTS database: A global database of how local terrestrial biodiversity responds to human impacts. Ecol. Evol. 4, 4701–4735. doi:10.1002/ece3.1303
Primary production (Gross and Net)	Hudson, L.N., Newbold, T., Contu, et al.., 2014. The PREDICTS database: A global database of how local terrestrial biodiversity responds to human impacts. Ecol. Evol. 4, 4701–4735. doi:10.1002/ece3.1303
Protected species	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Soil and litter descomposition	Sitch, S., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K., Venevsky, S., 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Glob. Chang. Biol. 9, 161–185. doi:10.1046/j.1365-2486.2003.00569.x
Soil and subsoil pollution	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Soil erosion	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17965

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Soil moisture	Sitch, S., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K., Venevsky, S., 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Glob. Chang. Biol. 9, 161–185. doi:10.1046/j.1365-2486.2003.00569.x
Soil organic carbon	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17964
Species phenology	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Terrestrial and marine protected areas (% of total territorial area)	International Bank for Reconstruction and Development/The World Bank, 2016. World Development Indicators. Highlights: featuring the sustainable development goals, WDI 2016
Terrestrial Ecoregions of the World	Hudson, L.N., Newbold, T., Contu, et al.., 2014. The PREDICTS database: A global database of how local terrestrial biodiversity responds to human impacts. Ecol. Evol. 4, 4701–4735. doi:10.1002/ece3.1303
Threatened species (IUCN Red list status, CITES appendix)	Hudson, L.N., Newbold, T., Contu, et al.., 2014. The PREDICTS database: A global database of how local terrestrial biodiversity responds to human impacts. Ecol. Evol. 4, 4701–4735. doi:10.1002/ece3.1303_Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9629
Topography	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Trophic relationships	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Water-limited crop productivity	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17966
CLIMATE	
Acoustic pollution	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Aerosol Optical Depth (AOD) as a seasonal average over a region	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9629
Air pollution	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17965

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Atmosferic pressure	Sitch, S., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K., Venevsky, S., 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Glob. Chang. Biol. 9, 161–185. doi:10.1046/j.1365-2486.2003.00569.x
Atmospheric greenhouse gases concentration	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9633
Carbon footprint	Rees, W.E., Wackernagel, M., 2013. The Shoe Fits, but the Footprint is Larger than Earth. PLoS Biol. 11, 1–3. doi:10.1371/journal.pbio.1001701
Emission intensity (Of agriculture, domestic sector, manufacturing industry)	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17967
Energy imbalance at top-of- atmosphere,Wm–2	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9632
Exceedance of air quality limit values in urban areas	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17966
Fog frequencies	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Gases parcial pressure (O2)	Sitch, S., Prentice, I.C., Arneth, A., Bondeau, A., Cramer, W., Kaplan, J.O., Levis, S., Lucht, W., Sykes, M.T., Thonicke, K., Venevsky, S., 2003. Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Glob. Chang. Biol. 9, 161–185. doi:10.1046/j.1365-2486.2003.00569.x
Global Radiative Forcing (W m-2)	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9629
Mean precipitations	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Microclimates in ecosystem	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Precipitation extremes	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Production and consumption of ozone depleting substances	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17964

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

Production, sales and emissions ((Sulphur dioxide (SO2), Nitrogen oxides (NOX), Ammonia (NH3), Non-methane volatile organic compounds (NMVOC), Heavy metal (HM), Persistent organic pollutant (POP), acidifying substances, ozone precursors, fluorinated GHGs (F-gases), photochemical oxidators, primary particulate matter and secondary particulate matter precursors)	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Progress to greenhouse gas emission targets	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Relative moisture	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Solar irradiance	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9630
Stratospheric ozone depletion	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9630
Surface albedo	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9631
Temperature (Global land and ocean mean temperature and anomalies)	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Wind regimes	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
WATER	
% Potable freshwater	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Annual freshwater withdrawal, total (Billion cubic meters or % internal resources)	International Bank for Reconstruction and Development/The World Bank, 2016. World Development Indicators. Highlights: featuring the sustainable development goals, WDI 2016
Arctic sea-ice cover	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17966
Basin features (Distribution, geomorphic attributes, flow, scarcity, runoff, refill, transportation, drainage, flood, erosion, deposition, stability)	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.

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Coast dynamics	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Currents	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Fresh ground water	OECD Statistics [WWW Document], n.d. URL http://stats.oecd.org/
Fresh surface water	OECD Statistics [WWW Document], n.d. URL http://stats.oecd.org/
Freshwater resources (Uses, abstractions treatment, urban waste, % population connected, Maximum amount of consumptive blue water use (km3yr–1), Blue water withdrawal as % of mean monthly river flow, Total public sewerage (% of resident population connected to urban wastewater collecting system))	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963 _Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9629
Freshwater resources and reserves	OECD Statistics [WWW Document], n.d. URL http://stats.oecd.org/
Generation of wasterwater (all sources) (volume)	OECD Statistics [WWW Document], n.d. URL http://stats.oecd.org/
Glaciers	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17964
Ocean acidification (Carbonate ion concentration, pH)	Carpenter, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 348, 1217. doi:10.1126/science.aaa9629
Permafrost	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17967
Rising sea level	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17968
Seabed status	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa.
Snow cover	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17965
Total freshwater	OECD Statistics [WWW Document], n.d. URL http://stats.oecd.org/
Water footprint	Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M., Mekonnen, M.M., 2011. The Water Footprint Assessment Manual, Febrero 2011. doi:978-1-84971-279-8
Water quality (Physical-chemical and biologic quality. Nitrates, phosphates, carbonates, sulphates, salinity, extinction coefficient, trophic state, eutrophication)	Gómez Orea, D., 2002. Evaluación de impacto ambiental : un instrumento preventivo para la gestión ambiental. Ediciones Mundi-Prensa._European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963

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ENERGY	
Cumulative energy demand (CED)	King, C.W., Carbajales-Dale, M., 2016. Food-energy-water metrics across scales: project to system level. J. Environ. Stud. Sci. 6, 39–49. doi:10.1007/s13412-016-0390-10
Electricity (Consumption, power consumption per capita, production from sources (% of total or kWh): Coal, hydroelectric, natural gas, nuclear, oil, renewable sources, efficiency, uses)	European Environment Agency (EEA). Digest of EEA indicators 2014. (2014). doi:10.2800/17966_International Bank for Reconstruction and Development/The World Bank Group, 2016. World Development Indicators (WDI) http://www.worldbank.org/
Energy payback time (EPBT)	King, C.W., Carbajales-Dale, M., 2016. Food-energy-water metrics across scales: project to system level. J. Environ. Stud. Sci. 6, 39–49. doi:10.1007/s13412-016-0390-11
Energy productivity, GDP per unit of TPES	OECD Statistics [WWW Document], n.d. URL http://stats.oecd.org/
Energy return on investment (EROI)	King, C.W., Carbajales-Dale, M., 2016. Food-energy-water metrics across scales: project to system level. J. Environ. Stud. Sci. 6, 39–49. doi:10.1007/s13412-016-0390-12
Energy use (kg of oil equivalent per capita)	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17967
Ethanol and biodiesel production (billion litres)	REN21, 2013. Renewables 2013 Global Status Report, Production. doi:ISBN 978-3-9815934-0-5
Final energy consumption by sector	REN21, 2013. Renewables 2013 Global Status Report, Production. doi:ISBN 978-3-9815934-0-6
Final energy consumption intensity	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963
Investment in new renewable capacity (annual)	REN21, 2013. Renewables 2013 Global Status Report, Production. doi:ISBN 978-3-9815934-0-2
Life Cycle Analysis (LCA)	King, C.W., Carbajales-Dale, M., 2016. Food-energy-water metrics across scales: project to system level. J. Environ. Stud. Sci. 6, 39–49. doi:10.1007/s13412-016-0390-9
Net Energy Analysis (NEA).	King, C.W., Carbajales-Dale, M., 2016. Food-energy-water metrics across scales: project to system level. J. Environ. Stud. Sci. 6, 39–49. doi:10.1007/s13412-016-0390-9
Non-renewable power capacity (Coal, oil, natural gas, total)	Programa de las Naciones Unidas para el Desarrollo, 2007. Informe sobre Desarrollo Humano 2007-2008. La lucha contra el cambio climático: Solidaridad frente a un mundo dividido.
Nuclear energy and efficiency	Programa de las Naciones Unidas para el Desarrollo, 2007. Informe sobre Desarrollo Humano 2007-2008. La lucha contra el cambio climático: Solidaridad frente a un mundo dividido.
Overview of the energy system production and use	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17965
Primary energy consumption (Renewable, non-renewable, by	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17963

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fuel, total)	
Progress on energy efficiency	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17966
Rate of electrification	Programa de las Naciones Unidas para el Desarrollo, 2007. Informe sobre Desarrollo Humano 2007-2008. La lucha contra el cambio climático: Solidaridad frente a un mundo dividido.
Renewable power capacity (Hydropower, bio-power, solar PV, concentrating solar thermal power, wind power, ocean power, geothermal power and total (GW))	REN21, 2013. Renewables 2013 Global Status Report, Production. doi:ISBN 978-3-9815934-0-3
Share of renewable energy in final energy consumption	European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. doi:10.2800/17964
Total primary energy intensity	REN21, 2013. Renewables 2013 Global Status Report, Production. doi:ISBN 978-3-9815934-0-7
Total primary energy supply (TPES) tonnes of oil equivalent (toe)	OECD Statistics [WWW Document], n.d. URL http://stats.oecd.org/
Water heating: geothermal heating (Geothermal heating, solar collectors, modern bio-heat)	REN21, 2013. Renewables 2013 Global Status Report, Production. doi:ISBN 978-3-9815934-0-4

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