UNITED NATIONS 6 November 2012
ECONOMIC COMMISSION FOR EUROPE

CONFERENCE OF EUROPEAN STATISTICIANS

Meeting on climate change related statistics for producers and users
Geneva, 19-20 November 2012
Session 1

SCOPE OF CLIMATE CHANGE RELATED STATISTICS

Note prepared by Task Force, coordinating author Julie L. Hass, Statistics Norway[1]

I. INTRODUCTION

1. The purpose of this paper is to define climate change related statistics in the context of official statistics. The paper is prepared by the UNECE Task Force which aims to illuminate what the national statistical systems can do to better meet user needs for climate change related statistics. One of the first steps in this process is to define what is meant by climate change related statistics and identify the links with official statistics.

2. Climate change involves a global, systemic perspective with interactions between interrelated systems. Climate change is complex and multi-disciplinary and anchored largely in the natural sciences. In contrast, the statistical system is focused largely on anthropomorphic or human systems – such as the economy, education, population, human health and well-being – and is organized using administrative regions and is especially focused on national boundaries.

3. Statistics often do not put a great deal of emphasis on the interactions of the various systems and sub-systems they monitor. Identifying and modelling interactions is often the work of economists, academics, government ministries and others working outside of national statistical offices. But the analyses are only as good as the data – and this is where the statisticians come back into the picture. Recently, research has started to focus more on "assessing the socio-economic aspects of climate change and implications for sustainable development" [2] . These are areas where existing data from the statistical systems could be linked with climate information to provide a broader and more informed picture of the changes in the future.

4. The reason for studying the changing climate is that it "will affect people around the world. Rising global temperatures are expected to raise sea levels, and change precipitation and other local climate conditions. Changing regional climate could alter forests, crop yields, and water supplies. It could also affect human health, animals, and many types of ecosystems. Deserts may expand into existing rangelands, and features of some of our National Parks and National Forests may be permanently altered." [3]

---

[1] Contributing authors: Robert Smith, Statistics Canada; Velina Pendolovska, DG Climate Action; Angelica Tudini, Istat; Anu Peltola and Tiina Luige, UNECE; Julio Cabeça, Eurostat.

[2] Source: The 5th assessment report outline of IPCC, page 2, at www.ipcc.ch/pdf/ar5/ar5-leaflet.pdf

[3] Source: www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

A. Defining change, climate and climate change

5. Before looking at different models or frameworks for organising statistics related to climate change we need to define climate change - starting with the words *climate* and *change* individually and then examining the definition of “climate change”.

6. *Change* from a statistical perspective is a difference between two observations – usually between two or more time periods. To measure differences over time requires consistent time series of comparable data. The development of consistent, comparable time series is a core competence of the statistical system. Official statistics develop ways to compare things over time and adjust them, for example, for seasonal variation, changes in prices/inflation, temperature, etc. When adjustments are made, the effect of a known source of influence on the variation in the data is eliminated so that only the changes caused by unknown sources of influence and natural variation are left. This type of data treatment can be important when trying to investigate changes that may be due to climate. The statistical system also has routines for developing statistics that are internationally comparable – with an infrastructure to ensure that the definitions, classifications and data collection are harmonized.

7. When trying to define *climate*, it is also necessary to understand the relationship between weather, which we experience daily and climate. The US National Oceanic and Atmospheric Administration (NOAA) and NASA explain that,

> “the difference between weather and climate is a measure of time. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time… In short, climate is the description of the long-term pattern of weather in a particular area. Some scientists define climate as the average weather for a particular region and time period, usually taken over 30-years. It's really an average pattern of weather for a particular region…An easy way to remember the difference is that climate is what you expect, like a very hot summer, and weather is what you get, like a hot day with pop-up thunderstorms.” [4]

8. What is meant by *climate change*? Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC) defines it as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". In addition, the same article also defines the term *climate system*, which means "the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions".

9. Key elements in these definitions are: the human-induced causes of climate change (notwithstanding other natural causes), the fact that the climate is a system comprising several components (atmosphere, hydrosphere, etc.) and their interactions, and the consideration that climate change ultimately affects both the natural environment and the socio-economic aspects of life.

---

[4] Source: www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

10. In addition, Article 1 of the UNFCCC defines the term *adverse effects of climate* change as "changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare".

11. The chief specific *cause* of human-induced climate change cited in the definition is the release of greenhouse gases in the atmosphere. Thus, Article 2 of the UNFCCC[5], codifying the core objective of the Convention, explicitly addresses this cause:

> "The ultimate objective of this Convention… is *to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system*. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."
>
> *[emphasis added]*

12. Greenhouse gas emissions are released as a result of a number of human activities that underpin development and technological progress, such as, for example, industry, agriculture, transport and for example the combustion of fossil fuels for electricity production.

13. Therefore, climate change is not merely an environmental problem limited to the natural sciences but it has wider implications on human life, well-being and development. *Climate change related statistics* must include information relevant to emissions of greenhouse gases but it must also include information about environmental, economic and social conditions that are impacted by climate change. *Climate change related statistics* refer to environmental, social and economic statistics measuring the drivers, pressures, impacts and costs of climate change. In other words, these are statistics that measure climate sensitive phenomena. For example, on the impact side, these statistics could include changing crop yields, land cover, number of tourists, mortality, diseases etc.

14. As the purpose of this paper is to define climate change related statistics in the context of official statistics, it may prove useful to make a difference between the climate change related statistics and climate change statistics. The latter includes data that measures climate and weather directly; for example, temperature and precipitation. These data are usually collected and analysed by meteorological organisations and agencies that are not part of the national statistical systems. When speaking about the role of statistical systems, we may choose to focus on the data that are climate change "related" rather than on the climate change statistics.

B. The viewpoint of Official Statistics

15. A variety of information and data are needed to obtain a full picture of the changes that can be related to climate change. Identifying the different responsible actors and the various sources of data can be challenging. It is important to find the best information to use in a given analysis or policy context and to have confidence in the methods used to produce the results. Official statistics can be an important source of reliable, fit-for-purpose

[5] Full text of the Convention: http://unfccc.int/essential_background/convention/background/items/1349.php

information because of the strict conditions and quality criteria under which these statistics are produced.

16. *Official statistics* comprise any statistical activity carried out within a national statistical system, or under the statistical programme of an intergovernmental organization[6]. They are by definition compiled in accordance with the Fundamental Principles for Official Statistics,[7] the European Statistics Code of Practice[8] or a similar authoritative international framework ensuring professional standards.

17. *National statistical systems* comprise the ensemble of statistical organisations and units within a country that jointly collect, process and disseminate official statistics on behalf of national government. They also include the mechanisms of interaction between suppliers, producers, users and other stakeholders. One agency has the coordination role of the national statistical system, usually the national statistical office. The global system of official statistics comprises all national and international producers of official statistics.

18. The paper looks at climate change related statistics from the viewpoint of the statistical system rather than only statistical offices. This is because the organization of the statistical system differs in countries. Responsibility for specific statistical topics (like environment, transport, health, energy, etc.) can be either with the statistical office or with another institution that is part of the statistical system, for example a Ministry or specialised agency.

19. The comparative advantage of the statistical system in response to the climate change challenge is that it is the only worldwide, comprehensive, multi-layer information system covering a spectrum of social, economic, environmental and institutional themes. The statistical system has the responsibility for and control over definitions, classifications, nomenclatures, methodologies, certified measurements, accounting standards and data quality. These aim to ensure comparability and coherence over time and regions. Independence from the political process is an important feature of official statistics. Analysing the cause-effect relationships in climate change, however, is not the task of the statistical system. Instead, official statistics should provide existing data in a suitable form for users so that they could analyse whether a specific result or observation has been influenced by climate change or some other reason.

20. Statistical offices often provide geo-referenced data, but this remains a relatively new aspect of the statistical system. In the context of climate change, there are analytical needs related especially to coastal regions. Statistical data by definition include a spatial dimension. Traditionally this dimension is a postal address and not a geocode (e.g. a geographical coordinate). A task for the next rounds of population censuses or other basic data collection will be to "translate" addresses into geocodes and by adding that information, to open the data for additional uses. Trying to bridge the gap between the need for detailed geo-referenced data and the necessity to maintain the confidentiality of respondents will be an area that needs to be carefully considered.

---

[6] Statistical Data and Metadata eXchange 2009: www.sdmx.org/

[7] http://unstats.un.org/unsd/methods/statorg/FP-English.htm

[8] http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-32-11-955/EN/KS-32-11-955-EN.PDF

21. A major challenge for the statistical system today is to identify the components that should be incorporated into existing statistical systems or how the system could be modified to be able to identify and measure the changes which might be attributed to changes in climate.

II. EVALUATION OF VARIOUS FRAMEWORKS AND THEIR APPLICABILITY TO CLIMATE CHANGE RELATED STATISTICS

22. Currently, the information for fully understanding the causes and impacts of climate change is scattered across a wide variety of national and international organisations. Improvements to the measurement and organization of information are needed in order to adequately and comprehensively address different types of changes that can be attributed to climate change. Some frameworks may be more useful for certain purposes – and the use of a specific framework may have certain limitations or advantages.

23. The following frameworks will be examined briefly with respect to their usefulness:

- Driving forces – Pressure – State – Impacts – Response (DPSIR)
- Framework for the Development of Environmental Statistics (FDES, under revision)
- IPCC Schematic framework representing anthropogenic drivers, impacts and responses
- Natural capital approach
- Impact, mitigation and adaptation

24. This analysis does not aim to develop and establish a new system of climate change related statistics. It focuses on how the different, relevant frameworks could be applied for organizing climate related information in a meaningful way. The latest version of the UN Framework for the Development of Environment Statistics (FDES) has applied the IPCC schematic framework for representing climate information included in environment statistics. Therefore, the IPCC framework is not discussed separately. Regardless of this choice, we will take into account the wider interpretation of the IPCC framework that exceeds the range of its application in the FDES which focuses on environmental issues.

A. Driving forces – Pressure – State – Impacts – Response (DPSIR)

25. Climate change related statistics could be examined and structured according to the so called Driving forces-Pressure-State-Impact-Responses (DPSIR) model. The DPSIR model is used by the European Environment Agency (EEA) to "structure thinking about the interplay between the environment and socio-economic activities."[9] DPSIR uses a systems analysis view towards assessing environmental phenomena. It is used by the EEA[10] in its State of the Environment Reports and it is an expansion of the OECD's predecessor called the pressure-state-response (PSR) framework[11] which was originally proposed for environmental

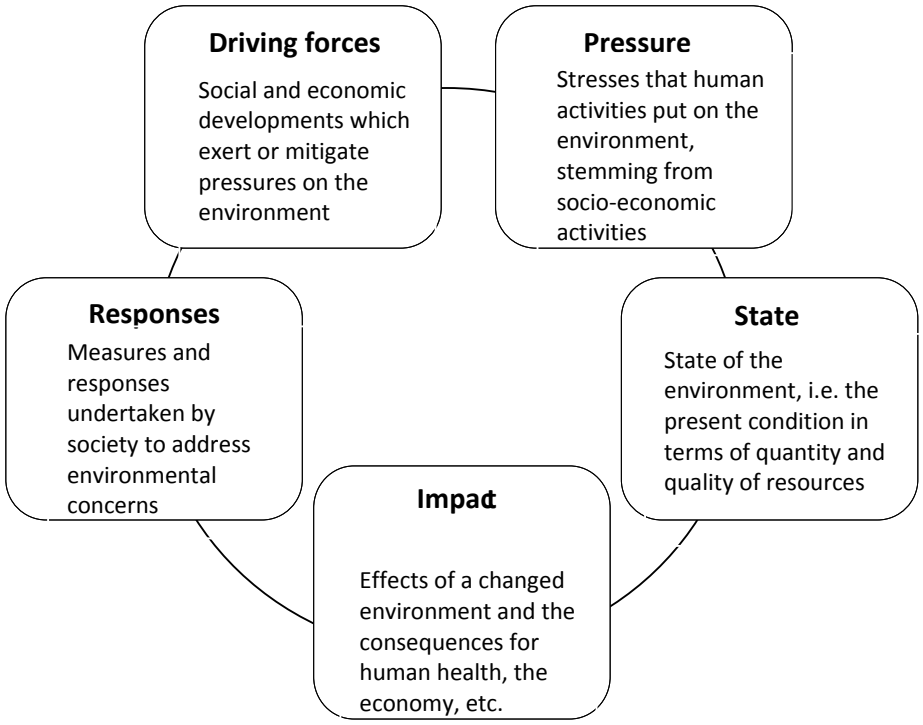
[9] http://ia2dec.ew.eea.europa.eu/knowledge_base/Frameworks/doc101182/

[10] http://glossary.eea.europa.eu/EEAGlossary/D/DPSIR

[11] http://stats.oecd.org/glossary/detail.asp?ID=2105 (OECD. OECD core set of indicators for environmental performance reviews. Organisation for Economic Co-operation and Development, Environmental Monographs, 83 1993:1-39.)

indicators and was based on the Stress-Response framework[12] developed by Statistics Canada.

Figure 1. The Driving forces-Pressure-State-Impact-Responses (DPSIR) model



26. The EEA describes the logic in the DPSIR as follows:

> "The DPSIR represents a systems analysis view: - social and economic developments exert pressure on the environment and, as a consequence, the state of the environment changes. This leads to impacts on e.g. human health, ecosystems and materials that may elicit a societal response that feeds back on the driving forces, on the pressures or on the state or impacts directly, through adaptation or curative action."[13]

27. Typically the DPSIR model is shown as a circle or with linear connections which implies, directly or indirectly, that there are causality links.

28. Gabrielsen and Bosch[14] argue that the existence of these interrelations in the DPSIR framework, although often presented as a linear chain or a circle, in fact resembles a very complex web of many interacting factors some of which may represent highly non-linear dynamics. This means that there can be a number of different causes which influence the system resulting in changes in the state of the environment. There can also be a mixture of results from policy responses and changes in driving forces that produce reductions in

[12] Rapport, D.J. and A.M. Friend (1979): Towards a comprehensive framework for environmental statistics : a stress-response approach, Minister of Supply and Services Canada, Ottawa, Statistics Canada Catalogue 11–510;

[13] http://ia2dec.ew.eea.europa.eu/knowledge_base/Frameworks/doc101182/

[14] Gabrielsen and Bosch (2003): Environmental Indicators: Typology and Use in Reporting. EEA internal working paper. http://www.iwrms.uni-jena.de/fileadmin/Geoinformatik/projekte/brahmatwinn/Workshops/FEEM/Indicators/EEA_Working_paper_DPSIR.pdf

relevant pressures. Although the model appears to be fairly simple, it also can represent a more complex system.

29. Although the DPSIR model has primarily been used with a focus on the environment, it could also be used when exploring other systemic issues such as climate change. Organising statistics relevant to climate change according to the DPSIR model can help to create a coherent framework for structuring the different statistical areas that inform the various aspects of the climate change phenomenon – from broad socio-economic developments, to specific sources of greenhouse gas emissions, to measures related to adaptation or curative action, etc.

30. The DPSIR model can be examined in closer detail by looking at each of the five components separately. Taking this approach, the relevant areas of statistics that provide data on trends and developments can be matched with each of the separate components. We will start with defining the State, since that will help us place other phenomena more easily into the other categories.

1. State

31. In this case, we will interpret the **State** component of the DPSIR model to encompass the state of the climate system and the environment as affected by climate change – this is a snapshot of the situation. Here, a good start can be provided by some of the so called Essential Climate Variables (ECVs) from the Global Climate Observing System (GCOS)[15]. These variables are presented in Annex 2. A very important indicator under **State** is the concentration of greenhouse gases in the atmosphere and their aggregation using the so called global warming potentials giving the aggregate measure of the amount of heat trapped by the different gases once they are released in the atmosphere.

32. Key information on the state of climate change often includes the following topics:

- **Atmosphere and climate:** earth's surface and the stratosphere, air temperature, hot and cold extremes; precipitation extremes; ozone concentrations
- **Cryosphere:** glaciers, Arctic sea ice, mountain permafrost, snow cover
- **Marine biodiversity and its ecosystems:** sea level rise, sea surface temperature, storm surges, retreat of shorelines due to erosion, distribution of marine species[16]

33. Currently, the role of NSOs in collecting data on the state of the climate is often very limited, or even non-existent. These indicators mainly aim to describe global developments that are not always easy to assign to individual countries, whereas the NSOs normally describe national events. The main authorities responsible for these data are typically national meteorological institutes, and at the international level, the climate observation networks coordinated by World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP). The two organisations established IPCC's Working Group I (WGI)[17] that assesses the physical scientific aspects of the climate system and climate change and contributes to the IPCC Assessment Reports.

---

[15] http://www.wmo.int/pages/prog/gcos/index.php?name=EssentialClimateVariables

[16] These are the categories four to seven of the state and impact indicators of climate change as defined by the European Environment Agency.

[17] https://www.ipcc-wg1.unibe.ch/

2. Driving forces

34. Driving forces encompass information on socio-economic developments that exert or mitigate pressure on the environment and that is particularly relevant to climate change including:

- Increasing population and migration movements
- Increasing urbanisation
- Structure of households with tendency for higher number of households with lower number of members
- Increasing levels of economic activity and wealth related to higher consumption and production, leading to:
  - increasing demand for energy and transport,
  - increasing demand for housing: more and bigger houses occupied by smaller households, more heated houses, more household appliances
  - intensive agricultural practices, higher demand for meat
- Increasing mining, manufacturing and construction levels to satisfy increasing demand
- Diets requiring the use of more energy throughout the food production chain (e.g. industrial scale food production, processed foods production, imported foods, etc.)
- Higher wealth of nations associated with increasing GDP and higher economic growth,
- Internationalisation of the economy, including the outsourcing of production in third countries, especially in the case of more polluting industries (e.g. the "carbon leakage" problem)
- More global trade and tourism that increases the need of international transportation
- Higher levels of waste from production and consumption activities

35. Statistics for each of these topics are normally already available in most National Statistical Offices. Such statistics include:

- Population, demography, migration statistics
- Household statistics (type, size, etc.)
- International trade statistics
- Energy statistics
- Agriculture and food statistics, including on agricultural production
- Economic and business statistics, including GDP, income, employment, output, etc.
- Waste statistics
- Tourism, Consumption and time use statistics

3. Pressures

36. The next component of the DPSIR model, **Pressures,** concerns the actual greenhouse gas emissions and all surrounding information on the underlying activities that produce the emissions. The data relevant to the latter are referred to as "activity data" and they cover, for example, information on:

- Combustion of fossil fuels in different industry sectors
- Production of fossil fuels
- Livestock in agriculture

- Emission factors
- Production of ozone depleting substances
- Waste treatment methods, etc.

37. Two approaches are in place for emissions reporting:

38. First, **national emission inventories** reported to the **UNFCCC**[18]. Allocation of emissions in the inventories currently follows the *Revised 1996 International Panel on Climate Change (IPCC) Guidelines*[19] methodologies for estimating anthropogenic emissions by sources and removals by sinks of greenhouse gases. Data are reported covering emissions and removals of direct GHGs (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) from six sectors (Energy, Industrial processes, Solvents, Agriculture, Land use, Land use change and Forestry (LULUCF) and Waste), and for all years from the base year or period to the most recent year. In most cases, the competent authorities responsible for inventory compilation are national environmental agencies, not NSOs.

39. In this process, statistical offices are particularly involved in terms of the activity data used for the estimation of the emissions. Fundamentally, the method of estimation considers emissions as a product of activity data and emission factors. Statistical offices often play a central role by providing data for the inventory compilation derived from:

- Energy statistics
- Transport statistics
- Industrial production statistics including wastewater treatment
- Waste and waste treatment statistics
- Agriculture statistics
- Forestry and land cover/use statistics

40. Currently, the statistical areas above are developed primarily with a view of the primary policies they serve (e.g. energy policy, agriculture policy, etc.), responding to their data needs and priorities. This means that climate change considerations are not always taken into account.

41. Second, **air emissions accounts** link economic activities with environmental pressures. Air emissions accounts, like other sets of environmental-economic accounts, are satellite accounts to national accounts and are in most cases developed by NSOs. In accounts, emissions are allocated not on the basis of the source (or sink) at which they occur (as in the inventories) but to the economic activity or industry responsible for them, following the same classifications of economic activities (ISIC, NACE)[20] used in national accounts. In this way, air emissions accounts are structurally fully consistent with national accounts, which allows for an integrated environmental-economic analysis and an exploration of the link between emissions and the economy.

---

[18] Art 4(1)a of the UNFCCC obliges Parties to "develop, periodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties".

[19] Available at: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html. The Subsidiary Body for Scientific and Technological Advice at its thirtieth session considered the use by Parties of the 2006 Intergovernmental Panel on Climate Change guidelines for national greenhouse gas inventories 2006 IPCC Guidelines starting in 2015.

[20] ISIC – International Standard Industrial Classification adopted as an UN standard; NACE - Statistical Classification of Economic Activities in the European Community

42. The System of Environmental-Economic Accounting (SEEA 2012)[21] recently adopted as an initial version of the international statistical standard for environmental-economic accounts by the United Nations Statistical Commission will enhance the work on environmental accounts. The SEEA contains the internationally agreed standard concepts, definitions, classifications, accounting rules and tables for producing internationally comparable statistics on the environment and its relationship with the economy. Similar developments would be needed for improving linkage of climate change information with economic and social data. So far NSOs have a more direct involvement in producing air emissions accounts than in the national emissions inventories. The predominantly used methodology for producing the accounts, however, depends on the availability of the inventory data first and only then are the emissions re-distributed to the relevant economic activity.

43. Environmental accounts, including air emission accounts, form a separate statistical area in themselves and are often organisationally developed by NSOs as a separate work area.

4. Impact

44. When it comes to climate change, **Impacts** can be viewed two-ways. First, the impacts can be seen in terms of natural phenomena such as:

- **Water quantity:** water availability; extreme events/floods/ droughts and water discharge
- **Freshwater quality and biodiversity:** lake/river temperatures; lake/river ice cover; water quality; aquatic ecosystems; movements of freshwater species
- **Terrestrial ecosystems and biodiversity**: shifts in plant species northward and uphill, seasonal cycles in plants; behaviour of birds and insects, composition of ecosystems
- **Soil:** carbon sequestration in vegetation and soils; water retention capacity[22]

45. Second, the impacts also entail impacts from these physical changes on human life, i.e. the socio-economic impacts on the well-being of society:

- **Agriculture and forestry:** growing season and yields of key crops; agricultural crops cycle; irrigation; pests and diseases; forest growth, forest fires
- **Human health:** mortality due to heat-waves; hospital admissions (allergies, hay fever); distribution of vector-borne diseases (e.g. malaria) and food-/waterborne diseases; vulnerable groups
- **Economic impacts:** insurance costs; electricity, gas and water consumption; shifts of major flows of tourism; vulnerable regions; losses resulting from weather and climate-related events in industry and transport sectors, changes in income levels and income distribution[23]

---

[21] http://unstats.un.org/unsd/envaccounting/seea.asp

[22] These are the first three categories of the state and impact indicators of climate change as defined by the European Environment Agency

[23] These are the last three main categories of the state and impact indicators of climate change as defined by the European Environment Agency.

46. The role of NSOs here is stronger when it comes to the latter type as the former is traditionally not the prerogative of NSOs but rather once again of environmental agencies. Relevant statistics typically from the statistical system regarding socio-economic impacts can include:

- Water statistics (including access to water, water stress index, etc.)
- Agriculture and food statistics (shifting crop patterns, production patterns, etc.)
- Marine and fisheries statistics (especially relevant for coastal areas, catch and by-catch, etc.)
- Economic development and poverty statistics
- Migration statistics
- Health statistics (e.g. on vector-borne diseases or heat-aggravated diseases, etc.)
- Heating degree days statistics

5. Responses

47. Finally, **Responses** cover measures taken to address the issue of climate change, inasmuch as they can be expressed in quantifiable terms.

48. The measures and responses are often expressed as official targets, such as, for example, the quantified emission limitations or reduction objectives under the Kyoto Protocol to the UNFCCC. In the European Union, official targets are devised under the Europe 2020 Strategy for smart, sustainable and inclusive growth[24] that put in quantifiable terms the objectives to reach by the end of the decade when it comes to climate change and energy. These targets include:

- 20% reduction of greenhouse gas emissions compared with 1990 levels
- 20% share of energy from renewable sources in gross final energy consumption
- 20% increase in energy efficiency

49. Responses should address not only measures to tackle climate change but also economic opportunities generated as a result of climate change like eco-industries, green jobs and green growth. The responses include community actions to mitigate the effects and adapt to climate change. Development of eco-friendly technology and technology exchange are part of responses. Methodological development is being done and sets of indicators are being developed (e.g. under the OECD's Green Growth Initiative[25]).

50. Relevant statistics here can include:

- Environmental protection expenditure and investment statistics
- Taxes and subsidies statistics and statistics covering other economic instruments such as tradeable permits, green certificates, etc.
- Price statistics (e.g. oil prices, energy prices, etc.)
- Renewable energies statistics (these can be an important mitigation measure)
- Energy, material and emissions efficiency indicators
- Recycling and other waste statistics
- Employment statistics
- Government finance statistics and other finance statistics
- Education statistics

[24] http://ec.europa.eu/europe2020/index_en.htm

[25] http://www.oecd.org/document/10/0,3746,en_2649_37465_44076170_1_1_1_37465,00.html

B. Framework for the Development of Environment Statistics (FDES)

51. The Framework for the Development of Environment Statistics (FDES) 'is a multipurpose conceptual and statistical framework that is comprehensive and integrative in nature. It provides an organizing structure to guide the collection and compilation of environment statistics and to bring together data from various subject areas and sources' (see UNSD 2012 Global Consultation version, § 2.2). This section shows the extent to which climate change related statistics can be described with the help of the FDES[26].

52. The primary objective of the FDES framework is to guide the formulation of environment statistics programs by: "(i) delineating the scope of environment statistics and identifying its constituents; (ii) contributing to the assessment of data requirements, sources, availability and gaps; (iii) guiding the development of multipurpose data collection processes and databases; and (iv) assisting in the co-ordination and organization of environment statistics, given the inter-institutional nature of the domain." (see UNSD 2012 Global Consultation version, § 2.3) Detailed information derived from the analysis of the framework is presented in Annex 1.

53. The FDES framework also allows description of climate change through its coverage of climate change related statistics in all of its six main components: (1) environmental conditions and quality, (2) environmental resources and their use, (3) emissions, residuals and waste, (4) extreme events and disasters, (5) human habitat and environmental health, (6) environmental protection, management and engagement.

54. The FDES describes each of these different components as follows:

> "The first component brings together statistics related to the conditions and quality of the environment and their change. The second component groups together statistics related to environmental resources (ecosystem provisioning services, land and subsoil resources) and their use. The third component includes statistics related to the use of regulating services of the environment for the discharge of residuals from production and consumption processes. Statistics related to extreme events and disasters (both natural and anthropogenic) and their impacts are covered by the fourth component. The fifth component brings together statistics related to environmental conditions and impacts within human settlements. The sixth component groups statistics relevant to societal responses and economic measures aimed at protecting the environment and managing environmental resources."
>
> (FDES Gobal consultation version 2012, §2.25)

55. Each of these components is examined in more detail with a focus on the relevance to climate change and statistics related to climate change.

[26] Reference is made to the September 2012 draft version for Global Consultation. The 2012 version is the work in progress update of the existing 1984 FDES. (http://unstats.un.org/unsd/environment/fdes/Global%20Consultation/Draft%20FDES%20Global%20Consultation.pdf).

B.1 Components of the FDES

1. Environmental conditions and quality

56. This first component of the FDES organizes information on the background of environmental conditions and processes describing the foundations of ecosystems. This component would belong to the State component of the DPSIR model and includes the following data relevant to climate change:

- **Physical conditions**: data on atmosphere, climate and weather, hydrological systems, terrestrial, marine coastal area and island characterizations, geographic information
- **Soil and Land cover:** soil characteristics (including degradation) and land cover
- **Biodiversity and ecosystems:** state of and changes in ecosystems, flora, fauna and terrestrial and marine biodiversity, forests, existence of protected areas and species, extent, localization, health, characteristics, main patterns, trends and vulnerabilities of ecosystems
- **Environmental quality:** concentrations of climate process drivers (emissions of these pollutants will be covered under component 3); biological, hydromorphological and physico-chemical parameters of fresh and marine water; and finally soil quality.

57. The main sources for these data are outside the statistical system in most countries. They consist of meteorological and atmospheric monitoring networks and data of the hydrological, geographical and geological institutions. Data on biodiversity and ecosystems are often collected and maintained by national environmental authorities.

2. Environmental resources and their use

58. Environmental resources or assets are the naturally occurring living and non-living components of the earth together comprising the biophysical environment that may provide benefits to humanity (see UNSD 2012 Global Consultation version, § 3.81). This component is linked with the State and Pressure elements of the DPSIR model and includes the following information with relevance to climate change:

- **Non-energy mineral resources:** stocks and changes (due to new discoveries, extraction, catastrophic losses, reappraisals, etc.)
- **Energy resources:** stocks and changes (due to new discoveries, extraction, catastrophic losses, reappraisals, etc.) renewable and non-renewable energy production, energy consumption
- **Land**: land use and land use change by land use category (e.g. agriculture, forestry, built up land and land used for maintenance and restoration of environmental functions with an impact to climate**)**
- **Biological resources:** stocks and changes in timber resources; changes in aquatic resources (different species) and other biological resources (flora and fauna organisms), crops and livestock
- **Water resources:** water stocks, use and returns, including in snow, ice and glaciers.

59. Some of these statistics are available from the statistical systems. The main sources include:

- Population statistics, such as household statistics

- Energy statistics
- Agriculture statistics
- Mining, forestry and land use statistics

3. Emissions, residuals and waste

60. This component contains statistical information on the volume and characteristics of emissions generated by human production and consumption processes. From the three subcomponents of this item in the FDES (for environment statistics), emissions to air are relevant for climate change analysis.

- **Emissions to air:** GHG released to the atmosphere and consumption of ozone depleting substances (ODS).

61. This information is usually produced in the form of emission inventories, available primarily from environmental ministries or environment protection authorities. Statistical systems provide source data for the inventories on activities in different sectors of the economy and they often produce air emission accounts, which allow to distinguish emissions due to production (broken down by economic activity) and those due to consumption. The relevant official statistics include:

- Energy statistics
- Transport statistics
- Industrial production
- Agriculture statistics
- Waste statistics

4. Extreme Events and Disasters

62. This part of the FDES consists of information relevant for climate change with regard to the occurrence of climate related extreme events and disasters and the main impacts of the changing climate on human society's wellbeing and infrastructure.

- **Natural extreme events and disasters:** frequency, location, intensity and impact (people affected, economic loss and ecosystem integrity) of disasters and extreme events deriving from climate change (storms, tornados, droughts, floods, extreme temperatures, mass movement, wildfires, earthquakes, volcano eruptions, tsunamis).

63. Data on natural extreme events are generally supplied by bodies other than statistical institutes such as emergency response services, operators for satellite information and seismic monitoring; the assessment of economic impact is often carried out by ministries of economic development, research institutions or insurance companies. Statistical institutes can also be a source of information for the fifth component of FDES via their supply of data on causes of death.

5. Human Habitat and Environmental Health

64. This part of the FDES contains statistics on the environment in which humans live and work, particularly with regard to living conditions and environmental health, including the following information with relevance to climate change:

- **Human habitat:** data on housing conditions allowing to identify houses in zones vulnerable to climate related natural disasters and extreme events, population exposed to air pollution
- **Environmental health:** data on epidemic changes (vector borne diseases) and incidences, morbidity and mortality related to climate change phenomena.

65. Housing and urban planning authorities, administrative records as well as censuses and surveys are likely to be the source of information on human habitat related aspects. The World Health Organization (WHO) is the global institution assessing the relationship between health and the environment, including climate change. In addition, the statistical systems often provide relevant data for this type of analysis, such as:

- Population and demographic statistics
- Health and mortality statistics

6. Environment protection, management and engagement

66. This component organizes information on the human activities to protect, regulate and manage various environmental issues and concerns, with the aim of improving the environment and maintaining the health of ecosystems.

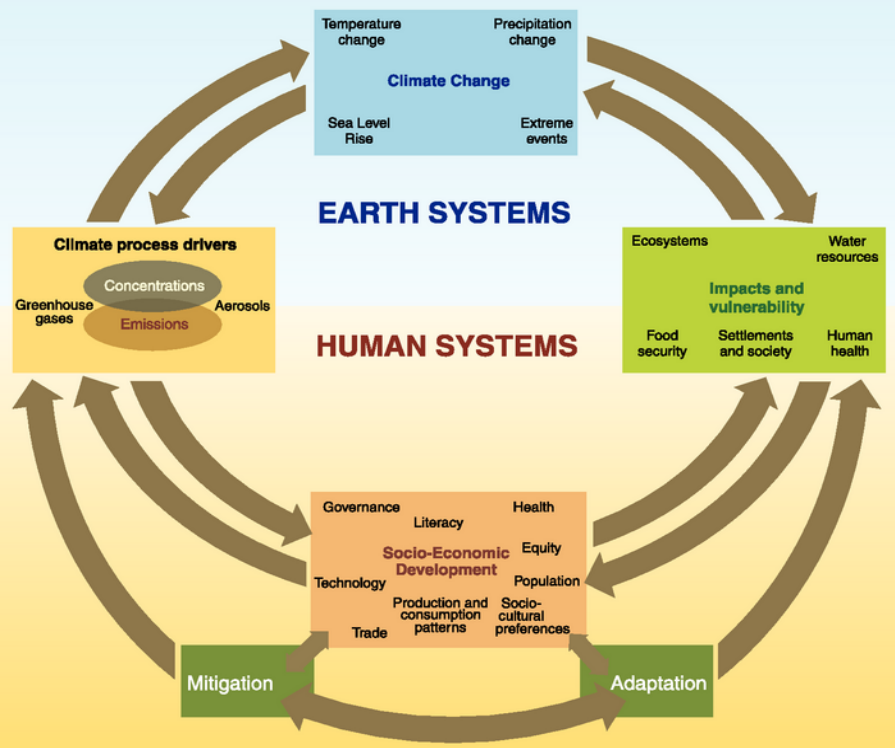
- **Protection and resource management expenditure:** costs of mitigation and adaptation measures
- **Environmental governance and regulation:** climate change related protection measures and climate conventions; regulation (norms, environmental licensing, recycling and energy efficiency programmes, number of quotas and other restrictive production norms, per sector or economic activity), economic instruments (climate change related taxes, subsidies, eco labelling, certification and other market instruments)
- **Extreme Event Preparedness and Disaster Management**: management systems address to cope with climate change related extreme events
- **Environmental Information and Awareness**: climate change related information education and perception

67. Part of the information required for the sixth component of the FDES consists of qualitative data including information on projects, programmes and norms related to protection of the climate system and to the management of climate change related extreme events. Part of it consists of monetary data on costs of mitigation and adaptation measures, taxes, subsidies and also statistics on the perception and attitude about climate change. The latter could possibly be available from official statistics, whereas most of the former is not likely to be produced by the current statistical system.

B.2 Application of FDES to climate change – IPCC schematic framework

68. The Synthesis Report of the IPCC (AR4, 2007) presents a schematic framework of how climate change relates to earth and human systems. It represents “anthropogenic drivers, impacts of and responses to climate change, and their linkages.” Initially, in 2001, only information about the linkages moving in a clockwise direction was available whereas in 2007 there was also information available for evaluating the linkages in the counter-clockwise direction. Since evaluations are made in either a clockwise or counter-clockwise direction, this implies that there is a sequence to these different steps.

Figure 2. Schematic framework representing anthropogenic drivers, impacts and responses to climate change and their linkages



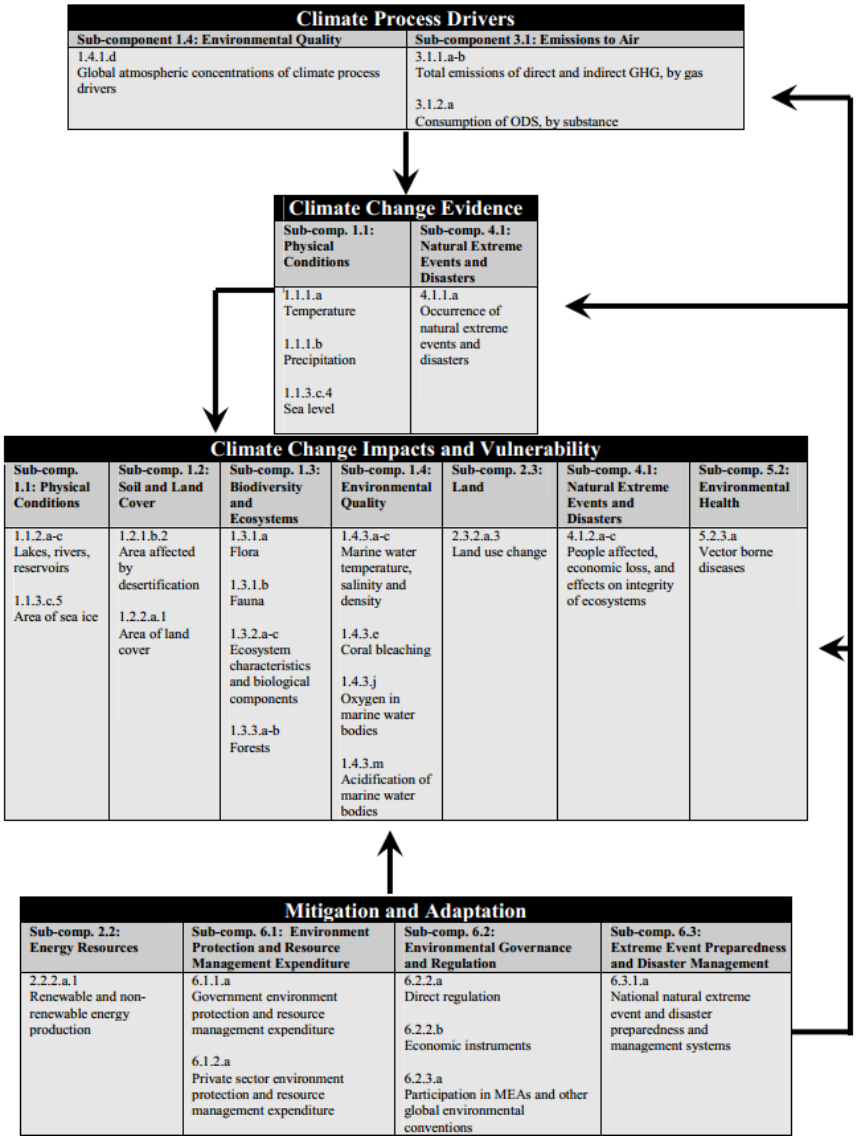
Source: (FDES Global consultation version 2012, §5.3 Climate change)

69. The IPCC schematic framework described above is used in the FDES as the reference point to identify which FDES statistics can be used to inform on the different aspects of climate change (see FDES Global consultation version 2012, §5.3 Climate change). The only important change introduced to the IPCC schematic framework applies to the Socio-Economic Development component, which in the FDES application is only considered in relation to those elements that belong to the realm of environment statistics.

70. The following Figure shows how several statistics included in the FDES can actually be used to describe climate change in the different steps identified by the IPCC[27]

[27] A similar Figure is also available at the level of individual statistics – see (see FDES Global consultation version 2012, Figure 5.9).

Figure 3. Topics in the FDES that relate to climate change – organized by the IPCC framework



Source: (FDES Global consultation version 2012, §5.3 Climate change)

C. Natural capital approach

1. Introduction

71. Another statistical framework allowing defining the scope of climate change statistics can be found in the body of thought around natural capital[28]. In it, environmental quality and

[28] The natural capital framework was given an early and full elaboration by Pearce and Turner (1990) in their popular textbook *Economics of Natural Resources and the Environment*. Herfindahl and Kneese (1974) drew on capital theory in an influential work on environmental economics nearly two decades earlier. The framework is today the subject of a large body of thought, much of which is found in the ecological economics literature (see Krishnan *et al.* [1995]). Daily (1997) offers an overview of natural capital from the perspective of ecology. Costanza *et al*. (1997) published a widely quoted

human well-being are seen to be linked through the flows of ecological goods and services (EGS).

72. In this section, we first introduce natural assets and then identify the EGS produced by these assets that are potentially affected by climate change. Then the statistical variables that are relevant to understanding the evolution over time of the quality of these natural assets are identified.

73. Detailed examples for the atmosphere and marine ecosystems are used to illustrate the use of the framework for this purpose. Space and time have prevented identification of the complete range of statistical variables the framework would define for climate change statistics but this could be done as a next step.

2. Natural assets relevant for climate change

74. Clearly, if ecological goods and services are what bind the environment and human well-being, then maintaining the capacity of the environment to produce these flows is of central importance. Declines in this capacity will lead to declines in the EGS flows and consequent declines in well-being, other things being equal. According to the natural capital framework, the capacity of the environment to yield EGS flows arises from the numerous separately identifiable, structured groupings of living and non-living elements that constitute the environment. These "structured groupings" function as units to deliver EGS flows and are said to have the characteristics of capital assets, much like the assets we are accustomed to thinking of in the economic context. They are commonly referred to as natural assets and the framework identifies three categories of them:

- ecosystems
- land[29]
- sub-soil resources

(a) Ecosystems

75. The most important and complex asset category is that of ecosystems. Ecosystems are structured groupings of living organisms and non-living matter that, given an on-going supply of solar energy, remain intact over long periods of time and yield continual flows of ecological goods and services. Ecosystems can be divided into two major groups: terrestrial and aquatic. A third system, similar to but distinct from terrestrial and aquatic ecosystems, must be mentioned: the atmosphere. Though not the permanent home of any species of plant or animal nor as complex in composition as either terrestrial or aquatic ecosystems, the atmosphere nonetheless provides a variety of essential ecological goods and services that must be recognized within the framework. Thus, when the term "ecosystems" is used in this paper, it should be understood to include the atmosphere.

76. Ecosystems are the source of many well-being enhancing flows. Food and other biomass (e.g., timber) provide important direct-use benefits, as does energy in the form of wind, tides and solar radiation. Recreational opportunities and aesthetic enjoyment of nature

---

study of the value of the world's natural capital in the journal *Nature*. Olewiler (2007) offers a more up-to-date commentary that reflects a Canadian perspective. Critical comments on the concept can be found in Victor (1991, 2007) and Hinterberger *et al*. (1997).

[29] Land in this context should be understood to be the "space" in which human and ecological activities take place. Land in the physical sense of soil, rock and vegetation is covered under the heading of ecosystem assets.

are other important categories of direct-use benefits. Ecosystems are also the source of many indirect-use benefits. Clean water is an obvious example. Equally important are the flood control function of forests and wetlands and the waste assimilation function of rivers. Finally, as the home to the world's plants and animals, ecosystems provide important non-use benefits to those who subscribe to the view that other species' mere existence is of value.

77. The ecological goods and services provided by ecosystems are fully renewable under appropriate conditions. If their use within a given period is less than or equal to their rate of renewal, there need not be any depletion or degradation as a result of human use. Degradation does not necessarily reduce the absolute size of ecosystems, but makes them less productive. Degradation can be the result of resource harvesting activities (e.g., changes to the age- and species-distribution of forests; unintended mortality of non-target fish species by fishing boats); of pollution impacts (e.g., acid rain); and of disturbance from urbanisation, agriculture, recreation and other land use changes. This degradation can negatively affect use benefits (e.g., lower quality material supplies, reduced aesthetic value) and non-use benefits (reduced options for the future).

(b) Land

78. In the case of land, it is the provision of space that is of interest (the other functions that are connected with land – such as the provision of timber – are captured in the ecosystem category). Space benefits humans in terms of the direct-use benefits associated with the occupation of space for human purposes (dwellings, transportation infrastructure, agriculture, recreation).

79. Planetary land area overall is, of course, not subject to quantitative depletion in any significant way. However, land areas of specific types can be augmented or diminished as a result of climate change and changes in the way in which land is used. For example, increasing use of land for urban purposes necessarily means reduced use of land for other purposes (ecosystems, agriculture, recreation, etc.).

(c) Sub-soil resources

80. Sub-soil resources provide ecological goods such as minerals, fossil fuels and water. Sub-soil resources represent stocks from which ecological goods are withdrawn for use in human activity. These materials provide direct-use benefits as inputs into industrial processes and home heating. Many of the resources humans require are found underground in deposits of various minerals, liquids and gases. These deposits are fundamentally different from ecosystems in that they are subject to permanent depletion as a result of use. Ecosystems, in contrast, have the ability to regenerate themselves over time if their use is kept within sustainable limits.

3. EGS flows that may be impacted by climate change

81. EGS are material goods and services that flow from the environment and are directly consumed by humans, yielding them well-being (Boyd and Banzhaf, 2006). EGS flows are consumed by humans in a variety of contexts, both public and private, collective and individual, market and non-market. They contribute to well-being in tangible and direct ways (as in the flows of raw materials we extract to build our homes and fuel our lives) and in

more intangible and indirect ways (as in the psychic benefit people derive from knowledge of the environment's continued existence).

82. As the term implies, climate change is predicted to alter the climate as we know it today by changing long-term patterns of precipitation, temperature and wind. The **relatively stable and predictable climate** that has prevailed for much of modern human history is one of the most important ecological services we enjoy and the predicted disruption to this service is perhaps the most serious consequence of climate change.

83. The predicted disruption to the climate will have impacts on other important ecological services.

- The **provision of space** for human activities may be impacted by changing patterns of rainfall and temperature and by flooding of coastal areas. Currently viable agricultural land may become less productive if rainfall decreases and/or temperatures increase (the opposite might also be true – marginal land may become more productive). Coastal areas that provide living space for millions of people and much of the world's economic activity may become less habitable.
- The **flood protection** service offered by forests and wetlands may be disrupted by changing rainfall patterns and, especially, the greater frequency of severe storms.
- Protection from the spread of **vector-borne diseases** may be hindered as changes to ecosystems allow the spread of insects and other disease-carrying organisms to areas where they did not previously exist
- The **transportation service** offered by rivers, lakes and oceans may be disrupted in places where water levels fall below historical averages as a result of decreased rainfall or where increased storms add additional risk to the use of the services. Increased rainfall leading to increased runoff and, ultimately, to increased siltation of river beds and harbours, with consequences for navigability.
- The **recreational opportunities** offered by the environment are likely to be reduced in a variety of ways. Forests, for example, may become less attractive as destinations if trees are unable to adapt quickly enough to changing conditions and die as a result (this is already happening in the lodge pole pine forests of the Rocky Mountains that have been impacted by the spread of mountain pine beetle as a result of warmer mountain winters). Similarly, the quality of seaside recreational experiences will decline if ocean levels rise sufficiently to flood beaches and if coral reefs die in large numbers.
- Those who appreciate the environment for its **aesthetic, cultural or existence value** may find fewer reasons to appreciate the environment for what it offers in these regards as a result of climate change.

84. In addition to the loss of ecological services, climate change may result in reduced flows of ecological goods.

- **Food production** may be reduced if rainfall and temperature patterns change such that agricultural land becomes less productive (the opposite may occur as well, if previously unproductive land becomes productive because of warmer temperatures or increased rainfall).
- **Flows of marine resources** (seafood, etc.) may be reduced if ocean temperatures and currents change.
- Timber and other **forest product flows** may be reduced if forest ecosystems are disrupted.

- **Surface and groundwater flows** may be reduced in areas where rainfall decreases. Increased temperatures may lead to warmer surface water and increased growth of organic matter, reducing water quality even where water quantity is not affected.

4. Natural assets that provide the EGS affected by climate change

85. Having identified the list of EGS that are potentially affected by climate change, the next step is to identify the natural assets that are the source of those EGS. Then the statistical variables that are relevant to understanding the evolution over time of the quality of these natural assets can be identified. Before taking these steps though, first the notion of what constitutes "relevant statistical variables" in the natural capital framework must first be discussed.

86. The natural capital framework identifies two key primary categories of statistical variables: those related to the **capacity of natural assets to deliver EGS** of the asset and those related to the **flows between the human sphere and natural assets.**

87. The capacity of natural assets to deliver EGS is a function of the physical size of assets and of their qualitative characteristics. For example, if the asset in question is a forest, then both the areal extent of the forest and the qualitative makeup of the forest (species type, age of trees, degree of fragmentation, etc.) are relevant to measuring the asset.

88. The flows between natural assets between the human sphere fall into four categories. Most importantly from a well-being perspective, there are the flows of EGS themselves from natural assets to the human sphere. Also highly relevant are the flows of waste materials and energy that leave the human sphere and return to the environment. The relevance of waste flows stems from their potential to impact the capacity of natural assets to continue providing EGS over time.

89. Next are the flows associated with human efforts to reduce the scale of waste material and energy flows that are released to the environment. These are often termed environmental protection expenditures and consistent of investments and operating costs associated with efforts to reduce waste flows or to rectify the damage done to natural assets as a result of earlier waste emissions.

90. Finally, there are flows associated with human efforts to adapt to the loss or reduction of EGS. One of the important conceptual underpinnings of the natural capital framework is the notion that the goods and services produced by one type of asset can, in some cases and with some important exceptions[30], be substituted by other assets with no loss of well-being. For example, the recreational service offered by a natural asset can be substituted by other recreational activities that do not rely directly on the environment; going to a movie, perhaps. To the extent that EGS flows are reduced as a result of climate change, humans will try to adapt where possible by substituting the services of other assets for those of the natural assets.

[30] Substitution of natural assets by other types of assets is possible only in the case of "non-critical" natural assets. Some natural assets, such as the ozone layer, produce services for which no known substitute exists and which are essential to well-being. Well-being losses associated with the loss of such "critical" assets can be catastrophic.

91. To summarize, then, the natural capital framework suggests the following range of statistical variables:

- Quantitative and qualitative variables related to the capacity of natural assets to deliver EGS
- Variables measuring flows of EGS from natural assets to the human sphere
- Variables measuring flows of waste materials and energy from the human sphere to natural assets
- Variables measuring flows related to environmental protection activities
- Variables measuring flows related to substitution of other asset services for natural asset services.

92. We can now return to the question of which natural assets are essential to providing the EGS that will potentially be impacted by climate change.

- The most important impact of climate change will be to reduce the service flow associated with a relatively **stable and predictable climate**. The natural assets primarily associated with this service are the *atmosphere, the oceans and the forests*.
- In term of the **provision of space** for human activities, the relevant natural asset is land.
- **Flood protection** services are offered by *forests and wetlands*.
- **Protection from the spread of vector-borne diseases** is a general ecological function supported by the prevailing climate regime under which the world's ecosystems have evolved. Changes to the overall climate regime are what are threatening this service and so it makes sense to attribute this service to the sources of climate control: the *atmosphere, oceans and forests.*
- ***Transportation*** *services are offered by the oceans, rivers, lakes, land and the atmosphere*.
- **Recreational, aesthetic, cultural and existence value services** are offered by ecosystems of every type. Some ecosystems are more at threat from climate change than others, however, with *coastal marine ecosystems, freshwater aquatic ecosystems and forest ecosystems* near the top of the list.
- **Food production** is largely the output of *agricultural ecosystems.*
- **Marine resources** are obviously the produce of *marine ecosystems*.
- **Timber and other forest product flows** are the product of *forest ecosystems*.
- **Surface and groundwater flows** are the product of *freshwater ecosystems, including groundwater systems*.

93. To summarize then, the scope of climate change statistics as defined by the natural capital framework includes statistics related to: the atmosphere, marine ecosystems, forest ecosystems, freshwater ecosystems (including groundwater), agricultural ecosystems and land (in the role as the provider of space).

5. Identifying relevant statistical variables

94. Having identified the range of EGS that are likely to be impacted by climate change and the range of natural assets that are associated with delivering these services, the final step is to identify the statistical variables that are relevant to measuring these assets. Doing so comprehensively is obviously a large task and beyond the scope of this paper. For the purposes of illustration, the most important variables related to the atmosphere and marine

ecosystems have been presented in the tables in the Annex 3. A similar exercise could be undertaken for the remaining natural assets to identify the full scope of climate change statistics.

D. Impacts, Mitigation and Adaptation

95. Another simple way for categorising climate change related statistics is a division along the main blocks along which climate change discussions typically are structured – impacts, mitigation and adaptation. Such a framework is much simpler than any of the ones presented above. Its advantage is the direct link to the three major categories in climate policy. Its disadvantages concern the lack of much detail (it allows for only three categories of statistics) and the much less comprehensive description of climate change as a complex phenomenon.

96. Impacts here are considered to entail broadly the **consequences** of climate change – i.e. the impacts from the changing climate in terms of natural impacts (e.g. heat waves, rising oceans, glaciers retreats, droughts, etc.) and the socio-economic impacts (e.g. reduced crop yields, changes in crop patters, changes in disease patters, etc.).

97. Adaptation covers the actual **actions and measures** taken by governments to adapt to the inevitable consequences of climate change as far as they are statistically quantifiable (measures typically listed in so called National Adaptation Strategies may not always be expressed in quantifiable terms). Furthermore, educational work is important for effective adaptation.

98. Mitigation can be considered in broad terms to encompass efforts to control the **causes** of climate change. These are, more specifically,the greenhouse gas emissions and all the underlying activities behind them (e.g. the activities in the different inventory sectors such as energy, industrial processes, agriculture, waste, etc.) as well as the broader socio-economic phenomena such as population growth, urbanisation, industrialisation, etc. that have an impact on increased emissions. Mitigation also includes the measures taken to address these causes, i.e. any emission reduction action which can be statistically quantified (e.g. energy taxes, transport taxes, data on the carbon market and trade, renewable energy resources, etc.).

99. This impact-mitigation-adaptation framework has certain links to the previously discussed DPSIR model – in particular to the Responses, Impacts and Driving forces/Pressures components of the model. There are inherent challenges to the mitigation-adaptation framework, mostly related to causality, especially when it comes to climate impacts and links to wider socio-economic consequences. An additional challenge comes from the high level of scientific competences which are needed for analysis. For example, the attribution of weather events to climate change and not to natural climate variability is in itself a difficult task that falls into the sphere of competence of climate science, not statistics. Furthermore, attributing specific changes in socio-economic phenomena (e.g. crop yields in agriculture) to climate change can also be problematic as they may be due to other reasons (e.g. changes in food preferences, discontinuation of specific subsidies, etc.). Discerning causality goes beyond the task of the statistician and should rather be the job of specialised analyses or targeted studies.

III. FINDINGS

100. Each framework, presented above, provides a different viewpoint to organizing climate change related information. Many of the necessary statistics are already available in official statistical systems, but may need to be developed further for the purposes of climate analysis. The main question is not which tool is the best organizational framework for measurement of climate, but how all of them help to define the scope of climate change related statistics.

101. The Classification of Statistical Activities (CSA Rev. 1, 2009) can be used as a tool for assessing the coverage of statistical issues in these frameworks. The classification provides a comprehensive list of the topics covered by the statistical system. The first level of the CSA classification consists of five domains and their subgroups. For analyzing the relevance of existing data in the statistical system, we review the three substance oriented domains: social; economic; and environment and multi-domain statistics. The classification allows synthesizing the different views on climate change related statistics of the frameworks discussed above.

A. Coverage of statistical topics by the frameworks

102. Table 1 below summarizes the statistical areas covered by each framework according to the Classification of Statistical Activities. A cross indicates good coverage of the climate relevant issues in that topic, whereas some statistical topics may be only partly covered. The latter means, for example, that the framework only covers part of the issues relevant for climate change within that statistical area. In addition, based on this analysis, the statistical topics are grouped into *closely related*, *related* and *indirectly related* with regard to climate change. A more detailed summary of issues covered by the different frameworks including descriptions of the covered content is presented in Annex 4.

103. Statistical areas that either influence climate change or are directly influenced by it are considered *closely related*. Statistics that fall into the *related* category may be influenced by climate change or vice versa, but the relation is not so direct. These economic, social and environment statistics are also needed to put issues related to climate change in context. *Indirectly* related areas are not included in the scope of climate change related statistics, although climate change may have implications on them and vice versa.

Table 1. Coverage of statistical topics by the frameworks and their relevance to climate change

Statistical area	**Frameworks**					**Relevance**
Demographic and social statistics	**DPSIR**	**FDES**	**IPCC**	**Capital**	**IMA**	**Related**
1.1 Population and migration	x	x	x		x	related
1.2 Labour	partly					indirectly
1.3 Education	x	x	x		x	indirectly
1.4 Health	x	x	x	partly	x	**closely**
1.5 Income and consumption	x	partly	partly		x	related
1.6 Social protection	partly				x	indirectly
1.7 Human settlements and housing	x	x	x	x	x	**closely**
1.8 Justice and crime						indirectly
1.9 Culture			x	partly		indirectly
1.10 Political and other community activities	x	partly	x		x	indirectly
1.11 Time use	x		x	partly	x	**closely**

Statistical area	Frameworks					Relevance
Economic statistics	**DPSIR**	**FDES**	**IPCC**	**Capital**	**IMA**	**Related**
2.1 Macroeconomic statistics	x				x	indirectly
2.2 Economic accounts	x			x	x	indirectly
2.3 Business statistics	partly	partly	partly	x	partly	indirectly
2.4 Sectoral statistics						
2.4.1 Agriculture, forestry, fisheries	x	partly	partly	x	x	**closely**
2.4.2 Energy	x	partly	partly	x	x	**closely**
2.4.3 Mining, manufacturing, construction	x	partly	partly	x	x	**closely**
2.4.4 Transport	x	partly	partly	x	x	**closely**
2.4.5 Tourism	x	x		x	x	**closely**
2.4.6 Banking, insurance, financial statistics	partly	partly			partly	indirectly
2.5 Government finance, fiscal, public sector	partly	partly	partly		partly	indirectly
2.6 International trade, balance of payments	x		x	x	partly	indirectly
2.7 Prices	x				x	indirectly
2.8 Labour cost						indirectly
2.9 Science, technology and innovation	x		x		x	related

Statistical area	Frameworks					Relevance
Environment and multi-domain statistics	**DPSIR**	**FDES**	**IPCC**	**Capital**	**IMA**	**Related**
3.1 Environment	x	x	x	x	x	**closely**
3.2 Regional and small area statistics	x	x	x	x	x	**closely**
3.3 Multi-domain statistics and indicators						
3.3.1 Living conditions, poverty and social issues	x	x	x	partly	x	related
3.3.2 Gender and special population groups	x	partly	x	partly	x	related
3.3.3 Information society						indirectly
3.3.4 Globalisation	x		x	partly	partly	related
3.3.5 Indicators of the Millennium Development Goals	partly	partly	partly	partly	partly	related
3.3.6 Sustainable development	x	x	x	x	x	**closely**
3.3.7 Entrepreneurship	partly	partly	partly	partly	partly	related

104. Of course, the identification of any given statistical areas as being related to climate change or not is strongly dependent on the particular issue in question which may be influenced by climate change (e.g. migration) to a varying degree. Nonetheless, the above table provides a useful means to assess the extent to which the various frameworks discussed might be helpful in defining the scope of climate change.

105. According to the assessment in Table 1, the DPSIR and IMA frameworks could be considered to be the most relevant to climate change, as they cover more of the areas considered related to climate change than the others. There is good reason why this is so. Both DPSIR and IMA are highly flexible and comprehensive frameworks that can be used to organize essentially any variable that might be related to climate change. Put another way, it is hard to imagine any climate change variable that could not be defined as either a driving force, a pressure, a state, an impact or a response (or, in the case of IMA, as an impact, a mitigation effort or an adaptation effect). It is not surprising then that these frameworks appear to cover so much of what is relevant to climate change. There are, however, challenges with their use.

106. The principle challenge is deciding *what variables* should be measured and placed into the framework. While both DPSIR and IMA are useful for organizing variables into intuitively appealing categories, the frameworks say little about what variables should be collected in the first place. For this, appeal to some other source is required. In the case of climate change, both climate science and climate policy provide guides as to what should be

collected. This combination of climate science/policy and either the DPSIR or IMA framework could be used to define the scope of climate change statistics in what might be called a “hybrid framework”. Climate change statistics so defined could be robust and complete.

107. There are risks in using such hybrid frameworks in general however. On the one hand, they risk being overly detailed if informed too much by science. Science is by its nature reductionist and ever-evolving, meaning that it tends to define phenomena in terms of large and increasing sets of variables. On the other hand, a hybrid framework informed largely by policy may risk being narrowly focused in areas where policy exist, leaving other potentially important areas unmeasured. Policy formulation itself is greatly reliant upon sufficient information. Thus, while policy needs could point to what indicators may be needed, oftentimes when the indicators are *apriori* not available, it might be difficult to formulate policies at all. We end up in a vicious cycle where the lack of data translates into lack of policy and the lack of policy is interpreted as lack of interest in the data, which in turn reinforces the lack of data.

108. Another challenge, particularly of the DPSIR framework, is deciding which variables go into which component of the framework. For example, it is not always obvious what the “state” component includes. Some variables of the state of climate change might also be legitimately considered impacts; for example, is the condition of a forest (say a pest infestation caused by warming winters) a state or an impact variable?

109. Another challenge with the frameworks is the assumption of causality. Has the “driver” contributed to climate change and is the “impact” really a result of changing climate? Analyzing causal relations and factors that contribute to change is typically done outside of the statistical system. In this context, the DPSIR model should be treated as an intuitive tool for organizing the climate change related information, not as a model for analyzing causality between its parts. While DPSIR seems to be a comprehensive tool, the challenge is to point to the most relevant information among all the possible statistics that are covered.

110. Turning to the FDES, it is also covers a fair number of areas considered relevant to climate change. It does not emphasize the causes of climate change or consider all socio-economic impacts of climate change. FDES includes some of the implications to human health and well-being from the point of view of environment. These statistics should, however, be complemented with additional social and economic statistics.

111. Due to its focus on the state and use of environmental resources, FDES does not consider economic possibilities or limitations caused by climate change nor the impact of globalization and trade to climate. With regard to the economy, it focuses more on raw material use, emissions, waste and consequences of natural disasters, than on the link between the level of economic activity and climate change. Changes in human settlements and time use are also not directly included. FDES can be very helpful in structuring information available from environmental statistics because of its detailed mapping of statistical topics.

112. Whereas the IPCC schematic framework is developed for analyzing climate issues and is highly comprehensive for that purpose, further consideration of the practical issues of data availability could support the use of this framework. The framework offers a general

baseline for the IPCC assessment reports to help assess current knowledge in climate issues. Currently, it is mainly used by IPCC and the related scientific network, which is why application guidelines and explanations of what data to be included are not very detailed.

113. The natural capital approach offers a comprehensive and rigorous means of defining the scope of climate change statistics by focusing on the links between environmental quality and human well-being. It is based on a robust scientific literature and is part of a broader effort to expand the traditional notion of capital into other domains[31]. The approach constrains the scope of climate change statistics to those variables that are directly relevant to measuring natural assets and the flows between these assets and the human sphere. It also provides a justification for measuring human activities related to mitigation of climate and adaptation to its effects.

114. The scope the natural capital approach suggests is narrower than that of other frameworks. For example, it limits measures of human health issues to just those that are attributable to the loss of EGS flows due to climate change. Economic measures are limited to activities that are undertaken either to mitigate the causes of climate change or to adapt to the associated loss of EGS flows. It does not extend the scope of climate change statistics to the broad social measures such as income distribution and poverty, but does include social variables to the extent that they are influenced by loss of EGS flows. One can argue that the narrower scope implied by the natural capital framework is an advantage. The inclusion of many indirectly related statistics within the scope of climate change statistics, as suggested by the DPSIR and IMA frameworks, makes the scope very large, covering nearly every kind of information collected by government.

IV. CONCLUSION

115. Changes in climate pose measurement challenges, which spurred the development of a wide set of climate change statistics as well as climate change related statistics. This paper helps assessing the best use of the existing, extensive and established monitoring, surveying and reporting systems of national statistical offices for analysing climate change related issues. For that usefulness to be realized, the scope of climate change statistics must first be defined.

116. Several frameworks have been presented here to help define the scope of climate change statistics. They share a number of features in common. All address issues that cross the full range of national statistics, economic, social and environmental. They all suggest the need to measure the factors that are the cause of climate change, the impacts of climate on human and natural systems and the efforts of humans to avoid climate change and live with whatever of its consequences are not unavoidable.

117. The frameworks differ in important ways. Some are effective organizational tools, allowing statistics to be grouped into intuitively appealing categories for reporting and analysis. Others are more conceptually founded, allowing the inclusion of any given statistical variable within the scope of climate change to be justified on clear and defensible grounds.

[31] See the literature on human and social capital.

118. At the moment, no one framework could be argued to be sufficient on its own. Drawing the best elements from each does, however, allow an initial definition of the scope of climate change statistics to be put forth for discussion:

> *The scope of "climate change related statistics" includes environmental, social and economic data that measure the human causes of climate change, the impacts of climate change on human and natural systems, the efforts of humans to avoid its consequences as well as their efforts to adapt to those consequences that are unavoidable. When focused on the point of view of official statistics, the scope excludes statistics that measure state of climate and climate change directly (such as precipitation data) that may not be collected within the boundaries of the national statistical systems.*

119. This very general scope statement is, of course, only the starting point for defining the specific statistics that are needed to measure climate change. For that, there appears to be two possible approaches.

120. One approach is to allow existing climate science and climate policy to define the specific variables. Given the relatively mature state of each of these, the possibility of defining an exhaustive and relevant suite of statistics *via* this approach is good. The risks, as noted earlier, are that the suite is excessively large (if based too much in the science of climate change) or missing important elements (if focussed too much on existing policy).

121. The other approach is to use a conceptually rooted framework, such as natural capital, to define the specific variables. This approach has the advantage of providing a clear and explicit basis for the inclusion of any given variable. Just as important, it can provide a clear and explicit basis for *excluding* any given variable. The possibility for the scope of climate change statistics to be very large is real. The science is complex and the reach of climate change in terms of its impacts on both nature and society is potentially vast. It is easy to see how the scope of climate change related statistics, if left unconstrained, could become effectively coincident with the scope of all national statistics. This would not be a useful outcome, as the exercise here is intended to help statistical offices understand where their relative strengths and weaknesses are *vis à vis* climate change statistics. For this to happen, the scope of climate change statistics must, obviously, be narrower than the scope of all statistics.

122. At this point, further discussion will be required to determine what to include in the scope of climate change related statistics. For now, achieving agreement on the general scope statement is a necessary first step.

V. REFERENCES

Boyd, J. and S. Banzhaf, 2006, What Are Ecosystem Services? The Need for Standardized Environmental Accounting Units, Discussion Paper RFF DP 06-02, Resources for the Future, Washington.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton and M. van den Belt, 1997, "The Value of the World's Ecosystem Services and Natural Capital", in Nature, vol. 387, pp. 253–260 (May 15).

Daily, G. C., Editor, 1997, Nature's Services: Societal Dependence on Natural Ecosystems: Island Press, Washington, D.C.

Krishnan, R., J. M. Harris, and N. R. Goodwin, Editors, 1995, A Survey of Ecological Economics, Island Press, Washington, D.C.

Herfindahl O. and A. V. Kneese, 1974, Economic Theory of Natural Resources, Charles E. Merrill Publishing Company, Columbus, Ohio.

Hinterberger, F., F. Luks, and F. Bleek-Schmidt, 1997, "Material Flows versus 'Natural Capital' – What Makes an Economy Sustainable?", in Ecological Economics, 23, pp. 1-14.

Olewiler, Nancy, 2007, "Natural Capital: Securing Natural Capital and Ecological Goods and Services for Canada" in Leonard, J., C. Ragan and F. St-Hilaire, Editors, A Canadian Priorities Agenda: Policy Choices to Improve Economic and Social Well-Being, Institute for Research on Public Policy, Ottawa.

Pearce, David W. and Turner, R. K., 1990, Economics of Natural Resources and the Environment, Harvestor Wheatsheaf, London.

Victor, P., 1972, Pollution: Economy and Environment, University of Toronto Press, Toronto.

Victor, P., 1991, "Indicators of Sustainable Development: Some Lessons from Capital Theory," in Economic, Ecological and Decision Theories: Indicators of Ecologically Sustainable Development, Canadian Environmental Advisory Council, Minister of Supply and Services, Ottawa.

Victor, P., 2007, "Nature as Capital: Concerns and Considerations," in Leonard, J., C. Ragan and F. St-Hilaire, Editors, A Canadian Priorities Agenda: Policy Choices to Improve Economic and Social Well-Being, Institute for Research on Public Policy, Ottawa.

Annexes

Annex 1. List of climate change statistics included in the FDES (Global consultation 2012 draft version) framework
Annex 2. GCOS Essential Climate Variables
Annex 3. Tables related to the natural capital approach
Annex 4. Summary of issues covered by the different frameworks

Annex 1. List of climate change statistics included in the FDES (Global Consultation version of Sept 2012 draft version) framework

This annex analyses the usefulness of applying the FDES approach to climate change related statistics, specifically:

- the first column of the Table lists all climate change related statistics covered by the FDES
- the second column shows the corresponding FDES codes, with reference to the FDES three main layers:
    - the first layer (1-digit code), includes five main groups of statistical components describing: (1) environmental conditions and quality, (2) environmental resources and their use, (3) emissions, residuals and waste, (4) extreme events and disasters, (5) human habitat and environmental health, (6) environmental protection, management and engagement.
    - the second (2-digit) and the third (3-digit) layers, named respectively sub-components and statistical topics, further categorize the different statistical aspects included in each component of the first layer[32].
- column three provides a brief description of the specific climate change related statistics identified in the first column
- finally, in the fourth column the degree of relevance for climate change analysis of each climate change related statistics is assessed on the basis of the Classification of Statistical Activities (CSA) partition into *closely related*, *related* or *of indirectly related* provided in the Istat's paper 'review of existing statistics' (presented at the April 2012 Geneva conference).
-

In one row, the character of the text is grey: it means that the information is reported for the sake of completeness but, for reasons explained in the Table itself, is likely not to be very relevant for climate change analysis.

[32] The FDES Core Set of Environment Statistics (i.e. the proposed minimum set of environmental information, see FDES, chapter 4) is used in many cases for column 1 to list examples of individual statistics covered by different topics.

Climate change related statistics included in the FDES	FDES reference code	Reasons why these statistics are relevant to climate change and data sources (text adapted from FDES or quote from FDES when in italic)	Degree of relevance for climate change analysis (CSA code and activity, see chapter 4 for the CSA)
- Environmental data sets on climate and the atmosphere (long time series on temperature, precipitation) - Surface area and location of lakes, rivers and reservoirs - Sea level and area of sea ice	1. Environmental conditions and quality – 1.1: Physical Conditions - Topic 1.1.1: Atmosphere, climate and weather (1.1.1.a – 1.1.1.b) Topic 1.1.2: Hydrographic characteristics (1.1.2.a – c) Topic 1.1.3:: Geological and geographic information (1.1.3.c.4 – 5)	Data on physical conditions provide the reference data to measure the change in climatic conditions and other climate related physical features; Principal data sources: • atmospheric, weather and climate authorities using a network of monitoring stations scattered throughout the country; statistical treatment is needed to provide information at the national and sub-national levels; • national hydrological institutions and water authorities • national geographical and geological institutions and authorities	closely related (3.1 environment)
- Soil characterization and degradation - Land cover	1. Environmental conditions and quality – 1.2: Soil and Land cover - Topic 1.2.1:Soil characteristics (1.2.1.a – 1.2.1.b) Topic 1.2.2: Land cover (1.2.2.a.1)	Among the important functions of soil, carbon sequestration, is particularly relevant for climate change Data on soil typologies covering the national territory are primarily produced by scientific research institutions as well as by geological, geographical and, sometimes, agricultural authorities. The main source of land cover information is remote sensing data, usually satellite images or aerial photographs, that are interpreted and transformed into geospatial data and statistics, mapping the different categories that cover the land.	closely related (3.1 environment)

Climate change related statistics included in the FDES	FDES reference code	Reasons why these statistics are relevant to climate change and data sources (text adapted from FDES or quote from FDES when in italic)	Degree of relevance for climate change analysis (CSA code and activity, see chapter 4 for the CSA)
- Flora and fauna (species population, extinct species) - Ecosystem characteristics: general, physical, chemical, biological - Forests	1. Environmental conditions and quality 1.3 Biodiversity and ecosystem Topic 1.3.1: Biodiversity (1.3.1.a-b) 1. Environmental conditions and quality 1.2 Biodiversity and ecosystem Topic 1.3.2. Ecosystems (1.3.2.a-c) 1.3 Biodiversity and ecosystem Topic 1.3.3: Forests	Human activities affect flora, fauna and ecosystems both directly and indirectly, resulting in changes that are reflected by statistics on the status of flora and fauna species and ecosystems. Data on species populations are usually available on species of specific significance. Data are often obtained from expert and ad-hoc scientific studies and assessments, as well as research. While information on ecosystems is well developed and increasingly available from ecosystem science and different disciplines, using them for statistics describing ecosystems are rather scarce and non-systematic. Developing meaningful statistics on ecosystems needs the collaboration of scientists and statisticians. Data on forest cover and its changes, as well as on biophysical characteristics may be obtained from remote sensing, forest inventories and forestry statistics from forest management agencies (e.g., agricultural and forestry authorities).	closely related (3.1 environment)
- Concentrations of of climate process drivers, - Marine water temperature, salinity, density - Coral bleaching - Oxygen in marine water bodies - Acidification of marine water bodies	1. Environmental conditions and quality 1.4: Environmental Quality 1.4.1: Air quality (1.4.1.d) 1.4.3 Marine water quality (1.4.3.a-c, e, j, m)	Climate change drivers under this topic refer to those relevant at a global scale, and include global concentrations of CO2 (carbon dioxide) and of CH4 (methane), which are two main greenhouse gases Marine water quality statistics are an indicator of impact of climate change. Data sources are typically either national or international monitoring stations, associated with scientific research. The data from these monitoring stations require further processing to produce environment statistics on the water quality of specific locations.	closely related (3.1 environment)
- Renewable and non-renewable energy production - Total consumption of energy (also by economic activities) - Electric energy	2. Environmental resources and their use 2.2 Energy resources Topic 2.2.2: Production and use of energy	Energy production, distribution and use are made with different efficiency rates and these processes cause distinct environmental impacts in terms of GHG emissions; The main sources of statistics on renewable and non-renewable energy resources are energy statistics and energy balances that are available from national energy authorities or NSOs in most countries.	Closely related (3.1 environment and 2.4.2 energy)

Climate change related statistics included in the FDES	FDES reference code	Reasons why these statistics are relevant to climate change and data sources (text adapted from FDES or quote from FDES when in italic)	Degree of relevance for climate change analysis (CSA code and activity, see chapter 4 for the CSA)
- Land use area by category (e.g. agriculture, forestry, built up land and land used for maintenance and restoration of environmental functions, …) - Land use change	2. Environmental resources and their use Sub-component 2.3: Land Topic 2.3.1: Land use area Topic 2.3.2: Land use change	Understanding the use of land in a territory, policy makers are better able to determine impacts on ecosystems caused by e.g. climate change. Statistics on land use are usually obtained by the combination of field surveys and remote sensing, mostly satellite images. Land use data may also be obtained from administrative land registers where available.	Closely related (2.4.1 Agriculture, forestry, fisheries) other
- Timber resources and other forest production - Fish capture, stock of fish resources - Amount produced by crop	2. Environmental resources and their use Sub-component 2.4: Biological Resources Topic Timber resources and their use (2.4.1 a,c) Topic Aquatic resources and their use (2.4.2 a,f) Topic Crops (2.4.3 a,3, 2.4.3 c,2)	Change in forest products, aquatic resources and crops may be indicators of impact of climate change	Closely related (2.4.1 Agriculture, forestry, fisheries)
- Surface water stocks in snow, ice and glaciers	2. Environmental resources and their use Sub-component 2.5: Water Resources Topic 2.5.1: Water Resources (2.5.1.c)	The water stocks in snow, ice and glaciers and their change are indicators of impact of climate change.	Closely related (3.1 environment)
- Emission of GHGs from socio-economic processes including by sector or economic activity (ISIC) - consumption of ozone depleting substances (ODS)	Component 3: Emissions, Residuals and Waste Sub-component 3.1 Emissions to Air Topic 3.1.1: Emissions of greenhouse gases (3.1.1.a-b)	For data sources see text	Closely related (3.1 environment)
- Occurrence of natural extreme events and disasters - People affected (killed, homeless, injured, …) - Economic loss - Impact on ecosystem	4. Extreme Events and Disaster Sub-component 4.1: Natural Extreme Events and Disasters Topic 4.1.1: Occurrence of natural extreme events and disasters (4.4.1.a) Topic 4.1.2: Impact of natural extreme events and disasters (4.1.2.a-c)	*§ 3.175. There is now sufficient evidence to show that climate change has been associated with the increasing frequency and severity of extreme weather events. Climate change has resulted in increased global temperatures, rising sea levels, increased storms and precipitation, droughts, tropical cyclones, hurricanes, tornadoes and other climatic disruptions in many places around the world.*	Closely related (3.1 environment)
- Houses in zones vulnerable to natural disasters and extreme events	5. Human Habitat and Environmental Health Sub-component 5.1: Human Habitat Topic 5.1.3: Housing conditions (5.1.3.b)	Statistics on housing conditions allow to identify zones particularly vulnerable to climate related natural disasters and extreme event	Closely related (1.7 Human settlements and housing)

Climate change related statistics included in the FDES	FDES reference code	Reasons why these statistics are relevant to climate change and data sources (text adapted from FDES or quote from FDES when in italic)	Degree of relevance for climate change analysis (CSA code and activity, see chapter 4 for the CSA)
- Vector borne diseases and conditions: • Incidence • Morbidity • Mortality • Loss of work days • Estimates of economic cost in monetary terms	5. Human Habitat and Environmental Health Sub-component 5.2: Environmental Health Topic 5.2.3: Vector borne diseases	*3.228. This topic includes vector borne diseases that are transmitted by vectors (e.g., insects and arachnids) that carry viruses, bacteria, protozoa and other pathogens, as defined by the WHO.* *Common vector borne diseases include, but are not limited to, malaria, dengue fever, yellow fever and Lyme disease.* *Some vector borne diseases are being directly affected by climate change, notably by the change in rain patterns and floods.*	Closely related (3.1 environment and 1.4 health)
- Climate change related prevention, reduction or treatment actions and activities	Component 6: Environment protection, management and engagement Sub-component 6.1: Environment Protection and Resource Management Expenditure Topic 6.1.1: Government environment protection and resource management expenditure Topic 6.1.2: Corporation, non-profit institution and household environment protection and resource management expenditure	*3.239. Environment protection activities are those activities whose primary purpose is the prevention, reduction and elimination of pollution and other forms of degradation of the environment.. 3.240. The Classification of Environmental Protection Activities (CEPA) has been in place since 2000, covering the classes of activities pertaining to environment protection.* Class 1 of CEPA covers 1. Protection of ambient air and climate	Closely related (3.1 environment)

Climate change related statistics included in the FDES	FDES reference code	Reasons why these statistics are relevant to climate change and data sources (text adapted from FDES or quote from FDES when in italic)	Degree of relevance for climate change analysis (CSA code and activity, see chapter 4 for the CSA)
- Climate change related regulation (relevant norms, number of environmental licensing of productive projects and facilities, recycling and energy efficiency programmes, number of quotas and other restrictive production norms, per sector or economic activity, …) - Climate change related economic instruments (climate change related taxes, subsidies, eco labelling, certification and other market instruments)	Component 6: Environment protection, management and engagement Sub-component 6.2: Environmental Governance and Regulation Topic 6.2.2: Environmental regulation and instruments	Mostly based on qualitative data such as projects, programmes and norms on climate issues. Data on taxes and subsidies could possibly be extracted from official statistics.	not currently included in the statistical system, therefore, not analysed using the CSA; however such indicators are often used in policy monitoring
- Climate change related MEAs and conventions	Component 6: Environment protection, management and engagement Sub-component 6.2: Environmental Governance and Regulation Topic 6.2.3: Participation in MEAs and environmental conventions	Mostly based on qualitative data such as climate conventions and targets.	not included in the statistical system, therefore, not analysed using the CSA
- Management systems addressed to cope with climate change related extreme events	Component 6: Environment protection, management and engagement Sub-component 6.3 • Extreme Event Preparedness and Disaster Management Topic 6.3.1: Preparedness for extreme events and natural disasters	Partly based on qualitative data	not included in the statistical system, therefore, not analysed using the CSA

Climate change related statistics included in the FDES	FDES reference code	Reasons why these statistics are relevant to climate change and data sources (text adapted from FDES or quote from FDES when in italic)	Degree of relevance for climate change analysis (CSA code and activity, see chapter 4 for the CSA)
- Climate change related information, education and perception	Component 6: Environment protection, management and engagement Sub-component 6.4: Environmental Information and Awareness Topic 6.4.1: Environmental information Topic 6.4.2: Environmental education and awareness Topic 6.4.3: Environmental perception	Partly based on qualitative data such as awareness raising campaigns and education on climate issues. As regards environmental awareness and perception: *3.274. The main institutional partners in this case include the environmental authority and the NSO, along with other possible institutions where environmental perception surveys could be carried out (e.g., local governments). These statistics are produced through surveys designed for data collection on this topic. Statistics belonging to this topic are mainly qualitative, and are usually compiled at the sub-national level.*	not included in the statistical system, therefore, not analysed using the CSA

Annex 2. GCOS Essential Climate Variables

Source: http://www.wmo.int/pages/prog/gcos/index.php?name=EssentialClimateVariables

The 50 GCOS Essential Climate Variables (ECVs) (2010) are required to support the work of the UNFCCC and the IPCC. All ECVs are technically and economically feasible for systematic observation. It is these variables for which international exchange is required for both current and historical observations. Additional variables required for research purposes are not included in this table. It is emphasized that the ordering within the table is simply for convenience and is not an indicator of relative priority.

Domain	GCOS Essential Climate Variables
Atmospheric (over land, sea and ice)	**Surface:**[1] Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget. **Upper-air:**[2] Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance). **Composition:** Carbon dioxide, Methane, and other long-lived greenhouse gases[3], Ozone and Aerosol, supported by their precursors[4].
Oceanic	**Surface:**[5] Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton. **Sub-surface:** Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.
Terrestrial	River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.

[1] Including measurements at standardized, but globally varying heights in close proximity to the surface.

[2] Up to the stratopause.

[3] Including nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6), and perfluorocarbons (PFCs).

[4] In particular nitrogen dioxide (NO_2), sulphur dioxide (SO_2), formaldehyde (HCHO) and carbon monoxide (CO).

[5] Including measurements within the surface mixed layer, usually within the upper 15m.

Last modified on Mon, 04 Jun 2012; Accessed on 7 August 2012.

Annex 3. Tables related to the natural capital approach

Table 1 - Ecological goods and services likely to be impacted by climate change and statistical variables related to the atmosphere as a natural asset

Category of statistical variables	Climate stability	Transportation	Space for human activities	Flood protection	Protection from spread of vector-borne diseases	Recreation, aesthetic, cultural and existence services	Food production	Timber and other forest products	Surface and groundwater supplies	Marine resources
Capacity to provide EGS	- global average atmospheric concentrations of greenhouse gases - frequency and severity of extreme weather events	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Flows of EGS	- global and regional average surface air temperatures - global and regional average precipitation levels	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Flows of waste materials and energy	- greenhouse gas emissions	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Flows related to environmental protection	- efforts to reduce greenhouse gas emissions - efforts to protect against flooding and other extreme weather events	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Flows related to service subsitution	- efforts to modify agricultural systems to adapt to lower precipitation and/or high temperatures - effortsto adapt buildings and other infrastructure to deal with changes in precipitation, temperature or wind	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 2 - Ecological goods and services likely to be impacted by climate change and statistical variables related to marine ecosystems as a natural asset										
Category of statistical variables	**Climate stability**	**Transportation**	**Space for human activities**	**Flood protection**	**Protection from spread of vector-borne diseases**	**Recreation, aesthetic, cultural and existence services**	**Food production**	**Timber and other forest products**	**Surface and groundwater supplies**	**Marine resources**
Capacity to provide EGS	- global concentrations of dissolved carbon dioxide - global and regional ocean surface temperatures -global and regional salinity levels and major ocean current patterns	- ice-free days in Arctic shipping routes	n/a	n/a	n/a	- areas of coastal zones offering opportunities to undertake experiences with recreational, aesthetic, cultural or existence value benefits	see marine resources	n/a	n/a	- stocks of marine resource species
Flows of EGS	- frequency and severity of extreme ocean weather events	- number of ships/cargo using Arctic shipping routes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	- harvest of marine species
Flows of waste materials and energy	- carbon dioxide emissions	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Flows related to environmental protection	- efforts to protect coastal ecological zones from the impacts of rising ocean levels	n/a	n/a	n/a	n/a	- efforts to protect coastal ecological zones from the impacts of rising ocean levels	n/a	n/a	n/a	- efforts to protect marine species from the rising ocean temperatures and dissolved carbon dioxide levels
Flows related to service subsitution	- efforts to protect coastal infrastructure (housing, ports, etc.) from the impacts of rising ocean levels	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-efforts to artificially raise marine resources

Annex 4. Summary of issues covered by the different frameworks

	DPSIR	FDES	IPCC	Capital	Mitigation-adaptation
Demographic and social statistics					
1.1 Population and migration	**Drivers:** population and migration movements	**Human habitat:** total population	**Socio-economic development:** population	-	**Mitigation:** of population growth, urbanization **Adaptation:** migration movement
1.2 Labour	**Responses:** green jobs	-	-	-	-
1.3 Education	**Responses:** climate related education	**Environment protection:** climate related information education and awareness	**Socio-economic development:** literacy	-	**Adaptation:** education to cope with changing climate
1.4 Health	**Impact:** climate related mortality, allergies, hay fever, vector-borne diseases, food-/waterborne diseases	**Human habitat:** Water related, airborne and vector-borne diseases, UV and pollution exposure, morbidity and mortality	**Impacts and vulnerability:** impacts on human health; **Socio-economic development:** Health	**EGS flows:** disrupted protection from vector-borne diseases	**Adaptation:** to changes in health environment due to climate change
1.5 Income and consumption	**Drivers:** level of wealth, consumption, **Impact:** electricity, gas and water consumption, changes in income distribution, economic losses	**Extreme events:** economic losses due to disasters; **Environmental resources:** as a source of income and consumption habits	**Socio-economic development:** consumption patterns	-	**Adaptation:** changes in income and consumption due to climate change
1.6 Social protection	**Responses:** protection of vulnerable groups/regions, finance	-	-	-	**Adaptation:** actions taken for social protection

1.7 Human settlements and housing	**Drivers:** urbanisation, structure of households, demand for housing; **Impact:** heating days, economic losses, disasters	**Emissions and waste:** greenhouse gas emissions, generation of waste; **Extreme events:** economic losses due to disasters; **Human habitat:** pressure from built environment, living conditions	**Impacts and vulnerability:** settlements and society	**EGS flows:** changes in the provision of space, in flood protection, in the recreational opportunities and cultural value of environment	**Mitigation:** urbanization
1.8 Justice and crime	-	-	-	-	-
1.9 Culture	-	-	**Socio-economic development:** socio-cultural preferences	**EGS flows:** changes in the aesthetic, cultural and existence value of environment	-
1.10 Political and other community activities	**Responses:** political measures, adaptation and mitigation, financing	**Environmental protection:** environmental governance and protection activities	**Socio-economic development:** governance, mitigation, adaptation	-	**Mitigation:** energy taxes, transport taxes, data on the carbon market and trade, renewable energy resources
1.11 Time use	**Drivers:** changing habits and diets	-	**Socio-economic development:** socio-cultural preferences	**EGS flows:** changes in recreational use and attractiveness of environment	**Adaptation:** changes in time use to adapt to climate change
Economic statistics					
2.1 Macroeconomic statistics	**Drivers:** level of economic activity, GDP	-	-	-	**Mitigation:** level of economic activity
2.2 Economic accounts	**Drivers:** level of economic activity by sectors, **Impact:** changes in economic activity by sector/industry	-	-	-	**Mitigation:** level of economic activity; **Adaptation:** changes in activity of industries
2.3 Business statistics	**Impact:** economic performance, economic opportunities and limitations, eco-industries	**Environmental resources and use:** land use, timber resources, crops, livestock **Emissions and waste:** greenhouse gas	**Socio-economic development:** production patterns	**Natural assets:** availability of inputs and raw material	**Mitigation:** eco-industries, environment friendly technologies; **Adaptation:** finding new economic opportunities,

		emissions, generation of waste; **Extreme events:** losses of revenue due to disasters			adaptation to economic limitations
2.4 Sectoral statistics					
2.4.1 Agriculture, forestry, fisheries	**Drivers:** agricultural practices, demand for meat; **Pressures:** livestock in agriculture, production of fossil fuels, forestry and land use, greenhouse gas emissions; **Impact:** growing season and crop yields, irrigation, pests and diseases, forest growth, fires, losses from climate-related events	**Environmental resources and use:** land use, timber resources, crops, livestock **Emissions and waste:** greenhouse gas emissions, generation of waste; **Extreme events:** economic losses, crop losses and damage due to disasters	**Climate process drivers:** greenhouse gas emissions	**Natural assets:** degradation leading to changes in ecosystems and in the distribution of and quality of different types of land and forests; **EGS flows:** changes in timber and other forest product flows	**Mitigation:** reduction of greenhouse gas emissions, renewable energy resources; measures to mitigate these; **Adaptation:** to reduced crop yields, changes in crop patters and seasons, crop varieties, forest fires
2.4.2 Energy	**Drivers:** demand for energy and heating; **Pressures:** production of fossil fuels, greenhouse gas emissions; **Responses:** energy, material and emissions efficiency	**Environmental resources and use:** production of energy (renewable and non-renewable), energy consumption; **Emissions and waste:** greenhouse gas emissions, generation of waste; **Extreme events:** economic losses due to disasters	**Climate process drivers:** greenhouse gas emissions	**Natural assets:** changes in the energy resources and sub-soil resources; **EGS flows:** changes in flows of waste and energy, and inputs to industrial processes and home heating	**Mitigation:** reduction of greenhouse gas emissions, use of the carbon market and trade, renewable energy resources; **Adaptation:** in energy demand and use
2.4.3 Mining, manufacturing, construction	**Drivers:** mining, manufacturing and construction levels, changes in food production; **Pressures:** production of fossil fuels, greenhouse gas emissions, production of ozone depleting substances; **Impact:** economic losses from climate-related events	**Environmental resources and use:** minerals; **Emissions and waste:** greenhouse gas emissions, generation of waste; **Extreme events:** economic losses due to disasters	**Socio-economic development:** production patterns; **Climate process drivers:** greenhouse gas and aerosol emissions	**Natural assets:** changes in the sub-soil resources, mineral, liquids and gases and sub-soil resources; **EGS flows:** changes in inputs to industrial processes and construction	**Mitigation:** reduction of greenhouse gas emissions, use of the carbon market and trade, renewable energy resources; **Adaptation:** in energy demand and use

2.4.4 Transport	**Drivers:** demand for transport; **Pressures:** production of fossil fuels, greenhouse gas emissions; **Impact:** economic losses from climate-related events	**Environmental resources and use:** pressures on the climate	**Climate process drivers:** greenhouse gas emissions	**Natural assets:** changes in the provision of space; **EGS flows:** changed transportation services of waters and atmosphere	**Mitigation:** reduction of greenhouse gas emissions, renewable energy resources
2.4.5 Tourism	**Drivers:** levels of tourism, demand for transport **Pressures:** production of fossil fuels, greenhouse gas emissions; **Impact:** shifts of tourism flows, economic losses from climate-related events	**Emissions and waste:** greenhouse gas emissions, generation of waste; **Extreme events:** economic losses due to disasters	-	**EGS flows:** changes in the attractiveness of destinations for tourism, and in the aesthetic, cultural and existence value	**Mitigation:** reduction of greenhouse gas emissions; **Adaptation:** changes in tourism flows
2.4.6 Banking, insurance, financial statistics	**Impact:** insurance costs; **Responses:** financial costs of responses and protection	**Environment protection:** climate protection expenditure	-	-	**Mitigation:** financial tools; **Adaptation:** costs of adaptation
2.5 Government finance, fiscal and public sector	**Responses:** financing and government measures in adaptation and mitigation	**Environment protection:** climate protection and management expenditure, regulation related to climate, participation in climate conventions	**Socio-economic development:** governance, mitigation, adaptation	-	**Mitigation:** using financial and legislative tools, governance; **Adaptation:** of legislation and institutional mechanisms, adaptation measures
2.6 International trade and balance of payments	**Drivers:** Internationalisation of the economy, carbon leakage	-	**Socio-economic development:** trade	**EGS flows:** changed transportation services	**Mitigation:** responsible trade
2.7 Prices	**Responses:** energy prices, oil prices and others	-	-	-	**Adaptation:** through changes in pricing
2.8 Labour cost	-	-	-	-	-
2.9 Science, technology and innovation	-	**Responses:** eco-friendly technology development and technology exchange	**Socio-economic development:** technology	-	**Mitigation and adaptation:** through technology transfer and capacity building

Environment and multi-domain statistics

3.1 Environment	**State:** atmosphere and climate, cryosphere, marine biodiversity and its ecosystems; **Drivers:** waste from production and consumption **Pressures:** combustion of fossil fuels, waste treatment methods, greenhouse gas emissions; **Impact: w**ater quantity, freshwater quality and biodiversity, terrestrial ecosystems and biodiversity, soil, access to water; **Responses:** reduction of emissions, renewable energy, energy efficiency, environmental protection expenditure, recycling and waste, environment taxes and subsidies, permits and certificates	**Environmental conditions:** atmosphere, climate, weather; hydrographic issues, geological and geographic conditions, soil characteristics, land cover, biodiversity, ecosystems, forests; air, freshwater and marine water quality; **Environmental resources and use:** aquatic and water resources, use and returns of water; **Emissions and waste:** greenhouse gas emissions, wastewater, generation of waste, waste management; **Extreme events:** occurrence of disasters; **Human habitat:** urban environmental concerns; **Environment protection:** protection expenditure, regulation, conventions, measures taken and education	**Climate change:** temperature change, precipitation change, sea level rise and extreme events; **Impacts and vulnerability:** Impacts on ecosystems and water resources; **Climate process drivers:** greenhouse gas and aerosol emissions and concentrations	**Natural assets:** changes in ecosystems, land and sub-soil resources; **EGS flows:** provision of space, flood protection service of forests and wetlands, transportation services by waters, recreational opportunities and aesthetic, cultural and existence value, marine resources	**Adaptation:** to heat waves, rising oceans, glaciers retreats, droughts, seasonal changes, different variety of species, water supply changes, new crop varieties, changes in ecosystems including biodiversity and ecosystem goods and services; **Mitigation:** of the adverse impacts of the above changes
3.2 Regional and small area statistics	**Impact:** extreme events, regional impacts on environment, agriculture, economy and humans; **Responses:** regional measures	**Extreme events:** occurrence of disasters, people affected by disasters; **Human habitat:** location of habitats, specific concerns of urban habitat, vulnerable	**Impacts and vulnerability:** regional impacts on ecosystems and water resources, settlements, society, food security and human health	**Natural assets:** changes in ecosystems, land and sub-soil resources; **EGS flows:** food production, space at coastal areas, floods	**Mitigation:** of the impacts of extreme events; **Adaptation:** to changed local conditions

		groups			
3.3 Multi-domain statistics and indicators					
3.3.1 Living conditions, poverty and cross-cutting social	**Drivers:** level of wealth, consumption habits, **Impact:** electricity, gas and water consumption, changes in income distribution, economic losses	**Human habitat:** access to water, sanitation and energy; specific concerns of urban habitat, green areas	**Impacts and vulnerability:** impacts on human settlements and society; **Socio-economic development:** socio-cultural preferences, equity	**EGS flows:** food production, marine resources, forest products, space, floods, transportation services, recreation, aesthetic, cultural or existence value of environment	**Mitigation:** against hunger and poverty; **Adaptation:** to changed environmental conditions and changes in income distribution
3.3.2 Gender and special population groups	**Impact:** vulnerable groups, redistribution of wealth; **Responses:** social protection and financing	**Human habitat:** vulnerability to disasters	**Impacts and vulnerability:** impacts on vulnerable settlements, society, food security and human health; **Socio-economic development:** equity	**EGS flows:** food production, space at coastal areas, floods	**Mitigation:** against adverse effects of climate change towards vulnerable population groups; **Adaptation:** to changed conditions
3.3.3 Information society	-	-	-	-	-
3.3.4 Globalisation	**Drivers:** Internationalisation of the economy, carbon leakage	-	**Socio-economic development:** changes in trade patterns	**EGS flows:** changes in transportation services	**Mitigation:** responsible trade
3.3.5 Indicators related to Millennium Development Goals	**Impact & responses:** links to MDG1 on poverty, MDG6 on diseases, MDG7 on environmental sustainability	**Human habitat:** links to MDG6 on diseases, MDG7 on environmental sustainability	**Socio-economic development:** links to MDG1 on poverty, MDG6 on diseases, MDG7 on environmental sustainability	**Natural assets and EGS flows:** link to MDG1 on poverty, MDG6 on diseases, MDG7 on environmental sustainability	**Mitigation and adaptation:** link to MDG1 on poverty, MDG6 on diseases, MDG7 on environmental sustainability
3.3.6 Sustainable development	**Responses:** links to sustainable development, e.g. through reduction of emissions, renewable energy, energy efficiency, environmental protection, recycling, environment taxes and	**Environmental resources and use:** sustainable use of natural resources; **Environmental protection:** sustainable use of natural resources	**Impacts and vulnerability:** impacts on ecosystems; **Socio-economic development:** governance, mitigation	**Natural assets:** level of sustainable use of natural assets	**Mitigation:** measures in support of sustainable development, environmental protection, taxes and subsidies, permits and

	subsidies, permits and certificates, green growth and green jobs	related to climate			certificates, green jobs
3.3.7 Entrepreneurship	**Drivers:** level of economic growth **Impact:** economic performance, economic opportunities and limitations, eco-industries	**Extreme events:** losses of revenue due to disasters	**Socio-economic development:** opportunities of technology exchange	**Natural assets:** availability of inputs and raw material	**Mitigation:** eco-industries, environment friendly technologies; **Adaptation:** economic opportunities, adaptation to limitations