



European
Commission

Science for environmental sustainability

JRC thematic report

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Research
Centre (JRC)

*The European Commission's
in-house science service*

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Introduction

Many take the environment for granted, but pressure on the Earth's finite resources is growing at an unprecedented rate. There is a need for an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected. If we do not change current trends, which are further challenged by the consequences of climate change and the growing demand for energy and resources, our future is compromised.

Efforts must be employed to raise awareness of these pressing global environmental challenges and the need for a collective action involving the EU, national, regional and local governments, businesses, NGOs and ordinary citizens.

Through the 7th Environment Action Programme (EAP) that is guiding European environment policy until 2020, the EU has agreed to step up its efforts to protect our natural capital, stimulate resource-efficient, low-carbon growth and innovation, and safeguard people's health and well-being – while continuing to respect the Earth's natural limits.

In this context, the Joint Research Centre (JRC), which is the European Commission's in-house science service, supports EU Member States in implementing environmental policies and participates in international efforts to promote the sustainable use of resources and improve land-use management.

This report describes the work of the JRC supporting sustainable development. It shows which tools, methods, analyses and activities contribute to a better understanding, monitoring and anticipation of the complex interactions between human activity and the natural environment. By doing this, the JRC supports the development and implementation of policies that protect the global environment and ensure that strategic resources (water, land, forests, food and minerals) are managed in a more sustainable manner for the benefit of present and future generations, within and outside the EU. As climate change is inevitable, with long-term implications for sustainable development, the report also presents JRC activities in this field.

The JRC's work presented in this publication is organised into six chapters, each focusing on a given area of

research and its relevant scientific outputs, linked to its policy background and context. It also provides a list of partners, publications, contacts and useful links.

CHAPTER 1 Natural capital



Caring for natural capital is at the heart of sustainable development. It is fundamental for human existence and underpins our economy and society. Limited and vulnerable, natural capital is under constant pressure from agriculture, fisheries, forestry and urban development. Climate change also adds to this by putting it at risk and undermining its resilience. The JRC carries out research and informs EU policy-making in this area. Its monitoring and assessment activities allow for a definition of the state of play and ongoing trends. This is crucial in order to give an indication of the environmental sustainability of our economy and society.

CHAPTER 2 Ecosystem services and biodiversity



Biodiversity is still being lost in the EU, and many ecosystems are becoming seriously degraded, so greater efforts are needed. The JRC aims to address these challenges by improving the way data and other information are collected, managed and used across the EU.



It invests in research to fill knowledge gaps, and is developing a more systematic approach to new and emerging risks to biodiversity.

CHAPTER 3 Resource efficiency



A more efficient use of resources often reduces environmental costs, while new environmentally-friendly technologies may create employment, thus strengthening the competitiveness of European industry. The circular economy, which requires more re-use and high quality recycling to reduce dependence on primary raw materials, is key for achieving the overall objective of resource efficiency. In this context, the JRC promotes a life-cycle approach and supports EU policies fostering a more efficient use of resources.

CHAPTER 4 Sustainable urban living



The JRC supports innovation and sharing best practice to help cities become more sustainable. The aim is to ensure that, by 2020, most cities in the EU are implementing policies for sustainable urban planning and design in areas such as air quality, buildings, energy and transport.

CHAPTER 5 Climate change mitigation and adaptation



The EU's strategy for reducing climate change risks relies on mitigation and adaptation. The JRC has long-standing expertise in monitoring and modelling climate change and its impacts, thereby supporting the European Commission services and EU Member States in their climate change mitigation, preparedness and adaptation efforts.

CHAPTER 6 Innovation for sustainability



With the rapidly growing global population, unsustainable use of natural resources, environmental degradation and the consequences of climate change, we are already pushing our planetary boundaries to tipping points of no return. Innovation can bring solutions, but it needs to be addressed not only from an economic, but also social and environmental dimensions. In this context, the JRC is currently looking into new methods to recycle water, share and process big environmental data, as well as helping innovative environmental technologies to reach the market through its Environmental Technology Verification programme.



1 Natural capital

Caring for natural capital is at the heart of sustainable development. It is fundamental for human existence and underpins our economy and society. With the global population projected to reach over 9 billion by 2050, the sustainable use of natural resources, food security, and the socio-economic policies of our society are a major concern.

Natural capital is the stock of natural resources (including biodiversity) that provides vital ecosystem services such as the pollination of plants, natural protection against flooding, and regulation of our climate. Limited and vulnerable, it is under constant pressure from agriculture, fisheries, forestry and urban development. Climate change also adds to this by putting natural capital at risk and undermining its resilience.

The JRC carries out research and informs EU policy-making in this area. Its monitoring and assessment activities allow for a definition of the state of play and ongoing trends. This is crucial in order to give an indication of the environmental sustainability of our economy and society. The EU has already taken action to maintain and enhance our natural capital both by integrating it into the relevant policies such as the Common Agriculture Policy (CAP), the Common Fisheries Policy (CFP) or adopting specific legislation such as the Water Framework Directive (WFD).

1.1 Providing guidelines to safeguard clean water and healthy ecosystems

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Directive 2000/60/EC of 23 October 2000 establishing a framework for Community action in the field of water policy, the EU Water Framework Directive (WFD)
- Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption
- Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality.

Safeguarding water resources, aquatic ecosystems and the water we drink and bathe in is one of the cornerstones of environmental protection in Europe. Given the issues at stake, which transcend national boundaries, concerted action at EU level is an absolute necessity. The JRC's key role is to

ensure that EU water policies and their practical implementation are based on state-of-the-art scientific knowledge.

The Water Framework Directive (WFD) is the main EU legislative framework for water policy. Its objective is to achieve good ecological and chemical status for all surface waters. Ecological status is quantified using biological indicators, such as fish, plants and plankton, supported by indicators for nutrients and hydromorphology, such as flow regime and river habitats. Chemical status is based on environmental quality standards (EQS) for a list of priority substances that pose a significant risk to water ecosystems or human health. Since the entry into force of the WFD in 2000, the JRC has collaborated closely with the Commission's Directorate-General for the Environment to support its implementation.

Member States have developed a multitude of biological indicators tailor-made to local conditions to assess the health of water ecosystems. The JRC is facilitating an EU-wide intercalibration exercise involving hundreds of experts from all EU countries to ensure the comparability of all these methods. This work is crucial for the WFD implementation as it enables the setting up of harmonised environmental objectives to be reached by the Member States through their river basin management plans. The intercalibration exercise is a formal requirement of the WFD, with legally binding results.

The JRC provides Member States with guidance and training on analytical methods to fulfill their chemical-status monitoring requirements. It also facilitates the identification of priority substances based on the latest scientific knowledge. Recently, the JRC contributed to the creation of a 'watch list' of a maximum of ten substances of high concern, including antibiotics, hormones, insecticides and pesticides, which all Member States should monitor at the European scale for four years. Based on JRC expertise in the analyses of emerging pollutants, Member States have developed novel approaches to pan-European snapshot monitoring.

The JRC also works on the harmonisation of standards for nutrients in water and is developing innovative methods to use remote sensing information for characterising the hydromorphology of rivers. These methods, currently being tested, should help design European river restoration.

In addition to the WFD, the JRC provides scientific support to the Drinking Water Directive (DWD) and Bathing Water Directive (BWD) focusing on chemical and microbiological parameters. The JRC is leading the activity of the European Microbiology Expert Group and recently coordinated the revision of the DWD.

For these activities, the JRC collaborates with scientists and government experts from all EU Member States and European Commission services. Further partners include the World Health Organization (WHO), and European agencies dealing with chemicals (European Chemicals Agency – ECHA), food (European Food Safety Authority – EFSA), and medicine (European Medicines Agency – EMA).

The JRC has led and contributed to several important guidance documents on the classification of ecological status, intercalibration, ecological flows, the monitoring of chemical substances and environmental quality standards. This work has led to legally binding and harmonised environmental objectives for Member States' river basin management plans. The JRC successfully coordinated a European-wide campaign to assess the implementation of existing and innovative biological-based assays for testing the effects of chemical mixtures, the results of which will guide future research on those mixtures posing a risk to aquatic ecosystems even at low concentration. To better assess the scientific value of the information generated on the fate and occurrence of chemical substances, the JRC is promoting an Open Data Sharing Approach by giving access to chemical monitoring data via the Information Platform for Chemical Monitoring Data (IpChem).

Work in progress

The JRC is working to complete the WFD intercalibration exercise for biological methods by 2016. Issues of growing importance expected in the coming years include the development of innovative methodologies for cost-effective monitoring, such as remote sensing for hydromorphology and the application of molecular methods to support the assessment of chemical and ecological status. The JRC will be closely involved in the assessment of the second river basin management plans carried out by the European Commission, in close collaboration with the European Environment Agency (EEA). The JRC will study the mode of action of chemical pollutants, helping to address issues such as chemical mixtures and multiple stressor effects on ecosystems and human health.

1.2 Supporting sustainable and profitable fisheries and aquaculture

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy
- Council Regulation (EC) No 199/2008 of 25 February 2008 concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy

- Commission Decision 2010/93/EU of 18 December 2009 adopting a multiannual Community programme for the collection, management and use of data in the fisheries sector for the period 2011-2013
- Regulation (EU) No 508/2014 of the European Parliament and of the Council of 15 May 2014 on the European Maritime and Fisheries Fund
- Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for Community action in the field of marine environmental policy (Marine Strategy Framework Directive)
- Commission Decision 2010/477/EU of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters
- Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 29 April 2013 – Strategic Guidelines for the sustainable development of EU aquaculture, COM(2013) 229
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 13 September 2012 – Blue Growth opportunities for marine and maritime sustainable growth, COM(2012) 494.

Marine fish stocks constitute a major natural renewable resource, which can greatly help to address the challenge of sustainable food security. However, the vast majority of commercial fish stocks worldwide are currently fully or over-exploited, depleted or recovering from depletion. A change in the management and governance of natural marine resources is required to ensure compatibility between the increasing demand for fish as a source of protein and the need to preserve jobs and income, while reducing pressure on our oceans.

As commercially exploited fish are part of marine ecosystems, the Common Fisheries Policy (CFP) is following an ecosystem-based approach to fisheries. Such an approach is seen not only as a way of achieving long-term growth in the EU fisheries sector, but also as a duty towards the environment and its natural resources. Aquaculture also plays a vital role in alleviating the pressures exerted by fishing and in producing more fish for consumption. Moreover, the aquaculture industry has the potential for economic growth, jobs and income. The need to boost EU aquaculture has been recognised in the EU Blue Growth strategy and in the contributions of the oceans and seas to the Europe 2020 objectives.

The JRC provides the EU's CFP and global stakeholders with scientific solutions and technical support towards sustainable and profitable fisheries and aquaculture. It has an established and widely acknowledged role in collecting, disseminating and analysing fisheries data through the EU's Data Collection Framework. The JRC

delivers scientific advice through coordination of the Scientific, Technical and Economic Committee for Fisheries (STECF), an advisory body composed of independent experts. It plays a key role in providing the STECF annual evaluations of economic performance indicators for the fisheries, aquaculture and fish-processing industries, and the STECF opinions regarding the setting of the annual amount of fish that can be caught by EU fishermen, referred to as Total Allowable Catches.

JRC research focuses on bio-economic and fisheries modelling, analysis of socio-economic data, fish genetics and evaluation of management plans. Fishery modelling aims to make a greater number of commercially exploited stocks accessible for stock assessment, and to develop decision-making tools for fishery management. The bio-economic modelling approach attempts to bridge the biological and economic lines of research to develop more sustainable long-term fisheries management plans and a more economically viable fisheries sector. JRC scientists study the seafood trade and carry out spatial analysis of fisheries and aquaculture to allow policy-makers to define better policies for aquaculture. They use genetic and genomic approaches to identify species and genetic stock and to assign origin.

The JRC develops statistical methods for estimating the status of all stocks being exploited in European waters, and tests the robustness of related management policies for sustainable and profitable fisheries and aquaculture.

Using novel approaches to fisheries modelling, the JRC is involved in the 'Assessment for All' (a4a) initiative, which is developing methods and procedures for assessments of large numbers of stocks (over 300). The JRC is also working on the development of statistical methods for bio-economic analysis for impact assessments of multiannual fisheries management plans.

Finally, the JRC participates in the Management Strategies Evaluation (MSE) to forecast the dynamics of stocks and fisheries, supporting harvest control.

Work in progress

The JRC is conducting research to provide scientific advice for fisheries and aquaculture management, under the EU's CFP and in an international context. The aim is to further improve fish-stock and marine-ecosystems assessment methods. This includes the integration of environmental and socio-economic analyses of the fisheries and aquaculture sector. The JRC is also exploring novel and advanced approaches that can help improve current fisheries management schemes such as the integration of data emerging from the Automatic Vessel Identification System (AIS) with other information to obtain a more comprehensive and realistic picture of fishing intensity across sea basins in Europe.

1.3 Protecting soil through advanced soil mapping and modelling techniques

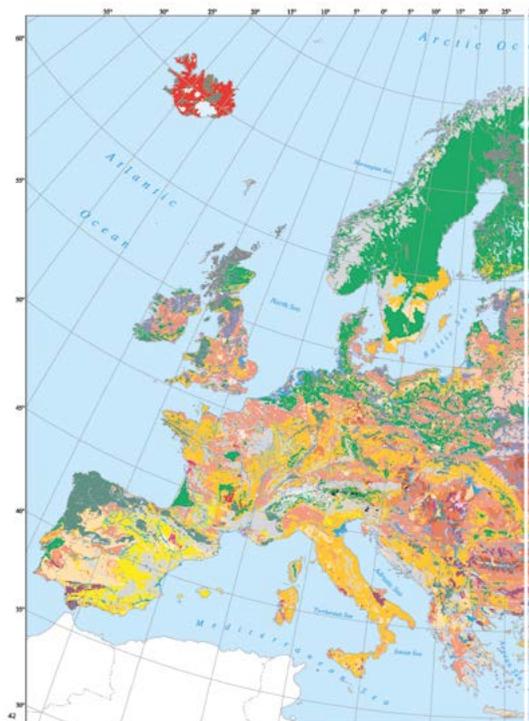
The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – Thematic Strategy for Soil Protection, COM(2006) 231
- Regulation (EU) No 1306/2013 of the European Parliament and of the Council of 17 December 2013 on the financing, management and monitoring of the common agricultural policy
- Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions – Our life insurance, our natural capital: an EU biodiversity strategy to 2020, COM(2011) 244)
- Kyoto Protocol and Use, Land-Use Change and Forestry (LULUCF)
- United Nations 2030 Agenda for Sustainable Development: Transforming our world.

Soil underpins a range of life-critical ecosystem services. The most readily perceived are food and fibre production. Other natural benefits provided by soils include water purification, flood reduction, global nutrient cycles, raw materials and preservation of cultural heritage. The amount of fertile soil available is limited and currently under threat from a series of degradation pressures, resulting from land-use changes such as urban expansion, housing and infrastructure development, inappropriate land management and climate change. Soil data and information are relevant to a number of EU policy areas: food security, agriculture, soil protection, bio-energy, water protection, nature protection, development policy, health and sustainable development. The JRC supports the EU Thematic Strategy for Soil Protection, which addresses these different policy areas in a coherent manner and proposes a framework for effective soil protection in Europe, based on four main pillars of activity: legislation, integration, research and awareness-raising.

The JRC provides information on the distribution of soils in Europe and their current status and trends via its European Soil Data Centre (ESDAC). Developed in close collaboration with other EU services and national soil survey institutions, the ESDAC collects, harmonises and distributes policy-relevant soil data and information to users in the European Commission as well as to third parties and other stakeholders in Europe. As a thematic centre for soil, it comprises two main elements: a catalogue of soil resources and a map viewer.

The JRC uses advanced modelling techniques, indicators and scenario analyses to provide soil information to end users in relation to major threats to the soil, as identified in the EU's Thematic Strategy for Soil Protection: erosion, decline of organic matter, compaction, salinisation, landslides, sealing, contamination and loss of soil biodiversity.



JRC soil map of Europe shows the diversity and geographical variability of soil cover across Europe.

The JRC provides estimates of the overall extent and economic impact of soil erosion by water and wind. It develops European maps of soil susceptibility to salinisation and compaction and produces guidelines on best practices to limit, mitigate and compensate for soil sealing. The JRC is also working on the harmonisation of methods to map areas prone to landslides and is producing indicators and reference materials to assess soil contamination, for instance from domestic and industrial sewage sludge. Data from the European Soil Data Centre underpin the soil assessments in the European Environment Agency's State of Environment Reports (SOER).

Large volumes of waste production and widespread use of chemicals in recent decades have resulted in soil contamination. The JRC tracks the progress of the management of contaminated sites via a data collection campaign conducted with National Reference Centres for Soil belonging to the European Environment Information and Observation Network (EIONET). Results of the latest campaign, in which 27 EIONET countries participated voluntarily, were published in the 2014 report 'Progress in the management of contaminated sites in Europe'. The 2014 report estimated the number of potentially contaminated sites in Europe – where soil contamination is suspected and detailed investigations are needed. Of the approximately 115 000 contaminated sites that had already been identified in Europe, nearly half (46 %) had already been remediated. Most of the contaminated sites were found to be managed using 'traditional' techniques such as excavation and off-site disposal. Mining activities, metal industries and petrol stations were the most frequently reported sources of soil and groundwater contamination, with a significant variation in

the range of polluting activities from country to country. The most frequently occurring contaminants appeared to be mineral oils and heavy metals. The report concluded that the annual national expenditure for the management of contaminated sites in Europe was on average about € 10 per capita (5 billion EUR for the EU28).

Work in progress

Despite its clear relevance to society, soil resources are still seen as a second-tier priority and there is currently no international governing body that advocates and coordinates initiatives to ensure that knowledge and recognition of soils are appropriately represented in global-change dialogues and decision-making processes.

Jointly with the Food and Agriculture Organization of the United Nations (FAO), the JRC will maintain its active participation in the Global Soil Partnership (GSP) and the European Soil Partnership (ESP) – the latter being the regional version that was created in 2014 – which are voluntary collaborations promoting sustainable soil management. These networks aim to bring together the various scattered networks and soil-related activities into a common framework, open to all institutions and stakeholders that are willing to actively contribute to sustainable soil management.

In June 2015, the GSP endorsed a concept note on developing Voluntary Guidelines for Sustainable Management of Soil Resources (VGSMS), which while not legally binding, would be a major step towards a more efficient global effort to establish a coherent strategy for soil protection. The JRC will provide this initiative with the necessary scientific and technical support, especially by chairing the Intergovernmental Technical Panel on Soils (ITPS).

1.4 Measuring forest change and related carbon emissions through remote sensing

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions of 20 September 2013 – A new EU Forest Strategy: for forests and the forest-based sector COM(2013) 659
- United Nations Climate Summit 2014 of 23 September 2014 – New York Declaration on Forests and Action Agenda
- United Nations Framework Convention on Climate Change (UNFCCC) – Decisions relevant for reducing emissions from deforestation and forest degradation in developing countries (REDD+)
- Outcome of the Rio+20 United Nations Conference on Sustainable Development of 20-22 June 2012 (Rio de Janeiro, Brazil).

Forests constitute one of the most important aspects of the biosphere. They provide habitats and nutrients for organisms, modulate hydrologic flow, store carbon, help to regulate the climate, conserve soil resources, purify water and mitigate natural hazards such as floods. Forests also contain roughly 90 % of the world's terrestrial biodiversity. However, each year around 13 million hectares are deforested worldwide; 96 % of this annual deforestation occurs in tropical regions. The JRC is addressing forest cover and cover-change issues with respect to EU commitments to multilateral environmental agreements, especially to United Nations (UN) conventions.

Since the early 1990s, the JRC has been monitoring tropical forests through remote sensing, estimating changes in forest cover, deforestation and forest regrowth, with the aim of reducing uncertainties in the measurement of forest change and related carbon emissions. Compared to the cost of field inventory in the tropics and the lack of comparable historical national forest inventory data, the use of satellite imagery enables the consistent monitoring of forest cover change over very large regions. Results are combined with pan-tropical biomass maps to estimate carbon losses, as deforestation results in the immediate release of the carbon 'originally stored in the trees' as CO₂ emissions. The JRC's work is contributing to the FAO's Remote Sensing Survey of the Global Forest Resources Assessment, which provides a sample of spatially explicit data distributed across the whole tropical belt.

In 2014, the JRC released the results of a study estimating tropical deforestation rates and carbon losses for the last two decades. The analysis showed a yearly gross loss of 8 million hectares of tropical forests in the 1990s and 7.6 million in the 2000s. Carbon losses from loss of forest cover were estimated at 887 million tonnes of carbon per year during the 1990s and 880 million tonnes of carbon annually for the first decade of the 21st Century. The carbon losses between 2000 and 2010 represent around 10 % of carbon emissions from fossil fuel combustion and cement production. The annual removal of carbon from forest regrowth was estimated at 115 million tonnes of carbon per year the 1990s and 97 million tonnes of carbon per year for the 2000s.

Work in progress

Forest degradation is the result of different processes, including unsustainable logging, shifting cultivation, and firewood collection or burning. It leads to a reduction of biomass, the opening up of forest canopies and changes in the structure of forests, as well as modifying the composition of species, thereby affecting ecosystem services, including future potential for carbon capture and storage. However, methods for estimating emissions from forest degradation are still lacking, mainly because of the finer spatial scales at which degradation occurs, and the fact that traces in the canopy disappear within a matter of months.

Satellite imagery, such as that proposed under Copernicus (the European Earth Observation Programme) by the European Space Agency's Sentinel-2 satellite sensor, is freely available and allows for a more accurate and more frequent assessment of forest conditions. The JRC aims to respond to these challenges by developing methods for monitoring forest degradation, organising training and workshops at national or regional levels, strengthening the Forest Observatory of Central Africa (OFAC), and providing thematic analysis to decision-makers in the EU and partner countries.

1.5 Analysing the competition for land: energy, agriculture, infrastructure

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Copernicus is the European Programme for the establishment of a European capacity for Earth Observation
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 23 July 2014 – Sixth report on economic, social and territorial cohesion: investment for jobs and growth, COM(2014) 473
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 20 September 2011 – Roadmap to a Resource Efficient Europe, COM(2011) 571
- Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds
- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions of 22 September 2006 – Soil Thematic Strategy COM(2006) 231
- Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

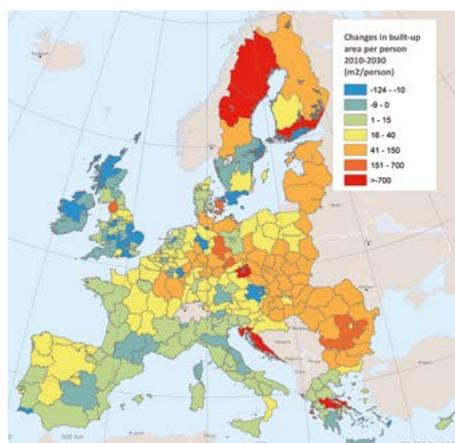
In 2011, global population exceeded 7 billion and has been growing by 155 additional people every minute ever since. Less than a third of Earth's surface is land; a fifth of this is desert, snow and ice. Vegetation grows on the remaining land except where it is taken over by urban infrastructure – the EU alone loses some 1000 km² of agricultural land each year, but less than 18 % of this has soil that is naturally capable of supporting sustained crop production. Yet we rely on the land for 99 % of our calories. As land is a finite non-renewable resource providing food, fibre and fuel, while acting as carbon sink, water reservoir and home for biological diversity, competition for it is fierce. Since the mid-20th Century, population growth and migration from rural to urban areas has increased the pressure on agricultural land, forests and protected areas, which is now required to support more people with fewer resources than previously. The issues of migration,

an ageing population and the economy will be among the main driving forces behind how our land and landscape will change in the coming decades.

EU policy aims to keep land-resource use and regenerative capacity balanced. This has the best chance of success when based on sound information concerning how, when and where land and soil resources are being used and how this is changing. Copernicus (the European Earth Observation Programme) aims to provide some of the required information from its global land service.

The JRC supports the European Commission and international organisations in analysing competition for land, with the objective of protecting endangered species and ensuring local communities have access to agricultural land. Using satellite imagery from Copernicus, and data gathered from ground surveys, the JRC studies changes in land use and land cover in conjunction with socio-economic changes, and assesses new ways of managing land. Its work contributes to European environmental policies such as the Biodiversity Strategy, the WFD, the Soil Thematic Strategy, the Roadmap to a Resource Efficient Europe, and implementation of the Natura 2000 network.

Change in built-up area per inhabitant in m² per person between 2010 and 2030, according to the EU Reference Scenario 2014 in EU-28 at the level of the 287 NUTS2 regions in the European Union. Blue areas on this map indicate regions where every inhabitant is anticipated, by 2030, to have less land available for



housing, industry and services, either due to considerable population increases or reduction in built-up land. Yellow to red areas indicate regions where every inhabitant is expected to have more built-up land available in 2030, either because of population loss or considerable increases in built-up land. From an environmental point of view, less built-up area per capita is usually considered desirable; for example, by limiting growth of built-up areas in regions with substantial population growth, the loss of ecosystem services and landscape values may be contained. NUTS2 are territorial units in the EU's Member States.

The JRC has developed the Land Use-based Integrated Sustainability Assessment (LUIA) modelling platform as a tool for the ex-ante evaluation of EU policies that have a direct or indirect territorial impact. LUIA is based on the novel concept of dynamic land function, which can be societal (provision of housing, leisure and recreational opportunities), economic (transport, provision of employment, provision of food and biofuels) or environmental (provision of regulation services and maintenance of ecosystem processes).

LUIA's final output is a set of spatially explicit indicators that are typically projected in time to the years 2030 or 2050, which reflect impacts of various land-use scenarios on land functions. This allows decision-makers to pinpoint sensitive regions, and to trace impacts back to certain driving factors that are assumed in the definition of the scenarios.

LUIA can provide useful insights into the potential land conflicts arising from different economic, demographic and political drivers, and the associated economic and environmental impacts. It can be used to evaluate, at a local scale, the land resources needed for the production of energy, and the possible implications for the production of food and feed, especially in terms of land suitability and productivity.

It has also been applied to assess the spatial impact of regional and urban policy in Europe, for which it provides quantitative indicators of land-use intensity, urban sprawl, and the implications on accessibility in the EU regions and the provision of ecosystem services.

The Land Use-based Integrated Sustainability Assessment (LUIA) platform has been applied to assess EU regions and cities with regard to a wide range of issues, such as renewable energy, natural hazards, the land-use efficiency of cities, and ecosystem services. The assessment highlighted the great potential of vast areas of Europe to produce electricity from solar radiation, and thus contribute to cleaner energy production and the diversification of energy sources. Further analysis identified regions in Europe that are particularly vulnerable to heatwaves and river floods, as they are exposed to high risk and have not yet developed the necessary adaptation capacity.

An analysis of the land-use efficiency of cities and regions has helped to improve the knowledge base on European urban areas, from which it emerged that cities which have more compact morphology are more efficient in terms of land consumption. The JRC also studied the capacity of cities and their green areas to remove atmospheric pollutants. The analysis led to the conclusion that investing in green infrastructure would help increase the services provided by ecosystems.

Work in progress

The JRC is currently developing tools to facilitate integrated land-use analyses at the continental scale and is carrying out validation activities using historical datasets and cross-model comparisons with relevant International organisations.

JRC scientists are continuously updating the LUIA platform, integrating new policy inputs and making technical improvements. The LUIA platform will be enriched progressively with a common baseline scenario updated on a yearly basis in line with policy developments, a refined economic rationale in land-use conversions, and data on public transport. Such a baseline scenario will act as a reference for ex-ante policy evaluations. It is typically based on the reference projections of all sectoral models that feed into LUIA, and the effects of established EU policies that will affect land functions. Its coverage will be extended to European countries beyond the EU-28 Member States.

2

Ecosystem services and biodiversity

The EU has taken action to halt biodiversity loss and achieve a good ecological status for Europe's lands, waters and marine environment. Legally binding commitments have been put in place, including the Water Framework Directive (WFD), Alien Species Regulation, and the Habitats and Birds Directives, together with financial and technical support. Nevertheless, our environment is under considerable pressure: biodiversity in the EU and on a global scale is still being lost, and many ecosystems are being seriously degraded, which means greater efforts are required. Human life depends on the living environment.

The JRC aims to address these challenges by improving the way data and other information is collected, managed and used across the EU, investing in research to fill knowledge gaps, and developing a more systematic approach to new and emerging risks to biodiversity.

2.1 Mapping and analysing of ecosystem services

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 3 May 2011 – Our life insurance, our natural capital: an EU biodiversity strategy to 2020, COM(2011) 244 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 20 September 2013 – A new EU Forest Strategy: for forests and the forest-based sector, COM(2013) 659 final
- Common Agricultural Policy (CAP): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future COM(2010) 672
- Common Fisheries Policy (CFP): Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy
- Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds

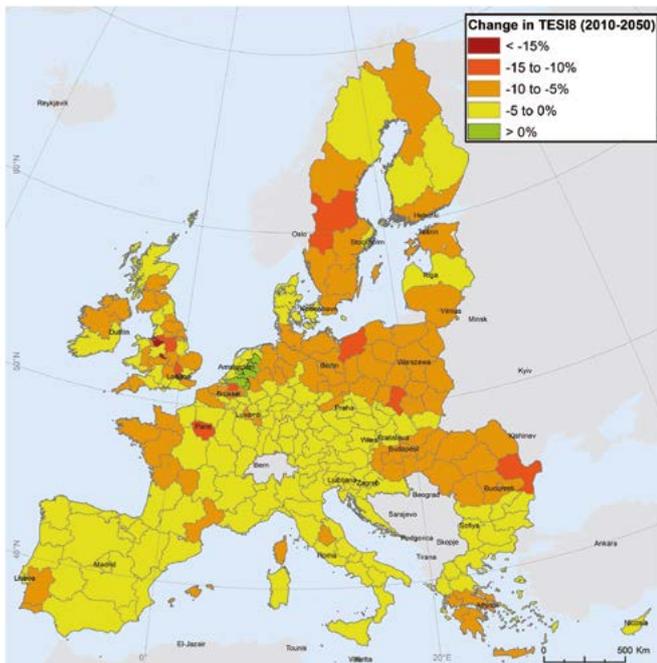
- Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora
- Water Framework Directive (WFD), Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
- UN Convention on Biological Diversity 2020 (CBD)
 - Aichi Target 14 (Ecosystem services), target 17 (National biodiversity strategies).

Ecosystem services can be defined as both the direct and indirect contributions of nature and ecosystems to human well-being and our economy. The protection of natural capital that ecosystems services depend on is high on the EU political agenda.

Examples of activities promoting ecosystem services include: the sustainable management of forests which can then act as carbon sinks, the source of raw products and home to much European biodiversity, or the purification of wastewater in constructed artificial wetlands, which provide services such as urban storm water management and maintenance of bird habitats.

The EU Biodiversity Strategy to 2020 required Member States, with the assistance of the European Commission, to map and assess the state of ecosystems and their services in their national territory by 2014. They are also required to assess the economic value of such services and integrate them into national and EU accounting and reporting systems by 2020. Therefore, reliable and high-quality information on the condition of the ecosystems and their services at different scales is needed.

The JRC coordinates scientific efforts at EU level to provide the European Commission and Member States with spatial information on where ecosystem services are produced and how they benefit citizens, through the Mapping and Assessment of Ecosystems and their Services (MAES). MAES also provides valuable information for the development and implementation of related policies on water, climate, agriculture, forest, and regional planning. Consistent MAES throughout the EU is ensured by a structured framework and a broad set of key policy questions that link human societies and their well-being with the environment.



Ecosystem services are measured using the Total Ecosystem Services Index (TESI8), an aggregation of eight ecosystem services indicators, including for instance the provision of water, pollination of crops and nature based recreation. The map above presents change (%) in TESI8 expected for 2050 under the reference scenario for land use change relative to 2010.

This framework was tested through four thematic pilot studies on forests, agro-ecosystems, freshwater and marine ecosystems. The pilots included stakeholders and experts working at different scales and levels of governance who contributed indicators to assess the state of ecosystem services. Indicators were scored according to different criteria and assorted per ecosystem type and ecosystem service harmonised according to the Common International Classification of Ecosystem Services (CICES). Results highlighted the potential to develop the first EU-wide ecosystem assessment on the basis of existing data. However, substantial data gaps remain to be filled before a fully integrated and complete ecosystem assessment can be carried out.

JRC scientists developed a model called ESTIMAP (Ecosystem services mapping at European scale) which uses land-cover and land-use maps as a starting point to which other spatial information is added for mapping several ecosystem services. Using the new model, they estimated that in the EU every 1 % increase in artificial lands (roads, buildings) should be compensated with an increase of 2.2 % in green infrastructure (natural or semi-natural areas) within the same region, in order to maintain ecosystem services at 2010 levels – the base year of the EU Biodiversity strategy to 2020. Projections of land-use and ecosystem services are based on LUISA, the JRC's Land-Use based Integrated Sustainability Assessment modelling platform. Outcomes of modelling efforts on a European scale are subject to uncertainty which may limit the application of mapping and assessment for decision-making. Therefore, the JRC has been collaborating

with other research teams in Europe to address these issues of error and uncertainty. Such studies involved cross-scale analysis of ecosystem services as well as comparison of ecosystem service maps at the European scale. Despite differences emerging across methods and scales, this collaborative research has provided encouraging results and contributed to delivering a coherent message on the health of global ecosystems and the benefits they offer to society.

Work in progress

As the natural environment's contribution to human well-being has remained unknown or overlooked for a long time, many ecosystems across the EU have been degraded, and their capacity to provide services is currently compromised. Mapping and assessing the ecosystems and services provided by the EU territory and associated waters are fundamental for the implementation of Action 5 in the EU Biodiversity Strategy. Quantifying services such as water purification, nature-based recreation, or forest-associated carbon storage would highlight how the economy depends on natural capital, thereby contributing to the better integration of impacts and dependencies on ecosystems in decision-making.

The JRC is engaged in several pilot studies and projects to further develop the mapping of ecosystem services, namely in forests, soil and urban areas.

The JRC will also work with EU Member States and other European Commission services in the framework of the recently established Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). In the years to come, IPBES will promote regional and global assessments of biodiversity and ecosystem services. The mapping of ecosystem services has already been acknowledged as providing essential inputs to these upcoming assessments.

2.2 Preserving biodiversity and protected areas through monitoring and assessment

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 3 May 2011 – Our life insurance, our natural capital: an EU biodiversity strategy to 2020, COM(2011) 244 final
- Regulation (EU) 1143/2014 of the European Parliament and of the Council of 22 October 2014 – On the prevention and management of the introduction and spread of invasive alien species (Art. 25: Information support system to be established by the Commission).

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A Blueprint to Safeguard Europe's Water Resources COM(2012) 673
- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
- Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy
- Communication from the Commission to the Council and the European Parliament establishing an Environment Strategy for the Mediterranean {SEC(2006) 1082}
- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – Thematic Strategy for Soil Protection {SEC(2006) 620} {SEC(2006) 1165}
- Common Agricultural Policy (CAP): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future COM(2010) 672
- Common Fisheries Policy (CFP): Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy
- Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds
- Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora
- UN Convention on Biological Diversity 2020 (CBD) – Aichi Target 9 (alien species), target 14 (Ecosystem services), target 17 (National biodiversity strategies) The EU Biodiversity for Life (B4Life) Flagship Initiative: B4Life is a flagship initiative of the European Commission Development and Cooperation - EuropeAid, for the period 2014-2020
- Global Soil Partnership (GSP) of the FAO.

Biodiversity is facing serious pressure, with around one in four species currently threatened with extinction. In order to achieve this objective, a better understanding is needed of the links between biodiversity, ecosystem functions, ecosystem services and human well-being.

The JRC provides the technical and scientific basis to support the implementation of several European policies and strategies that aim to promote the conservation of biodiversity and ecosystems and the efficient use of natural resources. Such policies include the EU Biodiversity Strategy to 2020, the 2012 Blueprint to Safeguard Europe's Water Resources, the EU Water Framework

Directive, the EU Marine Strategy Framework Directive, the Environmental Strategy for the Mediterranean, the EU Thematic Strategy for Soil Protection, the Common Agricultural Policy (CAP), the Birds Directive, the Habitats Directive, the Biodiversity for Life initiative, the Regulation on the prevention and management of the introduction and spread of invasive alien species, as well as the Convention on Biological Diversity. The JRC's main activities include mapping and assessment of the threats to biodiversity in soils, freshwater, seas, agricultural lands, forests, protected areas and by invasive alien species (IAS).

Rich **soil** biodiversity provides many benefits for ecosystems, contributing to a range of services such as food production, water filtration and nutrient cycling. In reality most terrestrial ecosystem services are linked to soil organisms. In addition, soil is a vibrant habitat in its own right: about 25 % of all living creatures are believed to live underground, and a teaspoon of soil can contain several billion organisms from thousands of different species.

The JRC assesses the state of soil biodiversity and raises awareness about this important issue. It has set up an international expert group to develop a soil biodiversity inventory for Europe and worldwide with the aim of evaluating and harmonising ongoing soil monitoring activities. In 2010, the JRC published the first European Atlas of Soil Biodiversity, which highlights the potential threats to soil biodiversity from multiple factors, including land-use change, habitat disruption, intensive use, invasive species, and soil compaction, erosion and pollution. These efforts were largely instrumental in getting soil recognised as a specific habitat within the UN Convention on Biological Diversity. JRC scientists are currently working on the first ever Global Soil Biodiversity Atlas.

When it comes to **fresh water**, the poor ecological state of many freshwater ecosystems is a global concern, especially given that they are intimately involved in ensuring water availability, which is likely to decline in the future. The JRC's scientific ecosystem modelling and monitoring services contribute to efforts to implement sound policies that will ensure the protection of these crucial ecosystems.

Marine biodiversity is scrutinised by the Marine Strategy Framework Directive (MSFD) which establishes a framework within which Member States must take the necessary measures to achieve or maintain good environmental status (GES) in the marine environment by the year 2020 at the latest. Member States are required to adopt marine strategies and action plans to be delivered in several stages and reviewed every six years, taking into account elements such as marine biodiversity, exploited fish, food webs and sea-floor integrity.

Through the MSFD Competence Centre (MCC), the JRC provides scientific methods, guidance and modelling tools for the MSFD Common Implementation Strategy (CIS). Work is done in close collaboration with other European Commission services, The European Environment Agency (EEA), EU Member States, Regional Sea Conventions (RSCs), the International Council for the Exploration of the Sea (ICES) and the research community.

Agricultural biodiversity can be threatened by the intensification of farming practices (e.g. increased use of agro-chemicals, simplification of crop rotations, increase of field size, removal of landscape elements) as well as by land abandonment. Environmental concern has been introduced to the Common Agriculture Policy (CAP) since the early nineties to mitigate the impacts of these two major drivers of agro-biodiversity loss, and to enhance the contribution of agriculture to biodiversity maintenance and an enhanced supply of ecosystem services (e.g. pollination, pest control, soil erosion mitigation), while reducing negative impacts (nutrient leaching, GHG emissions etc.). The JRC supports the implementation of CAP by assessing the impacts of agricultural practices on the environment through geospatial and modelling activities, both in ex-ante and ex-post evaluations, at regional and farm level.

Forests cover nearly 40 % of the European surface. In addition to the supply of wood, to which most forested European land is dedicated, forests provide multiple benefits in terms of climate regulation, human health, recreation, fresh water supply and reservoirs of biodiversity. Forests and biodiversity are strongly interlinked. On the one hand, biodiversity depends on a large extent on the integrity, health and vitality of forested areas. On the other hand, a decline in forest biodiversity will lead to losses in forest productivity and sustainability. Therefore, sustainable forest management aims to support the provision of forest goods and services and to enhance biodiversity levels.

The JRC delivers policy-relevant information on the status and trends of forests. It derives this information from advanced remote sensing, forest models and multi-sectorial sources via its information systems and spatial modelling tools. The JRC acts as the focal point for forest information at a European level via its European Forest Data Centre (EFDAC).

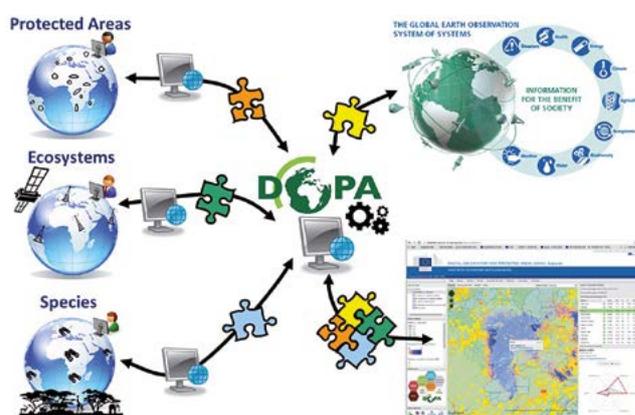
Invasive alien species are another area of concern. Human activities, such as shipping, aquaculture, canal construction and trade, have removed some of the physical barriers between bio-communities, thereby allowing species to enter regions outside their native ranges. Europe is severely affected by biological invasions, which are considered as one of the most important direct drivers of biodiversity loss, and a major pressure to several types of ecosystems, with both ecological and economic impact.

In 2012, the JRC launched the European Alien Species Information Network (EASIN) to facilitate the exploration of information on existing alien species and to assist in the implementation of European policies on biological invasions and of the United Nations Convention on Biological Diversity (CBD). At the core of EASIN, there is an inventory of all known alien species and of those species which 'origins are unknown' in Europe with their taxonomic classification, pathways of introduction, year and country of first introduction. All this information is publicly available through a widget framework, providing user-friendly online tools for searching and mapping. The EASIN datasets have been used for pan-European or regional assessments of pathways and gateways of alien invasions, towards

the fulfilment of the related targets of the Convention on Biological Diversity and of European policies. EASIN is also the supporting tool for the implementation of the Regulation 1143/2014 on invasive alien species (IAS), in force since 1 January 2015. To this end, the system is undergoing further development with a creation of an Early Warning system, through which Member States must notify the EU Commission and the other Member States about the detection of an IAS of EU concern, and to report on the eradication measures applied and their efficacy.

Protected areas are essential for the conservation of biodiversity and ecosystems, and their expansion is a main objective of the EU and the United Nations. They are also particularly important in developing countries where populations generally depend on natural resources. The international community is therefore committed to protect at least 17 % of terrestrial and inland water areas and 10 % of coastal and marine areas by 2020 (Aichi target 11).

In support of this process, the JRC has developed the Digital Observatory for Protected Areas (DOPA) to help end users to assess, monitor and forecast biodiversity in protected areas. Recognised by the CBD, DOPA's open source web-based tools reinforce the capacity of policy-makers, managers and experts to use biodiversity data. DOPA integrates global reference datasets, such as the International Union for Conservation of Nature (IUCN)'s Red List of Threatened Species, the United Nations Environment Programme's World Conservation Monitoring Centre (UNEP-WCMC)'s World Database on Protected Areas and the JRC's modelling tools and remote sensing products such as the Global Land Cover 2000 database.



DOPA provides online information about protected areas.

Furthermore, the JRC is supporting the setting up of information systems in Bolivia (PACSBio project) and the deployment of regional observatories in African, Caribbean and Pacific (ACP) countries, as planned by the Biodiversity and Protected Areas Management Programme (BIOPAMA) which is supported by the European Development Fund.

A new interface to the Digital Observatory for Protected Areas, DOPA Explorer 1.0, is now available online in four languages. Covering all protected areas with a surface area equal to or greater than 100 km², it represents nearly 16 000 protected areas worldwide.

DOPA Explorer 1.0 is a unique tool which provides key indicators on species, pressures and the ecological features of protected areas in a simple interface that is suitable for reporting purposes. DOPA's analytical tools have been further used to support the UNEP World Conservation Monitoring Centre in preparing the Protected Planet Report 2014, which provides an overview of global progress towards the Aichi Biodiversity Targets, as well as assisting the EU Delegation during negotiations of the CBD's 11th Conference of the Parties (COP 11).

Work in progress

In 2015, the JRC worked on the Mid-term Report (MTR) on the implementation and achievement of the EU Biodiversity Strategy. In the coming years, it will contribute to the final report, which is due in 2020.

2.3 Supporting green infrastructure to prevent further fragmentation of ecosystems

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 3 May 2011 – Our life insurance, our natural capital: an EU biodiversity strategy to 2020, COM(2011) 244 final
- Habitat Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Natura 2000 network)
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A new EU Forest Strategy: for forests and the forest-based sector COM(2013) 659, on Sustainable forest management and the multifunctional role of forests
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Green Infrastructure (GI) - Enhancing Europe's Natural Capital, COM(2013) 249
- Forest Europe, Ministerial Process on the Protection of Forest in Europe: State of Europe's Forest 2011 report (Forest Europe, 2011 and 2015): indicator 4.7 Landscape Forest Spatial Pattern
- Convention on Biological Diversity 2020 (CBD) – Aichi Target 5 (Fragmentation/Degradation), Target 11 (Connectivity of Protected Areas)
- Pan-European process 'Streamlining European Biodiversity Indicators (SEBI)' of the European Environment Agency (EEA): (SEBI 2010-report 4 and 5, 2012 report and forthcoming SEBI2015 assessment): indicator ecosystems fragmentation and connectivity

- United States Department of Agriculture (USDA) Forest Inventory and Analysis, Fiscal Year 2013 Business Report.
- USDA Forest Service 2010 Resources Planning Act (RPA) Assessment
- National Forest Inventories (Brasil, Columbia)
- United Nations Framework Convention on Climate Change, REDD+ for reducing emissions from deforestation and forest degradation.

In Europe and beyond, the continued expansion of grey infrastructure, such as urban and transport infrastructures, and of intensive agriculture are increasingly eroding and fragmenting our natural capital or green infrastructure. This fact constitutes one of the biggest threats to biodiversity. Both the area and the spatial pattern of natural ecosystems change in the landscape, with impacts on the functioning and resilience of ecosystems, including among others, species dispersal and the spread of alien species and pests. These changes modify the capacity of ecosystems to sustain ecological services like habitat provision, disturbance and climate regulation as well as recreation. The effects of such changes will likely be exacerbated in the context of climate change. Green Infrastructure (GI) is introduced as one policy tool to mitigate fragmentation and achieve connectivity and 'smart conservation'. This includes developing and protecting networks of green, natural features, and increasing the spatial and functional connectivity of ecosystems between protected (such as Natura 2000 sites) and un-protected areas. Besides the GI political process of raising awareness and calling for multi-sectoral integration, there is the need to map, measure and monitor GI at multiple scales. Species-specific connectivity assessments are mainly conducted on a local and regional scale, but there is still a lack of a 'macro-scale' spatially explicit and harmonised view of the fragmentation and connectivity of ecosystems and protected spaces in Europe (and beyond). Furthermore, tools and methodological guidance for connectivity are also needed in ecosystem management and planning to better guide conservation and restoration efforts and support the GI process.

The JRC supports European environmental policies on biodiversity, forestry, Natura 2000 and green infrastructure by developing spatially explicit models and a standardised set of indices to help map and assess green infrastructure in Europe (and beyond), which allows for better tackling habitat fragmentation and reduced connectivity caused by grey infrastructure and land-use intensification.

The JRC has developed an integrated modelling framework including a core set of indicators to measure fragmentation, pattern and connectivity, which are applied to European-wide forests and natural and semi-natural lands reporting processes (Forest Europe 2015). The set of indicators has also been tested to map and measure the connectivity between the Natura 2000 protected sites network at country level. Within a regional case study, connectivity between Natura 2000 sites was evaluated in the context of fire, transport infrastructure

and climate change. The relevance of this set of indicators and results for forest management, conservation and restoration were discussed with practitioners and planning authorities at regional level. The set is currently being amended to better support the mapping of green infrastructure in Europe. In parallel, the JRC has developed the Guidos Toolbox freeware (Graphical User Interface for the Description of image Objects and their Shapes), which offers a collection of JRC-developed generic image-processing methodologies for the analysis of pattern morphology. It has recently been enriched for the analysis of structural and functional connectivity, fragmentation, edge interface, distance and change analysis. The Guidos Toolbox is used for the analysis and official reporting of national forests and grasslands (for example in the United States) and the distribution of the resulting national maps as image overlays in Google Earth. It is being tested in countries such as Brazil and Colombia. The JRC's core set of indicators is currently being made available from the Guidos Toolbox. The JRC organises training for the Guidos Toolbox free software at scientific conferences and national agencies.

Work in progress

The JRC is working on the development of a new version of the Guidos Toolbox freeware integrating the latest developments. It will continue working on the application of the core set of indicators to support forest fragmentation reporting within Europe and beyond as well as to support the mapping of Green Infrastructure for an improved ecosystem and landscape management in Europe.

2.4 Measuring landscape impacts of farming practices

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Common Agricultural Policy (CAP): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future COM(2010) 672
- European Landscape Convention (Council of Europe, Florence 2000)
- COM(2010) 672 final; Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future
- Regulation (EU) No 1305/2013 of the European Parliament and of the Council, of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005.

The adaptation of agricultural and farming practices to local conditions and the land-use changes driven by the CAP have led to a wide variety of landscapes in Europe. Landscape management is one of the most relevant public goods provided by agriculture. Apart from being important drivers of tourism, landscapes in specific geographical areas also enable the development of products with quality labels, such as Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI). Nowadays, the role of agriculture in providing public goods in rural areas is acknowledged in the future of agriculture and in agricultural policy.

However, robust information on the connection between agriculture, agricultural policy, landscape, biodiversity and the rural economy is still lacking. The JRC is supporting the design of an effective CAP policy for improved landscape management. It provides insights on the ability of landscapes to contribute to creating added value for society in rural areas. This includes analysing the impact of CAP design on the landscape, understanding the contribution of landscape management to socio-economic development and agricultural competitiveness in rural areas, and reflecting on possible ways to enhance it. Based on a literature review and case studies analysis, JRC scientists have analysed how the design and implementation of the CAP have influenced agricultural landscapes.

The JRC has provided a catalogue of past, current and future CAP measures and their potential effects. Based on nine case studies, the role of the CAP in fostering landscape change and its contribution to socio-economic development has been assessed, including a rise in employment, income per capita and competitiveness. The JRC has also outlined some recommendations to steer CAP design in the direction of improved landscape management, to foster a more sustainable agriculture. Analysis showed clearly that different agricultural practices such as soil tillage and irrigation have diverse environmental impacts on carbon sequestration, water pollution, soil erosion and maintaining biodiversity. The JRC has proposed a typology characterising the scales relevant to managing agricultural landscapes as well as actions to achieve an integrated landscape planning and to maintain the diversity and coherence of European landscapes. It has also analysed how the recognition and transposition of the European Landscape Convention could promote trans-frontier landscape cooperation.

Work in progress

The JRC will keep working on the final implementation of the CAP post-2015 instruments at Member State, regional and farm level in order to restore, preserve and enhance the state of European landscapes. A key remaining challenge is to assess policy instruments aiming at coordinating landowners' actions in order to maintain the diversity of agricultural landscapes.



3 Resource efficiency

The environment, society and the economy are interlinked. A more efficient use of resources often reduces environmental costs, while new environmentally-friendly technologies may create employment, thus strengthening the competitiveness of European industry. The circular economy, which requires more re-use and high quality recycling to reduce dependence on primary raw materials, is key for achieving the overall objective of resource efficiency under the Europe 2020 Strategy. With the Roadmap to a Resource Efficient Europe in 2011, the Commission proposed a framework for action and underlined the need for an integrated approach across many policy areas and levels in order to make Europe's economy more sustainable by 2050. This ensures synergies and coherence between EU policies, while ensuring a level playing field for the business sector and preventing obstacles undermining the Single Market. The Circular Economy Package, which was adopted in December 2015, further strengthens this approach by delivering ambitious measures to cut resource use, reduce waste and boost recycling and thus consider each step of the value chain; from production to consumption, repair and remanufacturing, waste management, and the use of secondary raw materials.

In this context, the JRC promotes a life-cycle approach and supports EU policies fostering a more efficient use of resources in areas such as recycling, waste management or best available techniques for industrial installations.

3.1 Enhancing waste management to contribute to a European circular economy

The JRC's activities in this area provide scientific support to the following policy initiatives:

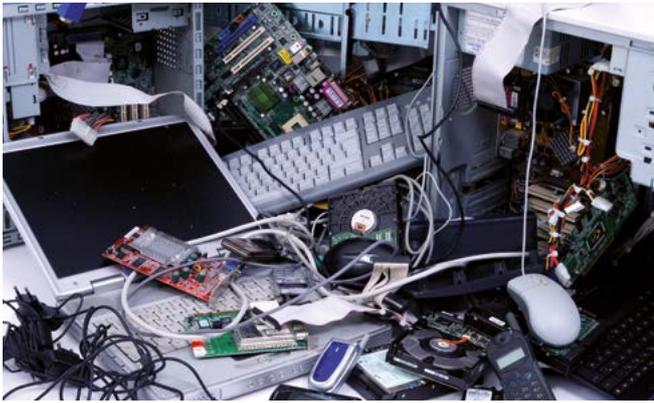
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 20 September 2011 – Roadmap to a Resource Efficient Europe, COM(2011) 571
- Communication from the Commission to the Council and the European Parliament of 18 May 2010 on future steps in bio-waste management in the European Union COM(2010) 235
- Communication from the Commission to the European Parliament and the Council of 4 November 2008 – The raw materials initiative: meeting our critical needs for growth and jobs in Europe, COM(2008) 699

- Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives
- Directive 2009/125/ of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products
- Regulation No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 21 December 2005 – Taking sustainable use of resources forward – A Thematic Strategy on the prevention and recycling of waste COM(2005) 666 final.

European policies are establishing more and more ambitious targets and requirements for waste disposal, recycling and prevention to make waste management more sustainable and able to contribute to the creation of a solid European circular economy. Waste management has a great potential to help reduce reliance on imported raw materials, thereby addressing security-of-supply concerns, and to facilitate competitive advantage through more socially and environmentally preferable goods and services.

However, existing policies do not always provide guidance on how to identify the best options to reach these targets. At the same time, European waste management is becoming increasingly complex due to the massive generation of waste and the growing number of different waste streams requiring specific treatment routes. This makes it difficult to assess the environmental performance of European waste management and to identify options for improving this performance. The JRC has extensive expertise in the field of waste management, recycling and resource efficiency, which is essential for establishing a sustainable, strong circular economy in Europe.

The JRC has developed a series of technical documents that provide step-by-step guidance on how to use Life Cycle Thinking (LCT) and Life Cycle Analysis (LCA) in order to determine the most environmentally sound waste management options. Such guidance is provided at both the general level, for municipal solid waste, and at the level of specific waste streams such as biodegradable waste. Since about one third of the food produced is wasted throughout the food supply chain, the JRC is currently focusing on fine-tuning its methodology for food waste prevention and recycling.



The LCA allows the impacts of different waste streams and different management steps, such as collection, landfill and recycling, to be evaluated. New approaches are needed to better inform decision-makers on how best to deal with waste.

The JRC has also developed life-cycle-based quantitative indicators to monitor the environmental performance of European waste management. These indicators can be used to evaluate the overall environmental impact of European waste management. Such indicators have been applied to Waste Electrical and Electronic Equipment (WEEE), plastic waste, discarded vehicles, paper and cardboard, and metallic waste.

In order to turn waste into a resource, it is important to implement systematic preventive actions to ensure that products put on the market either do not become waste too quickly – by ensuring durability and reparability – or can be handled efficiently in waste management facilities – by ensuring recyclability. In recent years, the JRC has developed the ‘resource efficiency assessment of products’ method to assess product resource-efficiency performance according to various criteria. The results of such assessment can be used in policy-making to define the minimum criteria with which products put on the market must comply. This method can also be applied to enhance the efficiency of reuse and recycling specific waste streams which contain critical raw materials.

In order to implement prevention measures and enhance the better recycling of complex products, the JRC has developed a new method to assess and improve the resource efficiency of energy-using products, with a particular focus on their end of life. The ‘Resource Efficiency Assessment of Products’ (REAPro) method includes a set of different environmental indexes, based on a life-cycle approach, related to reusability, recyclability and recoverability, recycled content, durability and the use of hazardous substances. The method identifies product components that are relevant to some environmental aspects and possible design measures to improve the product’s overall efficiency. To test this method, the JRC conducted a case study on a Liquid Cristal Display (LCD). Possible measures to improve the resource efficiency of LCD televisions were identified, such as: improving product recyclability by setting time thresholds for their dismantling; setting a minimum amount of recycled

content to be included in large plastic parts; and declaring the amount of indium (a critical raw material) content in the displays. Results were notably being used for the the revision of EU Ecodesign implementing measures for electronic displays (TVs and computer screens), and revision of the EU Ecolabel criteria for Televisions and for Personal & Notebook Computers.

3.2 Estimating environmental footprints of products and promoting life-cycle thinking

The JRC’s activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 19 May 2015 – Better regulation for better results. An EU agenda, COM(2015) 215 final
- Communication from the Commission to the European Parliament and the Council of 9 April 2013 – Building the Single Market for Green Products – Facilitating better information on the environmental performance of products and organisations, COM(2013) 196 final
- Commission Recommendation 2013/179/EU of 9 April 2013 – On the use of common methods to measure and communicate the life cycle environmental performance of products and organisations
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 2 July 2014 – Towards a circular economy: A zero waste programme for Europe COM(2014) 398 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 20 September 2011 – Roadmap to a resource efficient Europe COM(2011) 571 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 21 December 2005 – Taking sustainable use of resources forward – A Thematic Strategy on the prevention and recycling of waste COM(2005) 666 final.

When people go shopping for a ‘green’ product today, they are faced with a wealth of information. For instance, there are more than 400 labels aiming to communicate environmental information to consumers. While some environmental labels are very similar, others that appear to be similar actually differ in terms of what they evaluate and how they do it. According to a Eurobarometer survey published in 2013, 48 % of European consumers are

confused by the volume of environmental information they receive. This also affects their readiness to make green purchases.

Life Cycle Assessment (LCA) is a tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its life cycle. To decide whether a product can be 'green', different aspects need to be considered, such as its effects on climate change, land and water use, and the environmental impacts of its components, especially toxic substances like heavy metals. All the environmental impacts of its entire life cycle must be quantified, from the sourcing of raw materials, through manufacturing, retail, use, recycling, energy recovery and final disposal, including relevant transport. Therefore, a systematic approach is needed to ensure that important issues are not overlooked and that their resolution does not create other issues elsewhere in the product's life cycle.



Life-cycle assessment allows to evaluate the environmental aspects of a product or service through all stages of its life cycle.

Companies intending to produce 'green products' in the EU are faced with a confusing choice of methods and initiatives, some of which are mandatory to prove a product's green credentials. This is becoming a barrier to the circulation of green products within the European Single Market.

To address this situation, in 2013 the European Commission launched the Single Market for Green Products initiative, which includes the setting up of two methods for Member States to measure the environmental performance of their organisations and products throughout their life cycle, namely the Product Environmental Footprint (PEF) and the Organisation Environmental Footprint (OEF). This comprises a three-year testing period to develop product- and sector-specific rules and to define principles for communicating environmental performance in order to pre-empt the so-called 'green-washing'. This initiative is contributing to international efforts towards the better coordination of methodological development and data availability, notably through the United Nations Environment Programme (UNEP).

As part of this initiative, the JRC leads the technical and scientific development of the 'environmental footprint'

method, based on Life Cycle Assessment (LCA). This method is used to assess the environmental performance of products and organisations in a harmonised and robust way, and to identify 'hot spots' along a product's lifecycle and how the environmental performance of the product can be improved.

The JRC is also working on quantifying the environmental impact associated with food production and food consumption, by estimating food products' footprints, in particular carbon footprints (total GHG emissions measured in CO₂-equivalents), nitrogen footprints (total losses of reactive nitrogen in the food production chain), and water footprints (consumption of surface and groundwater resources associated with food consumption). Study results have identified that livestock products like meat have carbon and nitrogen footprints about 10 times higher than vegetable products, with significant differences within food groups and across countries and production systems. Livestock production alone has been estimated to contribute to 14.5 % of the total anthropogenic GHG emissions, adding to air, water and soil pollution.

The JRC is part of international dialogues and initiatives under the leadership of the United Nations Environment Programme (UNEP) that aim at facilitating the availability and quality-assurance of data, methods, and studies. In this context, the JRC in co-ordination with the Directorate General for the Environment, runs the European Platform on Life Cycle Assessment (EPLCA) that supports both Life Cycle Thinking and Assessment. Through this platform, the JRC provides comprehensive information on LCA services, tools, databases and providers on a global scale, as well as on existing assessments and related ecodesign and labelling. The platform is a valuable source of information not only for business, but also governments.

Work in progress

Together with participants from industry and other stakeholders, and under the leadership of the European Commission's Directorate-General for the Environment, the JRC is participating in the ongoing environmental footprint pilot tests to generate product and sector specific guidelines. These pilot tests cover a wide range of products and sectors such as detergents, T-shirts, meat, dairy, leather, pet food, paper, olive oil as well as copper-producing companies. The JRC is leading the last three of 25 pilot tests. The robust and focused guidance documents specific to each product category and sector will enable a fair comparison of products within the same category. All pilot tests, which conducted in a transparent and inclusive manner, will be completed by the end of 2016, upon which the evaluation of the entire process and policy options will be evaluated.

A key challenge remaining is to develop a method that compares the relevance of the different environmental

problems. This should help to determine for instance whether it is more important to consider toxicity rather than climate change or the consumption of natural resources. This ‘weighting’ of different environmental impacts is very useful for business and policy decision-makers.

To bring in a more comprehensive and consistent evaluation of EU policy initiatives, the new Better Regulation Guidelines that aim to design EU policies and laws so that they achieve their objectives in the most efficient and effective way possible, now refer to life-cycle analysis among tools in the ‘Better Regulation Toolbox’ that can be used in the required policy impact assessment.

3.3 Reinforcing sustainable product policies, best environmental practices and end of waste

The JRC’s activities in this area provide scientific support to the following policy initiatives:

- Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 16 July 2008 – Public procurement for a better environment COM(2008) 400
- Directive 2009/125/EC/ of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products
- Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products
- Regulation (EC) No 1221/2009 of the European Parliament and of the Council of 25 November 2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS)
- Communication from the Commission of 8 December 2011 — Establishment of the working plan setting out an indicative list of sectors for the adoption of sectoral and cross-sectoral reference documents, under Regulation (EC) No 1221/2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS)
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 31 January 2013 – Setting up a European Retail Action Plan, COM(2013) 36
- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – Taking sustainable use of resources forward - A Thematic Strategy on the prevention and recycling of waste {SEC(2005) 1681} {SEC(2005) 1682}

- Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives
- Council Regulation (EU) No 333/2011 of 31 March 2011 establishing criteria determining when certain types of scrap metal cease to be waste under Directive 2008/98/EC of the European Parliament and of the Council
- Commission Regulation (EU) No 1179/2012 of 10 December 2012 establishing criteria determining when glass cullet ceases to be waste under Directive 2008/98/EC of the European Parliament and of the Council
- Commission Regulation (EU) No 715/2013 of 25 July 2013 establishing criteria determining when copper scrap ceases to be waste under Directive 2008/98/EC of the European Parliament and of the Council.

Sustainable product policies

In Europe, mandatory or voluntary policy instruments address consumption and production of the goods whose use and manufacture affect the environment. Their objective is to exclude the most damaging products from the European Single Market, and give greater visibility to environmentally friendly products.

The JRC operates the European Product Bureau (EPB), which manages the policy implementation process for the EU Ecolabel Regulation, the Green Public Procurement Communication, and the requirements of the Ecodesign and Energy Labelling Directive, thus helping consumers and companies to design and buy energy-efficient products. The Bureau assesses the minimum technical, economic and environmental requirements for products to be placed on the European Single Market, and develops proposals for product specifications which are achievable by the 10-20 % best performing products. The EPB organises consultations with stakeholders from EU countries, industry and NGOs, and prepares draft legal texts for the respective policies. These texts are then passed for consultation within the European Commission and voted upon by the Member States in the Regulatory Committee.

Best Environmental Management Practices

The JRC investigates the Best Environmental Management Practices (BEMPs) based on an in-depth review of scientific literature, interviews with experts and stakeholders, and site visits. It identifies comprehensive sets of environmental performance indicators and benchmarks of excellence, taking into account their economic viability and technical feasibility. These indicators, validated by a technical working group, enable companies to monitor and compare their environmental performance over time, across facilities and sectors, and to estimate their improvement potential and establish priorities for action. As an example of an excellence indicator, heat consumption of 0 kWh/m² year can be achieved by large food retailers by recovering waste heat from the refrigeration cycle.

End of waste

Today, more than ever, the European Commission is working hard to preserve limited natural resources. In recent decades, waste has grown constantly in the EU because of the unsustainable 'take-make-consume and dispose' pattern of growth adopted: a linear model which assumes that resources are abundant, available, cheap and sustainable to dispose of. The real environmental impacts of the disposal of man-made materials and products are better known now and the need for a more circular economy has been recognised. This means re-using, repairing, refurbishing and recycling existing materials and products in order to recover the effort employed in manufacturing them and avoid the cost of disposal.



End of waste criteria facilitate recycling.

In 2004, the Commission launched the Thematic Strategy on the prevention and recycling of waste, which has since been reinforced by the Raw Materials Initiative (2008) and the revision of Circular Economy Package (2015). This Thematic Strategy aims to help Europe become a recycling society that avoids waste and uses any unavoidable waste as a resource. Since its inception, the JRC has been collaborating closely with the Commission's Directorate-General for the Environment to implement EU waste policies. As one of the tools envisaged in the Waste Framework Directive to stimulate the development of the recycling sector, the JRC has developed the framework of 'end-of-waste status' for certain waste streams to be reintegrated into the production cycles again. To this end, the JRC has coordinated a rigorous and transparent consensus building exercise of stakeholder techno-economic groups.

The JRC has prepared the technical proposals for the first EU Regulations on end-of-waste criteria for aluminium, iron and steel scrap, for glass cullet, and for copper scrap. It has also furthered end-of-waste criteria proposals on paper, plastics and on biodegradable waste subject to biological treatment, such as compost and digestate. The JRC has monitored the implementation of end-of-waste for metals in the EU. Results of the research indicate that only two years after the

introduction of the Regulation, end-of-waste scrap already represented 10 % and 15 % respectively of the European scrap markets for aluminium and steel.

Work in progress

The JRC is currently working on identifying the best environmental management practices and is developing related sectoral reference documents for the following sectors: agriculture, crop and animal production, food and beverages, cars, electronic and electrical equipment, waste management, fabricated metal products, and telecommunications.

In order to assess the feasibility of additional materials with the potential to receive end-of-waste status, the JRC has undertaken studies on the methodology regarding limit values for pollutants in aggregates and on the suitability of different waste-derived fuels for end-of-waste status. In the future, the JRC will offer its scientific input to develop end-of-waste criteria on other recyclable waste streams such as fertilisers, and waste plastics.

3.4 Providing knowledge on critical raw materials

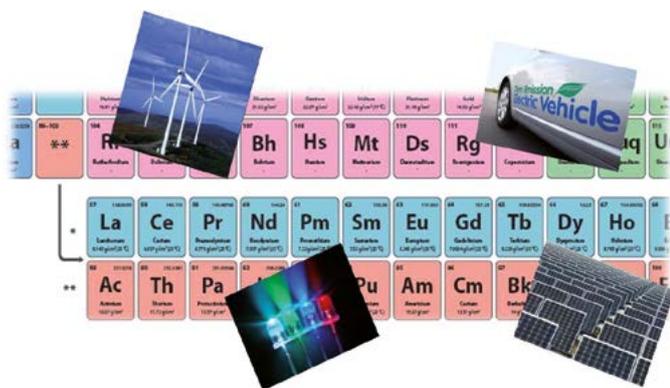
The JRC's activities in this area provide scientific support to the following policy initiative:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 26 May 2014 – On the review of the list of critical raw materials for the EU and the implementation of the Raw Materials Initiative COM(2014) 297 final and annexed SWD(2014) 171 final (JRC activities are explicitly highlighted).

European industry relies on raw materials, many of which are supplied by a limited number of countries outside the EU. These raw materials can be extracted, harvested, or come from waste. Some raw materials can be critical to entire sectors of European business with the obvious high risks associated with supply interruption.

The European Commission has established the Raw Materials Initiative with the aim of facilitating competitiveness and growth through the sustainable supply of raw materials. In support of this Initiative, the JRC participates in the review of the methodology to identify critical raw materials, collated in a list that is updated every three years. The JRC is also contributing to the development of the Raw Material Scoreboard, which aims to help monitor related growth and competitiveness. Complementing these, the JRC is supporting the development of the European Union Raw Materials Knowledge Base (EURMKB).

Together with other experts, JRC scientists model the supply chains, including waste management operations to assess the origins of raw materials from extraction



Some low-carbon energy technologies rely on critical raw materials.

and from recycling. They assess the associated risks and economic importance of various raw materials to European businesses. This facilitates the analysis of different factors influencing the materials' security-of-supply, as well as the sustainability of supply from extraction, harvesting and from waste. This includes modelling supply chains to understand where raw materials are consumed, and assessing more sustainable alternatives.

In March 2015, the JRC launched the Raw Materials Information System (RMIS), an online repository of information on policies, activities and data related to the European raw materials sector. It provides a structured database of knowledge on non-energy-related raw materials. This includes links to data, methods, approaches and indicators related to the most relevant activities on raw materials. The system aims at strengthening the visibility and competitiveness of the EU raw materials sector, while promoting sustainable growth. The RMIS contributes to the EU Raw Materials Initiative and supports the activities of the European Commission's Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs in the context of non-energy raw materials, including the European Innovation Partnership (EIP).

The JRC has developed life-cycle data, methods and studies in order to quantify the knowledge base on critical raw materials. These data outline the resources consumed, emissions, and social pressures associated with the supply chains, use, and end-of-life waste management operations of different goods and services produced and consumed in the EU. This knowledge is widely used in business and governance to support decision-making to help monitor and identify options for improvements. The European Platform on Life Cycle Data is a key foundation of these activities that is managed by the JRC.

Work in progress

The JRC will continue to support the advancement of the knowledge base and methodology required for the sustainable supply of raw materials, facilitating growth and competitiveness. This includes further development of the Raw Materials Information System, the analysis of critical raw materials' risk and resilience, the Raw Material Scoreboard and the European Platform on Life Cycle Assessment.

3.5 Assessing water resources and their socio-ecological implications

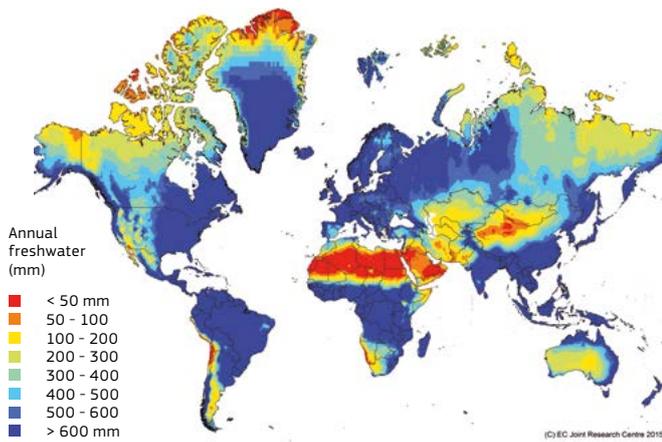
The JRC's activities in this area provide scientific support to the following policy initiatives:

- The Water Framework Directive 60/2000/EC and related legislation, setting objectives of good status of water, equilibrium of the water balance, and full recovery of the costs of water services
- Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (setting objectives of protection from floods and management of related risks)
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A blueprint to safeguard Europe's water resources COM(2012) 673 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – An EU Strategy on adaptation to climate change, COM(2013) 216 final
- European green growth objectives in the context of the Europe 2020 strategy
- European Union Water Initiative (EUWI), launched at the 2002 Johannesburg World Summit for Sustainable Development
- Joint Africa-Europe Strategy (JAES) Water Partnership
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions European Union Strategy for Danube Region COM(2010)0715 final
- European Neighborhood Policy.

Water is a critical element: food and energy production and the functioning of society and ecosystems depend on water, and all human activities have an impact on water quantity and quality. Analysis of the nexus between water, food, energy and ecosystems is at the core of the JRC's water research. The JRC provides policy-makers with scientific support in the design and implementation of strategies, legislation and measures to ensure sustainable development through the appropriate use of water resources.

By combining economic analysis of the use of water, hydrology and ecology, JRC scientists study how land use, human activities and climate change may affect future water quality and availability, and the state of water-dependent ecosystems. Through a cross-analysis of environmental and socio-economic development indicators, the JRC identifies main actions that policies could take to address future challenges.

By analysing the status of river basins, existing water abstractions, pollution or the artificial modification of rivers and lakes, JRC scientists help water and land planners to identify the most cost-effective solutions to improve the health of water and ecosystems and to address water scarcity and flood hazards.



The map presents total annual freshwater renewal (mm) in the world.

The JRC's integrated hydro-economic models are jointly used in an integrated water modelling platform' combining hydrology, water and habitat quality, and human water use and water economics. These models have been used extensively to assess the impact of future scenarios of land use, climate change and variability, economic development and policy implementation on a European scale, for selected European macro-regions and partner countries. JRC simulations have supported, among others, the impact assessment of the Commission's Blueprint to Safeguard Europe's Water Resources.

On a regional scale, the JRC is supporting the EU Strategy for the Danube Region and the International Commission for the Protection of the Danube River (ICPDR) in the development of the Danube river basin management plan and identification of strategies for sustainable development in the region, the so-called Danube Water Nexus.

In a global context, the JRC is part of the EU Water Initiative (EUWI) coordination group for the Mediterranean, Africa, Latin America, Eastern Europe, Caucasus, Central Asia and China, participating in development and cooperation activities in the water sector.

As regards the activities implemented together with EU countries, JRC scientists have developed a Water Knowledge Management Platform, AQUAKNOW.NET, to support water practitioners by providing them with online capacity-building courses, guidelines, case studies, data and information. The JRC has also developed two continental networks of centres of excellence on water in Africa and Latin America. Coordinated by the JRC, these centres provide technical and scientific support and capacity-building to the African Ministers' Council on Water (AMCOW) and Latin American Water Directors (CODIA). The JRC has developed the EU Water Project Toolkit, available on the AQUAKNOW platform, which provides practitioners with a strategic approach to managing water resources efficiently and sustainably. Some of the measures analysed include nutrient management, water efficiency and natural water-retention measures, to achieve satisfactory flood management, modulation of water availability and reduction of nutrient loads flowing into the sea.

Work in progress

Furthermore, the JRC is working on integrated assessments to identify the most effective ways to manage the water nexus in transboundary European river basins and in partner countries, particularly in Africa and in the Mediterranean region.

Important applications of the JRC hydro-economic modelling concern the analysis of water prices that will affect water use in Europe, and the effectiveness of implementation of the EU water-related legislation in the Member States. The models are also applied on a global scale to quantify global water resources and their variability, and map the distribution, causes and extent of regional water cooperation and conflicts.

3.6 Providing standards for European installations to reduce industrial emissions

The JRC's activities in this area provide scientific support to the following policy initiative:

- Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control).

Agro-industrial activities contribute to sustainable growth in Europe, but also account for a considerable share of the overall pollution. This is why emissions into air, water and soil arising from industrial installations are subject to EU legislation, notably the Industrial Emissions Directive (IED). The IED regulates the emissions into air, water and soil of about 50 000 industrial installations across the EU, including large combustion plants, refineries, the chemical industry, the production and processing of metals, the mineral industry such as cement, lime, glass and ceramics, management and treatment of waste including incinerators, and intensive rearing of poultry and pigs. The installations covered by the Directive must be operated in accordance with a permit granted by the competent authorities in the Member States. Permit conditions must be based on the use of best available techniques (BAT), with the 'BAT conclusions' adopted by the Commission serving as the reference for setting those conditions. The JRC hosts and manages the European Integrated Pollution Prevention and Control Bureau (EIPPCB), set up to exchange information between the Commission, the EU Member States, industry and environmental NGOs on BAT. This has led to the development of BAT reference documents, called BREFs, containing the 'BAT conclusions', as well as background information on the sectors concerned, techniques applied and information on emerging techniques which could become future BAT. BAT conclusions are implementing acts under the industrial emissions legislation. They are necessary for EU Member States to update permit conditions and ensure compliance with the Directive. Without them, there is no legal regime to incorporate environmental performance levels into national legislation. Therefore,

they constitute the environmental technical standards that European installations must meet and contribute to the achievement of a level playing field in the European Union by aligning environmental performance requirements for industrial installations.



BAT conclusions help limit industrial emissions in the EU.

To draft the BREFs, the European Integrated Pollution Prevention and Control Bureau is in charge of setting up and steering the work of large technical working groups (TWGs) for each of the 34 industrial sectors covered by the IED. These groups are composed of up to 260 experts from EU countries, industry and NGO representatives as well as other European Commission services. Observers in TWGs include representatives of third countries such as Turkey and Norway, for example. It takes around three years to draw up and review a BREF using a procedure which is codified in the Commission Implementing Decision on the rules concerning guidance on the collection of data and on the drawing up of BAT reference documents and on their quality assurance (2012/119/EU).

In the international context, the European information exchange on best available techniques is considered to be an EU contribution to the global process initiated in 2002 at the World Summit on Sustainable Development to also enable non-EU countries to reap the benefits of this ambitious work.

The JRC's procedure and work on BREFs is recognised internationally by countries such as Brazil, Chile, China, India, Israel, Korea, Russia, Turkey and Ukraine as well as among organisations such as the World Bank which use the BREFs and are developing similar documents. In 2013, there were 173 000 BREF downloads all over the world. At the time of writing, the EIPPCB is working with a network of over 2400 experts on drawing up and reviewing BREFs. In the last four years, it has successfully managed to bring seven sets of BAT conclusions to formal adoption through the Member States Committee procedure.

Work in progress

BREFs are not limited to emissions but also cover other aspects, such as energy and material efficiency, waste prevention and recycling in a given industrial sector. They represent important guidance to Member States and

are relevant to many EU policies, such as the Circular Economy Package, the Energy Union action plan, the Clean Air Quality Package and the Water Framework Directive.

The JRC's EIPPCB is currently working on drawing up and reviewing several reference documents, namely on the intensive rearing of poultry and pigs, the large volume organic chemical industry, waste treatment, large combustion plants, waste incineration, and the preservation of wood and wood products with chemicals and surface treatment using organic solvents.

3.7 Supporting the development of standards and indicators for the bioeconomy sector

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 13 February 2012 – Innovating for Sustainable Growth: A Bioeconomy for Europe, COM(2012) 60 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 6 June 2012 – Renewable Energy: a major player in the European energy market, COM(2012) 271
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 20 September 2013 – A new EU Forest Strategy: for forests and the forest-based sector, COM(2013) 659 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 22 January 2014 – A policy framework for climate and energy in the period from 2020 to 2030, COM(2014) 15 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 22 January 2014 – For a European Industrial Renaissance, COM(2014) 14
- Communication from the Commission to the European Parliament and to the Council of 23 July 2014 – Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy, COM(2014) 520 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 2 July 2014 – Towards a circular economy: A zero waste programme for Europe, COM(2014) 398 final.

With a growing population and finite natural resources, Europe needs renewable biological resources to secure food, energy and materials. Sustainable production and exploitation of biological resources will enable more to be

produced from less, including from waste, while limiting the negative impacts on the environment and reducing the heavy dependency on fossil resources and mitigating climate change.

In this context, the EU Bioeconomy Strategy and its Action Plan aim to pave the way for a more innovative, resource efficient and competitive society that reconciles food security with the sustainable use of renewable resources for industrial purposes, while ensuring environmental protection. The Action Plan foresees the establishment of a Bioeconomy Observatory by the JRC aimed at regularly assessing the progress and impact of the bioeconomy and developing forward-looking and modelling tools. The bioeconomy encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value-added products:

i) food and feed, ii) bio-based products and iii) bioenergy – the so-called three pillars of bioeconomy.

In the framework of the Bioeconomy Observatory, the JRC is performing a comprehensive, independent and evidence-based environmental sustainability assessment of various bio-based supply chains, divided into the above mentioned pillars of bioeconomy. Such assessment is conducted on the basis of a methodology – developed by the JRC – which evaluates the environmental sustainability performance of bio-based supply chains, using a life-cycle perspective. The methodology allows for quantitative understanding of a wide range of environmental aspects such as climate change, human toxicity, land-use and resource depletion. This, in turn, also serves the purpose of identifying knowledge gaps and opportunities for improvements of the overall environmental performance. Results are available in the form of guidance documents on good practices in LCA. This work supports the development of standards and indicators for the bio-based sectors.

The lack of common bio-based product definitions and statistical classification references continue to make it difficult to comprehensively estimate their corresponding markets. Standards are also central to the development of labels for bio-based products. The EU is driving the development of clear and unambiguous standards for bio-based products on a European and international level, while ensuring their consistency across sectors. Such standards should neither add significant costs to the development of innovative products nor hinder market access for SMEs.

The Bioeconomy Observatory website has published a first set of data and information on the bioeconomy, including: statistics and visualisation of investments in research, innovation and skills, the mapping of policy initiatives, bioeconomy profiles for EU Member States and EU regions, socio-economic analysis of bio-based value chains, and environmental sustainability assessment of bio-based products. The national bioeconomy profiles have been produced by a group of Member States from the Standing Committee on Agricultural Research (SCAR) and more specifically the

Strategic Working Group on Sustainable Biomass for a Growing Bioeconomy.

In addition, the JRC has published 14 environmental sustainability factsheets, divided into three groups that reflect the three pillars of bioeconomy: food and feed, industrial bio-based products and bioenergy, including biofuels. The factsheets summarise in a uniform way different bioeconomy value chains and provide information on their environmental performance.

Work in progress

The JRC will further enrich the Bioeconomy Observatory website through a continuous mapping and collection of data from various sources, complemented by critical review, analysis, assessment and calibration.

3.8 Conducting biomass assessment

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions of 13 February 2012 – Innovating for Sustainable Growth: A Bioeconomy for Europe, COM(2012) 60
- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions of 20 September 2013 – A new EU Forest Strategy: for forests and the forest-based sector COM(2013) 659
- Communication from the Commission to the European Parliament and the Council of 23 July 2014 – Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy, COM(2014) 520.
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 6 May 2013 – Green Infrastructure (GI) – Enhancing Europe's Natural Capital, COM(2013) 249
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 6 June 2012 – Renewable energy: a major player in the European energy market, COM(2012) 271.

Biomass is material of biological origin, which derives from living or recently living organisms. To meet its needs, the EU uses biomass for food, feed, energy and for the production of derived materials, such as solid-wood materials, pulp and paper, fibres, bio-chemicals and bio-based industrial products. However, land that produces biomass is a finite resource and policy-makers need to know the economic, environmental and social impacts of increasing biomass demands, also taking into account the competition for different land uses. It is therefore important to quantify the availability of biomass and assess the amount that

can be extracted to meet the demands of EU citizens in a sustainable way. In this context the JRC carries out research activities on biomass assessment in support of EU policy-making.

Combining statistics, advanced satellite image processing, ground survey, modelling and statistical methods, the JRC is also looking at assessing the potential for using biomass in the EU and is setting up a unique harmonised database on biomass.

Work in progress

The current efforts are focused on integrating assessments of biomass from different sectors, such as agriculture and forestry, considering potential interactions and synergies. The JRC is also working on expanding the assessment from EU to a global scale and modelling the evolution of the biomass availability, supply and demand to project the sustainable production and citizens' needs of forest biomass in the near future.

3.9 Investigating the pathways to achieve sustainable growth

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 22 January 2014 – For a European Industrial Renaissance, COM(2014) 14
- Commission contribution to the European Council of 7-8 February 2013 – Trade: a key source of growth and jobs for the EU
- Communication from the Commission of 9 November 2010 – Trade, Growth and World Affairs – Trade Policy as a core component of the EU's 2020 strategy, COM(2010) 612, SEC(2010) 1268 and Accompanying Commission Staff Working Document – Trade as a driver of prosperity.

In today's globalised economy, more and more attention is being paid to how trade flows affect employment and income. The European Commission has identified trade policy as a core component of the European Union's 2020 strategy. Gathering reliable and comparable economic information is a main priority in order to support evidence-based policy-making. To this end, the JRC and the European Commission Directorate-General for Trade (DG TRADE) have worked together to produce a series of indicators to illustrate comprehensively the relationship between trade, employment and income, using the World Input-Output Database (WIOD).

According to the Kyoto Protocol (KP), under the principle of consumer responsibility, all global emissions attributed to the final use of goods and services in a country are

added up to calculate the national GHG footprint. Producer responsibility reflects the emissions produced in a country either for domestic or foreign consumption. The difference between producer and consumer responsibility is denoted as the emission trade balance. The JRC has a long-standing expertise in this field. It has quantified the emission trade balances of countries for a number of environmental dimensions using the WIOD which considers land use, material extraction, water use, acid emissions, ozone precursors and GHG emissions.

The JRC provides comprehensive datasets of comparable environmental and economic information to improve understanding of how the use of global resources and the emissions of air pollutants around the world have evolved in relation to economic activities such as production, consumption and trade. The 'production' indicators report on the use of resources as primary inputs (i.e. domestic extraction of materials or land cultivated) and the emissions directly generated by national economic activities for each country. The 'consumption' or 'footprint' indicators show the resources or pollution embedded in the domestic final demand of one country, regardless of where these resources/emissions were used/emitted. Finally, the 'trade' indicators show how resources and pollution are embodied in international trade.

Data are presented in two pocket books; the first one presents the global evolution of each indicator, and the second shows a series of country factsheets. The timeframe covered is the period between 1995 and 2008, and the geographical scope includes the EU-27 Member States plus Brazil, China, India, Japan, Russia, the United States and the rest of the world.

Work in progress

Analysis of the environmental and socio-economic effects of globalisation requires high-quality data and advanced methods. The JRC will continue to work closely with Eurostat to develop the methodologies and data necessary to carry out studies on trade and environmental policy analysis and their repercussions on employment, income and growth in the EU.

The JRC will also continue to strengthen its current collaboration with international agencies, such as the national statistical institutes in EU Member States, the OECD, the UN Statistical Division and the European Central Bank.

4 Sustainable urban living

Sustainable living is a lifestyle that attempts to reduce the use of natural resources and cause the least possible environmental damage for current and future generations to deal with. In practice, it implies that we have to change the way we live, build, travel, as well as produce and consume energy, water or food.

Europe is densely populated and by 2020 it is estimated that 80 % of its citizens will probably live in or near a city. Urban areas drive economic development and deliver many public services such as education, healthcare and transportation, but they are also associated with environmental degradation. Cities often share a common set of problems, such as poor air quality, high levels of noise, GHGs, water scarcity, and waste.

The JRC supports innovation and sharing best practices to help cities become more sustainable. The aim is to ensure that, by 2020, most cities in the EU will be implementing policies for sustainable urban planning and design, in areas such as air quality, buildings, energy, transport, and more.

4.1 Conducting air quality controls

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe
- Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A Clean Air Programme for Europe, COM(2013) 918 final
- Commission Implementing Decision of 12 December 2011 laying down rules for Directives 2004/107/EC and 2008/50/EC of the European Parliament and of the Council as regards the reciprocal exchange of information and reporting on ambient air quality
- Proposal for a Directive of the European Parliament and of the Council on the reduction of national emissions of certain atmospheric pollutants and amending Directive 2003/35/EC, COM(2013) 920 final
- Proposal for a Directive of the European Parliament and of the Council on the limitation of emissions

of certain pollutants into the air from medium combustion plants, COM(2013) 919 final

- Proposal for a Council Decision on the acceptance of the Amendment to the 1999 Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground-level Ozone, COM(2013) 917.

EU Member States still face problems in complying with the EU's air quality limit values in the EU air quality Directives, particularly in the case of particulate matter (PM), nitrogen dioxide (NO₂) and ozone (O₃), which have been proved to seriously affect human health. About 75 % of the EU population currently lives in urban areas where high traffic intensities, domestic heating and other polluting sources result in a large amount of pollutants being emitted into the atmosphere. The latest European Environmental Agency (EEA) assessment indicates that more than 90 % of the urban population is exposed to levels above the recommended World Health Organisation (WHO) guidelines. In a study released in 2014, the WHO stated that, in 2012, around 7 million people died – representing one in eight global deaths – as a result of exposure to air pollution. According to the WHO, air pollution is now the world's largest single environmental health risk and reducing it could save millions of lives.

The JRC actively supports the European Commission and Member States in implementing the current air quality Directives. The JRC is working on improving and harmonising the assessment techniques used to assess air quality. It provides Member States with specific tools to assess the most important sources of air pollution and cost-benefit impacts of measures and abatement plans.

While over the last couple of decades the EU air quality policy has made important progress in curbing emissions of harmful pollutants (such as fine particulate matter, sulphur dioxide, lead, nitrogen oxides, carbon monoxide and benzene), ambient concentrations of several pollutants are still beyond levels that could be considered safe. Fine particles and ozone, in particular, still present significant health risks and the WHO's air quality guidelines are generally not being met. Many EU Member States are still falling short of agreed EU air quality standards, resulting in high costs for the healthcare system and for the economy at large. With the dual objective of achieving compliance with existing air quality legislation as soon as possible, and making more and substantial progress towards the EU's long-term objective, in 2013, the European Commission adopted the Clean Air Policy Package.

The JRC has contributed to the impact assessment of the Clean Air Policy Package by evaluating the potential economic impacts. This includes an ex-ante analysis of the update of the EU's strategy on air pollution and input to the development of accompanying legal proposals and non-regulatory actions. The JRC's contribution to the impact analysis used a combination of economic models able to assess the macro-economic and competitiveness effects of different policy options. The analysis took into account GDP, sectoral activity, exports and imports, employment, household consumption and welfare.

The World Health Organization (WHO) and the JRC have identified the main human activities emitting particulate matter in urban air in different cities around the world. On average, traffic is the biggest source of air pollution, responsible for one quarter of particulate matter in the air. As it is important to know which emitting sources are the most important, the JRC contributed to the analysis and collection of measurements of fine particle concentrations measured at urban sites. The JRC also contributes to the understanding of long-range transport of air pollution beyond European borders and under the Convention on Long-Range Transport of Air Pollution, provides a global emission inventory and a tool to assess the health and crop yield impact of emission reductions such as from EU air quality policies and technology progress over the past four decades.

The JRC has led efforts to harmonise air quality modelling and measurement techniques steered by its European networks dealing with air-quality measurements (National Air Quality Reference Laboratories – AQUILA) and air quality modelling (Forum for air quality modelling in Europe -FAIRMODE) It has coordinated quality assurance programmes, developed guidance documents and promoted capacity building in the Member States. The AQUILA and FAIRMODE networks have provided important input into the review of the Thematic Strategy on Air Pollution, concerning an easier and more cost-effective assessment of air quality. The JRC has also worked on the implementation of a new improved mechanism to report air quality data in line with air quality Directives and the Directive for spatial information in Europe. It has also assessed the overall economic impact of the Clean Air Policy Package. Results showed that the European Commission's proposal would imply a total GDP loss of only 0.018 %, without any net negative effects on employment. The analysis also demonstrated that the improved labour productivity from avoided morbidity and healthcare expenditure would have positive macro-economic impacts on the European economy, possibly even exceeding the costs of the policy. Moreover, JRC scientists found that the benefits to crop yield from reduced air pollution would compensate for the negative impacts of the abatement efforts required by the agricultural sector.

Work in progress

The JRC will continue its efforts in the standardisation and harmonisation of EU Member States air quality monitoring and modelling methodologies. Particular emphasis is being put on model quality objectives, new indicators of model performances, inter-comparison exercises and tools for model assessment. The JRC will continue to assist the European Commission Directorate-General for the Environment in the policy process for air quality and will carry on its capacity-building activities with national and regional authorities.

It will also develop methods for integrated urban and regional assessment, to evaluate in a coherent and coordinated manner the environmental policies in urban and metropolitan areas, including related to air quality.

4.2 Contributing to making cities sustainable

Increasing urbanisation, together with climate change and environmental degradation, calls for the improvement of the urban environment and making our cities more sustainable. The challenge is enormous as over half of the world's population are now living in urban areas and this is expected to reach almost two thirds by 2030.

The way today's cities are built and managed will have implications for their sustainability and the quality of life of their citizens. At present, cities consume 75 % of the world's natural resources, 80 % of the global energy supply and produce approximately 75 % of the global carbon emissions.

In addition, urban green infrastructure (parks, forests, street trees, green roofs, gardens and cemeteries) also plays an important role in making our cities sustainable. It delivers multiple ecosystem services, contributes to biodiversity in urban areas and generates human well-being. To help better understand how future landscape changes could be mitigated and sustainable urban planning strategies developed, JRC models, such as the GUIDOS Toolbox presented in section 2.3, are relevant to mapping and analysing urban patterns and the connectivity of urban green spaces.

Sustainable buildings

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC
- Communication from the Commission of 3 March 2010 – Europe 2020, A Strategy for smart, sustainable and inclusive growth, COM(2010) 2020 final

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 26 January 2011 – A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy, COM(2011)21
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 31 July 2012 – Strategy for the sustainable competitiveness of the construction sector and its enterprises, COM(2012) 433
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 1 July 2014 – Resource efficiency opportunities in the building sector, COM(2014) 445.

The construction of buildings corresponds to the largest industrial sector both in terms of economic and resource flows. Energy consumption in the building sector can reach up to 40 % of the total energy demand from an industrialised country. In the EU, national laws and EU Directives have introduced limits and restrictions on energy consumption in buildings and requirements for the energy certification of new buildings. The European Commission's Communication on Resource efficiency in the building sector aims to reduce resource use in buildings and develop the market for recycled construction materials.

As already mentioned in Chapter 3, the JRC has developed the Product Environmental Footprint (PEF) and Organisation Environmental Footprint (OEF) methods. They are recommended by the European Commission Communication 'Building the Single Market for Green Products'. Construction products, such as pipes, thermal insulation, metal sheets, paints and photovoltaic panels are under consideration with such methods.

The JRC is developing life-cycle-based environmental assessment methods applicable during the R&D process of innovative construction products. JRC scientists evaluate the effects of selected components and materials, in terms of their environmental impact, at building, regional and European level. Research projects focus, for instance, on the potential of multifunctional glass-polymer windows to harvest solar energy, or on cement-based composites.

In 2015, the JRC launched the Life Cycle Data Network (LCDN) which aims to provide an infrastructure for consistent and quality assured LCA data from different organisations. The LCDN is a web-based infrastructure to ensure LCA data is readily accessible via searches, filtering and sorting. The databases already include many construction materials and products compliant at the International reference Life Cycle Data system (ILCD) entry level which is a step further toward the availability of reliable life-cycle datasets in this sector.

The JRC is also developing life-cycle-based macro-level monitoring indicators for resources, products and waste from housing in the EU. The research aims to define the average environmental impacts related to housing for each citizen. At the macro scale, the JRC is evaluating how the demand for materials and resources may change under different resource-efficiency policies, promoting the use of bio-based material or the circular economy, for instance.

Finally, the JRC supports the development of sustainable buildings standards, and particularly regarding life-cycle impact assessment.

The JRC is working on the LCA of innovative window technologies or 'smart windows' to reduce energy consumption in buildings, while ensuring the continuous efficient use of other resources. Through specific LCA-tailored methodology and associated tools, it has been possible to orient decisions towards better environmental performances from a life-cycle perspective, balancing energy during use, the impact of production and logistics, and recyclability at the end of life.

Work in progress

Since January 2015, the JRC has been working on a project dealing with 'eco-energy efficient envelopes for innovative buildings'. This exploratory research project aims to develop cement-based composites able to store energy (heat) in building envelopes and thus to reduce the peaks in heat fluxes and energy consumption for heating and cooling. Each phase of the product development is analysed using LCA.

Electric vehicles

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank of 25 February 2015 on Energy Union Package – A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, COM(2015) 80
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 30 July 2014 – The annual Union work programme for European standardisation for 2015, COM(2014) 500
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 24 January 2013 – Clean Power for Transport: A European alternative fuels strategy, COM(2013) 17

- United Nations Economic Commission for Europe (UNECE) Global technical regulation No. 15, Worldwide harmonized Light vehicles Test Procedure, ECE/TRANS/180/Add.15, November 2013.

Road transport contributes about one-fifth of the total carbon dioxide emissions in Europe, having grown by nearly 23 % between 1990 and 2010. In Europe, transport is the only major sector where emissions are still increasing. The EU is committed to reducing them by at least 20 % below 1990 levels by 2020, and by 80-95 % by 2050, in order to reduce GHGs, and maintain the global temperature increase below 2°C, under the Kyoto Protocol. This implies a complete revision of Europe's mobility plans, following the guidelines outlined by the European Commission's White Paper in 2011, which called for a reduction in transport's dependence on oil and set a target of a 60 % reduction in GHG emissions from transport by 2050. Electricity has the potential to increase the energy efficiency of road vehicles and to contribute to a CO₂ reduction in transport to improve air quality and reduce noise in densely populated urban and suburban areas. This suggests the need for a set of policy initiatives, including the development of a sustainable alternative fuels strategy plus the appropriate infrastructure.

Within this framework, a new activity has been initiated at the JRC which involves the collection of activity data from conventional vehicles to develop a Transport Technology and Mobility Assessment (TEMA) tool, interfaced with Global Navigation Satellite System (GNSS)-based digital geographic mapping systems. The scope of this study includes exploring the possible use of big data and data-mining techniques to support transport policy, enabling a wide range of mobility analyses, characterising the driving behaviour of the vehicles in specific geographical areas and investigating the potential of innovative vehicle technologies in a sustainable transport system. This is helping to determine the demand from hybrid and electric vehicles for electric energy and its impact on the electricity grid.

Directive 2014/94/EU of 22 October 2014 on the deployment of alternative fuels infrastructure states the need to build recharging points with adequate coverage and accessible to the public in order to enable electric vehicles to operate in urban areas. A JRC study is looking into points of interest (POI), such as parking lots and shopping malls, as possible locations for installing public charging spots, assessing their ability to meet the charging requirements of urban vehicles, and estimating the number of charging spots to be installed in a specific location.

Standardisation will be needed to implement the European alternative fuels strategy and infrastructure according to the Work Programme for European Standardisation for 2015. A letter of intent regarding closer cooperation between the JRC and the United States Department of Energy's Argonne National Laboratory (ANL) was signed in 2011. On the basis of this agreement, the joint

development of a transatlantic centre for pre-normative research on electric vehicles and their interoperability with future smart grids has started, with new complementary laboratory capacities built at both Argonne and JRC sites (Ispra and Petten). Conjoint work of the ANL and the JRC is ongoing with the automotive industry on both sides of the Atlantic to facilitate the harmonisation of connectivity and standard testing of the communication protocols between electric vehicles and the recharging devices.



An electric vehicle being tested at the JRC Vehicle Emissions Laboratory (VELA).

The JRC is supporting international efforts to develop regulations for hybrid and electric vehicles. The electric driving range, fuel and electricity consumption, efficiency under different environmental conditions (such as high and low temperatures) and the impact of using a vehicle's auxiliary features, such as the cabin heating system, are some of the open issues being addressed by JRC testing.

The JRC has carried out a study to demonstrate how driving pattern databases and data mining can be used to appropriately design electric-vehicle recharging infrastructures. This application focuses on 28 000 vehicles monitored in two Italian provinces, accounting for more than 35 million kilometres and 4.5 million trips. The results are very similar for the two provinces and predict a fleet share shift from conventional fuel vehicles to battery electric vehicles from 8 % to 57 %, corresponding to a kilometre share varying from 1.4 % to 40 %, depending on the scenario. This corresponds to an increase in electric energy demand from 0.7 % to 18 % of the total monthly electric energy demand in the provinces, with the resulting infrastructure accounting for a number of charging spots two to six times higher than the number of electric vehicles in circulation, in a fully developed recharging infrastructure scenario. In addition, the JRC has explored the potential of a vehicle-to-grid interaction strategy showing how it can contribute to a reduction from 5 % to 50 % of the average daily demand for electric energy recharging in specific locations. The resulting transport technology and mobility assessment tool demonstrates the valuable potential of the proposed methodology in supporting future policies for designing alternative fuel infrastructure in urban areas.

Work in progress

The JRC has set up a new climatic test chamber for hybrid and electric vehicles to investigate their performance at different temperatures (from -30°C up to +50°C) and with vehicle speeds of up to 140 km/h. The aim of these activities will be to evaluate experimentally the functionality of fully or partially electrified road vehicles, their energy efficiency and, for hybrid vehicles, exhaust emissions against existing and possible future standards and regulations.

Efficient and reliable communication between the vehicle and the grid and other intelligent systems, such as GPS, is essential for the deployment of these advanced technologies. Within this framework, the JRC has built a new testing facility consisting of a semi-anechoic chamber in which to experimentally evaluate the electromagnetic compatibility of fully or partially electrified road vehicles against electromagnetic emission and immunity standards and regulations. This pre-normative research will include developing technological suggestions for future measurement procedures on an international level, identifying the potentially critical operation states of electric vehicles, under charge and in wired or wireless communication with smart grids.

4.3 Sharing best practices and expertise on smart grids

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 12 April 2011 – Smart Grids: from innovation to deployment, COM (2011) 202 final
- Communication from the Commission of 3 March 2010 – Europe 2020. A strategy for smart, sustainable and inclusive growth, COM(2010) 2020 final.

Meeting the EU's climate change and energy objectives for 2020 and beyond requires a major transformation of the electricity infrastructure, which needs to be upgraded and reshaped to foster sustainability, increase energy efficiency and enhance grid security. As the EU power grid is one of the largest and most complex systems in the world, this is a major technological, financial, societal and regulatory challenge.

A smart grid is an electricity network that is set up to continuously process and respond to the behaviour and actions of producers and consumers in order to deliver electricity supplies efficiently. Many countries in Europe and worldwide are now promoting concepts for smarter grids and 'super grids' (wide-area transmission networks to trade high volumes of electricity across great

distances) so as to integrate new actors and technologies in the power system, such as renewable energies, storage devices and electric vehicles.

The JRC monitors the transition of the EU's energy network towards smart grids by developing models and performing analyses. It also carries out cost-benefit analyses of smart-grid projects, and has become an international reference point for information on smart-grid pilot and demonstration projects. It monitors developments, maintains a smart-grid simulation centre, analyses the technological, social and economic factors involved, and disseminates information on smarter electricity systems.

In the last few years, smart grid projects have been growing in number, size and scope throughout Europe. In 2011, the JRC launched the first comprehensive inventory of smart grid projects in Europe (updated in 2012 and 2103), which includes over 450 located across Europe. Project results provide an encouraging indication of how smart grids can help integrate more renewable energy, accommodate electric vehicles, give more control to consumers over their energy consumption, avoid blackouts and restore power quickly when outages occur.

The JRC has also defined a comprehensive approach for cost-benefit analyses of smart grid projects. One such project, InovGrid, was used as a case study to fine-tune and illustrate the proposed methodology and perform a cost-benefit analysis on a real project. This work draws on a methodology proposed by the Electric Power Research Institute (EPRI) and on the collaboration between the JRC and the US Department of Energy (DoE).

The JRC report 'Smart Grids Laboratories Inventory 2015' is the first edition of a periodic report that will gather and disseminate information on the smart grid laboratories active in Europe and beyond. The report gives an overview of smart grid technologies operational at laboratory level in order to identify trends and gaps in smart grids research and innovation. The JRC has also launched a dedicated webpage, for which new interactive visualisation tools have been developed to allow the user to generate customisable maps, graphs and charts to track progress on smart grid projects realised in all the EU Member States, plus Switzerland and Norway. The objective is to create an interactive platform to share best practices and knowledge on smart grid activities, facilities, technologies and standards.

Work in progress

The JRC is working on the development of a smart grid laboratory to investigate the characteristics and assess the performance of components, systems and technologies and their interactions. It is also setting up a laboratory equipped with an advanced power system real-time simulator which can be used, amongst other things, for alternating-current power-grid simulation, global control development and protection system testing.

5

Climate change mitigation and adaptation

According to the Intergovernmental Panel on Climate Change (IPCC), warming of the climate system is unequivocal, and many of the changes observed in recent decades are unprecedented. There is significant confidence that global temperatures will continue to rise for decades to come, largely due to the GHGs produced by human activities. More importantly, climate change will alter the frequency, duration, intensity and spatial extent of weather and climate extremes such as heatwaves, heavy precipitation events and floods, drought, and tropical cyclones. Multiple climate hazards will result in large human and economic losses especially in vulnerable areas. The impact on energy, transport and industrial infrastructures in Europe could amount up to EUR 8.3 billion by 2080s.

The EU's strategy for reducing climate change risks relies on mitigation – by reducing GHG emissions, and adaptation – by tackling exposure, vulnerability and impacts. With its climate action programmes, the EU and its Member States have set ambitious goals for climate change mitigation by defining stringent reductions in GHG emissions for the coming decades. Its targets for reducing its greenhouse gas emissions are set in the 2020 climate and energy package and 2030 climate and energy framework. These two strategic documents propose cuts by at least 20 % by 2020 and then by 40 % by 2030 (from 1990 levels), leading to the shift to a low-carbon economy, with at least 80 % emissions reduction by 2050. However, given the long time lag between mitigation measures and their effect on the climate, in 2013 the EU adopted a Strategy on adaptation to climate change to increase the EU's preparedness. This includes the effective integration of climate issues into existing policy, planning and governance across different sectors. Climate change mitigation and adaptation are also essential considerations in growth and development strategies, as for instance reflected in the newly agreed Sustainable Development Goals.

The JRC has a long-standing expertise in modelling climate change and its impacts, which supports European Commission services and EU Member States in their climate change mitigation, preparedness and adaptation efforts.

5.1 Modelling climate change for better policy choices

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 16 April 2013 – An EU Strategy on adaptation to climate change, COM(2013) 216 final, through the implementation of the European Climate Adaptation Platform (Climate-ADAPT)
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Mainstreaming sustainable development into EU policies: 2009 Review of the European Union Strategy for Sustainable Development
- EU climate and energy package of 2009 on the 20-20-20 targets.

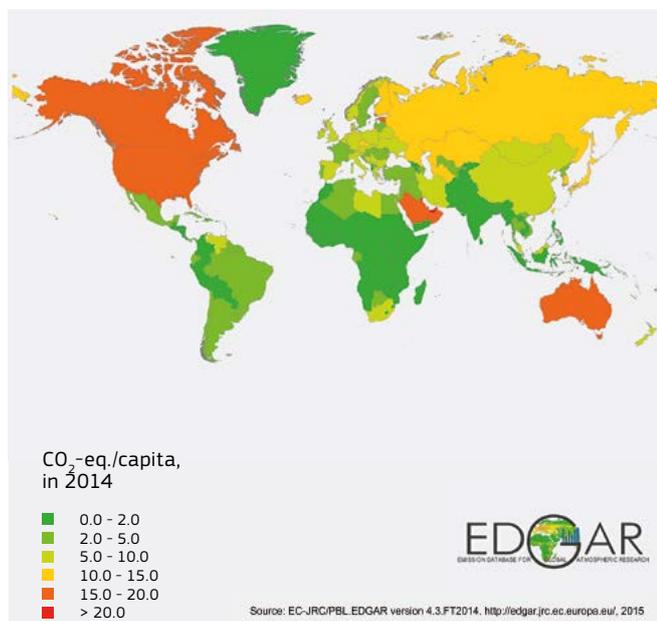
Preventing climate change is a key priority for the EU. In order to limit the most severe impacts of climate change, global warming must be kept below 2°C compared to the average temperature in pre-industrial times. However, latest projections suggest that without appropriate action being taken to reduce global GHG emissions, by the end of this century, global warming is likely to exceed the 2°C target and could be as much as 5°C.

Climate models simulate the interactions of the atmosphere, oceans, land surface and ice. The ability of climate models to realistically simulate climate variables, such as surface temperature and precipitation, has greatly improved over the years, constantly enhancing confidence in the suitability of the models to be applied to future projections.

In collaboration with a wide network of international partners, the JRC is at the forefront of scientific research in the production and evaluation of climate change projections and the assessment of climate change impacts on key areas such as floods, forest fires and agriculture. This work helps to define the most appropriate and effective climate adaptation options in Europe and in vulnerable developing regions such as Africa, where projected climate change may lead to severe impacts on many vital sectors such as agriculture, water management and health.

Developing climate change policies requires a sound analysis of past GHG emission trends which helps to identify major drivers, adjust emission projections and evaluate mitigation policies. Although emission drivers such as economic activity and fuel prices are widely assumed to be significant, the quantitative relationships linking them to emissions have not been systematically and comprehensively investigated using robust statistics.

The JRC has been statistically analysing the trends of income and GHGs, looking for causal relation between time series of GDP and of CO₂, as JRC has a unique Emissions Database for Global Atmospheric Research (EDGAR), providing the country-specific emissions time series starting in 1970 and for CO₂ running up to 2014.



CO₂ emissions per capita in the world in 2014.

Netherlands Environmental Assessment Agency (PBL) published the latest CO₂ figures in the 'Trends in global CO₂ emissions; 2015 Report'. After a decade of rapid growth in global CO₂ emissions (with an average annual rate of 4 %), much smaller increases were registered in 2012 (0.8 %), 2013 (1.5 %) and 2014 (0.5%). In 2014, when the emissions growth was almost at a standstill, the world's economy continued to grow by 3 %. The trend over the last three years thus sends an encouraging signal on the decoupling of CO₂ emissions from global economic growth. It is however still too early to confirm a positive global trend. The EU continued to show leadership on CO₂ emission reductions with a 5.4 % decrease of CO₂ emissions in 2014 when compared to the previous year and despite an overall increase of 1.4 % in the GDP. For the first time, the EU's share of global CO₂ emissions fell below 10 %. Responsible for 9,6 % of the global emissions, the EU is still the third largest emitter globally after China (30 %) and the United States (15 %). Apart from the EU, other countries such as Japan (-2.6 %) Russia (-1.5 %), and Australia (- 2.1 %) also reduced their emissions.

China, the largest emitter world-wide, has also managed to slow down its emissions growth to 0.9 % in 2014, the same rate as the United States.

Work in progress

Despite recent progress in climate modelling, there is still room for improvement to increase the robustness and reduce the uncertainties of climate projections for decision-makers. This will require the development of a new generation of climate models (the so-called Earth-system models) capable of resolving finer details such as cloud systems and ocean eddies, and incorporating new components such as biogeochemical processes and their effect on the climate. The JRC will work on evaluating the performance of different models in order to reach a better understanding of physical processes and interactions between the atmosphere, land surface, ice sheet and ocean.

The JRC will continue to update the emission time series in EDGAR so as to provide a robust insight on the evolution of GHGs for all countries worldwide. JRC scientists will also work on collecting longer time series data aggregated per country in order to enable country specific analysis and targeted emission-reduction policies, since the emissions of different Member States are determined by different fuel consumption and industrial and agricultural processes.

5.2 Seeking ways to cut GHG emissions and assessing the impacts of global mitigation efforts

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Energy Union Package: Communication from the Commission to the European Parliament and the Council of 25 February 2015 – The Paris Protocol – A blueprint for tackling global climate change beyond 2020, COM(2015) 81 final
- Commission Staff Working Document accompanying the Document Communication from the Commission to the European Parliament and the Council – The Paris Protocol – A blueprint for tackling global climate change beyond 2020, SWD(2015) 17 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A policy framework for climate and energy in the period from 2020 to 2030, COM(2014) 15 final.

In support of the Paris Protocol, which calls for a blueprint to tackle global climate change beyond 2020, the JRC investigated pathways to cut CO₂ and other GHG emissions. It also assessed the macroeconomic impacts of global mitigation efforts by studying interactions between the economy, the energy system and the environment.

The JRC's report 'Global Energy and Climate Outlook: Road to Paris', which was published in February 2015, played a key role in setting out the European Union's vision ahead of a new international agreement. Its main conclusions show that global efforts to put economies on track to low-emission development and the integration of climate action into economic policy can simultaneously deliver climate goals, improved energy security and efficiency and do not hamper significantly economic growth.

Using models, the JRC has studied two separate climate scenarios: 'business as usual', which evaluates existing climate policies and current trends in fossil fuel consumption; and a 'global mitigation' scenario where global action limits global temperature rise to below 2°C. Results show that under the global mitigation scenario, a combination of domestic efforts to move to low-emission development pathways adapted to national contexts could halve global emissions by 2050, compared to 1990 levels. Such a global transition to a low-emission economy implies increasing the low-carbon energy supply such as renewables, improving energy efficiency across all regions in the world, and adopting low-emission technologies in all sectors of the economy, especially in the power and industry sectors.

Under the global mitigation scenario, the global yearly growth rate of Gross Domestic Product (GDP) for the decade 2020-2030 would fall slightly from 3 % to 2.87 % compared to the business as usual scenario, although emerging and lowest-income economies would maintain high rates of economic growth. Modelling work also provides evidence that the use of smart fiscal policies tailored to each region, such as increasing emission taxes, reducing indirect taxes on consumption and investment, and/or lowering labour taxes, could further increase GDP growth and reduce the gap compared to the business as usual scenario to less than 0.1 %.

Although climate and air quality are traditionally considered as different policy areas, an integrated or coordinated policy approach may lead to significant benefits and avoid trade-offs. The JRC has developed in-house knowledge and tools to address climate and air quality issues in an integrated way, considering both classical air pollutants as climate forcers and air-quality benefits from climate action.

JRC research is at the forefront in identifying the role that Short-Lived Climate Pollutants (SLCPs) will play in determining near-term climate change over the next 20-30 years. SLCPs are air pollutants released by man-made activities, such as aerosol particles, ozone and methane, which stay in the atmosphere for a much shorter time than GHGs such as CO₂, and respond more directly to emission reductions. The JRC, in collaboration with European and international partners, is evaluating the benefits of improving air quality and short-term climate change mitigation. To this aim, it has developed an 'Air Pollutant Impact Assessment Platform' to compile GHG and air pollutant emission inventories on a global scale, using information on those sectors and activities producing GHG emissions and their potential to reduce these emissions under a 2°C scenario.

This tool allows for the quick screening of combined climate and air quality benefits of targeted air quality measures. It has been used in several international assessments and notably to monitor and predict environmental change in the Arctic region caused by the long-range atmospheric transport of SLCPs.

The JRC contributes to several European and international efforts to reduce air pollutant emissions, such as the European Monitoring and Evaluation Programme (EMEP), the United Nations Environment Programme (UNEP), Integrated Assessment of Black Carbon and Tropospheric Ozone, the United Nations Convention on Long-range Transboundary Air Pollution (UNECE LRTAP) and its Task Force on Hemispheric Transport of Air Pollution (TF HTAP), the UNEP World Meteorological Organization (WMO) and the Climate and Clean Air Coalition (CCAC).

The report 'Global Energy and Climate Outlook: Road to Paris', co-authored by the JRC and the European Commission's Directorate-General for Climate Action (DG CLIMA), provided analytical results of the climate and economic consequences of a potential international agreement ahead of the United Nations Climate Change Conference (COP21, Paris, December 2015).

It explored possible domestic mitigation pathways, such as cutting CO₂ and other GHG emissions set according to specific national economic and policy conditions. The results highlighted the fact that global efforts to put economies on track towards low-emission development and the integration of climate action into economic policy can simultaneously deliver climate goals, improve energy security and efficiency, and boost economic growth.

Work in progress

In addition, the JRC will work with DG CLIMA on analysing the pledges from various countries on GHG reductions in support of the COP21 international conference and perform further analysis of agreed outcomes.

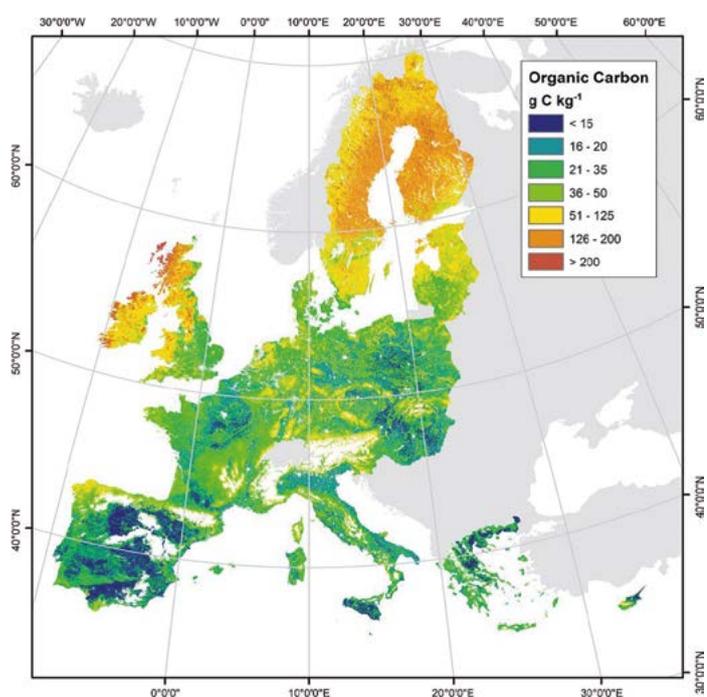
5.3 Mapping soil organic carbon to mitigate climate change

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – EU Thematic Strategy for Soil Protection (COM(2006) 231 final).
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 16 April 2013 – An EU Strategy on adaptation to climate change, COM(2013) 216 final

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Roadmap to a Resource Efficient Europe (milestones on land and soil), COM(2011) 571 final.

As the greatest terrestrial carbon pool, soils play a key role in climate change regulation processes. Soils can either act as a carbon source or sink and their status in the carbon cycle can be influenced by land use and management practices. As it contains a great proportion of nutrients necessary for plant growth, soil organic carbon (SOC) is the major component of soil organic matter which improves the physical properties of soil such as its structure, stability, nutrient availability, water retention and resilience capacity. It is composed of partially decayed plant residues, micro-organisms and the by-products of microbial growth and decomposition.



The map shows the amount of organic carbon in EU soils.

With an estimated global stock of 2300 gigatonnes (Gt) of carbon, soil organic matter contains more than three times the amount of carbon in the atmosphere. The distribution of SOC varies greatly with climatic conditions and land use. Around 1700 Gt of carbon is stored in soils in the northern permafrost region. The thawing of the permafrost could lead to a substantial release of GHGs into the atmosphere, which would further increase global warming. Changes in SOC from cropland and grassland management are evaluated in the reporting on GHG emissions under the UNFCCC and KP for the agricultural sector.

The JRC contributed to the European Soil Database, on a scale of 1:1 000 000, which represents one of the most homogeneous and comprehensive databases on the organic carbon/matter content of European soils. It includes information from associated databases on land

cover, climate and topography harmonised according to a standard international classification (Food and Agriculture Organization of the United Nations). The European Soil Data Centre (ESDAC) makes available maps of organic carbon content in the surface horizon of soils in Europe. An interactive application enables the user to navigate through the organic carbon map and print customised maps.

JRC work has also contributed to the United Nations Environment Programme - World Conservation Monitoring Centre's carbon and biodiversity map. The JRC's Soil Atlas of the Northern Circumpolar Region (2009) was the first compilation to provide available information on the carbon pool.

In the past, global estimates of SOC stocks have been produced to support calculations of potential CO₂ emissions from the soil under scenarios of changing land use/cover and climatic conditions (IPCC, 2006), but very few global estimates have been presented as spatial data. To respond to the increasing demand for up-to-date SOC data for global environmental and climatic modelling, in 2015, the JRC produced a map of the organic carbon content of topsoil in Europe.

The map was created by applying digital soil-mapping techniques to the first European harmonised geo-referenced topsoil (0-20cm) database, evolving from the Land Use/Cover Area frame statistical Survey (LUCAS). This monitoring project is aiming to produce the first coherent, comprehensive and harmonised EU topsoil dataset based on common sampling and analytical methods. Uncertainties in the organic carbon content predictions were estimated by using a model to support the careful use of the map. It revealed larger uncertainties in northern latitudes, wetlands, moors and heathlands, whereas small uncertainties were found in croplands. The resulting map gives the most up-to-date overview of topsoil organic carbon content on a EU scale.

Work in progress

The JRC will continue to support the Commission's commitment to the Rio+20 Action Plan, the Global Soil Partnership and the Resource Efficiency Roadmap, by providing updated assessments of topsoil via the new LUCAS sampling campaign in all EU-28 Member States. The survey will also be extended to candidate countries.

5.4 Estimating GHG emissions from land use, land use change and forestry

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Regulation 525/2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC
- Commission Implementing Regulation (EU) No 749/2014 on structure, format, submission processes and review of information reported by Member States pursuant to Regulation (EU) No 525/2013 of the European Parliament and of the Council
- Decision 529/2013/EU of the European Parliament and of the Council of 21 May 2013 on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities
- Communication from the Commission to the European Parliament and the Council of 23 July 2014 – Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy, COM(2014) 520.
- United Nations Framework Convention on Climate Change (UNFCCC) – Decisions relevant for the Land Use, Land Use Change and Forestry and for reducing emissions from deforestation and forest degradation in developing countries (REDD+).

According to the Intergovernmental Panel on Climate Change (IPCC), mitigation actions in the land use sector are key to meet the 2-degree target. Likewise, the UN Framework Convention on Climate Change and its Kyoto Protocol acknowledge the importance of the land-use sector as a potential way of mitigating climate change. In this context, industrialised countries prepare annual inventories of their estimated greenhouse gas (GHG) emissions from the Land Use, Land Use Change and Forestry (LULUCF) sector, using the methodological guidance prepared by the IPCC.

Contributing to the IPCC's work on methodological guidance, the JRC develops methods to estimate emissions and removals in the LULUCF sector. The JRC is in charge of the annual compilation of LULUCF and the Kyoto Protocol LULUCF chapters of the EU's GHG inventory. Every year, it performs quality assurance and quality control of the LULUCF estimates provided by each of the Member States. The JRC also forecasts the impact of different policy scenarios on future GHG emissions, particularly with regard to using forest as carbon dioxide sinks. The JRC also reviews GHG estimates from non-EU countries, in the context of LULUCF and REDD+. Its research involves direct interaction with the scientific community working on the carbon cycle, the GHG

inventory experts from the 28 EU Member States, the IPCC, the UNFCCC, the EEA and the European Commission's Directorate-General for Climate Action (DG CLIMA), and its expertise on LULUCF methodologies, reporting and review is considered to be world class.

Work in progress

The JRC is helping Member States to implement the new requirements on cropland and grazing land management, as well as the latest rules on forest management accounting, as foreseen in EU LULUCF decision (529/2013).

Together with the European Commission's DG CLIMA, the JRC is working on the impact assessment of a legislative proposal on the inclusion of the land-use sector in the EU's 2030 climate and energy policy, following the European Council Conclusions of 24 October 2014. The JRC has also provided active technical and scientific support to the preparation to the Paris climate change conference.

5.5 Running early-warning systems to reduce the impacts of extreme events

The JRC's activities in this area provide scientific support to the following policy initiatives:

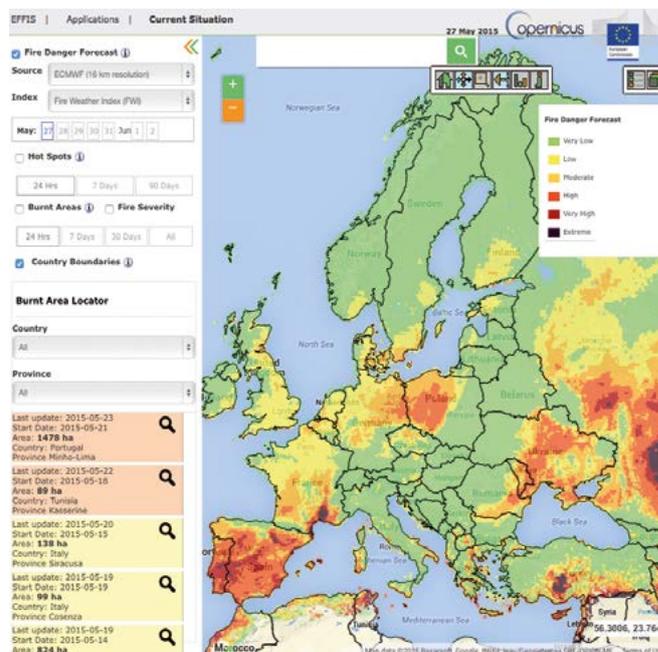
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 16 April 2013 – An EU Strategy on adaptation to climate change, COM(2013) 216 final
- Decision No 1313/2013/EU of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism
- Communication from the Commission to the Council and to the European Parliament of 23 February 2009 – EU strategy for supporting disaster risk reduction in developing countries, COM(2009) 84
- Regulation (EU) No 377/2014 of the European Parliament and of the Council of 3 April 2014 establishing the Copernicus Programme and repealing Regulation (EU) No 911/2010
- Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks
- Council conclusions of 26 April 2010 on prevention of forest fires within the European Union
- Regulation (EU) No 1303/2013 of the European Parliament and of the Council of 17 December 2013 laying down common provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund.

- Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions of 20 September 2013 – A new EU Forest Strategy: for forests and the forest-based sector COM(2013) 659
- European Parliament Resolution of 28 April 2015 on a new EU Forest Strategy: for forests and the forest-based sector
- Communication from the Commission to the European Parliament and the Council on 18 July 2007 addressing the challenge of water scarcity and droughts in the European Union, COM(2007) 414 final
- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive).

Floods, droughts and wildfires rank amongst the most damaging and costly disasters recurrently affecting Europe and the rest of the world. The intensity and frequency of such weather-driven natural disasters are expected to increase with rising global temperatures, developing industrialisation and rapid urbanisation. While their negative impacts constitute a threat to more developed countries, they represent an even greater obstacle to poverty reduction and stability in less-developed countries.

Early-warning systems have been recognised as an important ‘soft’ adaptation measure to extreme events. They give decision-makers enough time to take preventive measures and reduce the impact of extreme events. This is particularly important for cross-border occurrences requiring coordination of actions between different authorities. However, extreme events often have limited predictability due to uncertainty in the weather forecasts. Long-term forecasts are very uncertain which makes it difficult to produce meaningful information and indicators for decision-makers.

Over the past ten years, the JRC has been developing pan-European monitoring and early-warning systems for: forest fires and fire danger assessment, through its European Forest Fire Information System (EFFIS), floods through the European Flood Awareness System (EFAS), and droughts through the European Drought Observatory (EDO). These systems provide comparable results across Europe, helping decision-makers to assess the situation in particular for cross-border events. These systems directly support the European Commission’s Emergency Response Coordination Centre with early-warning information for the coordination of aid during major disasters requiring international assistance. They provide tools and data to assess the impact and damage caused by events under both present and future climates, and give access to added-value information and a reference baseline to the national services.



EFFIS screenshot showing risks of forest fire in Europe.

This work directly supports EU policies such as the EU Civil Protection Mechanism, the Copernicus Emergency Management Service, the Strategy on adaptation to climate change, as well as specific policies for individual hazards.

In response to the growing demand for global early-warning systems, as highlighted in the Sendai Framework for Disaster Risk Reduction 2015–2030 or the Sustainable Development Goals to which Europe has committed, the JRC is also working on the extension of the European systems on a global scale in collaboration with international networks and experts.

For tsunamis, the JRC has developed and operates the only worldwide operational automatic impact-based alerting system. This is different from the official UNESCO warning systems, as it provides information about the potential impact (estimated wave heights affecting populated coastlines) and not only about confirmed threats (seismic activity and observed sea level). This alert system is based on pre-calculated tsunami scenarios and the alerts can be fed into international or national warning systems. The JRC’s tsunami assessment modelling system is part of the EU-UN Global Alert and Coordination System (GDACS). Apart from tsunamis, GDACS also alerts about earthquakes, cyclones or floods and it presents not only the strength of these events, but also the affected population and the capacity of the affected country to cope with the disaster.

The European Flood Awareness System (EFAS) became one of the first operational systems under the Copernicus Emergency Management Service in 2012. Since then, EFAS has provided national hydrological services and the European Response Coordination Centre (ERCC) with daily updates of flood probabilities up to 10 days in advance – a time window that is now being complemented with monthly outlooks.

EFAS has become an important tool for the European Commission and the national services, enabling better preparedness for disasters and aid management during trans-national flood events. Furthermore, EFAS provides a unique repository of data and information relevant for researchers to advance flood forecasting and risk assessment methodologies worldwide such as during the Balkan floods in 2014.

The European Forest Fire Information System (EFFIS) is a complex system for wildfire monitoring comprising the full cycle of fire management, from fire prevention and damage assessment to the analysis of vegetation regeneration in burned areas, begun in 2000. Within EFFIS, fire-danger prediction is produced up to 10 days in advance, providing information on the potential intensity and spread of wildfires. EFFIS currently supports environmental and civil protection services in the EU and in the 39 countries of its network.

The European Drought Observatory (EDO) provides for the continuous monitoring and forecasting of drought conditions across the entire European continent through a series of indicators targeted at rainfall, soil moisture and vigour of the vegetation cover. Indicators have been developed and agreed in collaboration with EU Member States, the EEA and representatives from the energy and water industries. The modular structure of the EDO allows more detailed information to be accessed from national, regional and local information systems.

The Observatory has been run and developed continuously by the JRC since 2009. This pan-European database contains past meteorological drought events for the period 1950-2012 which enables the impact of droughts to be investigated in different economic sectors (crop yields, energy production, hydropower generation and river navigation) and the impact of droughts under climate change to be analysed.

The Global Disaster Alert and Coordination System (GDACS) provides a unique multi-hazard alert service to more than 20 000 registered professional emergency managers. Managed by the JRC, GDACS allows for the sending of automatic alerts via e-mail, fax or SMS to the international first responders community. This platform, which is in practice a system of existing disaster information management systems, provides real-time access to web-based disaster information systems and related coordination tools.

The Global Flood Partnership is an informal network of scientists and practitioners from public, private and international organisations interested in global flood monitoring, modelling and forecasting. The overall objective of the Partnership is the development of flood observational and modelling infrastructure, leveraging on existing initiatives for better predicting and managing flood disaster impacts and flood risk globally. The Partnership is led by the JRC and the Dartmouth Flood Observatory.

Work in progress

With years of experience in developing early-warning systems for Europe, the JRC is now moving towards the development of global systems for floods, droughts and wildfires. The work is done in close collaboration with international expert groups and partnerships aimed at bringing together scientific communities, service providers, as well as decision- and policy-makers to strengthen the overall capacity for disaster risk management. The systems' capabilities will be further strengthened as soft adaptation tools for extreme weather-driven hazards in current and future climates.

The JRC aims at improving hazard monitoring, impact modelling and automatic situation awareness systems, for instance by incorporating new promising technologies such social media or satellite technology that may lead to faster and more efficient and effective emergency management.

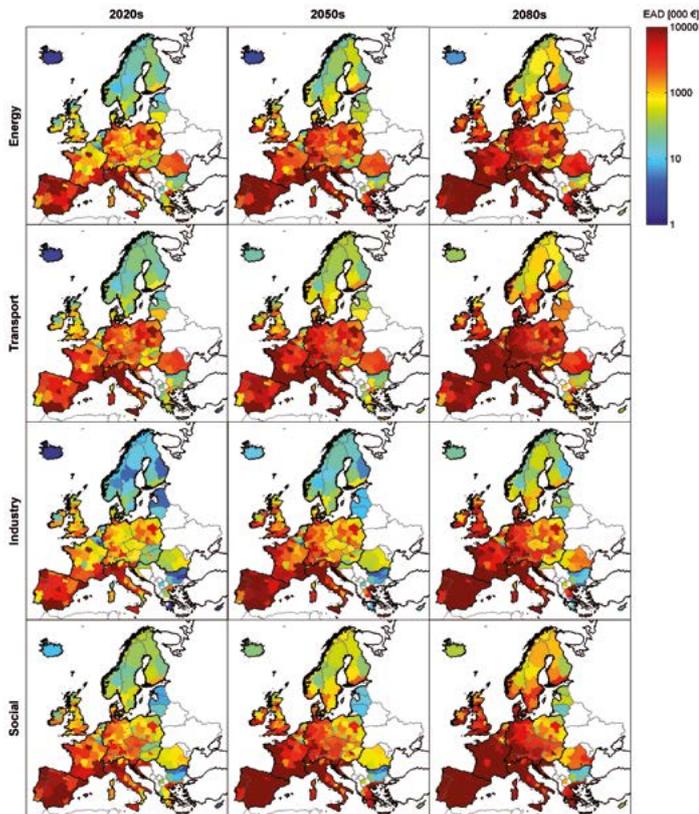
The JRC has established the European Crisis Management Laboratory for testing, comparing and benchmarking mature situation awareness technology in a real crisis room environment, to demonstrate its added value and encourage its update by emergency authorities.

5.6 Assessing multi-hazard risks for better preparedness

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – An EU Strategy on adaptation to climate change, COM(2013) 216 final
- Communication from the Commission to the European Parliament and the Council of 26 October 2010 – Towards a stronger European disaster response: the role of civil protection and humanitarian assistance, COM(2010) 600 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 23 February 2009 – A Community approach on the prevention of natural and man-made disasters, COM(2009) 82
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 18 July 2007 – Addressing the challenge of water scarcity and droughts in the European Union, COM(2007) 414
- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive)
- Directive 2007/60/EC the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks

To better prioritise adaptation strategies to a changing climate, there is a need for quantitative regional-level assessments that are systematic and comparable across multiple climate hazards. In this context, a multi-hazard assessment taking into account possible regional variations in intensity and frequency of climate extremes is essential to identify those areas potentially more exposed to hazards under climate change.



Multi-hazard risk scenarios for critical infrastructures in the energy, transport, industry and social sector. The maps show expected annual damage for each sector in three future time slices, aggregated over NUTS2 regions, in thousands of euros. NUTS2 are territorial units in the EU's Member States.

In collaboration with different European modelling groups, the JRC has produced and analysed a set of consistent pan-European climate-hazard modelling data, including heat- and cold waves, river and coastal floods, droughts, wildfires and windstorms. This work provides the first comprehensive multi-hazard assessment for Europe under climate change and focuses in particular on the comparability among single-hazard physical impacts and on the degree of overlap between areas exposed to multiple hazards throughout this century.

Furthermore, the JRC has assessed the economic impacts of different hazards to industry, energy and transportation infrastructures throughout the 21st Century. The methodology combines climate-hazard projections with a detailed representation of sectorial physical assets and systems, and quantitative estimates of their vulnerability, based on expert views and recorded climate disasters.

The analysis shows that meteorological drought events tend to be longer, more frequent, intense, and severe in Southern Europe – especially in the Mediterranean region and the Balkans – mainly due to the key role of continuous warming. In Northern Europe, meteorological

drought events tend to be shorter, less frequent, intense, and severe – especially in Scandinavia – mainly due to projected increases in precipitation. The damage functions, applied to the projected drought events, show a more frequent reduction in cereal yields in Southern Europe. Even though Southern Europe will suffer most from more frequent and intense cuts in hydropower supply, Northern Europe will also be exposed to negative, although less severe, impacts.

JRC researchers have explored possible ways to limit economic losses from flooding. They suggest that a larger part of the financial losses can be shared by increasing the levels of flood insurance among those households likely to be affected by flooding, or by increasing the budget of the EU Solidarity Fund. However, the most effective option for loss reduction seems to be investment in flood defences. An investment of around EUR 1.75 billion today could reduce the estimated annual flood losses by around EUR 7 billion, a reduction of almost 30 %, by 2050. Because of the uncertainty in climate and social models and the costs of building and maintaining flood-protection measures, investments should aim for acceptable, rather than optimal levels of protection.

The JRC is developing a global integrated coastal flood-risk management system that links climate, wave, surge, flood and impact modelling tools. For a range of socio-economic, climate and sea level rise trajectories, European and global-scale decadal projections of future coastal risks will be generated to obtain a solid evidence base for investment in coastal defences. The system will perform real-time coastal-flood detection and monitoring for improved post-event recovery, as well as short-term coastal-flood warning for better preparedness. The scale of application allows for the identification of regions in Europe that may be particularly vulnerable to coastal hazards in view of global warming, and complements national and local studies that often provide more detailed small-scale information. As regards heatwaves, the JRC has introduced a new Heat Wave Magnitude Index (HWMI) that can be compared across different regions and time periods. It takes into account both the duration and intensity of heatwaves and can serve as a benchmark for evaluating the impacts of future climate change and under different Representative Concentration Pathways, adopted by the IPCC in its Fifth Assessment Report (AR5).

Work in progress

The JRC is currently calculating the HWMI for different regions of the world, such as Europe and Africa, under different future scenarios of GHG emissions, by using the latest results of high-resolution climate models. These results may be used to assess the impact of climate change on human health and other key sectors such as energy production, and to define the most appropriate and effective adaptation options.

5.7 Assessing climate change impacts on agriculture

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 16 April 2013 – An EU Strategy on adaptation to climate change, COM(2013) 216 final, through the implementation of the European Climate Adaptation Platform (Climate-ADAPT)
- Commission staff working document accompanying the White Paper – Adapting to climate change: Towards a European framework for action COM(2009) 147 final.

It is estimated that world food production will have to double by the mid-21st Century to feed a global population of about 9 billion. The EU is currently spending about 39 % of its budget on the CAP to provide affordable and secure food for consumers. Understanding and characterising the impact of climate change on agriculture at both the European and the global scale is of utmost importance. In the coming decades, projected changes in the climate system pose a serious threat to food security. This is in the context of potential increases in the global population and cereal consumption, competition for land and the significant vulnerability of agricultural production systems to climate change in many global regions. Therefore, in the near future, ensuring food security and market stability will represent key societal challenges.

The JRC collaborates with international partners – and has also developed its own modelling capabilities – to actively address open scientific issues on climate change, variability, extremes and impacts on agriculture. It works on bridging the gap between climate change and crop models, advancing the current understanding of key uncertainties, and assessing exposure and vulnerabilities with respect to agriculture both within and outside Europe.

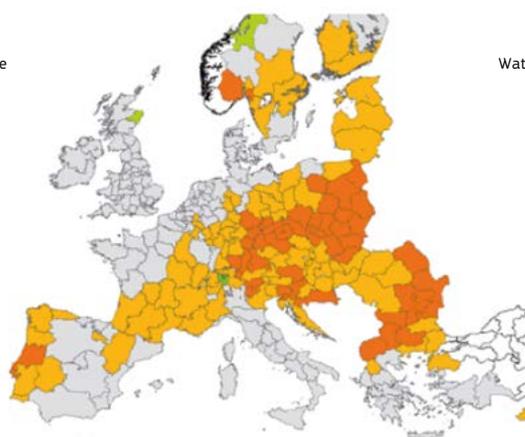
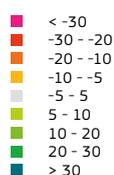
JRC has developed the flexible BIOMA modelling environment which, at high spatial resolution, can use a variety of crop models, different meteorological (climate change) scenarios, and assimilate other datasets. By using a specific climate scenario for the 2030s, it has been estimated that crop yields in Europe may diminish by 5 to 20 % compared to those in the current climate. Adaptation to climate change (for example, improved irrigation, choice of different crop varieties or different crops, improved timing of the cropping calendar to avoid heat and drought stress) may partially or fully compensate for climate change, but may also be subject to other factors such as water scarcity. Using tools from the JRC agro-economic modelling platform iMAP, the impact of different GHG mitigation policy options for EU agriculture is assessed. The JRC actively participates in and contributes to the main international initiatives, such as the Agricultural Model Intercomparison and Improvement Project (AgMIP), and the Agricultural Market Information System (AMIS).

Work in progress

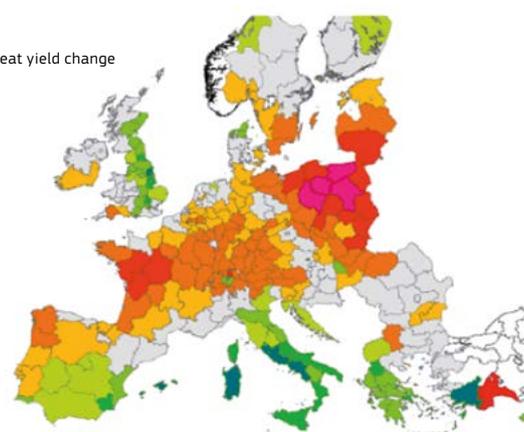
Understanding the possible effects of climate change on agricultural production in Europe and globally is still limited. Several improvements are required to further enhance confidence in impact estimates. The modelling system needs to be expanded with further processes, like pests, diseases and nutrients, which may change under climate change conditions. The impacts of climate extremes under current conditions need to be better understood to improve future simulations. A more robust assessment of the variety of climate change conditions and timescales is also needed. Currently, the impact of concurrent climate extremes on a world scale and their effect on crop yields and global markets is not well understood. Adapting the choice of varieties and more efficient water management indicate possible ways of increasing yields, but in general the analysis framework ignores other factors, such as nutrients, farming practices, and the socio-economic situation that may become important under changing conditions.

Potential wheat yield change

Change in wheat crop yields (%)



Water limited wheat yield change



The maps present change in wheat crop yields between the 2030s and 2000s (IPCC HadleyCM3 scenario) analysing the effects of changing rainfall and temperatures. The left panel shows potential yield assuming that the availability of water is not a limitation, and temperature effects are more important in Central and Eastern Europe than in Southern Europe. For rain-fed water-limited wheat production, the increasing rainfall in this climate scenario in Southern Europe leads to better yields, while in Central and Eastern Europe, due to higher temperature and less rain, yields are decreasing. (Probabilistic multi-model multi-scenario analysis is needed to identify areas at risk for reduced crop production).

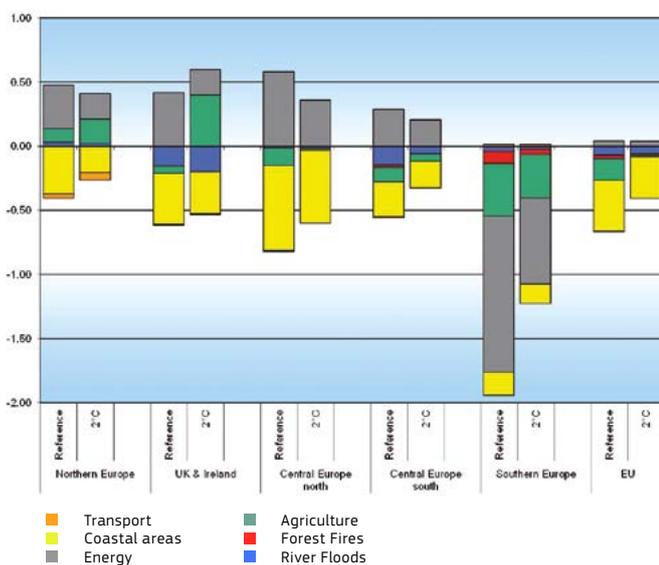
5.8 Measuring economic impacts of climate change across sectors

The JRC's activities in this area provide scientific support to the following policy initiative:

- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 16 April 2013 – An EU Strategy on adaptation to climate change, COM(2013) 216 final.

Adaptation to climate change intends to reduce the possible negative impacts of climate change and maximise the potential benefits. The JRC hosts cross-disciplinary teams studying climate impacts and adaptation options in Europe across a range of impact areas, such as agriculture, forest fires, energy and river floods. Understanding climate impacts is important in order to define how best to adapt to climate change.

The EU launched its adaptation policy in 2013, with the adoption of the EU Adaptation Strategy Package. One of the objectives of this strategy is to improve the knowledge base so as to better support adaptation policies and measures. The JRC is in a good position to provide valuable expertise in this respect, as it provides a series of high-resolution biophysical impact models able to simulate possible impacts due to climate change, and how specific adaptation measures can reduce them.



The PESETA II report assessed the expected welfare impacts (as percentage of GDP) in EU regions under two main simulations: A reference scenario assuming current trends are maintained in time and under a mitigation scenario, where coordinated action achieved to maintain global temperature increase below 2°C.

In 2014, the JRC published an assessment of the possible economic impacts of climate change in Europe – the JRC PESETA II project. The objective of this project was to gain insights into the sectorial and regional patterns of climate change impact in Europe by the end of this century.

The study used a large set of climate model runs and impact categories (ten categories: agriculture, energy, river floods, droughts, forest fires, transport infrastructure, coasts, tourism, habitat suitability of forest tree species, and human health). The project integrated biophysical direct climate impacts (from eight of the impact categories) into a macroeconomic model, which enables the comparison of the different impacts based on common economic metrics. It was found that the geographical distribution of climate damage is very asymmetric with a clear bias towards southern European regions.

If no further action is taken and global temperature increases by 3.5°C, climate damages in the EU could amount to at least €190 billion, a net welfare loss of 1.8 % of its current GDP. Several weather-related extremes could roughly double their average frequency. As a consequence, heat-related deaths could reach about 200 000, the cost of river flood damages could exceed €10 billion and 8000 km² of forest could burn in southern Europe. The number of people affected by droughts could increase by a factor of seven and coastal damage, due to sea-level rise, could more than triple.

These economic assessments are based on scenarios where the climate expected by the end of the century (2080s) occurs in the current population and economic landscape.

Work in progress

The GAP PESETA study fills some of the knowledge gaps in the JRC PESETA II project. In particular, it covers two additional impact categories – droughts and ecosystem services, deepens the analysis of river floods, and explores how impacts in the rest of the world could affect the EU in economic terms.

Further work is foreseen in the context of the JRC PESETA III project, which will enlarge the previous analyses with a different focus: the next few decades, adaptation measures, extreme events and possible spillovers.

5.9 Developing fit for purpose indicators for climate resilient growth and development

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Annex to the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A Global Partnership for Poverty Eradication and Sustainable Development after 2015, COM(2015) 44
- Communication from the Commission to the European Parliament and to the Council of 25 February 2015 – The Paris Protocol – A blueprint for tackling global

- climate change beyond 2020, COM(2015) 81.
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 2 June 2014 – A decent Life for all: from vision to collective action, COM (2014) 335 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 27 February 2013 – A decent Life for all: Ending poverty and giving the world a sustainable future, COM(2013) 92
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 16 July 2013 – Beyond 2015: towards a comprehensive and integrated approach to financing poverty eradication and sustainable development, COM(2013) 531
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Increasing the impact of EU Development Policy: an Agenda for Change, COM(2011) 637
- Communication from the Commission of 3 March 2010 – Europe 2020: A strategy for smart, sustainable and inclusive growth, COM(2010) 2020
- Communication from the Commission – Building a Global Climate Change Alliance between the EU and poor developing countries most vulnerable to climate change, COM(2007) 540 final
- Communication from the Commission to the Council and the European Parliament of 11 March 2003 – Climate change in the context of development cooperation, COM(2003) 85.

Global efforts to set the world on a climate resilient development pathway require an understanding of the relationship between climate change and development, as well as metrics for identifying the countries, groups of people and sectors most seriously threatened by climate change. Despite the proliferation of alternative indicators, most existing measures do not capture the multidimensional aspects of climate resilient development. Climate risk indices often show some limitations as their theoretical framework is vaguely defined or even missing. As a result, commonly used indicators may not always consider future hazards or economic and ecological aspects.

Climate-risk assessment indices often show a lack of information on the latest developments in the international policy debate, especially with respect to the loss and damage concept and climate resilient development. JRC work in this field aims to fill this gap. The first focus has been on identifying the criteria and fit for purpose indicators to be built, in order to prioritise the allocation of funding to the poorest developing countries in coherence with the new Sustainable Development Goals. Special attention is given to defining resilience and adaptive

capacity from an economic perspective, and how the preservation of natural capital contributes to adaptation and development.

In order to help identify those countries, sectors and populations most seriously threatened by climate change and to put in place targeted policy actions, the JRC developed a global index to monitor the progress of climate resilient development policies. This open source index facilitates the ex-ante evaluation of the structural features of the vulnerability to climate change of the target countries of the EU Global Climate Change Alliance (GCCA+) programme. The index includes metrics on extreme climate events, climate vulnerability and adaptive capacity, taking into account the climate vulnerability of ecosystem services and the role of natural resources in climate adaptation. It covers social, economic and environmental aspects of achieving climate-resilient development by aggregating 34 country-level 'fit-for-purpose indicators'. These have been identified on the basis of their relevance for the EU GCCA+ initiative and their compliance with criteria such as reliability, open source, consistency, scientific robustness, global coverage, and publicly available data. The GCCA+ index can be consulted via an online knowledge platform that acts as an interface between science and policy, and provides transparent, reliable, accurate, and open source information on the indicators, data and methodology applied to build the index. It allows users to examine the factors behind the index and the indicators in relation to climate-related and weather-driven hazards, vulnerability, adaptive capacity, mitigation and resilience.

Work in progress

The JRC is establishing a knowledge platform supporting the Sustainable Development Goals (SDGs) in order to ensure their implementation is backed by evidence. It will focus on the link between economic, social and environmental dimensions of the SDGs in order to understand the viability of reaching multiple objectives simultaneously.

6 Innovation for sustainability

With the rapidly growing global population, unsustainable use of natural resources, environmental degradation and the consequences of climate change, we are already pushing our planetary boundaries to tipping points of no return. As a consequence, there is a lot of pressure on countries, organisations and people as we seek new ways to change our approach to using natural resources and patterns of consumption and production.

Innovation can bring solutions, but it needs to be addressed not only from an economic, but also a social and environmental dimension. The recently adopted Sustainable Development Goals and the EU's Circular Economy package now present us with an opportunity to take concerted action.

In this context, the JRC is currently looking into new methods to recycle water, share and process 'big' environmental data, as well as helping innovative environmental technologies to reach the market through its Environmental Technology Verification programme.

6.1 Proposing innovative solutions to address water challenges

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 10 May 2012 on the European Innovation Partnership on Water COM(2012) 216 final.

While Europe is conscious of the water challenge, the topic is losing importance for individual citizens who are used to having easy access to sufficient and clean drinking water or enjoying good quality bathing water. In addition, despite its economic relevance and numerous links to other economic sectors, the EU water sector is highly fragmented and the potential for growth is not being sufficiently exploited.

Within this framework, the European Innovation Partnership on Water (EIP Water), which is an initiative within



JRC model installation of sub-surface flow constructed reed bed for water reuse.

the EU Innovation Union, has identified eight priorities to overcome this situation and to promote genuine European know-how and solutions for better and cleaner water. These priority areas are water governance, decision-support systems and monitoring, financing for innovation, water reuse and recycling, water and wastewater treatment including recovery of resources, the water-food-energy nexus, flood and drought risk management, and ecosystem services. In all these areas, smart and key-enabling technologies are also being considered and attention is paid to engage with the citizen directly or through municipalities.

The JRC plays an important role in the daily management of the EIP Water. JRC scientists provide the necessary technical and scientific input to assess, for example, new proposals for so-called action groups, which are tackling selected challenges in the above-mentioned priority areas.

In the field of the water-food-energy nexus, JRC scientists are helping to address the interconnected challenges and key issues of the three sectors together. Here, innovation should be considered in a wider sense going beyond the sheer technological scale. In fact, issues like water

governance or innovation financing have the same need for 'out-of-the box' thinking.

In addition, JRC scientists are studying the ecological, chemical or other footprints of related technologies, such as constructed reed-beds, desalination or aquifer recharge. The JRC is involved in experiments in both large and small scale pilot plants aiming at improving the water-food-energy nexus in tourism sites, but is also engaged to promote integrated water management at local level.

As regards the issue of water in cities, the JRC facilitates dialogue between municipalities and helps them to exchange best practices relying also on political and social sciences. This approach aims to provide a platform of solutions. To this end, the JRC works with the Network for Water in European Regions and Cities as well as the Water supply and sanitation Technology Platform to achieve a situation of mutual benefit and acceptance among municipalities, water-supply services and the citizen.

The JRC is also studying the link between the exploitation of unconventional gas sources (shale gas) and risks related to near-by water bodies. In this context, there is an increasing need to anticipate chemical risks for novel and less well investigated structures.

Recently, the JRC assessed national and international guidelines to implement water reuse in Europe. To this end, the associated technical, environmental, health and socio-economic challenges for such reuse were analysed and described. Given the lack of formal guidelines at European level to address the reuse of treated wastewater, the JRC compared relevant national and international measures and provided a risk-based management approach. It identified needs for and barriers to technological innovation and regulation.

The results indicate that the convergence of water reuse regulations represents a very important challenge for the global development of water reuse and its integration into urban water management. New regulations should be based on health and environmental protection, and should include treatment goals and adequate and affordable techniques for monitoring water quality. The economic viability of water reuse projects is another significant challenge that can be met by appropriate water management policies, as the value of reclaimed water is determined by the use to which it is put.

6.2 Helping innovative environmental technologies to reach the market

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Decision No 1639/2006/EC of the European Parliament and of the Council of 24 October 2006 establishing a Competitiveness and Innovation Framework Programme (2007 to 2013)
- Horizon 2020 Work Programme 2014-2015
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Innovation for a sustainable future – the Eco-innovation Action Plan (EcoAP), COM(2011) 899 final.

The JRC provides scientific and technical support to the EU's Environmental Technology Verification (ETV) pilot programme. With the set-up phase now complete, the JRC is mainly focusing on running the EU ETV scheme. The EU ETV Pilot programme started in 2012 and will stop at the end of 2016. During its last year, the Pilot Programme will be evaluated in order to allow the Commission to decide on a permanent EU-wide ETV programme. ETV is a new tool to help innovative environmental technologies reach the market. It validates the performance claims put forward by technology manufacturers, on a voluntary basis, by qualified third parties called Verification Bodies (VBs). This should help manufacturers prove the reliability of their claims, and help technology purchasers identify innovations that suit their needs. As a result, technological lock-in is overcome, while innovative environmental protection measures can emerge. The EU ETV pilot programme, launched in 2011 as part of the Eco-Innovation Action Plan (Eco-AP) is run on an experimental basis and covers three technological areas: water treatment and monitoring; materials, waste and resources; and energy technologies.

The JRC chairs and coordinates the work of three ETV Technical Working Groups (TWGs), one per technological area. These TWGs, comprising experts invited by the Commission and experts representing the Verification Bodies, aim, among other things, to ensure the harmonisation of practices across the VBs by providing concrete guidance for the implementation of the ETV. Other tasks comprise identifying potential environmental impacts related to certain technologies, and initiating scientific and technical discussions on the dedicated work platform in order to exchange information and good practices.

One of the initial tasks of the JRC consisted in the communication and dissemination of the pilot programme and its results, including running the EU ETV website which includes the registry of verified technologies, and presenting the ETV at scientific conferences and workshops.

Furthermore, the JRC provides support for cooperation and standardisation activities on an international level, both in the International Working Group on ETV and at

the International Organization for Standardization (ISO), where a global standard for ETV will be finalised in 2016. The International Working Group on ETV is the result of an international agreement between the EU, Canada and the USA. It has now expanded to The Philippines, Korea and Japan. The Group, composed of participants all having their own ETV scheme, is working on the mutual recognition of ETV verifications and has initiated the ISO process.

The ETV TWGs have been operational since early in 2013. Up to now, 13 VBs have been accredited (ISO 17020) for ETV in seven Member States (UK, DK, FR, IT, FI, PL, CZ), and 50 ETV verifications have been initiated in six European countries since the launch of the programme. The JRC publishes the verification documents on the dedicated work platform to enable scientific and technical discussions among the TWG experts. Where relevant, the JRC has initiated these discussions and provided its expertise in the process. So far, five verifications have been completed. The first verification was completed and published on the JRC website in December 2014 and as of September 2015 four more have been completed; others should follow shortly.

Work in progress

ETV is currently a well-functioning scheme, which is still in a phase of technical/scientific deployment with a high number of guidance documents being prepared. These guidance documents have a triple objective: to simplify the work of VBs by providing concrete guidance on a number of issues; to ensure that practices are harmonised among VBs; and to enhance the reliability of the scheme through the implementation of sound and robust verification methods. Most of the current guidance documents focus on generic issues related to the verification process, while new documents are expected to focus more on technology-specific topics, capitalising on the practical experience being gained from ongoing verifications. The JRC will also participate in the evaluation of the pilot phase, which shall allow the Commission to make the appropriate decisions for the possible deployment of a full-scale ETV programme in 2017.

6.3 Analysing 'big data' and interoperability

The JRC's activities in this area provide scientific support to the following policy initiatives:

- Directive 2013/37/EU of the European Parliament and of the Council of 26 June 2013 amending Directive 2003/98/EC on the re-use of public sector information
- Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)

- Communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Towards interoperability for European public services, COM(2010) 744 final
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 2 July 2014 – Towards a thriving data-driven economy, COM(2014) 442 final

A recent study carried out by SINTEF (the largest independent research organisation in Scandinavia) estimates that 90 % of all the data in the world have been collected in the last two years alone. There are many definitions of 'big data'. According to Gartner, 'big data' is high-volume, high velocity and/or high variety (3Vs) information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision-making and process automation. 'Big data' includes business transactions, photos, surveillance videos and activity logs as well as scientific data from satellites, sensors and unstructured text posted on the web, such as blogs and social media. Combining and analysing this vast amount of data has enabled large commercial companies to segment their markets more carefully and target customers with more personalised offers.

The rapid development of technology, particularly with respect to mobile phones with internet connections, and social media platforms to share information and data, are also creating new opportunities to engage the public. Citizen science refers to the increasing number of projects in which members of the public collect, analyse or process data for research, education, community building, awareness raising or impact assessment. Citizen content is a major contributor to 'big data'.

The European Commission has recognised the opportunities arising from both big data and citizen science/citizen engagement. In July 2014, the Commission outlined a new strategy on big data, supporting and accelerating the transition towards a data-driven economy in Europe. It also launched a Big Data Public Private Partnership initiative to harness the opportunities of 'big data' in Europe.

Although 'big data' and citizen science offer many opportunities, they also set a few challenges with respect to the methodology for data analysis, data access, data quality, ethical issues, as privacy, and interoperability. These are issues in which the JRC, as a Commission in-house service, has a key role to play.

As regards interoperability, the JRC is the technical coordinator of the 2007 INSPIRE Directive which establishes a European web-based infrastructure for sharing spatial environmental and location data. This infrastructure is being developed in all 28 EU Member States, addressing 34 key data themes necessary to

support environmental policies and policies that affect the environment. Therefore, interoperability of both the data and the systems is key to finding, accessing, understanding and sharing information across the EU. INSPIRE has been recognised as one of the few EU-wide initiatives promoting interoperability in public administration in the environmental sector. Lessons learnt in INSPIRE are now being considered for the revision of the European Interoperability Framework and Strategy to address specific measures to ensure the interoperability of location-based services.

Because INSPIRE requires a sustained effort across all EU countries for 10 to 15 years it is important that the standards and technologies used are open to the rapid pace of technological and social development. For this reason, back in 2008, the JRC had already started to consider the future evolution of INSPIRE and had identified the need to develop interoperability arrangements across disciplines, in particular with the emerging e-government and open data initiatives, and with the new forms of data collection, including web-enabled sensors, new satellites, and the public through mobile platforms and social media.

As regards 'big data', the JRC launched a pilot project in 2015 on Earth Observation and Social Sensing, recognising that such data is increasingly relevant to almost all areas of research at JRC.

There is a general perception that data collected or generated by the public is of a lesser quality than data collected through official and scientific means. To assess these claims, in 2010 the JRC launched a large-scale project to compare the identification of forest fires obtained by analysing social media, such as Twitter and Flickr, with the official data coming from satellite and incorporated in the EFFIS. The study showed very promising results, with up to 80 % of forest fires identified correctly.

JRC scientists are also analysing the interoperability challenges of using mobile sensor systems in drones, and communication protocols between mobile and fixed air-quality sensors.

The JRC is also involved in several research projects on sensor architectures and platforms and multi-disciplinary interoperability. The JRC is establishing a digital archive of EU-funded citizen science projects and the data they have collected.

The digital economy in Europe cannot develop fully unless there is a high degree of interoperability between information systems, data and processes across the 28 EU Member States. The work done by the JRC, within the framework of INSPIRE, to develop standards for documenting data resources, making them discoverable and accessible through web services and, above all, efforts to harmonise data content in INSPIRE's key 34 themes has been pioneering and has made JRC a recognised world performer in interoperability. The fact that these standards have been grounded in European legislation, which has been unanimously approved by the Member States, is also a major achievement because it required effective consultation and partnership with all the key stakeholders in Europe. This experience in interoperability is now contributing to open data and 'big data' initiatives in Europe and is building the basis for integrating heterogeneous data from the public sector, private sector and the public in the conceptual framework of developing a participative 'digital earth'. The vision for digital earth developed by JRC with international partners in Europe, USA, China and Australia was published in 2012 in the prestigious Proceedings of the US National Academies of Science.

Acronyms

a4a	Assessment for All	ILCD	International reference Life Cycle Data system
ACP	African, Caribbean and Pacific	INSPIRE	Infrastructure for Spatial Information in Europe (EU directive)
ADO	African Drought Observatory	IPBES	Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services
AgMIP	Agricultural Model Intercomparison and Improvement Project	IPCC	Intergovernmental Panel on Climate Change
AMIS	Agricultural Market Information System	IPChem	Information Platform for Chemical Monitoring Data
AQUILA	National Air Quality Reference Laboratories	ISO	International Organization for Standardization
BIOPAMA	Biodiversity and Protected Areas Management Programme	ITPS	Intergovernmental Technical Panel on Soils
BISE	Biodiversity Information System for Europe	KP	Kyoto Protocol
BWD	Bathing Water Directive	LCA	Life-cycle assessment
CAP	Common Agricultural Policy	LCD	Liquid-crystal display
CBD	Convention on Biological Diversity	LCDN	Life Cycle Data Network
CFP	Common Fisheries Policy	LCT	Life-cycle thinking
CICES	International Classification of Ecosystem Services	LUCAS	Land Use/Cover Area frame statistical Survey
CIS	Common Implementation Strategy	LUISA	Land Use-based Integrated Sustainability Assessment
CCAC	Climate and Clean Air Coalition	LULUCF	Land Use, Land Use Change and Forestry
CO ₂	Carbon dioxide	MAES	Mapping and Assessment of Ecosystems and their Services
CODIA	Latin American Water Directors	MSFD/MCC	Marine Strategy Framework Directive Competence Centre
CORDEX	Coordinated Regional climate Downscaling Experiment	MSE	Management Strategy Evaluation
DOPA	Digital Observatory for Protected Areas	MSFD	Marine Strategy Framework Directive
DWD	Drinking Water Directive	MTR	Mid-term Report
EAP	Environment Action Programme	NGO	Non-Governmental Organization
EASIN	European Alien Species Information Network	OEF	Organisation Environmental Footprint
ECHA	European Chemicals Agency	OFAC	Forest Observatory of Central Africa
EDGAR	Emissions Database for Global Atmospheric Research	PACSBio	Programa de Apoyo a la Conservación Sostenible de la Biodiversidad
EDO	European Drought Observatory	PDO	Protected designation of origin
EEA	European Environment Agency	PEER	Partnership for European Environmental Research
EFAS	European Flood Awareness System	PEF	Product Environmental Footprint
EFSA	European Food Safety Authority	PESETA	Projection of Economic impacts of climate change in Sectors of the European Union
EFDAC	European Forest Data Centre	PGI	Protected geographical indication
EFFIS	European Forest Fire Information System	POLES	Prospective Outlook on Long-term Energy Systems
EIP	European Innovation Partnership	R&D	Research and development
EIPPCB	European Integrated Pollution Prevention and Control Bureau	REDD+	Reducing Emissions from Deforestation and forest Degradation in developing countries
EMA	European Medicines Agency	RSC	Regional Sea Convention
EMEP	European Monitoring and Evaluation Programme	SCADO	South and Central American Drought Observatory
EIONET	European Environment Information and Observation Network	SCAR	Standing Committee on Agricultural Research
ENSEMBLE	Methods to Reconcile Disparate National Forecasts of Medium and Long-range Atmospheric Dispersion	SLCPs	Short-lived climate pollutants
EPRI	Electric Power Research Institute	SOC	Soil organic carbon
EQS	Environmental Quality Standard	STECF	Scientific, Technical and Economic Committee for Fisheries
ESDAC	European Soil Data Centre	SUSPROC	Sustainable Production and Consumption
ESP	European Soil Partnership	UN	United Nations
ESTIMAP	Ecosystem services mapping at European scale	UNECE	United Nations Economic Commission for Europe
ETV	Environmental Technology Verification	UNEP	United Nations Environment Programme
EU	European Union	UNEP-WCMC	United Nations Environment Programme - World Conservation Monitoring Centre
FAO	Food and Agriculture Organization of the United Nations	UNEP-WMO	United Nations Environment Programme - World Meteorological Organization
FAIRMODE	Forum for air quality modelling in Europe	UNFCCC	United Nations Framework Convention on Climate Change
GEM-E3	General Equilibrium Model for Economy - Energy - Environment	USDA	United States Department of Agriculture
GES	Good environmental status	VBs	Verification Bodies
GHG	Greenhouse gas	VGSMS	Voluntary Guidelines for Sustainable Management of Soil Resources
GI	Green Infrastructure	WEEE	Waste electrical and electronic equipment
Gt	Gigatonnes	WFD	Water Framework Directive
GloFAS	Global Flood Awareness System	WHO	World Health Organization
GNSS	Global Navigation Satellite System	WIOD	World Input-Output Database
GSP	Global Soil Partnership		
Guidos	Graphical User Interface for the Description of image Objects and their Shapes		
HWMI	Heat Wave Magnitude Index		
IAS	Invasive Alien Species		
ICES	International Council for the Exploration of the Sea		
ICPDR	International Commission for the Protection of the Danube River		

Useful tools

1. Natural capital

JRC Water Portal: <http://water.jrc.ec.europa.eu>
Information Platform for Chemical Monitoring data: <http://ipchem.jrc.ec.europa.eu/>
Scientific fisheries data dissemination tool: <https://fishreg.jrc.ec.europa.eu/web/datadissemination/home>
Assessment for All: enhancing fisheries modelling: <https://fishreg.jrc.ec.europa.eu/web/a4a>
Marine fish population geobrowser: https://fishpoptrace.jrc.ec.europa.eu/map/genetics_geobrowser/
Fish habitat mapping: <https://fishreg.jrc.ec.europa.eu/fish-habitat>
Spatial economic analysis of coastal fishing communities: <https://fishreg.jrc.ec.europa.eu/web/coastalcommunities>
The Global Remote Sensing Survey: <http://www.fao.org/forestry/fra/remotesensingsurvey/en/>
Observatory of Central African Forests: <http://www.observatoire-comifac.net/>
European Soil Data Centre: <http://esdac.jrc.ec.europa.eu/>
Land Use-based Integrated Sustainability Assessment (LUISA) platform: http://sa.jrc.ec.europa.eu/?page_id=763
European Forest Data Centre (EFDAC): <http://forest.jrc.ec.europa.eu/efdac/>
JRC Forest Information for Europe: <http://forest.jrc.ec.europa.eu/>
JRC modelling on pattern, fragmentation and connectivity: <http://forest.jrc.ec.europa.eu/activities/forest-pattern-fragmentation/> and GUIDOS Toolbox: <http://forest.jrc.ec.europa.eu/download/software/guidos/>

2. Ecosystem services and biodiversity

The Ecosystem Services Partnership Visualization tool: <http://esp-mapping.net/>
European Forest Data Centre (EFDAC): <http://biodiversity.europa.eu/>
Biodiversity Information Systems for Europe (BISE): <http://biodiversity.europa.eu/>
Mapping and Assessment of Ecosystems and their Services (MAES): <http://biodiversity.europa.eu/maes>
Digital Observatory for Protected Areas Explorer (DOPA): <http://dopa.jrc.ec.europa.eu/explorer/>
The Biodiversity and Protected Areas Management Programme Regional Reference Information system: [http://www.biopama.org/](http://biopama.jrc.ec.europa.eu/)
European Alien Species Information Network (EASIN): [http://easin.jrc.ec.europa.eu/Digital Observatory for Protected Areas \(DOPA\):](http://easin.jrc.ec.europa.eu/Digital%20Observatory%20for%20Protected%20Areas%20(DOPA):) http://ehabitat-wps.jrc.ec.europa.eu/dopa_explorer/
JRC modelling on pattern, fragmentation and connectivity: <http://forest.jrc.ec.europa.eu/activities/forest-pattern-fragmentation/>
GUIDOS Toolbox: <http://forest.jrc.ec.europa.eu/download/software/guidos/>
Graphical User Interface for the Description of image Objects and their Shapes (GuidosToolbox): <http://forest.jrc.ec.europa.eu/download/software/guidos/>
Forest pattern and fragmentation: <http://forest.jrc.ec.europa.eu/activities/forest-pattern-fragmentation/>
Digital Earth Lab: <http://digitalearthlab.jrc.ec.europa.eu>

3. Resource efficiency

European Platform on Life Cycle Assessment: <http://eplca.jrc.ec.europa.eu/>
European reference Life-Cycle Database: <http://eplca.jrc.ec.europa.eu/ELCD3/>
Life-Cycle Assessment Resources Directory: <http://eplca.jrc.ec.europa.eu/ResourceDirectory/>
Film explaining the work on product resource efficiency: <https://ec.europa.eu/jrc/en/research-topic/green-and-resource-efficient-europe>
Sustainability Assessment website: <http://sa.jrc.ec.europa.eu>
The Product Environmental Footprint Pilots: http://ec.europa.eu/environment/eussd/smgp/pef_pilots.htm
The Organisation Environmental Footprint Pilots: http://ec.europa.eu/environment/eussd/smgp/oef_pilots.htm

European Product Bureau: <https://ec.europa.eu/jrc/en/network-bureau/product-bureau>
Sustainable Production and Consumption (SUSPROC): <http://susproc.jrc.ec.europa.eu/activities/emas/index.html>
Raw Materials Information System: <http://rmis.jrc.ec.europa.eu/>
Water Knowledge Management Platform: <http://www.aquaknow.net>
Water Project Toolkit: <http://www.aquaknow.net/en/water-guidelines>
European Integrated Pollution Prevention and Control Bureau (EIP-PCB): <http://eippcb.jrc.ec.europa.eu/>
Bioeconomy Observatory: <https://biobs.jrc.ec.europa.eu>
Data on Agriculture, Trade and Models (DataM): <http://www.datam-web.com/datam/>
World Input-Output Database: <http://www.wiod.org>

4. Sustainable living

National Air Quality Reference Laboratories and the European network (AQUILA): <https://ec.europa.eu/jrc/en/aquila>
Forum for Air-quality Modelling in Europe (FAIRMODE) network: <http://fairmode.jrc.ec.europa.eu/>
DELTA tool: <http://aqm.jrc.ec.europa.eu/DELTA/>
Source apportionment: <http://source-apportionment.jrc.ec.europa.eu/>
Opera tool: <http://www.operatool.eu/html/eng/index.html>
General Equilibrium Model for Economy - Energy - Environment (GEM-E3): <https://ec.europa.eu/jrc/en/gem-e3/>
Regional Frequency Analysis of Climate Variables: <http://www.aquaknow.net/en/news/regional-frequency-analysis-climate-variables-refran-cv-software-version-10>

5. Climate change mitigation and adaptation

Emissions Database for Global Atmospheric Research (EDGAR): edgar.jrc.ec.europa.eu
Methods to Reconcile Disparate National Forecasts of Medium and Long-range Atmospheric Dispersion (ENSEMBLE): <http://ensemble2.jrc.ec.europa.eu/public/>
Coordinated Regional Climate Downscaling Experiment (CORDEX): <http://www.cordex.org/>
Climate Limited-area Modelling-Community: <http://www.clim-community.eu/index.php?menuid=218&reporeid=302>
Coupled Model Intercomparison Project Phase 5: <http://cmip-pcmdi.llnl.gov/cmip5/>
General Equilibrium Model for Economy - Energy - Environment (GEM-E3): <https://ec.europa.eu/jrc/en/scientific-tool/gem-e3>
Prospective Outlook on Long-term Energy Systems (POLES): <https://ec.europa.eu/jrc/en/scientific-tool/peles-prospective-outlook-long-term-energy-systems>
European Flood Awareness System (EFAS): <https://www.efas.eu/>
Global Flood Awareness System (GLOFAS): <http://www.globalfloods.eu/>
European Drought Observatory (EDO): <http://edo.jrc.ec.europa.eu/edo2/php/index.php?id=1000>
African Drought Observatory (ADO): <http://edo.jrc.ec.europa.eu/ado/ado.html>
European Forest Fire Information System (EFFIS): <http://forest.jrc.ec.europa.eu/effis/>
Heat Wave Magnitude Index: http://sizes.com/natural/heat_wave.htm
European Drought Impact Inventory Database (EDI): <http://www.geo.uio.no/edc/droughtdb/edr/impactdatabase>
AGRI4CAST Resources Portal: <https://ec.europa.eu/jrc/en/scientific-tool/agri4cast-resources-portal>
Projection of Economic impacts of climate change in Sectors of the European Union (PESETA): <http://peseta.jrc.ec.europa.eu/>
Climate-ADAPT: <http://climate-adapt.eea.europa.eu/home>
The Global Climate Change Alliance plus (GCCA+) index: <http://knows-dgs.jrc.ec.europa.eu/>

6. Innovation for sustainability

Environmental Technology Verification: <http://iet.jrc.ec.europa.eu/etv/>

Latest publications

This is a selection of JRC publications that cover the main topics in this report. More publications are available on the Science Hub (<https://ec.europa.eu/jrc/>). Most scientific publications are freely available thanks to the European Commission's open access policy.

1. Natural capital

Water

Intercalibration of aquatic ecological assessment methods in the European Union: Lessons learned and way forward, Poikane S, Zampoukas N, Borja A, Davies SP, van de Bund W, 2014, *Environmental Science & Policy* 44:237–246. doi:10.1016/j.envsci.2014.08.006

Mixtures of Chemical Pollutants at European Legislation Safety Concentrations: How Safe are They? Carvalho R N, et al., *Toxicological Science* 2014; doi:10.1093/toxsci/kfu118

Combination Of Multiple Biological Quality Elements Into Waterbody Assessment Of Surface Waters, Caroni R, van de Bund W, Clarke R, Johnson R, 2013, *Hydrobiologia* 704:437–451. doi:10.1007/s10750-012-1274-y

Development of the First Watch List under the Environmental Quality Standards Directive, Negrão de Carvalho R, Ceriani L, Ippolito A, Lettieri T. *EUR* 27142,2015

Oceans

Model averaging to streamline the stock assessment process, Millar C, Jardim E, Scott F, Osio G, Mosqueira Sanchez I, Alzoriz Gamiz N, 2015, *ICES Journal of Marine Science* 72 (1); 93–98, JRC84992. doi:10.1093/icesjms/fsu043

What if stock assessment is as simple as a linear model? The a4a Initiative, Gamito Jardim J, Millar C, Mosqueira Sanchez I, Scott F, Osio G, Ferretti M, Alzoriz Gamiz N, Orio A, 2015, *ICES Journal of Marine Science* 72 (1); 232–236, JRC85006. doi:10.1093/icesjms/fsu050

Simulation testing the robustness of stock assessment models to error: some results from the ICES strategic initiative on stock assessment methods, Deroba J, Butterworth D, Methot R, De Oliveira J, Fernandez C, Nielsen A, Cadrin S, Dickey-Collas M, Legault C, Ianelli J, Valero J, Needle C, O'Malley J, Chang Y, Thompson J, Canales C, Swain D, Miller D, Hintzen N, Bertignac M, Ibaibarriaga L, Silva A, Murta A, Kell L, De Moor C, Parma A, Dichmont C, Restrepo V, Ye Y, Gamito Jardim J, Spencer P, Hanselman D, Blaylock J, Mood M, Hulson P, 2015, *ICES Journal of Marine Science* 72 (1); 19–30, JRC87099. doi:10.1093/icesjms/fst237

Modelling of European Hake Nurseries in the Mediterranean Sea: An Ecological Niche Approach, Druon J, Fiorentino F, Murenu M, Knittweis L, Colloca F, Osio G, Merigot B, Garofalo G, Mannini A, Jadaud A, Sbrana M, Scarcella G, Tserpes G, Peristeraki P, Carlucci R, Heikkonen J, 2015, *Progress in Oceanography* 130; 2015; 188–204, JRC90269. doi:10.1016/j.pocean.2014.11.005

From cooperative data collection to full collaboration and co-management: a synthesis of the 2014 ICES symposium on fishery-dependent information, Doerner H, Graham N, Bianchi G, Bjordal Å, Frederiksen M, Karp WA, Kennelly S J, Martinsohn JT, Murray K, Pastoors M, Gudbrandsen NH, 2014, *ICES Journal of Marine Science*, JRC 90340. doi:10.1093/icesjms/fsu222

The 2014 Annual Economic Report on the EU Fishing Fleet (STECF 14-16), Scientific, Technical and Economic Committee for Fisheries (STECF), Paulrud A, Dentes de Carvalho Caspar, N, Borrello, A, 2014, *Scientific and Policy Report*, JRC92507. doi:10.2788/19812

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JRC Thematic Report: Science for environmental sustainability

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Abstract

The Joint Research Centre (JRC), the European Commission's in-house science service, supports EU Member States in implementing environmental policies and participates in international efforts to promote the sustainable use of resources and improve land-use management.

This report describes the work of the JRC in support of sustainable development. It shows how its tools, methods, analyses and activities contribute to a better understanding, monitoring and anticipation of the complex interactions between human activity and the natural environment. In this way, the JRC supports the development and implementation of policies that protect the global environment and ensure that strategic resources (water, land, forests, food and minerals) are managed in a more sustainable manner for the benefit of present and future generations, within and outside the EU.

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