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Integrated climate change research following the release of the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and most recent research developments

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1. Introduction

There is now clear evidence, presented in the 4th Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC¹), that humankind is contributing to significant changes in the Earth climate system and these changes are adversely affecting natural ecosystems, humans, communities and economic activities. It is also clear that if nations do not act quickly to reduce substantially the emissions of greenhouse gases, global temperatures will rise significantly within the following decades with uncontrollable consequences that will affect the living conditions of many countries around the globe, especially the less advantaged.

Climate change research findings and IPCC assessments have provided the basis for global policy action, such as the UN Framework Convention on Climate Change (UNFCCC²), the Kyoto Protocol and the international post-2012 process launched in the UNFCCC Conference in Bali (December 2007). The EU together with its international partners are now aiming at a new comprehensive global agreement tackling climate change which will set priorities, commitments and goals for the near to long term.

Also the European contribution to the global post-2012 policy action is based on climate change research findings and IPCC assessments. In March 2007, the European Heads of State or Government confirmed the EU policy goal to keep global temperature increase less than 2 °C above preindustrial levels, calling for substantial reductions of global greenhouse gas emissions in order to avoid dangerous climate change³. For the EU the 'triple 20 objective' was set: 20% reduction of greenhouse gas emissions, 20% improvement in energy efficiency, 20% of energy coming from renewable sources by 2020. The Green Paper from the European Commission entitled 'Adapting to Climate Change in Europe-Options for EU action'⁴ initiated a further line for EU action: '*reducing uncertainty by expanding the knowledge base through integrated climate research*', emphasizing issues such as understanding and prediction of impacts, comprehensive datasets, modelling and technologies, and cooperation and networking with the scientific community in EU and non-EU countries.

The role of research within the context of international policies and actions to combat climate change is pivotal. It provides the basis for i) understanding the causes of climate change and project future changes ii) assessing and quantifying the impacts and vulnerabilities at global and regional scale and iii) designing effective adaptation and mitigation policies and their practical implementation. In this context, research on climate change should be addressed in an integrated way, through joined effort and closer collaboration between the relevant scientific disciplines. The importance of climate change research is becoming more evident in the knowledge-based society of the 21st century, where the role of science in policy making is pervasive, providing problem analysis, new knowledge and concepts and innovative solutions.

1 <http://www.ipcc.ch>

2 <http://unfccc.int>

3 http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/93135.pdf

4 <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52007DC0354:EN:NOT>

2. The IPCC 4th Assessment Report and EU-funded research

The IPCC was set up by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP) to provide decision-makers with an objective source of information about climate change. During 2007, IPCC finalised its 4th Assessment Report (AR4 - "Climate Change 2007").

The IPCC's periodic assessments of the state of understanding of causes, impacts, vulnerabilities and possible adaptation and mitigation strategies to climate change are the most comprehensive and widely-agreed surveys available on these subjects, and form the standard reference for all concerned with climate change in academia, government and industry worldwide. Many hundreds of international experts contributed to the IPCC AR4. The report has received unprecedented attention by policymakers, scientists, industry, and the general public. The award of the 2007 Nobel Peace Prize to the IPCC (jointly with Al Gore Jr) recognises its outstanding impact.

IPCC is a key interface between the global science community and international climate policy process. The IPCC does not conduct research. Its role is to assess on a comprehensive, objective, open and transparent basis the latest scientific, technical and socio-economic literature produced worldwide, relevant to the understanding of the risk of human-induced climate change, its observed and projected impacts and options for adaptation and mitigation.

The AR4 and its findings help guide future strategies for climate change observations and research by highlighting both robust findings as well as key uncertainties and research needs clarifying gaps and shortcomings in the assessment.

The European Community (EC) is one of the main actors that are driving forward the climate science as testified by the vast amount of research activities funded under the 4th, 5th, the 6th Research Framework Programmes, as well as those envisaged under the current 7th Research Framework Programme (FP7)⁵. The EC is funding research on the scientific, technical and socioeconomic aspects of human-induced climate change, its potential impacts and options for adaptation and mitigation. In addition the EC's Joint Research Centre (JRC) has greatly enhanced its direct research activities in the field of climate change during recent Framework Programmes. Even though the main focus is on Europe, a considerable amount of EC-funded research activities address key scientific questions in vulnerable ecosystems/regions outside Europe. In that respect the geographical domain covered by the Framework Programme is global, and participation is open to third countries. A detailed list and description of current EU-funded climate change research projects can be found in the publication 'European Research on Climate Change – Catalogue of FP6 Projects'⁶.

European research teams and projects have played a major role both in providing the scientific input and in the analysis within the IPCC process, and have thereby had a significant bearing on international policy making on climate change. In addition, the EC is invited to provide comments to the IPCC documents during the review process. Conversely, the IPCC process has helped to identify major areas of scientific uncertainty and of social and

⁵ <http://cordis.europa.eu/fp7>

⁶ http://ec.europa.eu/research/environment/pdf/european_research_climate_change_en.pdf

political sensitivity, and this has been helping to direct the efforts under the Framework Programmes.

As a major player in global climate research, the EC has a key interest to be closely involved in addressing research needs identified by the IPCC and ensure, to the extent possible, that project results are available on time to be included in IPCC's next assessments.

On the 19th and 20th November 2007, immediately after the official release of the AR4 (17 November, Valencia, Spain), The European Commission, Directorate General for Research, organised in Brussels the International Symposium on '*Future Climate, Impacts and Responses – The IPCC 4th Assessment Report and EC Integrated Climate Research*'⁷. Key European figures from the IPCC AR4 (including the IPCC Secretary, the Vice Chair of Working Group I, the Head of Technical Support Unit, lead authors, contributing authors and review editors) were invited in order to present and discuss important results from the report. We must note that the AR4 analysed research findings presented in peer review literature before the end of 2005. In order to enrich further the debate and discussions during the symposium, research findings made available after that date by key ongoing EU-funded research projects, were also presented. In that respect, the Symposium provided the platform for presenting and discussing the current state-of-the-art on climate change research with special emphasis on the European efforts.

The Symposium was structured around the following three principal themes: *1) future climate projections, 2) impacts of climate change, and 3) adaptation and mitigation strategies*. The main objectives of the symposium were to present and discuss results from EU-funded research projects that have been instrumental in producing the scientific basis and knowledge used by the IPCC experts, identify current knowledge gaps and pinpoint high priority areas for climate research as identified by both the AR4 and key ongoing EU-funded research projects. Results of the symposium are providing important input to FP7 calls for proposals.

The following sections outline the main research priorities and knowledge gaps based on the presentations and discussions during the symposium, together with examples of key, current and planned, EU-funded activities on climate change research.

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ftp://ftp.cordis.europa.eu/pub/fp7/environment/docs/agenda_ipcc_final.doc

3. Future climate, impacts and responses: future research needs

3.1 FUTURE CLIMATE PROJECTIONS

There is an **increasing need for more accurate regional climate change information** to improve the analysis of impacts and contribute to adaptation policy needs. Consistency between models in simulated regional temperature and precipitation needs to be improved. High resolution global and regional models (to capture local effects, circulation regimes and natural modes of variability), seamless prediction to increase model reliability, and probabilistic prediction based on large ensembles of simulations are necessary in order to quantify uncertainties due to model differences and improve our understanding of climate change variability and its impacts at regional level.

Development of Earth System Models (ESMs) and increased **understanding of coupled system processes and associated feedbacks** (e.g. chemistry-climate interactions, air-sea fluxes, biosphere-atmosphere interactions, stratosphere/troposphere exchange, stability of the great ice sheets on Greenland and West Antarctica, oceanic circulation stability and aerosol-cloud interactions) remain key challenges. Models differ considerably in the estimated strength of different feedbacks in the climate system. Confidence in projections is higher for certain variables (e.g. temperature) than others (e.g. precipitation), and higher for larger spatial-scales and for longer time-averaged periods. Advancing our understanding of coupled system processes and associated feedbacks, and inclusion of new processes call for increases in spatial and temporal model resolution.

Examples of current and future EC research activities on Earth-System Modelling

The EU-funded research project ENSEMBLES⁸ develops an ensemble prediction system based on state-of-the-art high resolution global and regional ESMs developed in Europe and validated against quality controlled datasets. The aim is to quantify and reduce uncertainties in representing physical and bio-chemical processes and exploit prediction results to a range of applications such as agriculture, food security, energy, air quality.

Initial actions under FP7 are addressing some of the key issues in Earth-System Modelling such as the incorporation of new components in ESMs (e.g. carbon and nitrogen cycle, ocean biochemistry, cryosphere) and process oriented evaluation of ESMs with particular emphasis on climate feedbacks.

There is a need to **strengthen climate observations and maintain long term records** in order to be able to study and understand key processes and associated feedbacks and analyse extreme events. Climate data coverage remains limited in some regions with marked scarcity in developing countries. Essential aspects include: maintenance and digitization of existing long term records, better data recovery and homogeneity of records, better measurements of the slow components of the climate system (oceans, land), better measurements of hydrological cycle variables, integration of products in climate information services tailored to the users needs.

⁸ <http://www.ensembles-eu.org>

Emphasis should also be given to palaeo-research that would allow for a rather direct inference on climate system properties that are informative on climate change projections.

There is a need for a **dedicated computing infrastructure** to meet current and emerging research needs. Reliable global and regional climate change predictions cannot be achieved without substantial increases in computing resources. These are needed so long-term simulations can incorporate important climate features, bio-chemical and physical processes and regional details and perform more extensive ensemble runs.

Improve our understanding of the sources and sinks of terrestrial carbon and other greenhouse gases (e.g. methane, nitrous oxide) through integrated, multiple-constraint regional observations combined with satellite observations, in order to quantify responses in terrestrial ecosystems including hot spot regions (e.g. Siberia, Congo basin, Amazon), and achieve early detection of unforeseen events. The magnitude of CO₂ emissions from land-use change and individual methane sources remains a key uncertainty.

Process studies and manipulative experiments are needed to identify drivers, quantify responses and test/develop further models. Integration of process information into model components of comprehensive Earth System Models and incorporation of biochemical and physical feedbacks in next generation coupled carbon-climate models is absolutely necessary in order to improve future climate change projections and quantify more accurately the magnitude of the future carbon-climate feedbacks.

Sustain long-term observations of ocean carbon fluxes, starting from the North Atlantic observing system which has been built-up, in order to further investigate the biochemical and physical processes controlling the magnitude and distribution of ocean carbon sources and sinks at different timescales. Determine how realistic model simulations are and proceed with a **systematic calibration of ocean carbon models and coupled Earth Systems Models with respect to observations**. Study new processes on ocean vulnerability such as sub-sea permafrost melting in the Arctic, growing hypoxia in the oceans, ocean acidification, ocean methane and nitrogen cycle, and look out for surprises in the system.

Examples of current and future EC research activities on carbon cycle

Several research projects are currently addressing some aspects of the terrestrial and ocean carbon cycle, with the aim to understand, quantify and predict the terrestrial carbon balance in Europe (CARBOEUROPE⁹), in key hot spots such as Sub-Saharan Africa and North Russia (CARBOAFRICA¹⁰ and CARBONORTH¹¹ respectively) and the Atlantic Ocean (CARBOOCEAN¹²)

Initial actions under FP7, will address some important aspects of the global carbon cycle including the impacts of climate variability and extreme events on terrestrial carbon storage and carbon soil dynamics, and attribution of annual-to-decadal changes in carbon (and other greenhouse gases) to human and natural drivers in European ecosystems.

⁹ <http://www.carboeurope.org>

¹⁰ <http://dwms.fao.org/temp/carboafrika-e..asp>

¹¹ <http://www.carbo.org>

¹² <http://www.carboocean.org>

Understand better the **links between the Arctic Ocean and the climate system** through better representation of ice dynamics, thermohaline circulation and sea ice. Future evolution of the **Greenland** and also the **Antarctic ice sheet** mass needs to be better quantified as it influences heavily (together with heat penetration into the oceans) sea level rise projections.

Examples of current and future EC research activities on Arctic

Current actions under the DAMOCLES¹³ Integrated Project focus on the reduction of uncertainties in our understanding of climate change in the Arctic and the impacts thereof.

Initial actions under FP7 will address some of the current key scientific questions such as the stability of the thermohaline circulation (THOR integrated project), and the quantification of the risk of substantial acceleration of sea level rise due to continental ice melting.

3.2 IMPACTS OF CLIMATE CHANGE

Impacts on ecosystems, agriculture and forestry: Detection and attribution of changes to climate change and the ozone layer in various ecosystems is a fundamental research priority. Efforts should focus on monitoring, modelling and validating critical climatic thresholds for most vulnerable ecosystems. There is a need to improve further ecosystem models and address issues such as: a) effect of key processes (e.g. CO₂ fertilisation, air pollution, drought effects, land management practices), in regulating services such as carbon sequestration b) regionalisation and downscaling of model results, c) estimation of uncertainties in modelled precipitation patterns, d) investigate how much land we can spare for agriculture (including biofuels), e) assessment of the habitats, species and natural resources most at risk.

It is necessary to better understand vulnerability in the face of land-use and climate change. That will require an integrated evaluation of social and ecological vulnerability, a more robust and systematic estimation of the values of ecosystem services, in-depth assessment of multiple impacts (e.g. well being, food security, health, water) and identification of tipping points beyond which resilience is lost. Furthermore, research should investigate the causal links between land use, ecosystem processes and ecosystem services and their dependence on biodiversity in a climate change perspective. Research should also investigate how to use the ecosystem approach for adaptation efforts to infrastructure projects (green infrastructure concept).

Regarding **agriculture and forestry**, planning future management requirements in view of changing climatic conditions will benefit from a better estimation of impacts at finer spatial scales and shorter timeframes than current assessments. Improvement of understanding and estimation of a) future precipitation patterns, b) the frequency of occurrence of extreme events c) implications of climate change (combined effects of CO₂, warming, humidity) for biotic disturbances (pest, weeds and diseases) and d) implications for crop production, livestock and food security as well as the role of land management activities in the preservation of environmental values in rural areas, by taking into account that impacts of climate change will occur in the context of an evolving socio-economic context.

¹³ <http://www.damocles-eu.org>

Emphasis should also be given to **mountain regions**, as there is a fundamental need for integrated long-term observations and analysis across different disciplines in order to assess issues such as the type and level of services mountains provide, the frequency of climate-related disasters we risk in mountain regions, the type of economies involved, the type of ecosystems that will persist in mountains and the type of governance structures to promote adaptation.

Examples of current and future EC research activities on climate change impacts

A number of research projects are currently addressing the impacts of climate change in Europe and beyond. For example the CIRCE Integrated Project¹⁴ focuses on the prediction of climate change impacts in the Mediterranean basin and evaluates the consequences of such impacts for the society and economy.

The CLARIS¹⁵ project strengthens the collaboration between Europe and South America in assessing climate change impacts and developing common research strategies in the subtropical region of South America at different scales (local-regional-continental).

The CIRCLE-ERANET¹⁶ provides climate impact analysis by networking and aligning national research programs in 19 European countries, with the final aim to implement a European Research Area (ERA) in the field of climate change.

Impacts on human health: Research efforts should address the major challenges that exist today in the area of health and climate change: a) development of methods to investigate which health impacts and to what extent are attributable to climate change b) integration of human health into relevant climate change research projects and development of health impact models for projecting climate change related health impacts under different climate and socio-economic scenarios c) assessment of the costs of such climate-related health impacts as well as the cost of inaction, d) identification of tipping points by exposure to multiple stresses. Particular emphasis should be given to research actions focusing on low-income countries (as they are most vulnerable to such impacts) and the appropriate incorporation of research findings into policy decisions.

Examples of current and future EC research activities on climate change and health

The EDEN¹⁷ research project is studying how changes in European environment and ecosystems, whether caused by altered human activity patterns or changes in climate, can influence the spatial and temporal distribution and dynamics of pathogenic agents. The project contributed to the establishment of the European Centre for Disease Prevention and Control, with the aim to create a European Environment and Epidemiology network to monitor environmental change and its effects on infectious diseases.

The MICRODIS¹⁸ integrated project addresses health and socio-economic impacts of extreme events in order to strengthen prevention, mitigation and preparedness strategies.

¹⁴ <http://www.bo.ingv.it/circeip>

¹⁵ <http://www.claris-eu.org>

¹⁶ <http://www.circle-era.net>

¹⁷ <http://www.eden-fp6project.net>

¹⁸ <http://www.microdis-eu.be>

Initial actions under FP7 will strengthen further research on climate change and health by addressing some key issues such as climate change and water-related health issues as well as quantification of climate change impacts on health in low income developing countries.

Impacts on hydrology and sectorial effects: Research actions should address the following issues: attribution of past and future changes in water resources to climate and non-climate drivers; impacts of climate change on water quality, data consolidation and improved monitoring of key parameters; regional analysis of water use and the potential consequences to water-intensive sectors (e.g. agriculture); exploration of extremes (floods and droughts) and global and regional analysis of effects of water scarcity, in terms of river discharge and soil moisture, upon different water-dependent sectors (such as rain-fed and irrigated agriculture, terrestrial and inland aquatic systems, industries and households).

Examples of current EC research activities on climate change and water resources

The Integrated Project WATCH¹⁹ brings together the hydrological, water resources and climate communities in order to analyse, quantify and predict the components of the current and future global water cycle, evaluate related uncertainties and assess the future vulnerability of water as a resource and the consequences for key sectors (agriculture, industry, drinking water sectors).

The integrated project EURO-LIMPACS²⁰ focuses on pressures and drivers of aquatic ecosystem change such as land-use, nutrients, pollution, and examines their interaction with climate change in order to better understand and manage the ecological consequences of these interactions.

Impacts on extreme events: It was recognised that the analysis of the frequency and intensity of extreme events (e.g. droughts, floods, wild fires, tropical cyclones) in observations and coupled models is underdeveloped. Lack of longer data time-series of adequate spatial and temporal resolution, model uncertainties and few detection studies, restrict in depth analysis of extreme events. To that end, detection and attribution studies are very important. Furthermore, assessing the impacts of extreme events, as well as the socio-economic implications of adaptation to these extremes, represent a major scientific challenge.

Ocean acidification: There is a need to improve our understanding of ocean acidification impacts through long term observation of spatial/temporal chemical changes; experimental studies of impacts on organisms, ecosystems and their services; and global integrated ocean biogeochemical-climate models and regional shelf sea ecosystem models. There is a need to determine important thresholds and 'points of no return', as well as adaptation and feedbacks to climate change.

¹⁹ <http://www.eu-watch.org>

²⁰ <http://www.eurolimpacs.ucl.ac.uk/index.php>

Examples of EC research activities on ocean acidification

Under FP7, research activities on ocean acidification are strengthened mainly through the new integrated collaborative research project EPOCA which is focusing on the identification of temporal/spatial changes of ocean chemistry and biogeography due to increased CO₂ uptake and the quantification of the impacts to marine biota and ecosystems in the Atlantic Ocean.

Impacts on the economy: In order to quantify the impacts of climate change on the economic system there is a need for high-resolution climate change impact studies, including transient scenarios for the next few decades but also longer periods.

Furthermore, research efforts should focus on the development of large scale quantitative modelling including aspects such as assessment of adaptation measures, cost-benefit analysis, equity, winners and losers and treatment of cascade of uncertainty. Costs of climate change impact as well as costs saved by adaptation/mitigation measures need to be quantified. Linkages between the various sectors need to be identified through multi-sectorial analysis.

Impacts of climate change in vulnerable world regions: There is an urgent need to better quantify the impacts of climate change across key economic sectors (e.g. agriculture, forestry) for regions that are particularly vulnerable to climate change (e.g. Africa, South-East Asia, Latin America, low-lying islands) in order to be able to develop effective adaptation measures on appropriate scales. Within this context, international cooperation in climate change research is of paramount importance as it facilitates the sharing of knowledge, skills, risks and financial resources, provides better global coverage of climate monitoring, ensures coherence and quality of collected data and practices, develops further scientific capabilities and assists in building trust and supporting effective policies and agreements at international level.

Examples of current and future EC research activities on climate change impacts in vulnerable world regions

Currently a number of research projects funded under FP6 provide in depth analysis of the impacts of climate change in such vulnerable regions. For example the AMMA²¹ integrated project reinforces interactions and partnerships between European and African research institutions in order to improve the forecasting ability of seasonal variations in the Western African Monsoons, identify short and longer terms impacts that changes in Western African Monsoons are likely to have on agriculture, water resources, health and food security, and investigate adaptation options to these impacts.

Initial activities under FP7 are addressing some important aspects such as : past and future climate change impacts in the Parana-Plata river basin in South America; climate change predictions, quantifications of impacts and assessment of adaptation measures in Sub-Saharan Africa; extreme hydrological events in Europe and neighbouring countries as a threat to security; addressing deforestation (socio-economic drivers, impacts and options for greenhouse gas emissions reduction) in tropical areas; climate change impacts and thresholds in Arctic ecosystems.

Case study on current collaboration on climate change research between EU and India

India represents a key partner for climate change research as a) has active research communities and research infrastructure on a broad spectrum of climate research issues, b) is particularly vulnerable to climate change c) experiences sharp increases in greenhouse gas emissions due to its rapid economic development d) significant partnerships and bilateral dialogue already exist within the broader climate change context (e.g. energy efficiency, zero emission plants activities etc).

Current (FP6) research actions targeting India, include a comprehensive assessment of the costs and benefits of technological, market-based measures to control air pollution and greenhouse gas emissions in India (GAINS-ASIA²² project), and evaluation of climate change mitigation options for India and the conditions for strategic cooperation on research, development and technology transfer with the EU (TOCSIN²³).

In order to strengthen further the EU-India research collaboration on climate change research, an international '*EU-India Science and Technology Strategic Workshop on climate change research needs*' was organised in New Delhi India (8-9 February, 2007) with the participation of key officials and distinguished scientists from Europe and India. The workshop clearly identified research needs of common interest and benefit and underlined the potential of increasing further the scientific co-operation between India and EU. Research areas of common interest include:

- *Himalayan glaciers*
- *Monsoons, extremes and climate variability*
- *Ways to ensure climate protection without compromising economic growth*
- *Air pollution studies*
- *Impacts of climate change on agriculture.*

Following the workshop recommendations, a Specific International Cooperation Action (SICA) topic targeting India entitled '*Impacts of Himalayan glaciers retreat and monsoon pattern changes on water resources in Northern India and adaptation strategies*' was published in the 2008 Work Programme under the Cooperation Theme 'Environment (including Climate Change)'. It is envisaged that the successful proposal, - which encompasses strong Indian participation - will be linked with existing relevant Indian national research activities.

²¹ <http://www.amma-eu.org>

²² http://www.iiasa.ac.at/rains/gains_asia

²³ <http://reme.epfl.ch>

Case study on current collaboration on climate change research between EU and China

China is a key international partner in the area of climate change due to its rapid economic development, sharp increase of greenhouse gas emissions, and its vulnerability to climate change. In addition China has developed significant research capabilities and has active scientific communities in many areas of climate change research.

Current EU-funded climate change research projects targeting China, focus on the assessment of the costs and benefits of technological, market-based measures to control air pollution and greenhouse gas emissions (GAINS-ASIA project) and evaluation of climate change mitigation options for China and the conditions for strategic cooperation on R&D and technology transfer with the EU (TOCSIN).

Within the context of existing China-EU initiatives such as the EU-China Partnership on Climate Change and following the results of the *EU-China Workshop on Energy Technology and Climate Change Research (Guangzhou, China, 6–7 March 2008)* the following key research themes of mutual interest have been identified and include:

- *Climate Change, Mega-Cities and Emissions*
- *Impacts and Adaptation in Vulnerable Regional Sectors*
- *Low carbon and Climate resilient cities*

These priority areas represent the basis for further bilateral discussions at institutional level with the aim to define and agree upon concrete actions that will further strengthen the EU-China collaboration on climate change research.

Investigate synergistic impacts of a future changing world (e.g. changes in CO₂ and other greenhouse gases concentrations, changes in pH, temperature, UV radiation, pollutants, etc.) on ecosystems, species and biogeochemistry and their feedback to the earth system. It is recognised that the impacts of climate change are most damaging when they occur in the context of multiple stresses; therefore studies should address the interactions between climate change and other human induced impacts on ecosystems and human systems.

3.3 RESPONSES: ADAPTATION AND MITIGATION TO CLIMATE CHANGE

Adaptation:

There is a need to improve **Europe-wide risk, impact and cost/benefit assessment for adaptation responses**, as compared with no action. A **comprehensive analysis of presently developed/adopted adaptation strategies of EU Member States**, including a systematic analysis/evaluation of existing EU policies, directives, funding mechanisms and their implementation with regard to support or constraints for adaptation at European, national and regional level is necessary. Identification of further adaptation policies and measures that could be implemented, sector by sector, region by region, with an assessment of the costs involved. Assess and analyse barriers and constraints that are specific of local and of sectorial contexts, and the means to overcome them.

Quantification of the relative costs of adaptation to climate change is a key research priority. There is a need for better integrated assessment modelling. Current tools and models and policy instruments need to be re-assessed and re-developed in view of medium and longer-term uncertainty in climate change/variability projections. Attention should also be given to studies related to **urban adaptation**.

In depth analysis of the present and possible future **role of the financial flows** in the insurance sector. Special emphasis should be given to **weather related insurance schemes and practices**, including evaluation of the vulnerabilities of key players in the sector as a whole. The role and effectiveness of relevant public financial authorities should also be assessed.

Analysis of the ways **damage and repair costs of extreme weather events are distributed** over the parties affected in the different EU countries.

Launch Europe-wide studies on present and future plans of coastal regions to strengthen **coastal protection**.

Stepping up research and monitoring activities in the field of climate change with the aim to create the world standard in weather and climate prediction.

Research ways to **enable and stimulate activities aiming to create new opportunities for innovation in the field of adaptation to climate change** while improving the quality of life with regard to environment, landscape, health, urban life and reliability of public systems such as electricity and transport. Emphasis should also be given to research that anticipates market failures to adaptation, i.e. provides the very information that would not be acquired or implemented by markets themselves.

Current and future EC research activities on adaptation to climate change

The ADAM²⁴ integrated project will provide a better understanding of the complementarities, trade-offs and distinctions that exist between adaptation and mitigation policies in the EU and internationally and assess emerging adaptation strategies for Europe.

Initial activities under FP7 will address some of the key research needs/priorities such as: the development of integrated methodology for cost-effective adaptation measures and the quantification of damage and adaptation costs for global emission scenarios covering countries important for international negotiations.

The PESETA²⁵ project of the EC Joint Research Centre provides estimates of the cost of climate change impacts in a range of economic sectors in Europe. It is based on a consistent set of climate change scenarios linked to appropriate impact models.

Mitigation:

Development of world-scale **low emission scenarios** using both bottom-up and top down approaches, which would be able to attain the 2°C objective set by the EC and contribute to the international debate about the ultimate objective of the climate change convention.

The **development, commercialization and cost reduction of key mitigation technologies** such as 2nd generation biofuels, concentrated solar photovoltaic, hydrogen-fuel cells, carbon capture and storage, represent a fundamental challenge at international level. Mitigation solutions for non-CO₂ gases, such as reducing CH₄ releases from livestock (ruminants) should also be investigated.

A European Strategic Energy Technology Plan (SET-Plan)

On 22 November 2007 the European Commission presented a Communication entitled 'A European Strategic Energy Technology Plan (SET-Plan) - towards a low carbon future'²⁶, putting forward a targeted approach to achieve the technological improvements required in order to meet the energy and environmental challenges over the medium and long-term. The main objective of the SET-Plan is to strengthen, accelerate and give coherence to the overall innovation and research effort in Europe in cutting edge low carbon technologies. The SET-Plan proposes joint strategic planning to allow for more effective implementation through coordination of national innovation and research programs, the development of a European Energy Technology Information System, the establishment of six European Industrial Initiatives and the creation of a European Energy Research Alliance and a reinforced approach to international cooperation.

Research efforts should also address the **environmental and socio-economic impacts of climate change mitigation technologies**. Mitigation activities may compete with other activities, therefore the related trade-offs must be fully explored (e.g. biomass potential and

²⁴ <http://www.adamproject.eu>

²⁵ <http://www.peseta.jrc.ec.europa.eu>

²⁶ http://ec.europa.eu/energy/res/setplan/communication_2007_en.htm

trade-offs with food production, biodiversity and forestry). Identify discontinuities, both in ecosystem functioning and in the resulting economic value of ecosystem services, is also important to the selection of priority mitigation policies and measures.

There is a need to understand **the effects of present and future lifestyle changes** on climate change and sustainable development, and the factors that influence them.

Consistent **cross-sectorial** scenarios for improved analysis of mitigation potentials and integrated **bottom-up/top-down analysis**. This should be accompanied by fundamental methodological development to facilitate comparisons between results of bottom-up and of top-down analyses (which is often complicated due to the difference in the scale of observations and the difficulty to reconcile them). Research should focus on improved understanding of induced technological change and technology diffusion and assess the effectiveness of relevant policy instruments, including the gradual development of emission trading schemes and other flexible market mechanisms. There is a need for better understanding of the relationships between rates of adoption of mitigation technologies and national/regional policies (climate and non-climate), technology evolution, and market mechanisms.

There is a need to quantify **mitigation costs** and reduce uncertainties in calculating these costs, that are due to assumptions regarding long-term technology performance, consumption patterns, pathways of future economic growth, and drivers regulating technology diffusion. Research and policy definition would greatly benefit from close collaboration and integration with research communities in third countries that are large emitters of greenhouse gases.

Study the various **synergies and trade-offs between sustainable development and climate change policies**.

Improve **accuracy and reliability of emission inventories by sector**, particularly for non-CO₂ greenhouse gases, as well as CO₂ from deforestation, peat fires and biomass decay.

Emphasis should be given to research related **to land use and land cover changes in relation to greenhouse gas mitigation**. There is a need to maintain continuous time series of remote sensing data, monitor subtle land changes such as forest degradation due to selective logging, soil erosion, pest impacts, and shifts in land management practices. Understand land-use transitions due to urbanisation, migration and globalisation.

Examples of current and future EC research activities on climate change mitigation

Current activities focus on the identification of emerging technologies and measures to reduce greenhouse gas emissions and assessment of cost effective policies and measures for important sectors and gases and implication for the European security of energy supply (SERPEC-CC, CESSA²⁷, EUSUSTEL²⁸, SECURE²⁹, REACCESS). Special emphasis is given to the synergies and trade-offs between adaptation and mitigation (ADAM), and the assessment of climate change mitigation options in key countries such as India, China and Russia (GAINS-ASIA, TOCSIN). The use of Clean Development Mechanism (CDM) for stimulating technology transfer to developing countries is analysed in the project ENTTRANS³⁰.

Initial activities in FP7 will address some important aspects of mitigation to climate change including the assessment of the efficiency of current and future land-use adaptation and mitigation policies at European level; quantification of mitigation costs for various global emission scenarios and covering countries important for international negotiations; study the implications of novel options to limit climate change; and multiple pathway analysis of emerging economies to engage in climate protection under a post-2012 regime.

²⁷ <http://www.cessa.eu.com>

²⁸ <http://www.eusustel.be>

²⁹ <http://www.secureproject.eu>

³⁰ <http://www.enttrans.org>

4. Conclusions – the way forward

There is a long and distinguished history of European research on many aspects of climate change, providing valuable insights in our understanding of the earth-climate-human system. Research efforts at the EC level, especially within the context of the Research Framework Programmes and the European Research Area (ERA), make strong contribution to European policies and measures, support EC's international negotiating efforts and underpin EU's contribution to international initiatives and protocols.

Despite the considerable advancements of climate change science in recent decades -also evident by the results of the various Assessment Reports of the IPCC-, important uncertainties and knowledge gaps still remain. It is now evident and widely recognised, especially after the IPCC AR4, that we have enough evidence to start acting through adaptation and mitigation; however, a better understanding of the causes and evolution of climate change and its impacts on humans, and ecosystems will allow us to act with greater efficiency. Research efforts should be strengthened at national and international level, in order to address existing knowledge gaps and advance further our understanding.

Under FP7, a strong, interdisciplinary, balanced climate change research programme needs to be implemented, built on the firm foundations of past experience and achievements and incorporating significant new elements of research aimed at improving our basic understanding of the earth-climate system as well as key elements related to impacts, vulnerabilities, and response measures. The ultimate goal is to empower Europe with the necessary science-based knowledge in order to better manage the risks and opportunities of climate change. Under FP7, particular emphasis will be given to the following research elements:

- Quantification of climate change feedbacks in Europe and beyond.
- Regional climate change projections, aiming at local-scale information.
- Quantification of climate change impacts on vulnerable ecosystems, and key economic sectors.
- Climate change and human health
- Coupling between climate and economic models
- Feasibility and related costs of adaptation and mitigation policies and measures in Europe and beyond.
- Assessment of the effectiveness and risks of novel options to combat climate change.

Given the complexity of the earth system and the magnitude of the challenge in hand, an integrated approach in climate change research -at both scientific and institutional level- needs to be employed. At the scientific level, that should be translated to closer coordination and linkages between the various scientific disciplines involved (including better integration of natural, social and economic aspects), within well-designed, focused research efforts centred on answering key fundamental scientific questions. Such integration, will permit a better understanding of the complex earth-climate system, a more accurate identification of

likely climate change impacts on natural and human systems and potential adaptation and mitigation options, and facilitate the visibility and better assimilation of research results in the broader science-policy debate.

At the institutional level, a better coordination between the various FP7 activities and other EC actions and initiatives (including GEO and the newly established Kopernikus initiative with the aim to sustain long term operational observations) as well as closer collaboration between major national research programs in Europe and Framework Programme activities will be necessary, in order to make best use of human resources, modelling capacities, field activities, and infrastructures, maximising therefore the impact of scientific results and reinforcing the European Research Area for climate change science. In addition to enhancing scientific excellence, the improvement of the interaction between science, policy and society remains an issue for consideration.

At the international level, closer cooperation with key third countries should be pursued, by exploring possibilities provided by existing Science & Technology agreements and focusing on important, mutually agreed, research questions and topics. Special attention will be given to regions/countries that are particularly vulnerable to climate change. In addition, alignment with major international research efforts on relevant priorities (e.g. World Climate Research Programme, International Geosphere-Biosphere Programme) should also be envisaged.

The implementation of the climate change research component of FP7 along the lines and principles mentioned above, in conjunction with a closer partnership between the EC and the IPCC, will ensure that research activities under FP7 will continue to produce new knowledge and to empower policy makers with necessary tools. It will also provide indispensable support to the IPCC process, proliferate mutual benefits and interests, and guarantee the leading role of Europe in the next (5th) comprehensive climate change assessment report of the IPCC.

Glossary

EC: European Commission

IPCC: Intergovernmental Panel on Climate Change

AR4: 4th Assessment Report

UNFCCC: United Nations Framework Convention on Climate Change

UNEP: United Nations Environment Programme

FP7: 7th Research Framework Programme

EU: European Union

ESM: Earth System Model

SET-Plan: European Strategic Energy Technology Plan

GEO: Global Earth Observations