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COACCH

CO-designing the Assessment of Climate CHange costs

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D2.1 Protocol of information exchange flow and model integration

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Contributors:	Francesco Bosello (CMCC), Ramiro Parrado (CMCC)

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Version log

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1.1	03/08/2018	CMCC	First draft
1.2	12/08/2018	CMCC	Second draft
1.3	21/08/2018	CMCC	Draft to be checked by WP leader
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Deliverable Summary

This deliverable (D2.1) substantiates that part of the activity of COACCH Task 2.1 consisting in facilitating the exchange of information and interactions among modelling teams to ensure WP2 analysis accounts for multi-causal impact chains. In particular it describes the input output flows from the different teams to enable model integration, and establishes the protocol for the information exchange across COACCH modelling teams and sectoral studies. Eventually, quantitative assessment within COACCH are expected to carry out the investigation of major impact chains following these guidelines.

1. Introduction

The COACCH project research relies on the application of a wide set of quantitative modelling and non-modelling investigation approaches. A major challenge within COACCH is to reach an effective and fruitful integration across the investigations exercises performed with these different tools. The integration sought for, is not just a "vertical one", i.e. that leading from the climate information to the final holistic macroeconomic assessment of climate change impacts (see Figure 1), but also an "horizontal one", linking different studies focussing on specific impact areas, allowing to capture impacts' interaction (see Figure 2).

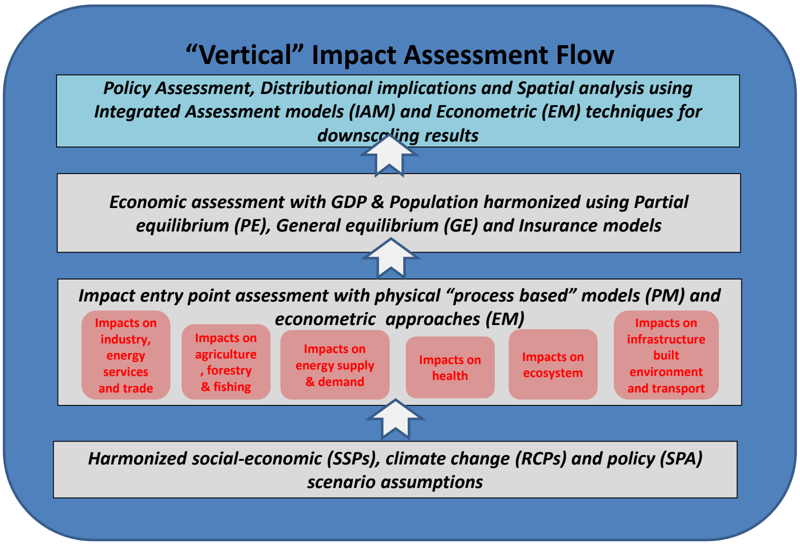

Figure 1. Example of "vertical" integration in impact assessment

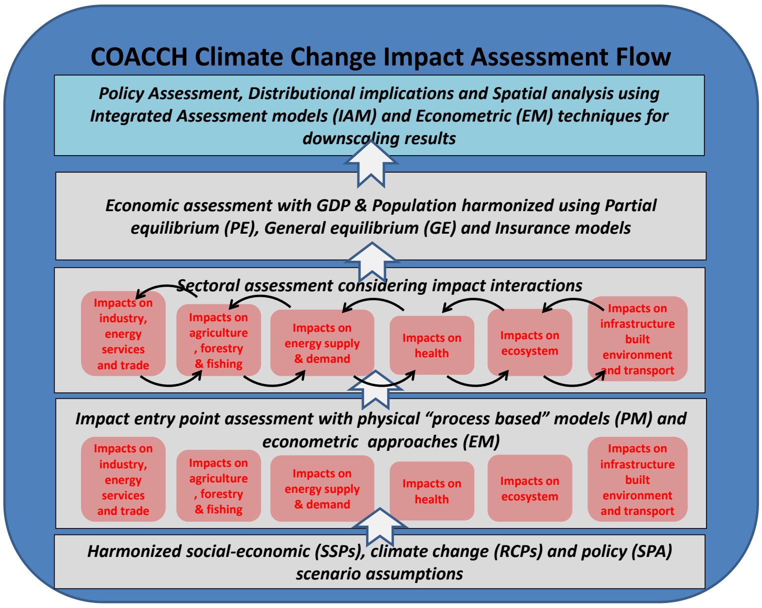

Figure 2. COACCH approach for integrated climate change impact assessment

To enable this cross fertilization the following steps are followed:

(a) inventory of the COACCH quantitative toolkit, that spans from climate models, to process based physical models, to partial and general equilibrium economic models, to econometric approaches, including the description of model capabilities and devised role in COACCH;

(b) identification of models' input-output flows and of exogenous and endogenous variables to each model and study, to identify the potential information exchange flows across COACCH quantitative assessments,

(c) on the basis of (a) and (b), definition of the effective exchange flows across models that will occur during COACCH lifetime.

Eventually, following steps (a), (b) and (c) each partner in COACCH will know exactly which kind of information she/he is expected to receive/provide and by/to whom.

The scrutiny of interactions across quantitative assessments in WP2 was substantiated in a process of bilateral information exchanges coordinated by CMCC and culminated in a dedicated session of the Graz Modelling Workshop in M8 (July 2018). See also for further detail the minutes of COACCH milestone M4: "2nd Project meeting".

As a final remark, it is worth stressing that, even though this deliverable focuses on the workflow of WP2, the evaluation methodologies and the foreseen linkages hereby described, are also useful guidelines to develop the scrutiny of tipping points and of policy actions conducted in WP3 and WP4 respectively.

In what follows, section 2 presents the COACCH model/quantitative toolkit, section 3 the interactions identified and to be activated across quantitative studies.

In annex A a table reports the complete list of models input, output, (endogenous, exogenous) variables which ultimately allows the exact identification of the information chain linking structurally and functionally the different quantitative assessment exercises. Finally, a separate excel file, attached to this deliverable summarizes model interactions in WP2 and, due to their strict connections, in WP3 and WP4.

2. The COACCH toolkit for quantitative assessment

The COACCH project research relies on the application of a wide set of quantitative modelling and non-modelling investigation approaches. Models, their characteristics and role in the project are summarized in Table 1. This is followed by a short model description.

Table 1: COACCH Model suit

Model name	**Type of model**	**Type of analysis**	**Sectors covered**	**Regional coverage**	**Main reference**	**Policy impact**	**Application in COACCH**
ICES (FEEM)	Economic Computable General Equilibrium (CGE) model	Climate change impacts, autonomous adaptation and mitigation policy assessment.	Macro-economic with sectoral resolution: Agriculture (12), Forestry, Fishing, Energy (12), Industry (26), Services (12)	Global, 22 macro-regions, EU with country to NUTS2 resolution	Parrado & De Cian, 2014	Deep Decarbonization Project (Virdis et al. 2016) , Asian Development Bank (Raitzer et al. 2015) DG Clima (EU adaptation strategy)	Task 2.7: Multi-scale cross-sectoral macroeconomic assessment; Task 3.2: Climate tipping points; Task 3.4: Implications of socio-economic tipping points
WITCH (FEEM)	Hard linked (climate-energy-economy) dynamic optimization Integrated Assessment Model (IAM) CEA and CBA	Climate change impacts, autonomous adaptation and mitigation policy assessment. Air Pollution Impacts	Macro-economic (one sector model with energy detail)	Global, 13 macro-regions	Emmerling et al., 2016	IPCC AR5, SSP, UNEP Adaptation Finance Gap Report 2016	Task 4.3: Macroeconomic assessment of policy effectiveness
IMAGE framework (including GLOBIO) and IMAGE-FAIR (PBL)	Process IAM (framework) andcoupled cost-benefit IAM	Climate change impacts, planned adaptation, and mitigation policy assessment	All sectors, often in biophysical terms, overall macro-economic description	Global, 26 macro-regions	Den Elzen et al., 2014; Stehfest et al., 2014; Van Vuuren et al., 2017	Model used in multiple assessments, IPCC, including the development of RCPs and SSPs.	Task 4.3: Macroeconomic assessment of policy effectiveness
GLOBIOM (IIASA)	Economic land use	Climate change	Agriculture, forestry,	Global, 31 macro regions,	Havlik et al., 2011;	Capros et al., 2016; European	Task 2.2: Impacts on agriculture, forestry & fishery;

Model name	Type of model	Type of analysis	Sectors covered	Regional coverage	Main reference	Policy impact	Application in COACCH
	model for the agriculture & forestry sector (PE, PM)	impacts, Adaptation, Mitigation	Ecosystems, water, bioenergy, trade.	Europe with national and NUTS2 resolution	Havlik et al., 2014	Commission 2016a; European Commission 2016b; Valin et al., 2015;	Task 2.5: Non-market impacts: ecosystems and biodiversity; Task 3.3: Analysing socio-economic tipping points
COIN (UNIGRAZ)	Economic Computable General Equilibrium (CGE) model	Climate change impacts, autonomous adaptation and mitigation policy assessment	Macro-economic with sectoral resolution (40 sectors) and impacts in the following fields: agriculture, forestry, water, energy, tourism, transport infrastructure, manufacturing and trade	National (Austria, Germany), global 24 regions	Steininger et al. 2015, 2016; Bachner 2017	Austria's State of the Environment Report 2016, European State of the Environment Report 2016, The Economic Consequences of Climate Change (OECD 2015)	Task 3.2: Climate tipping points; Task 3.4: Implications of socio-economic tipping points
EC Trade (UNIGRAZ)	Econometric Trade model	Econometric climate change impact assessment	sectoral / regional resolution of EORA database (26 sectors)	International (country level, 189 countries)			Task 2.4: Impacts on industry, energy, services, and trade
CATSIM (IIASA)	Probabilistic disaster risk assessment model	Climate change impacts, and adaption policy assessment	Macro-economic, approach to disaster risk reduction with emphasis on infrastructures	Global, Europe with national resolution	Hochrainer-Stigler et al. 2014	Inter-American Development Bank, UNISDR	Task 4.2: Sectoral assessments of policy effectiveness
REMIND (PIK)	Climate-energy-	Mitigation	Macro-economy, energy, transport	Global, 11 macro-regions	Leimbach et al. 2010,	IPCC AR5, IPCC SRREN, SSP,	Task 4.3: Macroeconomic assessment of policy effectiveness

Model name	Type of model	Type of analysis	Sectors covered	Regional coverage	Main reference	Policy impact	Application in COACCH
	economy (dynamic optimization) model (IAM, CEA)				Luderer et al. 2015		
MAgPIE/LPJmL (PIK)	Economic model of agriculture and landuse (PE, PM)	Mitigation, impacts, adaptation	Agriculture: crops, livestock, grassland, bioenergy, forest, water, nutrients	Global, macro-regions and clustered 0.5° grid cells	Lotze-Campen et al. 2008, Stevanović et al. 2016	IPCC AR5, IPCC SRREN,SSP, AgMIP, ISIMIP, FAO, Shock Waves (WB)	Task 2.2: Impacts on agriculture, forestry & fishery; Task 2.5: Non-market impacts: ecosystems and biodiversity; Task 4.2: Sectoral assessments of policy effectiveness
DIVA (GCF)	Sea-level rise model (PM)	Impacts and adaptation policy assessment	Built environment, infrastructure, agriculture, ecosystems, beach tourism	Coastline segments, aggregated to Nuts2, Country, Macro regions and global	Hinkel et al. 2014, 2013, Spencer et al. 2016	State of the Environment Report, EEA	Task 2.3: Impacts on infrastructure, built environment, and transport; Task 3.3: Analysing socio-economic tipping points. Task 3.2: Climate tipping points; Task 4.2: Sectoral assessments of policy effectiveness
FIAT/GLOFRIS LISFLOOD (DELTARES)	Flood risk assessment modelling framework (RA/PM)	Impacts and adaptation policy assessment	Several land use categories (now mostly categories of built environment)	Global, Europe with country, NUTS2, or gridded (50km) resolution Gridded (12,5km) Europe	Winsemius et al. 2016 Alfieri et al. 2016	World Bank Country risk profiles WRI Aqueduct	Task 2.3: Impacts on infrastructure, built environment, and transport; Task 3.3: Analysing socio-economic tipping points
Climate models	Ensembles of GCMs, RCMs	Not applicable	Not applicable	Global , regional with	Taylor et al. 2012,	IPCC, World Bank	Task 3.2: Climate tipping points; Task 3.3: Analysing socio-economic

Model name	Type of model	Type of analysis	Sectors covered	Regional coverage	Main reference	Policy impact	Application in COACCH
(CMCC)	from EUROCORDEX			gridded resolution (200-11 km)	Jacob et al. 2013		tipping points
CLIMRISK (VU)	IAM CEA and CBA	Impacts	Macro-economic	Global with gridded resolution (50x50 km) and 13 regions	Estrada et al., 2015	UNDP and Government of Mexico	Task 2.7: Multi-scale cross-sectoral macroeconomic assessment; Task 3.2: Climate tipping points; Task 3.4: Implications of socio-economic tipping points; Task 4.3: Macroeconomic assessment of policy effectiveness
DIFI (VU)	PE, RA	Impacts, Adaptation	Flood risk, insurance	Europe with NUTS2 resolution	Hudson et al., 2016	.	Task 4.2: Sectoral assessments of policy effectiveness
EPIC (IIASA)	Cropping system model (PM)	Impacts and adaptation policy assessment	Crops, grassland, Agriculture	Europe with gridded resolution (1x1 km), Global (5x5 arc-min)	Izaurralde et al., 2006	.	Task 2.2: Impacts on agriculture, forestry & fishery; Task 3.3: Analysing socio-economic tipping points
G4M (IIASA)	Forestry model (PM/PE)	Impacts and adaptation policy assessment	Forests	Europe with gridded resolution (1x1 km), Global (5x5 arc-min)	Kindermann et al., 2013	Capros et al., 2016; European Commission, 2016b	Task 2.2: Impacts on agriculture, forestry & fishery
SFM/FLAM (IIASA)	Forest fire model (PM)	Physical impacts	Forests	0.25 x 0.25° (Europe), 0.25x0.25° (global)	Khabarov et al. 2016, Krasovskii et al. 2016	.	Task 2.2: Impacts on agriculture, forestry & fishery

Notes: IAM=Integrated Assessment Model, CGE=Computable General Equilibrium model, PE= Partial Equilibrium model, PM=Physical Model, RA=Risk Assessment model, GCM=General Circulation Model, RCM=Regional Climate Model, EM=Econometric model, CEA= Cost Effective Analysis, CBA=Cost Benefit Analysis.

ICES (Inter-temporal Computable Equilibrium System) is a top-down recursive-dynamic multi-sector and multi-country computable general equilibrium (CGE) model for the word economy, based upon the latest GTAP database. Its structure describes domestic and international linkages between economic activities, energy use, including renewables, and GHG emissions (including non-CO2 from agriculture and livestock). ICES will be applied to provide a macroeconomic assessment (on GDP, competitiveness, production, trade, prices) of climate change impacts at NUTS2 level for Europe, at the macro-regional level for the rest of the world and with sectoral detail, under climate change and tipping points. In COACCH it will assess cross-sectoral linkages and impact interaction including non-market impacts on ecosystems and health and by highlighting asymmetries of macroeconomic impacts within countries.

WITCH (World induced Technical Change) is a top-down, hard-linked climate-energy-economy dynamic optimization Integrated Assessment Model offering a detailed breakdown of the energy sector and a game theoretic setup. It accounts for impacts from global warming, which are currently implemented through one region-specific damage function, mitigation policies and adaptation investments that are endogenously determined. In COACCH the model will be used to capture the interactions between adaptation and mitigation policies under deep uncertainty. In COACCH it will be further developed estimating sector-specific damage functions, explicitly taking into account sea-level rise, and uncertain and irreversible impacts (tipping points).

IMAGE is an IAM modelling framework that describes the interaction between the human system (in particular energy and land use) with the earth system (climate, land cover and different key natural cycles). The system explicitly includes several impacts that are modelled in biophysical terms such as sea-level rise, and the impacts of climate change on energy use, agriculture and the water cycle. IMAGE has been often used to look at different mitigation strategies in the energy and land-use system. In this role, the IMAGE modelling system has, for instance, been used in developing both the RCP and SSP scenarios. Within the IMAGE modelling system, various sub-models exits. One of them is the IMAGE-FAIR model that can also look into the policy interactions between adaptation and mitigation. In FAIR, a damage-function approach is used to look into the costs of impacts and adaptation. In COACCH, the existing FAIR model will be improved by separating impacts across sectors using sector-specific damage functions, explicitly taking into account sea-level rise, and uncertain and irreversible impacts (tipping points) and coupling these curves to the biophysical modelling of impacts in the main IMAGE model. The **GLOBIO** model forms part of the IMAGE framework and is able to describe biodiversity impacts of various drivers, including climate change itself and land-use change that may result from climate policy mitigation policies.

GLOBIOM is an economic land use model for the EU agriculture and forestry sector. It provides a bio-economic assessment of climate impacts on these sectors regarding agricultural production, LULUCF, ecosystems, water, land-use, bioenergy, trade, and GHG-emissions at national and regional levels with high spatial resolution. In COACCH, it will model climate effects on the agriculture (crops and livestock), forestry and fishery sector as well as feedback effects to other sectors. Furthermore, it will develop flood damage functions to estimate the effects of floods on food systems and food security and develop a stochastic version of the model to capture uncertainty in production caused by climate change uncontrollable elements (e.g. weather variability, floods, and droughts). GLOBIOM is linked to **EPIC** and **G4M**. EPIC is a cropping system model that provides biophysical parameters and constraints of crop production to GLOBIOM for the estimation of water use, carbon, phosphorus and nitrogen cycling, as well as erosion and impacts of management practices on these cycles. Crop yields, biomass, and environmental variables are generated at the grid cell level by soil/site conditions, climate, and crop management information (tillage and crop residue management as well as fertilization and irrigation practices). Since EPIC is driven by daily weather data, it allows flexible projections of climate change impacts including weather extremity and drought events. In COACCH it will assess crop yields and associated environmental externalities under different climate scenarios through model linkages with GLOBIOM. G4M is a dynamic forest growth model that estimates how growth rates in forest net primary production (NPP) are affected by changes in climate drivers like temperature, precipitation, radiation, or CO2 concentrations. G4M provides the biophysical basis of the forestry sector in GLOBIOM. It models forest biomass and carbon stocks and estimates forest area change, carbon sequestration and emissions in forests, as well as impacts of carbon incentives (e.g., avoided deforestation) on the supply of biomass for bio-energy and timber.

COIN is a top-down comparative static multi-sector and multi-region computable general equilibrium (CGE) model. It can focus on Austria or Europe (global version). It provides an economic assessment of climate change impact chains in 10 climate sensitive sectors (agriculture, forestry, water, energy, buildings, tourism, transport, manufacturing, flood risk management, cities). In COACCH COIN will be innovated by i) integrating the global supply chain risks due to climate change for business and industry, ii) integrating the insurance sector as novel impact and adaptation sector, and iii) assessing interactions of climate action and other policy areas in public budgeting (mid and long term).

CATSIM is a risk-based (hazard, exposure, vulnerability) probabilistic modelling framework able to assesses direct economic impacts and the macroeconomic consequences of natural disasters as well as the benefits of measures for reducing the associated climate-related risks. More specifically, CATSIM assesses risks, economic resilience and fiscal vulnerability of public budgets to extreme events, and provides policy insights to support public financing strategies for disaster risk management. In COACCH it will consider risk management as a cross-cutting sector, infrastructure.

REMIND couples a highly resolved energy system to a macroeconomic growth model. The model includes a detailed representation of buildings/industry/transport in the energy system and a detailed representation of air pollutants. Climate change mitigation policies and implications on growth and welfare can be assessed for several major regions (in particular Europe). In COACCH it will innovate by developing an aggregated representation of sectoral climate change impacts – enabling the model to be used for CBA analysis.

MAgPIE links crop, livestock, pasture and bioenergy production, consumption, prices and trade with spatially explicit resource availability for water and land, option for flexible regions (in particular Europe). To assess climate impacts, it is coupled to the global gridded vegetation and hydrology model **LPJml**; for mitigation scenarios, it can be coupled to REMIND, as for instance for the simulation of the Shared Socioeconomic Scenarios (SSPs). In COACCH it will innovate by simulating the climate impacts on forestry and fishery.

DIVA is an engineering sea-level rise model which assesses both physical and direct economic implication of climate change impacts on coastal areas in their multidimensionality: land lost and agricultural activity, built environment and infrastructure, forced migration, ecosystems, beach tourism. The model can consider mean sea-level rise, extreme events (e.g. storm surges), low probability/high impact events, tipping situations. In COACCH it will i) incorporate accommodate and retreat options, ii) downscale socio-economic coastal development and urbanisation scenarios, iii) account for optimal adaptation responses as well as adaptation under robust decision making.

LISFLOOD, FIAT/GLOFRIS build together a risk assessment framework linking risk evaluation tools and physical models to provide an assessment of climate change impacts of river floods across several dimensions (built environment and infrastructures, agriculture, ecosystems) at the basin level. In COACCH they will model economic tipping points, and co-deliver improved cost estimates and refinement of flood risk management strategies.

CMCC Climate models provide climate and weather parameters projections for impact models and can characterise changes in climate change average conditions, extreme events, low probability/high impacts events at global and regional level with high spatial resolution. In COACCH it will i) identify the climatic conditions that can trigger socioeconomic disruptive situations and characterise their probability distribution under different RCPs, ii) assess potential physical implications of climate tipping points relevant for Europe.

CLIMRISK assesses the dynamic GDP impacts of climate change at the local scale (50x50 km) under various socio-economic and climate change projections at the global scale. This is done by combining local GDP exposure information with climate predictions obtained using pattern scaling of the MAGICC/SCENGEN climate model. Regional impact functions are derived from RICE model estimates of the GDP impacts of temperature changes and encompass a broad range of economic sectors. The extension within COACCH will consist in updating the damage functions with the new estimates developed in the project, explicitly taking into account uncertain and irreversible impacts (tipping points).

DIFI (Dynamic Integrated Flood Insurance Model) simulates the impacts of climate change scenarios on stylised versions of existing European insurance arrangements for covering flood risk. The DIFI model estimates the expected annual per capita flood loss and variance of losses at a 100x100km scale across Europe which are aggregated to NUTS2 regions. The expected annual loss per capita and the variance of losses are converted into household insurance premiums for the modelled insurance arrangements. Important outputs of the model are insurance-related variables such as insurance penetration rate; incentivised risk reduction by insurance; affordability of premiums; and the premium burden on low(er) risk households. In COACCH it will examine the impacts of climatic and socioeconomic tipping points for the insurance sector through model linkage with the UNIGRAZ COIN model.

SFM/FLAM provides explicit estimation of burned areas, validated for the EU. The model will be used to assess impacts and risks related to forest fires under climate change and socio-economic scenarios. These will be expressed in terms of estimated burned areas. In COACCH, SFM/FLAM will: i) provide updated impact estimates using latest climate projections for the European domain (EURO-CORDEX or ISI-MIP), ii) extend the set of management options to reflect measures limiting fire spread (e.g. fire breaks).

Models are not the only quantitative tools supporting COACCH investigations. **Econometric** analyses are indeed applied in WP2 to assess climate change impacts on industry and services, labor supply, and energy demand and supply (COACCH Task 2.4) and on the non-market dimensions of ecosystems and biodiversity (COACCH Task 2.5) and Health (COACCH Task 2.6).

Next section describes the information exchange flows identified between these different branches of COACCH research.

3. COACCH information exchange flow and protocol

In what follows, the interactions that will be activated within COACCH are presented graphically and then commented. Figure 3 reports the overall picture. This is the transposition, referring explicitly to COACCH modelling/quantitative tools, of Figure 2 following the bilateral exchanges between partners and the feedback submitted after the Modelling Workshop in Graz.

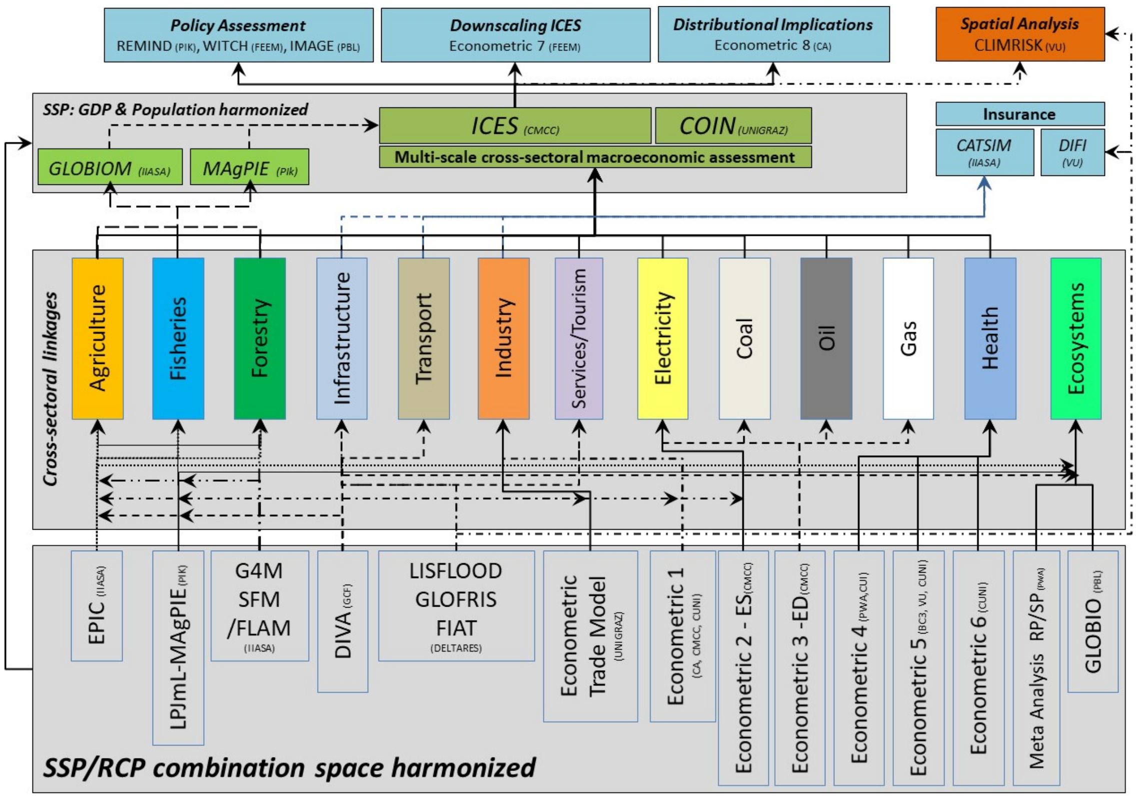

Figure 3. Representation of the vertical and horizontal integrated information exchange flows within the COACCH project

In its bottom part, Figure 3 reports the list of quantitative approaches COACCH applies to conduct the different sectoral impact assessments. These evaluations will be performed within the boundaries of a harmonized SSP/RCP scenario space, whose definition is the outcome of a process engaging COACCH researchers and stakeholders in an intense co-design dialogue. For more information on this phase of COACCH co-designing, the interested reader is directly addressed to COACCH D1.5: “Impact and policy scenarios co-designed with stakeholders” and D1.6: “Protocol for impact assessment studies”. The central part of Figure 3 reports the sectors or “impact areas” addressed by the different tools. Arrows link each tool to its specific impacted sector, but also highlight the cross linkages between studies and thus “horizontal” input output exchanges across them when the arrow ends up in a line. The top part of Figure 3 describes the final COACCH investigation steps: how information from the sectoral

studies are expected to feed macro-economic models for a comprehensive evaluation of higher order consequences of climate change impacts, risks and, eventually of climate change policies. It also encompasses the policy assessment including distributional and spatial analysis either by downscaling results from macroeconomic models or by running a spatial analysis at gridded scale.
The next sub-sections disentangle Figure 3 in its components that are commented in detail to highlight integration and, in doing so, substantiating the "protocol" for information exchange.

3.1 Agriculture forestry and fishery

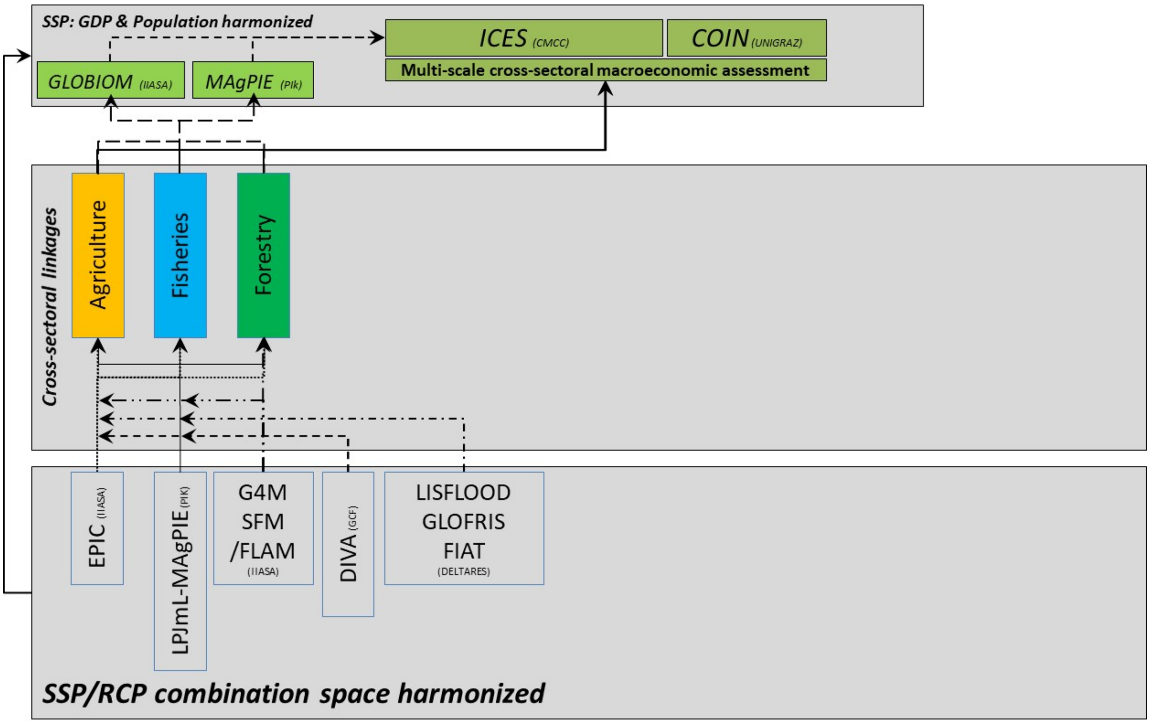

Figure 4. Representation of the vertical and horizontal integrated information exchange flows in the assessment of climate change impacts in the agriculture, fishery and forestry sectors.

Climate change impacts on agriculture will be addressed initially with the EPIC (IIASA) and LPJmL (PIK) models. Although with different characteristics, these models will produce changes in crop yields under different SSPS/RCPs combination. This information is direct input for the GLOBIOM (IIASA) and MAGPIE (PIK) models. GLOBIOM assesses impacts on agricultural production, LULUCF, ecosystems, water, land-use, bioenergy, trade, and GHG-emissions at national and regional levels with high spatial resolution; MAGPIE assesses impacts on the markets of agricultural commodities, price effects and implication for food security.

The analysis of impacts in the agricultural sector is strictly linked to that of forestry as the dynamics triggered by climate change, either in terms of land suitability or land use in one, directly affect the other, being both sectors, agriculture and forestry, competing for land. The models addressing impacts on forestry are G4M (IIASA), a dynamic forest growth model that estimates how growth rates in forest net primary production (NPP) are affected by climate change, and SFM/FLAM (IIASA) addressing fire risk with estimation of burned areas. Linkages between the agriculture and forestry impact assessments is granted by the fact that GLOBIOM is already integrated "downstream" with EPIC, G4M and SFM/FLAM. Therefore, it can incorporate simultaneously the information from all models. MAGPIE will directly use inputs from LPJmL and provide an assessment considering the economic features embedded in the model to represent agricultural activities.

Further information that need to be integrated in the analysis of impacts on agriculture and forestry is the agricultural land loss (permanent or temporary) induced by river floods and sea-level rise, when this affects crops in coastal areas. These data could be provided respectively by the LISFLOOD (Deltares) and DIVA (GCF) models and incorporated into MAGPIE and GLOBIOM paying attention to the spatial scale of each model.

The climate-induced effects on fish farming productivity, disease management, aquaculture expansion, and carrying capacity, and the resulting impact on global production, trade, and consumption, and GHG emissions of both aquaculture and fisheries will be analysed in GLOBIOM (IIASA). Aquaculture is integrated via fish farming systems and their linkages to the agricultural sector through the feed markets. Fisheries are included via a linkage with biophysical models of wild fish stocks, fishing fleets, and fishing efforts. MAgPIE (PIK) will also look at marine fish and analyse substitution effects on land when fish catches are reduced by climate change.

Economic impacts on agriculture, forestry and fishery will be evaluated also in their higher order dimension, i.e. assessing their consequences on GDP, welfare and trade patterns of the EU countries and regions. This will be done applying two macro-economic computable general equilibrium (CGE) models ICES (CMCC) and COIN (Graz university). The two models will implement information on changes in crop yields, in net forestry primary production, loss of agricultural and forest land due to river floods, forest fires and sea-level rise from respectively EPIC, LPJmL, G4M, DIVA and LISFLOOD "translated" in the form of changes in the productivity of primary factor of production used in the agriculture, forestry and fishery sectors. The information from the process based models, produced with spatially resolved detail (see Table 1) will be upscaled at the "administrative" resolution of the two CGE models. ICES in particular, features a regional aggregation varying from country level to NUTS2 description of the EU economic systems. This characteristic will enable a sub national assessment of macro-economic implications of climate change impacts, one of the distinctive and more innovative features of the COACCH project.

Information from MAGPIE and GLOBIOM cannot be incorporated directly in the CGEs as their economic variables' output is also an output of the CGEs. Nonetheless, the comparison of the different set of results, those from MAGPIE and GLOBIOM obtained in a "partial equilibrium setting", and those from ICES and COIN obtained in a general equilibrium context, will remain extremely useful to give an estimation of the size and relevance of general equilibrium market adjustment mechanisms (e.g. domestic and international trade patterns) in determining the final economic impact.

3.2 Infrastructure, built environment, and transport

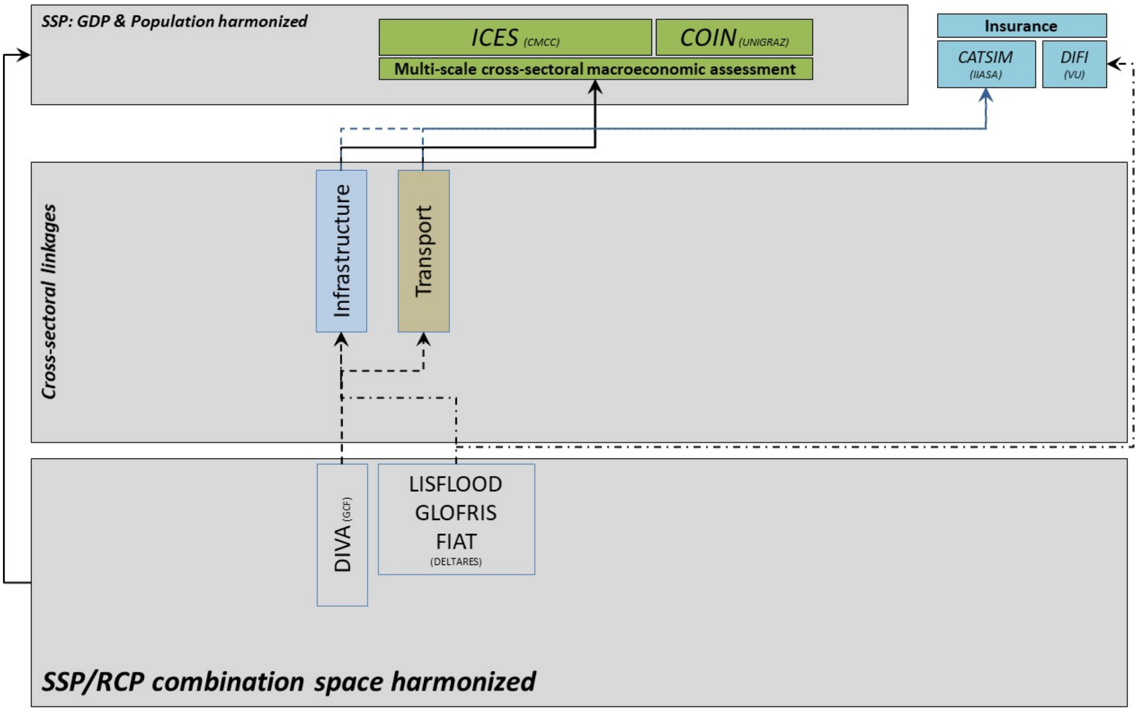

Figure 5. Representation of the vertical and horizontal integrated information exchange flows in the assessment of climate change impacts on infrastructure, built environment and transport.

The analysis of climate change impacts on infrastructure, built environment and transport is based upon the application of the LISFLOOD/FIAT models (Deltares) and DIVA (GCF)[1].

LISFLOOD is a physical model of floods that together with FIAT provides an assessment of climate change impacts of river floods across the dimension of built environment and infrastructures, agriculture (see section 3.1) ecosystem (see section 3.4) at the basin level.

DIVA assesses both physical and direct economic implication of climate change impacts on coastal areas in their multidimensionality: land lost and agricultural activity (see section 3.1), built environment and infrastructure, forced migration, ecosystem (see section 3.4).

[1] The models encompass also the dimension of ecosystem losses and tourism. These issues will be addressed in the dedicated sections.

LISFLOOD/FIAT and DIVA work “in parallel” on different domains. Both will provide information on land loss and asset losses in different “macro sectors” (residential, industry, agriculture, ecosystem) to ICES and COIN for the subsequent macro-economic assessment.

LISFLOOD will also provide input information (flood risk estimates) to the DIFI model that considers residential flood risk in terms of direct property losses and the associated residential flood risk insurance arrangements.

The issues to consider are the following: the information from these models will be up-scaled at a suitable geographical scope for ICES and COIN; care will be placed in avoiding “double counting” in physical and direct economic losses when sea-level rise, especially in the case of the analysis of extreme climate tipping point, could overlap with flooded areas.

3.3 Industry, energy, services, and trade

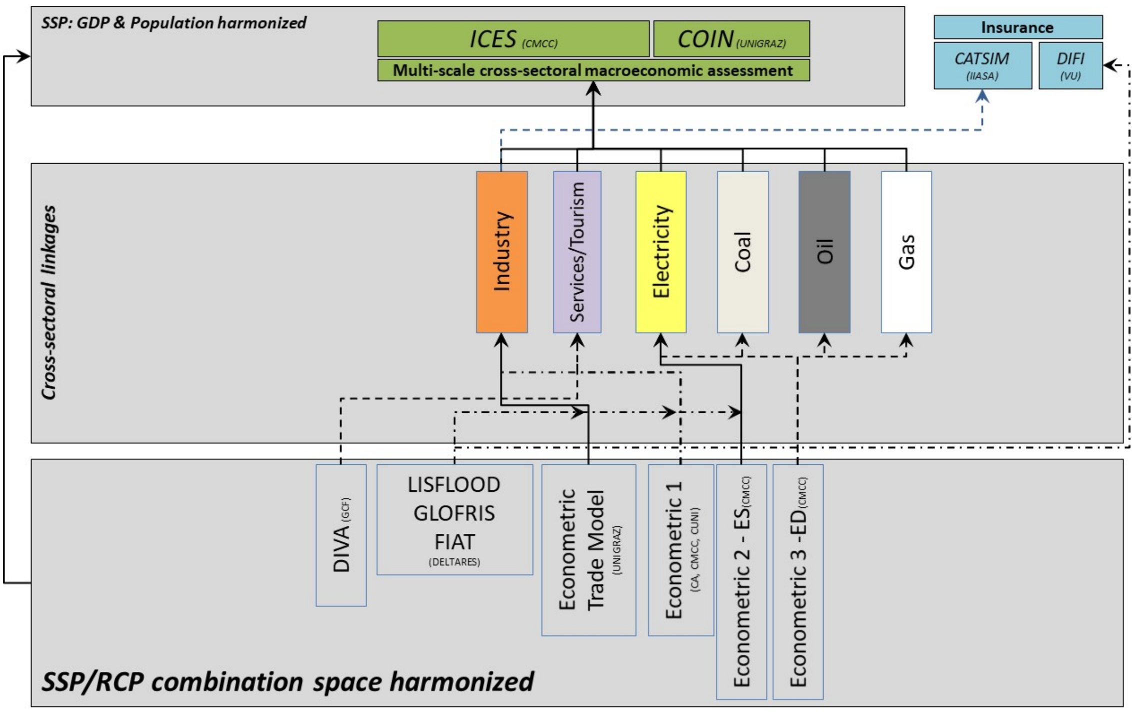

Figure 6. Representation of the vertical and horizontal integrated information exchange flows in the assessment of climate change impacts on industry, energy, services and trade.

Climate change impacts on energy demand and supply will be assessed through econometric analyses developed by CMCC. The analysis of supply focuses on hydro and wind electricity production, that of demand relates to the four major energy vectors: coal, oil, gas and electricity. The work consists of two phases: the first one is the estimation step, where historical energy supply and demand data will be regressed on spatially resolved climate variables to estimate supply and demand elasticities; the second one is the projection phase where the estimated relations will be projected to the future following the given set of SSPs/RCPs combinations. Results from the econometric analysis could be complemented with data from the LISFLOOD model that could provide data on damages that could affect energy supply and other economic activities.

Changes in energy demand and supply will be used as input to the general equilibrium models ICES and COIN. Changes in energy supply are modeled as a change in the productivity of the input bundles of the energy sectors or as a direct change in the availability of fossil/renewable input. Energy demand changes will be implemented as a change in preferences for consumption items in households' utility.

3.4 Non-market impacts: ecosystems and biodiversity

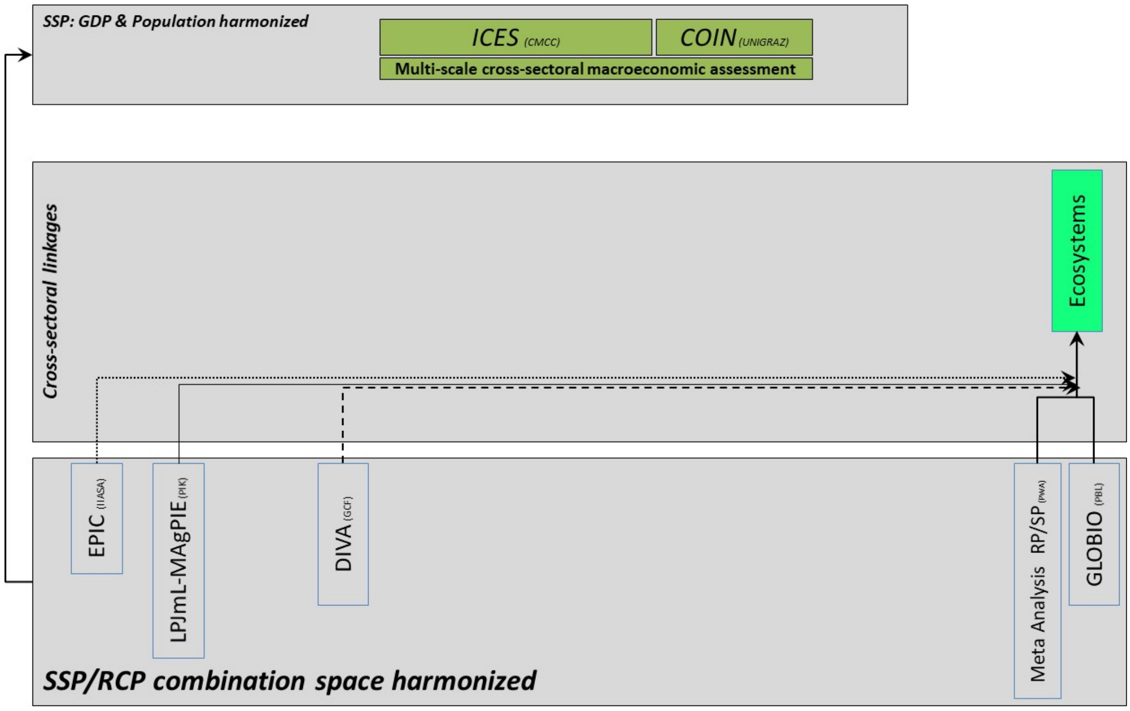

Figure 7. Representation of the vertical and horizontal integrated information exchange flows in the assessment of climate change impacts on ecosystem and biodiversity.

Biophysical impacts on ecosystems are measured using the GLOBIO (PBL) model of biodiversity reporting estimates of climate change impacts on mean species abundance (MSA), an indicator of the degree to which an ecosystem is intact.

The economic assessment of these impacts will be performed following two distinct approaches. Ecosystem "market losses" will be quantified through the "production function" approach which is described in section 3.1

Non-market, non-use ecosystem losses will be assessed developing a meta-analysis of the relevant literature by PWA. The result of the meta-analysis will allow to "price" changes in biodiversity indicators like MSA, the direct output from GLOBIO, but also potentially others that can be extracted from GLOBIOM or MAGPIE such as changes in nitrate concentration in soils. Furthermore, the DIVA model will compute changes in wetland area with specific reference to fresh/salt marshes and mangroves on a local base that can be then aggregated on national and/or European level and subsequently assessed in economic terms.

Non-market impacts related to ecosystems and biodiversity will not be assessed in their macro-economic implications as the CGE modelling approach is not suitable to capture the feedback originated outside observable market transactions.

3.5 Non-market impacts: health

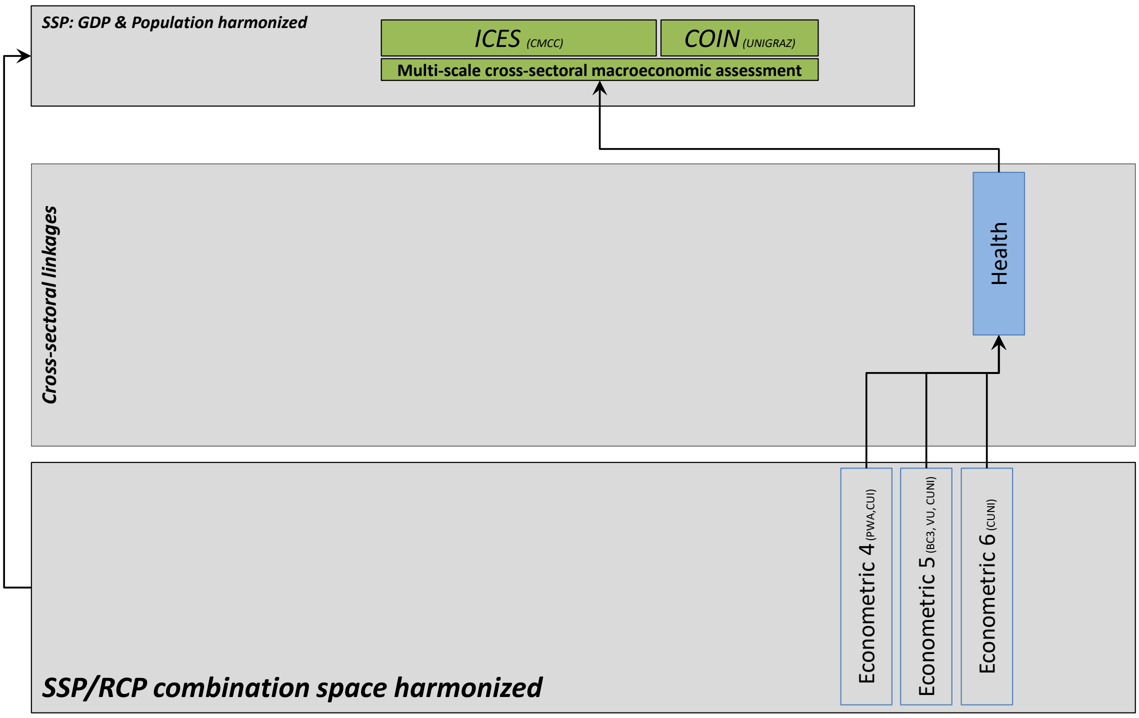

Figure 8. Representation of the vertical and horizontal integrated information exchange flows in the assessment of climate change impacts on health.

The assessment of climate change impacts on health focuses on extreme heat events and on vector water- and food-borne diseases.

The investigation methods applied are econometrically based and consist of: use of heatwave hotspot mapping, including urban heat island effects, for major European urban areas and related premature mortality risks (BC3, VU); survey-based estimation of the Value of Statistical Life using discrete choice experiments conducted in the

Czech Republic, Spain and UK (CUNI, PWA, BC3); valuation surveys to analyse averting behaviour (i.e. adaptation) and to estimate WTP and Cost-Of-Illness (medical and off-pocket expenditures, loss of productivity due to sickness leave) in the Czech Republic, Sweden, Austria and Denmark (CUNI).
To derive direct cost (monetary values) for other health outcomes, results from the literature will be surveyed by PWA and CUNI and adopted using value transfer methods.
The macroeconomic (indirect costs) will be estimated by feeding the results from the survey and literature survey described above - specifically changes in health care expenditure and productivity - to the CGE models ICES and COIN.

3.6 Integrated assessment: Policy, distributional and spatial analysis

The final stage of the COACCH assessment is in the incorporation of the updated climate change macro-economic assessments in WP2 in the integrated assessment models in WP3 as well as downscaling the results to provide insights on their distributional implications. This step is represented in Figure 8, with the CGE models at the bottom estimate reduced-form damage functions which will be included in the integrated assessment models REMIND (PIK), WITCH (FEEM), IMAGE(PBL) and CLIMRISK (VU).

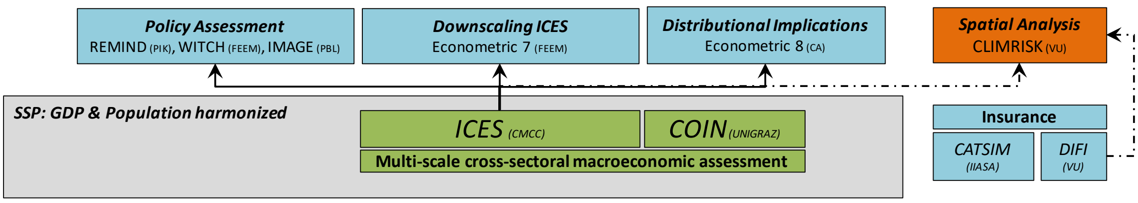

Figure 9. Representation of the integrated assessment including distributional and spatial aspects.

In addition, results from the ICES model will be downscaled at different levels using econometric techniques to complement the analysis with a finer granularity level than NUTS2. Along with these analysis, the insurance dimension will be covered using the models CATSIM (IIASA) and DIFI (VU).

3.7 Timing

This final section proposes an indicative timing for the exchange of information across tasks in WP2. It is “indicative” as, even though setting deadlines, it leaves some flexibility to the initiative of task leaders and modelling teams to structure the communication flow according to the respective workload and time required to perform the simulation exercises with the respective models.
This said, according to the DOW, the deliverables containing the sectoral impact analyses, namely: D2.2 “Impacts on agriculture including forestry & fishery” (IIASA),

D2.3 “Impacts on infrastructure, built environment, and transport” (GCF), D2.4 “Impacts on industry, energy, services, and trade” (CA), D2.5 “Non-market impacts: ecosystems and biodiversity” (PWA), D2.6 “Non-market impacts: health” (CUNI), are all due on month 22 (September 2019). Therefore, all the input information allowing the completion of the sectoral analyses, should be made available, prudentially, 2 months ahead of that deadline, i.e. month 20. This should leave sufficient time to the teams to perform the last run of integrated simulations while allowing them enough time to complete a first round of individual simulation rounds. An important checkpoint of the information exchange process will be the 3rd project meeting foreseen at month 18 when the interaction channels established by this deliverable 2.1 are expected to be activated and operationalized, i.e. the specific models’ variables list to be exchanged and the exact time and spatial format of each of them need to be set.

4. References

Bosello F., Parrado R. and Standardi G. (2018). M4 Minutes of the 2nd Project meeting. Milestone of the H2020 COACCH project.

5. Annex A: input-output variables in COACCH quantitative toolkit

Model	Partner	Model Type	Variable	Unit	OUTPUT	INPUT	Spatial resolution
CLIMRISK	VU	IAM Reduced-form climate change damage function	Precipitation (probabilistic)	% change	X		0.5x0.5
			GDP|MER	billion $US2005/yr	X	X	0.5x0.5
			Aggregated economic damages (RICE2010)	billion $US2005/yr, % change	X		0.5x0.5
			Aggregated economic damages (RICE2010-PERSISTENCE)	billion $US2005/yr, % change	X		0.5x0.5
			Aggregated economic damages (RICE2010-PERSISTENCE-URBAN)	billion $US2005/yr, % change	X		0.5x0.5
			Aggregated economic damages (RICE2010-URBAN)	billion $US2005/yr, % change	X		0.5x0.5
			Emissions scenarios	Different units per gas		X	6 regions
			Population	million	X	X	0.5x0.5
			Temperature (probabilistic)	ºC (delta)	X		0.5x0.5
			Economic and climate risk measures	Probability, dates	X		0.5x0.5
			Multivariate risk indices	Unit free, dates	X		0.5x0.5
COIN	Graz University	Macro/CGE	change in agricultural yields	% change wrt 2008		X	Country level
			Changes in labour productivity in manufacturing and trade sectors	% change wrt 2008		X	NUTS3
			Relative price changes by sector	% change wrt 2008	X		Country level (sectors)
			Wage rate of labor	% change wrt 2008	X		Country level
			Fossil fuel prices	% change wrt 2011		X	Country level
			autonomous energy efficiency improvements (AEEI)	% p.a.		X	Country level
			Adaptation measures against flooding	€		X	Country level
			Adaptation measures in Agriculture	€		X	Country level
			Adaptation measures in Forestry	€		X	Country level

			Change in tourism demand	€		X	Country level
			Changes in Electricity infrastructure requirements	€		X	Country level
			Changes in Heating and Cooling demand	€		X	Country level
			Changes in urban green space requirements	€		X	Country level
			Damages from riverine flooding to assets	€		X	Country level
			Damages in Forestry sector	€		X	Country level
			Damages to road transport infrastructure	€		X	Country level
			Damages to Water Supply and Sanitation infrastructure; water demand	€		X	Country level
			Baseyear unemployment	€ (foregone wage earnings)		X	Country level
			Global/regional CO2 tax (or emission cap)	€ (or tCO2/yr)		X	Country level
			GDP	€ 2008/yr	X	(x)	Country level
			Changes in tax income components	€ and in %	X		Country level
			exports by sector	absolute and % change wrt 2008	X		Country level (sectors)
			imports by sector	absolute and % change wrt 2008	X		Country level (sectors)
			Output by sector	absolute and % change wrt 2008	X		Country level (sectors)
			Public and private consumption	absolute and % change wrt 2008	X		Country level
			Welfare	absolute and % change wrt 2008	X		Country level
			Change in unemployment rate	in %-points	X		Country level
			CO2 emissions	Mtons of CO2	X		Country level (sectors)
COIN_INT			change in agricultural yields by crop	% change wrt 2011		X	Country level
			Changes in labour productivity	% change wrt 2011		X	0.5x0.5 aggregated weighted to model regions
			Fossil fuel prices	% change wrt 2011		X	Global
			Relative price changes by sector and region/country	% change wrt 2011	X		Country level (model regions and sectors)
			Wage rates of skilled and unskilled labour	% change wrt 2011	X		Country level (model regions)
			autonomous energy efficiency improvements (AEEI)	% p.a.		X	Country level (model regions)
			GDP growth	% p.a.		(calibration)	Country level (model regions)

			Growth rate of crop land cover, driving the growth of land resources	% p.a.		X	5 macro regions (OECD, REF, ASIA, MAF, LAM)
			exports by sector and region/country	absolute and % change wrt 2011	X		Country level (model regions and sectors)
			imports by sector and region/country	absolute and % change wrt 2011	X		Country level (model regions and sectors)
			Output by sector and region/country	absolute and % change wrt 2011	X		Country level (model regions and sectors)
			Public and private consumption	absolute and % change wrt 2011	X		Country level (model regions)
			regional Trade Balance	absolute and % change wrt 2011	X		Country level (model regions)
			Welfare	absolute and % change wrt 2011	X		Country level (model regions)
			Working age population	million		X	Country level (model regions)
			Annual cost of construction of new dikes as well as rising of existing dikes	million US$/year		X	Country level
			Annual cost of maintaining existing dikes	million US$/year		X	Country level
			Expected annual damages to assets due to sea level rise	million US$/year		X	Country level
			CO_2 emissions (incl. Process emissions)	Mtons of CO_2	X		Country level (model regions and sectors)
			Global/regional CO_2 tax (or emission cap)	US$ (or tCO_2/yr)		X	Global/regional
			Change in GDP	US$ and in % (relative to Baseline)	X		
DIVA	GCF	Impact Model Sea-level rise	GDPC change	--		X	Country level
			Population change	--		X	Country level
			Annual land loss due to submergence	km²/year	X		Coasline segments, aggregated to Nuts2, Country, Macro regions and global
			Climate induced sea-level change	m		X	Coastline segments, derrived from 1km x 1km gridded GCM outputs
			Nonclimate induced sea-level change	m		X	Coastline segments, derrived from multiple sources
			Annual cost of construction of new dikes as well as rising of existing dikes	million US$(2014)/year	X		Coasline segments, aggregated to Nuts2, Country, Macro regions and global
			Annual cost of maintaining existing dikes	million US$(2014)/year	X		Coasline segments, aggregated to Nuts2, Country, Macro regions and global
			Expected annual damages to assets	million US$(2014)/year	X		Coasline segments, aggregated to Nuts2, Country, Macro regions and

							global
			Population	thousands	**X**	X	1km x 1km GRUMP data
			Expected annual number of people flooded per year	thousands/year	X		Coasline segments, aggregated to Nuts2, Country, Macro regions and global
			GDPC	US$(2014)	X	C	Nuts2 to Country level
EcTrade	Graz University	Macro	Export Flows		X		Product class and 189 countries
			GDP			X	189 countries
			Network Measures			X	26 Sectors attached to Product classes and 189 countries
			Network Measures * Weather (Climate) Shock			X	26 Sectors attached to Product classes and 189 countries
			Population			X	189 countries
			Trade Cost measures			X	Product and 189 countries
EPIC	IIASA	Impact	slope	%		X	1x1 km (Europe), 5x5 arc-min (global)
			daily maximum air temperature	°C		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			daily minimum air temperature	°C		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			crop-specific calendar	DOY		X	1x1 km (Europe), 5x5 arc-min (global)
			relative humidity	fraction		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			crop distribution mask	ha		X	1x1 km (Europe), 5x5 arc-min (global)
			crop-specific N,P fertilization	kg/ha		X	NUTS2 (Europe), (sub)country (global)
			Nitrogen applied	kg/ha	X		1x1 km (Europe), 5x5 arc-min (global)
			Phosphorus applied	kg/ha	X		1x1 km (Europe), 5x5 arc-min (global)
			Water use efficiency	kg/mm	X		1x1 km (Europe), 5x5 arc-min (global)
			elevation	m		X	1x1 km (Europe), 5x5 arc-min (global)
			wind speed	m/s		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			solar radiation	MJ/m2		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			crop-specific irrigation	mm		X	1x1 km (Europe), 5x5 arc-min (global)

			daily precipitation	mm		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			Growing season evapotranspiration	mm	X		1x1 km (Europe), 5x5 arc-min (global)
			Irrigation volume applied	mm	X		1x1 km (Europe), 5x5 arc-min (global)
			soil properties	n.a.		X	1x1 km (Europe), 5x5 arc-min (global)
			atmospheric CO2 concentration	ppm		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			Crop yield	t/ha	X		1x1 km (Europe), 5x5 arc-min (global)
G4M	IIASA	Impact Forestry model	slope	%		X	1x1 km (Europe), 5x5 arc-min (global)
			daily maximum air temperature	°C		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			daily minimum air temperature	°C		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			Nitrogen applied	kg/ha		X	1x1 km (Europe), 5x5 arc-min (global)
			elevation	m		X	1x1 km (Europe), 5x5 arc-min (global)
			growing stock volume	m3/ha	X		1x1 km (Europe), 5x5 arc-min (global)
			solar radiation	MJ/m2		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			daily precipitation	mm		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			Irrigation volume applied	mm		X	1x1 km (Europe), 5x5 arc-min (global)
			land cover, forest type	n.a.		X	1x1 km (Europe), 5x5 arc-min (global)
			soil properties	n.a.		X	1x1 km (Europe), 5x5 arc-min (global)
			atmospheric CO2 concentration	ppm		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			aboveground biomass	tC/ha	X		1x1 km (Europe), 5x5 arc-min (global)
			mean annual increment, MAI by forest type	tC/ha/year	X		1x1 km (Europe), 5x5 arc-min (global)
GLOBOIM	IIASA	Impact	(Changes in) Area by crop (see GLOBIOM products)	1000 Ha	X		0.5x0.5, NUTS2 for EU-member states, country and GLOBIOM region

			Land and land use change (Cropland, Primary forest, Managed forest, Plantation forest, Natural land, Grassland)	1000 Ha	X		0.5x0.5, NUTS2 for EU-member states, country and GLOBIOM region
			(Changes in) Consumption of products (see GLOBIOM products)	1000 t	X		GLOBIOM-region
			(Changes in) Exports of products (see GLOBIOM products)	1000 t	X		GLOBIOM-region
			(Changes in) Imports of products (see GLOBIOM products)	1000 t	X		GLOBIOM-region
			(Changes in) Production (see GLOBIOM products)	1000 t	X		0.5x0.5, NUTS2 for EU-member states, country and GLOBIOM region
			(Changes in) Production used for feed	1000 t	X		0.5x0.5, NUTS2 for EU-member states, country and GLOBIOM region
			(Changes in) Production used for food	1000 t dm	X		0.5x0.5, NUTS2 for EU-member states, country and GLOBIOM region
			(Changes in) Animals (Cattle, sheep and goats, pigs, poultry)	1000 TLU	X		0.5x0.5, NUTS2 for EU-member states, country and GLOBIOM region
			GDP	billion €		X	GLOBIOM region
			(Changes in) Yield of products (see GLOBIOM products)	dm t/ha	X		GLOBIOM-region
			Technological change of agricultural products	factor		X	GLOBIOM region
			(Changes in) Calorie consumption of products (see GLOBIOM products)	kcal/cap/d	X		GLOBIOM-region
			Population	Mln pers		X	GLOBIOM region
			(Changes in) Emissions	Mt CO2eq/yr	X		0.5x0.5, NUTS2 for EU-member states, country and GLOBIOM region
			(Changes in) Price of products (see GLOBIOM products)	USD 2000 per ton	X		GLOBIOM-region
Health impact assessment	BC3	Impact Econometric analysis	heat warning plans (?)			X	city- level or Sub-national (EU Statistics)? Check available dataset
			check for proxies for exposure and vulnerability (selection of these variables will be part of the conceptual framework construction)			X	city- level or Sub-national (EU Statistics)? Check available dataset
			daily mean air temperature	°C		X	(Resolution 12x12 km, e.g. Cordex)

			daily minimum temperature	°C		X	(Resolution 12x12 km, e.g. Cordex)
			daily maximum temperature	°C		X	(Resolution 12x12 km, e.g. Cordex)
			Threshold temperature based on percentile (we can calculate from the above) or based on epidemiological studies at city level in EU	°C		X	(Resolution 12x12 km, e.g. Cordex)
			Other variables: wind speed, atmospheric pressure, relative humidity, cloud cover, etc…	relevant unit		X	(Resolution 12x12 km, e.g. Cordex)
			PM2.5			X	
			PM10			X	
			SOX			X	
			NOX			X	
			OZONE			X	
			Historical daily mortality summertime (June-September, maybe add all year)	# deaths		X	City level for selected representative cities for EU macro-regions
			Historical daily hospitalisations summertime (June-September, maybe add all year) ? To be decided	# hospitalisation		X	City level for selected representative cities for EU macro-regions
			Health personnel mobilised during heatwaves	€		X	Country/regional
			VSL/VOLY	€		X	Country
			Health care costs estimated	€		X	Country
			Cost of heat warning systems	€		X	Country- City
			Areas and locations mostly at risk looking at hazard	spatial mapping	X		at chosen spatial resolution
			Areas and locations mostly at risk looking at hazard and exposure	spatial mapping	X		at chosen spatial resolution
			Areas and locations mostly at risk looking at hazard, exposure and vulnerability	spatial mapping	X		at chosen spatial resolution
			Population	Thousands/million		X	city- level or Sub-national (EU Statistics)? Check available dataset
			Future heatwave mortality	number of deaths (maybe mapped?)	X		City level for the selected subset
			Economic impacts mortality	millions € or %GDP (maybe mapped?)	X		City level for the selected subset

			Benefits acclimatisation?	millions € or %GDP(maybe mapped?)	X		City level for the selected subset
			Benefits HEAT WARNING SYSTEMS	millions € (maybe mapped?)	X		City level for the selected subset
			GDP PPP	€		X	city- level or Sub-national (EU Statistics)? Check available dataset
			Number hospitals or hospital beds or other proxy for health access			X	city- level or Sub-national (EU Statistics)? Check available dataset
			popultion by age groups and gender			X	city- level or Sub-national (EU Statistics)? Check available dataset
			population by other socio-economic factors depending on available and resolution of data at the required scale			X	city- level or Sub-national (EU Statistics)? Check available dataset
			use of air conditioning (?)			X	city- level or Sub-national (EU Statistics)? Check available dataset
Energy demand and supply assessment	CMCC	Impact Econometric analysis	Heating and cooling degree days			X	
			Price, technology and income independent variables			X	
			Change in demand for energy vectors (coal, gas, oil, electricity	% changes in energy demanded (GW)	x		Households, macro sectors (industry, services, agriculture) country
			Daily temperature			x	
			Daily precipitation			x	
			Daily groundwater runoff			x	
			SPI (3, 6, 12, and 24 months)			x	
			1-hourly/3-hourly wind speed			x	
			Supply of renewable electricity (hydro and wind)	% changes in energy produced (GW)	x		Analysis developed at the dam and NUTS2 level
ICES	CMCC	Macro CGE	exports by sector and region/country	% change wrt 2011	X		Nuts2 to Country level
			imports by sector and region/country	% change wrt 2011	X		Nuts2 to Country level
			Price by sector and region/country	% change wrt 2011	X		Nuts2 to Country level
			Production by sector and region/country	% change wrt 2011	X		Nuts2 to Country level
			GDP|MER	billion €2007/yr	X	C	Nuts2 to Country level
			Annual land loss due to submergence	km^2/year		X	Nuts2 to Country level
			labour stock	million		X	Nuts2 to Country level
			Population	million		X	Nuts2 to Country level

			Annual cost of construction of new dikes as well as rising of existing dikes	million US$/year		X	Nuts2 to Country level
			Annual cost of maintaining existing dikes	million US$/year		X	Nuts2 to Country level
			Expected annual damages to assets	million US$/year		X	Nuts2 to Country level
			GHG (CO2, CH4, N2O) emissions	Mtons of CO2	X		Nuts2 to Country level
			Expected annual number of people flooded per year	thousands/year		X	Nuts2 to Country level
			change in agricultural yields by crop			X	Nuts2 to Country level
			Changes in energy demand (coal)			X	
			Changes in energy demand (electricity)			X	
			Changes in energy demand (gas)			X	
			Changes in energy demand (oil)			X	
			Changes in fisheries net primary productivity			X	
			Changes in forest net primary productivity			X	
			Changes in health care expenditure			X	
			Changes in labour productivity (health - morbidity)			X	
			Changes in labour quantity (health - mortality)			X	
			Tourism demand			X	
IMAGE-FAIR	PBL	IAM	Capital formation rate	%		X	Country
			Adaptation costs	billion US$2005/yr	X		Region
			Capital loss	billion US$2005/yr	X		Region
			Capital stock	billion US$2005/yr		X	Country
			Consumption loss	billion US$2005/yr	X		Region
			Damage costs	billion US$2005/yr	X		Region
			GDP loss	billion US$2005/yr	X		Region
			GDP|MER	billion US$2005/yr		X	Region
			GDP|PPP	billion US$2005/yr		X	Region
			Marginal abatement costs	billion US$2005/yr		X	Region
			Mitigation costs	billion US$2005/yr	X		Region

			Temperature	Celsius	X		Region
			Population	million		X	Region
			GHG Emissions: CO2, CH4, N2O, halocarbons	tons		X	Region
			Other emissions: CO, NMVOC, SO2, BC, OC, NOx	tons		X	Region
Network I/O		Macro	Input and Output flows	million		X	26 Sectors and 189 countries
			Different Network Measures		X		26 Sectors and 189 countries
REMIND	PIK	IAM	Changes in output	%		X	macro region
			Consumption	billion US$2005/yr	X		macro region
			GDP|MER	billion US$2005/yr	X	C	macro region
			goods trade	billion US$2005/yr	X		macro region
			Investments	billion US$2005/yr	X		macro region
			mitigation costs	billion US$2005/yr	X		world
			energy production (primary, secondary, final) by energy carrier and region	EJ/yr	X		macro region
			trade by energy carrier and region	EJ/yr	X		macro region
			capacities by energy carrier	GW	X		macro region
			Population	million		X	macro region
			emissions trade	Mt CO2-equiv/yr	X		macro region
			CO2 emissions	Mtons of CO2	X		macro region
			welfare		X		macro region
SFM/FLAM	IIASA	Impact	daily mean air temperature	°C		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			lightning frequency	flashes/km2/month		X	0.5 x 0.5° (Europe), 0.5x0.5° (global)
			relative humidity	fraction		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
			above ground biomass (cwd+litter)	gC/m2		X	0.01 x 0.01° (Europe),0.01 x 0.01° (global)
			historical burnt area	ha		X	0.25 x 0.25° (Europe), 0.25x0.25° (global)
			projected burnt area	ha	X		0.25 x 0.25° (Europe), 0.25x0.25° (global)
			population density	habitats/km2		X	0.01 x 0.01° (Europe),0.01 x 0.01° (global)
			wind speed	m/s		X	0.25 x 0.25° (Europe), 0.5x0.5°

							(global)
			daily precipitation	mm		X	0.25 x 0.25° (Europe), 0.5x0.5° (global)
WITCH	FEEM	IAM	Changes in output	%		X	macro region
			Consumption	billion US$2005/yr	X		macro region
			GDP|MER	billion US$2005/yr	X	C	macro region
			labour stock	million		X	macro region
			Investments	billion US$2005/yr	X		macro region
			policy costs	billion US$2005/yr	X		macro region
			energy production (primary, secondary, final) by energy carrier and region	EJ/yr	X		macro region
			trade by energy carrier and region	EJ/yr	X		macro region
			capacities by energy carrier	GW	X		macro region
			Population	million		X	macro region
			emissions trade	Mt CO2-equiv/yr	X		macro region
			CO2 emissions	Mtons of CO2	X		macro region
			welfare		X		macro region

Color Key

- Model directly involved in the assessment of the specific sectoral impact
- Model providing further input through cross sectoral linkages
- Macro-model receiving as input the output from sectoral assessments

WPs AND TASKS	EPIC (IIASA)	GLOBIOM (IIASA)	MAgPIE/LPJmL (PIK)	G4M (IIASA)	SFM/FLAM (IIASA) Fire model	DIVA (GCF)	PCRGLOBWB, FIAT (DELTARES)	GLOFRIS (DELTARES)	LISFLOOD (DELTARES)	Econometric 1	Econometric Trade Model	Econometric 2 - ES	Econometric 3 -ED	GLOBIO (IMAGE) (PBL)	Meta Analysis / Revealed and State Preference Potential	Econometric 4	Econometric 5	Econometric 6	Climate models (CMCC)	ICES (CMCC)	Econometric 7	CLIMRISK (VU)	Econometric 8	COIN (UNIGRAZ)	DIFI (VU)	CATSIM (IIASA)	REMIND (PIK)	WITCH (FEEM)	IMAGE framework (PBL)	Total
Reply	Y	Y	Y	Y	Y	Y				Y	Y					Y	Y	Y		Y		Y		Y	Y		Y	Y	Y	
WP2 Impact chains																														
2.1. Cross-sectoral linkages and model integration (CMCC)																														
2.2. Impacts on agriculture, forestry & fishery (IIASA)																														
Agriculture	1	1	1																											3
Forestry		1	1	1	1																									4
Fishery		1	1																											2
2.3. Impacts on infrastructure, built environment, and transport (GCF)																														
Sea level Rise (infrastructure, built environment and transport) (GCF)						1																								1
River flooding (infrastructure and buit environment) (VU, DELTARES)							1	1	1																					3
Flooding and sea-level rise/storm surges on road infrastructure and transport operation (DELTARES)							1	1	1																					3
2.4. Impacts on industry, energy, services, and trade (CA)																														
Effect on sectoral production and labour productivity (CA, CMCC, CUNI)										1																				1
International supply chain risks under extreme events (UNIGRAZ)											1																			1
Energy supply (CMCC)						?						1																		1
Energy Demand by sector (needs for cooling and heating) (CMCC)													1																	1
2.5. Non-market impacts: ecosystems and biodiversity (PWA)																														
Impacts on ecosystems (PBL)														1						?										1
Land and ecosystems (IIASA, PIK)		1	1																	?										2
Economic valuation of Impacts on ecosystems (PWA)															1					?										1
2.6. Non-market impacts: health (CUNI)																														
Review and new VSL estimates (PWA, CUNI)																1		New		?										1
Health: Extreme events - Premature mortality risk and heatwave hotpost vulnerability (BC3, VU, CUNI)																New	1	New						maybe						1
Health: Vector borne diseases (CUNI)																New		1		?										1
2.7. Multi-scale cross-sectoral macroeconomic assessment (CMCC)																														
Single impact assessment (CMCC)																				1										1
Joint impact assessment (CMCC)																				1										1
Downscaling ICES Output (FEEM)																					1									1
Spatial resolution (VU)																						1								1
Distributional implications (CA)																							1							1
WP3 Tipping points																														
3.1. Operationalizing tipping points (DELTARES)																														
3.2. Climatic tipping points (CMCC)						1									?	1			1	1		1		1						6
3.3. Analysing socio-economic tipping points (UNIGRAZ)	1	1				1	1	1	1										1											7
3.4. Implications of socio-economic tipping points (VU)																				1		1		1						3
WP4 Policy assessment																														
4.1. Risk attitudes and preferences for climate policy analysis (Lead: BC3)						1		1	1											?New								?New		
4.2. Sectoral assessments of policy effectiveness (Lead: VU)			1			1					1														1	1				5
4.3. Macroeconomic assessment of policy effectiveness (Lead: FEEM)																														
i) Revisiting the concept of damage functions (CMCC, CA)																				1										1
ii) Macroeconomic assessment of climate action and policy interaction																						1		1			1	1	1	5

Spatial resolution	Europe grid (1x1 km)	NUTS 2	1x1 km	NUTS 2		NUTS 2	NUTS 2 gridded (50 km)	NUTS 2 gridded (50 km)	NUTS 2 gridded (50 km)	NUTS 2											Global Europe NUTS 1-2	gridded (50x50 Km)		National Austria	Europe NUTS2	Global Europe (national)	Global (11 macro-regions)	Global (13 macro-regions)	Global (26 macro-regions)
Input		Impact flood risk (ISI MIP)G4M model data			EURO-CORDEX	ISI-MIP					Inpu/output model	GeoRef data	Enerdata			Survey	Survey	Survey											