SOCLIMPACT

Downscaling climate impacts and decarbonisation pathways in EU islands, and enhancing socioeconomic and non-market evaluation of Climate Change for Europe, for 2050 and beyond

SoClimPact project has received funding from the European Union´s Horizon 2020 Research and Innovation Programme under Grant Agreement No 77661

Work Package 3:

Climate change vulnerability assessment framework and complex impact chains

Deliverable 3.4. Specifications for climate, climate impacts and economic modelling – Report on modelling chains.

Coordinated by GWS (Ulrike Lehr, Mark Meyer) with the participation of all Soclimpact partners and reviewed by UNIBO Paolo Figini paolo.figini@unibo.it, GUF Bodo Ahrens Bodo.Ahrens@iau.uni-frankfurt.de, according to the quality review internal process.

O: Other

PU: Public Usage. No restrictions on access (in secured PDF format).

First version – 7.12.2018

Second version – 19.12.2018

Table of Content

1 INTRODUCTION

1.1 TASK OF THIS WORK PACKAGE

Policy-makers need information on the likely climate change in the coming decades and the socio-economic damage that may result from the changes or from (resulting) extreme weather events. Quantifying the damage that climate change will cause to the global community in the coming decades makes it easier for public and private actors to recognise the need to reduce GHG emissions and to analyse which sectors and regions of a country will be particularly affected by climate change and which adaptation measures can reduce this impact. Policy-makers can only implement a good climate policy if they are as well informed as possible about the changes facing the planet and humanity.

The impacts of climate change are often determined at a (world) level that is not very regionalised, with the help of Integrated Assessment Models (IAM). These combine modules that map macro-level economic activity, global climate (in simple stylised form) and the impacts of economic and climate change on the socio-economic system and the natural environment. The aim is to explore the complex relationships between the traditionally separate spheres in an integrated way and to estimate future developments and their outcomes, with the focus of these efforts being very long-term and therefore subject to considerable uncertainties.

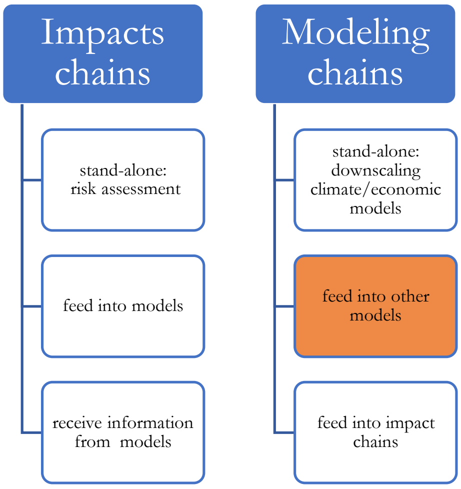
In the SOCLIMPACT project a different route is taken. It requires the implementation of a sophisticated modelling chain, articulating climate projections, Climate Change impact assessment, modelling of socio-economic impacts, and scenario building. This requires a strong focus on consistency different areas of research, because the results of climate models flow into (bio)physical models, then turn into economic damages and are taken up in the economic market and non-market models. A whole phase of the research project therefore has been devoted to defining the relevant concepts, ensuring a joint language and ensuring data transfer flows. This task is mainly technically oriented. It was set at the first months of the large research effort of downscaling the different climate and economic models involved, so that the modelers can pay particular attention on the respective data, variables and quantities and no delays evolve in the modeling chain.

However, after the delivery of the deliverable, the internal structure for the data flow has been enhanced by institutionalizing sector modelling teams in the four Blue Economy sectors analyzed (Tourism, Maritime Transport, Energy and Aquaculture). This new institution has a focus on the operationalization of Impact Chain. For information on the indicators used there, the reader is referred to the deliverable D3.1. The results will be published as a deliverable from Task 4.5. The work of the sector modelling teams, however, has been supported by the data collection described below, and the data flow in the sector modeling teams also benefited from the data availability outlined below. It is important to note, however, that this is a co-benefit to this work package, which is solely concerned with the modeling chain, not the impact chain.

To clarify further, we specified in the proposal the aims and content of this task as follows:

"This task aims at quality control and management of the data flow between Climate Change, impacts and economic models. For an efficient workflow between the climate models and the economic models, early communication of data needs, time horizons etc. are necessary. The task develops a data template at an early stage, to collect and organize the data outputs of WP4 and 5 and the data needs of WP6. The template serves as a reference for the case studies, on the sector specific and the impact specific level. It covers the time horizons, priority indicators, reference socio-economic scenarios (RCPs….), type of results expected, data formats and transfer to other WPs. This task will also compare the island specific approaches and data needs with the literature and elaborate the specific requirements for climate, economic and impact models on this particular regional scale."

Figure 1 gives an overview of the two strands of assessment chains for the effects and risks of climate change. Each strand has individual outputs (marked as stand-alone output), and outputs which feed into the other strand or into elements further down in the respective chain. This report is about the highlighted box in Figure 1.



Impact chains provide a framework for risk assessment. They need Inputs Routines for operationalization (D3.2) Inputs: Indicators (D3.3) Routines for aggregation, normalization, weighting (SMT)	Modeling chains describe the linkage between models in projects involving several models. The models in Soclimpact have the following output: - Stand-alone outputs, for publications in the respective expert journals (respective WP) - inputs for the Impact Chains (D3.3) - inputs for other models (D3.4)

Figure 1: SOCLIMPACT understanding of modeling chains and impact chains.

1.2 OUTLINE

The next section gives a literature overview of the most popular modeling approaches and the respective modeling chains. It will show that the literature knows a wide range from rather simple functional forms relating climate impacts to economic models to sophisticated coupling of (bio-)physical, climate and economic models. The section will also establish the approach chosen in the Soclimpact Project.

Section 3 then turns to the development of a template for data exchange. Starting from a survey among the project partners regarding earlier data exchanges with models from other discipline, the most important features of such a template were identified. The first test template was presented on a participants' meeting and further detailed and improved in a joint effort. The modified template was sent out to all Island focal points. Chapter 4 summarizes the templates filled in by the respective island focal points, by island and by sector and identifies data gaps and barriers. Chapter 5 summarizes suggestions how to close this gap and chapter 6 concludes.

2 OVERVIEW OF MODELING APPROACHES IN THE FRAME-WORK ENHANCING SOCIO-ECONOMIC AND NON-MARKET EVALUATION OF CC

According to Weitzman (2009a), three important structural uncertainties relate to inaccurate knowledge about the future extent of future GHG emissions in the atmosphere (1), the design of the feedback processes of the CO2 cycle (2) and the relationship between temperature and GHG emissions (3). The first two aspects relate to the fact that not only the GHG emissions released by direct human activities in the future are unknown, but that there are feedback processes that have not yet been taken into account in climate models. For example, rising temperatures lead to a melting of permafrost soils, in which large quantities of CO2 are stored and which escape into the atmosphere as a result of melting. These processes can trigger a self-reinforcing climate change with catastrophic consequences for the earth. The third uncertainty relates to the temperature response to the increase in GHG emissions, known as "climate sensitivity". IPCC (2007a) defines this as average surface warming when GHG emissions double. “Once the world has warmed by 4°C, conditions will be so different from anything we can observe today (and still more different from the last ice age) that it is inherently hard to say where the warming will stop" (Weitzman 2009a).

All modeling approaches are facing this uncertainty. They also all need an interface between the economic modeling world and the biophysical and climate modeling outputs. These connections are often subsumed under the name of damage functions. They give numerical results for the damages from climate change to market and non-market values under different scenarios of climate change.

In integrated assessment models, these functions are designed fairly simple as a (linear or quadratic) function of the temperature change. Typically, at least one aggregated function is assumed for each region, which establishes a relationship between the temperature rise since the beginning of industrialization or often the reference period from 1960 to 1990 and the share of GDP lost as a result. The temperature used as input (usually the average global surface temperature) or other characteristics of climate change, such as sea level rise, are themselves determined by a function whose calibration is based on the assumed climate sensitivity, i.e. for example the temperature response to a doubling of atmospheric CO2 concentration, usually in 2050. It should be noted that only a subset of the conceivable categories of damage is taken into account, since areas such as politics, armed conflicts or scarcity of resources cannot be modelled easily.

Stanton et al. (2009) identify three problems associated with the known loss functions, e.g. $D = aT^b$ in IAMs: The choice of exponents and other parameters is often arbitrary, and the form of the damage function prevents discontinuities from being mapped in the model. In addition, losses are expressed as income losses and not as capital losses.

Choice of parameters: The exponent b in the loss functions is often 2, so that the loss is a quadratic function of the temperature changes (or similar). The functional form is assumed because it is assumed that the losses are also small with small temperature changes and then rise more dramatically with high temperature changes. In the literature other functional forms are experimented with. Although damage caused by climate change is increasingly observable, the findings are not yet sufficient for econometrically derived correlations. There is therefore no empirical evidence. However, it should be noted that the choice of exponent strongly influences the result of an IAM and the political implications of such a model calculation.

Loss of income: As already mentioned, losses in IAM are represented as losses of GDP, which is equivalent to a reduction in income and consumption. This would mean that the capital stock of an economy would remain unchanged. In reality, however, damage to health, human settlements or natural ecosystems, for example, leads to reductions in the capital stock. The assumption that climate events reduce output and thus income and investment once is unrealistic, since they influence the capital stock as well as future production and consumption (Stanton et al. 2009).

Continuity: Many damage functions imply that climate change occurs gradually and continuously, without taking into account potential thresholds at which a rise in temperature can lead to catastrophic scenarios.

In the last two decades, numerous IAMs have been developed with the aim of illustrating the relationship between climate and economy and analyzing the economic consequences of climate change in the coming decades (sometimes centuries). Some of the most popular models are DICE (e.g. Nordhaus 2007), or the regionalized version RICE (e.g. Nordhaus 2011), FUND (e.g. Anthoff & Tol 2014), MERGE (e.g. Manne & Richels 2004), PAGE (e.g. Hope 2011) and for Germany the model WIAGEM (e.g. Kemfert 2002), which introduce different damage functions to map the interactions between climate conditions and impacts on the economy.

Our approach pursued in the SOCLIMPACT project rest upon and extends two strands of experience: the PESETA projects and the EconCCAdapt project.

The PESETA projects (I, II, III) funded by the European Commission, take a different route than the IAMs. The (bio-)physical effects of climate change in Europe and previously defined regions were investigated on the basis of a climate model and selected (bio-)physical impact models. In addition, the direct and indirect economic effects were evaluated using the General Equilibrium Model for Energy-Economy-Environment Interactions (GEM-E3-CAGE CGE model[1]). Some impact categories coincide with the blue economy sectors considered in SOCLIMPACT: tourism, transport, energy and forest fires are considered and physical climate impacts are translated into economic parameters. The potentially warmer summer and winter months change the demand for heating and cooling. This is captured in the model by changing residential and tertiary sector demand for energy. Forest fires are implemented as capital and reforestation costs as additional compulsory household consumption. Changes in tourist flows are modelled as trade shocks in those sectors where tourism activities can be found.

The PESETA modelling chain flows from (bio-)physical effects of climate change simulated with a climate model and selected (bio-)physical impact models to the economic models. Capital losses, additionally required work hours, loss of tourists' expenditures are quantified by the work packages preceding the economic modeling work packages. Non-market valuation, however, is not included in the analysis.

The EconCCAdapt project (Lehr et al. 2016) uses a macro econometric model, based on time series of Input-Output-tables and maps the change in economic structures and the behavior of economic agents over time. The modeling chain in EconCCAdapt is comparable to that pursued in the PESETA family of studies, although most of the bottom up results are taken from the literature and are not explicitly modelled for the respective analysis. In this project, an input output based macroeconomic model is extended to allow for the modeling of damages resulting from extreme weather events and modeling of adaptation measures. In the model, each of the industries of the German economy is described in detail and macroeconomic variables are aggregated bottom up. The demand side of the economy is econometrically estimated, based on time series data. These construction principles are maintained modeling the impacts of extreme weather events and adaptation measures. Heat waves affect particularly companies depending on the cooling of their processes, for instance power plants, since environmental protection laws restrict withdrawal of water and the emission of used cooling water into the river, if stream water temperature exceeds a certain threshold. This leads to reductions or even losses in production. Extreme weather events act as shocks to the model and previous economic interdependences are temporarily overridden. Capital stock, for example, has over

[1] The GEM-E3 Model is also part of the SOCLIMPACT model family.

decades served as a production factor depending on the expected demand and market signals. Severe extreme weather events create a different situation: parts of a company's production sites and facilities may be destroyed and its capital stock reduced, even if the demand for (intermediate) goods is the same as before the event. This damage results in substitution of domestic products with imports in the short run. However, along the international value chains, climate change damages may distort import chains by interruption of production in the country of origin or interruption of transport modes.

Though this approach is suited to follow developments over time, the results also leave wanting. As the authors from the PESETA III project conclude, "The scope of climate impact and adaptation studies could be extended into several directions: enrich their spatial resolution (going local and regional), better understand the role of extreme events (many impact models mainly focus on gradual climate change, i.e. not considering the existence of thresholds beyond which impacts become highly non-linear and irreversible), include non-market climate impact areas (e.g. natural ecosystems, climate catastrophes, migration) further integrate the various impact models (e.g. the land-water-energy nexus), and improve the cost-benefit analysis of adaptation."

The SOCLIMPACT project addresses the spatial resolution, extreme weather events and non-market values and contributes to a better picture of climate change effects and adaptation.

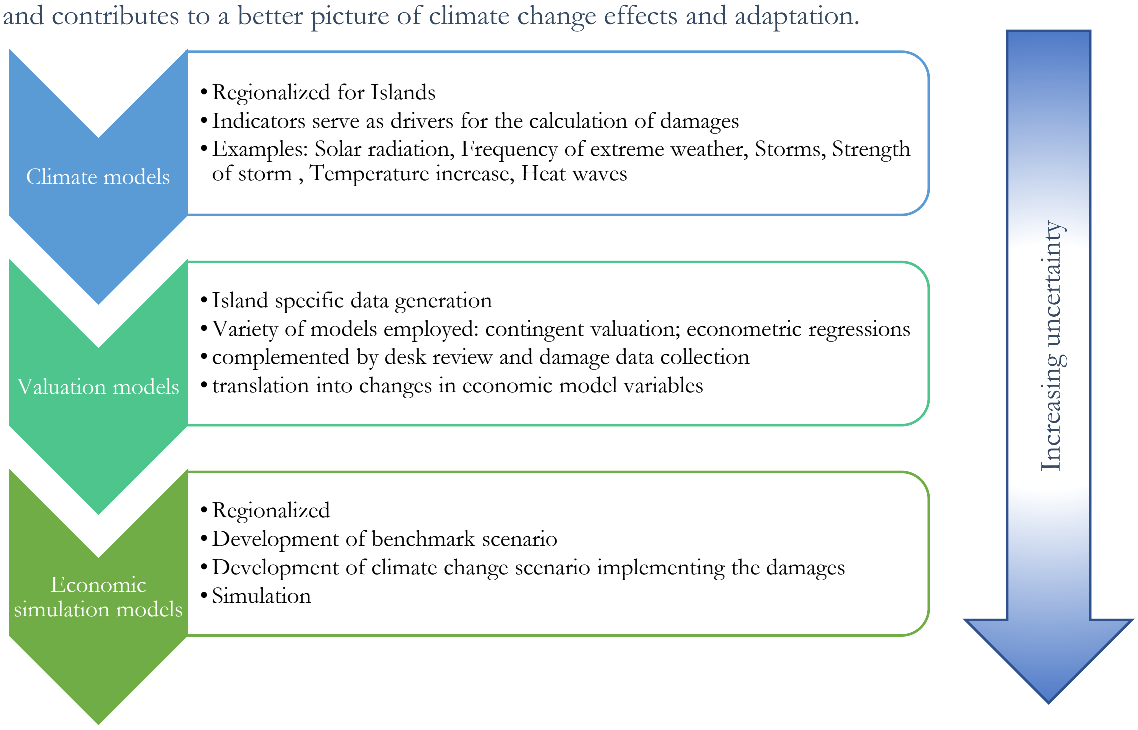


Figure 2: Modeling chain of Soclimpact

In the Soclimpact project, the modeling chain also follows the logic: Climate change effects – impact analysis/ valuation – economic simulation model. The impacts at each level are quantified. As the data availability templates show, this impact quantification still presents a difficult task.

Climate models yield increases in surface temperature, changes in sea PH, sea level rise, wave climate, beach topography, storms and other data on extreme weather events. Impact models yield indicators for water transparency, vulnerability of Posidonia, changes in the Fire Index (FW), evolutions of flag species, percentage of beach reduction and other beach related indicators, increase of tropical nights and the index of emergent diseases. The market and non-market valuation yields demand changes due to these factors and the economic models turn these changes into changes in expenditures, demand, investment and /or prices into general economic effects. In the next chapter, these data, their sources, the data exchange and the remaining open questions are described.

The economic models are receiving information from the valuation results and the climate models. The simulation in the economic models projects the respective quantities to the future and analyses economic effects on economic quantities, such as GDP and its components, welfare, value added, employment etc.

The climate models and the economic simulation models are dynamic. GINFORS even explicitly contains time, as in time series and annual results until 2050. The climate models project the climate related drivers mentioned above into the future. The damages are in some cases kept at the literature values also for the future, examples are the increase in cooling need with cooling degree days (as projected from the climate model) is the same along the cooling degree day curve. This means, we assume peoples' preferences for cooling and the preferred room temperature staying the same, i.e. being static. For the tourism sector, contingent valuation analysis transfers peoples' preferences for adaptation measures into willingness to pay or willingness to accept monetary valuation. Also, these preferences are assumed to remain static over time. We are aware that this can only be a first order approximation to the development of future behaviour. However, Soclimpact does not include a behavioural change estimation module, which should be integrated in future research.

Other drivers from climate modelling directly relate to damages or losses in economic quantities, such as the forest fire index relating to losses of forests, salinity relating to yield in aquaculture etc. prices to value these yields are simulated in their future development on a national or international scale, assuming that changes in product from the islands will not distort the global markets, e.g. for fish.

Three remarks are in order at this stage of the project:

Firstly, as Harrison et al. 2016[2] note, "Climate change impact assessments often apply models of individual sectors such as agriculture, forestry and water use without considering interactions between these sectors. This is likely to lead to misrepresentation of impacts, and consequently to poor decisions about climate adaptation". Our modelling chain allows for interlinkages only on the level of the macro simulation models, not between individual models used in the phases before.

Secondly, as figure 2 points out, the level of uncertainty is perpetuated through the different steps of the modelling chain. The only way, econometric simulation models or CGEs can cope with uncertainty, is to run different scenarios and thus exploring the results space and the sensitivity of the results to certain assumptions. It is standard economic practise[3] to treat both the climate impact and model parameters as certain with ad hoc sensitivity analysis carried out on one or more model parameters[4] or to explore shock uncertainty through scenario analysis[5].

In the remainder of this contribution the data understanding, availability and gaps will be presented, using

[2] Harrison, Paula A. AU - Dunford, Robert W. AU - Holman, Ian P. AU - Rounsevell, Mark D. A. TI - Climate change impact modelling needs to include cross-sectoral interactions JO - Nature Climate Change PY - 2016/05/23/online VL - 6 SP - 885 EP - PB - Nature Publishing Group SN - UR - https://doi.org/10.1038/nclimate3039

[3] Allowing for uncertainty in exogenous shocks to CGE models: The case of a new renewable energy sector, Euan Phimister and Deborah Roberts

[4] Allan, G., Hanley, N., McGregor, P., Swales, K. and Turner, K., (2007). The impact of increased efficiency in the industrial use of energy: a computable general equilibrium analysis for the United Kingdom. Energy Economics, 29(4): 779-798.

[5] Mardones, C. (2015) An Income Tax Increase to Fund Higher Education: A CGE Analysis for Chile, Economic Systems Research, 27:3, 324-344

a data template as described in the Grant Agreement. Firstly, the development of the data template is described, and secondly, results of the work with the template is reported. For details, the reader is referred to the original filled in xls tables in the appendix.

Thirdly, the concrete data transfer will be explained in the respective work-packages, mainly in the valuation exercise and the economic simulation work package, because the assumptions and data inputs are decisive for the discussion of results.

3 A TEMPLATE TO SURVEY THE AVAILABILITY OF DATA

The template collects data streams from climate models -for impact models -for economic models -for….. from environmental models for economic models from other sources to economic models **The template does not collect data!**

To facilitate exchange and to guarantee the availability of the relevant data at an early phase in the project, a template has been developed which was handed out to the so-called Island focal points. These are teams of experts, who channel data requests to the respective institution, monitor the exchange of information and data and collect the results into Island reports. Moreover, the IFP organize stakeholder meeting on the respective Islands and keep the Soclimpact results relevant and in the discussion. The template is an Excel folder which helps to collect the relevant information in a standardized matter. The most important characteristics are:

- Simplicity
- Transparency
- Comprehensiveness

Simplicity refers to the ease of use for the island focal points, transparency to information about the data flows (who is in charge, when to expect, etc.) and comprehensiveness to the attempt to make sure that all data will be available when needed.

To connect the data availability template to the experiences of the participants, prior to filling in the tables, a small questionnaire has been developed. The answers are given in detail in table 1.

• **For the climate/ biology/ ecology models:**
Has your model provided inputs to economic models? Which data did you share/provide? Hard link or soft link?
• **For the economic models:**
What have you received from climate change models? Hard link or soft link?
• **For all:**
Do you have experience with data transfers between climate change/ Biological/ other scientific models and economic models?

Source: Template developed by GWS.

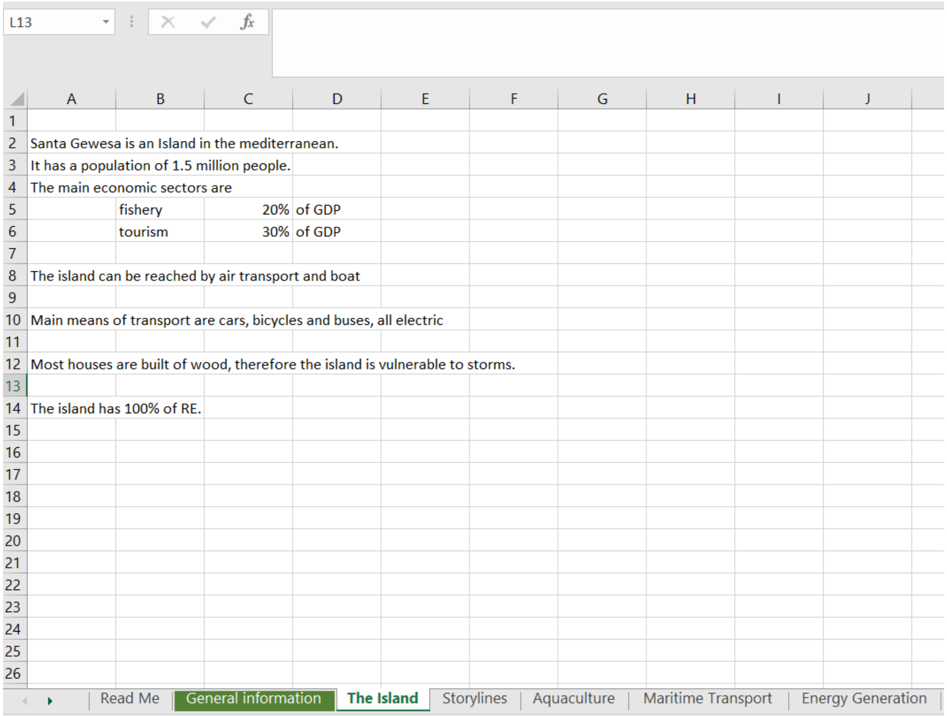
Seven participants answered the survey (details in the appendix). The results show that the macro-economic models have experience in receiving data from models from natural sciences and experts on scenario development. Inputs are needed for the identification of damages from climate change to be able to model the economic effects of adaptation, which are driven by the expenditures on adaptation and the mitigated damages. Energy models feed into economic models and the experience is available in the project consortium. The CORDEX data base provides climate change impacts in terms of temperature, precipitation, but also number of hot days, salinity of the sea etc. at regionally detailed levels.

With this mixed availability and experience, the challenges increase for the collection of meaningful data and to enable the data chain and thus the modeling chain.

The template is in Excel and provides sheets for the collection of different types of information. The general information sheet contains relevant settings for the whole Soclimpact project. The CC scenarios selected are the representative concentration pathways (RCP) 8.5, in some case studies RCP 4.5 and few analyses also use RCP 2.6. All Shared Socio-economic Pathways (SSPs) are possible, but the focus lies on SSP 2. Spatial resolution will be at least Islands, or higher. The first sheet then collects narratives about the Island under scrutiny. This information serves as background information for the modelers and gives a first impression of the respective Island. The sheet is not standardized regarding the type of information. However, most people followed the structure given in the example template (Figure 3).

The sheet called Storylines collects a very brief version of the impact chain (see figure 1) for the blue economy sectors. It summarizes the information from the Work packages WP 3.2 and 3.3. This serves as an orientation for the reader and the user of the template.

Figure 3: Screenshot of the template. The example of the virtual Island Stª Gewesa



Source: Template developed by GWS.

The next four tabs contain the modeling chain information for each of the Blue Economy sectors under scrutiny in Soclimpact. The structure is always the same and is shown in Figure 4

Figure 4: The example of Aquaculture for the example island.

	A	B	C	D	E	F	G	H	I	J	K
1	**Relevant climate change effects**			**From climate models/ who?/ source?/units?**			**Specification/ comment**	**Expected quality**			
2			available	who	source	unit					
3	Nutrients and seawater parameters		x								
4	Salinity		x								
5	Storm		x	UIB/ Cordex	own calculation	Storm of a certain category per decade					
6	Sea surface temperature increase		x								
7	Change in currents and waves		x								
8	**Description of aquaculture**			**From sector expert**							
9			available	who	source	unit					
10	Turnover		Eurostat								
11	Amount of fish		Eurostat								
12	Prices		Eurostat								
13	Production structure		x								
14	**Future development of aquaculture with out climate change**			**From sector expert**							
15	until 2050, or in decades	available	who	source	unit						
16	Turnover	x					will stay the same, the boundaries on Santa GEWESA are reached				
17	Amount of fish										
18	Prices										
19	Production structure						will shift away from pharmazeuticals due to EU law				
20	**Translation into changes of economic variables**			**From sector expert**							
21			available	who	source	unit					
22	Production loss /annual percentage changes		x	UL	Literature	%					
23	since the island keeps a species in aquaculture which is very sensitive to temperature, it will loose up to 50% of turnover of this industry										
24	the special fish is very relevant in the local dishes, prices will go up by up to 200%										
25	Expected annual damages of aquaculture infrastructure										
26	Change in yield										
27											
28											
29											
30											

... General information | The Island | Storylines | **Aquaculture** | Maritime Transport | Energy Generation | Tourism

Source: Template developed by GWS.

The first block lists the relevant effects from climate change on the sector. In the case of aquaculture, these comprise seawater parameters, salinity, nutrient content, storms, sea surface temperature and changes in currents and waves. The first column should be checked, if the quantity will be available, followed by who is in charge. The source contains literature references, references to official statistics etc. The next column contains the units, the example given reads: storm of a certain category per decade. Obviously, this has to be adjusted with respect to the different physical impacts. The rows conclude with a column for remarks and a column for the expected quality.

The next block describes the sector in physical and economic terms. For the Aquaculture example in Figure 2, this is the amount fish, the turnover generated from fish, prices and the input structure. Next, projections of these quantities until 2020, 2030 or 2050 are needed to benchmark the economic models. These data can be taken from a strategy, a plan, or a governmental program.

The last part of each sector sheet asks for a quantification of damages to the sector from climate change. Usually, this is expressed as losses of turnover or production given as a percentage loss.

All sector-sheets have the same structure. The example template for the hypothetical island has been designed to illustrate the type of data needed. The template has been developed and discussed in a meeting in Corsica with most participants. It was then finished by GWS and sent out to Island Focal Points. All participants were asked to indicate if they knew how to fill the template.

4 RESULTS

4.1 INITIAL REMARKS

For the Island Focal Points, the collection of sector specific information created a challenge. Almost all Islands, however, filled in the template so that a fairly comprehensive picture arose. Different sectors are pictured by islands' statistical offices by different degrees. Obviously, the two Islands, which are EU Member States at the same time, Malta and Cyprus, have the best homogenous data coverage by Eurostat.

Often, information is only available in the respective local language. This makes a quick overview a little more challenging, but will not lead to problems in the long run. Generally, this is mostly the case for projections of certain sectors' development, for instance under climate change.

4.2 CLIMATE CHANGE DATA

The climate change data will be taken from the CORDEX data base according to the Island focal points. However, the experts from work package 4 point out, that additional simulations will be either done or processed in WP4. Additionally, for example, sea level rise or storm frequency is not an output of CORDEX models, but has to be post-processed. Anyway, the following quantities are identified as relevant and available:

Table 1: Data availability from CORDEX and works in work package 4 as indicated by participants in the template

Relevant climate change effects	units
Temperature increase	Degrees Celsius
Coastal erosion	Changes in shoreline
Deterioration of biodiversity attractions	Number of lost species
Change in precipitation	Millimeters
Sea level rise	Meters
Solar radiation	W/m2
Extreme weather events	Frequency/severity
Storms	Frequency
Dust level rise	µg/m3
Rise in humidity	g/m3
Extreme wind speeds	km/h
Storm surges	Frequency/severity
Increased wave height	Meters
Sea surface temperature increase	Degrees Celsius

Some IFP were less specific, but the majority detailed the climate data and checked availability from CORDEX with positive results.

4.3 SECTOR CHARACTERISTIC DATA

Table 2 gives an overview of the data availability by source and island.

Table 2: Summary of results from the availability template

Sectors	Azores	Baleares	Canary Is-lands	Corsica	Crete	Cyprus	Madeira	Malta	Sicily	Result
Maritime transport Current actual data	x	x	x	x	x	x	x	x		8
Maritime transport forecast		x	x			x	x	x		5
Maritime Transport Climate change impact							x	x		2
Coastal and maritime tourism	x	x	x	x	x	x	x	x		8
Tourism forecast						x	x	x		3
Tourism Climate change im-pact	x	x	x	x	x	x	x	x		8
Aquaculture	x	x	x		x	x	x	x		7
Aquaculture forecast	x	x	x			x	x	x		6
Aquaculture climate change impact							x	x		2
Energy	x	x	x	x	x	x	x	x		8
Energy forecast	x		x			x	x	x		5
Energy climate change impact	x	x	x				x	x		5

Source: Compilation GWS.

4.3.1 AQUACULTURE

Eurostat defines: "Aquaculture, also known as aquafarming, refers to the farming of aquatic (freshwater or saltwater) organisms, such as fish, molluscs, crustaceans and plants, for human use or consumption, under controlled conditions. Aquaculture implies some form of intervention in the natural rearing process to enhance production, including regular stocking, feeding and protection from predators. Farming also implies individual or corporate ownership of, or contractual rights to, the stock being cultivated".

EU definitions are found in "Aquaculture in the EU: Tapping into Blue Growth", EU Parliament document "Directorate-General for Internal Policies Structural and Cohesion Policies: Regulatory and Legal Constraints for European Aquaculture" and from the Food and Agriculture Organization of the United Nations – FAO. In Soclimpact (see Briche 2018), "the aquaculture sector will involve only marine-based operations and will exclude freshwater aquaculture, as well as land-based operations (e.g. ponds and recirculated aquaculture systems -RAS). Despite the apparent impacts of climate change on terrestrial and freshwater operations, these operations are not common on islands and will not be considered. There will not be boundaries on the proximity of aquaculture sites to the island itself; both offshore and coastal operations will be included. Considering the small size of the aquaculture sector, all marine-based and coastal aquaculture operations will be analyzed in the impact chains to collect as much data as possible.

Under Soclimpact, "Aquaculture is the farming of aquatic organisms and is an activity aimed at the production of animal proteins in the aquatic environment, including fish, mollusks, crustaceans, algae and aquatic plants. Farming implies some form of intervention and control (partial or total, direct or indirect) in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated."

Sector characteristic data have been collectable for each island. Aquaculture on the Azores is still at an infant stage, the Azores-IFP describes it as follows. In 2017 the first aquaculture project was installed off the Port of São Fernando do Porto Martins (Terceira island). Currently there are three projects offshore with authorized procedures to install the aquaculture facilities. One project in Terceira island (algae), one in Ribeira Quente – São Miguel island (fish and algae) and one in Faial (algae and echinoderms – sea urchin and sea cucumbers). Employment projections for the three approved projects are 20 to 30 persons, when installation and production start. Employees numbers can vary due to seasonality related with tourism and production.

Projections of the amount of fish, algae and echinoderms produced lie around 200 tons in 5 years. Considering already submitted projects' descriptions higher production is estimated in 10-15 years. The sector still in the test phase and shall start production soon.

In Malta, aquaculture is already established and producing. It is marine based. A pilot hatchery was established in 2005 with the aim to test the feasibility of aquaculture in Malta. In 2015, production of non-tuna species was 2,364 tons, whilst the Atlantic bluefin tuna production was 8,051 tons (FAO 2005-2018). Currently, the sector generates 964 full-time equivalent jobs (FTE), including 197 FTE employed in the aquaculture sector itself and an additional 767 FTE jobs generated by way of indirect and induced economic impacts. These jobs are mainly concentrated in the wholesale and retail trade, transport and communication, financial intermediation and manufacturing sectors (Applied Economics Consulting Ltd.,2009 as cited in FAO 2005-2018).

The National Statistics Office (2017) describes the production in terms of output, intermediate inputs, value added and costs. This structure can be used in the economic models to identify aquaculture effects from the aggregated data on fisheries. Box 1 gives an excerpt as an example for the information available.

Box 1: The gross output of the aquaculture industry, which comprises mainly Tuna farming and closed cycle species, amounted to €160.5 million, up by 21.9 per cent from € 131.6 million in 2015. The gross value added of the aquaculture industry in 2016 amounted to €15.3 million, a drop of 25.1 per cent from €20.5 million in the preceding year. Taking fixed capital consumption and exchange rate differences into consideration, the factor income amounted to €12. 0 million. Compensation of employees amounted to €3.8 million, while entrepreneurial income stood at €6.7 million. In 2016, the volume of fresh fish sold amounted to 12,466 tons, an increase of 15.4 per cent over the preceding year. This was due to increases in the sales of Seabass and Tuna of 43.7 and 25.5 per cent, respectively. On the other hand, sales of other fish and Seabream decreased by 73.0 and 5.0 per cent respectively. When compared to 2015, intermediate consumption which takes int o account the costs incurred in the production of Tuna farming and closed cycle species, increased by 30.6 per cent. This resulted due to increases in overheads, selling costs, variable production costs, and in purchases of live Tuna and other fish, by 77.8, 65.2, 42.0 and 14.2 percent respectively.(NSO Malta (2017)

For the Canary Islands, the Spanish fishery statistics are detailed enough to cover aquaculture and the Islands in terms of turnover in Euro and fish. However, the statistics are in Spanish, therefore some support from the Spanish speaking participants will be necessary. In section 3, we detail how this support shall be organized.

Cyprus has an established aquaculture sector, too, and data are available through European Union as well as through the statistical office in Cyprus. For the Azores, aquaculture is at its infancy. However, future projections and current turnover will be available from the project partners. The Baleares have the aquaculture sector covered by data in detail from different authorities. Production in monetary terms as well as in physical units is reported for different years in different classifications, which might cause a problem in the integration into impact assessment or economic models. Economic data in terms of employment, and turnover are available. The projection of future development of aquaculture under climate change is published by FAO for Spain by APROMAR, the Spanish Aquaculture Business Association. Corsica does not have aquaculture. For Madeira, turnover, production, species etc. are provided by the national statistics office.

4.3.2 MARITIME TRANSPORT

All Islands depend on the Maritime Transport sector, i.e. harbours, infrastructure for loading, unloading, fuelling and ships. To model the impacts of climate change on maritime transport, data on turnover from maritime transport, prices, the production structure, the number of ports, ship arrivals, passengers and freight are needed. Information about investment in the respective infrastructure would be an asset. Eurostat has data on freight in tons and passengers in number of people. Turnover of harbors, investments in harbors infrastructure, people employed need to be taken from other sources if available.

Cyprus has a comprehensive data set on maritime transport, issued by the Statistical service of Cyprus. It comprises the production value, inputs and value added, turnover by activity, employment data and labor costs, investment data, data on value added, administrative expenses, taxes and rents. Data on the number of vessels, type of freight or type of passengers complete the very detailed picture.

The Azores are situated at the largest distance from any landmass of all Islands under consideration, 1369 km West of Europe and 1930 km East of Canada. Maritime Transport and air transport a very relevant to supply the islands. However, data availability comprises only physical quantities. Turnover or investment is not indicated as available.

Malta refers to Eurostat and therefore also only to physical quantities and no monetary quantities. The same holds true for the Canaries. Madeira's maritime transport sector is also well covered. The IFP moreover made an interesting suggestion how to estimate losses from climate change: Comparing the financial reports of the port authorities from different years and under different meteorological conditions could give rise to first estimates. The Balearic Islands have again a wealth of information on turnover, loads and future development. Corsica refers to the Island's data collection, data on maritime transport have 2013 or 2014 as the last year. The Azores report movement of passengers and goods in the ports of the Azores, by Island and per year, movement of passengers and goods in the ports of the Azores, by Island and per year, recreational craft and crews entering the ports of the Azores, by Island and per year, number of passengers (maritime transport-Passengers and goods), passengers embarking per island, cruise ships and shipping and freight shipping per region, island, year from the regional statistical center.

4.3.3 ENERGY

The energy sector is vulnerable to climate change effects mainly as a consequence of extreme weather, floods and other extreme events. Changes in radiation and wind speeds can also affect the energy sector.

The European commission is aiming increasing electricity generation from renewables for the more than 2200 inhabited islands in the EU. The share of renewable energy currently differs widely across the Islands under consideration. To estimate vulnerability, the template also asked for connections to the respective mainland and substitutionary electricity generation possibilities.

Cyprus has data on electricity consumption by sector, production of electricity from renewable energy sources (photovoltaic systems, biomass systems, wind systems), production of heat by renewable energy sources (solar thermal, geothermal, biomass systems), households' annual energy consumption by fuel & end use (heating, cooling, cooking, appliances & lighting),sales and stock changes of petroleum products, electricity use per capita / unit of GDP, installed capacity of electric generators and imports & exports of petroleum products for the Island available. Crete's energy balances are included in the modeling tools of E3-Modeling. Electricity generation on the Azores, future outlook and damages from past events are available as data sets from the Azores' Electricity company (EDA). Malta has a full set of Eurostat energy balances, a projection from the European Environmental Agency and provides newspaper coverage of past damages.

The Baleares have data on electricity generation by sources and energy supply and demand provided by the Statistical Office of the Baleares (IBStat). The Canaries publish annual Energy reports (Regional Ministry of Economy, Trade, Industry and Knowledge), which includes future projections. ADEC (Agence Développement Economique de la Corse) provides energy data, such as electricity prices, annual CO_2 emissions from electricity production, hours of photovoltaic facilities disconnection, electricity production load, by sector, production and storage facilities, production facilities (end 2016), and annual consumption per city for different time scales, which will be used to characterize the energy system.

Summing up, the energy systems on the respective islands are mapped well by the available data, and first ideas are provided how to project the development of the systems and how to estimate damages from climate change impacts.

4.3.4 TOURISM

Tourism is one of the main activities on all Islands studied in this analysis. Therefore, the economic relevance of tourism, the number of visits, the impact of certain touristic activities and in some cases the projected future development are very well covered on all island. The damages from climate change to this particular blue economy sector will be mapped in the work package concerned with measuring non-market costs of climate change. A comprehensive survey will be carried out, measuring tourists' changes in preferences under climate change. Beyond the results of that work package, Cyprus has an explicit Tourism Strategy, covering future development. Moreover, Cyprus IFP refers to the Tourist Climatic Index and the Beach Climate index, indicating changes of the usability of the island's touristic attractions under climatic/climate change. Lately, this has been developed into a holiday Climate Index by Scott et al. (2016). In addition, Malta points out to several media sources reporting on damages from climate change in the tourism sectors.

5 FILLING THE GAPS

The least entries in the templates described above have been made in the identification of climate change damages in economic terms. As laid out in chapter 3, there are different routes taken to solve this identification problem in the literature. The more empirical approaches rely on bottom-up modeling or analysis of past damages. The latter has been applied predominantly for the damages from extreme weather events, for instance in the COIN project (Steininger et al. 2016) or in the econCCadapt project (Lehr et al. 2015). We are referring to this more extensively, because it could provide one way of dealing with the climate change damages in the modeling exercise at hand.

To effectively integrate extreme events and adaptation measures into an economic model, it is essential to firstly identify economic sectors most severely affected by extreme events in the past. Since no time series exist concerning extreme weather events in in Europe or in the member states or regions, cost and damages of river flood events and heat waves can be derived from past events' coverage. In Lehr et al. 2015, impacts of the Oder/Elbe flood in 2002 and the heat wave in 2003 function as reference events or benchmark. Table 1 gives an overview of the observed physical impact, its translation into model variables and economic quantities and the literature used.

Damages	Target variables	Expected main effects	Sources
Damages of a river flood on…			
…production sites	- Capital stock of: *Machinery* - Other current transfers	Increase in buildings investment and investment in plant and equipment, loss in production	Muenchner Rueck (2003) Braeuer et al. (2009)
…dwellings	- Capital stock of: *Real Estate* - Other current transfers - Disposable income	Increase in buildings investment and investment in plant and equipment, decrease in consumption	Muenchner Rueck (2003) Braeuer et al. (2009)
…transport infrastructure	- Capital stock of: *Public Administration* - Other current transfers - Production output	Increase in buildings investment, unit costs and depreciation, loss in production	Muenchner Rueck (2003)
…production	- Imported intermediate goods: *Chemicals* *Machinery* *Metals and semi-finished products* *Basic Metals* *Automobiles and parts* *Agriculture*	Increase in imports and prices	Ludwig and Brautzsch (2002) BMI (2013)

Damages	Target variables	Expected main effects	Sources
…disaster management	- Government spending: *Defense* *Public order and safety* - tax increases for private households	Lower government spending in fields other than defense and public order and safety (e.g. for education), lower disposable income for private households	BMI (2013)
Damages of a heat wave on…			
…agriculture	- Imported intermediate goods: *Agriculture*	Increase in imports and prices and decrease in production value	Braeuer et al. (2009) Fischer and Schaer (2010)
…energy sector	- Electricity imports	Increase in imports and prices and decrease in production value	Rademaekers et al. (2011)
…labor productivity	- Labor productivity	Decrease in average wages per hour, increase in employment	Huebler et al. (2007) PIK (2014)
…ship traffic	- Input coefficients of land and ship transport services - Imported intermediate goods: *All*	Increase in imports and prices	Jonkeren et al. (2011)

A flood event on the Rhine, where numerous production sites of the machinery industry are located, leads to damages on buildings and production sites in the machinery sector. Companies decrease output, because the capital stock is damaged, i.e. the production machinery is damaged, wet, spoiled etc. The industry will rebuild and claim reimbursement from insurances. The economy experiences a slowdown from the lacking output and growth from the repair measures. There is a time lag between the damage and the full recovery, which depends on the industry analyzed. Intermediate input production slows and is replaced by imports. Transport infrastructure damages impede the transport of intermediate goods. All this leads to an increase of imports in the economic model. Similar proceeding holds for heat waves. More detailed information on the approach of including extreme weather events in the environmental economic model PANTA RHEI can be found in Nieters et al. (2015).

Some islands suggested a similar procedure to identify the damages from climate change on the blue economy sector (see evaluation of the results above).

The alternative route is to calibrate damages to literature values, e.g. from the PESETA III study. Here, extensive bottom up modeling has taken place and some of the results are suitable for the questions in this study. However, applicability to the islands could be discussed with the island focal points or with stakeholders at the respective islands.

6 CONCLUSIONS

The modeling chain in the Soclimpact Project does not show obvious gaps according to this analysis. The IC concept provides useful guidance and orientation for the identification of effects. Current status of the blue economy can be mapped in great detail at Island level. Future development and targets are set for several islands and sectors. However, future targets under climate change are sparse, here will be an important channel for dissemination of results during and at the end of the Soclimpact project.

However, a detailed analysis of the data flow cannot be replaced by this report at this stage. The data availability tables shown above will be more detailed and specified during the modeling work packages.

7 REFERENCES

BMI (2013) Bericht zur Flutkatastrophe 2013: Katastrophenhilfe, Entschaedigung, Wieder-aufbau. Kabinettbericht des Bundesministeriums des Inneren.

Braeuer, I., Umpfenbach, K., Blobel, D., Gruenig, M., Best, A., Peter, M., Lueckge, H. (2009) Klimawandel: Welche Belastungen entstehen für die Tragfaehigkeit der Oeffentlichen Finanzen?. Endbericht. Ecologic Institute, Berlin.

Briche, E. and Dubois, G. (2018), Definition and Operationalization of the Impact Chain. Report to deliverable 3.1, Forthcoming.

Chorynski, A., Pinskwar, I., Kron, W., Brakenridge, G. (2012) Catalogue of large floods in Europe in the 20th century. In Kundzewicz, Z.W. (Ed.) Changes in Flood Risk in Europe, Special Publication 10. IAHS Press, Wallington, Oxfordshire.

De Bruin, K., Dellink, R., Agrawala, S. (2009) Economic Aspects of Adaptation to Climate Change: Integrated Assessment Modelling of Adaptation Costs and Benefits. OECD Environment Working Paper, 6, OECD Publishing http://dx.doi.org/10.1787/225282538105.

Fischer, E. M., Schaer, C. (2010) Consistent geographical patterns of changes in high-impact European heatwaves. In Nature Geoscience 3(6), pp. 398-403.

Gruenig, M., Troeltzsch, J., Schulze, S. (2013) Gutachten zu den oekonomischen Folgen des Klimawandels und Kosten der Anpassung für Hamburg, Hamburg.

Hallegatte, S., Ranger, N., Mestre, O., Dumas, P., Corfee-Morlot, J., Herweijer, C., Wood, R. M. (2011) Assessing climate change impacts, sea level rise and storm surge risk in port cities: a case study on Copenhagen. In Climate Change 104 (1), pp. 113-137.

IPCC, 2018: Summary for Policymakers. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

Jonkeren, O., Jourquin, B., Rietveld, P. (2011) Modal-split effects of climate change: The effect of low water levels on the competitive position of inland waterways transport in the river Rhine area. Transportation Research Part A: Policy and Practice 45(10), pp. 1007-1019.

Lehr, U., Nieters, A. & Drosdowski, T. (2016): Extreme Weather Events and the German Economy: The Potential for Climate Change Adaptation. In: Leal Filho, W., Musa, H., Cavan, G., O'Hare, P., Seixas, J. (eds): Climate Change, Adaptation, Resilience and Hazards, pp. 125-141, Springer.

Ludwig, U., Brautzsch, H-U. (2002) Die Hochwasserkatastrophe und das Sozialprodukt in Deutschland. Wirtschaft im Wandel, 12, pp. 353-356.

Lutz, C., Meyer, B., Nathani, C., Schleich, J. (2005) Endogenous technological change and emissions: The case of the German steel industry. In Energy Policy 33, pp. 1143-1154.

Muenchner Rueck (2003) Topics. Jahresrueckblick Naturkatastrophen 2002.

Muenchner Rueck (2004) Topics geo. Jahresrueckblick Naturkatastrophen 2003.

Scott, D, Rutty, M., Amelung, B., Tang, M. (2016) An Inter-Comparison of the Holiday Climate Index, (HCI) and the Tourism Climate Index (TCI) in Europe, Atmosphere 2016, 7, 80.

Steininger, K.W., König, M., Bednar-Friedl, B., Kranzl, L., Loibl, W., Prettenthaler, F. (Eds.) (2015): Economic Evaluation of Climate Change Impacts. Development of a Cross-Sectoral Framework and Results for Austria. Springer.

UNEP (2004) Impacts of summer 2003 heat wave in Europe. Environment Alert Bulletin.

8 APPENDIX

	Has your model provided inputs to economic models?	Which data did you share/ provide?	What data did you use from WP6 or WP5 type models?
NOA	NOA is using regional climate models from EuroCordex database selecting those with the highest spatial resolution currently at ~12km. We process the model output and make it available for the target regions (here the SOCLIMPACT islands). We can provide tailor-made climate model output to form input to WP5 and WP6 models in the format required.	Typically, we are able to provide basic climate variables of interest (such as temperature or precipitation) on a daily or a monthly basis for the regions of interest over a continuous time period extending up to 2100 and utilizing different climate scenarios (moderate or more extreme). Additionally, after further processing and calculations, we can provide pre-calculated indicators of interest to the sector (i.e energy, tourism, economy etc)) targeted (eg. number of hot days per year or extreme precipitation events per year).	
CMCC	yes: storm surge model has provided data on sea level extremes (there is the similar possibility for wave model providing data on extreme offshore) wave height	extreme sea levels corresponding to several return times (5-50, 1000 years ....)	wave and storm surge models were used using surface winds and mean sea level pressure (3-6hourly) from regional climate models that were driven by CMIP5 models (this is similar to what will be done in WP4)
ULPGC	WP5 is in charge of transforming the CC outputs expressed in biophysical indicators in economic values to feed GEMs. So yes, outputs from WP4 will be inputs in economic modelling.	estimated by WP5 partners using market and non-market methods. And these economic values will be the inputs to be used in GEMs to estimate the whole effect of climate shocks on the economy of the selected European islands.	
UCLM	Solar energy resource analysis with climate model data; Climate model data (wind) for wind energy resource analysis ; Analysis of precipitation and temperature extremes with climate model data	solar radiation, temperature, sea level pressure, wind, geopotential data; precipitation, temperature	no direct additional use of the data for or from economic models
GWS	Energy balances, frequency of extremes, damage estimates for extreme events	GDP; Population; Value added	

E3-Modelling	**Previous experience** PESETA I, II (DG JRC); Climate Cost (FP5), Bank of Greece, 2011, "The environmental, economic and social impacts of climate change in Greece"; A multi-model assessment of potential economy-wide effects from impacts of and adaptation to coastal flooding due to sea level rise in a well-below 2°C world (in preparation, under CD-LINKS Horizon 2020 project)	Productivity change for crops (yield), Change in energy demand, Capital loss (due to sea level rise, river floods, destruction of transport infrastructure etc.) Change in tourism expenditure by origin and destination. Change in labor supply (due to health impacts). Labor productivity change (due to temperature increase). Adaptation expenditure
INTER-	Regarding WP6, Interfusion has not had experiences with modelling/data templates concerning climate change models, or their coupling with other models.	

pot@soclimpact.org

www.soclimpact.com

(+34)928458234