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

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WORKING PACKAGE 5

MEASURING MARKET AND NON-MARKET COSTS OF CLIMATE CHANGE AND BENEFITS OF CLIMATE ACTIONS FOR EUROPE

Deliverable 5.6.

Integration and coordination of non-market and big data analysis of economic values resulting from Climate Change impacts to GEM-E3-ISL and GINFORS models.

Coordinated by UNIBO and ULPGC with participation of other SOCLIMPACT partners of WP4, WP5 and WP6. Reviewed according to the quality review internal process.

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v1.2	13.08.2020	Carmen García & Matías González	Final revision of Energy and Tourism sector, and update of results.
v1.3	26.08.2020	Carmen García	Update of figures and final revision of Energy and Maritime Transport sectors. Version to be submitted.

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1. Introduction

The purpose of this Deliverable is to transfer values estimated in WP5 through big data and non-market evaluation to GEM-E3-ISL and GINFORS modelling. This is a crucial step of the project, requiring active participation of partners involved in WP4, WP5 and WP6. Climatic projections built by WP4 provide the fundamental inputs for a series of key indicators (e.g. beach flooding index, humidity index, etc.). Moreover, economic impacts presented by WP5 in Deliverables 5.2, 5.3 and 5.5 (respectively, transfer impact analysis, Big Data analysis, and non-market evaluation based on survey data) are adapted in order to link them to WP4 indicators. Finally, the merge of WP4 and WP5 inputs provide projections for a range of sector-specific real and/or monetary indicators. These figures (which constitute the output of the Report) will subsequently be used as inputs in GEM-E3-ISL and GINFORS economic models developed in WP6, with the ultimate aim of providing comprehensive projections of economic impacts of climate change for the Blue Economy sectors of the European Islands, in the near future (around 2050) and in the distant future (around 2100).

Accordingly, this Deliverable is tailored to WP6 needs and requirements in several aspects. One, the technical features of the GEM-E3-ISL and GINFORS models determined the selection of Representative Concentration Pathway (RCP) scenarios and the type of the output variables to be considered. Two, since macroeconomic modelling will not be conducted for Fehmarn and West Indies, this report only considers the ten remaining regions: Azores, Balearic Islands, Canary Islands, Corsica, Crete, Cyprus, Madeira, Malta, Sardinia, and Sicily.

The report is structured as follows. Section 2 describes the techniques developed to adapt the methods from D5.2, D5.3 and D5.5 to transfer values for respective Blue Economy sectors. Section 3 provides sectoral tables linking climatic projections from WP4 to a range of sector-specific indicators for the four sectors, Section 4 provides a critical overview of potential caveats of the analysis, and Section 5 concludes the report. Given the operational purpose of the Report, its tables are also provided in Excel format (see the attached file "D5.6 for WP6.xlsx"), to facilitate transferring to WP6 models.

2. Methodology

Value transfer methodologies are sector specific and are hence discussed in respective subsections 2.1-2.4. Before moving to the four Blue-economy sectors investigated by SOCLIMPACT, we first recall a few remarks that are of common interest for all areas.

- *Climatic projections*: for each island, climatic projections come from the output of WP4 (particularly Deliverable 4.2) and cover a wide range of variables. As required by GEM-E3-ISL and GINFORS models, these projections are linked to RCP2.6 and RCP8.5 scenarios.
- *Time horizon*: WP4 provides projections for the near (2046-2065) and distant (2081-2100) future, which yields four outcomes (two for each RCP scenario) for each climatic indicator.
- *WP5 estimates*: climatic projections are used as inputs and adapted to the range of different evaluation approaches undertaken by WP5 in Deliverables 5.2, 5.3 and 5.5 to provide desired output variables (note that not all climatic indicators could possibly be tailored to WP5 methodologies).
- *Output variables*: These are expressed in terms of percentage change of specific variables (e.g., tourism expenditure, or energy demand for cooling) with respect to the reference case (at present time). Values will then be used as inputs for GEM-E3-ISL and GINFORS models. In some cases, the climatic indicator projection is not available for a given scenario-island pair, and the corresponding cell of the output table is filled with "N/A".

2.1. Maritime Transport

The costs for the maritime transport sector of the European islands imputed to climate change are approximated in such terms that in principle may be directly used to estimate the economic effect of those impacts on the entire economy. The maritime transport system includes the ports and the maritime traffic subsystems. In this context, we assume that when ports keep operative, maritime transport regularly works. In other words, the risk of stopping or slowing maritime transport, thus affecting the island's economy as a whole, mainly arises from the risk of ports becoming non-operatives. Consequently, we have considered two possible approaches of economic valuation:

1. The estimation of inoperability time due to climate change related events and then, the assessment of the economic loss in terms of reduction of annual value added of ports' activity, under a non-additional protective actions' scenario. In this case, costs include those associated to the value added lost due to cancelled operations, and the costs of fixing structures that are eventually damaged by the climate events.
2. The definition of the interventions required to keep ports always operative, with the annual splitting of the total costs. This entails having detailed information on the physical characteristics of the different parts of the investigated ports, and the timespan of the interventions that keep them working.

Each approach has lights and shadows. The shortcomings of the first approach arise from the extraordinary difficulty of predicting the number of days of port shutdown or slowdown due to climate conditions. According to direct expert information, so far, most of the islands' ports under study have not stopped working due to weather conditions. Although some assumptions have been made on the specific weather conditions under which ports are not operative, the factual conditions remain unknown. Thus, estimating the number of days of port shutdown would reveal arbitrary.

The alternative option is not free of shortcomings either. It demands having very detailed information on ports' characteristics that, additionally, must be interpreted by experts. Deciding the time horizon in which different parts of the ports' infrastructures will require heightening/strengthening interventions also necessitates expert assistance. Summarizing, when having the proper expert facilitation and consultancy, the second approach becomes more feasible to implement than the first one. Hence, this second approach, hereafter referred as the need to Keep Ports Operating (KPO), has been preferred by Soclimpact researchers to assess the economic value of climate change impacts on islands' ports activity.

The two approaches measure different things, so estimated figures might differ. The economic valuation of climate change impacts on ports, according to the first approach, would be very much higher than the one obtained by the KPO method. In fact, the first approach (assessing the costs derived by inaction to protect ports operativity against climate change impacts) does not seem reasonable due to the extreme dependence of islands' economy on port activity. In fact, the consequence would be that, at a certain time horizon, ports activity will come to a halt, and islands' economies will become severely hit. Soclimpact researchers strongly think that this is an unlikely outcome and, hence, the KPO approach is more realistic and feasible, providing more reliable figures.

Therefore, the output provided for macroeconomic modelling is the **cost of maintaining ports operability**, which is going to be measured in monetary terms and, in this respect, will be similar to the originally proposed "damage to ports infrastructure" indicator.

The workflow of the KPO method can be summarised as follows:

1. Identify the relevant ports to be analysed. As European islands/archipelagos are usually endowed with a port system including several ports, the selection criterion is based on their economic relevance and the biggest ones to reach at least 90% of the island's foreign trade have been considered. For instance, in the case of the Canary Islands we considered the ports of Las Palmas de Gran Canaria and Santa Cruz de Tenerife.
2. Obtain a scaled map of the port infrastructures, to measure the physical units in terms of length or surface.
3. Find and seek for collaboration of experts who can provide the required information.
4. Obtain from experts detailed information on the interventions required on different parts of the port infrastructure to keep them operative (under climate change impacts), including the description of the size (length and surface), type and unit costs of the intervention. By default, unit costs figures have been obtained from the literature. Most of interventions perform on standardised patterns and just some of them do not (dredging, mostly).
5. Estimate the cost of the intervention on each port element and the corresponding time horizon, based on the information on expected hazards under RCP2.6 and RCP8.5 scenarios of GHG emissions (provided by Soclimpact climatologists).
6. Allocate annually the estimated costs.
7. Interpret the estimated figures as extra average fixed costs of port activity, to be used in the macro modelling process.

Ports operability mainly depends on bad weather conditions (wind, strong waves, storms) and sea level rise (SLR). As regards extreme weather conditions, Soclimpact climate modellers predict that figures for 98th percentile of extreme wind speed, wave height and storm surges will be on average slightly less than those of the reference period (1985-2005) (see D4.3 and Annex: these estimations are perfectly aligned with the literature, see for example, the EEA). Since ports operability has not been interrupted in the reference period, conclusions regarding the expected future impact of these three hazards on islands' ports activity is that it may be assumed negligible over the present century.

Experts are more concerned about the impact of SLR on ports and maritime transport activity, as it increases the inland penetration of high waves and storm surges. Even for the recently built dikes and other parts of port infrastructures, experts agree that structures will have to be strengthened and heightened over the next decades.

In line of the above, we revisit the set of input-output indicators in the format desired by WP6. First, we note that three out of four climatic inputs (Storm surge extremes, Frequency of strong winds and Wave height extremes) will not be considered in our analysis since, according to WP4 projections, they are not going to intensify in the near and distant future under any of RCP scenarios for the islands. Second, for the remaining climatic input variable (Mean sea level rise) we provide a different output from the one originally requested (damage to port infrastructure), which is going to be the "costs of keeping ports operability" – KPO). Therefore, for maritime transport, the following output is provided (Table 2.1.1):

Table 2.1.1. Summary of indicators for the maritime transport sector.

WP4 Climate damages estimation	Output (input for GEM-E3-ISL and GINFORS)	Units	Reference Deliverables
Mean Sea Level Rise	Cost of Keeping ports' operability	€ in 2020-2100 period by island	D4.3 & Annex

A template was developed to gather accurate information on the interventions required to counteract SLR and the other hazards that work over it to damage Mediterranean and Atlantic islands ports. In what follows, we describe the case of Las Palmas de Gran Canaria.

The case of the port of Las Palmas de Gran Canaria.

This port, together with the one of Santa Cruz de Tenerife, represents most of the Canary Islands' port activity. Based on the above referred template and two interviews with the person leading the engineering department of Las Palmas port, Soclimpact researchers have obtained figures for the economic valuation of climate change impacts on the port of Las Palmas de Gran Canaria, measured by the investment required to protect port infrastructures from sea level rise an associated hazards and keep it operative over the 21st century.

The port was first built in mid-19th century. Since then, it has been increased in length, through parallel dikes from the shoreline. The Spanish Port Authority is now starting the formulation of an action plan to get Spanish ports capable of coping with climate change hazards. Soclimpact's work will be an input for the preliminary phase of the planning process.

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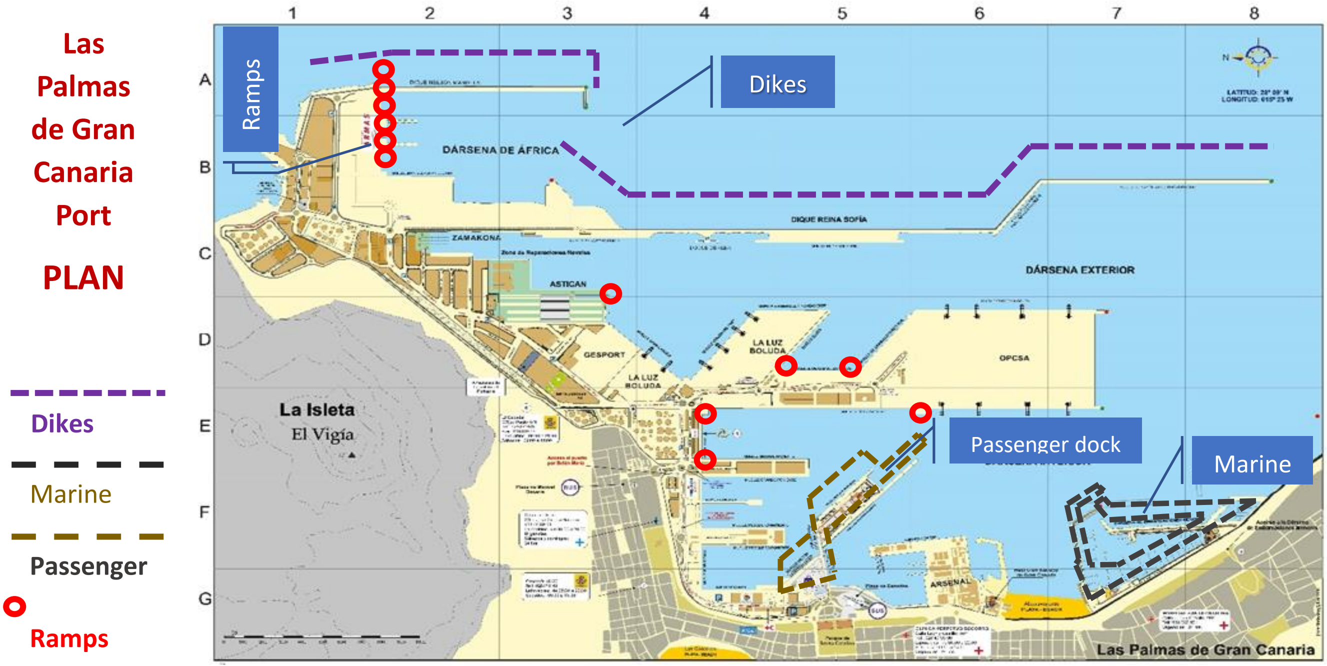
Figure 2.1 – Port characteristics and required interventions



The map above shows the chief elements of the port. The interventions required to keep the port operating over the 21st century, according to the experts' opinion, are underlined as showed on the left side of the picture. Then, a conservative estimation of the costs needed to keep the port operative has been made by identifying the areas potentially floodable due to the combination of the expected sea level rise, the height of waves and storm surges. Applying the unit costs obtained from the literature, Table 2.1.2 shows the partial and total costs of the required interventions: increasing the height of 5.6 km of external dikes of 1 metre; elevating 12 ramps, 137,051 sqm of passenger docks and 116,021 sqm of marine; and the loss of near 6000 sqm of buildings next to the marina valuated at their reposition cost.

Table 2.1.2. Costs of keeping different elements of port infrastructure operative assuming climate change under RCP8.5 scenario of emissions.

Port Element	Surface/length	Phy.unit	Unit cost (range)	Unit cost (applied)	Total cost
Dikes Nelson Mandela & Reina Sofía	5652	km	1-4 mill. €	2.5	14.13 mill. €
Ramps	10800	m²	225 €	225	2.43 mill. €
Passenger dock	137051	m²	425 €	425	58.25 mill. €
Marina	116021	m²	425 €	425	49.31 mill. €
Building next to Marina	5907	m²	2500 €	2500	14.77 mill. €
					138.88 mill. €

This very conservative approach is not considering the loss of 1 m height with respect to the average and maximum sea level for the remaining port infrastructures. This loss should be considered a decapitalisation of the port since SLR is using part of the height surplus those structures exhibit. Therefore, a more realistic

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approach should add to the assessment showed in Table 2.1.2 the costs of elevating one meter the whole set of the elements of the port that are susceptible to be affected by SLR in the future. By doing this, the costs would result increased by nearly fourteen times, as it is depicted in Table 2.1.3.

Table 2.1.3. Costs of keeping port natural capital as in the reference period (1985-2005)

TOTAL COST OF KEEPING PORT OPERATIVE					**133.88 mill. €**
Remaining apron areas and platforms	2948960	m²	425 €	425	1253.31 mill. €
Remaining buildings	515000	m²	1000€	1000	515.00 mill. €
TOTAL COST OF KEEPING PORT ENV. CAPITAL					**1907.19 mill. €**

In order to transfer these figures to the economic modelling of climate change impacts, the costs estimated should be allocated annually. Under the assumption of a steady SLR, the once-off adaptation of the ports should be done in due time and costs equally distributed over the period of reference.

Finally, costs have been estimated for the increase of infrastructures' height by 1 m. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures. Some aspects of the coastal hydrodynamic and the shape of dikes influence that relationship. By experts' recommendation, we have assumed that 1 m increase in port height is required to cope with the SLR under RCP 8.5 scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality. Resulting projections are reported in the Maritime transport sector table (Section 3.1).

2.2. Tourism

As regards the tourism sector, WP4 projections were adapted to serve as inputs for models used in D5.5 and D5.3. We first provide a quick recall of data and methods employed in these analyses. For ease of representation and for a more vivid comparison, the information summarizing the main features of data, methods, and their use for value transfer from D5.3 and D5.5 are presented in Table 2.2.1.

Table 2.2.1. D5.5 and D5.3 data and methods summary.

Data and methods used in D5.3				
Data Types and sources	**Characteristics (relevant for D5.6)**	**Methodology**	**Use for D5.6**	**Other remarks**
Prices from Booking.com and weather forecasts from weather.com	Prices offered by 132, 157 and 67 hotels in Sicily, Sardinia and Corsica respectively, during the period from May to September 2019 (inclusive), for all available room types and booking leads from 0 to 14 (for 3 islands yielding about 5.5 million observations). Merged with daily weather forecasts for 0 to 14 days ahead.	Linear regression, establishing the impact of weather forecast variables on prices offered.	Deriving projections of price response to changes in human being comfort.	The published version of D5.3 works with a shorter time-span (May-June 2019).
STR-SHARE data	Daily data on hotels occupancy rates (the share of available rooms that are sold over a given period), revenues and ADR (average daily rate). Collected for 2018 and	Regression analysis.	Estimating the relationship between ADR (representative	In D5.3 these data serve a different purpose: analyzing impact of wildfire

	2019 for Mallorca, Malta, Tenerife, Gran Canaria, Fuerteventura and Lanzarote, comprising 4380 observations.		of price) and occupancy rate (representative of quantity).	on Gran Canaria on hotels performance. For this research question, a different methodology is applied.
Instagram data	For Tenerife, Gran Canaria, Lanzarote, Fuerteventura, Malta, Cyprus, Crete and Sicily, pictures published on Instagram in the period June-September 2019 with the name of the destination in the hashtag and travel-related keywords in the caption. About 745.000 pictures in total.	Original images are processed via Google Cloud Vision, which yields a set of up to 10 labels representing the content of each image. Using frequency rankings of these labels for each island, an IDDI (Index of Distance in Destination Image) matrix is calculated.	Use the IDDI matrix to calculate weights, to extrapolate projections for Islands other than Sicily, Sardinia and Corse.	
Data and methods used in D5.5				
Data Types and sources	**Characteristics (relevant for D5.6)**	**Methodology**	**Use for D5.6**	**Other remarks**
Survey data collected at origin countries	2538 EU citizens (frequent travelers) have been surveyed at their country of origin (United Kingdom, Germany, France and Sweden) to understand how climate change affects their travel decisions to all Soclimpact islands. Respondents are posed with hypothetical scenarios, in which two EU islands suffer several climate change impacts and they are asked to choose between visiting either of the two islands at a specified price or "staying at home" (at price 0€). Each investigated attribute presented three potential levels of CC impact, coded categorically: *no impact* (current situation), *moderate impact* or *strong impact*. Each subject answered to eight different choice sets.	The conditional logit (McFadden's choice) model has been applied to estimate the results of the discrete choice experiment.	Elicit how CC-induced impacts (among others: human being comfort, forest fires, loss of marine habitats, disease spread, beach loss) affect tourists' expenditure.	D5.5 also analyzes the impact on WTP of other risks (loss of land habitats, damages to infrastructures, water availability, damages to cultural heritage). It was not possible to link these attributes to CC projections provided by WP4, therefore, in the current report they are not be covered.
Survey data collected at islands destinations	2528 tourists were surveyed at ten islands destinations: Azores, Balearic Islands, Canary Islands, Crete, Cyprus, Fehmarn Island, Madeira, Malta, Martinique & Guadeloupe (Antilles) and Sicily. Respondents are posed with hypothetical scenarios, in which two alternative sets of adaptation policies to climate change impacts are presented, they are asked to choose between one of the options for which they have to pay an extra price per day and "no policy" (at price 0€). Each climate change impact was accompanied a generic adaptation policy that could be implemented at the destination to ameliorate its impact, and only two levels	The conditional logit (McFadden's choice) model has been applied to estimate the results of the discrete choice experiment.	Elicit willingness to pay (WTP) for adaptation policies, for each island.	Due to the formulation of questions, for respondents it was not possible to tie RCP-island-horizon specific projections to the WTP for adaptation policies. More details on this analysis, as well as results, can be found in the Appendix of this report.

	were considered: the policy is implemented or not. Each subject answered to six different choice sets.			

For the tourism sector, the indicators to be tailored to the abovementioned WP5 approaches are presented in Table 2.2.2. To make numeric values applicable for D5.5 approach, all indicators (except for Humidex, T98p and Beach Area Loss) were transformed into categorical form. It should be highlighted that perceptions of "moderate" and "strong" changes can vary among respondents and are, therefore, subjective.

Table 2.2.2. Summary of indicators for the tourism sector.

WP4 Climate damages estimation	Proposed indicator	Output (input for GEM-E3-ISL and GINFORS)	Additional information - Adaptation Policies (Generic Policies)	Reference Deliverables
Seagrass Evolution	No deterioration / moderate deterioration / severe deterioration of the conservation status of marine habitats	% change in total tourists' expenditure	WTP for adaptation policies at destination: Marine habitats restoration	D4.4e D5.5
Fire Weather Index (FWI)	No fire / Moderate increase in burnt areas / Strong increase in burnt areas	% change in total tourists' expenditure	WTP for adaptation policies at destination: Forest Fire Prevention	D4.3 & Annex D5.5
Beach Area Loss	Percentage of beach surface reduction	% change in total tourists' expenditure	WTP for adaptation policies at destination: Beaches Protection	D4.4d D5.5
Humidity Index (Humidex)	Number of days when Humidex > 35	% change in total tourists' expenditure % change in tourism arrivals	WTP for adaptation policies at destination: Heat waves amelioration	D4.3 & Annex D5.5 D5.3
98th Temp. Percentile (T98p)	Share of days when t > T98p	% change in total tourists' expenditure	WTP for adaptation policies at destination: Heat waves amelioration	D4.3 & Annex D5.3
Length of the window of opportunity for vector-borne diseases	Habitat Suitability Index for tiger mosquito. No risk of infection / moderate risk of infection / strong risk of infection	% change in total tourists' expenditure	WTP for adaptation policies at destination: Infectious diseases prevention	D4.3 & Annex D5.5

We now describe in detail how respective indicators were transformed to serve as inputs for D5.5 and D5.3 models.

Seagrass evolution is treated as a proxy of **marine habitats evolution**, acknowledging that seagrass is a foundation species. A foundation species refers to any species that has a large contribution towards creating and maintaining habitats that support other species. It has a strong role in structuring a community. According to Ellison (2019), there are three defining characteristics that identify foundation species (Ellison et al., 2005). First, they are numerically abundant and account for most of the biomass in an ecosystem. Second, they are at or near the base of the directional interaction networks that characterize ecosystems. Third, their abundant connections to other species in an ecological network mostly reflect non-trophic or mutualistic interactions, including providing structural support for other species, significantly altering ecosystem properties to [dis]favour other species, altering metabolic rates of associated species, and modulating fluxes of energy and nutrient flow through the system (Baiser et al., 2013).

Posidonia Oceanica and Zostera are foundation species in Mediterranean waters (Chefaoui et al., 2017) as Cymodosea Nodosa and Cystoseira are for the Canary Islands and Corals for the Caribbean islands. The evolution of most of specific species in their respective marine habitats, including the species which have a high recreational value in tourism, is narrowly linked to the evolution of their respective foundation species. Accordingly, changes in surface of those foundation species are very good predictors of changes in populations that attract tourists for purposes like diving, snorkelling or glass-bottom boating.

Additionally, those foundation species have the property of fixing suspended organic solids so avoiding turbidity and keeping water transparency. This is relevant not just for marine wildlife watching based activities but also for sea bathers. There is a quite linear relationship between the studied seagrass surface reduction and the diminishing of biodiversity for which the willingness to pay of tourists was asked.

Seagrass Evolution is originally measured as the relative change (in %) of the coverage of the main seagrass for each island. To translate it into a categorical variable, as required by using survey analysis in D5.5, where deterioration of marine habitats is categorized into *moderate* and *strong*, the change between 10 and 30% is considered as moderate loss of the most spread seagrass, whereas a change above 30% is treated as strong negative impact on seagrass coverage[1], thus leading to a significant loss of marine habitat. In these cases, a negative change in the level of expenditure by tourists in all islands is documented. However, in those cases where the climate models suggest no change (0 values of the climatic variable) above the reference case, the impact on tourists' expenditure is assumed to be null. Transition from original indicators provided by D4.4e to categorical values are presented in Table 2.2.3 below.

Table 2.2.3. Present coverage (in km^2) of the most prevalent seagrass species and respective projections of its relative change (D4.4e, p. 8)

Island	*Specie*	*Area (km2)*	*% loss RCP2.6 near*	*% loss RCP2.6 distant*	*% loss RCP8.5 near*	*% loss RCP8.5 distant*
Balearic	Posidonia	1002	0	0	0	35.1
Canary	Cymodocea	83.1	0	0	0	0
Crete	Posidonia	17.4	0	0	0	0

[1]Translating numerical variables to categorical here and elsewhere was done using expert judgement in collaboration with WP4 participants.

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Sardinia	Posidonia	1963.2	0	0	0	14.4
Corsica	Posidonia	2258.9	0	0	0	0
Cyprus	Posidonia	84.3	0	0	0	0
Malta	Posidonia	143.6	0	0	0	20.1
Sicily	Posidonia	966.3	0	0	0	28.3

Categorical change

Island	*Specie*	*Area (km2)*	*loss RCP2.6 near*	*loss RCP2.6 distant*	*loss RCP8.5 near*	*loss RCP8.5 distant*
Balearic	Posidonia	1002	no change	no change	no change	strong
Canary	Cymodocea	83.1	no change	no change	no change	no change
Crete	Posidonia	17.4	no change	no change	no change	no change
Sardinia	Posidonia	1963.2	no change	no change	no change	moderate
Corsica	Posidonia	2258.9	no change	no change	no change	no change
Cyprus	Posidonia	84.3	no change	no change	no change	no change
Malta	Posidonia	143.6	no change	no change	no change	moderate
Sicily	Posidonia	966.3	no change	no change	no change	moderate

The potential impact of **forest fires** in the surveys is categorized into *moderate* and *strong* increase of burnt areas. Therefore, linking these with the Fire Weather Index, using EFFIS fire danger category classification, a change from a given category to the neighbouring one is considered as moderate, while a shift to the second next category is viewed as a strong change. If climatic models do not predict a considerable change in FWI, we assume that tourists' expenditure will remain unaffected. Table 2.2.4 presents transitions from non-normalized FWI projections to categorical representation.

Table 2.2.4. Non-normalized FWI projections (elaborated from D4.3, pp.21-22)

Island	*Reference value*	*RCP2.6 near*	*RCP2.6 distant*	*RCP8.5 near*	*RCP8.5 distant*
Baleares	0.237	0.245	0.233	0.264	0.313
Corse	0.226	0.238	0.226	0.269	0.329
Sardinia	0.305	0.316	0.302	0.361	0.433
Sicily	0.349	0.371	0.365	0.409	0.506
Malta	0.283	0.294	0.292	0.309	0.363
Crete	0.483	0.534	0.525	0.579	0.67
Cyprus	0.527	0.554	0.555	0.608	0.644

Note: colors represent respective Fire Danger Categories (see EFFIS classification), increasing from green to orange.

Categorical change

Island	*Reference value*	*RCP2.6 near*	*RCP2.6 distant*	*RCP8.5 near*	*RCP8.5 distant*
Baleares	0.237	no change	no change	no change	no change
Corse	0.226	no change	no change	no change	no change
Sardinia	0.305	no change	no change	moderate	moderate
Sicily	0.349	no change	no change	no change	moderate

Malta	0.283	no change	no change	no change	no change
Crete	0.483	no change	no change	moderate	moderate
Cyprus	0.527	no change	no change	moderate	moderate

The impact of **infectious disease** in D5.5 framework is coded in the categorical terms of *moderate* and *severe* risk of infection due to vectors spread. Translation of the Habitat Suitability Index (HIS) for Asian tiger mosquito (Aedes Albopictus) to fit the surveys categories is done in a similar fashion as FWI in accordance with categorical suitability levels, as depicted in Table 2.2.5 below. As appears from WP4 projections, suitability of habitats for the tiger mosquito tends to decrease in the future and under the most severe emissions scenario (RCP8.5). In this respect it is important to note that these projections apply to this particular vector (*Ae.albopticus*). Other vectors were not considered within WP4.

Table 2.2.5. HSI projections (Table 3 from D4.3, p.34)

Island	*Reference value*	*RCP2.6 near*	*RCP2.6 distant*	*RCP8.5 near*	*RCP8.5 distant*
Cyprus	68.7	71	69.4	60.6	47.2
Crete	74.8	76.2	76.2	69.8	62.8
Sicily	83.7	85.4	86.1	79.8	67.7
Sardinia	87.1	87.2	90.2	83.7	74.7
Corsica	84.9	87.2	89.9	87.8	83.8
Balearic	66.1	66.8	69.2	62.5	52.3
Malta	62.9	69.7	67.5	60.3	46.4
Note: colors represent suitability categories (see D4.3 p.33) increasing from green to red.					
Categorical change					
Island	*Reference value*	*RCP2.6 near*	*RCP2.6 distant*	*RCP8.5 near*	*RCP8.5 distant*
Cyprus	68.7	no change	no change	no change	moderate decrease
Crete	74.8	no change	no change	no change	no change
Sicily	83.7	no change	no change	moderate decrease	moderate decrease
Sardinia	87.1	no change	no change	no change	moderate decrease
Corsica	84.9	no change	no change	no change	no change
Balearic	66.1	no change	no change	no change	moderate decrease
Malta	62.9	no change	no change	no change	moderate decrease

As regards **beach availability**, respondents were posed with hypothetical scenarios which were linked to numerical values: a moderate decrease of beach surface was defined as a 35% reduction, whereas a strong decrease was defined as 50% reduction. Such formulation allows making inference using continuous values as inputs. Therefore, Beach area Loss projections provided by WP4 and measured as the percentage of lost beach area, did not require any alteration. However, D4.4d provides precise estimation only for Balearic Islands (numerical projections can be found at D4.4d, p.19). To obtain projections for other islands, we apply the procedure that is outlined in the very same Deliverable:

"In order to translate this information to quantitative indicators to be used in the operationalization of the impact chains, a suggestion would be the following. First, we can assume that the distribution of beach types is similar in the different islands.

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Thus, a rough estimate of the beach surface loss in each island could be derived from the results obtained for the Balearic Islands, by scaling the percentage by the mean flood level in each island." [D4.4d, p.19].

The results are presented in Table 2.2.6

Table 2.2.6. Percentage of beach surface loss under mean conditions (D4.4d and own elaboration)

Island	*RCP2.6 near*	*RCP2.6 distant*	*RCP8.5 near*	*RCP8.5 distant*
Balearic	34%	45%	51%	70%
Canary	38%	48%	62%	80%
Crete	27%	38%	53%	68%
Madeira	48%	57%	78%	95%
Sardinia	25%	35%	42%	58%
West	35%	46%	52%	77%
Azores	53%	62%	85%	99%
Corsica	23%	32%	38%	54%
Cyprus	22%	30%	38%	54%
Malta	28%	40%	58%	70%
Sicily	24%	34%	47%	61%

Data analysis from surveys allow to confirm that tourists' expenditure levels are likely to decrease if climate change affects beach surface availability. As changes in expenditure levels were estimated per each cm of beach loss, some elaboration was required starting from the original values of the climatic variable.

One of the **human being comfort** variables (number of days with Humidex > 35) was also tailored to the design of the survey analysis and it was assumed that days with Humidex > 35 are perceived as extremely hot by tourists, even for sea, sun and sand activities. The moderate and high increases in the number of extreme heat days were also linked to numerical values: as opposed to the reference point which was set at 25 days of heat per year, a moderate increase implied 50 such days per year, whereas a strong increase – 75 days. Therefore, WP4 Humidex projections were used as inputs in their raw (continuous) form. The original projections for this climatic variable, as well as for T98p (which is adopted only to D5.3, as described below) can be found in the Annex to D4.3 and in the respective sectoral table of this Deliverable (Section 3.2).

Values provided by D5.5 are measured as percentage change in expenditure per tourist per trip. To unify outputs obtained within D5.5 and D5.3 approaches, an assumption is made that in D5.5 framework changes in tourists' expenditure occur at constant arrivals rate. Therefore, the dynamics of per-tourist expenditure is taken as an approximation of total tourism expenditure dynamics.

The willingness to pay for each attribute *j* has been computed as $WTP_j = -\frac{\beta_j}{\beta_{price}}$, and results are presented in Table 2.2.7. Here *price* is total price per person per day, for a 5-days trip, including transportation cost and the cost of a four-star hotel accommodation. However, the WTP is computed per person, over the 5-days trip, given that the climate impacts persist during the whole trip[2]. It takes value 0 if the respondent chooses to stay home.

Table 1.2.7. Estimation results and willingness to pay (WTP) (CC impacts)

	Estimation	WTP (€)
Heat Waves	-0.00934*** (0.001)	-5.05
Infectious diseases (*Moderate*)	-0.29020*** (0.032)	-156.86
Infectious diseases (*Severe*)	-0.73540*** (0.034)	-397.51
Beach availability	-0.00343*** (0.00)	-1.85
Water shortages	-0.02919*** (0.005)	-15.78
Forest fires (*Moderate*)	-0.15636*** (0.05)	-84.52
Forest fires (*High*)	-0.46624*** (0.054)	-252.02
Terrestrial habitats (*Moderate*)	-0.22630*** (0.044)	-122.32
Terrestrial habitats (*Strong*)	-0.38184*** (0.049)	-206.40
Marine habitats (*Moderate*)	-0.09523** (0.042)	-51.48
Marine habitats (*Strong*)	-0.28467*** (0.045)	-153.88
Infrastructures (*Moderate*)	-0.21595*** (0.045)	-116.73
Infrastructures (*Strong*)	-0.26488*** (0.044)	-143.18
Cultural heritage (*Moderate*)	-0.12128*** (0.046)	-65.56
Cultural heritage (*Strong*)	-0.26799*** (0.046)	-144.86
Price	-0.00185*** (0.000)	-
Antilles	2.81681*** (0.316)	1522.60
Azores	2.73110*** (0.291)	1476.27
Balearic Islands	2.78419*** (0.291)	1504.97
Canary Islands	2.98224*** (0.287)	1612.02
Corsica	2.86439*** (0.29)	1548.32
Crete	3.00329*** (0.29)	1623.40
Cyprus	2.92211*** (0.291)	1579.52
Madeira	2.85363*** (0.289)	1542.50
Malta	2.88672*** (0.286)	1560.39
Sardinia	2.89303*** (0.288)	1563.80
Sicily	2.86384*** (0.29)	1548.02
No. Of tourists surveyed	2538	

Note: *p<0.1; **p<0.05; ***p<0.01 significance test. Standard errors within parentheses. Sociodemographic characteristics included in the regression.

[2] The WTP for heat waves is expressed in €/day; for beach availability in €/1% of beach loss; and for water shortage in €/hour.

These values, matched to CC projections, allow to derive RCP-island-horizons specific projections of changes in tourists' expenditure, which are presented in Section 3.2 of this report. In addition, the results of surveys at the islands destinations were used to provide estimations of willingness to pay for adaptation policies corresponding to climate risks. The respective tables summarizing these findings, as well as methodological notes, are presented in the Appendix.

To provide evidence from an alternative approach, **human being comfort** variables (Humidex and T98p) were adopted to the framework of D5.3 in their original form. However, producing a desired output variable (% change in total tourists' expenditure) was done in four steps. In the first step we exploited the relationship between weather forecasts and accommodation prices (Sections 3.1 and 4.1 of D5.3) to derive estimates of price changes for days when forecasted Humidex > 35 and, separately, when forecasted t > T98p. Specifically, a linear equation of the following form is estimated separately for Sardinia, Corse, Sicily (Catania area only) and Sicily (other seaside area) - the islands for which price data are available:

$$lnPrice_{rt\Delta} = f(hotel_{FE}, room_{FE}, \Delta_{FE}, search_{day_{FE}}, checkin_{day_{FE}}, breakfast_{FE}, \\ FreeCanc, roomsleft, \#sleeps_{FE}, view, discomfort_{t\Delta}) + \varepsilon_{rt\Delta}$$

where $lnPrice_{rt\Delta}$ is the natural logarithm of price for room of type *r* observed at date *t* for a check-in date $t + \Delta$. Controls include hotel fixed effect ($hotel_{FE}$), room type fixed effect ($room_{FE}$), booking lead fixed effect (Δ_{FE}), day of week fixed effects for search date t ($search\_day_{FE}$) and check-in date $t + \Delta$ ($checkin\_day_{FE}$), board type ($breakfast_{FE}$), indicator of free cancellation option available ($FreeCanc$), number of available rooms ($\#roomsleft$), number of sleeps fixed effect ($\#sleeps_{FE}$), indicator of "room with a view" ($view$). The main variable of interest in this model is $discomfort_{t\Delta}$, which is the forecasted value of the human being comfort parameter observed at date *t* for the date $t + \Delta$, with Δ ranging from 0 to 14. The variable $discomfort_{t\Delta}$ takes value 1 if Humidex is larger than 35 and 0 otherwise. Analogously, for T98p indicator, the $discomfort_{t\Delta}$ = 1 if t > T98p and 0 otherwise. For Sicily only, in order to capture difference in response of Catania hotels and other areas of the Eastern coast of Sicily, which comprises the sample of hotels under investigation, separate coefficients are derived. To approximate impacts for Sicily as a whole, a weighted impact as $0.3 * (\beta_{discomfort\_cityarea}) + 0.7\beta_{discomfort\_seaside}$ is calculated. Percentage change in prices is derived as $(e^{\beta_{discomfort}} - 1)$. For more details regarding the data and methodology, please refer to Sections 3.1 and 4.1 of D5.3.

Next, to move from the impact of uncomfortable weather on a given day to the impact in a given year, a simplifying assumption is made that all extreme heat episodes as well as tourism arrivals occur in the relevant season period, which is taken as half a year; to calculate average price over the season respective values are weighted as follows:

$$(1 - \mathrm{sh}_{\mathrm{discomfort}})^* p_0 + \mathrm{sh}_{\mathrm{discomfort}} * (e^{\beta_{discomfort}} - 1) * p_0$$

Here $\mathrm{sh}_{\mathrm{discomfort}}$ is the share of discomfort days in the season, while p_0 is a numeraire price at a comfortable day, normalized to 1. This way weighted per-season prices can be calculated for every scenario based on scenario-specific value of $\mathrm{sh}_{\mathrm{discomfort}}$, derived from WP4 projections.

In the second step, since the D5.3 main analysis for monetary outcomes was carried out for Sicily, Sardinia and Corsica, there is a need to adopt a procedure to derive projections for the other islands. First, it is assumed that being leisure destinations, Canary Islands, Balearic Islands, Azores and Madeira respond to climatic changes in the same way as Sardinia and Corsica, therefore, projections for the former four destinations are derived as average of projections for the two latter islands.

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Second, an extrapolation procedure is adopted to provide estimates for other islands (Cyprus, Crete and Malta), which, like Sicily, have a pronounced city/cultural component. In particular, we make use of the Index of Distance in Destination Image, which is a dimensionless metric characterizing how similar or different selected destinations are (see Sections 3.2 and 4.2 of D5.3 for details) and available for Canary Islands, Cyprus, Crete, Malta, and Sicily.

Table 2.2.8 below provides the values of IDDI (Canary archipelago values are originally provided for individual islands, and then aggregated). To give an idea of how these can be interpreted, consider Crete, Cyprus and Sicily: distance between Crete and Cyprus is estimated to be 1.5, whereas distance between Crete and Sicily is 3.1; therefore, Crete and Cyprus are about 2 times more similar, than Crete and Sicily.

Table 2.2.8. Index of Distance in Destination Image for available islands

	Canary Islands	Cyprus	Crete	Malta	Sicily
Canary Islands	-	2.3	2.5	7.4	4.0
Cyprus	2.3	-	1.5	4.5	3.4
Crete	2.5	1.5	-	3.5	3.1
Malta	7.4	4.5	3.5	-	2.8
Sicily	4.0	3.4	3.1	2.8	-

In the third step it is assumed that images of Sardinia, Corse, Azores, Madeira, Canary and Balearic Islands are similar enough to be grouped together and lie on one side of the spectrum, whereas Sicily resides on the opposite side, and values from Table 2.2.7 are then transformed into weights calculated for each of the remaining islands as normalized inverse distances, so that price response to extreme heat is derived as weighted average. Table 2.2.9 below summarizes the resulting changes in observed prices (in %) on a day when extreme heat is observed.

Table 2.2.9. Estimated Δprice in response to extreme heat events (derivation formula and % change in price on a day with uncomfortable conditions)

	Δprice formula	Δprice (in %) when Humidex > 35	Δprice (in %) when t > T98p
ΔSicily	Separate for each, as described above: $(e^{\beta_{discomfort}} - 1)$	5%	5%
ΔSardinia		43%	36%
ΔCorse		39%	45%
Δ Others (Canary Islands, Balearic Islands, Azores, Madeira)	$0.5\Delta_{Sardinia}+0.5\Delta_{Corse}$	41%	41%
ΔCyprus	$0.41.\Delta_{Sicily} + 0.59\ \Delta_{Others}$	27%	26%
ΔCrete	$0.45\Delta_{Sicily} + 0.55\ \Delta_{Others}$	25%	25%
ΔMalta	$0.72\Delta_{Sicily} + 0.28\ \Delta_{Others}$	15%	15%

Having approximated the price reaction in response to extreme heat for all islands that were not part of price data analysis, scenario-specific projections in terms of percentage changes from the reference case are derived as described above for Sicily, Sardinia and Corse.

In the last step, we make use of STR data explored in Sections 3.3 and 4.3 of D5.3 to derive a relationship between accommodation prices and quantity; this allows to derive an estimate of how much total expenditures, and not just prices, will change in response to shifts in human comfort parameters. We find that, on average, a 1% higher hotel price is associated with 0.2% higher amount of bookings.[3] This information is used to derive the change in total expenditures as a product of price change and quantity change. All vital parameters mentioned above (island-specific $\beta_{discomfort}$, reference and projected island-specific $\mathrm{sh}_{\mathrm{discomfort}}$ and their elaborations can be found in the accompanying Excel file "D5.3 for D5.6.xlsx").

The final projections of percentage changes in tourists' expenditures with respect to reference scenarios may be found in Section 3.2 of this report. It is crucial to highlight that, on top of the all abovementioned assumptions, the analysis hinges upon an assumption that long-term tourists' behaviour is subject to the same patterns as short-term responses and changes of total tourists' expenditure are proportional to changes in accommodation expenditures.

From a qualitative perspective the results can be summarized as follows:

- **Marine habitats loss**, measured by seagrass loss, appears to have a very moderate impact on expenditure. It is important to note that this report only considers seagrass as a representative of marine habitats, however, it is not the most pivotal group of species. Projections on other species evolution were not available for this analysis.
- Increased **risk of forest fires** in the future leads to a relatively moderate decrease in expenditure. This is consistent with the literature which suggests that the most negative impact of forest fires events on tourists' decision making tends to occur in the short and medium term.
- For all islands, projected **beach reduction** results in a considerable decrease in expenditure.
- Given that **Habitat Suitability Index** for tiger mosquito is projected to stay stable or even decrease in all islands, these changes do not lead to any shifts in tourists' expenditure.
- Tourist surveys and Big Data approaches lead to qualitatively different conclusions: while surveys, being a stated preference method, suggest a negative impact of **extremely hot days** on tourists' expenditure, the adoption of Big Data techniques which can be considered as revealed preference method yields a positive impact of extreme heat on the outcome. The latter can be explained by the fact that in the summer period, rather than staying in the city during very hot days, people prefer to move to the seaside where the heat is more bearable. It is important to note that both methodologies have their weak sides, e.g. surveys may suffer from subjectivity and a mismatch between respondents' statements and actions, whereas the Big Data analysis was originally carried out using weather forecasts data and therefore hinges upon an assumption that the relationships we find in the very short term are going to hold also in the long and very long run.

[3] This relationship between arrivals and prices is not as counterintuitive as it seems, and it should not be read as a strange "positive" elasticity of demand. First, we are analysing the reaction of price to an increase in demand: technically, we are not moving along the curve, but there is a shift of the whole demand curve upwards (due to different climatic conditions). Second, when demand increases, hotels react by increasing prices to maximise profits. Hence, the changes in both price and arrivals should be read as the simultaneous new equilibrium under new external conditions.

- Though it was not possible to tailor both Human being comfort indicators to the D5.5 methodologies, the results obtained with D5.3 tools suggest that the two indicators (**Humidex** and **T98p**) provide similar results. We therefore suggest that projections derived using **Humidex** are adopted for WP6 purposes.

2.3. Energy

Delimiting the research scope

There are some potential climate change related risks that may impose welfare reductions to the European islands' societies by affecting the costs of producing and distributing energy, and the demanded quantity of energy required to keep thermal comfort.

While several climate change related impacts show ambiguity in terms of whether they imply higher costs for similar welfare level at the European islands' societies or not, other impacts undoubtedly translate into wellbeing reductions. The former ones include climate variables like average and extreme wind speed, also considering wind droughts, that may alter wind energy farms productivity and losses of electric grids; or insolation and the average and extreme temperatures that affect PV panels productivity and electric energy transport efficiency. About it, climate modelling results do not allow to derive either negative or positive impacts on the systems of production and distribution of energy across the European islands.

Regarding the demand of energy required to maintain the set standards of thermal comfort, however, it is expected that climate projections announce increasing costs for the islanders. Particularly, the assessment of the economic impact of climate change on the energy sector is going to be centred, i) on the evaluation of the additional demand of energy to lead with higher temperatures during the season prone to heat and ii) on the estimation of the costs associated to a higher consumption of water to compensate more elevated temperatures across the different domains of humans' activities (householding, gardening, etc.).

Selected indicators and assumptions

Cooling Degree Days (CDD)

The estimation of the increase of energy demand due to the thermal discomfort associated to climate change has been undertaken using indicators widely used in literature on the quantitative relationship between changes in temperature and changes in energy demand. The relationship between the increase of temperature and the increase of energy demand for cooling is underpinned on the indicator denominated *cooling degree days* (hereafter CDD). CDD are a measure of how much (in degrees), and for how long (in days), outside air temperature was higher than a specific base temperature. They are usually used for calculations relating to the energy consumption required to cool buildings. Complementary, there exists the heating degree days indicator (HDD), related to the extra demand of energy to heat buildings.

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The EEA reported that, for the whole Europe, "the annual population-weighted cooling degree days (CDD) increased by 33 % between the periods 1950–1980 and 1981–2017; the increase during the period 1981–2017 was on average 0.9 CDDs per year. The largest increase occurred in southern Europe" (…) "The annual population-weighted heating degree days (HDD) decreased by 6 % between the periods 1950–1980 and 1981–2017; the decrease during the period 1981–2017 was on average 6.5 HDDs per year. The largest decrease occurred in northern Europe and possibly in Italy" (…) "The decrease in HDDs in Europe is projected to be much larger than the increase in CDDs in absolute terms. However, a given change in CDDs generally has larger economic impacts than the same change in HDDs, because cooling is almost exclusively produced from electricity, whereas heating is often derived from energy carriers with lower specific costs and primary energy requirements. The projected increase in cooling demand in southern Europe may further exacerbate peaks in electricity demand in summer. This can threaten the stability of electricity networks during summer heatwaves, unless appropriate adaptation measures are taken".

This is the case for the islands, where their short energy systems exhibit additional vulnerability regarding instability in energy demand and supply factors. In this report only the CDD has been considered as it is by far the most relevant to explain changes in energy demand in the European islands.

Standardised Precipitation-Evapotranspiration Index (*SPEI*)

To estimate the increase of energy demand due to the increase in water demand, it was assumed that most of the islands (all the Mediterranean, the Canary Islands and, at least partially, the West Indies) will have to produce desalinated seawater (or groundwater) to meet further increases of demand. Since that, the estimate of the increase in energy demand to produce more drinking water has been done based on the energy consumption required to desalinate seawater.

The indicator used to translate the increasing temperatures into increases of drinking water demand is the so-called *Standardised Precipitation-Evapotranspiration Index* (SPEI). The SPEI is an extension of the widely used Standardized Precipitation Index (SPI). The SPEI is designed to take into account both precipitation and potential evapotranspiration in determining drought. Thus, unlike the SPI, the SPEI captures the main impact of increased temperatures on water demand. The impact chain follows the pathway through precipitation and evapotranspiration to water demand, and then, to energy demand.

Procedure

To estimate the increase of energy demand for cooling due to climate change in islands, the mathematical expression used was the following:

$$Q_{cooling}^{useful} = Q_{cooling} * A * PNT$$

Where $Q_{useful/cooling}$ is the annual residential space cooling demand potential in a particular NUT-3 region, in kWh/a; $Q_{cooling}$ is the specific cooling demand which depends on the CDD value of a particular NUTS-3 region in kWh/m^{2}a; *A* is the residential building stock in a NUTS-3 region in m^2, and *PNT* is the estimated percentage of households using Air Conditioning technology as a function of the CDD value of a NUTS-3 region. In our context, $Q_{cooling}$ = 0.051*CDD + 1.483.

Data from households having AC equipment and its usage was collected from USEID databases. Finally, energy demand was estimated under the four scenarios used in Soclimpact Project, RCP2.6 for near and distant future, and RCP8.5 for near and distant future.

For the case of the energy demand for water desalination induced by climate change, once SPEI was calculated for the set of islands using precipitation and evapotranspiration historic data and projections, the increase of water demand was estimated using population projections from specialised boards. Water desalination was assumed as the technology that would be used to satisfy the increasing water demand for most of the islands. Even for the few islands which still have the option of pumping more groundwater, it is a matter of fact that the natural hydrological balance is already broken and additional water elevation would impinge environmental costs in terms of ecosystems degradation; thus, desalination would be the most efficient technology if not just the conventional but also the environmental cost was taken into account.

Table 2.3.1. Summary of indicators for the energy sector.

WP4 Climate damages estimation	Output (input for GEM-E3 and GINFORS)	Reference Deliverables
Cooling Degree Days	Change in expenditure for energy services by end user (Households, Service sector, other)	Annex of D4.3
Available water: Standardized Precipitation Index	Change in expenditure for energy services by end user (Households, Service sector, other)	D4.3

Table 2.3.2. Energy demand for desalination

		RCP2.6		RCP8.5	
	Energy consumption (GWh/year)	Near	Distant	Near	Distant
Cyprus (CY)	294.00	388.08	388.08	517.44	760.64
Crete (GR)	13.10	17.30	17.30	22.01	33.90
Sicily (IT)	192.78	239.05	239.05	300.74	458.97
Sardinia (IT)	21.13	24.51	22.82	31.27	45.09
Corsica (FR)	-	-	-	-	-
Balearic Isl. (ES)	71.44	94.30	88.59	114.31	181.06
Malta (MT)	79.34	104.73	107.90	133.29	205.26
Canary Isl. (ES)	1121.40	1749.38	1794.24	2063.38	3428.79
Madeira (PT)	5.12	6.76	6.56	8.20	13.26
Azores (PT)	-	-	-	-	-

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Table 2.3.3. Energy demand for cooling

		RCP2.6		RCP8.5	
	Energy consumption (GWh/year)	Near	Distant	Near	Distant
Cyprus (CY)	858.10	1500.02	1398.01	2053.02	3024.62
Crete (GR)	185.66	285.56	199.65	459.65	586.63
Sicily (IT)	1527.41	2430.53	1705.70	3720.94	5112.23
Sardinia (IT)	374.15	618.18	424.53	965.91	1424.44
Corsica (FR)	34.57	77.08	68.34	131.49	295.01
Balearic Isl. (ES)	241.98	384.23	289.75	588.34	912.13
Malta (MT)	177.11	298.73	238.82	420.76	601.36
Canary Isl. (ES)	195.99 (RCP2.6) 504.06 (RCP8.5)	309.01	315.84	1178.4	1839.99
Madeira (PT)	0 (RCP2.6) 16.62 (RCP8.5)	4.98	5.62	59.00	117.42
Azores (PT)*	0 (SRES B1) 1.73 (SRES A1B)	3.16	-	17.92	-

*There are no climatic projections available for RCP2.6 and RCP8.5 for the case of Azores. Instead, scenarios of emissions SRES B1 (low emissions) and A1B (high emissions) have been considered.

Table 2.3.4. Energy demand for desalination + cooling

		RCP2.6		RCP8.5	
	Energy consumption (GWh/year)	Near	Distant	Near	Distant
Cyprus (CY)	1152.10	1888.10	1786.09	2570.46	3785.26
Crete (GR)	198.76	302.86	216.95	481.66	620.53
Sicily (IT)	1720.19	2669.58	1944.75	4021.68	5571.20
Sardinia (IT)	395.28	642.69	447.35	997.18	1.469.53
Corsica (FR)	34.57	77.08	68.34	131.49	295.01
Balearic Isl. (ES)	313.42	478.53	378.34	702.65	1093.19
Malta (MT)	256.45	403.46	346.72	554.05	806.62
Canary Isl. (ES)	1317.39 (RCP2.6) 1625.46 (RCP8.5)	2058.39	2110.08	3241.78	5268.78
Madeira (PT)	5.12 (RCP2.6) 21.74 (RCP8.5)	11.74	12.18	67.20	130.68
Azores (PT)*	0 (SRES B1) 1.73 (SRES A1B)	3.16	-	17.92	-

*There are no climatic projections available for RCP2.6 and RCP8.5 for the case of Azores. Instead, scenarios of emissions SRES B1 (low emissions) and A1B (high emissions) have been considered.

Table 2.3.5. Percentage of increase for desalination + cooling

	RCP2.6		RCP8.5	
	Near	Distant	Near	Distant
Cyprus (CY)	63.88	55.03	123.11	228.55
Crete (GR)	52.37	9.15	142.33	212.20
Sicily (IT)	55.19	13.05	133.79	223.87
Sardenia (IT)	62.59	13.17	152.27	271.77
Corsica (FR)	122.97	97.69	280.36	753.37
Balearic Isl. (ES)	52.68	20.71	124.19	248.79
Malta (MT)	57.32	35.20	116.05	214.54
Canary Isl. (ES)	56.25	60.17	99.44	224.14
Madeira (PT)	129.30	137.89	209.11	501.10
Azores (PT)*	-	-	935.84	-

*There are no climatic projections available for RCP2.6 and RCP8.5 for the case of Azores. Instead, scenarios of emissions SRES B1 (low emissions) and A1B (high emissions) have been considered. Moreover, the percentage increase cannot be computed when the reference is 0.

2.4. Aquaculture

The impact of climate change on the aquaculture sector was analysed by SMT Aquaculture (see D4.5 for details) via two approaches: the AHP (Analytic Hierarchy Process) method and the GIZ Risk Assessment method. For the purposes of the current Deliverable. GIZ method is a more suitable approach as it aims at evaluating changes in risk under different RCP scenarios.

Among the islands under investigation in the project. only Mediterranean islands. Azores and Madeira were considered due to data unavailability and/or absence of active marine cage aquaculture operations in the remaining islands. Table 2.4.1 presents climatic indicators relevant for the Aquaculture sector and the corresponding output to feed GEM-E3-ISL and GINFORS models.

Table 2.4.1. Summary of indicators for the aquaculture sector.

WP4 Climate damages estimation	Output (input for GEM-E3-ISL and GINFORS)	Reference Deliverables
Sea surface temperature	Change in productivity of the sector	D4.3 & Annex. D4.5
Wave amplitude (significant wave height)	Change in the productivity of sector	D4.3 & Annex. D4.5

Therefore. D4.5 accounts for these two hazards and evaluates changes in risk induced under respective RCP scenarios for mid-century and end-of-century horizons. **Sea surface temperature** hazard is constructed as a composite normalized indicator which considers sensitivity of various species and their share in total aquaculture production on each island. As regards **wave amplitude**, this indicator is also built as weighted average of two normalized subcomponents: significant wave height and return time. Estimations for return time were obtained using 3 different models; CMCC. CNRM and GUF, which provided highly variable results. For this reason, a best- and worst-case scenario were distinguished. where in the best-case scenario the minimum risk value was used and in the worst-case scenario the highest value was used. The current report presents and discusses results for the worst-case scenario, since results for best-case scenario are qualitatively similar. Table 3.3 contains projections of the two hazard variables for each RCP-timespan[4] pair and the corresponding estimated level of risk.

The main conclusions can be summarized as follows:

- projected changes in **wave amplitude** lead to negligible changes in risk on the Mediterranean islands, whereas too high levels of model uncertainty do not allow making any conclusion for the Atlantic islands (for this reason the output for this hazard for Azores and Madeira is omitted from Table 3.3);
- projected changes in **sea surface temperature** lead to increases in risk on both Mediterranean and Atlantic islands.

There is, however, no established methodology that would allow to translate the estimates of changes in risk to a quantitative change in sector productivity. Hence, we refrain from making any statement on the impact of thermal stress on aquaculture productivity. However, it would be correct to assume that if there is no change in risk, the associated change in productivity is zero. Therefore, we conclude that for the Mediterranean islands, projected changes in wave amplitude do not result in any change of aquaculture productivity.

[4] Unlike the other sectors, the analysis conducted for aquaculture employs RCP4.5 scenario instead of RCP2.6.

3. Sectoral Tables

This section consists of tables which provide the final outputs of this Deliverable. For each sector and projections of the climatic indicators, a corresponding projection for the output variable is provided for each island-scenario-horizon combination. Climatic projections for each island come from WP4 and cover a wide range of variables. As required by GEM-E3-ISL and GINFORS models, these projections are linked to RCP2.6 and RCP8.5 scenarios. As regards the time horizon, WP4 provides projections for the near (2046-2065) and distant (2081-2100) future (whereas the reference period is typically defined as 1986-2005 period). This yields four outcomes (two for each RCP scenario) for each climatic indicator. Zero values imply that the projected impacts are nil. Whenever a climatic indicator projection is not available for a given scenario-island pair, the corresponding cell of the output table is filled with "N/A", as it is not our aim to impose any assumption on how to impute missing climatic projections. If there is a strong necessity to impute values for other islands, one may adopt a weighting procedure at own risk.

How to read the Table (example): according to the results obtained by WP4, in the Balearic Islands the total beach surface loss will be 34% under the RCP2.6 in the near future (2046-2065), see Table 2.2.6. We know from Table 2.2.7 that 34% of beach loss will translate into a WTP of -12.60€ (given that the WTP is -0.37€ per day 1% of beach loss, see Table 2.2.7). Taking into consideration the average daily expenditure for visiting the Balearic Islands under the current situation (162€/person), the change in tourist expenditure is -7.78% (obtained from -12.60/162), under RCP2.6 near future. This is the value reported in the corresponding cell of Table 3.2.3. in Section 3.2.

3.1. Maritime Transport

3.1.1 – Cost of keeping ports operative due to sea level rise (values in € - total cost for the whole period)

	Mean Sea Level Rise																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Climatic variable projection (cm)	Damage of port infrastructure *(mill. €)*	*Climatic variable projection (cm)*	Damage of port infrastructure *(mill. €)*	*Climatic variable projection (cm)*	Damage of port infrastructure *(mill. €)*	*Climatic variable projection (cm)*	Damage of port infrastructure *(mill. €)*	*Climatic variable projection (cm)*	Damage of port infrastructure *(mill. €)*	*Climatic variable projection (cm)*	Damage of port infrastructure *(mill. €)*	*Climatic variable projection (cm)*	Damage of port infrastructure *(mill. €)*	*Climatic variable projection (cm)*	Damage of port infrastructure *(mill. €)*	*Climatic variable projection (cm)*	Damage of port infrastructure *(mill. €)*	*Climatic variable projection (cm)*	Damage of port infrastructure *(mill. €)*
reference		-		--		-		-		-		-		-		-		-		-
RCP2.6 near (2046-2065)	12	**3.10**	14	**9.23**	14	**152.49**	12	**49.63**	12	**26.46**	10	**37.26**	12	**12.04**	11	**10.84**	11	**18.12**	11	**31.62**
RCP2.6 distant (2081-2100)	24	**12.42**	27	**35.60**	27	**588.18**	25,0	**206.00**	24	**105.85**	20,0	**149.05**	23	**46.15**	21,0	**41.39**	22	**72.50**	23	**132.24**
RCP8.5 near (2046-2065)	34	**8.79**	37	**24.40**	37	**403.01**	33	**136.48**	32	**70.57**	29	**108.06**	32	**32.10**	29	**28.58**	30	**49.43**	31	**89.12**
RCP8.5 distant (2081-2100)	69	**35.69**	75	**98.90**	74	**1612.05**	66	**545.94**	65	**286.67**	58	**432.23**	63	**126.41**	58	**114.31**	60	**197.72**	63	**362.22**

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3.1.2 – Cost of keeping ports operative due to sea level rise (values in € - cost per year)

	Mean Sea Level Rise																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	SLR (cm)	Cost of keeping port operative (mill. €/year)	*SLR (cm)*	Cost of keeping port operative (mill. €/year)	*SLR (cm)*	Cost of keeping port operative (mill. €/year)	*SLR (cm)*	Cost of keeping port operative (mill. €/year)	*SLR (cm)*	Cost of keeping port operative e (mill. €/year)	*SLR (cm)*	Cost of keeping port operative (mill. €/year)	*SLR (cm)*	Cost of keeping port operative (mill. €/year)	*SLR (cm)*	Cost of keeping port operative (mill. €/year)	*SLR (cm)*	Cost of keeping port operative (mill. €/year)	*SLR (cm)*	Cost of keeping port operative (mill. €/year)
Reference		-		--		-		-		-		-		-		-		-		-
RCP2.6 near	12	**0.062**	14	**0.185**	14	**3.050**	12	**0.993**	12	**0.529**	10	**0.745**	12	**0.241**	11	**0.217**	11	**0.362**	11	**0.632**
RCP2.6 distant	24	**0.124**	27	**0.356**	27	**5.882**	25,0	**2.068**	24	**1.058**	20,0	**1.490**	23	**0.461**	21,0	**0.417**	22	**0.725**	23	**1.322**
RCP8.5 near	34	**0.176**	37	**0.488**	37	**8.060**	33	**2.730**	32	**1.411**	29	**2.161**	32	**0.642**	29	**0.572**	30	**0.989**	31	**1.782**
RCP8.5 distant	69	**0.357**	75	**0.989**	74	**16.120**	66	**5.459**	65	**2.867**	58	**4.322**	63	**1.264**	58	**1.143**	60	**1.977**	63	**3.622**

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3.2. Tourism

Table 3.2.1 – Impact of loss of attractiveness of tourism marine environments

	IC#1 – Loss of attractiveness of tourism marine environments (seagrass evolution - % loss of most spread seagrass) – from D5.5																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Climatic variable projection (% loss)	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% loss)*	Change in total tourist expenditure *(% change from reference case)*
Reference	*Average daily expenditure (€/person)*	90.5		123.94		138.9		162		115.00		75		95		63		83		129.7
	Average stay (days)	13		8.9		9.09		6.7		7		9		7		3.7		4.6		9.1
	Average expenditure per person (€)	1172		1199.85		1139		1088		807		674.7		663		-		-		1180
RCP2,6 near	N/A		N/A		0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
RCP2,6 distant	N/A		N/A		0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
RCP8,5 near	N/A		N/A		0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
RCP8,5 distant	N/A		N/A		0	**0**	35.1	**-19.00**	20.1	**-8.95**	0	**0**	0	**0**	0	**0**	14.4	**-12.40**	28.3	**-7.94**

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Table 3.2.2 – Impact of increased danger of forest fire in tourism areas

	IC#1 – increased danger of forest fire in tourism areas (Fire Weather Index – FWI) – from D5.5																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Climatic variable projection (normalized FWI mean values)	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (normalized FWI mean values)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (normalized FWI mean values)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (normalized FWI mean values)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (normalized FWI mean values)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (normalized FWI mean values)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (normalized FWI mean values)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (normalized FWI mean values)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (normalized FWI mean values)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (normalized FWI mean values)*	Change in total tourist expenditure *(% change from reference case)*
Reference	*Average daily expenditure (€/person)*	90.5		123.94		138.9	0.237	162	0.283	115	0.527	75	0.483	95	0.226	63	0.305	83	0.349	129.7
	Average stay (days)	13		8.9		9.09		6.7		7		9		7		3.7		4.6		9.1
	Average expenditure per person (€)	1172		1199.85		1139		1088		807		674.7		663		-		-		1180
RCP2,6 near	N/A		N/A		N/A		0.245	**0**	0.294	**0**	0.554	**0**	0.534	**0**	0.238	**0**	0.316	**0**	0.371	**0**
RCP2,6 distant	N/A		N/A		N/A		0.233	**0**	0.292	**0**	0.555	**0**	0.525	**0**	0.226	**0**	0.302	**0**	0.365	**0**
RCP8,5 near	N/A		N/A		N/A		0.264	**0**	0.309	**0**	0.608	**-22.54**	0.579	**-17.79**	0.269	**0**	0.361	**-20.37**	0.409	**0**
RCP8,5 distant	N/A		N/A		N/A		0.313	**0**	0.363	**0**	0.644	**-22.54**	0.67	**-17.79**	0.329	**0**	0.433	**-20.37**	0.506	**-13.03**

Table 3.2.3 – Impact of beach reduction

	Beach Reduction (% from reference) – from D5.5																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Climatic variable projection (% beach surface loss)	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% beach surface loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% beach surface loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% beach surface loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% beach surface loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% beach surface loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% beach surface loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% beach surface loss)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% beach surface loss)*	Change in total tourist expenditure *(% change from reference case)*
Reference	*Average daily expenditure (€/person)*	90.5		123.94		138.9		162		115		75		95		63		83		129.7
	Average stay (days)	13		8.9		9.09		6.7		7		9		7		3.7		4.6		9.1
	Average expenditure per person (€)	1172		1199.85		1139		1088		807		674.7		663		-		-		1180
RCP2,6 near	53	**-21.72**	48	**-14.36**	38	**-10.14**	34	**-7.78**	28	**-9.03**	22	**-10.88**	27	**-10.54**	23	**-13.54**	25	**-11.17**	24	**-6.86**
RCP2.6 distant	62	**-25.40**	57	**-17.05**	48	**-12.81**	45	**-10.30**	40	**-12.90**	30	**-14.83**	38	**-14.83**	32	**-18.83**	35	**-15.64**	34	**-9.72**
RCP8,5 near	85	**-34.83**	78	**-23.34**	62	**-16.55**	51	**-11.67**	58	**-18.70**	38	**-18.79**	53	**-20.69**	38	**-22.37**	42	**-18.76**	47	**-13.44**
RCP8,5 distant	99	**-40.56**	95	**-28.42**	80	**-21.36**	70	**-16.02**	70	**-22.57**	54	**-26.70**	68	**-26.54**	54	**-31.78**	58	**-25.91**	61	**-17.44**

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Table 3.2.4 – Impact of change in human being comfort (from D5.3)

	IC #2 – human being comfort (number of days per year with Humidex > 35°C) – from D5.3																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Climatic variable projection (number of days)	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*
Reference	16.3	-	0.2 (for rcp2.6)	-	6.4 (for rcp2.6)	-	52.9	-	48.1	-	92.1	-	31.3	-	14.4	-	49.7	-	52.0	-
RCP2.6 near	27.15	**2.9**	0.6	**0.1**	11.5	**1.4**	67.7	**3.6**	66.7	**1.8**	112.4	**3.1**	48.4	**2.7**	27.1	**3.2**	65.3	**4**	68.5	**0.5**
RCP2.6 distant	N/A	**N/A**	0.8	**0.2**	12.7	**1.7**	66.1	**3.2**	67.7	**1.9**	114.0	**3.4**	51.0	**3.1**	27.1	**3.2**	64.0	**3.7**	70.1	**0.6**
RCP8.5 near	35.55	**4.5**	5.2 (ref 1.9)	**0.9**	27.2 (ref 14.8)	**5.3**	69.9	**4.1**	71.2	**2.2**	118.4	**4.1**	55.7	**3.9**	28.9	**3.6**	68.6	**4.9**	74.1	**0.7**
RCP8.5 distant	N/A	**N/A**	29.7 (ref 1.9)	**7.6**	75.5 (ref 14.8)	**18.6**	114.7	**15.3**	118.2	**6.7**	161.7	**10.9**	103.0	**11.5**	72.1	**14.7**	112.2	**16.3**	118.7	**2.1**

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Table 3.2.5 – Impact of change in human being comfort (from D5.5)

	IC #2 – human being comfort (number of days per year with Humidex > 35°C) – from D5.5																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Climatic variable projection (number of days)	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*
Reference	16.3	90.5	0.2 (for rcp2.6)	123.94	6.4 (for rcp2.6)	138.9	52.9	162	48.1	115	92.1	75	31.3	95	14.4	63	49.7	83	52	129.7
		13		8.9		9.09		6.7		7		9		7		3.7		4.6		9.1
		1172		1199.85		1139		1088		807		674.7		663.00		-		-		1180
RCP2,6 near	27.15	**-0.84**	0.6	**-0.01**	11.5	**-0.23**	67.7	**-1.17**	66.7	**-1.63**	112.4	**-4.20**	48.4	**-1.43**	27.1	**-1.21**	65.3	**-2.21**	68.5	**-1.48**
RCP2,6 distant	N/A	**N/A**	0.8	**-0.02**	12.7	**-0.26**	66.1	**-1.14**	67.7	**-1.65**	114	**-4.26**	51	**-1.51**	27.1	**-1.21**	64	**-2.16**	70.1	**-1.52**
RCP8,5 near	35.55	**-1.10**	5.2 (ref 1.9)	**-0.12**	27.2 (ref 14.8)	**-0.55**	69.9	**-1.21**	71.2	**-1.74**	118.4	**-4.43**	55.7	**-1.64**	28.9	**-1.29**	68.6	**-2.32**	74.1	**-1.60**
RCP8,5 distant	N/A	**N/A**	29.7 (ref 1.9)	**-0.67**	75.5 (ref 14.8)	**-1.52**	114.7	**-1.99**	118.2	**-2.88**	161.7	**-6.05**	103	**-3.04**	72.1	**-3.21**	112.2	**-3.79**	118.7	**-2.57**
Alternative outcome measure for RCP8,5 near: % change in tourist arrivals																				
RCP8,5 near	*35.55*	*-51,0% arrivals*	*5,2 (ref 1,9)*	*-69,84% arrivals*	*27,2 (ref 14,8)*	*-68,33% arrivals*	*69.9*	*-87,35% arrivals*	*71.2*	*-58,43% arrivals*	*118.4*	*-72,48% arrivals*	*55.7*	*-9,38% arrivals*	*28.9*	*-46,55% arrivals*	*68.6*	*-46,55% arrivals*	*74.1*	*-32,76% arrivals*

Table 3.2.6 – Impact of change in human being comfort (alternative indicator)

	IC #2 – human being comfort (Percentage of days when T > 98th percentile - T98p) – from D5.3																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Climatic variable projection (% of hot days)	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% of hot days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% of hot days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% of hot days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% of hot days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% of hot days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% of hot days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% of hot days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% of hot days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (% of hot days)*	Change in total tourist expenditure *(% change from reference case)*
Reference	2	-	2	--	2	-	2	-	2	-	2	-	2	-	2	-	2	-	2	-
RCP2.6 near	4.35	**2.3**	8.2	**6**	5.4	**3.3**	7.0	**4.8**	9.1	**2.5**	6.3	**2.7**	5.5	**2.1**	5.5	**3.8**	5.0	**2.6**	5.0	**0.3**
RCP2.6 distant	N/A	**N/A**	10.5	**8.3**	6.8	**4.6**	6.6	**4.5**	9.1	**2.5**	6.5	**2.8**	5.9	**2.3**	5.0	**3.2**	4.9	**2.5**	5.2	**0.4**
RCP8.5 near	6.4	**4.3**	7.8	**5.6**	6.9	**4.7**	7.6	**5.4**	11.2	**3.2**	7.8	**3.6**	7.4	**3.2**	5.5	**3.8**	5.3	**2.8**	5.9	**0.45**
RCP8.5 distant	N/A	**N/A**	25.7	**23.5**	24.9	**22.7**	23.3	**21.1**	26.8	**8.8**	22.1	**12.7**	21.4	**11.5**	19.2	**18.9**	18.3	**14.1**	19.3	**2**

Table 3.2.7 – Impact of the change in length of the window of opportunity for vector-borne disease

	Length of the window of opportunity for vector-borne diseases (Habitat Suitability Index for tiger mosquito) – from D5.5																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Climatic variable projection (HSI value)	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (HSI value)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (HSI value)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (HSI value)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (HSI value)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (HSI value)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (HSI value)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (HSI value)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (HSI value)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (HSI value)*	Change in total tourist expenditure *(% change from reference case)*
Reference		-		--		-	66.1	-	62.9	-	68.7	-	74.8	-	84.9	-	87.1	-	83.7	-
RCP2.6 near	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	66.8	**0**	69.7	**0**	71	**0**	76.2	**0**	87.2	**0**	87.2	**0**	85.4	**0**
RCP2.6 distant	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	69.2	**0**	67.5	**0**	69.4	**0**	76.2	**0**	89.9	**0**	90.2	**0**	86.1	**0**
RCP8.5 near	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	62.5	**0**	60.3	**0**	60.6	**0**	69.8	**0**	87.8	**0**	83.7	**0**	79.8	**0**
RCP8.5 distant	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	52.3	**0**	46.4	**0**	47.2	**0**	62.8	**0**	83.8	**0**	74.7	**0**	67.7	**0**

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3.3. Energy

Table 3.3.1 – Change in energy demand due to change in cooling degree days – Risk Score

	IC #2 - changes in energy demand due to changes in precipitations and temperatures (Cooling Degree Days)																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Climatic variable projection (CDD)	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)
Reference		-		--		-		-	286.5	-	460.2	-		-		-		-		-
RCP2.6 near		N/A		N/A	127.4 (ref. 80.7)	4.1		N/A	416.9	4.3	628.8	5.7		N/A		N/A		N/A		N/A
RCP2.6 distant		N/A		N/A	146.6 (ref. 80.7)	6.2		N/A	425.7	3.9	635.4	5.3		N/A		N/A		N/A		N/A
RCP8.5 near		N/A		N/A	211.4 (ref. 130.2)	16.3		N/A	458.1	8.2	675.7	11.4		N/A		N/A		N/A		N/A
RCP8.5 distant		N/A		N/A	479.0 (ref. 130.2)	38.3		N/A	887.8	16.7	1183.5	21.8		N/A		N/A		N/A		N/A

Table 3.3.2 – Change in energy demand due to change in precipitation and temperatures – Risk Score

	IC #2 - changes in energy demand due to changes in precipitations and temperatures (Available water: Standardized Precipitation-Evotranspiration Index)																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Climatic variable projection (SPI)	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)
reference		-		--	0	-		-	0	-	0	-		-		-		-		-
RCP2.6 near		N/A		N/A	-1.4	60.2		N/A	-0.8	13.7	-0.8	3		N/A		N/A		N/A		N/A
RCP2.6 distant		N/A		N/A	-1.5	64.5		N/A	-0.9	15.4	-0.8	3		N/A		N/A		N/A		N/A
RCP8.5 near		N/A		N/A	-2.1	90.4		N/A	-1.7	29.1	-1.9	7		N/A		N/A		N/A		N/A

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RCP8.5 distant		N/A		N/A	-2.4	103.3		N/A	-2.4	41.1	-2.4	8.9		N/A		N/A		N/A		N/A

Table 3.3.3 – Change in energy demand due to change in cooling degree days – Energy Demand $(Q_{cooling}^{useful} = Q_{cooling} * A * PNT)$

	IC #2 - changes in energy demand due to changes in precipitations and temperatures (Cooling Degree Days)																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Climatic variable projection (CDD)	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)	*Climatic variable projection (CDD)*	Change in **cooling** energy demand (% change from reference case)
Reference: Energy consumption (GWh/year)	16.09 (SRES B1) 28.22 (SRES A1B)	**0 (SRES B1) 1.73 (SRES A1B)**	13.69 (RCP2.6) 74.22 (RCP8.5)	**0 (RCP2.6) 16.62 (RCP8.5)**	94.42 (RCP2.6) 186.72 (RCP8.5)	**195.99 (RCP2.6) 504.06 (RCP8.5)**	194,15	**241.98**	286.5	**177.11**	460.2	**858.1**	221.84	**185.66**	92.43	**34.57**	169.53	**374.15**	210.40	**1527.41**
RCP2.6 near	35.33	**-**	41.77	**-**	143.14	**57.67**	305.01	**58.79**	441.86	**68.67**	653.96	**74.81**	344.75	**53.81**	159.85	**122.97**	268.43	**65.22**	325.64	**59.13**
RCP2.6 distant	N/A	**N/A**	48.90	**-**	170.05	**61.15**	288.90	**19.74**	425.74	**34.84**	635.39	**62.92**	333.70	**7.54**	149.72	**97.69**	254.72	**13.47**	314.05	**11.67**
RCP8.5 near	90.84	**935.84**	207.71	**254.99**	395.66	**133.78**	424.96	**143.14**	579.15	**137.57**	841.02	**139.25**	500.56	**147.58**	238.74	**280.36**	379.16	**158.16**	454.09	**143.61**
RCP8.5 distant	N/A	**N/A**	410.93	**606.50**	665.24	**265.03**	711.52	**276.94**	887.85	**239.54**	1183.49	**252.48**	781.85	**215.97**	457.56	**753.37**	656.71	**280.71**	746.00	**234.70**

Table 3.3.4 – Change in energy demand due to change in precipitation and temperatures – Energy Demand

	IC #2 - changes in energy demand due to changes in precipitations and temperatures (Available water: Standardized Precipitation-Evotranspiration Index)																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Climatic variable projection (SPI)	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)	*Climatic variable projection (SPI)*	Change in **desalination** energy demand (% change from reference case)
Reference: Energy consumption (GWh/year)	N/A	**N/A**	0	**5.12**	0	**1121.40**	0	**71.44**	0	**79.34**	0	**294**	0	**13.10**	0	**N/A**	0	**21.13**	0	**192.78**

RCP2.6 near	N/A	**N/A**	0.32	**32.03**	0.56	**56.00**	0.32	**32.00**	0.32	**32.00**	0.32	**32.00**	0.32	**32.06**	0.12	**N/A**	0.16	**16.00**	0.24	**24.00**
RCP2.6 distant	N/A	**N/A**	0.28	**28.13**	0.6	**60.00**	0.24	**24.01**	0.36	**36.00**	0.32	**32.00**	0.32	**32.06**	0.04	**N/A**	0.08	**8.00**	0.24	**24.00**
RCP8.5 near	N/A	**N/A**	0.6	**60.16**	0.84	**84.00**	0.6	**60.01**	0.68	**68.00**	0.76	**76.00**	0.68	**68.02**	0.4	**N/A**	0.48	**47.99**	0.56	**56.00**
RCP8.5 distant	N/A	**N/A**	0.96	**158.98**	0.96	**205.76**	0.92	**153.44**	0.96	**158.71**	0.96	**158.72**	0.96	**158.78**	0.8	**N/A**	0.84	**113.39**	0.92	**138.08**

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3.4. Aquaculture

Table 3.4.1 – Change in risk for aquaculture due to an increase of wave height and return time

	IC #2 – increased fragility of the aquaculture activity due to an increase of extreme weather (Significant Wave Height and Return Time)																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score
Reference		-		--		-		-	0.4	0.40	0.07	0.24		-	0.21	0.25	0.31	0.35	0.27	0.37
RCP4.5 near	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	0.46	0.43	0.07	0.23	N/A	**N/A**	0.21	0.25	0.32	0.36	0.32	0.41
RCP4.5 distant	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	0.45	0.43	0.09	0.24	N/A	**N/A**	0.26	0.28	0.32	0.35	0.32	0.40
RCP8.5 near	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	0.63	0.54	0.07	0.23	N/A	**N/A**	0.24	0.27	0.32	0.36	0.31	0.40
RCP8.5 distant	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	N/A	**N/A**	0.3	0.34	0.07	0.23	N/A	**N/A**	0.23	0.26	0.31	0.35	0.2	0.33

Table 3.4.2 – Change in risk for aquaculture due to an increase in thermal stress

	IC #2 – increased fragility of the aquaculture activity due to an increase of extreme weather (Thermal stress)																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score	Level of hazard score	Risk score
Reference		-	0	0.17		-		-	0.3	0.57	0.4	0.49		-	0.1	0.36	0.1	0.47	0.4	0.57
RCP4.5 near	N/A	**N/A**	0.2	**0.24**	N/A	**N/A**	N/A	**N/A**	0.5	0.62	0.6	0.57	N/A	**N/A**	0.3	0.4	0.3	0.52	0.5	0.62
RCP4.5 distant	N/A	**N/A**	0.2	**0.22**	N/A	**N/A**	N/A	**N/A**	0.6	0.64	0.7	0.59	N/A	**N/A**	0.4	0.44	0.4	0.54	0.6	0.64
RCP8.5 near	N/A	**N/A**	0.1	0.22	N/A	**N/A**	N/A	**N/A**	0.6	0.63	0.6	0.57	N/A	**N/A**	0.5	0.48	0.3	0.53	0.5	0.63

RCP8.5 distant	N/A	**N/A**	0.5	0.33	N/A	**N/A**	N/A	**N/A**	0.7	0.68	1	0.67	N/A	**N/A**	0.6	0.48	0.5	0.59	0.7	0.67

4. Discussion and implications

Important issues and limitations come to light in this Report, also due to its key position in Soclimpact project. One, despite the close-up on specific islands and sectors, and despite the production of downscaled climate projections, change in risks and in their economic consequences are still very difficult to estimate, requiring additional assumptions to be made in each sector.

Two, as regards tourism, estimations produced through different methodologies show different and sometimes contrasting results, which well pin down the difference in underlying assumptions. Choice experiments are based on hypothetical decisions made by tourists facing alternative scenarios. Whether these stated preferences, elicited on paper, will translate in real decisions should the scenario take place, is debatable. Big data, on the other hand, reveal the preferences of economic agents. However, for the very nature of big data, those preferences are elicited now, in the baseline scenario of 2019, when these data were collected. The underlying assumption used in this Report for big data analysis is that preferences will be stable along different scenarios and time horizons, hence adapting to the different conditions, which is, in turn, an arguable assumption too.

The big data approach has been experimented for the first time in this kind of analysis, and what it captures is, to a large extent, a short-term reaction of the sector rather than the long-term likely trends. As we stand now, big data are probably not completely fit to monitor the behavioural response to future climate changes. However, this approach allows to highlight a couple of issues that will have to be addressed in future extensions of this type of research:

a. The "domestic-international" tourism dichotomy. Last minute price changes (analysed by the big data approach) are more likely to affect domestic rather than inbound tourism. In this regard, it is likely that future climate change will push individuals to choose leisure destinations (including those in islands) when temperatures are hot more often than today. Increased possibilities of working at distance, stemming from smart working developments, would make this impact even more pronounced for domestic tourism, especially in scenarios where temperatures increase everywhere, in cities as in leisure destinations. If this happens, it is likely that the future trends in domestic tourism will partially compensate for declining trends of inbound tourism projected by the choice experiment approach. For this reason, final effects are likely to be lower than those suggested by choice experiments.
b. Surveys ask what tourists choose if the temperature increases in the destination (implicitly suggesting that they could move to other destinations not subject to similar changes). However, the surge in temperatures is likely to hit all competing destinations more or less evenly, not substantially changing the relative position of the island. It is possible that new destinations at higher latitudes will enter the market, or that tourists will choose different types of destinations (e.g. mountain resorts). However, some of the respondents who declared to change destination are likely not to do so, because of "lack of feasible alternatives". Consequently, real decrease in arrivals and expenditure will probably be lower than the one estimated by choice experiments.

For these reasons we propose to consider the estimations derived from D5.5 with caution, as worst-case projections, knowing that effects (a) and (b) above will probably counteract the final impact. Operationally, when analysing the effect of future Human being comfort on tourism expenditure, and willing to account for the countereffect of domestic/inbound tourism and of the general increase in temperatures, it would be possible to merge D5.5 and D5.3 results by weighting the two projected changes using current shares of domestic and inbound arrivals in the total number of flows. This approach would require assuming that the domestic-international composition of overnights will remain constant. The formula would be:

D5*X + D3*(1-X)

where D5 is the percentage change in tourism expenditure estimated by D5.5 in Table 3.2.5; D3 is the percentage change in tourism expenditure estimated by D5.3 in Table 3.2.4; X is the share of inbound tourists over total arrivals and (1-X) is the complementary share of domestic tourists. For example, we know that in RCP2.6, near future, tourism expenditure will decrease by 0.58% in the Balearic Islands due to human being discomfort stemming from extreme temperatures (Table 3.2.5). However, expenditure would increase in the same scenario by 3.6% because of the "price effect" (Table 3.2.4). Knowing that in Balearic Islands inbound tourists are 83% of total arrivals (the remaining 17% being domestic tourists, the net effect would be 0.13% (= -0.58*0.83 + 3.6*0.17). This estimate can be considered the "best case" scenario built by merging the two alternatives, and is reported in the Appendix, Table A.3

Three, as regards aquaculture, we reported estimates coming from SMT Aquaculture (specifically, their Deliverable D4.5). Different methodologies, especially the ones based on production function technology, can entail contrasting results, as productivity can be found to increase as a consequence of the change in temperatures, while no firm conclusion can be attained as regards the impact of extreme events. The production function approach can entail interesting and useful results in the future, but the approach still needs to be refined and calibrated to parameters that more closely resemble the real conditions of the different islands. For this reason, the present report only considers the SMT Aquaculture findings, based on GIZ risk assessment method.

Four, as regards maritime transport, the negligible change in the frequency and intensity of extreme events projected in the scenarios applied to the islands under investigation allows us to conclude that the cost of interrupted transport service, in the future, will be almost non-existent. It is then possible to focus on the impact of SLR and make a simplifying assumption: as SLR happens slowly and gradually, it is likely that future investments will prevent any transport interruption: hence, the economic impact of SLR can be proxied by the cost of updating infrastructures to keep ports operating, and this is the approach followed in this report. Clearly, such procedure cannot be extended to regions where extreme events are likely to increase in the future.

Five, as regards energy, the major risk identified stems from the increase in temperatures and the decrease in precipitation, leading to shortage of water. Consequently, the demand of energy for desalinization of water is expected to increase steeply. On the other hand, the increase of energy demand for cooling degree days will also increase, but to a much lesser extent, as at the same time milder temperatures will decrease energy demand for heating degree days. Again, the specificity of these considerations (for example, water shortage is much more important for islands than for mainland destinations) make these simplifying assumptions not extendable to all scenarios and destinations.

With these caveats in mind, the Report however constitutes a starting point towards a better comprehension and evaluation of the socio-economic impacts of climate change. As this is an extraordinarily complex issue, further refinements in both the methodological approach and in translating the risks into economic figures will be addressed in future research.

5. Concluding remarks

This Report has a key position in the channel of transmission between the physical and climatologic sections of SOCLIMPACT project and the socio-economic one. Its aim is to associate the change of selected climatic indicators projected in different scenarios and at different points in time with the estimated economic response of the four Blue Economy sectors investigated by the project (aquaculture, energy, maritime transport, tourism).

As regards climate variables, values of selected indicators of climate change (linked to the three main Impact Chains considered by the project) in two reference scenarios (RCP2.6 and RCP8.5), in two different time horizons (near future, around 2050 and distant future, around 2100), in ten islands under investigation are estimated using the output of WP4 as reference. As regards the economic response of the Blue Economy sectors in these scenarios, values are estimated using the output of WP5, together with other outputs produced by aquaculture, energy, and maritime transport Sector Modelling Teams (SMT).

Results for the Aquaculture sector only find a marginal shift in the index of risk, leading to the conclusion that projected changes in wave amplitude and in sea surface temperature either do not result in any change of aquaculture productivity, or such changes cannot be ascertained with sufficient approximation.

Results for the Energy sector show that the impact of climate change is considerable, especially the one associated to an increase in demand for desalination energy due to change in precipitation and temperatures. Changes range from moderate in Cyprus (from 3% to 8.9%) to very high in the Canary Islands (from 60.2% in RCP2.6, near future to 103.3% in RCP8.5, distant future).

The increase in demand due to change in cooling degree days is less important, as it is partially outbalanced by a decrease in demand for heating degree days. Change in energy demand goes from about 4% to 6% in the two different time horizons of RCP2.6, and from 8.2% (Malta, near future) to 38.3% (Canary Islands, distant future) for RCP8.5.

Results for the Maritime tourism sector show that the economic impact stems from SLR, while changes in frequency and intensity of storms, winds and wave height are not projected to change in the considered scenarios. SLR impacts the economy through the cost of keeping ports operative, estimated to substantially differ in the two scenarios. If we focus on the distant future (2100), costs range from € 10.3 million (Azores) to € 515 million (Canary Islands) in RCP2.6, and from € 29.5 million (Azores) to € 1.41 billion (Canary Islands) in RCP8.5.

Results for the Tourism sector, stemming from the two different methodologies (choice experiments and big data) that were applied in D5.5 and D5.3 respectively, can be summarised as follows:

- Loss of marine habitat attractiveness, measured by the evolution of seagrass, would affect the islands only in the distant scenario of RCP8.5, implying a reduction of about 8-9% of per capita expenditure in Sicily and Malta, and more than 10% in Sardinia and in the Balearic Islands. No change is projected for the other islands.

- The increased danger of forest fires would affect only RCP8.5, but only a few islands (Cyprus, Crete, Sardinia, Sicily) bringing a reduction of about 13-20% of per capita expenditure.
- Beach reduction, on the contrary, would affect all islands and all scenarios, being also economically relevant. The drop in per capita expenditure would range from 6.86% (Sicily, RCP2.6 near) to 40.56% (Azores, RCP8.5 distant).
- The drop in per capita expenditure stemming from the increase in temperatures would range from 0.01% in Madeira to 4.20% in Cyprus (RCP2.6); from 0.67% in Madeira to 6.05% in Cyprus (RCP8.5). In the distant scenario of RCP8.5, most islands would experience a loss of about 2-4% of expenditure (Balearic Islands, Malta, Crete, Sardinia, Sicily).
- The use of an alternative approach (the one of big data), allows us to see things differently. Assuming that the worsening of human being comfort hits people anywhere they are, they would be willing to travel and go on holiday exactly when the temperature is higher, looking for more refreshing activities on the beach and the like. In this case it is possible to project that per capita expenditure would increase from 0.1% in Madeira (RCP2.6, near) to 18.6% (Canary Islands, RCP8.5 distant).
- As regards human being comfort, one might decide to merge these two alternative approaches by subtracting the values estimated in Tables 3.2.5 and 3.2.4 for the same island-time-scenario combination, hence considering the overall impact. This is done in Table A.3, in the Appendix.
- Finally, as the risk of increasing the window of opportunities for vector-borne disease would not change in the considered scenarios, no economic impact is projected for this reason.

Overall, the great heterogeneity of results among islands, scenarios and time horizons highlights the importance of downscaling climate projections and of adapting them to the different economic characteristics of the islands. In this respect, it is also important to underline that economic projections also substantially differ between islands of the same region (Mediterranean Sea; Atlantic Ocean), once more calling for specific in-depth investigation of each territory.

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Appendix: adaptation policies

A total of 2528 tourists were surveyed at ten island destinations: Azores, Balearic Islands, Canary Islands, Crete, Cyprus, Fehmarn Island, Madeira, Malta, Martinique & Guadeloupe (Antilles) and Sicily. Respondents were posed with hypothetical scenarios, in which two alternative sets of adaptation policies to climate change impacts were presented. They were asked to choose between one of the options for which they would have to pay an extra price per day and "no policy" (at price 0€). Each climate change impact was accompanied by a generic adaptation policy that could be implemented at the destination to ameliorate its impact, and only two levels were considered: the policy is implemented or not. The description of the adaptation policies and their levels are summarized in Table A.1. Each subject answered to six different choice sets.

Table A1. Description of attributes considered in the Choice Experiment (Survey at Destination).

Attribute	Description	Levels	Model
Price	Price per day per person. Extra payment above current expenses.	0€ if no policy 1 € 3 € 5 € 7 €	Defined as a continuous variable in the regression
Heat Waves Amelioration	This policy consists of early warning. proper information for vulnerable groups, air conditioning in public indoor and outdoor places, increasing green and watered areas and provision of proper medical care for heat-related diseases.	No Policy Policy	Defined as a continuous variable in the regression
Infectious diseases Prevention	This policy consists of proper information and advisement to face outbreaks, fumigation of mosquitoes' prone areas, and emergency medical care plans.	No Policy Policy	Defined as a categorical variable in the regression
Beaches Protection	This involves building seawalls and breakwaters, nourishment of sandy beaches when needed and building compensatory artificial beaches across coastal areas.	No Policy Policy	Defined as a categorical variable in the regression
Water Supply	This includes desalination plants and water facilities reinforcement to guarantee fresh water supply.	No Policy Policy	Defined as a categorical variable in the regression
Forest Fires Prevention	This policy consists of improving forest management to reduce combustibility, increasing firefighting technical and human resources. and investing more in post-fires landscape and habitats restoration.	No Policy Policy	Defined as a categorical variable in the regression
Marine Habitats Restoration	This involves removing death seagrass from the beaches sand, offering marine biodiversity-based facilities and providing accurate information on best places for each marine activity.	No Policy Policy	Defined as a categorical variable in the regression
Land Habitats Restoration	This involves reforestation and landscape restoration, enhancing protected areas network and encouraging botanic gardens and wildlife show places.	No Policy Policy	Defined as a categorical variable in the regression
Coastal Infrastructures Protection	This policy will provide proper information on prevention. and	No Policy	Defined as a categorical variable in the regression

	emergency facilities against disasters; reinforce coastal structures; and facilitate access to alternative safe places and attractions.	Policy	
Cultural Heritage Protection	This policy consists of reinforcing protection of exposed heritage and moving the endangered cultural assets to alternative safe locations.	No Policy Policy	Defined as a categorical variable in the regression

The conditional logit (McFadden's choice) model was applied to estimate the results of the discrete choice experiment. Elicited tourists' willingness to pay for the implementation of adaptation policies at islands destinations are summarized in Table A2. In this case, outputs to WP6 are measured as increase in expenditure by tourists in €/day above the current expenditure. In addition, average expenditure per day per tourist (in €) is provided for each island, obtained from the information asked to tourists about their trip. For some risks, information on WTP elicited from the literature (see D5.2) is also presented for comparison purposes.

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Table A.2. Tourists' willingness to pay for adaptation policies (in €).

	IC#1 – Loss of attractiveness of touristic marine environments (seagrass evolution)																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Measure	Increase in expenditure by tourist €/day above the current. *number of tourists *average no. nights stay is required	*Measure*	Increase in expenditure by tourist €/day above the current. *number of tourists *average no. nights stay is required	*Measure*	Increase in expenditure by tourist €/day above the current. *number of tourists *average no. nights stay is required	*Measure*	Increase in expenditure by tourist €/day above the current. *number of tourists *average no. nights stay is required	*Measure*	Increase in expenditure by tourist €/day above the current. *number of tourists *average no. nights stay is required	*Measure*	Increase in expenditure by tourist €/day above the current. *number of tourists *average no. nights stay is required	*Measure*	Increase in expenditure by tourist €/day above the current. *number of tourists *average no. nights stay is required	*Measure*	Increase in expenditure by tourist €/day above the current. *number of tourists *average no. nights stay is required	*Measure*	Increase in expenditure by tourist €/day above the current. *number of tourists *average no. nights stay is required	*Measure*	Increase in expenditure by tourist €/day above the current. *number of tourists *average no. nights stay is required
Reference case: Average expenditure (€) per day	FROM SURVEYS	117.2 €/day		139.3 €/day		148.8 €/day		173.5 €/day		75.6 €/day		124.2 €/day		102.5 €/day						129.7 €/day
	FROM OFFICIAL SOURCES	90.5 €/day		123.94 €/day		138.9 €/day		162 €/day		115 €/day		75 €/day		95 €/day		63 €/day		83 €/day		
Elicited from D5.5	Marine Habitats Restoration	10.03 €/day	Marine Habitats Restoration	10.34 €/day	Marine Habitats Restoration	12.54 €/day	Marine Habitats Restoration	0.61 €/day	Marine Habitats Restoration	5.74 €/day	Marine Habitats Restoration	5.93 €/day	Marine Habitats Restoration	1.38 €/day					Marine Habitats Restoration	3.24 €/day
Elicited from the literature							Marine restoration	WTPs 3.20 €/day.	Marine restoration	WTPs 3.20 €/day.	Marine restoration	WTPs 3.20 €/day.	Marine restoration	WTPs 3.20 €/day.	Marine restoration	WTPs 3.20 €/day.	Marine restoration	WTPs 3.20 €/day.	Marine restoration	WTPs 3.20 €/day.
	IC#1 – increased danger of forest fire in touristic areas (Fire Weather Index – FWI)																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Measure	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current.	*Measure*	Increase in expenditure by tourist €/day above the current.	*Measure*	Increase in expenditure by tourist €/day above the current.	*Measure*	Increase in expenditure by tourist €/day above the current.	*Measure*	Increase in expenditure by tourist €/day above the current.	*Measure*	Increase in expenditure by tourist €/day above the current.	*Measure*	Increase in expenditure by tourist €/day above the current.	*Measure*	Increase in expenditure by tourist €/day above the current.	*Measure*	Increase in expenditure by tourist €/day above the current.
Reference case: Average expenditure (€) per day	FROM SURVEYS	117.2 €/day		139.3 €/day		148.8 €/day		173.5 €/day		75.6 €/day		124.2 €/day		102.5 €/day						129.7 €/day
	FROM OFFICIAL SOURCES	90.5 €/day		123.94 €/day		138.9 €/day		162 €/day		115 €/day		75 €/day		95 €/day		63 €/day		83 €/day		
Elicited from D5.5	Forest fires prevention	3.71 €/day	Forest fires prevention	5.35 €/day	Forest fires prevention	5.28 €/day	Forest fires prevention	0.72 €/day	Forest fires prevention	Not applicable	Forest fires prevention	3.97 €/day	Forest fires prevention	1.43 €/day					Forest fires prevention	3.03 €/day
Elicited from the literature							FF Prevention	WTPs 5.0 €/day.	FF Prevention	WTPs 5.0 €/day.	FF Prevention	WTPs 5.0 €/day.	FF Prevention	WTPs 5.0 €/day.	FF Prevention	WTPs 5.0 €/day.	FF Prevention	WTPs 5.0 €/day.	FF Prevention	WTPs 5.0 €/day.
	Beach Flooding																			
	Azores		Madeira		Canary Islands		Balearic Islands		Malta		Cyprus		Crete		Corsica		Sardinia		Sicily	
	Measure	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current

Reference case: Average expenditure (€) per day	FROM SURVEYS	117.2 €/day		139.3 €/day		148.8 €/day		173.5 €/day		75.6 €/day		124.2 €/day		102.5 €/day						129.7 €/day
	FROM OFFICIAL SOURCES	90.5 €/day		123.94 €/day		138.9 €/day		162 €/day		115 €/day		75 €/day		95 €/day		63 €/day		83 €/day		
Elicited from D5.5	Beaches Protection	2.40 €/day	Beaches Protection	3.05 €/day	Beaches Protection	3.32 €/day	Beaches Protection	0.72 €/day	Beaches Protection	3.95 €/day	Beaches Protection	10.96 €/day	Beaches Protection	1.40 €/day					Beaches Protection	2.68 €/day
Elicited from the literature	Adaptation	WTPs $1 - $5 US/day	Adaptation	WTPs $1 - $5 US/day	Adaptation	WTPs $1 - $5 US/day	Adaptation	WTPs 0.5-1.49 €/day.	Adaptation	WTPs 0.5-1.49 €/day.	Adaptation	WTPs 0.5-1.49 €/day.	Adaptation	WTPs 0.5-1.49 €/day.	Adaptation	WTPs 0.5-1.49 €/day.	Adaptation	WTPs 0.5-1.49 €/day.	Adaptation	WTPs 0.5-1.49 €/day.
	IC #2 – human being comfort (number of days per year with Humidex > 35°C)																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Measure	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current
Reference case: Average expenditure (€) per day	FROM SURVEYS	117.2 €/day		139.3 €/day		148.8 €/day		173.5 €/day		75.6 €/day		124.2 €/day		102.5 €/day						129.7 €/day
	FROM OFFICIAL SOURCES	90.5 €/day		123.94 €/day		138.9 €/day		162 €/day		115 €/day		75 €/day		95 €/day		63 €/day		83 €/day		
Elicited from D5.5	Heat Waves Amelioration	1.14 €/day	Heat Waves Amelioration	2.31 €/day	Heat Waves Amelioration	4.71 €/day	Heat Waves Amelioration	0.96 /day	Heat Waves Amelioration	4.60 €/day	Heat Waves Amelioration	8.71 €/day	Heat Waves Amelioration	1.46 €/day					Heat Waves Amelioration	2.91 €/day
	Length of the window of opportunity for vector-borne diseases																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Measure	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current
Reference case: Average expenditure (€) per day	FROM SURVEYS	117.2 €/day		139.3 €/day		148.8 €/day		173.5 €/day		75.6 €/day		124.2 €/day		102.5 €/day						129.7 €/day
	FROM OFFICIAL SOURCES	90.5 €/day		123.94 €/day		138.9 €/day		162 €/day		115 €/day		75 €/day		95 €/day		63 €/day		83 €/day		
Elicited from D5.5	Infectious Diseases Prevention	4.59 €/day	Infectious Diseases Prevention	5.41 €/day	Infectious Diseases Prevention	7.66 €/day	Infectious Diseases Prevention	0.98 €/day	Infectious Diseases Prevention	9.16 €/day	Infectious Diseases Prevention	6.93 €/day	Infectious Diseases Prevention	1.96 €/day					Infectious Diseases Prevention	3.52 €/day
	Water available from natural sources																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Measure	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current
Reference case:	FROM SURVEYS	117.2 €/day		139.3 €/day		148.8 €/day		173.5 €/day		75.6 €/day		124.2 €/day		102.5 €/day						129.7 €/day

Average expenditure (€) per day	*FROM OFFICIAL SOURCES*	90.5 €/day		123.94 €/day		138.9 €/day		162 €/day		115 €/day		75 €/day		95 €/day		63 €/day		83 €/day		
Elicited from D5.5	Water supply reinforcement	8.43 €/day	Water supply reinforcement	8.20 €/day	Water supply reinforcement	11.52 €/day	Water supply reinforcement	1.04 €/day	Water supply reinforcement	8.19 €/day	Water supply reinforcement	6.77 €/day	Water supply reinforcement	1.38 €/day					Water supply reinforcement	2.56 €/day
	OTHER ADAPTATION MEASURES																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Measure	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current	*Measure*	Increase in expenditure by tourist €/day above the current
Reference case: Average expenditure (€) per day	FROM SURVEYS	117.2 €/day		139.3 €/day		148.8 €/day		173.5 €/day		75.6 €/day		124.2 €/day		102.5 €/day						129.7 €/day
	FROM OFFICIAL SOURCES	90.5 €/day		123.94 €/day		138.9 €/day		162 €/day		115 €/day		75 €/day		95 €/day		63 €/day		83 €/day		
Elicited from D5.5	Land Habitats Restoration	4.81 €/day	Land Habitats Restoration	3.59 €/day	Land Habitats Restoration	5.77 €/day	Land Habitats Restoration	0.98 €/day	Land Habitats Restoration	3.09 €/day	Land Habitats Restoration	3.26 €/day	Land Habitats Restoration	2.41 €/day					Land Habitats Restoration	2.45 €/day
	Coastal infrastructures protection	4.78 €/day	Coastal infrastructures protection	5.66 €/day	Coastal infrastructures protection	8.03 €/day	Coastal infrastructures protection	1.16 €/day	Coastal infrastructures protection	4.31 €/day	Coastal infrastructures protection	5.64 €/day	Coastal infrastructures protection	1.83 €/day					Coastal infrastructures protection	2.35 €/day
	Cultural Heritage protection	6.29 €/day	Cultural Heritage protection	5.41 €/day	Cultural Heritage protection	8.11 €/day	Cultural Heritage protection	0.70 €/day	Cultural Heritage protection	3.59 €/day	Cultural Heritage protection	2.77 €/day	Cultural Heritage protection	1.68 €/day					Cultural Heritage protection	3.50 €/day

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Table A.3 - IC #2 – human being comfort (number of days per year with Humidex > 35°C) – merging data from D5.3 and D5.5

	IC #2 – human being comfort (number of days per year with Humidex > 35°C) – merging D5.3 and D5.5																			
	Azores		**Madeira**		**Canary Islands**		**Balearic Islands**		**Malta**		**Cyprus**		**Crete**		**Corsica**		**Sardinia**		**Sicily**	
	Climatic variable projection (number of days)	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*	*Climatic variable projection (number of days)*	Change in total tourist expenditure *(% change from reference case)*
Reference	16.3	-	0.2 (for rcp2.6)	-	6.4 (for rcp2.6)	-	52.9	-	48.1	-	92.1	-	31.3	-	14.4	-	49.7	-	52.0	-
RCP2.6 near	27.15	**1.10**	0.6	**0.01**	11.5	**0.13**	67.7	**-0.36**	66.7	**-1.28**	112.4	**-2.81**	48.4	**-0.71**	27.1	**1.89**	65.3	**1.13**	68.5	**-0.38**
RCP2.6 distant	N/A	**N/A**	0.8	**0.03**	12.7	**0.17**	66.1	**-0.41**	67.7	**-1.29**	114	**-2.80**	51	**-0.71**	27.1	**1.89**	64	**0.98**	70.1	**-0.34**
RCP8.5 near	35.55	**1.80**	5.2 (ref .9)	**0.09**	27.2 (ref 14.8)	**0.73**	69.9	**-0.31**	71.2	**-1.33**	118.4	**-2.80**	55.7	**-0.69**	28.9	**2.15**	68.6	**1.56**	74.1	**-0.32**
RCP8.5 distant	N/A	**N/A**	29.7 (ref 1.9)	**1.05**	75.5 (ref 14.8)	**2.89**	114.7	**0.94**	118.2	**-1.90**	161.7	**-2.82**	103	**-0.51**	72.1	**9.37**	112.2	**6.99**	118.7	**0.03**
Arrivals	**Inbound Arrivals**	**Domestic Arrivals**	**Inbound Arrivals**	**Domestic Arrivals**	**Inbound Arrivals**	**Domestic Arrivals**	**Inbound Arrivals**	**Domestic Arrivals**	**Inbound Arrivals**	**Domestic Arrivals**	**Inbound Arrivals**	**Domestic Arrivals**	**Inbound Arrivals**	**Domestic Arrivals**	**Inbound Arrivals**	**Domestic Arrivals**	**Inbound Arrivals**	**Domestic Arrivals**	**Inbound Arrivals**	**Domestic Arrivals**
Number	243.774	262.383	882.289	232.003	9.903.885	2.785.739	10.417.139	2.124.829	1.783.366	203.584	2.659.405	626.501	4.537.000	949.392	812.230	1.916.412	1.208.724	1.400.968	2.007.547	2.521.312
Share	0.481617	0.518383	0.791793	0.208207	0.7804711	0.2195289	0.83058249	0.1694175	0.8975393	0.102461	0.8093369	0.1906631	0.8269551	0.173045	0.297668	0.702332	0.4631673	0.5368327	0.4432788	0.5567212

Appendix: Climate Change and Ports' Costs

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ISLAND	COUNTRY	PORT	Unit	Figure	Unit cost (€)	Partial cost	Total Cost Port	Island	SLR (cm) RCP2.6 (2046-2065)	SLR (cm) RCP2.6 (2081-2100)	SLR (cm) RCP8.5 (2046-2065)	SLR (cm) RCP8.5 (2081-2100)	Annual Cost (1m)	Cost per year (RCP2.6 Near)	Cost per year (RCP2.6 Distant)	Cost per year (RCP8.5 Near)	Cost per year (RCP8.5 Distant)	Total Cost (RCP2.6 Near)	Total Cost (RCP2.6 Distant)	Total Cost (RCP8.5 Near)	Total Cost (RCP8.5 Distant)
Crete	Greece	**Heraklion**	-	-			**200,646,650**	**200,646,650**	**12**	**23**	**32**	**63**	**2,006,467**	**240,776**	**461,487**	**642,069**	**1,264,074**	**12,038,799**	**46,148,730**	**32,103,464**	**126,407,390**
		Terminals (length)	m	3,254		0															
		Terminals (surface)	m2	456,998	425	194,224,150															
		Dikes	m	2,326	2,500	5,815,000															
		Ramps	N.	3	202,500	607,500															
Malta	Malta	**Marsaxlokk**	-				**441,033,278**	**441,033,278**	**12**	**24**	**32**	**65**	**4,410,333**	**529,240**	**1,058,480**	**1,411,306**	**2,866,716**	**26,461,997**	**105,847,987**	**70,565,324**	**286,671,630**
		Terminals (length)	-	3,767																	
		Terminals (surface)	-	1,032,078	425	438,633,278															
		Dikes	-	960	2,500	2,400,000															
		Ramps	-	0	202,500	0															
Azores	Portugal	**Ponta Delgada**	-				**51,731,600**	**51,731,600**	**12**	**24**	**34**	**69**	**517,316**	**62,078**	**124,156**	**175,887**	**356,948**	**3,103,896**	**12,415,584**	**8,794,372**	**35,694,804**
		Terminals (length)	M	1,727																	
		Terminals (surface)	m2	113,000	425	48,025,000															
		Dikes	m	1,402	2,500	3,504,100															
		Ramps	N.	1	202,500	202,500															
Madeira	Portugal	**Funchal Port (cruise)**	-				**69,231,525**	**131,870,350**	**14**	**27**	**37**	**75**	**1,318,704**	**184,618**	**356,050**	**487,920**	**989,028**	**9,230,925**	**35,604,995**	**24,396,015**	**98,902,763**
		Terminals (length)	m	1,927																	
		Terminals (surface)	m2	155,933	425	66,271,525															
		Dikes	m	1,103	2,500	2,757,500															
		Ramps	N.	1	202,500	202,500															
		Canical Port (container)	-				**62,638,825**														
		Terminals (length)	m	1,189																	
		Terminals (surface)	m2	141,933	425	60,321,525															
		Dikes	m	846	2,500	2,114,800															
		Ramps	N.	1	202,500	202,500															
Sardinia	Italy	**Cagliari**	-				**329,525,000**	**329,525,000**	**11**	**22**	**30**	**60**	**3,295,250**	**362,478**	**724,955**	**988,575**	**1,977,150**	**18,123,875**	**72,495,500**	**49,428,750**	**197,715,000**
		Terminals (length)	m	2,560																	
		Terminals (surface)	m2	730,000	425	310,250,000															
		Dikes	m	7,305	2,500	18,262,500															
		Ramps	N.	5	202,500	1,012,500															
Sicily	Italy	**Palermo**	-				**478,077,000**	**574,955,850**	**11**	**23**	**31**	**63**	**5,749,559**	**632,451**	**1,322,398**	**1,782,363**	**3,622,222**	**31,622,572**	**132,239,846**	**89,118,157**	**362,222,186**
		Terminals (length)	m	3,197																	
		Terminals (surface)	m2	1,102,840	425	468,707,000															
		Dikes	m	3,100	2,500	7,750,000															
		Ramps	N.	8	202,500	1,620,000															
		Imerese	-				**96,878,850**														
		Terminals (length)	m	1,224																	
		Terminals (surface)	m2	219,000	425	93,075,000															
		Dikes	m	1,522	2,500	3,803,850															
		Ramps	N.	0	202,500	0															
Balearic I,	Spain	**Palma de Mallorca**					**827,178,875**	**827,178,875**	**12**	**25**	**33**	**66**	**8,271,789**	**992,615**	**2,067,947**	**2,729,690**	**5,459,381**	**49,630,733**	**206,794,719**	**136,484,514**	**545,938,058**
		Terminals (length)	m																		
		Terminals (surface)	m2	1,913,115	425	813,073,875															
		Dikes	m	5,156	2,500	12,890,000															
		Ramps	N.	6	202,500	1,215,000															
Canary I,	Spain	**Santa Cruz de Tenerife**					**908,573,375**	**2,178,441,375**	**14**	**27**	**37**	**74**	**21,784,414**	**3,049,818**	**5,881,792**	**8,060,233**	**16,120,466**	**152,490,896**	**588,179,171**	**403,011,654**	**1,612,046,618**
		Terminals (length)	m																		
		Terminals (surface)	m2	2,104,155	425	894,265,875															
		Dikes	m	5,156	2,500	12,890,000															
		Ramps	N.	7	202,500	1,417,500															
		Las Palmas de Gran Canaria					**1,269,868,000**														
		Terminals (length)	m																		
		Terminals (surface)	m2	2,948,960	425	1,253,308,000															

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		Dikes	m	5,652	2,500	14,130,000															
		Ramps	N.	12	202,500	2,430,000															
Fehmarn	Germany	**Fehmarn**					**74,319,625**	**174,319,625**					**1,743,196**								
		Terminals (length)	m																		
		Terminals (surface)	m2	401,705	425	170,724,625															
		Dikes	m	1,114	2,500	2,785,000															
		Ramps	N.	4	202,500	810,000															
Corsica	France	**Bastia**					**80,430,225**	**197,085,025**	**11**	**21**	**29**	**58**	**1,970,850**	**216,794**	**413,879**	**571,547**	**1,143,093**	**10,839,676**	**41,387,855**	**28,577,329**	**114,309,315**
		Terminals (length)	m																		
		Terminals (surface)	m2	180,577	425	76,745,225															
		Dikes	m	988	2,500	2,470,000															
		Ramps	N.	6	202,500	1,215,000															
		Ajjaccio					**116,654,800**														
		Terminals (length)	m																		
		Terminals (surface)	m2	272,576	425	115,844,800															
		Dikes	m	-	2,500	-															
		Ramps	N.	4	202,500	810,000															
Cyprus	Cyprus	**Limassol**					**551,315,000**	**745,227,500**	**10**	**20**	**29**	**58**	**7,452,275**	**745228**	**1,490,455**	**2,161,160**	**4,322,320**	**37,261,375**	**149,045,500**	**108,057,988**	**432,231,950**
		Terminals (length)	m																		
		Terminals (surface)	m2	1,280,000	425	544,000,000															
		Dikes	m	2,845	2,500	7,112,500															
		Ramps	N.	1	202,500	202,500															
		Larnaca					**193,912,500**														
		Terminals (length)	m																		
		Terminals (surface)	m2	445,000	425	189,125,000															
		Dikes	m	1,834	2,500	4,585,000															
		Ramps	N.	1	202,500	202,500															

Appendix: Climate Change and Aquaculture Production

Climate change and aquaculture production. Memory

Juan M Hernández and Carmelo León

August 2020

1. Effect of temperature change on aquaculture production

1.1 Method

Let B_i be the total biomass produced in region (island/archipelago) i. We have

$i = \{$Azores, Madeira, Canary Islands (CI), Balearic Islands (BI), Malta, Cyprus, Crete, Corsica, Sardinia, Sicily$\}$.

We assume four main species cultured in these regions: Seabream (SB), Seabass (DL), Mediterranean Mussel (M) and Tuna (T). We assume that the production of species $j \in \{SB, DL, M, T\}$ in region i follows the expression:

$$B_i^j = \bar{B}_i \delta_i^j f^j(\theta), \tag{1}$$

where θ is the water temperature and function $f^j(\cdot)$ is the thermal effect on the biomass. $\bar{B}_i$ is the biomass obtained for each species in the hypothetical case of thermal effect equal one. Parameter δ_i^j is the production share of species j in region i, so $\sum_{j\in\{SB,DL,M,T\}} \delta_i^j = 1$.

As shown in equation (1), we assume that the biomass in each species is regulated by the thermal function $f^j(\theta)$. Several expressions have been proposed for this effect (see Seginer, 2016, for a review). We use the following expression:

$$f^j(\theta) = \frac{e^{\alpha_j(\theta_M^j - \theta)} - e^{\beta_j(\theta_M^j - \theta)}}{max_\theta \left(e^{\alpha_j(\theta_M^j - \theta)} - e^{\beta_j(\theta_M^j - \theta)} \right)}, \tag{2}$$

where θ_M^j is the lethal temperature for species j, α_j and β_j are other fit parameters. The expression in numerator was proposed by Muller-Feuga (1990). We add the denominator in order to normalize the thermal effect across different species.

Then, to calculate the biomass production in one year, we sum the production in every month h, where $h = \{1, 2, ..., 12\}$ represents the month from January to December. The production depends on the monthly water temperature in every region i, θ_i^h. Therefore:

$$B_i^j = \sum_{h=1}^{12} \bar{B}_i \delta_i^j f^j(\theta_i^h) = \bar{B}_i \delta_i^j \sum_{h=1}^{12} f^j(\theta_i^h).$$

We have four different future scenarios shown by IPCC estimations (RCP2.6 near, RCP2.6 distant, RCP8.5 near, RCP8.5 distant), which correspond to four water temperature increases in every region k_i. We note B_i^b and $B_i^{Ch}(k_i)$ the biomass production in region i in the baseline case (θ_i^h) and with water temperature increase $(\theta_i^h + k_i)$. Then, we calculate the *percentage of production increase* in region i, $\%\Delta B_i$, using the formula:

$$\begin{aligned} \%\Delta B_i &= \frac{B_i^{Ch}(k_i) - B_i^b}{B_i^b} = \frac{\sum_j \bar{B}_i \delta_i^j \sum_{h=1}^{12} f^j(\theta_i^h + k_i) - \sum_j \bar{B}_i \delta_i^j \sum_{h=1}^{12} f^j(\theta_i^h)}{\sum_j \bar{B}_i \delta_i^j \sum_{h=1}^{12} f^j(\theta_i^h)} \\ &= \frac{\sum_j \delta_i^j \sum_{h=1}^{12} f^j(\theta_i^h + k_i) - \sum_j \delta_i^j \sum_{h=1}^{12} f^j(\theta_i^h)}{\sum_j \delta_i^j \sum_{h=1}^{12} f^j(\theta_i^h)}. \end{aligned} \tag{3}$$

This expression does not depend on the total production $\bar{B}_i$ and it is used to calculate the production increase (or decrease) in the future scenarios.

1.2 Data

The production share of every species in every region was obtained from the following sources:

- Azores: European Parliament (2015).
- Madeira: Derivable 4.5 Soclimpact.
- CI and BI: Jacumar (2020)
- Malta: NSO-Malta 2018.
- Cyprus: FAO (2017) and Derivable 4.5 Soclimpact
- Crete: FAO (2016), assuming same proportion than national production.
- Corsica, Sardinia and Sicily: Derivable 4.5 Soclimpact.

The Table 1 presents the estimated production shares.

Table 1: Production share in every region

	Azores	Madeira	CI	BI	Malta	Cyprus	Crete	Corsica	Sardegna	Sicily
Seabream	0	1	0.26	0	0.1	0.34	0.38	0.265	0.08	0.30
Seabass	0	0	0.74	0	0.0	0.16	0.38	0.265	0.08	0.26
Med. Mussel	0	0	0.00	1	0.0	0.00	0.24	0.430	0.84	0.44
Bluefin tuna	0	0	0.00	0	0.9	0.50	0.00	0.000	0.00	0.00

The parameter estimates for the thermal function (2) can be found in the Table 2. They were calibrated starting from the values proposed for Seabream/Seabass by Muller-Feuga (1990) and the lethal and threshold temperature estimations in Derivable 4.5 Soclimpact. We have also considered the studies by Anestis et al. (2007) and Muhling et al. (2011) for the parameter estimations of the Mediterranean mussel and Bluefin tuna, respectively. Bluefin tuna spawns freely before being captured and fatten. Then, changes in water temperature can produce migration to other spawning areas. This effect is not considered in the calculations.

Table 2: Thermal parameters for the four species

	Seabream	Seabass	Mussel	Tuna
alpha	-0.08	-0.05	-0.13	-0.17
beta	-0.15	-0.15	-0.17	-0.20
Lethal Temp	33.00	35.94	27.00	26.17

Figure 1 presents the graph of thermal function for the four species analyzed.

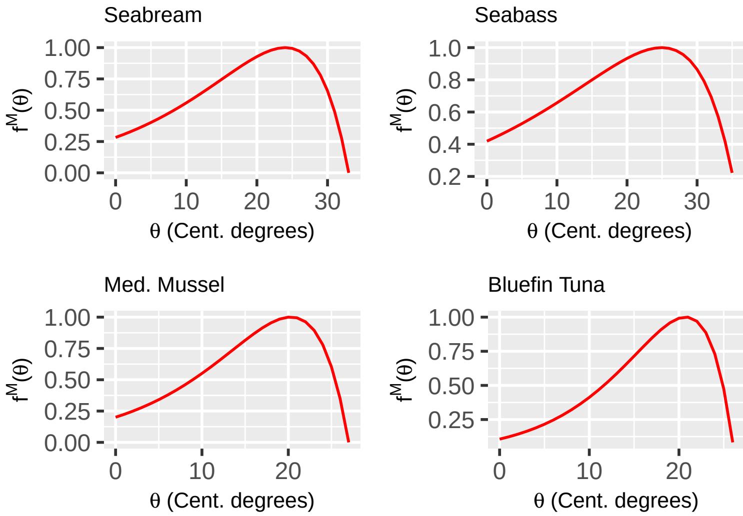

Figure 1. Thermal function for the four species analyzed.

Figure 2 shows the water temperature cycle in every region. The data was extracted from https://www.seatemperature.org/europe/

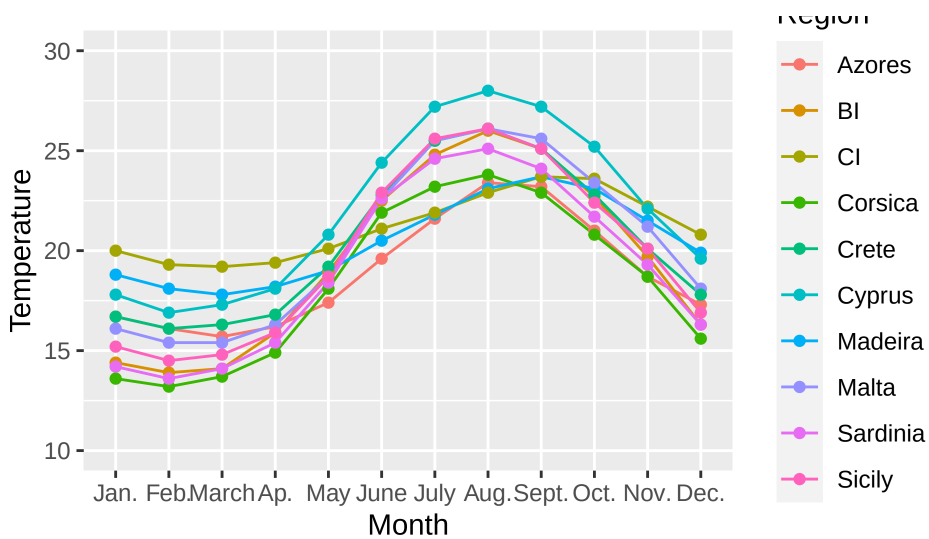

Figure 2. Water temperature cycle in the 10 regions.

The Table 3 shows the forecast of the water temperature increase in the four scenarios (RCP2.6 near, RCP2.6 distant, RCP8.5 near, RCP8.5 distant). They were extracted from the estimations in Derivable 4.5 Soclimpact.

Table 3: Estimations of water temperature increase according to RCP scenarios.

	Azores	Madeira	CI	BI	Malta	Cyprus	Crete	Corsica	Sardinia	Sicily
RCP2.6 near	0.48	0.88	0.70	0.9	0.8	0.9	0.8	0.9	0.8	0.8
RCP2.6 distant	0.40	0.73	0.60	0.8	0.7	1.0	0.9	0.8	0.7	0.8
RCP8.5 near	1.40	1.50	1.25	1.5	1.3	1.5	1.4	1.4	1.3	1.4
RCP8.5 distant	2.90	2.83	2.45	2.9	2.5	3.0	2.8	2.8	2.6	2.6

1.3 Results

The equation (3) was estimated using the data above. The results of the change in production are shown in the Table 4. Some islands show negative impacts because of the representative proportions of the production of tuna and mussels, which are the most affected species.

Table 4: Percentage of production change according to RCP scenarios

	Azores	Madeira	CI	BI	Malta	Cyprus	Crete	Corsica	Sardinia	Sicily
RCP2.6 near	NaN	0.021	0.013	-0.071	-0.123	-0.189	-0.005	0.007	-0.030	-0.020
RCP2.6 distant	NaN	0.018	0.011	-0.061	-0.104	-0.215	-0.007	0.007	-0.025	-0.020
RCP8.5 near	NaN	0.033	0.022	-0.140	-0.231	-0.362	-0.017	0.006	-0.059	-0.046
RCP8.5 distant	NaN	0.047	0.034	-0.390	-0.613	-1.005	-0.072	-0.025	-0.186	-0.132

2. Effect of an increase of extreme weather on aquaculture production

We assume that the main damage on aquaculture of an extreme event (cyclones, storms, strong winds, high waves, etc) is mortality (or escape) increase. We assume that extreme events influence identically to all farms, independently of the cultured species.

Let $\hat{B}_i$ be the biomass produced in region i in the abscense of extreme event. Let m_E be the mortatility rate due to an extreme event, p_0 and $p_0 + p_{Ch}$ the probability of an extreme event in the baseline and future climate change conditions, respectively. Then the expected biomass in baseline condition is:

$$E[B_i^b] = (1 - p_0)\hat{B}_i + p_0(1 - m_E)\hat{B}_i.$$

The expected biomass in the future conditions is:

$$E[B_i^{Ch}] = (1 - p_0 - p_{Ch})\hat{B}_i + (p_0 + p_{Ch})(1 - m_E)\hat{B}_i.$$

Therefore, the *expected percentage of production increase* in region i, $\%\Delta E[B_i]$, is:

$$\%\Delta E[B_i] \quad = \quad \frac{E[B_i^{Ch}] - E[B_i^b]}{E[B_i^b]} = \frac{(-p_{Ch}\hat{B}_i + p_{Ch}(1 - m_E)\hat{B}_i}{(1 - p_0)\hat{B}_i + p_0(1 - m_E)\hat{B}_i} = \frac{-p_{Ch}m_E}{(1 - p_0 m_E)}.$$

After reviewing several IPCC and other scientific reports, our conclusion is that there is not enough evidence of a future increase of extreme weather or wave height due to climate change. We extract some of the conclusions in the IPCC report "Changes in Climate Extremes and their Impacts on the Natural Physical Environment" click [here]:

- Regarding tropical cyclones: "In summary, there is low confidence that any observed long-term (i.e., 40 years or more) increases in tropical cyclone activity are robust, after accounting for past changes in observing capabilities. The uncertainties in the historical tropical cyclone records, the incomplete understanding of the physical mechanisms linking tropical cyclone metrics to climate change, and the degree of tropical cyclone variability provide only low confidence for the attribution of any detectable changes in tropical cyclone activity to anthropogenic influences." (p.163)
- Regarding extra-tropical cyclones: "In summary it is likely that there has been a poleward shift in the main Northern and Southern Hemisphere extratropical storm tracks during the last 50 years. There is medium confidence in an anthropogenic influence on this observed poleward shift. It has not formally been attributed. There is low confidence in past changes in regional intensity. There is medium confidence that an increased anthropogenic forcing will lead to a reduction in the number of mid-latitude cyclones averaged over each hemisphere, and there is also medium confidence in a poleward shift of the tropospheric storm tracks due to future anthropogenic forcings. [...] In addition, studies using different analysis techniques, different physical quantities, different thresholds, and different atmospheric vertical levels to represent cyclone activity and storm tracks result in different projections of regional changes. This leads to low confidence in region-specific projections" (p. 166)

- Regarding waves: "A number of regional studies have also been completed since the AR4 in which forcing conditions were obtained for a few selected emission scenarios (typically B2 and A2, representing low-high ranges) from GCMs or RCMs. These studies provide additional evidence for positive projected trends in SWH [Sea wave height] and extreme waves along the western European coast (e.g., Debernard and Roed, 2008; Grabemann and Weisse, 2008) and the UK coast (Leake et al., 2007), declines in extreme wave height in the Mediterranean sea (Lionello et al., 2008) and the southeast coast of Australia (Hemer et al., 2010), and little change along the Portuguese coast (Andrade et al., 2007)." (p. 182)
- Regarding waves: "There is low confidence that there has been an anthropogenic influence on extreme wave heights (because of insufficient literature). Despite the existence of downscaling studies for some regions such as the eastern North Sea, there is overall low confidence in wave height projections because of the small number of studies, the lack of consistency of the wind projections between models, and limitations in their ability to simulate extreme winds. However, the strong linkages between wave height and winds and storminess means that it is likely that future negative or positive changes in SWH will reflect future changes in these parameters." (p.182)

Therefore we do not have a confident estimation of p_{Ch} and the expected percentage of production increase cannot be calculated.

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