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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Work Package 5:

Measuring market and non-market costs of Climate Change and benefits of climate actions for Europe

Deliverable 5.2. Transfer Impact Analysis.

Coordinated by ULPGC with the participation of the WP5 partners and reviewed by Ulrike Lehr (GWS) and Christos Giannakopoulos (NOA), according to the quality review internal process.

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	Coastal and Maritime Tourism
	Aquaculture
	Energy
	Maritime transport

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1. Introduction

One of the specific objectives of the Work Package (WP) 5 of the project SOCLIMPACT is to contribute to the improvement of the economic valuation of climate change impacts and related policies for the Blue Economy sectors of the European islands. Appropriate tools such as revealed and stated preference methods will be adopted to achieve this purpose in the case of the tourism sector. However, in order to compare the obtained results to the existing ones in the literature on the one hand, and to complement the information related to economic values of climate change impacts in the mentioned sector and in the remaining ones (Aquaculture, Energy and Maritime Transport) on the other hand, additional methodologies could be used. Therefore, although the totality of the required values will be generated inside the project, we will also work with the values found in the literature. The potential transferability of those values will be assessed and the capability of Soclimpact values to contribute to enhance the future of the value transfer technique will be left outlined. At this time of development of the economic valuation of the impacts of climate change on the Blue Economy sectors, values mined from literature will be useful as benchmark to assess how values transferability is being built and the contribution of the Soclimpact project to it.

The main objective of this deliverable is to develop a first step in the process of learning about the concept of benefit transfer method, how it can be used and the reliability of this methodology. Moreover, a first overview of the available data in the literature is presented, trying to identify the potential gaps and uses of the estimated values of climate change impacts, aiming at adapting them to the SOCLIMPACT context.

2. Methodology

The benefit transfer method is a technique developed with the aim of estimating the economic value of environmental services when an original valuation is not viable (Navrud and Ready, 2007; Johnston and Resenberger, 2010; Barbera, 2010). Therefore, it is a second-best approach. The essence of this technique is to transfer the economic values estimated in the literature to our own study. The values should be taken from a study in an area with similar characteristics to the ones we are analysing. Boutwell and Westra (2013) claim that although the benefit transfer has been used for several years, it became a more used tool after the publication in a Special Issue of Water Resources Research in 1992. According to Barbera (2010), the conditions that should be fulfilled to consider that both areas are similar relate to spatial and socioeconomics characteristics. Moreover, we will need a wide variety of high-quality valuation papers in order to obtain accurate values to transfer.

Transfer benefit is wide extended among environmental agencies such as the NZ Ministry for Environment; the Australian Department of Sustainability, Environment, Water, Population and Communities; and the US Environmental Protection Agency. Furthermore, some valuation databases are being developed (such as the Environmental Valuation Reference Inventory).

Following Barbera (2010) we can distinguish two different approaches of benefit transfer: the value transfer and the function transfer. The first one is easier to develop, one of the simplest types is the unit day approach. This approach uses the existing values for an activity to value the same activity in another place. Thus, a weighted measure of the value obtained by one or various studies is taken. These values are often given in US dollars and on a per unit basis (based on an activity, on an outcome or on a per-person basis). The latter approach is more rigorous. It consists on transferring a benefit function from another study. These functions often relate peoples' willingness to pay (WTP) for the characteristics of the ecosystem to their socioeconomic and personal characteristics. Finally, some adjustment could be developed in order to take into account some differences between both locations. Boutwell and Westra (2013) affirm that function transfer requires for the valuation function to be calibrated with the value that is being transferred. Moreover, they say that one of the advantages of this approach is that it allows to relax the degree of similarity necessary for the transfer of benefits by allowing for differences in characteristics to be taken into account by a valuation function.

Barbera (2010) collects some advantages and disadvantages of the benefit transfer technique. She highlights that some advantages are the costs and time required, and the fact that it is an easy and quick tool for assessing recreational values. On the other hand, these techniques can cause an increment of the likelihood and magnitude of valuation errors, there may be scarce availability of studies and values, or even low quality of the existing studies. Furthermore, these values become obsolete very quickly, as society preferences change, or new and high-quality studies are developed. The value transfer method is limited by the assumption that the benefit measure is a constant. Thus, she proposes to look for similarities between both studies, to develop a meta-analysis and to use calibration functions (that means, using the values of the study case, to calibrate and prove the parameters of the utility function pre-determined).

Empirical studies often obtain an aggregate measure of welfare for a representative individual of the sample such as mean WTP for a given change in a good or ecosystem service/characteristic for a particular sample of individuals (Johnston et al, 2015). They call this marginal measure as $\overline{y_{Js}}$, where the sub-script j represents the site and s is the population sample of the primary study. Parallel estimations are required for a place where the site is i≠j and population are r≠s, called $\widehat{y_{\iota r}}$. Thus, the transferred unit quantities could be a single unadjusted value, a value adjusted depending on the attributes of the policy context or using expert's opinion, a measure of central tendency or a range of estimates from different prior studies. The simplest but less accurate is the single non-adjusted value. That means that we assume that per person WTP at the study site is equal to per person WTP in the policy site[1] ($\widehat{y_{\iota r}{}^{BT}} = \overline{y_{Js}}$), where BT means that these values have been taken using the benefit transfer approach). If the population at site is equal to W, then the aggregate value will be equal to W*$\widehat{y_{\iota r}{}^{BT}}$.

The second form of transferring values is to transfer a value adjusted depending on the attributes of the policy context or using expert opinion. Maybe we want to account for differences in currency value, income or other factors. This methodology consists on finding a function f ($\overline{y_{Js}}$) that satisfies $\widehat{y_{\iota r}{}^{BT}}$=f($\overline{y_{Js}}$). The functions can be determined by using objective or subjective factors, i.e. if we want to use a price index (P) as a proxy to account for differences in real currency values, we must use P*$\overline{y_{Js}}$. However, Johnston et al (2015) clarify that analysts should be aware of the strong assumptions needed by these types of scaling adjustments. To avoid these adjustments problem, we can use the administratively approved values. But an associated problem is that these values have been derived from a subjective and arbitrary processes, instead of by quantitative and formal estimations.

[1] When naming the case study (study site) we are referring to the places for which the literature has already calculated an economic value. On the other hand, when we talk about the policy case (policy site), we are mentioning the place in which those values taken from the literature are going to be applied.

There are two primary requirements to use the function transfer approach. The first one is to use a parameterized function which allows to calculate the empirical outcome as a function of variables. The second requirement is to obtain information of at least a subset of variables related with observable conditions at the policy site to be able to adjust the function from the study site to the policy site. The main differences between the forms of function transfer is the source. One can transfer the function from a single study and calculate a calibrated welfare estimate. Frequently, data from one country is needed, but one can also use data from multiple countries. A general form of benefit function adopts this form: $\widehat{y_{Js}} = g\ (x_{js}, \widehat{\beta_{Js}})$, where $\widehat{y_{Js}}$ is the predicted welfare, x_{js} is the vector of variables which have an impact on the predicted welfare estimated ($\widehat{y_{Js}}$) in place j for population s and is the parameters vector. This relationship can be described by a linear function or by more sophisticated benefit functions. When we develop a single-site function transfers, we have to assume that the parametrized valuation function is exactly the same at the study and policy sites.

According to Barbera (2010), once we have decided about the transfer benefit method, we need to determine the change in environmental benefits; identify existing studies, values and functions that could be used; evaluate these existing studies, values and functions and decide if they are appropriate for transferring; calibrate the existing values, and aggregate the individual values over the population affected. The first step is, therefore, to look for similarities between the case study and the policy case. It is necessary to find out several similarities between both of them, in order to be able to transfer the values/functions. If both places are quite different and their ecological systems are not similar, the values transferred would not be accurate.

Following Boutwell and Westra (2013), the common method used for the compilation of the data and its analysis is the meta-analysis method. It is a statistical approach, which analyses a large number of studies with the aim of integrating the different results discovered. The meta-analysis method is widely spread in the environmental resource valuation literature, using a benefit transfer approach due to its allowance to incorporate a structural utility framework without the need of strict-economic information.

This report presents a meta-analysis of the impacts and economic values found in the existing literature, together with some characteristics of the scenarios contemplated and the methodology used. This approach is useful to obtain an overview of what has been studied in the literature, and which may be the potential gaps. Moreover, an effort has been made to determine which of the results could potentially be transferred directly. However, in future tasks and reports of the project, a refinement of this first search will be made, and the methodology presented in this section will be applied more thoroughly in order to obtain values and results useful for the project from the benefit transfer methodology.

3. Benefit transfer: climate change impacts

According to Brouwer (2000), one can define the environmental value transfer as the transposition of monetary environmental values estimated at one site through several economic valuation techniques. Moreover, this author affirms that the main reason for using value transfer in environmental valuation is the cost-effectiveness. Environmental value transfer has been applied in a wide range of topics, from water quality management (Luken et al., 1992) and associated health risks (Kask and Shogren, 1994) to waste (Brisson and Pearce, 1995) and forest management (Bateman et al., 1995). In environmental economics, several techniques have been developed with the aim of measuring the value people give to natural resource and services. The objective is to obtain a monetary measure of these environmental values. Thus, two wide extended measures are the individual willingness to pay (WTP) or the willingness to accept (WTA)[2]. Often, they can be calculated by directly asking people through a survey (that is contingent valuation) or indirectly by assuming that the valuation of these resources is implicit on the travel costs or the prices paid to live in a specific area. That is, people would only pay these amounts because these places/resources/services have a value for them.

Brouwer (2000) affirms that in 1992 the American Journal *Water Resources Research* published an article underlying the concept and technique of environmental value transfer. According to Wilson and Hoehn (2006), the first studies related with benefit transfer were published in the 1980s and in 1990, Smith and Kaoru published a first application of meta-analysis used for recreational values. Since 1992, several workshops were developed by different types of international organization. The Water Resource Research tried to fill the gap in the theory and method by providing new economic models for benefit transfer and by providing systematic tests of theoretical validity and statistical reliability. With the increase in the non-market valuation literature, the meta-analysis became a stronger and widespread tool in the benefit transfer literature (Bateman and Jones, 2003; Bergstrom and De Civita, 1999; Rosenberger and Loomis, 2000; Shrestha and Loomis, 2003; VandenBergh and Button, 1997; Woodward and Wui, 2001). Since the year 2000, the literature about benefit transfer has increased considerably.

3.1. Climate change economic impact on tourism

The literature review to identify transferable economic values from climate change impacts in the tourism field sheds lights and shadows. By the side of lights, the review has allowed to gather values for all the tourism impacts chains defined in Work Package 3 (Deliverable 3.2). However, these values are represented very differently: while the risk of loss of tourism attractiveness due to the reduction of beach surface counts for 19 papers providing a priori useful data, just one paper has been found containing some information on the potential effects of infectious diseases, pushed by climate change, on tourism demand. Table 3.1.1 presents the distribution of the mined data amongst the considered risks for the tourism sector due to climate change

Table 3.1.1. Risk-based distribution of economic values mined

Risk	Number of papers
Loss of beach surface	19
Marine habitats degradation	14
Thermal stress	5
Land habitats degradation	8
Water shortage	5
Infectious diseases	4
Cultural heritage	6
Forest fires	6
Damage to coastal tourism infrastructures	3
Total	**63**

Source: Own elaboration

[2] The willingness to pay (WTP) refers to the maximum price at or below which a consumer would definitely buy one unit of a product. The willingness to accept (WTA) is the minimum amount of money that a person is willing to accept to abandon a good or to put up with something negative.

By the side of shadows, the transferability of the economic values found is strongly conditioned by the extraordinary heterogeneity in the nature of the data provided, and the methodology used to elicit them. It means that value transfer will be far from a simple, direct attribution of values from some places to others, but it will require a quite laborious data refining process. Notwithstanding, at this time it is worthwhile to remind that values mined from the literature are just one source, and not the main one, to evaluate climate change impacts on tourism to feed general equilibrium modelling.

In order to facilitate the process of combining the obtained data to produce transferable values, the table summarizing the information distinguishes the different phases in which the climate change impact on tourism may be captured. Some papers provide information on i) biophysical impacts due to climate change hazards, such as beach erosion or percentage of habitat degraded; ii) then the next data column was devoted to capture the potential effects on the destination image of climate-based impacts; iii) the third column is devoted to gather impacts referring to quantitative reports of the effect on tourists' behaviour and intention of behaviour related to destination choice; and iv) the last data column to this purpose collects information on the estimated economic impacts of climate change hazards on particular destinations, expressed in different economic variables.

More precisely, the data collected from biophysical impacts are useful for transferring purposes when they show the rate of change of the ecosystem services with respect to some year or period taken as reference. We found this sort of data mainly for beach surface diminishing and, in a lesser extent, for marine environment degradation.

Unfortunately, literature referred to the relationship between climate-induced impacts and the effect of it on the destination image is almost inexistent. We sought this potential relationship as changes in the destination image are good predictors of tourists' destination choice. However, it is necessary to carry out a second round of searches to try to find some related evidence, at least performing as a proxy of this relationship.

With respect to data related to the behavioural effect of climate change impact on tourists, some relevant information was found even if the variables in which it is expressed show dispersion in nature, and treating them jointly requires some operations to give them enough homogeneity. They differentiate each other either on the variable selected to refer to the behaviour (willingness/unwillingness to revisit, choice of alternative destination, loss of number of visitors, etc.) or on the criterion followed to delimitate the tourist destination.

The data referred to the economic valuation of climate change hazards on tourism depicts also high heterogeneity. It ranges from very specific economic valuation in terms of changes in willingness to pay for tourism and for a unit change in a particular environmental service, i.e., the beach width, to very general economic evaluation referred to a percentage of GDP due to a climate-related impact. Sometimes, the geographical area of estimation reaches continents. Generally speaking, former-type data are more useful than latter-type ones, for our purpose of transferring economic values. In some other cases, the obtained information focuses on the costs of some adaptation policies enabled to reduce tourism vulnerability to climate change. This information may be useful to make estimations of the economic value of climate change impacts based on avoided costs-type methodologies.

The methodological heterogeneity of the sources of data may also add complexity to the task of value transfer. The literature shows that some observed differences in the economic valuation are intrinsic to the methodologies used to elicit the values. In the information mined from the literature, most of the cases used contingent valuation, or its evolved version, discrete choice experiments, to estimate the average willingness to pay, or accept, of the targeted population for environmental changes that bring improved/worsened recreational experiences. The minority of collected values come from the application of travel costs and hedonic prices methodologies, while in some cases, those three methodologies are combined to elicit economic values.

Finally, just a few study cases focus on the islands studied within the SOCLIMPACT project. The economies of the European islands are mostly tourism-based, which is the chief activity in terms of GDP and employment, and highly significant in terms of land occupancy and environmental impacts. Additionally, the European islands have developed mostly coastal and marine tourism modalities, extraordinary sensitive to a wide range of climate change related hazards. They also hold highly vulnerable ecosystems, representing an important proportion of the European biodiversity. Taking all these specificities into account, the transference of economic values of climate change events from mainland located territories should be modulated for this set of islands' specificities. It will be done using the methodological procedures which are explained in section 2 of this report.

The values found in the literature are collected and summarized in table 3.1.2, table 3.1.3, table 3.1.4, table 3.1.5, table 3.1.6, table 3.1.7, table 3.1.8, table 3.1.9 and table 3.1.10. The values that are highlighted in the tables are those values which we consider to be potentially transferable to the SOCLIMPACT framework.

Table 3.1.2. Values of climate change impact on tourism: loss of beach surface

Risk	Associated hazards	Physical impact	Impact on destination image	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Loss of beach surface	SLR 25 cm	↓ 87% of beaches availability				Spatial analysis based - GIS model.	Martinica	Schleupne, (2008)	(L-to-M)
	2 m inundation 7 m inundation	24% of land loss 59% of land loss				Spatial analysis based - GIS model.	Morocco	Snoussi et al (2008)	(M)
	SLR		**Image worsened**	**77% unwillingness to re-visit**	**46% reduction on tourism revenue**	**Survey sata analysis**	**Bonaire and Barbados**	**Uyarra et al (2005)**	**(M to H)**
	SLR	**1) Beach erosion, different scenarios; 2) Adaptation measures**		**1) 17-23% tourists opting for alternative destinations; 2) no change**	**1) 25-25 million$ reduction on tourism revenue; 2) no decrease**		**Australia**	**Raybould, (2013)**	**(M to H)**
	SLR, 25 cm projected by 2050			Redistribution of tourists flows	GDP loss ranging from 0.1% in South East Asia to almost no loss in Canada	Computable General Eq. (CGE) GTAP-EF (Global Trade Analysis Project) model.	Different countries	Bigano et al (2008)	(M)
	SLR by 2100: i) 516-1010 mm IPCC; ii) 1430 mm Rahmstorf; iii) Sardinia 1350 mm, partial flooding areas at 1 m.a.s.l.	5500 km2 inundated;					1) North Italy-Adriatic 2) Gulf of Taranto; 3) Sardinia	Antonioli et al (2017)	(L-to-M)
	SLR 500 mm by 2100, no protection measures				Annualised costs: 1) Europe: 7 billons; 2) Asia: 36 billons; 3) Rest of the world:10,5 billons		Global	Darwin and Tol (2001)	(L-to-M)

Risk	Associated hazards	Physical impact	Impact on destination image	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	SLR + Tropical cyclones	1) Degraded reef: wave height reduction 0,44 m. 2) Healthy reef: ↓0.1m, enough to reduce risk on coast and infrastructure						Hongo et al (2018)	(L)
	SLR, IPCC projections	1) Beaches will lose on average GHC 227,500 per year; 2) 31% of tourism facilities likely to be fully damaged		↓ 2000 visitors per beach facility per holiday		Historical orthophotos and topographic maps	Accra, Ghana	Sagoe-Addy and Addo (2013)	(M)
	SLR 1000 mm	1) Beach erosion; 2) 29% resort properties inundated (partially or fully); 3) 60% of resort properties affected indirectly				Geo-referenced database	19 Caribbean Community (CARICOM) countries	Scott et al (2012)	(L)
	El Niño events	↑ 76% erosion in winter					6 regions of US West Coast in winter 2015-2016	Barnard et al (2017)	(L)
	El Niño events				Immediate impact= US$11.5 billion globally		Globally	NOAA (2016)	(L)
					1) Implicit price of beach width was $1.57/m/person/night (2009US$) 2) Current rates of beach erosion would result in revenue losses to the resorts of $52 $100 million over the next 10 years	**Hedonic prices (properties around)**	**Dominican republic**	**Wielgus, Cooper, Torres and Burke (2010)**	**(M-to-H)**

Risk	Associated hazards	Physical impact	Impact on destination image	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	ADAPTATION				Assesses beach users' willingness to pay for protecting European beaches WTP an annual tax in the range of 13.2-16.4/household	Contingent valuation	Greece	Kontogianni et al (2014)	(L-to-M)
	ADAPTATION				Visitors WTP for beach defense against: 1) Mean WTPs 0.5-1.49/day. 2) Willing to donate on average 1.1 every five years for beach defense.	Contingent valuation	France Greece Italy	Koutrakis (2011)	(L-to-M)
	ADAPTATION Dune and beach maintenance				1) 78% expressed WTP $1 - $5. 2) Benefit was estimated to be $1.90/ week ($0.27/day). 3) Aggregating benefit in excess of $2.75 million annually	Contingent valuation	New South Wales, Australia	Pitt (1992)	(L-to-M)
	SLR of 7 cm in 2030 and, depending on the hypotheses, of 35 cm, or perhaps even 1 m, by 2100				Mean WTP is 36.4/household/year	Contingent valuation	France	Rulleau and Rey-Valette (2013)	(M)
	50% reduction in beach width:				**1) Annual WTP erosion $997,468 (2011 US Dollars); 2) Annual loss of revenue $73 million. 3) WTP improve beach conditions 36.9%**	**Contingent valuation**	**Colombia**	**Castano Isaza, Newball, Roach and Lau (2015)**	**(M-to-H)**

Risk	Associated hazards	Physical impact	Impact on destination image	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	Beach erosion				Revenue losses to the resorts of $52 $100 million over the next 10 years		US	Mendelsohn and Markowski (1999)	(M)

Table 3.1.3. Values of climate change impact on tourism: loss of marine biodiversity

Risk	Associated hazards	Physical impact	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Loss of marine biodiversity	2°C global warming and consequent inundation in the US	1) loss of habitat ranges from 20% to 70%; 2) coral reefs biodiversity and quality loss; 3) ↓ turtle nesting beaches;	↓ prob. of revisit the destination	1) ↓expenditure per-capita \$45-\$192; 2) economic losses amount to almost US\$18 million (for drop in coral quality Bonaire)	Stated preference method, applying a random utility framework, estimated via mixed logit model.	Bonaire	Uyarra et al (2005)	(M)
	↑ 2ºC global warming	1) 20-70% loss habitat range 2) 30% loss corals		2) economic losses US\$ 18 mill			1) Galbraith et al (2002) 2) Payet & Obura (2004)	(M)
	Impact of jelly fish blooms on			1) WTP average 3.20/beach visit 2) Gains associated reduction of jelly fish 422.57 million,11.95% tourism expenditures	Choice experiment	Catalonia	Nunes et al (2015)	(L)
	Seawater warming		Additionally, they estimate: 1) Fisheries, total impact less than \$2 million/ year for both regions. 2) Shoreline protection \$18-\$33million in Tobago and \$28-\$50 million in St. Lucia	1) \$101-\$130 mill Tobago and 2) \$160-\$194 mill St. Lucia.		1) Tobago 2) Santa Lucia	Burke, Greenhalgh, Prager and Cooper (2008)	(L)
	Adaptation measure			Average WTP for a 1%improvement in 25 years time is \$21.68 (AUD) per annum for five years.	Choice experiment WTP for policies to improve the Great Barrier Reef	Queensland, Australia	Rolfe and Windle (2012)	(L)

Risk	Associated hazards	Physical impact	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	Impacts of harmful algal blooms (HABs) on public health, commercial fisheries, recreation and tourism, and monitoring and management costs.			1) France: 181 mill euros 2) Spain: 178 mill euros 3) Italy: 115 mill euros	1) Accounting (fisheries) 2) Contingent valuation (tourism) 3) Health costs estimation	France, Spain, Italy	Stolte et al (2003)	(L)
				1) CS/recreational trip A$184.84 à→current reef quality. 2) Visit rate ↓ 80% if reef quality ↓. 3) CS ↓ by 80% (from A$285 million/year to A$56million/year). 4) Estimated total expenditure ↓ from A$250 million/year to A$50 million/year.	**Contingent valuation Changes in trip demand GBR due to ↓ in reef quality**	**Queensland, Australia**	**Kragt, Roebeling anad Rujis (2009)**	**(M-to-H)**
				1) Average annual personal WTP is $35.75 (US dollars) 2) Total annual WTP country level $0.43 bill.	Contingent valuation WTP Taiwanese to protect and restore coral reefs m potential CC.	Taiwan	Tseng, Hsu and Chen (2015)	(M)
				1) NPV benefits $320.2 mill Beau Vallon, 2) $159.4mill La Digue, 3) $359.5 mill St. Anne, 4) $95.7 mill Curieuse, 5) $31.9 mill Bird Island, and 6) $31.1 mill Port Glaud. 7) Total net benefits $210 mill and net costs of $109mill	Benefits and costs marine resources in the Seychelles 1) Contingent valuation 2) Travel costs method 3) Change in productivity	Seychelles	Cesar, Van Beukering, Payet and Grandourt (2004)	(M)

Risk	Associated hazards	Physical impact	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	Economic loss recreational fishing due to SLR			**1) Change CS → reduced beach width $5.82 in 2030 and $6.45 in 2080. 2) The PV total losses $140-$757 mill in 2030 and $224 - $1.291 bill in 2080**	**Travel cost**	**North Carolina, US**	**Whitehead, Poulter, Dumas and Bin (2008)**	**(M-to-H)**
				WTP coral cover 15%-25% → US$41 per 2-tank dive. Sea turtles WTP US$57 first encounter, and US$20 per 2-tank dive/additional encounter.	Choice experiment WTP for quality improvements in dive characteristics	Barbados	Schuhmann, Casey, Horrocks and Oxenford (2013)	(M)
				WTP US $5.61/ year for a 10% ↑ in coral coverage and biodiversity and US $142.22/year creation of protected areas. perceived a decline in reef health US$256.80. Perceived no change $102.50).	Choice experiment Perception of change in coral reef ecosystems affect WTP establishment of protected areas	Okinawa, Japan	McClenachan, Matsuura, Shah and Dissanayake (2018)	(M)
	Ocean acidification			Sscenario A1, annual damage $169 bill in 2100 (0.027% global GDP)	Meta-analysis	79 countries Economic value of ocean acidification 4 CC scenarios FUND model → estimate CO2 emissions	Van Beukering, Brander, Tol and Rehdanz (2009)	(L)

Risk	Associated hazards	Physical impact	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	seawater warming SRES A1B scenario of greenhouse-gas emissions	Seagrass density would rapidly decrease during the first 30 years to reach the threshold of shoot density below which meadow functionality is lost (the 10% of the present density) by year 2049					Gabriel Jord, Núria Marbà and Carlos M. Duarte (2012)	(M)

Table 3.1.4. Values of climate change impact on tourism: weather discomfort.

Risk	Associated hazards	Physical impact	Impact on destination image	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Weather discomfort	Climate Change projections by CSIRO				1) By 2030: losses \$27000 to \$184.000 2) By 2060: losses \$96000 to \$1.200.000	Forecasts of population growth	Brisbane (Australia)	Toloo et al (2015)	(L)
	Heat waves				1) ↑ demand for indoor activities 2) ↑ 25% of water consumption	Survey data analysis.	Spain	Gómez-Martín et al (2014)	(L)
	High temperatures				**1) WTA for the risk of health effects 547.17 (2010 European Euros) and WTP 283.27. 2) Risks of temperature rise, WTP 113.06 and WTA148.23.**	**Contingent valuation Compare WTP to avoid higher risks with WTA for accepting equal levels of higher risks of climate change effects**	**Canary Islands**	**Leon, Arana, Gonzalez and de Leon (2014)**	**(M-to-H)**
	High temperatures			↓ low-cost destinations attractiveness	Tourists are attracted to climates with an average daytime maximum of 30.7		Origin market survey, UK	Maddison (2001)	(L)
	Extreme temperature effects on intention of behaviour (visiting) of visitors to the Rocky Mountain National Park	Extreme heat impact on tourists' comfort		7% visitors stated they would visit less often the RMNP because of weather discomfort		Survey data analysis. This study uses OLS regression analysis to model the contingent behaviour of visitors as a function of climate scenario variables and demographic variables.	Colorado State (USA)	Richardson and Loomis (2003)	(L)

Table 3.1.5. Values of climate change impact on tourism: land habitats degradation

Risk	Associated hazards	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Land habitats degradation	Change in climate and natural resources	Visitors spend on average $52.40 /person/ day, $24.78 of which is spent locally.		Rocky Mountain National Park (Colorado, USA)	Richardson and Loomis (2003)	L-to-M
	Adaptation measures	Average cost for marine habitat restoration: US$80 000-$1,600,000 /1 hectarea (2010)		954 intervention/restoration projects of coastal habitats in Europe, US and Australia (benefits of adaptation measures)	Bayraktarov et al. (2013)	(L)
	Adaptation measures biodiversity preservation	2 WTP 30.8-38.6 euros/household/year for residents and 3.2 euros /vehicle/visit for visitors	Choice experiment	France	Bonnieux, Carpentier and Paoli (2006b)	(L-to-M)
	Landscape deterioration	1) Annual value current landscape $0.33-$1.03 bill. 2) Total annual values for the three pre-settlement $1.23 -$3.08 bill in Scenario 1, 3) $0.67-$2.37 bill in Scenario 2, 4) $0.50-$17.5 in Scenario 3.	Contingent valuation	Manitoba, Canada	Voora, V. and H. D. Venema (2008)	(M)
	Prevent forest loss	Mean household WTP for 60 years impacts: 1) $8.89 to prevent a 600 foot loss. 2) $46.91 to prevent a 1,200 foot loss. 3) $182.07 to prevent a 2,500 foot loss. 4) 150 year WTP $3.15-$87.74	Choice experiment	Colorado, US	Layton and Levine (2002)	(L)
		1) Total annual value $5.4bill. 2) Per hectare basis, forests ($5,913-$7,432) and wetlands ($4,017-$5,996) are the most valuable. The NPV $96-$270 bill. 3) In per capita terms, the NPV $43,678-$122,844 using population 2,197,918.	Estimate value of natural capital Unit transfer approach	British Columbia, Canada	Wilson (2010)	(L)
		1) Marginal WTP/visitor/trip to the wetland for generalist migratory species is 0.78, in 2013.	**Choice experiment Economic value to the Albufera Natural Park**	**Mallorca, Spain**	**Faccioli, Font and Figuerola (2014)**	**(M-to-H)**

Risk	Associated hazards	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
		2) Marginal WTP/visitor/trip for specialist species 1.17 -1.00.	**changes in the number bird species**			
	Total costs of the impacts of invasive non-native species (INNS)	1) Total annual costs £165.6 mill for Japanese knotweed, 2) £25.5 mill for floating pennywort, and 3) £2.7 mill for signal crayfish. 4) Total costs for England, Scotland and Wales £1,291 mill, £245 mill, and £125mill.	Actual expenditure/market price of output Replacement costs	UK	Williams et al (2010)	(L)

Table 3.1.6. Values of climate change impact on tourism: water shortage

Risk	Associated hazards	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Water shortage	Average and total costs of a water shortage	1) 10% reduction a total costs $6.8 billion in the short-run and $0.2 billion in the long-run. 2) Short-run → manufacturing sector highest total costs ($5.3 billion) and the livestock users highest total costs ($134 million). 3) 10 MCM reduction → mining highest total costs ($1.5 billion) in the short-run and the livestock sector ($231 million) highest total cost in the long-run		Alberta and Saskatchewan, Canada	Bruneau (2007)	(L)
		-HK$221.12 and HK$166.03 per month for 4 hour shutdown. -HK$559.13 and HK$332.06 per month for 8 hours; -HK$1607.78 and HK$581.11 per month for 14 hours. Water service interruption leads to welfare losses ranging from HK$221.12 to HK$1067.78 per capita per month. It is around between $44 and $215 per capita per month.	The demand function was estimated with monthly per capita water consumption as a function of: monthly water charges (HK$/cubic meter), monthly per capita income, monthly hours of water supply, monthly precipitation net of evaporation, average temperature, dummy variables for seasonality.	Hong-Kong	Woo, Chi-Keung. Managing Water Supply Shortage: Interruption vs. Pricing. Journal of Public Economics. Vol. (54), 1994, pp. 145-160.	
	WTP for avoiding water shutdowns	Respondents were then given a specific scenario regarding water shortage frequency (1 in 30 years to 1 in 3 years) and magnitude (10% to 50% shortage). It was found that respondents would be willing to pay between $16.92 more each month to avoid a 50% reduction in service that occurred once in 30 years and $11.67 to avoid a 10% reduction in service that occurred every 10 years.	Contingent valuation – dichotomous choice. 3,769 questionnaires. Analysis was completed using a double bounded logit model. Explanatory variables included water shortage magnitude, water shortage frequency, years as resident, number of people	California (USA)	Koss, P. and M.S. Khawaja (2001). Water Policy 3, 165-174	

			per household, living in a single family residence, age (18-34 and 35-54), income and education.			
		WTP 33 to 37/ household (one-off payment, in Euros) in order to assure scientific research	Economic values scientific information on CC, water quantity improvements Choice experiment	Northern Finland	Koundouri (2012)	(L-to-M)
		The WTA per customer per month for an increase in SASE probability (from 1/10 to 1/5) is $6.65. The WTA per customer per month for an increase in SASE probability (from 1/10 to 1/2) is $8.73. The WTA per customer per month for an increase in a standard annual shortage event (SASE) probability (from 1/300 to 1/100) is $4.53.	Contingent Valuation Method	Colorado (USA). Three cities.	Howe and Smith (1994) The Value of Water Supply Reliability in Urban Water Systems. Journal of Environmental Economics and Management 26, 19-30.	L 25 y.o., urban not tourist; periods longer than tourists ones.

Table 3.1.7. Values of climate change impact on tourism: infectious diseases

Risk	Associated hazards	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Infectious diseases	Chikungunya and dengue epidemics	↓ 4% international tourist-non endemic countries (US$)	↓ 4% international tourist-non endemic countries (US$): 1) Gujara: ↓ 8 mill. 2) Malaysia: ↓ 65 mill. 3) Thailand:↓363 mill.	Data analysis: tourist arrivals, expenditures, length of stay.	India, Malaysia and Thailand	Mavalankar et al. (2009)	(L)
	Curaçao chikungunya (2016) and Zika (2017) outbreaks	Using only arrivals data from 2014 to 2017, author reports just a slight reduction of tourists during the outbreaks periods, but it did not affect the occupancy rate declared by tourism industry managers		Secondary data from WB and interviews to tourism practitioners	Curaçao island (Caribbean Sea)	Grace Damaris Suradi (2019), Mater thesis dissertation, University of Utrecht	(L)
	Zika outbreaks in Latin America (2015)		-Zika Virus epidemic for 2016 in the Latin American and the Caribbean region: US$3.5 billion or 0.06% of GDP. -Some of tourism-dependent small islands in Caribe region could rich as high as 1.6% of GDP	- Estimation of the effort to avoid infection from tourists. -Time, labour and productivity losses due to time off from work.	Latin American and Caribe countries	World Bank Group (2016)	(L)
	Malaria due to vector borne transmission	It gives place to reduced productivity, absents to school, less foreign investment and demographic change, and imply more medical costs. There are several macro an micro approaches to estimate its impacts on the economy. We will consider WTP	-Weaver(1996), Central African Republic, WTP $7.98 individual's median. -Cropper et al. (2000), Ethiopia, average annual WTP per households $36.	WTP amongst other methodologies of estimation. A sample of the local population.	Central African Republic Ethiopia	Basili and Belloc (2015)	(L)

Table 3.1.8. Values of climate change impact on tourism: forest fire

Risk	Associated hazards	Behavioural effect	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Forest fires		1) 33% of tourists are not at all discouraged by this risk factor 2) ↓42% tourism arrivals only under very higher risk scenario		Interviews of managers of individual tourism firms.		Thapa et al (2013); Hystad and Heller, (2008); Cioccio and Michael (2007)	(L)
	Adaptation, fire protection		**WTP 39.5-47.2 euros/household/year for residents and 5.0 euros /vehicle/visit for visitors**	**Choice experiment**	**Calvi, Corsica**	**Bonnieux, Carpentier and Paoli (2006a)**	**(L to M))**
	ADAPTATION Reconstruction of coastal forests and the forest fire management activities		**WTP:** **1) Forest landscape in tourist areas of $1.50/tourist/day;** **2) Forest landscapes in the entire region $0.75/tourist/day ;** **3) Reconstruction NPV $2.8 mill, and rate of return 24%.** **4) Forest fire management NPV $7.7 mill and rate of return 13.0%.**	**Contingent valuation**	**Croatia**	**Pagiola (1996)**	**(L to M)**
			PV ecosystem service benefits of the GHG mitigation scenario is on average $3.5 billion (2005 US Dollars, using a 3% discount rate)	Cost approach to evaluate the benefits of GHG mitigation	US	Lee, Schlemme, Murray and Unsworth (2015)	(L)
			WTP 57.88 -74.89, for reducing fires with size over 500 ha. Mean yearly welfare cost of forest fire: 1) 317 France 2) 1778 Italy 3) 3165 Portugal 4) 2,900 Spain	WTP measured as reduction in household income necessary to maintain life satisfaction constant given a discrete decrease in the level of the fire indicator	1) France 2) Italy 3) Portugal 4) Spain	Kountouris and Remoundou (2011)	(M)
	Impact of forest fire on recreation value in National Forests		Mean value of a hiking trip $109-$222.	Combined revealed and stated preference approach	Colorado Wyoming Idaho	Englin, Loomis and Honzalez-Caban (2001)	(L)

Table 3.1.9. Values of climate change impact on tourism: damages on coastal infrastructures

Risk	Associated hazards	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Damages on coastal infrastructures	Impact of Hurricane Katrina on Mississippi business owners.	↑ losses $267-$1477 mill (SLR+hurricane) ↑ losses $15,6-$150,3 mill (SLR)	Linear probability models Data from Census Bureau's Longitudinal Business Database (LBD). ↑ short-term damage for all businesses.	Mississippi area	Moore et al (2010)	(L)
	Floods	Total expected annual cost $958,600 to $7,962,100 for best-case and worst CC scenarios	Contingent valuation and replacement costs	New-Brunswick, Canada	Lantz et al (2012)	(L)
	Floods	1) Mean WTPs US$2,237 -US$45,481 (no protection and depending scenario) 2) Mean WTPs US$957-US$34,031(protection bellow current 100-year) 3) Mean WTPs US$833-US$30,689(protection bellow future 100-year) 4) The annual mean WTP/ statistical household US$20,355 for Climate Scenario 1 and US$17,686 for Climate Scenario 2. With protection, the reductions 31.13% -54.03%	WTP to avoid flood risk Two level Nested Logit	Pennsylvania	Yang (1999)	(L-to-M)

Table 3.1.10. Values of climate change impact on tourism: cultural heritage

Risk	Associated hazards	Physical impact	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Cultural heritage	Hypothetic conservation program for heritage sites in Armenia		Benefits of the program = US $6.2-6.8 mill. or US $0.9 mill annually, which is roughly equal to annual costs.	survey- eliciting WTP; Bayesian updating model	Armenia, 2004	Alberini and Longo (2009)	(L-to-M)
		Corrosion ↑ conservation-restoration costs of limestone façades.	↑3% weathering costs	Dose-response functions	Krakow (Poland)	Grøntoft (2017)	(L)
	ADAPTATION WTP to protect and preserve the town traditional character		1) Willing to donate 30.4-45.6 to support the institution.; 2) Annual aggregate value 0.8-1.3 mill Euros	Contingent valuation	Greece	Giannakopoulou, Damigos and Kaliampakos (2011)	(L)
	ADAPTATION WTP to protect and preserve the heritage of Valdivia		Mean WTP ticket: 11,443 pesos (2009 Chilean pesos)	Contingent valuation	Chile	Báez-Montenegro (2015)	(L)
	ADAPTATION WTP to protect and preserve the Dead Sea basin		1) WTP $59,148,000 (2002 US dollars) 2) Travel cost:consumer surplus of $193 mill 3) Avoided damages and defensive expenditures $16.3 mill. 4) Water in agriculture and in mineral industry $314 mill and $143 mill	Contingent valuation Travel cost Avoided damages	Israel Jordan Palestine	Becker and Katz (2006)	(L)
			Economic benefits of preservation My Son sanctuary: 1) WTP one-time fee $5.92 (5.2 - 7.7) (2005 US Dollars) (Foreigners) 2) WTP 33.34 (20.95 - 45.8) (2005 Vietnamese currency in '000) (locals)	Contingent valuation Chioce Experiment	Vietnam	Tuan and Navrud (2006)	(M)

SOCLIMPACT

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3.2. Climate change economic impacts in aquaculture sector

The world's dependence on capture fisheries and the aquaculture sector is threatened not only by inadequate management of these aquatic resources but also by factors external to the sector such as climate change. Fisheries stakeholders in coastal and inland areas are particularly vulnerable to the direct and indirect impacts of Climate Change. As it was already mentioned in the previous deliverable (D5.1) of the project SOCLIMPACT, the basic effects of climate change on aquaculture are (Soto and Brugere, 2008):

1. Change in biophysical characteristics of coastal areas.
2. Increased invasions from alien species.
3. Increased spread of diseases.
4. Changes in the physiology of the cultivated species by changing temperature, salinity, oxygen availability and other important physical water parameters.
5. Changes in the differences between sea and air temperature which will alter the seasonality, frequency and severity of storms, cyclones and other extreme events (already experienced this in the Mediterranean for the first time in 2018 - South Italy to North Greece and Turkey 'Medicane'), affect the stability of the coastal resources and potentially increase the damages in infrastructure.
6. Sea level rise, acidification, changes in precipitation and other effects will also add to the changes in coastal ecosystems and environment, thus affecting production and infrastructure (=investments).

However, in this report we will focus on the climate change effects into the aquaculture production, because these values are the inputs that WP6 will need to continue with their task.

Troell et al. (2017) affirm that aquaculture is an important activity in many of the Artic regions. The total aquaculture production of these constitutes about 2% of the global production volumes and values (FAO, 2014). Within these regions, Norway accounts for 93% of the total value of aquaculture (Andreassen and Robertsen, 2014).

On his study, Lorentzen (2006) used a Gross Present Value function (GPV) of salmon farming in North European waters in order to include market data and the logistic growth function of the cultivated fish in weight. Different scenarios were considered: the first one was based on the increase of the temperature amplitude between ±0.5 and ±2.5 °C (increase in higher maximum and lower minimum temperatures, average temperature remains as is). Results showed that amplitudes up to ±2.5 °C based on the current average temperature may not affect the growth of the fish, except in the case when temperature falls below +1 °C (amplitude > -3.1 °C), which will result into the death of the fish because the temperature will fall in the zero growth-high mortality levels for the species. The second scenario was based on the increase of the average temperature by +0.5 to +3 °C. Due to the fact that salmon and similar species are cold-blooded, such an increase in temperature will result in the increase of the growth of the cultivated fish gaining around 2-4 months in the total production period. The third scenario was based on the change of both amplitude and average temperature. An increase of the average temperature by 3-4 °C and an increase of the amplitude by +3 to +4 °C will create an environment which is similar to 1 °C increase in average temperature alone (similar to the change expected in the next 20-50 years), and will be negative for the fish. Below these levels, the production cycle can be reduced by 3-4 months and even more. The sales and profit increase with a ratio of 0.8% per 1% increase of the average temperature. On the other hand, in the case of simultaneous change of temperature amplitude and the average temperature, the results showed that for every 1 °C increase, gross production value increases on average by 17% (12-21% based on country region). However, when changes above these levels occur, GPV drops substantially.

He calculated these GPV values and changes as $GPV = \sum_{n=1}^{\infty}(p_0\, w(t) N_n e^{-Mt}) e^{-rnt}$, where $p_0$is a constant representing the prices of the fish, *w(t)* is the weight of the fish at time *t*, represents the number of juvenile fish in the beginning of rotation *n*, *M* is the mortality rate, *r* is the real interest rate, *n* represents the number of rotations and *t* is the length of the rotation period measured by month.

Furthermore, Lorentzen (2008) developed a similar study, using the same GPV function applied to firms located in Lista and Skrova (Norway). He found that an increase in average temperature caused a positive effect on GPV. This effect is linear for temperature increases up to 5 degrees for Skrova, but when the temperature increment is higher, the effect on GPV becomes positive, but diminishing. A similar pattern of linear effect is observed in Lista, where this linear effect is up to 2.5 degrees. The author observes that an increase of 1ºC in the average temperature in Skrova will derive on an increment in GPV of 15-16% and an increase of 11% in Lista. Each percentage increase in average temperature will be translated into 1.07% increment in GPV in Skrova and 0.75% in Lista. However, this relationship is only valid in the average interval from 8.70ºC to 11ºC. Moreover, he finds that an increment on the average temperature of 1 degree will increase productivity in fish farming of Skrova and Lista by 20% and 12-13%, respectively. A simultaneous 1% increase on amplitude and average temperature increases the productivity about 15% in Skrova and about 12% in Lista.

On the other hand, the increase in the frequency of extreme events will have important impacts on the aquaculture production process by affecting production costs, reducing gross income and increasing the number of insurance costs and services.

Again, the main values found in the literature are collected and summarized in table 3.2.1, and the potentially transferable vales are remarked.

Table 3.2.1. Values of climate change impacts on the aquaculture sector: changes in productivity and adaptation policies

Risk	Associated hazards	Physical impact	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Productivity	Salmon farming in North European waters 1.Temp. amplitude ↑ ±0.5-±2.5 °C 2.Temp. average ↑ +0.5 to +3 °C. Temp. amplitude ↑ +3 to +4 °C, and average ↑ 3-4 °C	Gross-Present Value function (GPV)	1. No effects bellow +1ºC 2. ↑ growth of cultivated fish around 2-4 months. 3. Similar to ↑ 1ºC average temperature. Production cycle ↓ by 3-4 months	3. every 1 °C increase ↑ GPV on average by 17% ↑ sales and profits with a ratio 0.8% per 1% ↑ in average temperature	Norway	Lorentzen (2006)	(L)
	Salmon farming in Skrova and Lista 1. Temp. average ↑ +1 °C 2. Temp. average and temp amplitude ↑ +1 °C	Gross-Present Value function (GPV)	1. ↑ productivity 20% Skrova and 12-13% in Lista 2. ↑ productivity 15% Skrova and 12% in Lista	1. ↑ GPV of 15-16%(Skrova) and 11% (Lista) Each 1ºC ↑ → ↑ 1.07% GPV in Skrova and 0.75% in Lista	Norway -Skrova -Lista	Lorentzen (2008)	(L)
Adaptation and mitigation policies	Economic and ecological impacts of non-native invasive species in the EU		171 species (16.1% of the total) → ecological impact 1276 species (16.4% of the total)→ economic impacts	US, UK, Australia, South Africa and India 276 billion €/year Ireland 202 million € UK(marine species) 8 million €/year Germany (marine species) 14 million € Canada (marine species) 45.7 million €/year USA (only fish and molluscs) 2.3 million €/year EU 125 billion €/year Cots management and mitigation → 190 mill Euros (40-190)	EU	Vilà et al (2010)	(L)
	Adaptation and mitigation policies (Adaptation costs for the)			Value coastal infrastructure→ 0.5-0.9 bill Euros/year (SLR) Netherlands → > 1 bill Euros/year 2010-2100 UK → 440 mill Euros Japanese ports→ 97 bill Euros (1m SLR)	EU Member States	Policy Research Corporation and MRAG (2000)	(L)

Risk	Associated hazards	Physical impact	Economic impact assessment	Method/Model	Location	Source	Comments and usefulness: Low(L), Medium(M), High(H)
				Australia endangered infrastructure→ 142 bill euros (1m SLR)			

3.3. Climate change economic impacts on energy sector

When evaluating the impacts of climate change in the energy sector, one can distinguish between effects on the demand side, effects on the supply side and damages to transmission grids (energy distribution).

From the supply side, we will distinguish two phases, energy production and distribution, and mainly two modalities of renewable energy impacted by climate change, wind and photovoltaic. If relevant, we will take into account also the subsector of tidal and waves energy. To estimate climate change impacts costs, we will first consider the scenarios of renewables sources adoption for the islands, at the horizons 2030, 2050 and 2100, in turn aligned with those stablished for the whole the European Union. Then we will estimate losses in the productivity of wind and photovoltaic energy devices due to climate change impacts, specially heat waves and wind speed; the first affecting the productivity of PHV energy devices and the second affecting the productivity of wind energy devices.

More accurately, losses of productivity in PHV energy production come from higher temperatures affecting the efficiency of conversion of photo into electric energy. The losses in wind energy productivity come from the time in which generators cannot work because of too high and too low wind speed, and the deviation between the wind speed used for devices calibration and the actual wind speed. Climate change costs estimation requires to estimate the parameters giving account of productivity deviation of energy production due to climate change.

Economic valuation of the climate change impact on the energy sector at European islands will be undertaken from both the demand and supply side. As presented before, extreme temperatures are directly faced by heating and cooling, while extreme high temperatures are frequently associated to extra water consumption for hydration and refreshing. Both, air conditioning in the spaces being used and extra water consumption pose higher costs for families and business. Those costs fall under the category of *defensive* costs, i.e., costs to avoid negative impacts or externalities. They may be estimated by measuring the additional expenditure in heating, cooling and water that households and businesses must undertake to alleviate the effects of extreme temperatures. We will assume that people are indifferent to temperatures above and below some thresholds. By knowing these thresholds, the number of days per year that temperatures cross them, and the intensity of change of energy and water demand in response to a particular deviation of temperatures from the referred thresholds, the economic valuation of extreme temperatures on the islands' economy may be elicited.

Extreme weather affects the yielding of electric grids. Hurricanes break grids and electric transport stations involving extra costs to fix them; or request additional investment to prevent breakages. Additionally, extreme high temperatures increase electric losses in transportation.

The values found in the literature are collected and summarized in table 3.3.1, table 3.3.2 and table 3.3.3. Once again, values which are remarked are those that we consider potentially transferable to the SOCLIMPACT framework

Table 3.3.1. Values of climate change impacts on the energy sector: changes in power generation

Impact	Energy Source	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Changes in power generation due to long term CC and variability	Wind Energy	The impact of the North Atlantic Oscillation on the wind potential over the North Sea		Simulation results show that the wind power from offshore wind farms is likely to increase by 3–9%around the North Sea due to increases in wind speed		Sood and Durante (2006)	(M)
		Effects of changes in wind speed		10% change in wind speed--> alter energy yealds 13%-25% (depending on site and season)		Baker, Walker and Wade (1990)	(M)
		Analysis of European offshore wind speed		Over the past 40 years such as UK winter wind speeds rising by 15–20% over that period		Watson et al (2001)	(L)
		Implications of climate change for the UK's wind power resource.	Regional climate models	Wind speed ↓ in summer by 5%in much of the UK and by about 15% around the South-Eastern part of the Northern Ireland.		Cradden et al (2006)	(M)
		US		If solar incidence ↓ predicted by NASA → average wind speeds ↓ 10%–15% (which entails 30%–40% ↓ potential wind power generation) by 2040-2050		Pan et al. (2004)	(M)

Impact	Energy Source	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
		Mid-Norway		↑ wind power capacity	↓ deficit only 2% of additional wind generation is exported	François et al (2017)	(L)
		Changes in temporal characteristics of the wind power generation in scenarios RCP8.5 and RCP4.5	+five state-of-the-art global circulation models (GCMs) +Coupled Model Intercomparison based on circulation weather types. +Coarse-grained model of the electric power system	↑ backup and storage needs in Central, Northern and North-Western Europe ↓ backup and storage needs in Iberian Peninsula, Greece and Croatia		Weber et al. (2018)	(M)
		Europe **Annual energy yield of the wind farms under two GHG concentration scenarios**	**Multi-model of EURO-CORDEX ensemble. Nine GCM-RCM combinations comprise the ensemble.**	**Europe: annual energy yield stable across the 21st century** **Iberian Peninsula:** **↓power production of yield by 5%–10%/year,** **↓15% in autumn under the RCP8.5** **Poland-Baltic fleet energy yield ↑ due to sea ice melting**		**Tobin et al. (2016)**	**(M-to-H)**
		Impact of changes in atmospheric icing on large wind turbines in Scandinavia	Using different climate change projections	Most of the wind turbines gain efficiency due to CC. The time of icing ↓ 5-100% Windmills can operate up to wind speeds of around 25m/s--> higher speeds won't increase output		Laakso et al (2006)	(M)

Impact	Energy Source	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
		The wind climatology of Ireland under different climate change scenarios.		CC has a seasonally different impact on the wind power potential of Ireland: an overall increase in wind speeds in winter by about 4–8%and a decrease during the summer months.		Lynch et al (2006)	(L)
		Scottish wind resource availability under the forcing of the SRES A1B GCC scenario	The HadCM3 General Circulation Model (GCM)	Gordonbush: ↑ 31.7% the net annual elect.production Dun Law: ↓ 31.8% (2040)	Gordonbush: ↑ annual gross profit of £95,284 Dun Law: ↓£22,742	Miu (2015)	(L-to-M)
		46 sites on Baltic region. Potential impact of CC on wind power	Downscaling technique	Wind speed of 3m/s can produce 16W/m2 of wind power. A wind speed of 12m/s produce 1305 W/m2 Wind power potential ↑ to 15%in the Baltic Sea region(IPCC SRES A2 scenario)		Clausen et al (2007)	(L)
	Solar/photo voltaic energy	**Examine how projected changes in temperature and insolation affect photovoltaic (PV) and concentrated solar power (CSP) output IPCC SRES A1B scenario**	**Models HadGEM 1 and HadCM3**	**PV output 2010 to 2080 ↑ by a few percent in Europe and China (2%-6%), little change in Algeria and Australia (0%-(-2%)), and decrease by a few percent in western USA and Saudi Arabia (-4%-(-8%)). CSP output ↑ more than 10% in Europe, increase by several percent in China (5%-10%) and a few percent in Algeria and Australia(0%-5%), and decrease by a few percent in western USA and Saudi Arabia (-0%-(-5%)).**		**Crook, Jones, Foster and Crook (2011)**	**(M-to-H)**

Impact	Energy Source	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
		Nordic region		2% ↓ in global solar radiation --> ↓ solar PV cell output by 6%		Fidje and Martinsen (2006)	(M)
		Assesment of near future change in productivity of photovoltaic energy (PVE) in Europe and Africa IPCC SRES B2 scenario.	ECHAM5-HAM aerosol-climate model ,and a model for the performance of photovoltaic systems	Significant ↓ PVE productivity up to7% eastern Europe and northern Africa Increase 10% Western Europe and eastern Mediterranean		Gaetani et al (2014)	(M)
		Greece: Impact of changes in irradiance and temperature on the performance of photovoltaic systems	**RCM temperature and irradiance outputs for their biases.** **ENSEMBLES database-special report** **A1B emission scenario IPCC.**	**(2011–2050)** **↑ av. temp. up to 1.5∘C** **↑ irradiance projections 2-3W/m2** **(2061–2100)** **↑ av. temp 3∘C to 3.5∘C** **↑ irradiance projections 5W/m2** **↑ PV output western mainland and Peloponnese,** **↓ PV output Central Macedonia**		**Panagea et al (2014)**	**(M-to-H)**
		Effect projected changes in irradiance and temperature on photovoltaic systems in Greece	**5 regional climate models (RCMs) under the A1B emissions scenario**	**Performance photovoltaic systems → negative linear dependence projected temperature ↑→ outweighed by expected ↑ total radiation resulting in 4% ↑ in energy output** **Individual change in irradiance → ↑ PV energy output up to 5%** **Increas of temperature ↓ to 2%.**		**Panagea (2014)**	**(M-to-H)**

Impact	Energy Source	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
		Evaluate CC imapcts on photovoltaic energy generation	**EURO-CORDEX ensemble of high-resolution climate projections with a PV power production model**	**Alteration of solar PV supply by the end of this century compared with current climate conditions sh-14%/+2%. Largest decreases in Northern countries.**		**Jerez et al (2015)**	**(M-to-H)**
	Maritime energy	Cornwall, UK Impacts on wave energy generation	Global Climate Model and Regional Climate Models as well as a third generation wave model (WW3)	A1B scenario: ↑ wave power 2-3% B1 scenario ↓ 4-6% respect to A1B scenario WEC energy yield ↓ by 2-3% for both A1B and B1 scenarios		Reeve et al (2011)	(M)
		Western Scotland	Sensitivity study ↓ 20% in the mean wind and wave patterns on marine energy	↓ 67% available wave power levels	↑35%unit electricity costs.	Harrison and Wallace (2005)	(L-to-M)
	Hydrological energy	**South Europe Southeastern US Impacts of reduced river flows in thermoelectric power**	**Physically based hydrological and water temperature modelling framework with an electricity production mode**	**Summer capacity of power plants: South Europe ↓6.3–19% Southeastern US ↓4.4–16% Probabilities of extreme (>90%) ↓ in thermoelectric power production will on average increase by a factor of 3**		**Van Vliet et al (2012)**	**(M-to-H)**
		Europe Impact of changes in water availability, temperature and sectoral water use on thermoelectric power plant generation	Energy-water-climate model using power plant data set, a water quantity data set (both availability and demand), and a water temperature data set.	47 basins to 54 basins ↓ in power availability due to water stress rises (2014- 2030) The majority of vulnerable basins lie in the Mediterranean region, with further basins in France, Germany and Poland.		Behrens et al (2017)	(L)

Impact	Energy Source	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
		Western Europe Impact on electricity demand and hydropower supply	The numerical model LIBEMOD	total production of electricity ↓ 4%	↑ 1% producer price	Golombek et al (2012)	(L)
		Three hydroelectric power plants in Southern Spain. ↓ rainfall and changes in temperature Could affect the long-term profit margins and availability of water	Hydroclim model combining climatological, technical and economic data and projections	Southern: ↓ 30%-49% hydroelectric production (IPCC Scenario A2) Under this scenario 2 of 3 plants have negative operating margins (-6& and -27%). ↓ 10%-31% (IPCC Scenario B2) by the end of the century. One plant would cease to have has positive margins (-16%) This reduction would also affect new investments.		Solaun and Cerdá (2017)	(L)
		1. Alpine region 2. Austria Changes in river discharge characteristics and the power generation of run-of-river hydro power plants up to 2050.	lumped-parameter rainfall-runoff model at a monthly time step SRES greenhouse gas emission scenario pathway A1B	1. ↓ up to -8% annual electricity generation of run-of-river plants (2031–2050) 2. Austria: +5% to - 5% depending on the technical parameters of the power plants		Wagner et al (2017)	(L)
		Europe Impacts on electricity systems - in the absence of adaptation Scenarios for mid-21st century and the end of 21st century	Literature review	↓ thermal electricity generation ↑ RES production: - Hydroelectricity - Northern Europe - solar electricity – Germany, UK and Spain		Stanton et al (2016)	(L)

Impact	Energy Source	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
				wind electricity- Iberian peninsula, Baltic and Aegean Sea			
	Nuclear	The impact of changes in cooling water temperature on the thermal efficiency of nuclear power plants	Plant level data and an engineering model.	↑ 1ºC --> ↓ power output by 0.45% points		Durmayaz and Sogut (2006)	(L)
		Impact of climate change on electricity generation through thermal cooling		↑ 1ºC-->↓ nuclear power output by 0.8%, ↓ coal and gas power output by 0.6%		Linnerud et al (2011)	(L)
	General effects on supply of CC and mitigation/adaptation measures effects	Global scale	Asia-Pacific Integrated Model/Computable GeneralEquilibrium [AIM/CGE]) coupled with an end-use model		Global GDP change rates will range from +0.21% to -2.01% in 2100 under 4ºC change in the global mean temperature.	Park et al (2018)	(L)
		Power production in Central Europe			↑ temperature--> ↓ production 12%= losses 80 mill Euros for one single plant	Försters and Lilliestam (2010)	(L)

Impact	Energy Source	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
		South Australian region	Review	The 2008 heatwave reduced the instantaneous reserve margin up to 7%, which led to rocketing electricity market prices.	The cumulative↑ price was over AU$150,000. The electricity companies obtained extra revenues AU$200 million. Financial losses estimated AU$ 800 mill	WattClarity (2008)	(L-to-M)
		US	Review		The annual cost of weather-related power outages in the US ranged between \$25 and \$70 billion	Campbell (2012)	(L)
		Effects promoting renewable energy in Portugal (2000-2010)		↓ GHG=7.2 mill MtCO2eq	↑ GDP =1.557 Mill Euros ↑160 jobs-year	Behrens et al (2016)	(L)
		Benefits of climate change in the energy sector			By the year 2100 benefit of reduce heating 0.75% of GDP globally, increased cooling would be 0.45%.	Tol (2002a) Tol (2002b)	(L)
		Costs of power plants in EU for adapting CC			Annual monetary costs for adapting to CC in 2080à 400 mill Euros	Rademaekers et al (2011)	(L)
		US electric power sector			Without mitigation, total annual production costs in 2050 ↑ 14% (\$51 bill)	Jaglom et al (2014)	(L)

Table 3.3.2. Values of climate change impacts on the energy sector: changes in energy demand

Impact	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Changes in energy demand due to changes in precipitations and temperatures	Europe Impact of +2 ºC global warming on electricity demand	Construction of national temperature indices. Correction of national electricity consumption for non-climatic effects.	↓ heating electricity demand > ↑ in cooling electricity demand	France: ↓ consumer spending between €976 million and €1,713 million Italy: ↑ consumer spending by €68 million to €246 million. Overall: ↓ €3.8 billion to €6.6 billion in EU	Damm, A., et al (2017)	(M)
	How energy consumption responds to variations in temperature (energy, coal, gas, oil, and electricity). 31 countries period 1978-2000	**Panel data**	**Warmer countries elasticity of electricity demand respect to summer temperature 1.17 Colder regions -0.21. 1% increase summer temperature → 1.17% in warmer countries and ↓ 0.21% in colder. The elasticity of electricity demand with respect to winter temperature is 0.10 and -0.07 in warmer and colder countries.**		**De Cian et al (2007)**	**(M-to-H)**
	Estimate a household demand for 31 European countries 1995–2005. Projected changes in heating and cooling degree days (IPCC SRES emission scenario A1b)	**Panel data**	**1 ºC change in temperature→ change demand by 2kWh/ year per capita via changes in heating degree days. A unit increase in cooling degree days, the demand changes by 8 kWh/ year per capita.**		**Eskeland and Mideksa (2009)**	**(M-to-H)**

Impact	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	Slovenia (two cities) Scenarios in next 50 years: temperature ise (+1 ºC and +3º C) and solar radiation increase (+3% and +6%)	**Simulation of the indoor conditions and the energyuse for heating and cooling**	**Heating: -14 to -32% Cooling: -3 to +418%**		**Dolinar (2010)**	**(M-to-H)**
	USA 1. +1.2ºC (2025) 2. +3.4ºC (2025)	**Degree-days method: Heating degree-days (HDD) Coolingdegree-days (CDD)**	**1. Heating -6%, cooling +10%, +2% primary energy 2. Heating -11%, cooling +22%, -1.5%primary energy**		**Hadley (2006)**	**(M-to-H)**
	USA - residential sector +1 ºC January temperatures (2050)		2.8% for electricity only customers; 2% for gas customers; 5.7% for fuel oil customers		Mansur et al (2005)	(L)
	Switzerland (four cities) A2 and B2 IPCC SRES emission scenarios	Degree-days method: Heating degree-days (HDD) Cooling degree-days (CDD)	HDD: -13 to -87% CDD: up to + 20 times (2085 scenario)		Christenson (2006)	(L)
	USA Impact of CC on energy production, supply and consumption	Literature review	↓ energy demand for space heating ↑ energy demand for space cooling ↓overall thermoelectric power generation efficiency.		Wilbanks et al (2008)	(L)

Impact	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	California. ↑ 1.9 ºC	End-use energy models (heating and cooling of buildings and pumping and transport of water for farms and cities)	Electricity will increase by about 7500 GWh (2.6%) and 2400 MW (3.7%) by 2010		Baxter (1992)	(L)
	Greece A2 and B2 IPCC SRES emission scenarios - 2100 horizon	Econometric multivariate regression model	Increase of the annual electricity demand of 3.6-5.5%		Mirasgedis (2007)	(M-to-H)
	Five countries in Europe A2, A1B, and B1 IPCC SRES emission scenarios - 2050 horizon	**Econometric multivariate regression model**	**During summer, electricity demand will increase 2.5-4% by 2050 compared with 2007**		**Pilli-Sihvol et al (2010)**	**(M-to-H)**
	Maryland - residential and commercial sectors Mid-range (25 years) of temperature changes (+31F in spring and +41F in summer, fall and winter)	Econometric multivariate regression model	Future energy prices and regional population changes may have larger impacts on future energy use than future climate		Ruth and Lin (2006)	(L)
	Brazil - residential and commercial sectors A2 and B2 IPCC SRES emission scenarios	Degree-days method and COP effect	Increase in electricity consumption in the country of 8% by 2030 (worst-case)		Schaeffer et al (2008)	(L)

Impact	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	Dhaka city, Bangladesh Impact on residential energy consumption	Six global circulation model (GCM) Model intercomparison RCP2.6, RCP4.5, RCP6.0, and RCP8.5 scenarios	↑ 5.9–15.6 daily total residential energy demand ↑ 5.1–16.7%, peak energy demand		Shourav et al (2018)	(L)
	Global scale Impact on building operation and performance	Typical and extreme meteorological weather data for 25 locations (20 climate regions	In cold climates ↓ 10% energy use tropical climates ↑ 20% energy use mid-latitude climates: ↓ 25% heating energy- ↑ 15% cooling energy Low-energy buildings will be the least affected, with impacts in the range of 5–10%.		Crawley (2008)	(M)
	US Cost implications for Driving peak demand	Multiyear data from 166 load balancing authorities in the US were analysed using statistical models.	Average ↑ 2.8% peak demand by end of century ↑ costs of up to 180 billion dollars by the end of the century		Auffhammer et al (2017)	(M)
	Australia (four cities) - residential sector 1 °C increase in the average temperature	linear regression model adapted to include intraday variability	Change in peak regional demand between -2.1% and +4.6%		Thatcher (2007)	(L-to-M)

Impact	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	Australia (four cities) - residential sector a) Scenario 550 ppm (2050) b) Scenario 550 ppm (2100) c) IPCC SRES A1B (2050) d) IPCC SRES A1B (2100) e) IPCC SRES A1FI (2050) f) IPCC SRES A1FI (2100)	Software developed by coupling a frequency response building thermal model and a multi-zone ventilation model	a) -19 to +61% b) -27 to +112 c) -23 to +81% d) -37 to +193% e) -26 to +101% f) -48 to +350%		Wang, Chen and Ren (2010)	(L)
	Impacts on the European energy system **A1B scenarios**	**Prospective Outlook for Long-term Energy Systems (POLES) model, partial equilibrium model from the present day till 2100**	**↑ energy demand for air-conditioning by 2100 ≥50 Mtoe ≤ 65 Mtoe**	**Expenditure 2100:** **heating →↓$140 billion (A1B Scenario)** **space cooling → ↑ $136 billion** **Loss= 200 TWh (2070)**	**Mima and Criqui (2015)**	**(M-to-H)**
	Ontario Doubling of atmospheric CO2 concentrations (2 x CO2) assumed to occur during 2025-2065	Econometric multivariate regression model	Heating energy: -31 to -45%; Cooling energy: +6 to +7% (compared to 1976-1983)		Barthendu et al (1987)	(L)
	Massachusetts - residential and commercial sectors GHG emissions scenario assumed a 1% annual increase in equivalent CO2	Econometric multivariate regression model (Degree-days and others)	2.1% and 1.2% increase in per capita residential and commercial electricity consumption (2020)		Amato et al (2005)	(L)

Impact	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	Impact on residential energy demand for heating and cooling in Europe	The study estimated bias-corrected near-surface air temperature transmitted by GCMs.	↓ heating needs compared Long-term : -22% (2070-2100) -26%in 2100 Short-term : -5% (2020-2050). ↑ air cooling 44% - short-term and multiplied by a factor of 3 in the long-term,		Kitous and Despres (2017)	(M)
	Los Angeles changes in electricity demand		Without policy interventionà residential electricity demand ↑ 41-97% (2020-2060)		Reyna and Chester (2017)	(M)
	Switzerland Impact of a changing climate on the energy demand and supply system.	CGE model (GEMINI-E3)	↓ population requirements for heating purposes. ↑ energy demand for cooling ↓ efficiency and the load at which thermal power plants are operated	↓ prices	Gonseth and Vielle (2012)	(L)
	European power sector ↓ runoff of rivers ≥ 10%	Cooling water demand functions of thermal power plants	↑ electricity prices: ≥80%-Switzerland ≥ 30 %-France ↓ welfare for consumers		Rübbelke and Vögele (2013)	(L)
	Costs of summer cooling in European cities (Bilbao, Antwerp and London)	Methodology designed to be transferable from one city to another: urban climate modelling +	Cooling is expected to be needed when temperatures are over 27,6°C indoor. -Antwerp: 6200 kWh per summer cooling+ventila. Period 1986-2005. Expected for future: 2026-45→6600 kWh; 2081-2100→ 7800 kWh. -London, similar to Antwerp.		Hooyberghs et al., 2017	(L)

Impact	Case study / CC scenario	Method / Model	Supply Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
		building energy simulation. RCP8.5	-Bilbao: 8400 kWh for the reference period 1986-2005.			

Table 3.3.3. Values of climate change impacts on the energy sector: damages to transmission grids.

Impact	Case study / CC scenario	Method / Model	Demand Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
Damages to transmission grids due to extreme events	**US**	**Thermal models to estimate climate-attributable capacity reductions to aerial transmission lines.**	**By 2040–2060, ↑ ambient air → ↓ average summertime transmission capacity by 1.9%-5.8% (1990-2010 reference period). Peak per-capita summertime loads ↑ 4.2%-15% on average.**		**Bartos et al. (2016)**	**(M-to-H)**

Impact	Case study / CC scenario	Method / Model	Demand Effects	Economic impact	Source	Comments and usefulness: Low(L), Medium(M), High(H)
	Europe Analysis of power grid disruptions due to earthquakes, space weather and floods	Data-driven approach	Floods → associated with power outages. Erosion due to the floodwaters → undermine the foundations of transmission towers. Damage when electrified equipment comes in contact with water.		Karagiannis, G. M., et al (2017)	(M)
	Europe Impacts on supply of nuclear power and the national effects of induced changes in the exchange of power via the European grid	Power stations' freshwater demand equations	↓ power plant capacity	France: ↓ net-exports 10,595 MW to 9545 MW	Rübbelke and Vögele (2011)	(L)

3.4. Climate change economic impacts on maritime transport

The whole range of potential impacts of climate change on ports operations and throughput is still under study and it remains a high degree of uncertainty about it. Table 3.4.1 shows a panoramic view linking climate hazards with potential impacts which, in turn, are the references to estimate the economic impact of climate change on ports' economies.

Table 3.4.1. Climate Change Impacts on Port and Hinterland port infrastructure and operations

Climatic Factor	*Impact*
Rising sea levels	⇧ corrosion rate and degradation of materials designed for a particular range of sea level conditions.
Change in wind conditions and higher waves	Effects on offshore loading and unloading operations. Change in overtopping and threat to stability of breakwaters.
Erosion or accretion of beaches protecting port structures	Risks for safety of such structures and ⇧probability of flooding.
Changes in storm duration and/or frequency	⇩regularity of ports, ⇧downtime and requirements for more storage capacity at container terminals for use in times of closure.

Source: UNECE (2011) "Climate Change and International Transport Networks: Overview of Main Concerns and Considerations"

Different climate change stressors can affect both ports and shipping. Ports will be affected by the combination of SLR and tides, storm surges, waves and high-speed winds. Inundations due to the occurrence of any combination of those expressions of the marine and inland hydrodynamic may give place to interruptions or lowing the cadence of ports operations; both cases involving losses in productivity, expressed in terms of reduction in gross weight of goods handled per time unit. Some literature suggests that for a whole assessment of the impact of climate change in the maritime transport sector, it is also required to take into account the translation of the impacts on a particular port to the hinterland and the foreland of it. In our context, the effects we are interested in are those that are captured by the general equilibrium models for the economy of the Soclimpact islands.

The frequency and severity of extreme events increase the deterioration pace of infrastructure, as well as the probability of disruptions or delays of transport services. As a result of the projected increase in the frequency and severity of extreme events, according to several climate scenarios (Vousdoukas et al. 2017; ITF 2016), significant interventions may be required in planning, design, construction, operation and maintenance of the port infrastructure.

So far, the literature review (see table 3.4.1) shows that systematic economic valuations of the impacts of climate change on ports, measured by changes in the port contribution to GVA of the economies, are still lacking. Furthermore, most studies are very case specific, so they are not prone to facilitate the transferring of the elicited values. Values' transferability requires accurate information on the nature, intensity and lasting of climate hazards, port structural characteristics, port services and operations, and variables enabled to represent port throughput like shutdown days per year, changes in services productivity and so on. As ports are complex organizations assembling different services, each of them may be differently affected by different climate hazards. Finally, the economic impact of climate hazards on ports is also modulated by the capacity of port managers for re-scheduling maritime traffic in response to weather predictions.

Thus, the reviewed literature focusing on economic estimation of climate impacts on ports suffers from difficulties to be transferred to estimate the costs of climate-originated damages in other ports. So, economically quantified damages have been reported for the whole coastal areas impacted by extreme events (e.g., Katrina and Ike hurricanes) but not specifically for the economic value of ports output (Hallegate 2007 and 2011; Hanson et al., 2011). Some economic estimation of the impact of extreme events on specific ports provides just aggregated estimations without clear references to the applied methods (Peer 2006, Becker et al. 2012, Simpson et al. 2010, UNCTAD 2014, RDIA 2015, Ng et al. 2013, EQECAT 2012, Gharehgozli et al. 2017). Sometimes the applied methodologies are too specific to enable them for value transfer (Chhetri et al. 2106). In other cases, key information on hazards and ports operations is missing although some economic valuation is provided. Oppositely, some studies stop in physical impacts analyses, while the economic appraisal remains undone.

Summarizing, the task of transferring values from literature to the SOCLIMPACT islands' ports for different time horizons and emissions scenarios is very challenging for, at least, three reasons:

- It does not exist a systematic evaluation of the whole range of costs and a unified methodology to estimate them, so comparing and aggregating data coming from different studies is not feasible still.
- In many cases, there are no estimations of the economic value of ports' services and the contributions of them to the regional/national economies. This information is needed to estimate changes in the ports' economic output due to climate change impacts.
- As some ports have adopted measures to defend themselves from climate change impact at different degrees, the data gathered from different ports, even if referred to the same sort of impact, are not easily comparable.

Due to all the issues explained above, our approach to elicit reliable values of the economic impact of climate change on ports through allocating economic values to losses in productivity for different operations will be complemented by an estimation based on the avoided costs methodology. By doing that, we will double the opportunities to elicit reliable figures. The following paragraphs briefly show the pathways we will pursue to reach them.

On the one hand, the estimation of direct costs of climate hazards for the SOCLIMPACT islands' ports will be done through the following steps:

1. Figures obtained from the reviewed literature will be analysed from the perspective of their transferability, selecting those most suitable to relate hazards or impacts on port operations and economic losses from physical damages and operations disruption. The last column of the table shows the figures that have been selected.
2. Specific information from SOCLIMPACT ports will be obtained through a template delivered to port managers. It will allow for the comparison of the data from literature and SOCLIMPACT ports information by harmonizing physical, operational and economic units amongst them, to make feasible the value transfer.

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3. Finally, climate hazards projections from SOCLIMPACT climatologists will provide the base for estimating the economic valuation of climate change impacts for the relevant time horizons.

On the other hand, the economic valuation of climate change impact on ports can be obtained from estimating the costs of the whole range of measures that need to be undertaken to prevent physical impacts and operational disruptions. Along the last couple of decades, several ports, especially in advanced economies with world-level top-size ports, have been implementing adaptation measures to climate change impacts. The information of the expenditure in these measures can allow for the application of a type of "avoided costs" estimation methodology.

Experts' valuation published in the scientific literature has provided information on the costs of several measures that can be adopted to cope with the main climate hazards that threat normality in ports operations. Those measures go from building seawalls and bulkheads to move the port to another area, including also building dikes or levees. Following Shade et al. (2006 and 2013) and Hippe (2015), the unit costs of those measures are presented in table 3.4.2.

Table 3.4.2. Reference costs of some adaptation measures.

Measure	Cost in euros
Sea walk and bulkhead (per km)	Between 0,75 to 2 million
Dikes or levees to protect against 1 m water level rise (per km)	Between 1 to 4 million
Built and International port	4 billion

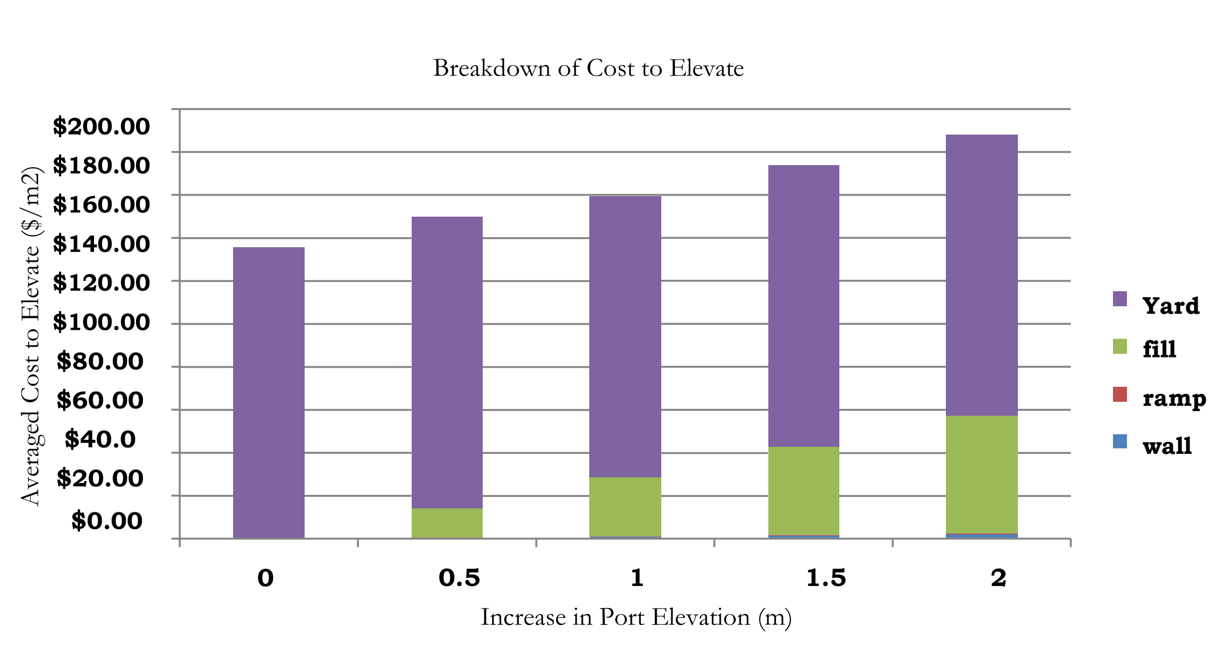
Source: Own elaboration

Additionally, Nicholls et al. (2010) provided the cost of 15 million US dollars per square kilometre to raise ground elevation by one meter, based on a 1990 IPCC report. Hippe et al. (2015) use regional climate projections and historical storm surge data to recommend the elevation necessary to raise the port infrastructure out of the future floodplain for 2070, based on regional projections for sea level rise and storm surge. Their estimations range from US$26.84 per m^3 for dredging, costs of elevating apron area range from US$425 per m^2 per 1m height; costs of increasing ramps range from US$ 225 per linear meter of berth and per 1m height; costs of accommodating the port primary yard to climate change pressures range from US$97 per m^2; and port secondary yard adaptation ranging from US$125 per m^2 for the area of container storage to US$370 per m^2 for the office space and parking area. More interestingly, these authors propose an equation to estimate the cost per m^2 of the adaptation of each part as a function of elevation increase as follows:

$$\text{US\$ per m}^2 \text{ of port area} = 1.1/435m(RWLC + RC + FCC * height * 435m + YC * 435m)$$

The following figure (figure 3.4.1) shows the costs of ports elevation disaggregated by main items:

Figure 3.4.1. Costs of ports elevation disaggregated by main items.



Source: Own elaboration

By combining information from the costs of conditioning ports to climate change impacts with predictions for different manifestations of climate change impacts affecting ports at considered time horizons (e.g., 2030, 2050, 2070 and 2100), we could estimate the expenditure needed to keep ports functioning as the year or period of reference. To proceed like this, the information that should be collected is the following:

- Relevant hazards simulation for the islands in 2030, 2050, 2070 and 2100 for chosen RCP scenarios (maybe RCP4.5 and RCP8.5).
- Measures needed to prevent extra-damages coming from climate change impacts, presented in physical units of different sorts of interventions.
- Define the unit costs for each adaptation measure, building on provided data from experts and published studies.

Once that information is gathered, the next step consists on estimating a figure for the annual expenditure needed to avoid the effects of climate change on ports operations; i.e. to keep ports operating as in a not climatologically modified scenario. As the literature suggests (Novalti, 2015), efficiency requires to plan adaptation measures under discrete instead of continuous bases, so it implies adopting some criteria for defining milestone for interventions and allocation of adaptation investment to each of years of the reference period. Figure 3.4.2 shows the relationship between the continuous evolution of protection necessities and the discrete investment in ports defences against climate change.

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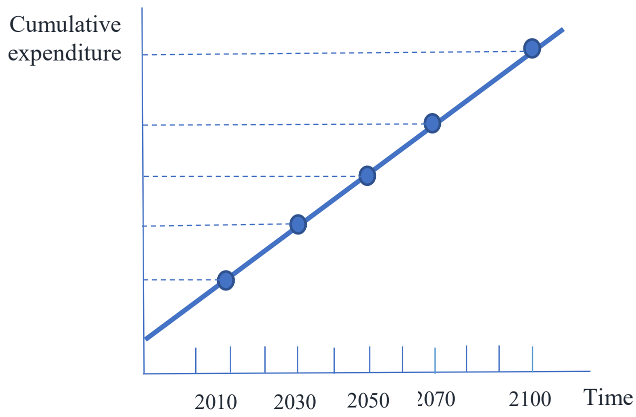
Figure 3.4.2. Relationship between continuous evolution of protection necessities and discrete investment



Source: Own elaboration

Finally, once the costs needed to keep ports working at their capacity by coping with climate change impacts are estimated, we will undertake the estimation of the relevant rates that will feed CGE and macroeconomic models, as long-term average total cost and so on.

To provide accurate outcomes of the economic valuation of the impact of climate change on ports, relevant information on structures and services as well as cargo handled has to be gathered. For this purpose, it has been developed a template to be filled up by experts at the SOCLIMPACT islands' ports. As a starting point, we took from Yang (2017) a comprehensive classification of climate change adoption measures (see table 3.4.3).

Table 3.4.3. Classification of climate change adoption measures.

Environmental driver (ED) due to climate change	Potential threat (PT) of ED on the Port	Adaptation measure to address the potential threat of ED on the Port
Sea level rise (SLR)	A) High waves that can damage the Port's facilities	a) Build new breakwaters or Increase breakwater dimensions
	B) Transport infra- and superstructures in the Port get flooded	a) Raise port elevation
		b) Improve transport infra and superstructures resilience to flooding
	C) Coastal erosion at or adjacent to the Port	a) Protect coastline and increase and Beach nourishment programs
	D) Deposition and sedimentation along the Port's channels	a) Increase and/or expand dredging
	E) Overland access (road/railway) to port/terminal will be limited due to flooding	a) Improve quality of land connection to port/terminal
		b) Diversity land connections to port/terminal

	F) All the risks and impacts above	a) Move facilities away from existing locations which are vulnerable to climate change risks and impacts
Storm surge (SS) intensity and/or frequency	A) Downtime in the Port operation due to high winds	a) Improve management to prevent effects
	B) High waves that will damage port/terminal's facilities, and ships berthed alongside	a) Build new breakwaters or Increase breakwater dimensions

Source: adapted from Yang et al (2017)

From that table, it will be easier for experts at ports to identify the sort of measures that will have to be adopted to defend their respective ports against climate change. Additionally, we will present the unit costs of adaptation measures taken from the literature as reference point (Hippe et al., 2015; Schade et al., 2006 and 2013). Table 3.4.4 synthetizes the information that may be required to experts at islands ports in order to reach an accurate information of the costs of coping with the impacts of climate change on ports, for different time horizons. On the other hand, the table 3.4.5 summarizes the main economic values of the costs needed to adapted the ports to the CC impacts.

Table 3.4.4. Concepts and units of expenditure in adaptation for different time horizons.

Adaptation measures needed to be adopted / **Time horizon**	**Unit**	**2010**	**2030**	**2050**	**2070**	**2100**	**Unit cost***
Upgrading breakwaters and bulkheads: km large and m height	Km/m	/	/	/	/	/	
Km large and m height of dikes or levees	Km/m	/	/	/	/	/	
Port elevation (ha and m height)	Ha/m	/	/	/	/	/	
Improve infra/superstructures resilience to flooding (ha)	Ha	/	/	/	/	/	
Dredging (m^3)	M^3						
Downtime operation i.s.o. adaptation (% total operation costs)	%						
Administrative extra-costs	%						

(*) Proposed by the surveyed expert once he/she has consulted the table of reference costs from literature (see below)

Table 3.4.5. Summary of economic values.

Measure	Cost
Sea walk and bulkhead (per km)	€ 0,75 to 2 million
Dikes or levees to protect against 1 m water level rise (per km)	€1 to 4 million
Built and International port	€4 billion
Port elevation	US$15 millon per km2 per m height
Dredging	US$26.84 per m3
Elevating apron area	US$425 per m^2 per 1m height
Increase ramps	US$ 225 per linear meter of berth and per 1m height
Accommodating port primary yard	US$97 per m2
Accommodating port secondary yard (container area)	US$125 per m2
Accommodating port secondary yard (office and parking area)	US$370 per m2

Source: Own elaboration

As in the previous sectors, we have elaborated a table summarizing the values found in the literature and remarked those that can be potentially transferable (see table 3.4.6).

Table 3.4.6. Values of climate change impacts on maritime transport: damage to ports' infrastructure and equipment

Hazard	Case study	Method	Environmental services / Non-market effects	Economic impact	Source	Transferability comment and degree: low(L), medium(M), high(H)
Damages to ports' infrastructures and equipment due to floods and waves	City of Copenhagen	Catastrophe risk assessment coupled to economic input-output model	Most optimistic scenario: SLR not exceed 25cm by end of century. Most pessimistic IPCC scenario: SLR would reach 25cm in 2050 and 60cm in 2100.	Total loss: No protection=3bil.€ 25cm SLR=4bill. € 50cm SLR=5bill. € 100cm SLR=8bil.€ Mean annual loss: 100,000€ if 180cm protection Null if >2m protect.	Hallegatte et al. (2011)	Related to the whole city of Copenhague. Not just the port and maritime transport: (L)
	Exposure of world's large port cities to coastal flooding, SLR and storm surge	Geographical Information Systems	40mill. People (0.6% of global population) exposed. ↑>3 times population exposed by 2070.	Total value exposed in 2005= US$3,000b. (5% global GDP) By 2070=9% global GDP	Hanson et al. (2011)	Related to the whole of a set of cities. Not just the port and maritime transport: (L)
	USA		10% increase in storm intensity would ↑ damages by 54%.	Loss= $8b to $12b per year	Hallegatte (2007)	Related to the whole city of Copenhague. Not just the port and maritime transport: (L)
	Recommend the elevation necessary to raise the port infrastructure out of the future floodplain for 2070	Regional climate projections and historical storm surge data		US$26.84 per m3 for dredging Costs of elevating apron area US$425 per m2 per 1m height Costs of increasing ramps US$ 225 per linear meter of berth and per 1m height Costs of accommodating the port primary yard to CC US$97 per m2 Port secondary yard adaptation US$125 per m2 for the area of container storage to US$370 per m2 for the office space and parking area.	Hippe et al. (2015)	Interesting for an "avoided costs" approach to estimate climate change impacts: (M)
	Southern Louisiana ports. Texas ports. Port in Grenada.	Projected SLR of 0.6m to 2m and doubling of category 4 & 5	130 ports hit by tropical cyclone every year. 35 of 44 Caribbean ports inundated by 1m SLR unless protected. Tsunami-related casualties in SIDS:	Hurricane Katrina: $1.7b to southern Louisiana ports. Hurricane Ike: $2.4b to Texas ports. Hurricane Ivan: $670,000 to Port in Grenada.	Becker et al (2012); Simpson et al (2010); UNCTAD	Could be used by relating estimated costs with the characteristics of climate stressors and ports: (M)

Hazard	Case study	Method	Environmental services / Non-market effects	Economic impact	Source	Transferability comment and degree: low(L), medium(M), high(H)
	Maldives Samoa	hurricanes by 2100.	>2,500 deaths. Transport sector damage due to tropical storm	Tsunamis: in SIDS= $660m; Maldives=$470m; Samoa=$150m. Tropical Storm Erika= US$303 mill (54% Dominica's GDP)	(2014); RDIA (2015)	
Damages to ships on route (open water and near cost) due to extreme weather events	125 Ice Regime System database events		Multi-year ice present in 73% of damage events to vessels in Arctic waters.		Kubat & Timco (2003)	Low utility for value transfer purposes: (L)
	Effects of Katrina in Mississippi's Commercial Public Ports		Estimated loss of assessed value at these three ports totals approximately $99,9mill.		PEER (2006)	Some utility by relating estimated costs with climate stressors and ports characteristics: (M)
	Australia New York Texas		5 cyclones in 6 weeks: A$3b. to Australia Hurricane Sandy: $50b. to New York. 5-day shutdown in Port of Houston due to Hurricane Ike: $322m.		Ng et al. (2013); EQECAT (2012); Gharehgozli et al. (2017)	Some utility by relating estimated costs with climate stressors and ports characteristics: (M)
	Accident information: HIS/Sea-Web & GISIS	Statistical analysis	54% of accidents: grounding & collision while vessel was within port limits. Smaller cargo ships more vulnerable. Accidents happen at lower significant wave heights & wind speeds than limits for adverse weather.		Ventikos et al. (2018)	Low utility, too specific; no relevant variables for our purposes: (L)
	Vietnam	**Tropical cyclone & socioeconomic model**	**Annual downtime ↑ from 0.23 to 0.37% by 2085**	**Loss: 0.015-0.035% of GDP growth/year (600-1400m.US$)**	**Esteban et al. (2012)**	**Quite interesting approach for our purposes, relating downtime and economic losses. It requires some information on port characteristics: (M-to-H)**

Hazard	Case study	Method	Environmental services / Non-market effects	Economic impact	Source	Transferability comment and degree: low(L), medium(M), high(H)
Risk of isolation due to transport disruption	**Shanghai Ningbo**	**Regression Estimation**	**2.67 disruption days/month for Shanghai port; 1.17 for Ningbo**	**Economic loss per year: 292.6m RMB for Shanghai; 109.0m RMB for Ningbo (>80% loss to ports)**	**Zhang & Lam (2015)**	**Quite interesting approach for our purposes, relating disruption and economic losses. It requires some information on port characteristics: (M-to-H)**
	4300 TEU container ship	Comparison Suez Canal & NSR routes.	Shipping through NSR saves 40% sailing distance (Asia-Europe)	<40% cost savings	Liu & Kronbak (2010)	It does not match with required information.
High temperature Heavy rain High speed wind Flooding	Sidney Port, simulation of climate impacts by using an ad hod designed Container Terminal Operation Simulation of port stoppage			Productivity reduction of cranes (in %): 1.08 13.04 13.04 0	Chhetri et al (2016)	It provides some useful information on the relationships between climate stressors and losses of productivity. It is too specific. (L-M)
Huracan Sandy	It shutted down the container port of New York for over a week			Losses by around $50 billion	Becker et al (2013)	Some utility. It relates shutdown and economic losses: (M)
SLR and hurricanes Katrina hurricane			SLR of 0.6 m to 2 m by 2100 Occurrence of category 4 and 5 hurricanes will double by 2100 6 years later still operates at 80% of the pre-Katrina event	Loss around $1.7 billion	Becker et al (2011)	Low utility. Too specific: (L)
A bunch of climate stressors: - SLR - Extreme winds.		Survey to 44 port managers on climate impacts	-- 50% reported had experienced little physical damages, while 31% reported significant damages. -- 55% reported some affections on operation -- 60% reported some or significant		UNCTAD (2018)	Too general; just aggregated information: (L)

Hazard	Case study	Method	Environmental services / Non-market effects	Economic impact	Source	Transferability comment and degree: low(L), medium(M), high(H)
- Floods from rainfall and storm surges			delays. -- 52% some and 26% significant interruptions in port services. -- Main climate stressors: high winds followed by precipitations and storm surges.			
SLR and higher waves simulation	In 2014 it was considered the third European port in terms of productivity with a throughput of 45.3 millions of tons, 1.9 million TEU and almost 3.5 million passengers (BPA, 2015). The current port land area is over 1000 ha with 22.3 km berthing length and a depth of up to 16 m.		RCP8.5: Port Inoperability days per year can reach till 7 days, around 2% of the time (maximum of 200 h/y)	Linearly, wave and storms can affect to the port as follows: - Around throughput reduction of 0,9 millions of tons. - 70.000 passengers	Sierra (2017)	Some utility. It relates climate hazards with port inoperability time and the latter with economic losses (M)
Coastal inundation due to SLR, storm surges, and waves	Kingston Freeport and Container Terminal; covers a land area of about 11.5 ha; sea access is provided by an artificial channel through a fringing reef, deep enough to facilitate access of large cruise ships. Since 1850, 135–144 tropical storms and hurricanes		RCP6.0: Assessments have been carried out for the 1.5 °C SWL (1) Identification of operational thresholds (2) Collection of climatic data. (3) Operational thresholds and climatic projections were compared. The 1.5 °C SWL, and different periods in the century under different scenarios, for nine return periods (1, 1/5, 1/10, 1/20, 1/50, 1/100,1/200, 1/500, 1/1000 years)	JAMAICA Port disruption (days/year) - Extreme Heat: 1986-2005: 4.40; 2006-30: 5.76: 2031-55: 13.45; 2056-2080: 22.21; 2081-2100: 29.67. - Flooding (crane operation stoppage), for the same periods: 3.70; 3.60; 4.59; 4.00; 3.11.	Monioudi et al (2018)	It provides useful information relating hazards and port disruption but does not provide relevant information on costs: (L-to-M)

Hazard	Case study	Method	Environmental services / Non-market effects	Economic impact	Source	Transferability comment and degree: low(L), medium(M), high(H)
	have passed within a 300-km radius of the critical transportation assets of Jamaica,					
Protection against storm surges with 2 m SLR by 2100, by port elevation	221 of the world's 3,300+ seaports; calculate the resource requirements for a coastal storm surge protection structure suited to current upper-bound projections of two meters of sea level rise by 2100	"Minimum assumption credible design" (MACD) to leverage available local information (topography, bathymetry and existing infrastructure), engineering knowledge and required materials	-- 436 million cubic meters of construction materials, including cement, sand, aggregate, steel rebar, and riprap. For cement alone, 49 million metric tons would be required. -- Main ports' climate stressor thresholds: Mean SLR between 1 and 2 metres; wind speed, most of reports between 50 and 100km/h; Extreme sea level between 3 and 5 metres; high temperatures: 36-60ºC; precipitation: 100mm/day;		Becker (2016)	Useful for "avoided costs" approach to climate change economic impacts. Adaptable to other ports with further information: (M)
	Estimation of floods damage by SLR episodes for the city of Copenhagen.	Damage functions due to extreme sea levels is built combining the expected distribution of extreme rise with flood defense to obtain the expected annual damage	Probability of occurrence of sea level rise over the defenses episodes is estimated, being 215,28 cm for Copenhagen and 135 cm for Kalundborg	There are not estimations for the costs of floods.	Boettle et al. 2016	Very Low. For the total of the city (not just for port area) and no costs provided.
	Estimation of damage and protection cost curves for coastal floods within the	Sea level rise and inundation depths function are estimated using climatic		- 5 m flood height: range from 139.60 billion € for UK to 102.28 for France, 127.83 for Italy, 45.22 for Spain, 139.73 for Germany, 13.81 for Greece, 5.55 for Portugal and 0.20 for Malta.		

Hazard	Case study	Method	Environmental services / Non-market effects	Economic impact	Source	Transferability comment and degree: low(L), medium(M), high(H)
	600 largest European cities, using land-use information systems data	models and land information systems to the estimate costs of sea level rise. Cost are estimated following the avoided costs method.		- From 40 to 80 €/m² damage cost in port areas for Copenhagen considering 2 m flood. 5 m flood: €29.7 billion - 25€/m2 is the damage cost estimated for transport devoted areas in the case of Germany. - Construction costs for flood barriers range of €67.1 million to €259.0 million per m height and km width. 5 to 12 greater that the unit costs for sea dykes in urban areas: between €15.5 and €22.4 million, same parameters.		

4. Transferability Assessment

Values transferability is as much a desirable as a complex issue. We aim at analysing the values found in the literature in order to assess to what extent the economic valuation of climate change impacts on the Blue economy sectors of the concerned European island could be conveniently undertaken using the benefit transfer methodology. Papers overviewing the issue give count of the difficulties that such task entails, most of them derived from the fact that the study cases were not originally designed to make their results transferable.

Although Soclimpact's proposal included an exploratory analysis of the potential and limits of value transfer, the aim was neither to rely on the values mined from literature nor to conclude anything on the economic impacts of climate change on the Blue Economy of the islands, nor to use them to feed the macroeconomic modelling and the subsequent evaluation of the impacts of climate change on the whole economy of the islands, via Blue Economy sectors.

Instead, Soclimpact's proposal defined a set of WP and tasks to primarily elicit all those values: i) from the demand side, by combining discrete choice experiments and big data analysis, for the tourism sector; and ii) from the supply side for the remaining sectors, through estimating changes in productivity and average costs of production.

The brief transferability assessment that is presented below will show how limited values transferability is in the context of the Soclimpact project; strengthening the intention of the Project to develop more transferable values than the ones found in the examined literature. It means to organise and properly present, in a structured and quantitative way, the contextual aspects that may help researchers to define value functions useful for their respective policy sites.

4.1. Tourism sector

- **Marine environment:**

  There are not studies focusing on the set of environmental services affected by the impact of climate change on marine habitats as Soclimpact aims at: water heating and acidification, giving place to reduced structuring species abundance and density, biomass and biodiversity diminishing; water turbidity; and death seagrass laying on beaches; in turn affecting tourism activities which are very important in the European islands as seawater and sun bathes, snorkelling, diving and glass-bottom boating.

  The recruited studies are not formulated in the terms they could be used to define a transfer function, bearing in mind the complex links between different tourism-relevant natural assets affected by climate change and the tourist activities that are supported on them.

  Economic values to assess the primary impact on tourists' welfare and demand, and to feed the macroeconomic modelling, will be elicited by WP5 in such terms that they will be transferable in the future.

- **Land environment:**

  In the European islands, from tourist attractiveness perspective, land biodiversity is relevant at ecosystem level. Generally, mammal and reptile species hosted in those ecosystems do not belong to any list of tourist flagship species, even if many of them are endangered ones. So nature and landscape singularities of islands remit to their differential natural systems. For example, in the Canary Islands, pine forest, laurisilva forest, palm forest and dune fields, are the most significant nature- and landscape-related land assets. It is almost the same for the remaining islands under study by Soclimpact.

Amongst the eight collected studies, there is no study that accomplishes time, environmental goods' definition and population of reference (tourists) characteristics to be transferred to the Soclimpact context.

- **Beach surface reduction:**

As beaches are very significant landmarks in coastal tourism across the world, study cases on the economic valuation of beaches have, *a priori*, potential for value transfer. On the other hand, there are a remarkable amount of studies in many different sites, from which we have selected 17 to analyse their transferability to the context of Soclimpact islands.

Required uniformity between study and policy sites rely on the relative homogeneity of the environmental goods to be valued, the motivational and behavioural profile of tourists visiting coastal destinations and the socioeconomic adscription of visitors, including a quite similar income level.

Amongst the set of papers mined from literature, some of them exhibit a medium-high potential for transferability. Studies by Uyarra et al. (2005) and Raybould (2013) provide relatively accurate information to build dose-response functions between reductions in beach surface and tourism demand, expressed in terms of both unwillingness to revisit the place and tourism revenues. Those results, even if they do not measure impacts on tourist welfare, give figures for variables that might be used for macroeconomic modelling.

The study by Wielgus, Cooper, Torres and Burke (2010), although using a different approach (hedonic prices), interestingly delivers economic values for changes in beaches width that match quite well with the method developed by Soclimpact WP5 researchers, which considers various levels of provision of the environmental good affected by climate change, i.e. beach surface. It also provides figures for revenue losses for the study site (Dominican Republic).

Finally, the study by Castano, Isaza, Newball, Roach and Lau (2015) for Colombia, presents two relevant factors for transferability, namely results are provided in terms of WTP to avoid beach erosion and the change in the provision of the environmental good (beaches availability) coincides with one of the levels adopted by WP5 researchers at Soclimpact.

Even though Soclimpact will deliver its own values for this climate change risk, it will be very useful testing the transferability of mined values from the literature developing a transfer function using al least the abovementioned papers. In case of convergence in values, it will allow to add those obtained from Soclimpact to the set of transferable values for future works, remarkably improving the prospect for transferability at least in this relevant climate change-induced risk for coastal destinations.

- **Water shortage at destination:**

Water is an essential commodity to make destinations run properly. It is a key resources in many tourist products and services, so water shortage may highly damage destination competitiveness. Yet, not all tourism modalities depend on water on the same way and intensity. Coastal tourism is highly demanding of drinking water for sanitation, food cooking, swimming and recreation. Water shortage at destination may affect tourists through lesser water-based recreation provision and water supply shutdowns in bedrooms. Thus, economic values for water restrictions can only be transferred from similar, coastal tourism-based, study sites.

The studies reported by ENVALUE database are very old (the more recent was published in 1991, almost 30 years ago), which makes values non-transferable at all.

Regarding EVRIS database, it provides some studies that approach the problem relatively close to what could be useful for Soclimpact purposes. However, there are no cases referred to water supply shutdowns affecting tourists' welfare at the destination or assessing changes in the probability of choosing a destination potentially affected by that problem. It makes the cases study referred to householders at their usual neighbourhoods, not valid to be transferred to the context of the comparatively short time which is relevant in tourism (see for example Koss and Khawaja (2001)).

- **Vector-born infectious diseases:**

Few studies focus on tourism welfare and/or demand being affected by vector-borne infectious disease outbreaks. We have collected four of them. None of them belongs to EVRI nor to ENVALUE database, as they do not provide any specific study on this issue. Collected studies are very heterogeneous in the definition of the environmental good, the time scale, the affected population and the methodology applied. One of them remits to a study in Central Africa Republic, eliciting the WTP of local citizens whose income is very far away from the European citizens' one. Two of them focus on the estimation of the aggregated economic impact in Latin American and Caribe countries where, in addition to tourist losses, there are other sectors being economically affected as well. Other studies not included in our report like those by Shepard et al. (2011), Halasa et al. (2012), Undurraga et al. (2015) and Shepard et al. (2014) report economic valuations that are not centred on tourism demand but on estimations of labour absents and medical illness attendance. The study by Mavalankar et al. (2009) on the impact of vector-borne infectious diseases on tourists' arrivals and expenditure for India, Malaysia and Thailand is apparently an interesting study case, as it reports estimations on international tourism contraction (4% in arrivals from non-endemic countries) and tourism revenues reduction. However, the methodology used is not trustable, as it makes reference to a missing citation as the origin of their estimations for the concerned destinations.

- **Coastal infrastructures:**

EVRI database does not provide any study eliciting an economic value that might be transferred to the economic valuation of the impact of climate change on the infrastructures that sustain coastal tourism activities. The same happens with ENVALUE database.

Those values found in the remaining sources are scarce and far from what is needed for Soclimpact's purpose of the economic valuation of climate change impacts. The ones referred to the Mississippi area and to New-Brunswick focus on highly multifunctional areas where it is not possible to dissect costs for tourism from costs for the other activities.

The third case study collected is based on a microeconomic approach which elicits the WTP for protection against floods in Pennsylvania. But again, the study site is very dissimilar to the policy site, i.e., the European islands. The area considered exhibits very mixed uses and the declared preference in monetary terms for avoiding floods comes from residents, not tourists. The Soclimpact project is interested in valuing the influence of potential damages to coastal infrastructures due to extreme weather events on tourist demand, which conceptually is very distant from what has been found in the literature. As a result, value transfer from collected study sites is not feasible.

- **Cultural heritage:**

Cultural heritage is site-specific by its nature. This is why transferring values obtained for study sites to policy sites faces important difficulties. There are not specific categories that can be used to compare this type of cultural goods and then transfer values from one to another site. For example, the size of the cultural area, oldness, UNESCO classification if so, and so on, do not allow for comparisons between different patrimonial places. This unfeasibility precludes any definition of a unit of valuation, what is a prerequisite for value transfer. Tuan and Navrud (2006) provide arguments to be very precautionary in transferring values between cultural heritage assets, particularly between heritage sites located in developed countries regarding those located in developing ones, and vice versa.

Notwithstanding, when talking about tourism, economic values for cultural heritage obtained in different latitudes may still have utility as benchmark values. When in vacation, tourists may not be very involved in the particular attributes of the heritage they visit, but they allocate a budget for different activities, including visiting cultural sites. Starting from this, they define a WTP for conservation of cultural heritage, which is more determined for being a particular percentage of the total tourist budget than for considerations about the intrinsic properties of the concerned cultural assets. Additionally, it is also conditioned by the image of the destination and the travel motivation. Tourists will pay more for cultural assets of more cultural imaged destinations and when culture is in the top side of travel motivations. For the case of the European islands under study, some values obtained from literature related to highly connoted cultural destinations could be taken as reference values for high culturally endowed islands. At this respect, the values in the papers by Alberini and Longo and by Tuan and Navrud will be taken into account to contrast with those obtained through Choice Experiments for some European islands.

- **Thermal stress (heatwaves):**

As coastal tourism strongly depends on weather parameters, destinations usually have tourist seasonality. That is the case of most of the European islands under study, except the Canary Islands (even in Martinica and Guadeloupe islands, dry and wet seasons define tourist seasonality). Climate change in islands (and everywhere) is about the increase of average temperatures (maxima and minima) but it is mostly about higher variability. It can affect seasonality patterns, with high uncertainty in the borders, and extreme temperature (thermal sensation) events. Because of the latitude and seasonality, the problem with extreme temperatures in European islands remits chiefly to extreme heat, through episodes known as heatwaves.

ENVAUE database does not register any study on this topic while EVRI just records one, but it is contextualized in the Rocky Mountain National Park and is referred to changes in the intention of behaviour (visiting) of visitors, to provide figures on the impact on the local economy of the expected variations in the number of visitors due to thermal discomfort. Anyway, it is a methodologically interesting paper as it produces estimations on the changes of intention of behaviour, one of the variables that can feed the macroeconomic modelling.

Regarding the remaining reported studies, just one provides results in terms that might be transferable to the context of Soclimpact. That study was conducted by the ULPGC's researchers that now are in the coordination team of Soclimpact, so value transfer could be undertaken at least for the Canary Islands. However, this risk is being economically reassessed by the WP5 research team, and also generated for all the participant islands, but using a modified methodology of stated preferences. Thus, the obtained values in 2014 will be useful to benchmark those elicited by Soclimpact, adding new ones to improve values transferability to other regions and destinations for the future.

- **Forest fires:**

Forest fires are a risk for tourism, which is in turn fuelled by changes in climate conditions as well as societal and management factors, in many places all around the world; also for the Soclimpact islands, especially those forested and relatively arid. According to the Soclimpact impact chain, forest fires potentially affect tourism demand due to landscape and biodiversity destruction, increase of health risk perception and deterioration of the destination image.

In Soclimpact, we are focusing on the risk for islands tourism activity of losing attractiveness (competitiveness) due to the increase of burned forest, before or during the visit.

The only one study in EVRI that matches with Soclimpact interest is by Pagiola (1996) for Croatia, while ENVALUE database does not provide any. From other different sources we collected another five studies that show different feasibility to transfer values to Soclimpact policy sites. Regarding those, one is related to the impact on the intention of behaviour of tourists but it does not provide any economic value. The study on Corsica focuses on WTP for enhancing fire protection, but it is not an economic valuation of the risk associated to forest fires at the destination. The study on Croatia is about WTP for implementing recovery plans in damaged (also burnt) forests, but is does not match with the environmental good under study in Soclimpact. The case study reporting WTP for enhancing capabilities to prevent forest fires for France, Italy, Portugal and Spain in 2011 focuses on residents, so it defines a valuation scenario different than the one required to transfer values to Soclimpact islands. The case study from Colorado, Wyoming and Idaho defines motivational profiles for visitors that do not match with those of the coastal destination visitors and make obtained values not transferable to the policy sites in Soclimpact.

4.2. Energy sector

- **Supply side impact chains:**

The nature and methodological support of economic figures obtained from literature on climate change impacts on the energy sector generally make those values more transferable than those obtained for tourism, reported above. The intermediate goods and the units in which changes in those environmental goods provision are measured are quite homogeneous across study and policy sites.

For example, assuming similar technology in wind energy generation worldwide, changes in wind speed and orientation, and their influence in productivity, obtained from literature might be transferred to the policy sites presuming the same relationship wind speed-productivity everywhere. Also, it could be said for photovoltaic energy generation. So once changes in climatic variables become known, changes in productivity and costs of energy production could be properly estimated for the policy sites, computed as the costs of climate change for the energy sector of the islands, and then being used to estimate the costs for the whole island economies through macroeconomic modelling.

From the collected studies reported above, for PV energy should be underlined the work by Crook, Jones, Foster and Crook (2011) as it provides clear results relating changes in temperatures with changes in the productivity of the PV solar panels in time scenarios that match with the Soclimpact ones. These results might be transferred to the Soclimpac policy sites just making some adjusting for technological innovation (e.g. panel thermal isolation) since the study date.

For the case of wind energy, the study by Tobin et al. (2016) estimates changes in wind farms yielding due to changes in wind conditions under climate change, for different time scenarios. The translation of those figures into those adapted to the Soclimpact conditions could be made almost directly as they were obtained recently.

For the case of costs of lost energy in distribution due to the exposition of transmission grids to higher temperatures, the case study by Bartos et al. (2016) provides some transferable relationships between the increase of extreme temperatures and the increase in energy transportation losses.

Mainly these references and values will be transported to the D5.6 to then feed the macroeconomic modelling, once the analysis and validation of those values by Soclimpact experts in energy is carried out.

- **Demand side impact chain:**

The estimation of the costs of the additional energy required to preserve current levels of welfare through cooling and water consumption in increasing heat scenarios is being developed ad hoc by the Sectoral Modelling Team of energy within Soclimpact partnership, through the collaboration between WP4, WP5 and WP6 researchers. The procedure is being carried out in three stages. During the first one, changes in the demand for energy for the set of islands involved in this case study is estimated using a linear correlation modelling considered variables like population, number of tourists, GDP, the Standardised Precipitation-Evapotranspiration Index (SPEI), etc.; all of it framed at the correspondent impact chain previously developed by WP3.

The second stage aims at estimating the increase in renewable energy capacities needed to meet the reported increase in energy demand. Using a specialised software as ENERGYPLAN, these new capacities are assessed taking into account the specificities of the renewable energy systems, the requirement of the islands electric grid and the changes in climate conditions.

The third stage consists on the estimation of the costs investment and maintenance of the added energy capacities needed to meet the increased energy demand due to climate change. Modelling is being customized for each of the engaged Soclimpact islands.

From the set of references collected from literature, that delivered by Mima and Criqui provides a useful reference for transferring values to the Soclimpact policy sites, additionally contemplating a time scenario till the year 2100. Also the paper by Pilli-Shvol et al. (2010) provides useful measurements of energy demand increase propelled by climate change, but in this case as far as the year 2050 horizon.

These values will perform as benchmark for the Soclimpact own estimations, while the latter ones will contribute to widen the bunch of transferable values for this climate change-induced risk.

4.3. Maritime transport sector

Potential for value transfer of results obtained from literature analysis has been conveniently done in section 3.4. There we said that i) it does not exist a systematic evaluation of the whole range of costs and a unified methodology to estimate them; ii) in many cases, there are no estimations of ports' output while it is crucial for estimating the economic impact of climate change in maritime transport; and iii) some references, even if they provide detailed information, refer to the cost of adaptation measures adopted by ports' authorities. As a result, comparing and aggregating data coming from different studies is not feasible still.

As the conclusion so far is that there are not transferable values from study sites mined from literature to the Soclimpact policy sites, the SMT of Maritime Transport, in collaboration with WP5 and WP6 researchers, and experts from the industry, are carrying out the work needed to properly shed light on economic values that can feed the macroeconomic modelling and will be reported in the forthcoming D5.6.

4.4. Aquaculture sector

The reviewed literature on the economic valuation of climate change impacts on the aquaculture sector shows very low potential for transferring values to the Soclimpact policy sites. Risks that climate change pose on aquaculture are related to the growth rate of fish and cages breakage with the subsequent stock losses. The first one linked to increase in variability of water temperature and acidification, by themselves and combined with other natural and human-induced changes; and the second one linked to extreme weather events, that in turn also affect the biomass growth.

We did not find studies assessing economic losses in aquaculture linked to climate change-induces hazards. Regarding the effects on fish net growth, including mortality, although there are many studies predicting either negative or positive effects of changes in sea surface temperatures (SST), depending on the specificities of places and products, most of them do not provide value estimations enabling the definition of dose-response functions upon which proceeding to transfer values.

The cases in which such relationships between temperature variations and fish growth have been estimated, as Lorentzen (2006, 2008) does, values transferability becomes weakened due to essential differences. Lorentzen studies for Scandinavian aquaculture sites differ from the Mediterranean and Atlantic sites (the Soclimpact context) in the most relevant variables: species are different as so are their physiological response to changes in temperature. Since that, no result from those studies might be transferred to Soclimpact policy sites without incurring in non-acceptable biases.

Again, the aquaculture SMT is currently working on an *ad-hoc*, experts- and practitioners-based, procedure to robustly elicit economic values for the damages the climate change may infringe to the aquaculture sector in the Soclimpact islands. The results of this work will be conveniently reported in D5.6 and then used to feed the macroeconomic modelling.

5. Concluding Remarks

The main objective of this deliverable is to develop a first step in the process of learning about the concept of benefit transfer method, how it can be used and the reliability of this methodology. Moreover, a first overview of the available data in the literature is presented, trying to identify the potential gaps and uses of the estimated values of climate change impacts, aiming at adapting them to the SOCLIMPACT context.

The values found in the existing literature may be combined with data coming from experts' knowledge (as climatologists) and tailored in order to introduce them in the computable general equilibrium models (task of WP6), with the purpose of obtaining an estimation of the macroeconomic impacts of climate change on the tourism, aquaculture, maritime transport and energy sectors in the islands interest of study.

This report presents a meta-analysis of the impacts and economic values found in the existing literature, together with some characteristics of the scenarios contemplated and the methodology used. This approach is useful to obtain an overview of what has been studied in the literature, and which may be the potential gaps. Moreover, given the heterogeneity of methodologies used in the different sectors to obtain the quantification of economic impacts of values, the meta-analysis approach allows for the comprehensive gathering of information and results.

In addition, an effort has been made to determine which of the results could potentially be transferred directly. However, in future tasks and reports of the project, a refinement of this first search will be made, and the methodologies presented throughout the report will be applied more thoroughly in order to obtain values and results useful for the project from the benefit transfer methodology and from different estimations.

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