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 6:

Deliverable 6.3: Report on Socioeconomic Impacts of Climate Change Scenarios

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1 INTRODUCTION

One tenth of the world-population lives on islands. Island communities are considered to be among the first and most adversely affected by the impacts of global climate change[1]. Rising sea levels, changing precipitation and storm patterns, and increasing air and sea-surface temperatures can put additional stress on already limited island resources. Resilience and risk management strategies of these vulnerable lands need to be improved, also by deeper insights in the mechanisms of climate change impacts and economic damages thereafter. Both must be downscaled from the vast amount of results and analyses already existing on a global or world regional level.

EU islands, including outermost regions, also are particularly vulnerable to Climate Change as pointed out by the Communication "An EU Strategy on Adaptation to Climate Change"[2]. Moreover, the EU touches upon the issue of Islands in several other strategies, such as the Clean Energy for Islands Initiative[3], the Western Mediterranean Blue Economy initiative[4], the Valletta Declaration of the European Ministers responsible for the Integrated Maritime Policy on Blue Growth[5], and last, but not least the new European Green deal.

Blue Economy activities have been discussed in the EU since 2012[6]. The latest Blue Economy Report by the EU has been published in 2020[7]. The EU seeks tin this series of reports to continuously improve the measuring and monitoring of the socio-economic impact of the Blue Economy, while also regarding environmental implications. The 2020 report connects the Blue Economy Strategy to the new European Green Deal[8] in the attempt to ensure that economic growth and employment go hand in hand with protecting and restoring nature and fighting climate change. The Report sees itself as “a tool to support relevant initiatives and policies under the new European Green Deal, which aims at implementing the United Nation’s 2030 Agenda by putting <<sustainability and the well-being of citizens at the centre of economic policy and the sustainable development at the heart of the EU’s policymaking and action>>[9]”.

The established EU Blue economy sectors include:

• Marine living resources.

• Marine non-living resources.

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[1] Sea Change: Island Communities and Climate Change, Heather Lazrus, Annual Review of Anthropology 2012 41:1, 285-301

[2] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52013SC0133

[3] https://www.euislands.eu/

[4] https://www.westmed-initiative.eu/about-us/westmed/

[5] https://data.consilium.europa.eu/doc/document/ST-10662-2017-INIT/en/pdf

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0494&from=EN

[7] https://blueindicators.ec.europa.eu/published-reports_en

[8] Commission Communication on “The European Green Deal” COM (2019) 640 final.

[9] COM (2019) 640 final, p. 3.

• Marine renewable energy.

• Ports activities.

• Shipbuilding and repair.

• Maritime transport.

• Coastal tourism.

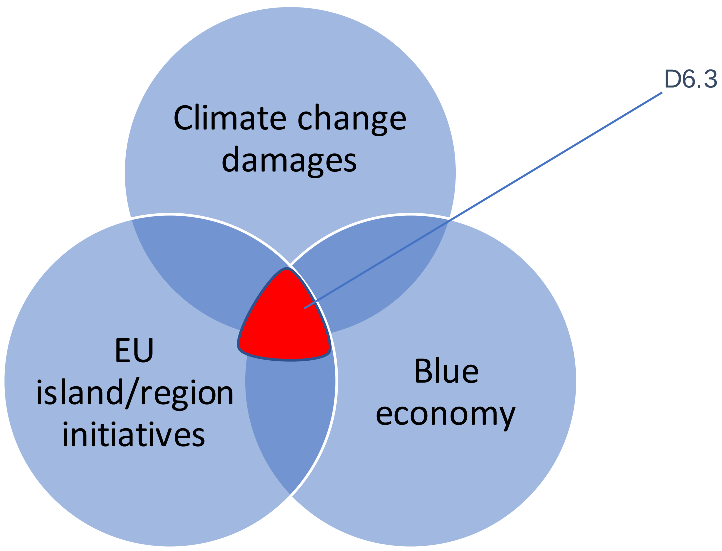
The Blue Economy Report additionally covers what the EU considers emerging Blue Economy sectors, such as ocean energy, blue bioeconomy and biotechnology, marine minerals, desalination, maritime defense, submarine cables.

Blue economy support activities obviously are important for islands, which by definition are surrounded by water. However, islands face different and often larger challenges than mere coastal regions due to their size and dependence on import of relevant consumption and investment goods, fuels, clothing and often food.

From this economic dependence and particularities, the socio-economic analysis described in this report has identified tourism, maritime transport, aquaculture, and energy on the islands as the most climate change sensitive and economically relevant sectors. The modeling approach is described for each sector in turn and is the same across islands. The results, however, are presented by island.

Thus, the results of this report can be seen in the overlapping between the assessment of climate change damages, under the special challenges of islands with regard to Blue Economy sectors (Figure 1).

Figure 1: Localizing the results



Source: GWS, own graph.

The most comprehensive attempt at measuring climate change damages and making the case

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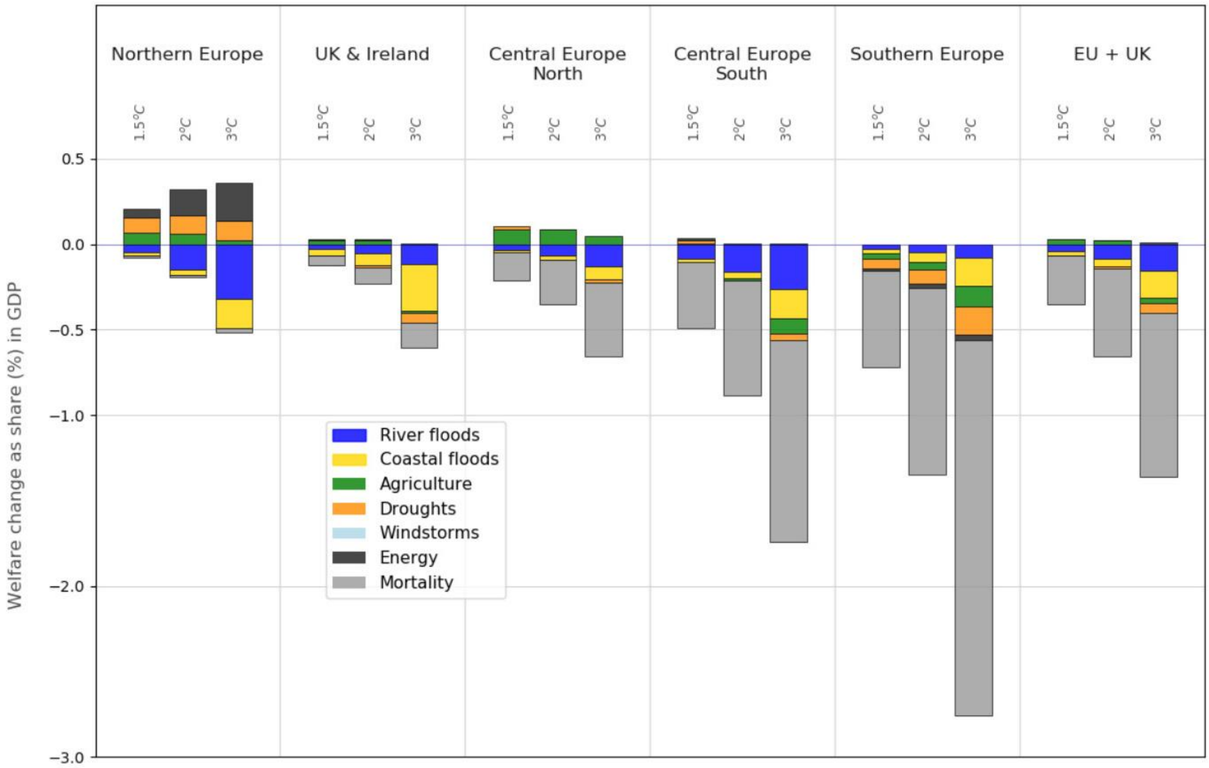
for adaptation in the EU has been provided by the Joint research center (JRC) with the PESETA [10]series of studies and cases. PESETA II project goes beyond PESETA (impacts in five areas: agriculture, coastal systems, river floods, tourism, and human health) by considering more impact categories and more climate runs. The coverage is extended by energy, transport infrastructure, forest fires, and habitat suitability. Furthermore, while PESETA looks at four climate runs, in PESETA II up to 15 climate runs have been modelled by some of the sectoral teams. Part three (PESETA III) uses the then new family of scenarios (Representative Concentration Pathways, RCPs; and Shared Socioeconomic Pathways, SSPs). Furthermore, EURO-CORDEX climate data consistent with the high-end emission scenario (RCP8.5 family) are used. PESTA IV is the latest project in the family and again has expanded the scope.

A typical result from the series of projects is given in Figure 2. Welfare losses are attributed to the five regions analyzed and to several climate change events. In total, welfare losses in the EU-28 are driven by health impacts and mortality. In Northern Europe, welfare losses outweigh gains from energy demand reduction under the 3°C scenario. The regional differences across Europe are large.

Figure 2: Welfare changes under climate change



Source: https://ec.europa.eu/jrc/en/peseta-iv/economic-impacts

The PESETA projects contain a wealth of information and have been an important progress

10 https://ec.europa.eu/jrc/en/peseta/peseta-i-results

from the projection of damage functions (linear or quadratic welfare losses with average temperature increase) as used in Integrated Assessment Models to well-founded bottom up modelling approaches which are sector specific and assess climate change in more dimensions than temperature.

However, climate change events take place often on a very local scale and the results presented in PESETA I-IV are aggregated to the regions given in Figure 2 above.

The core of the SOCLIMPACT project, in comparison, is a strong focus on downscaling. For the economic analysis, islands' Input-output tables have been updated in D6.1, to have a basis for the detailed analysis of the respective economy. Economic outlooks then haven been developed for the respective islands and described in D6.2[11]. In this report, these outlooks comprise the reference case to which the climate cases are compared. Climate change drivers on matching levels of scale are turned into economic direct impacts, as described in more detail in the next section. The economic modeling approach is twofold, one is close to the model also used for the PESTA studies, the second model applied is less constrained by the demands of equilibria.

The report is organized as follows. The next chapter outlines the methodology and traces the inputs from Work package 4 and 5 to the two economic models. The implementation strategies of either model are described by economic sector analyzed, since the input data differ largely for each sector, but the implementation is the same for each island. Chapter 3 contains the results. They are reported by island, so that interested parties can immediately access the results for "their" respective island. Chapter 4 summarizes findings and concludes with an outlook on future research questions.

[11] Soclimpact project Deliverable D6.2 Macroeconomic outlook for the islands´ economic systems and pre testing simulations

2 METHODOLOGY

Modeling damages from climate change is a challenge which is increasingly met with a combination of bottom-up sector specific models and macroeconometric models or CGEs. Initially, Integrated Assessment Models were used to map the overall economic damage caused by climate change and the benefits of climate policy in a consistent model system. This is accompanied by three major structural uncertainties (Weitzman 2009a): inaccurate knowledge of the future extent of GHG emissions present in the atmosphere (1), uncertainty regarding the feedback processes of the CO2 cycle (2), and the relationship between temperature and GHG emissions (3). "Once the world has warmed by 4°C, conditions will be so different from anything we can observe today (and still more different from the last ice age) that it is inherently hard to say where the warming will stop" (Weitzman 2009a).

The interface at which IAMs link climate change with the monetary and physical effects on humans is the damage function. Typically, at least one aggregated function is assumed for each region, establishing a relationship between the increase in temperature since the beginning of industrialization, or often the reference period from 1960 to 1990, and the share of GDP lost as a result. The temperature serving as input (usually the average global surface temperature) or other characteristics of climate change, such as sea level rise, are in turn determined by a function whose calibration is based on the assumed climate sensitivity, i.e., for example, the temperature response to a doubling of atmospheric CO2 concentration, usually in 2050. On the output side of this reduced relationship, monetary (rarely biophysical) values are shown. Often a function like $D = \alpha * T^b$ is applied, where D is the damage value (e.g. in US dollars or as a share of GDP) and T is the temperature increase compared to an earlier period. The exponent b indicates the form and steepness of the function. Exponents are calibrated and the damage function is typically continuous. Damage can be expressed in this model environment as a negative change in GDP, the capital stock of an economy remains unaffected.

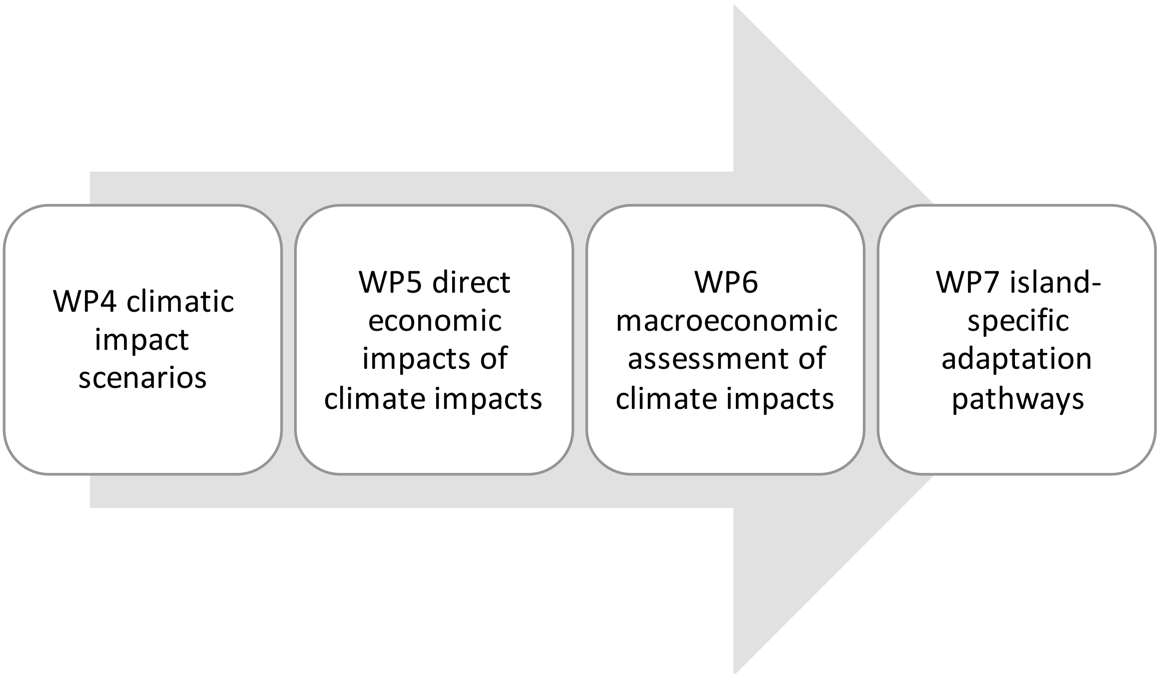
In the last two decades, numerous IAMs have been developed, such as the DICE model (e.g. Nordhaus 2007), or the regionalized version RICE (e.g. Nordhaus 2011), FUND (e.g. Anthoff & Tol 2014), MERGE (e.g. Manne & Richels 2004), PAGE (e.g. Hope 2011) and for Germany the WIAGEM model (e.g. Kemfert 2002). In 2018, William Nordhaus and Paul Romer were awarded the Nobel Prize because "their results (...) have significantly expanded the scope of economic analysis by developing models that explain the interaction between the market economy and nature and knowledge. A frequently used Integrated Assessment Model is the model FUND (Climate Framework for Uncertainty, Negotiation and Distribution), developed by Richard S.J. Tol (Tol 1997). The current version is called FUND 3.9 (Anthoff & Tol 2014; Máñez Costa et al. 2016). It includes a more advanced modeling approach for damages, with different functional forms differing by region and the vulnerability of a region to climate change as well as the speed of progressive climate change and temperature change. Vulnerability is determined by the size of the population, economic growth, and technological progress of the region.

The PESETA series of projects mentioned above in the introduction, however, pursues a different route. Ciscar et al. 2011 (p.1) state: “there is a clear need for further detail in the regional and sectoral dimensions of impact assessments to design and prioritize adaptation strategies. New developments in regional climate modeling and physical-impact modeling in Europe allow a better exploration of those dimensions." The studies in PESTA detail six European regions and a by modeling round increasing number of sectors.

In the following, we focus on highly deeper detailed regional resolution, i.e. we focus on ten European islands and archipelagos (Azores, Baleares, Canaries, Corsica, Crete, Cyprus, Malta, Madeira Sardinia, and Sicily), with two of them being member states in itself. Damages are assessed bottom-up with a range of different models and methods. All quantities along the modeling chain are estimated specifically on the scale of the respective islands.

Figure 3 depicts the modeling chain from the assessment of climatic impacts via the translation of these very impacts into economic damages, the implementation of the damages in the economic simulations for the respective islands and the conclusion of adaptation pathways as the result of this chain.

Figure 3: Modeling chain as reflected in work packages of the Soclimpact project.



Source: E3Modelling, Soclimpact.

The two macroeconomic models use a harmonized input of direct economic impacts associated with the climate hazards of selected impact chains. These direct economic impacts are obtained by D5.6[12]. In particular, the necessary input for the macroeconomic analysis of this report are provided in the tables of section 3 of D5.6. The inputs enable simulations for the macroeconomic impacts of all Blue Economy sectors analyzed in SOCLIMPACT project and

[12] Soclimpact project Deliverable D5.6 Integration and coordination of non-market and big data analysis of economic values resulting from Climate Change impacts to GEM-E3-ISL and GINFORS models.

in particular for the impact chains related to tourism, to energy demand for cooling and desalination, maritime transport and finally for aquaculture (GWS model only). With respect to the time frame, two periods are considered: i) the ***near*** period refers to the years from 2040 to 2065 and ii) the ***distant*** period refers to the years from 2080 to 2100.

With regards to tourism, input is provided in terms of changes of total touristic expenditure from the respective reference levels. The methodology applied by D5.6 so as to derive the necessary changes in touristic expenditure is explained in detail in section 2 of the respective report. The latter makes use of i) transfer functions from the literature, ii) survey data, iii) Big data analysis and iv) expert interviews.

With regards to maritime transport, the available input corresponds to investments necessary for the maintenance of port operability (Keep Ports Operating approach described in D5.6). This type of input can be considered in two ways in the context of macroeconomic models: i) as adaptation investments necessary to keep the ports operational after the climate events have occurred or ii) as damage to port infrastructure which indicates an overall destruction of the available capital stock, without however considering the potential impacts on the supply of goods to the islands.

With regards to energy, as mentioned in the introduction, all energy transformation technologies for the islands are considered, as well as energy demand. There are two main reasons from this deviation from the pure definition of the Blue Economy sector “Marine energy” or “Ocean energy”. Firstly, few islands in question have marine energy or plan to have ocean energy. Thus, the impact chains, following the vulnerability source book and the risk assessment therein, which is based upon vulnerability, and exposure today, are empty. Risks from climate change for technologies not yet built are highly uncertain, to say the least.

Secondly, climate change does have effects on the islands’ energy system. Since some islands have island electricity grids, for instance, relying on own generation the damages or strain from climate change can be severe. The risks identified were increased electricity demand for cooling and for desalination. These increased demands are estimated in Work Package 5 and the estimates are implemented in the islands’ economic modeling approach.

With regards to aquaculture, the exposure is more limited than in the other sectors. By far not all Islands plan or have aquaculture to an economically relevant extent. Some Islands are planning or having test facilities. Also, the experts are undecided about the impacts from climate change to aquaculture beyond a mere destruction from storms. However, production changes in the aquaculture sectors have been included in the GINFORS_E model. The effects are very small.

The next sections elaborate the scenarios and the channels through which the changes in economic quantities work in more detail for each sector in turn.

2.1 MODELLING IMPACTS ON TOURISM

2.1.1 TOURISM SCENARIOS

All climate impact scenarios are estimated for two different climatic projections, namely for

RCP2.6 and RCP8.5 concentrations, indicating the climate impacts under a well-below 2°C climate stabilization by the end of the century and under a business as us usual case respectively. These two climatic variants are derived from the output of D4.2[13] of WP4 and D5.6 of WP5 and form two variants of the following impact chain scenarios:

1. SeagrassLoss: Loss of attractiveness of touristic marine environments (seagrass evolution expressed in terms of % loss of most spread seagrass)
2. ForestFire: Increased danger of forest fire in touristic areas (Fire weather index)
3. Beach: Beach reduction
4. Thermal: Thermal comfort due to number of days higher temperature than 35°C. In these scenarios, the Humidity index was used to assess the thermal stress.
5. VDiseases: Length of the window of opportunity for vector-borne diseases (Habitat Suitability Index for tiger mosquito)
6. TourismICs: combination of all hazards referred above in order to obtain the tourism-related macroeconomic impacts.

Table 1: Macroeconomic scenarios for the tourism sector analysis

Number of scenarios	RCP 2.6	RCP8.5
TOUR- SC1	Seasgrass Loss	Seasgrass Loss
TOUR- SC2	Forest Fire	Forest Fire
TOUR- SC3	Beach	Beach
TOUR- SC4	Thermal	Thermal
TOUR- SC5	V-disease	V-disease
TOUR- SC6	TourismICs	TourismICs

2.1.2 METHODOLOGY OF SCENARIO IMPLEMENTATION IN GEM-E3-ISL MODEL

In GEM-E3-ISL tourists are treated as an individual agent category along with households, firms and government. Tourists consumption patterns and overall expenditures are exogenously specified. The allocation of tourism expenditures to different product categories and services is based on data provided by island-specific Tourism Satellite Accounts. In the different scenarios total expenditures are exogenously determined and are consistent with the specifications of each scenario variant.

A reduction in tourist expenditures because of the deterioration of island's attractiveness or an increase in risk factors will result in lower demand for certain service categories, an increase in unemployment and a reduction on tourism related income. This effect is straightforward; its

[13] SOCLIMPACT project Deliverable D4.2 High resolution wave and sea level climatology atlas.

magnitude depends on the structure of economic activity as well as on the reliance of economic activity from tourism-oriented activities. Islands that depend heavily on tourism, this initial negative impact is expected to further affect economic activity at least in the short-term, where the adjustment possibilities are limited. While for other islands, whose economic activity is more balanced the effect is expected to be more limited and funds are expected to be redirected to other economic activities.

2.1.3 METHODOLOGY OF SCENARIO IMPLEMENTATION IN GWS MODEL

In the extended GINFORS model, tourists' expenditure is modelled as demand of travelers for good and services on the respective island. We do not consider demand for touristic services by domestic population to travel outbound, such as travel agencies etc. These expenditures are included in the full assessment, e.g. the tourism satellite accounts. Domestic tourism expenditures, e.g. domestic travels to the beach, are included in the analysis.

Climate change yields changes in tourists' demand and expenditure patterns, which enters the model as an exogenous change. To estimate the damage, this change is not counter balanced in the model, so there is no adaptation measure or price change assumed. The demand decrease leads to changes in demands for intermediate goods from the respective industries and services, and thus to demand changes throughout the economy. The core equation to connect these demand changes in the model is the Leontief equation. Employment losses are derived from the respective changes in production of goods and services. Pattern changes within a year, however, are not implemented in the model.

2.2 MODELLING CHANGES IN ENERGY DEMAND

2.2.1 ENERGY SCENARIOS

Similarly, to the scenario framework for the analysis of impacts on the tourism sector, all energy scenarios are estimated for the two different climatic projections, RCP2.6 and RCP8.5. Two main effects due to climate change were identified, both of which increase electricity demand. Firstly, increased cooling degree days lead to increases in demand for cooling and secondly due to less precipitation and more droughts, energy demand for desalination will be increasing, for those islands which use desalination for freshwater provision. The Mediterranean introduced reverse osmosis technology early[14]. It started in the 1990s in the Balearic and Canary Islands. In the eastern Mediterranean, Limassol, Larnaca and Dhekelia were early desalination projects.

Energy demand for additional desalination ranges between 30-50% on the Baleares; 50-80% on the Canaries, and 30-76% in Cyprus. Energy demand for additional cooling more than doubles the current energy demand for cooling on most islands under the RCP 8.5 scenario. The detailed input by scenario variant is provided in the Results sections.

The notation used henceforth for the energy scenarios is the following:

[14] https://smartwatermagazine.com/blogs/carlos-cosin/evolution-rates-desalination-part-i

Table 2: Macroeconomic scenarios for the energy sector

Number of scenarios	RCP 2.6	RCP8.5
ENER- SC1	Water desalination	Water desalination
ENER- SC2	Cooling	Cooling
ENER- SC3	Water desalination + Cooling	Water desalination + Cooling

2.2.2 METHODOLOGY OF SCENARIO IMPLEMENTATION IN GEM-E3-ISL MODEL

In GEM-E3-ISL the increase in energy demand is simulated as increases in input per unit of output for sectorial activity (e.g. the cooling requirements of the service sector) and as an increase in minimum consumption for households. The former implies that for example accommodation will require more electricity per night spend as the increase in temperature will increase the overall operation of cooling services. Households will have to increase their overall electricity consumption to maintain the same level of utility given the increased appearance of heat waves. In addition, decreased precipitation rates imply higher supply of water from desalination facilities. The later use electricity intensive processes for providing freshwater.

As electricity input increases the unit cost of service-related activities is expected to increase leading to higher prices for domestic users and a potential deterioration of competitiveness. Furthermore, the increase in household related expenditure means that a smaller share of households' budget will be allocated to other product categories. To the extent that sectors are unable to deliver their excess production to markets outside of the island, economic activity is expected to be negatively affected. Moreover, increased demand for electricity will exert pressure on the electricity system, which is likely to result in higher electricity prices, especially for islands that are not interconnected to the main peninsula's electricity system. But even for interconnected islands it is highly likely that electricity prices will increase as temperature increase is expected to affect the whole country.

The GEM-E3-ISL features several power generation technologies. The power generation module of the CGE model is linked to a bottom up module.

2.2.3 METHODOLOGY OF SCENARIO IMPLEMENTATION IN GWS MODEL

In the extended GINFORS model, additional energy demand increases the turnover of the utilities. However, they have to expand their capacities over time to meet this demand. Alternatively, the amount of PV modules installed in roof tops of residential households, restaurants, hotels and public buildings needs to be increased. Either response will increase the price for electricity and cut into the expenditure possibilities of households and the profits of hotels and restaurants.

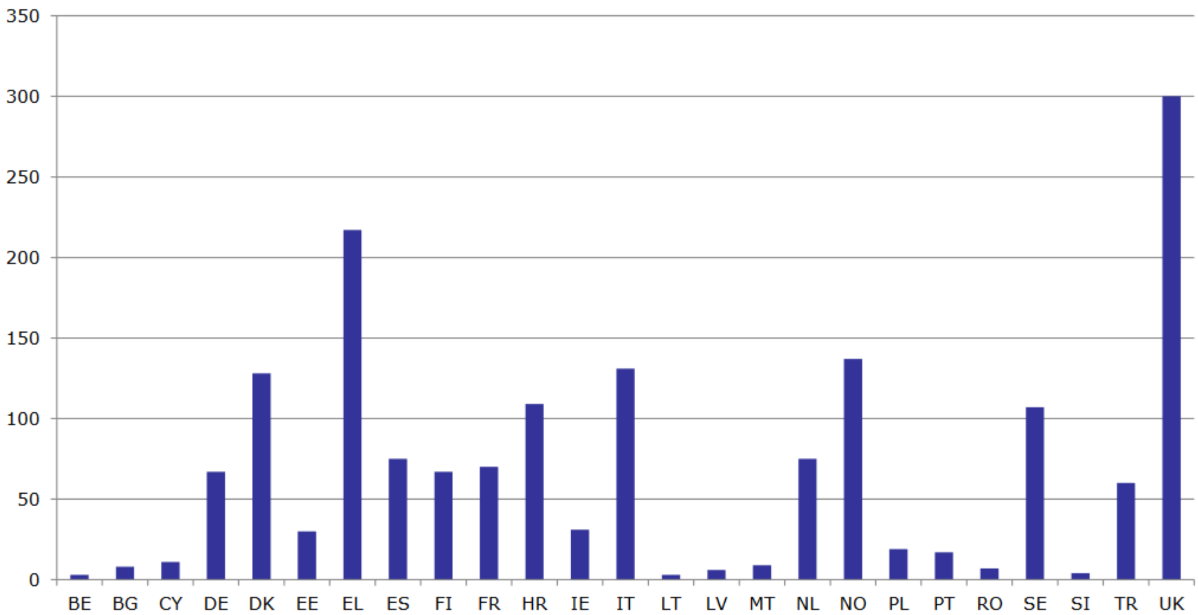
Utilities face additional demand and answer with additional output. Turnover of utilities increases and demand for intermediate goods increases as well. This exerts a positive impact. However, electricity prices will increase and exhibit thus a negative impact in the economy.

The net effect will differ across islands.

2.3 MODELLING IMPACTS ON MARITIME INFRASTRUCTURE

Maritime infrastructure, i.e. harbors and ports, are affected by climate change through waves, storm surges and other extreme weather events (Hails, strong rain etc.). However, in the respective risk assessment the main damage channel was identified to be sea level rise. Christodoulou et al. (2017)[15].(Figure 4) estimate risks for the Mediterranean generally lower than in Northern Europe. Islands, however, are very dependent on imports of essential goods, hence on port reliability. Thus, damages estimated as loss of GDP on the mainland, such as 0.04% for Spain, and up to 0.35% in the eastern Mediterranean, i.e. Greece or Cyprus, could be even higher on Islands.

Figure 4: Ports facing risk of inundation in 2100



Impacts of Climate Change on Transport - PESETA III27 March 2017 UNECE, Aris Christodoulou, JRC – European Commission, Panos Christidis, JRC – European Commission, Hande Demirel, Istanbul Technical University

On the other hand, as argued in D5.6, "In fact, assessing the costs derived by inaction to protect ports operativity against climate change impacts does not seem reasonable due to the extreme dependence of islands' economy on port activity. In fact, the consequence would be that, at a certain time horizon, ports activity will come to a halt, and islands' economies will become severely hit. SOCLIMPACT researchers strongly think that this is an unlikely outcome and, hence, the Keep-ports-operating (KPO) approach is more realistic and feasible, providing more reliable figures."

[15] https://www.unece.org/fileadmin/DAM/trans/doc/2017/wp5/4_EU_Mr_Aris_Christodoulou_Climate_Change_12th_27-28_March_2017.pdf

The estimates from the KPO approach are thus used for implementation in the models, so as to ensure a consistent link across the project Work Packages.

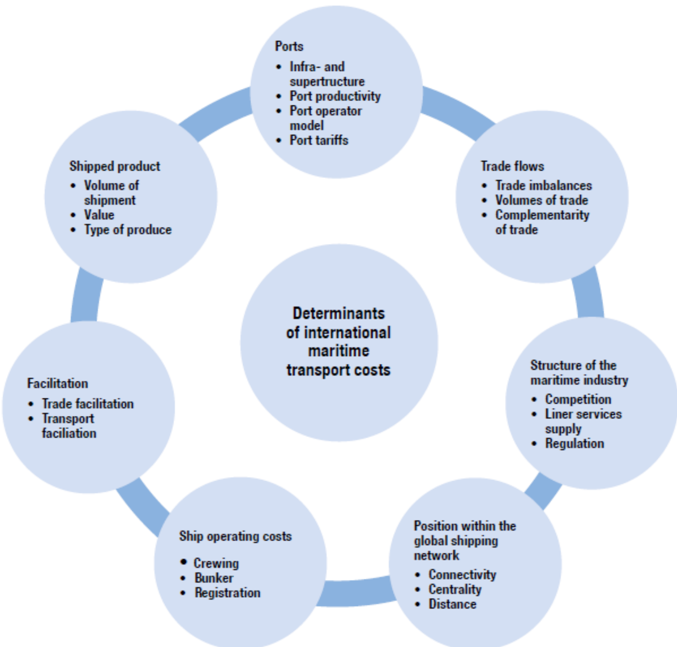
2.3.1 METHODOLOGY OF SCENARIO IMPLEMENTATION IN GEM-E3-ISL MODEL

In the GEM-E3 model the damaged infrastructure is modelled by reducing the capital stock of the respective economic sector. Capital stock losses increase capital cost which drive increases in investments in subsequent periods as long as activity levels and capital requirements are high. Investments in the GEM-E3-ISL follow the Tobin's Q approach where firm compares its user cost of capital with its replacement cost in order to formulate its investment decision. Higher demand for investments requires the increasing of financing resources (i.e. increase in savings). To the extent that savings can support financially the investments projects the rental cost of capital (the interest rate) is unchanged. Once investment demand increases more than savings then the interest rate starts to increase and a crowding effect takes place so that some investments are cancelled in order to ensure financing for others. As investments for replacing the damaged infrastructure increase, investments of other productive sectors decrease and this has negative repercussions for domestic activity. Increasing capital cost leads to higher production costs affecting eventually, competitiveness of domestic products.

2.3.2 METHODOLOGY OF SCENARIO IMPLEMENTATION IN GWS MODEL

Investment in infrastructure tends to exhibit positive effects in the GINFORS model. Climate change effects on ports, however, as outlined above, have negative effects on the islands and require additional efforts to keep the islands supplied with imported goods.

Figure 5: Determinants of maritime transport costs



Source: UNCTAD secretariat, based on Wilmsmeier, 2014[16].

Transport costs in developed economies sank to 6.8% of the cargo's value[17].the respective port infrastructure affects transport costs to a large extend. "Doubling port efficiency at both ends has the same effect on international maritime transport costs as would a "move" of the two ports 50 per cent closer to each other." (UNCTAD 2017, see footnote above). To implement the suggested KPO expenditures in GINFORS, we will thus adjust transport costs to the respective island accordingly.

2.4 MODELLING THE EFFECTS OF IMPCT-CHAINS WITH GINFORS AND GEM-E3

The estimation of impacts of biophysical changes has been performed using two classes of models: a macro-econometric model, GINFORS, and a general equilibrium model GEM-E3-ISL. The application of two different types of economic models provides useful insights for the analysis of climate impacts.

Computable General Equilibrium (CGE) models are based on neo-classical theory that households and businesses maximize their benefits and profits. The markets of different goods are cleared (are in an equilibrium), i.e. Supply and demand balance and economic resources are fully utilized. A demand-driven shock, such as the change in tourism revenues, in the CGE models apart from the direct impact in the activity of sectors will also induce a second-round of effects that emanate from the response of primary production factor markets (i.e. the labor and the capital market). As wages and capital rents adjust to reach a new equilibrium point, resources move towards more profitable activities which record competitiveness gains due to changes in production costs. This adjustment allows to partly compensate the first- order effects and determines the magnitude of the final impacts in the economy. The model features equilibrium unemployment, in contrast to the common CGE approach which implies full employment; the model closure rule states that agent's savings equal investments at all points in time. This is possible by the adjustment of regional interest rate, which denotes for the case of firms regional differentials in the cost of financing.

Macro-econometric models are based on the post-Keynesian theory that emphasizes the demand side, with both market sides playing an important role, unlike simple input-output approaches. Behavioural parameters are determined by econometric estimation of time series data, so the empirical estimation of model parameters is of great importance. Markets are usually not cleared, as the economy is assumed not to be in equilibrium. Involuntary unemployment and idle capital are included. Imbalances between supply and demand are more likely to be offset by demand-driven rather than price effects.

Hence the results of the two models should be seen as providing a reasonable range of the

[16] Wilmsmeier G (2014). International Maritime Transport Costs: Market Structures and Network Configurations. Ashgate. Farnham, United Kingdom.

[17] https://unctad.org/en/PublicationChapters/rmt2015ch3_en.pdf

impacts of simulated changes in the economy given the uncertainty embedded in long-term economic analysis.

3 RESULTS

This section presents in detail the results of various scenarios regarding tourism impacts on the economy. Changes are presented for both models; the comparison of different methodologies allow for a robust estimation of range of changes to be expected in the economy.

3.1 BALEARIC ISLANDS

3.1.1 SCENARIO DEFINITION

There are three sets of scenarios simulated for the Balearic Islands. The first set of scenarios examines the impact of climate change on tourism by assuming different expenditures by tourists due to biophysical climate impacts on the natural environment and temperatures. In particular, the changes in touristic demand are directly linked to the perception of tourists regarding certain features such as beach surface, the marine environment, the risk of forest fires and warmer conditions and depend on how these features are impacted by climate change. The second set of scenarios refers to changes in electricity consumption due to increased cooling demand and water availability. Finally, the third set of scenarios refers to infrastructure damages, specifically to port infrastructure, due to sea level rise.

The impact of climate changes on tourists' spending, electricity demand and capital losses are estimated in D5.6 and are used as inputs for the scenario simulations as described in the Methodology Section. The GEM-E3-ISL model assesses their impacts on the main macroeconomic variables (GDP, private consumption, investments, exports and imports), sectorial activity and employment. The inputs provided by D5.6 and incorporated in GEM-E3-ISL for the Balearic Islands are described in the following tables:

Table 3: Changes in tourists' expenditures with respect to the reference case (%)

	TOUR -SC1 (marine environment)	TOUR -SC2 (forest fire)	TOUR -SC3 (beach reduction)	TOUR -SC4 (thermal comfort)	TOUR -SC5 (V-disease)	TOUR –SC6 (aggregate)
RCP2.6 near	0	0	-7.78	-0.36	0	-8.14
RCP2.6 distant	0	0	-10.3	-0.41	0	-10.71
RCP8.5 near	0	0	-11.67	-0.31	0	-11.36
RCP8.5 distant	-19.0	0	-16.02	0.94	0	-34.08

Table 4: Changes in electricity consumption with respect to the reference case (%)

	ENER -SC1 (desalination)	ENER -SC2 (cooling)	ENER –SC3 (aggregate)
RCP2.6 near	1.7	9.1	10.8
RCP2.6 distant	1.3	3.1	4.4

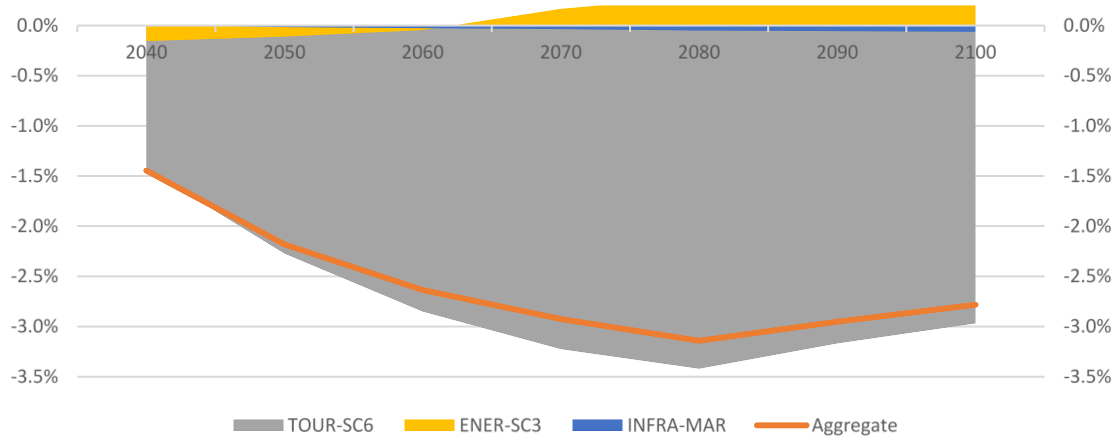
RCP8.5 near	**3.2**	**22.2**	**25.2**
RCP8.5 distant	**8.2**	**43**	**51.2**

3.1.2 GEM-E3-ISL RESULTS

3.1.2.1 Macroeconomic

3.1.2.1.1 Economic impacts of full scenario

The estimated impacts of combined changes (both those related to energy and tourism) on GDP are calculated cumulatively to -2.77% for the RCP2.6 (Figure 6) and -6.5% for the RCP8.5 (



Source: GEM-E3-ISL

Figure 7) over the period 2040-2100.The time profile of impacts varies between the two variants examined as in the RCP2.6 the effects for the *near* and the long period are of similar magnitude (-2.31% and -2.94% respectively) while in the RCP8.5 the effects in the long period are higher than in the near period (-8.73% and -3.44% respectively). The time profile of impacts is directly associated to the scenario assumptions as in the RCP2.6 the estimated aggregate impact of tourism revenues is of similar level for the two time periods while also electricity consumption increases are much lower in the *long* period compared to the first period. On the contrary in the RCP8.5 the aggregate impact on tourism revenues is much more pronounced in the long-term as the degradation of marine environment strongly influences tourists' decisions and electricity consumption increases considerably compared to the short-term. Disaggregating the results of the composite scenario into its components reveals that the driver of changes are the impacts of decreased tourist spending in the economy for both climatic variants.

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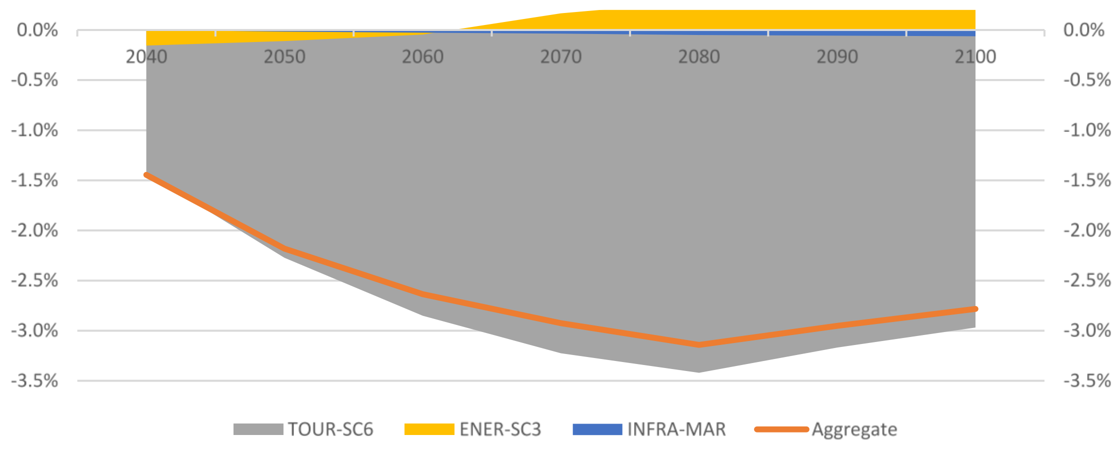
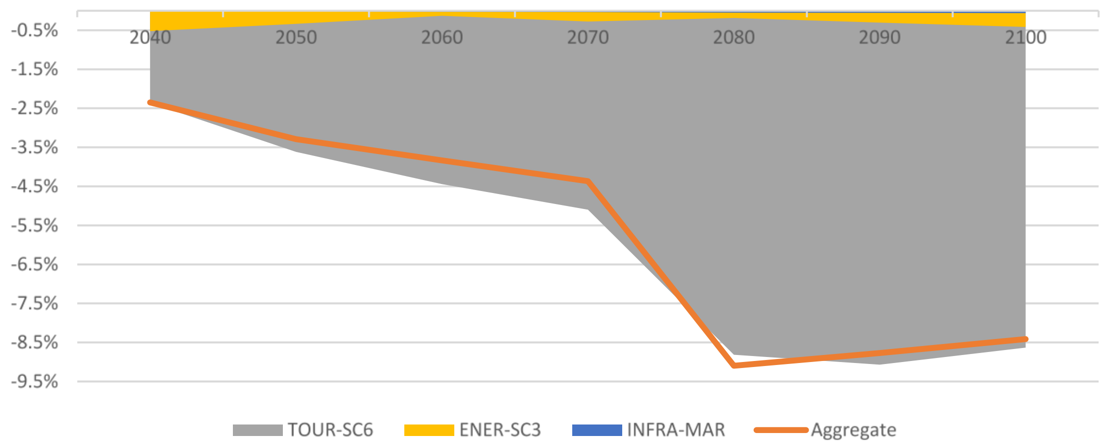
Figure 6: GDP changes from reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 7: GDP changes from reference (%) – RCP8.5



Source: GEM-E3-ISL

In both RCP2.6 and RCP8.5 aggregate scenarios, private consumption due to the decreased activity of tourism-related sectors which drives unemployment rates up and wages down. As household's income fall so does its expenditures for goods and services; firms face lower domestic demand and the overall activity in the economy drops further. In terms of trade, this slowdown of domestic activity yields competitiveness losses due to the decreased cost of primary factors of production (labor and capital) inducing firms to export more of their products. At the same time, lower consumption levels affect the level of imports as domestic consumers not only decrease their expenditures for acquiring goods and services but also turn towards the consumption of domestically produced goods. However, this substitution effect is small in magnitude and cannot compensate for the negative shock caused by lower tourism revenues. In the RCP2.6 the cumulative exports share to GDP raises to 24.6% and in RCP8.5 to 58% compared to the baseline for the period 2040-2100.

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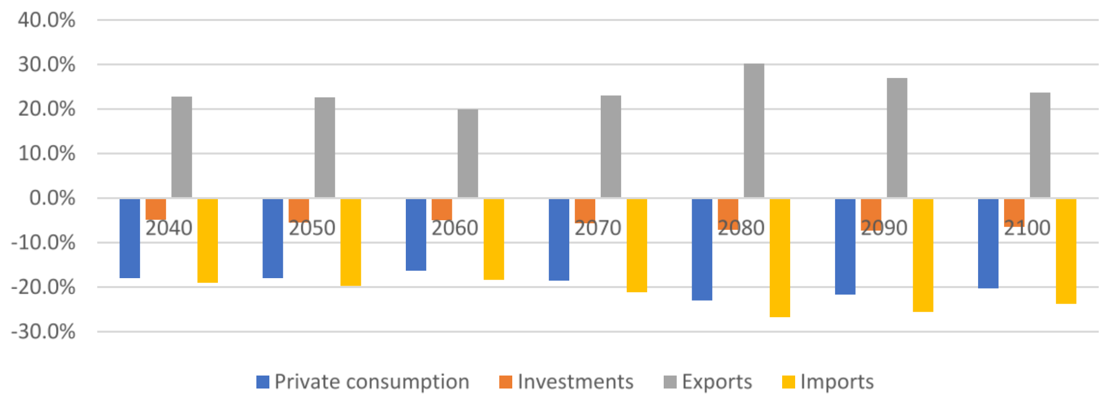
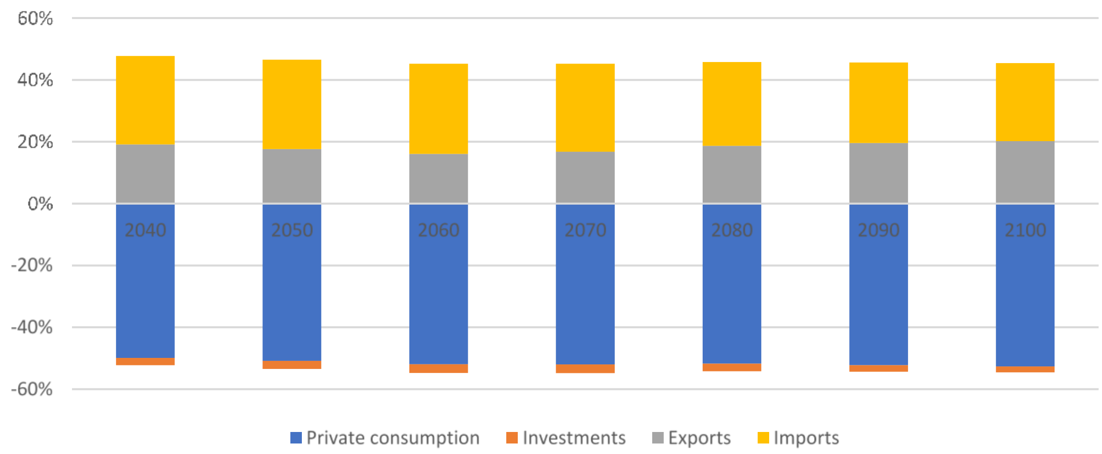
Figure 8: Changes from reference in selected macroeconomic variables (%) – RCP2.6



Source: GEM-E3-ISL

Figure 9: Contribution to GDP changes – RCP2.6



Source: GEM-E3-ISL

Figure 10: Changes from reference in selected macroeconomic variables (%) – RCP8.5

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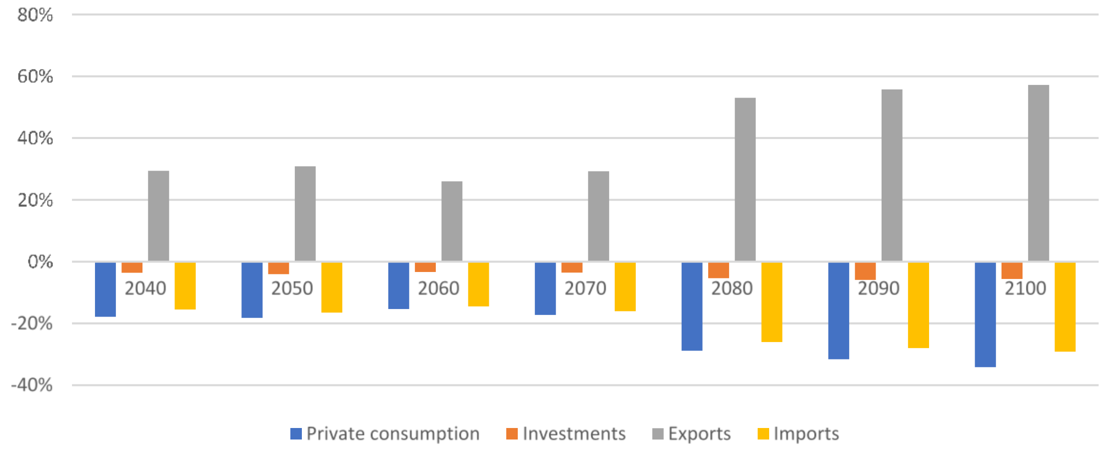
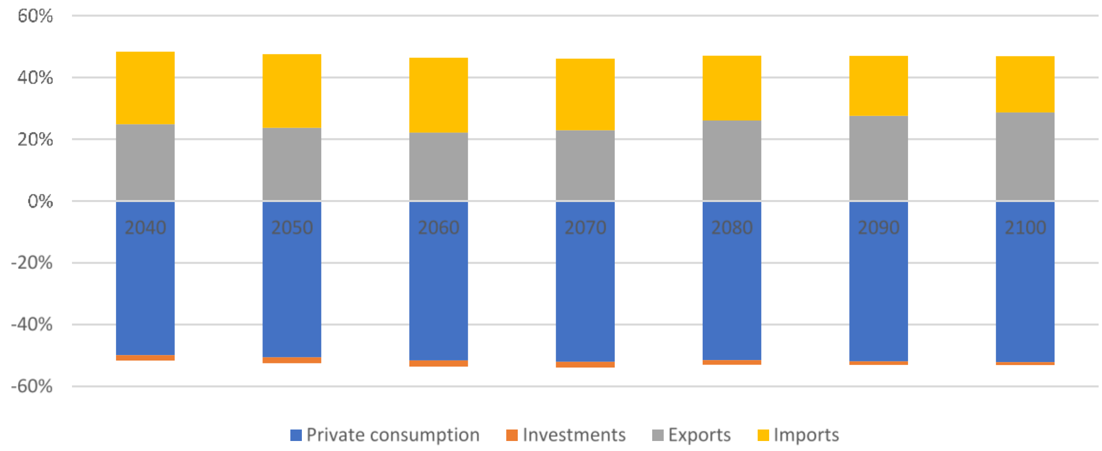


Source: GEM-E3-ISL

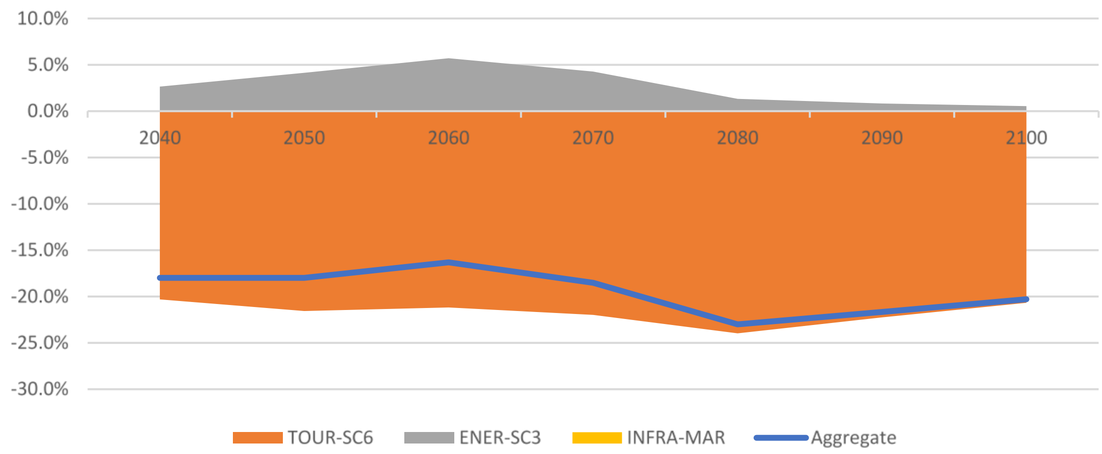
Figure 11: Contribution to GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

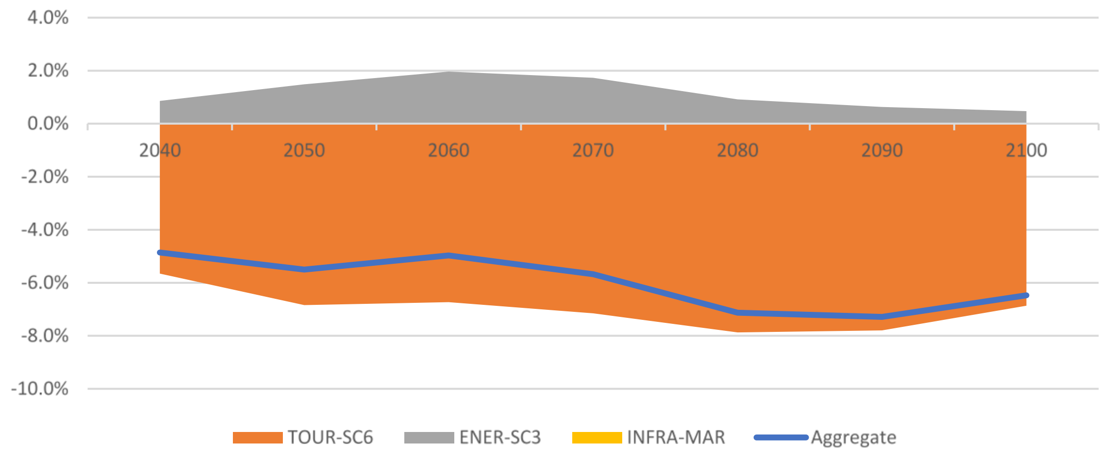
Decomposing private consumption and investment changes (in both climatic variants) we observe that the impact of the tourism component is significantly higher than that of the energy component (Figure 12-Figure 15) and is the driving force of the observed changes. In the ENER scenario increased demand for electricity leads to higher investments in order to expand the island's installed power generation capacity and has a positive effect on domestic activity levels. The increased demand for domestic resources increases household's income hence consumption. The effects on consumption and investments follow closely the assumptions on the time profile of electricity consumption and tourism changes, i.e. in the RCP2.6 we observe that the effects lessen over time for the energy component while in the RCP8.5 they intensify and that with respect to the tourism components in both variants the impacts strengthen over time.

Figure 12: Changes in private consumption % from reference – RCP2.6



Source: GEM-E3-ISL

Figure 13: Changes in investments % from reference – RCP2.6



Source: GEM-E3-ISL

Figure 14: Changes in private consumption % from reference – RCP8.5

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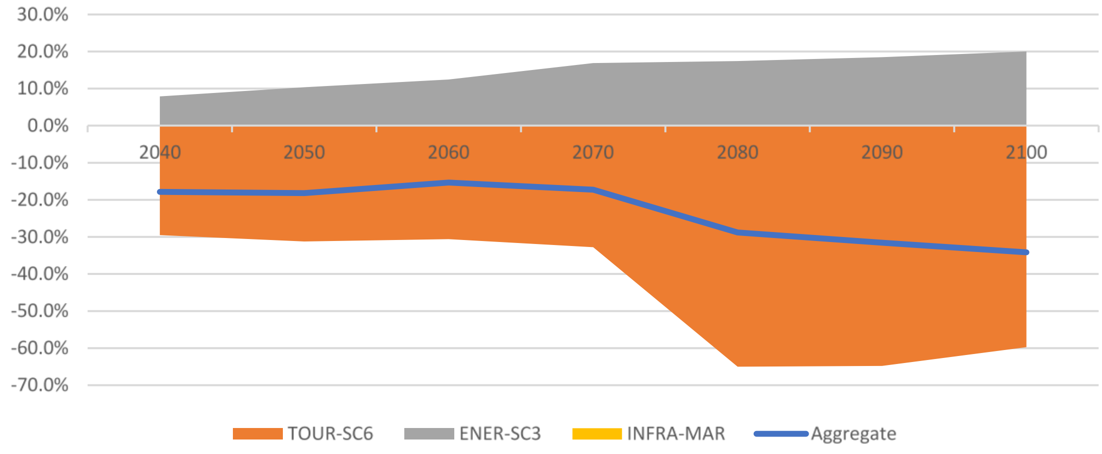
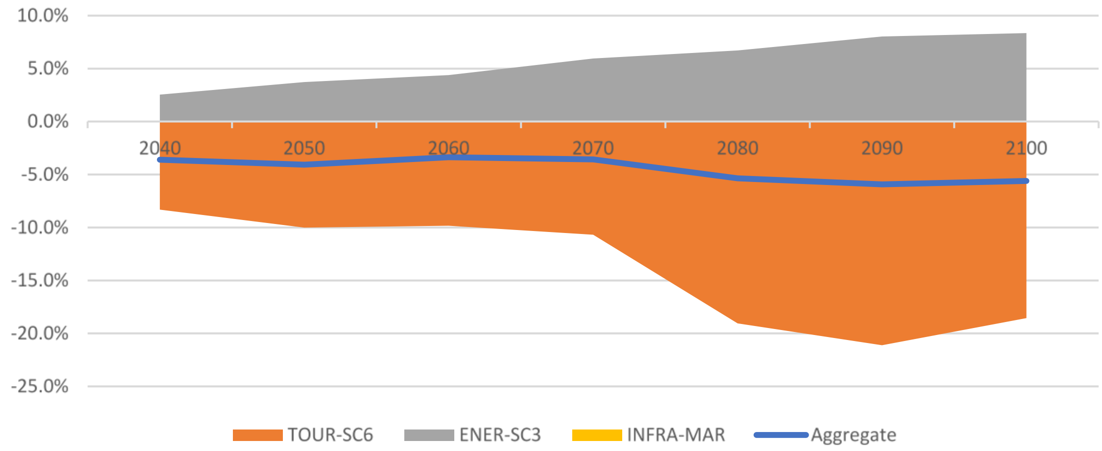


Source: GEM-E3-ISL

Figure 15: Changes in investments % from reference – RCP8.5



Source: GEM-E3-ISL

3.1.2.1.2 Macroeconomic impacts (tourism)

The tourism industry is a very important pillar of the economy of the Balearic Islands. In the base year tourism revenues are responsible for almost 30% of the regional gross value added; this share is projected to further increase in the future reaching 35% of regional GVA. The estimated regarding the impact of climate change on tourism receipts vary from modest (in the RCP2.6) to quite pessimistic and are expected to have important side effects for the islands' economy. The cumulative reduction in tourism expenditures in the RCP2.6 is 9.7% compared to their reference levels while in the RCP8.5 the reduction reaches 24.2%. The impact of the diminished tourism revenues on GDP is found to be equal to -3.0% and -6.9% in the RCP2.6 and in the RCP8.5 respectively while employment decreases on average by 1.7% and by 3.5% respectively over the simulation period.

In the RCP2.6, beach reduction (SC3) is identified as having the greatest impact on the economy, while on the RCP8.5 both SC3 and SC1 are responsible for the greatest part of the assessed impacts (Figure 16,Figure 17). All scenarios exhibit similar pattern with respect to the response of the main macro-economic variables to the implemented shock: i) private consumption decreases primarily due to the reduced revenues of tourism related activities which lead to lower labor income, ii) investments decrease relative to their reference levels as a result of lower activity of the tourism industries and iii) trade deficits reduce as imports fall (due to the overall decrease of domestic demand) and exports increase; the decreased demand for labor from tourism related industries exerts negative pressure on wages which in turns benefit all other sectors that employ labor intensively.

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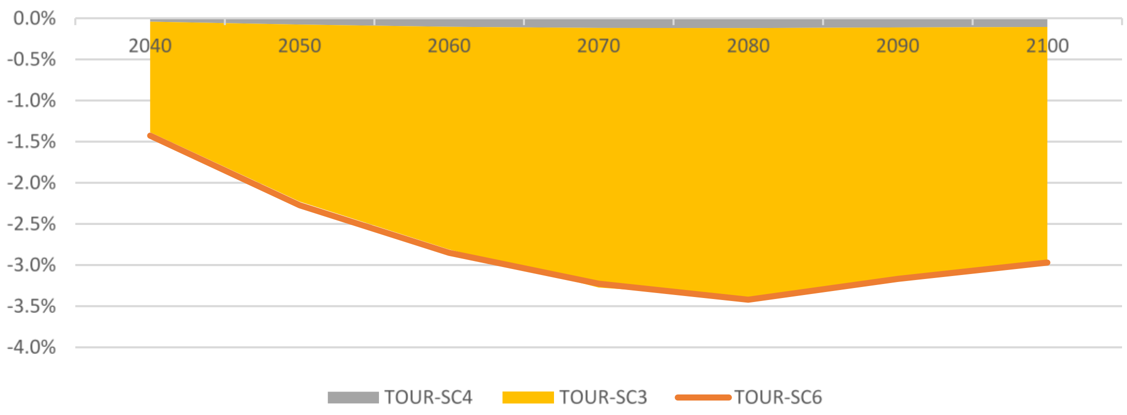
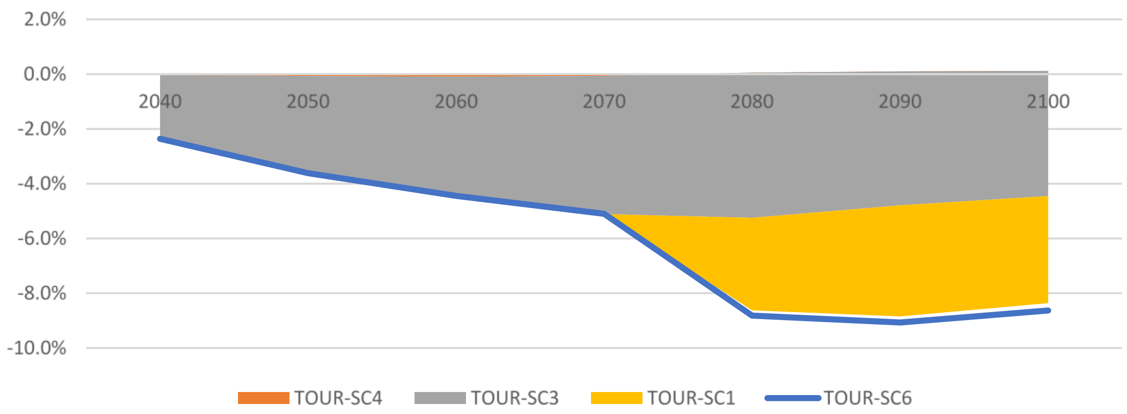
Figure 16: GDP change relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 17: GDP change relative to the reference (%) – RCP8.5



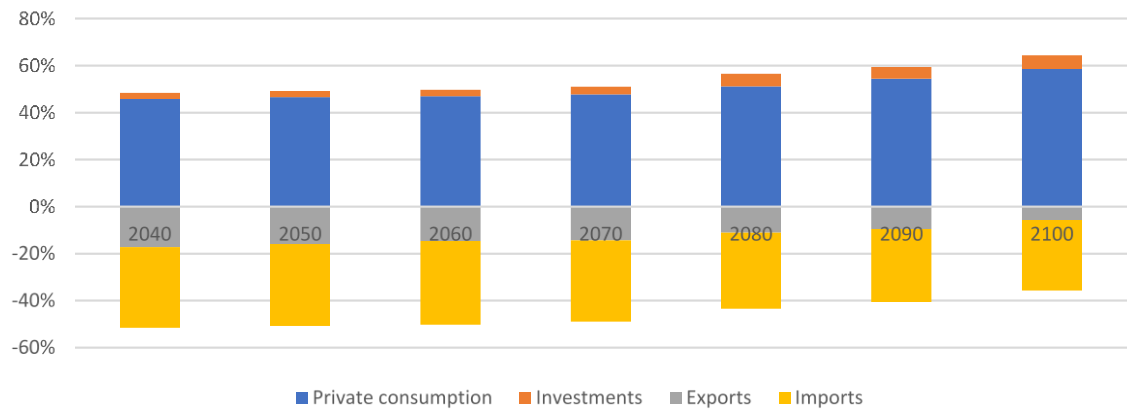
Source: GEM-E3-ISL

3.1.2.1.3 Macroeconomic impacts (energy)

The increased demand for electricity is found to have mixed impacts on the economy of Balearic Islands compared to the reference case depending on the scenario specification. In general, electricity consumption rises as a response to temperature increases and precipitation rates fall implying; cooling equipment are intensively utilized both in the production and in the residential sector and water shortages are covered from the increased supply of water from desalination facilities. These developments stress electricity markets increasing prices both for consumers and for firms. Consequently, firms face higher production costs and their competitiveness deteriorates. The latter results in lower exports and higher imports as consumers substitute the more expensive domestically produced goods with imported ones. In the RCP2.6 we observe that GDP increases in the long run due to lower (relative to the short period) increases in electricity consumption. Intuitively this means that the electricity system which has been already adjusted to meet satisfy even higher demand levels, by increasing existing capacity in the short term, can meet the new levels of electricity consumption at lower costs. In modelling terms and since the model lacks the engineering detail of bottom up models, the additional productive capacity created in the simulation period (2040-2065) is re-directed towards other more profitable activities.

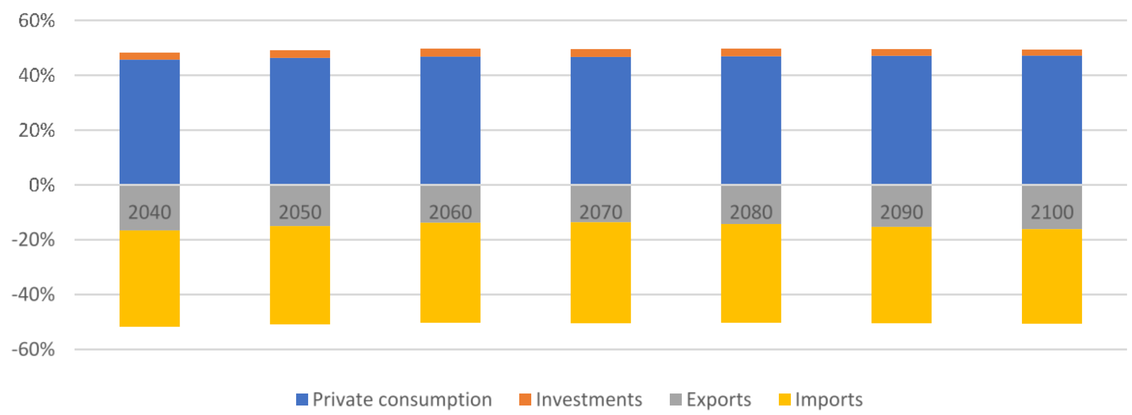
From the two energy-related scenarios examined, in the *long* period the effects are more pronounced in the cooling scenario as it foresees higher electricity consumption in both variants compared to the electricity consumption for desalination purposes.

Figure 18: Changes from reference in selected macroeconomic variables (%) – RCP2.6



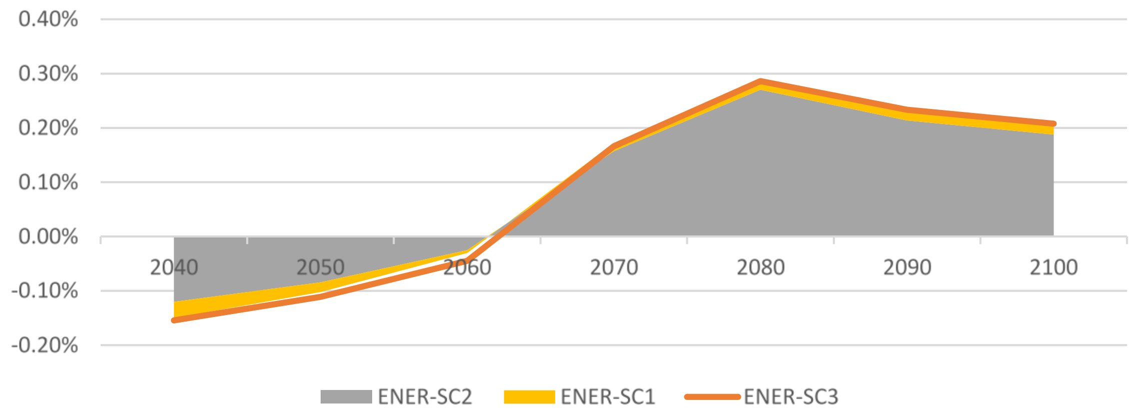
Source: GEM-E3-ISL

Figure 19: Changes from reference in selected macroeconomic variables (%) – RCP8.5



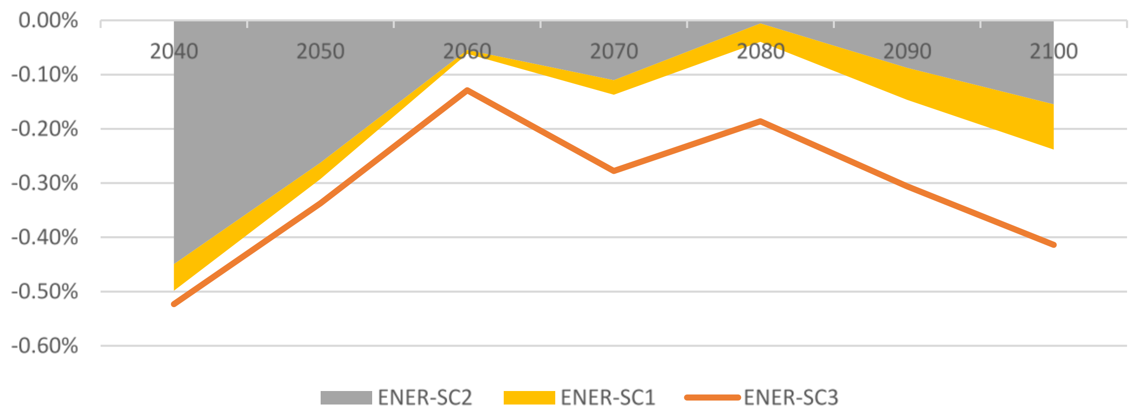
Source: GEM-E3-ISL

Figure 20: GDP changes relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 21: GDP changes relative to the reference (%) – RCP8.5

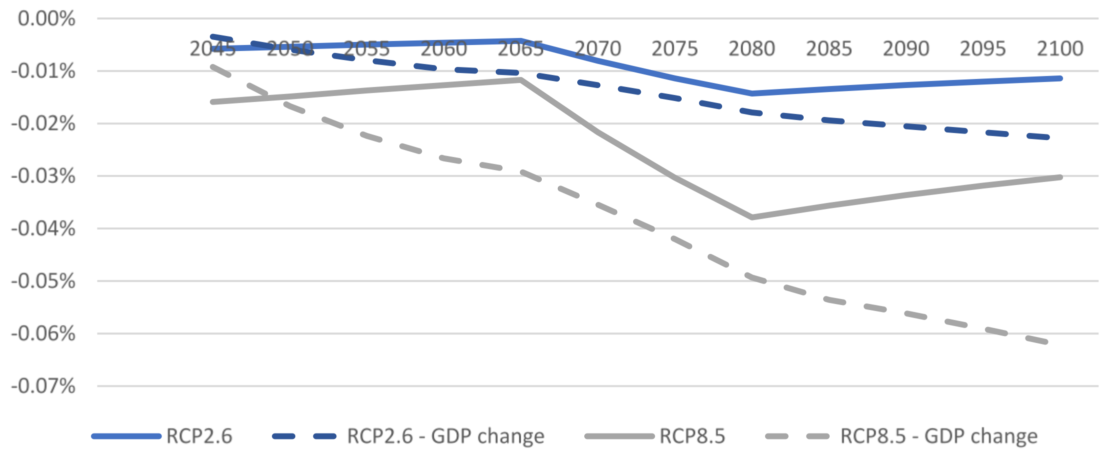


Source: GEM-E3-ISL

3.1.2.1.4 Macroeconomic impacts (maritime)

This scenario examined the effects of port infrastructure damages in the economy due to sea level rise. These damages are modelled as capital stock losses in the GEM-E3-ISL model. Lower capital stock stress the capital markets leading to increased capital rents affecting negatively sectorial activity as firms are now facing higher production costs and record competitiveness losses.

Figure 22: Capital losses (% of GDP)



Source: GEM-E3-ISL, D5.6

The scenario assessment shows that GDP contracts by 0.01% on average for the period 2045-2065 and by 0.02% for the period 2080-2100 in the RCP2.6; the respective figures for the RCP8.5 are 0.02% and 0.06%. Higher capital costs hinder the competitiveness of domestically produced who experience a decrease in their demand both from international markets (exports decrease over the period examined) and from domestic markets as they are substituted by cheaper imported goods.

3.1.2.2 Sectorial results

The simulation results of the abovementioned scenarios indicate that the sectors with that experience the steepest decrease, in terms of activity levels, are those associated to the delivery of services to tourists while sectors actively engaged in the realization of investments, such as construction, also record increases in their activity levels. On the tourism side, in both climatic variants activity levels of related industries fall relative to the baseline; in the RCP8.5 this effect is almost double due to the magnitude of the simulated changes. Moreover, in the RCP8.5 scenario electricity requirements continue to grow throughout the simulation compared to the RCP2.6 where the foreseen increases in electricity demand dwindle over the long-term.

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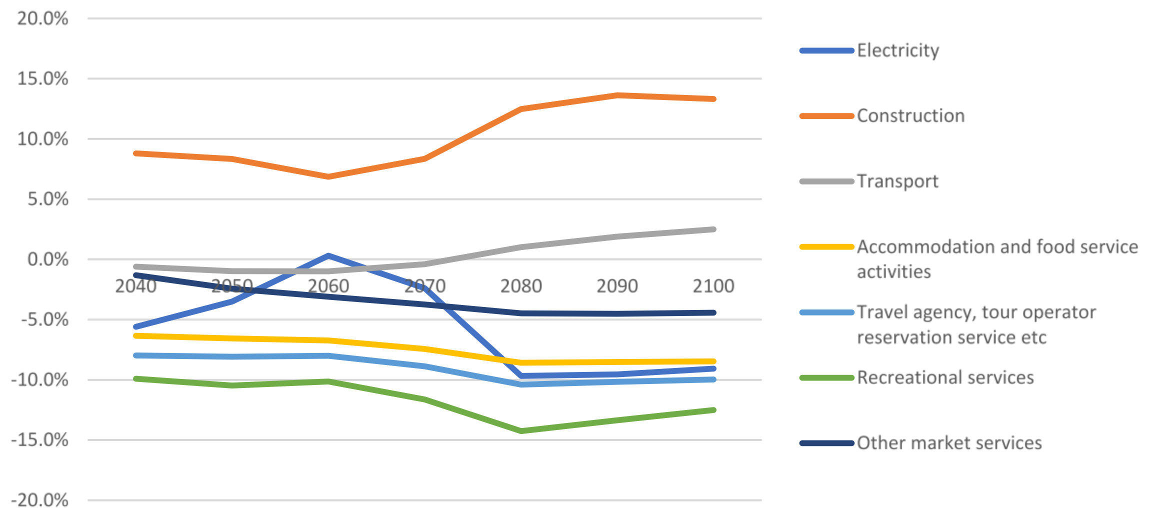
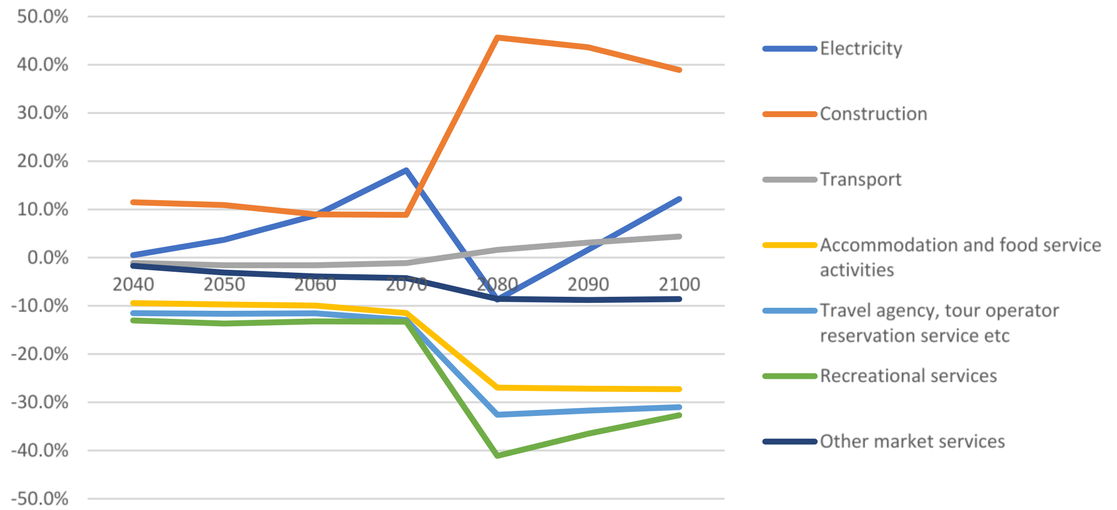
Figure 23: Sectorial activity (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 24: Sectorial activity (% from the reference) – RCP8.5



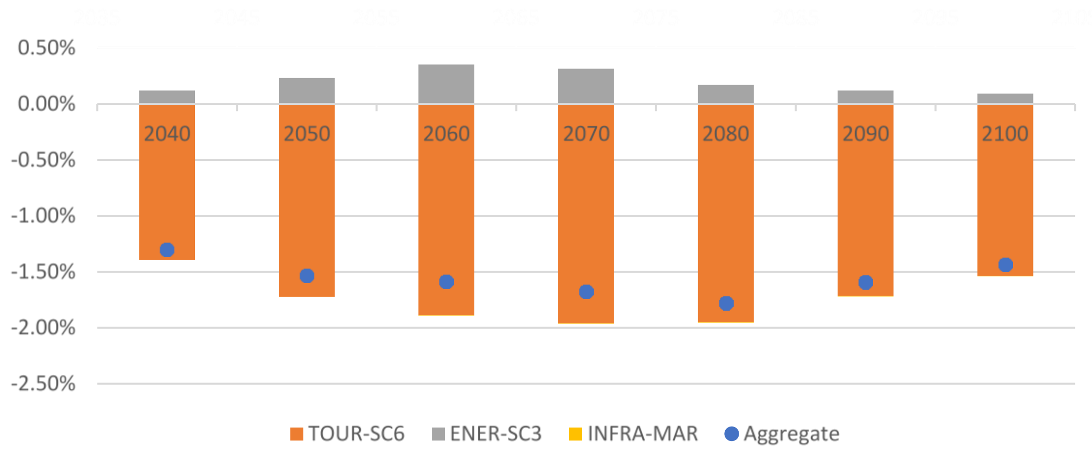
Source: GEM-E3-ISL

3.1.2.3 Labor market

With respect to the labor market developments, the simulation results show decreased employment levels for both climatic variants (RCP2.6 and RCP8.5) and for both periods (*near* and *long*) examined. The employment losses recorded are attributed mainly to the decreased employment of the tourism sectors: -8% on average in the RCP2.6 and -17.1% in the RCP8.5 for the core tourism sectors [18].

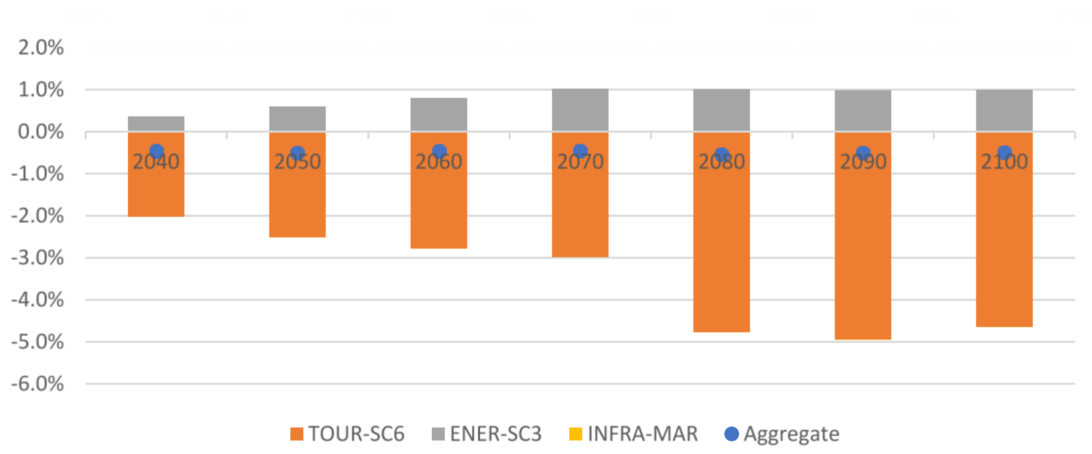
[18] Accommodation and restaurants, travel agencies and recreational services

Figure 25: Employment (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 26: Employment (% from the reference) – RCP8.5



Source: GEM-E3-ISL

3.1.3 GWS RESULTS

3.1.3.1 Macroeconomic

The Balearic Islands could expect higher growth than mainland Spain, comparing the economic outlook of islands' group (D6.2) with the reference scenario in the macro model GINFORS-E. GDP, and private and public consumption show favorable development. However, the large relevance of tourism for the Islands points to the vulnerable spot, as it also does today with the pandemic rendering tourism and travel often impossible. Direct tourism related activities, such as accommodation, tour operators and travel agencies make for a share of more than 16% of value added as compared to 7-8% in mainland Spain. Tourists expenditure obviously extends beyond these direct sectors and adds largely to consumption, renting vehicles, and other activities.

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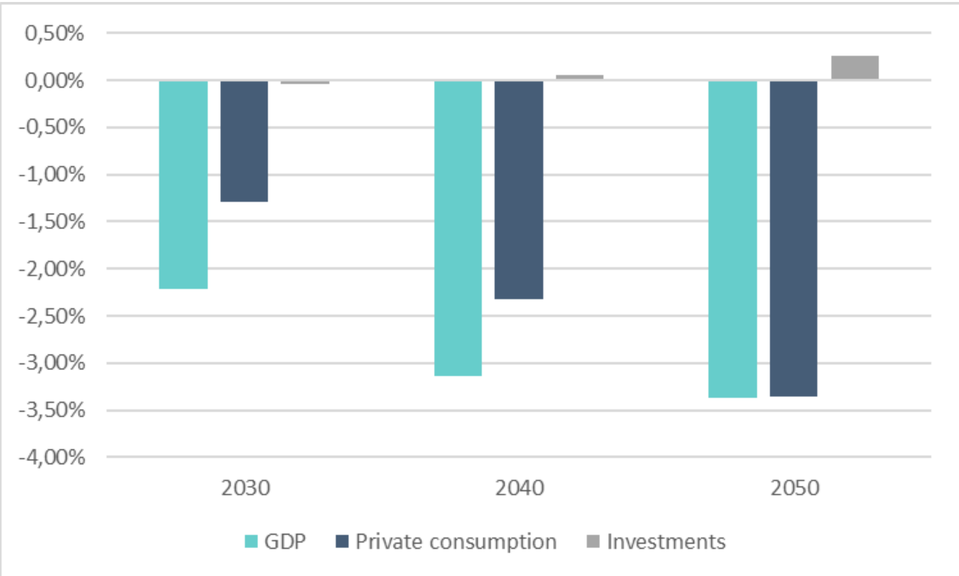
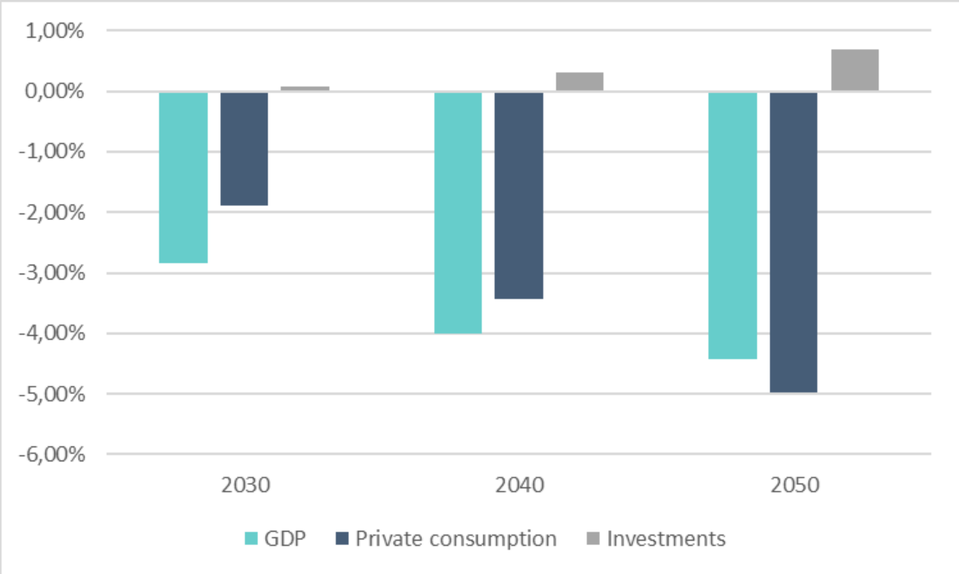
The energy sector on the Baleares has been described in D3.4 as follows. High growth of energy demand from a population of 1,2 million residents and 15 million tourists a year. Given the marked seasonality in tourism the energy demand in summer highly exceeds the autumn demand (August consumption is ~1.7 times larger than November consumption). The Islands depend on external fossil resources, but the expectations are that increases in renewable energy deployment will lower costs.

The islands are strongly dependent on the fuel supplies and/or the energy through the cable connected to the mainland. An HVDC cable runs from Mallorca to the Spanish mainland, Menorca is connected by cable with Mallorca. Electricity from Spanish mainland can cover up to 25% of Mallorca's energy demand. However, if energy demand from cooling increases as outlined in the scenario description, the islands will have to invest additional generation capacity. The loss of tourism expenditure and the gains from investment are the main drivers of the macroeconomic effects.

Figure 27: Baleares: Components of GDP, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own results.

In the RCP 2.6 scenario GDP will be around 2% lower in the period 2030 to 2050 compared to the baseline. This is mainly driven by a reduction of private consumption and international trade.

Figure 27 shows the higher decreases of consumption under the RCP8.5 scenario, but also the higher investment in the energy sector. Investment to cover the additional energy demand could be interpreted as defensive spending under higher radiation scenarios. This is often discussed in the adaptation literature as non-productive GDP increase, because the expenditure could go to more productive uses without climate change. In the case of air-conditioning, the additional demand for electricity should obviously be covered with electricity from renewable energy, not to increase the THG emission pressure on the global climate.

3.1.3.2 Sectorial results

Changes in value added are the result of several economic effects in the model. Changes in final demand lead to additional (or less) intermediate demand, which both are reflected in production. This connection is given by the Islands' input output tables, which were provided in D6.1. Additionally, changes in demand lead to the respective price changes and have effects on relative price levels, leading to demand changes in turn. Value added by sector reflects these effects.

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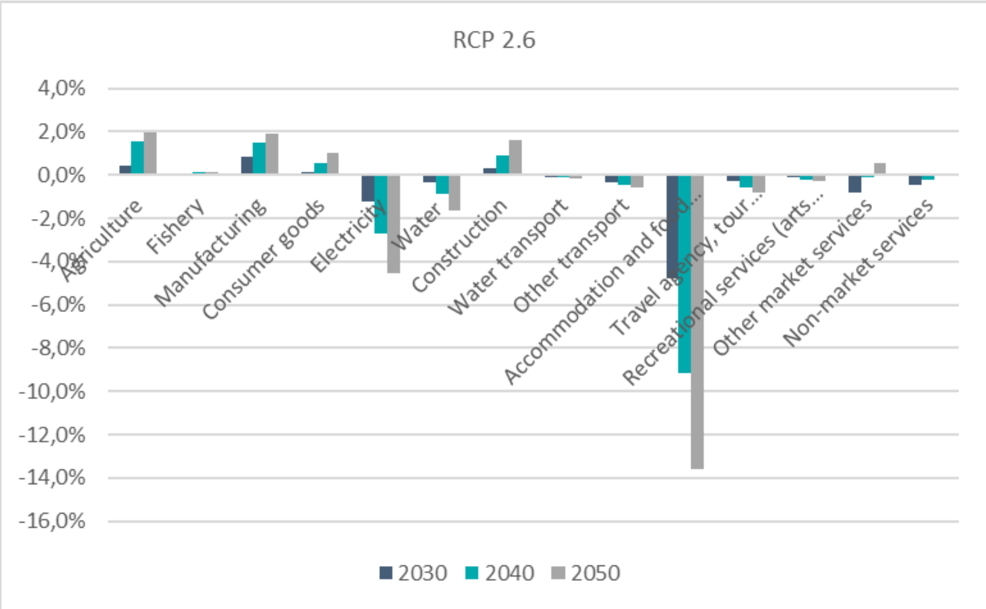
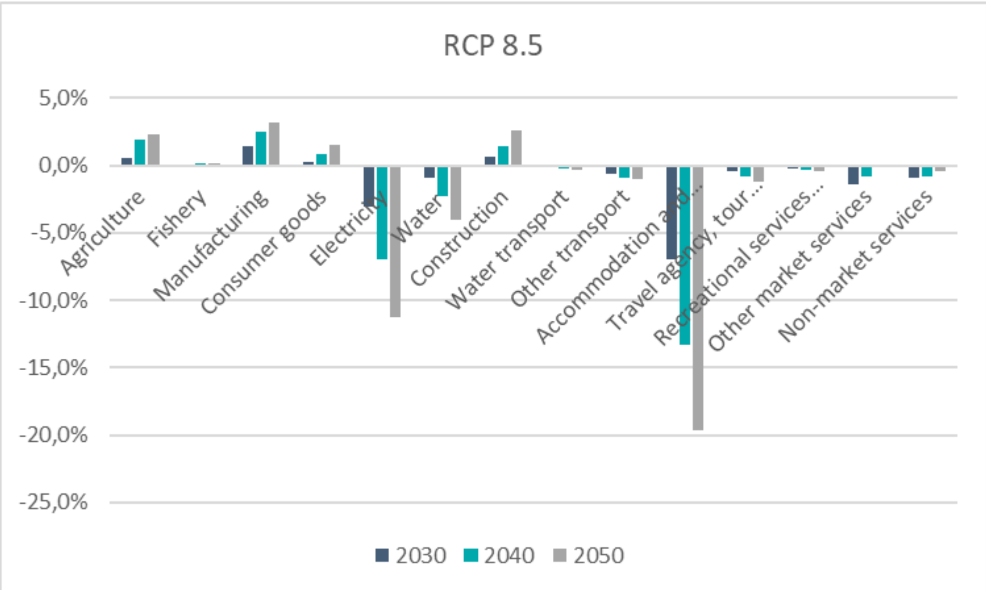
Figure 28: Baleares: Value added by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, ow n calculation.

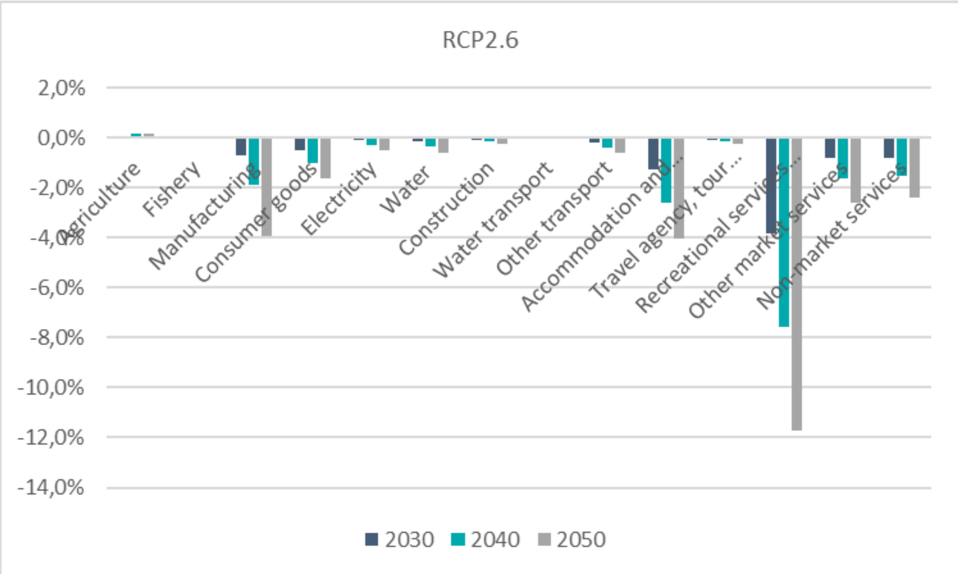
The figures clearly show the negative effects on the tourism related sectors. With less tourists, demand will be reduced. The highest negative effects can be seen in accommodation. Value added in electricity is reduced despite an increase in demand. This is driven by an increase in electricity prices. Positive effects of higher investment in renewable energy sources show up in other sectors, mainly in manufacturing, construction and in other market services.

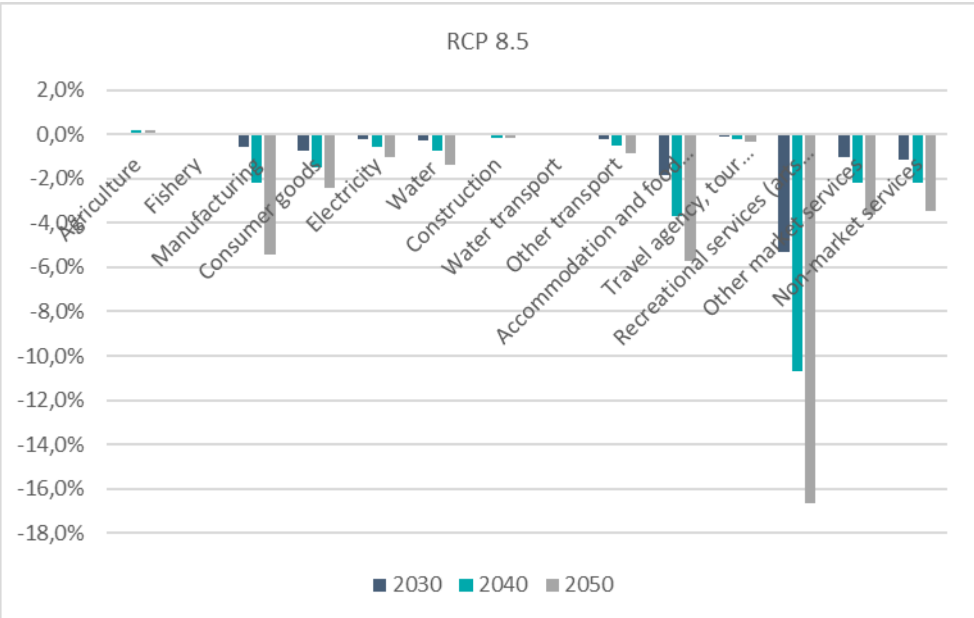
Construction, manufacturing, and other services benefit, mostly from additional investment. The effects increase severely under the RCP 8.5.

3.1.3.3 Labor market

The labor market is also affected by the reduction of GDP and the structural change induced by climate change in both RCP scenarios. Lower GDP means that wages per capita will increase more slowly than in the baseline. Employment effects (in people employed) are thus smaller than for production and value added and spread more evenly over the sectors.

Figure 29: Baleares: Employment by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation.

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3.2 CANARY ISLANDS

3.2.1 SCENARIO DEFINITION

As described in the previous sections, three sets of scenarios are simulated for each island. The first set of scenarios examines the impact of climate change on tourism by assuming different expenditures by tourists due to biophysical climate impacts on the natural environment and temperatures. In particular, the changes in touristic demand are directly linked to the perception of tourists regarding certain features such as beach surface, the marine environment, the risk of forest fires and warmer conditions and depend on how these features are impacted by climate change. The second set of scenarios refers to changes in electricity consumption due to increased cooling demand and water availability. Finally, the third set of scenarios refers to infrastructure damages, specifically to port infrastructure, due to sea level rise.

The impact of climate changes on tourists' spending, electricity demand and capital losses are estimated in D5.6 and are used as inputs for the scenario simulations as described in the Methodology Section. The GEM-E3-ISL model assesses their impacts on the main macroeconomic variables (GDP, private consumption, investments, exports and imports), sectorial activity and employment. The inputs provided by D5.6 and incorporated in GEM-E3-ISL for the Canary Islands are described in the following tables:

Table 5: Changes in tourists' expenditures with respect to the reference case (%)

	TOUR -SC1 (marine environment)	TOUR -SC2 (forest fire)	TOUR -SC3 (beach reduction)	TOUR -SC4 (thermal comfort)	TOUR -SC5 (V-disease)	TOUR –SC6 (aggregate)
RCP2.6 near	0	0	-10.14	0.13	0	-10.01
RCP2.6 distant	0	0	-12.81	0.17	0	-12.81
RCP8.5 near	0	0	-16.55	0.73	0	-12.64
RCP8.5 distant	0	0	-21.34	2.89	0	-18.47

Table 6: Changes in electricity consumption with respect to the reference case (%)

	ENER -SC1 (desalination)	ENER -SC2 (cooling)	ENER –SC3 (aggregate)
RCP2.6 near	6.0	0	6.0
RCP2.6 distant	6.4	7.2	13.6
RCP8.5 near	9.0	0	9.0
RCP8.5 distant	22.0	14.2	34.2

Table 7: Capital losses (% of GDP)

	INFRA-MAR
RCP2.6 near	-0.39
RCP2.6 distant	-0.43
RCP8.5 near	-1.03
RCP8.5 distant	-1.17

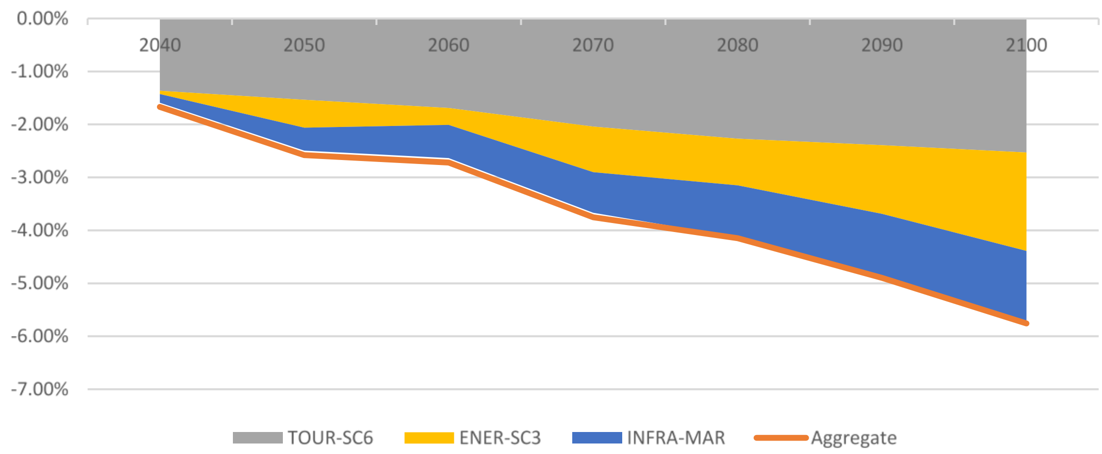
3.2.2 GEM-E3-ISL RESULTS

3.2.2.1 Macroeconomic

3.2.2.1.1 Macroeconomic impacts full scenario

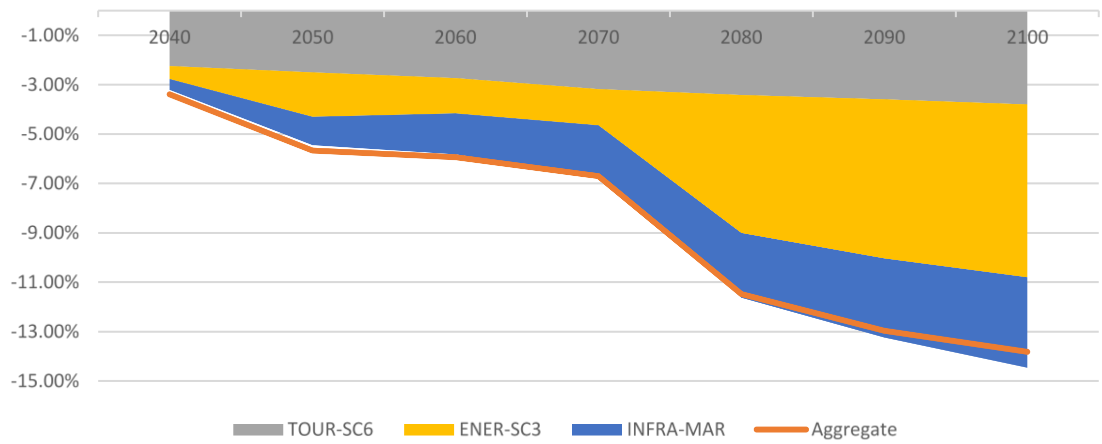
The estimated impacts of combined changes on GDP are calculated cumulatively to -4.2% for the RCP2.6 (Figure 30) and -9.7% for the RCP8.5 (Figure 31) over the period 2040-2100.The effects are found to be significantly higher in the *long* period for both scenarios examined. In the RCP2.6 cumulative GDP losses are approximately 2.8% in the *near* period and 5.1% in the *long* period, while in the RCP8.5 GDP losses are calculated to 5.6% in the *near* period and 13.1% in the long. Plotting the results of the aggregate scenario against the results of the tourism-aggregate scenario, energy-aggregate scenario and the INFRA-MAR scenario reveals that the impact of increased electricity requirements, which comes as a consequence of dryer and hotter climate, is significantly higher from the other two scenarios. This explains the time profile of the estimated impacts as electricity requirements more than doubles in the *long* term. Moreover, it highlights the importance of electricity markets in isolated place, as the diffusion of sectorial impacts in the economy is quite extensive.

Figure 30: GDP changes from reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 31: GDP changes from reference (%) – RCP8.5



Source: GEM-E3-ISL

Private consumption falls in both aggregate scenarios as tourism related income falls. The slowdown of sectorial activity, compared to the baseline, leads to a reduction in both wages and capital rents leading to export increases as domestically produced goods become cheaper. However, the increase of international demand for domestic products is not enough to counterbalance the negative pressure in the economy as the Canary Islands are characterized by low export intensity. Imports decrease as overall consumption shrinks and consumers turn towards domestically produced goods due to lower prices.

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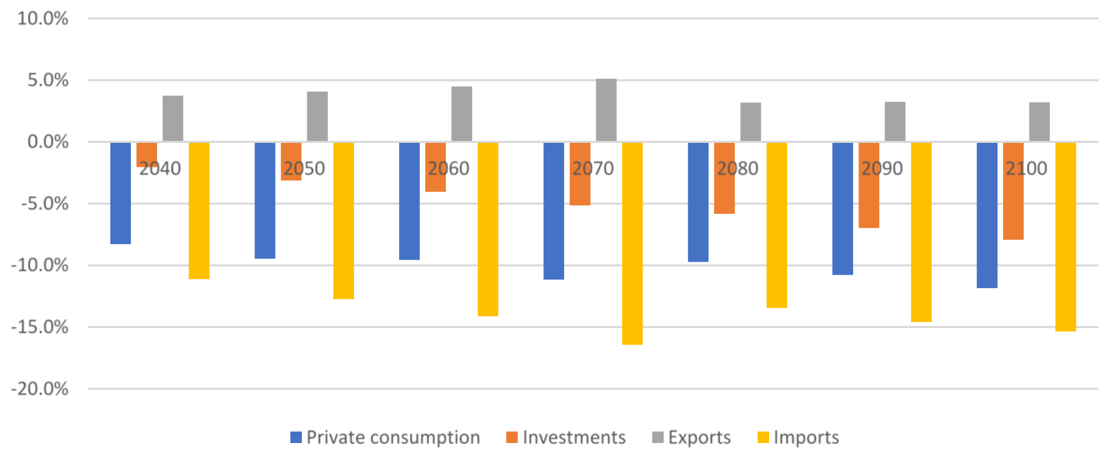
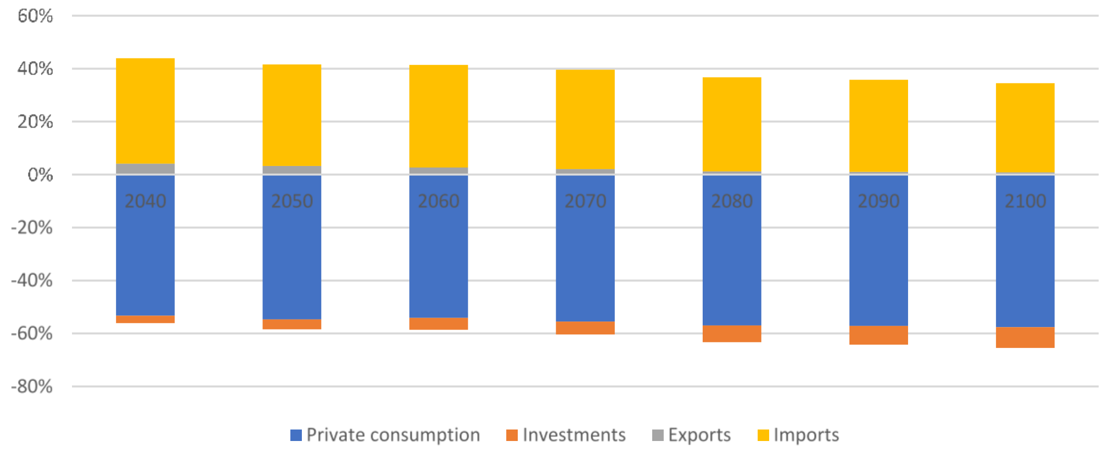
Figure 32: Changes from reference in selected macroeconomic variables (%) – RCP2.6



Source: GEM-E3-ISL

Figure 33: Contribution to GDP changes – RCP2.6



Source: GEM-E3-ISL

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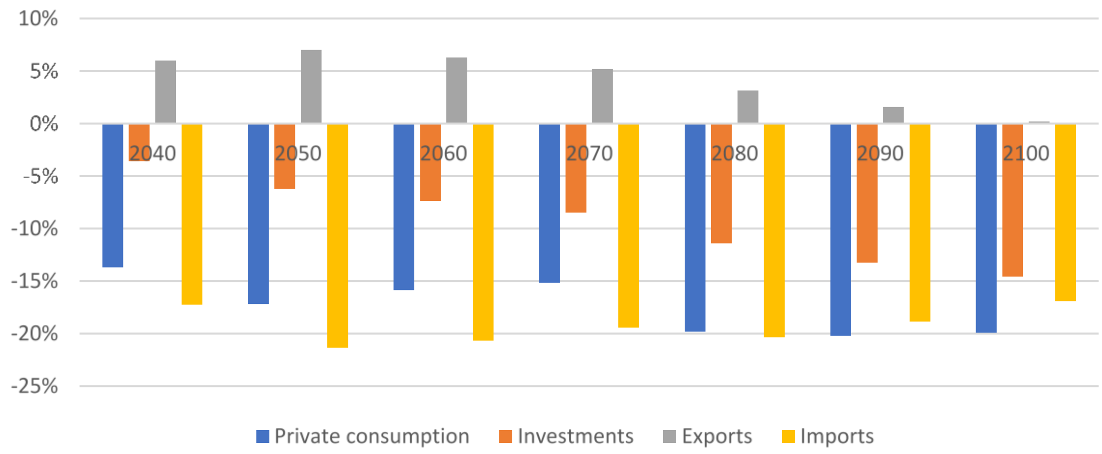
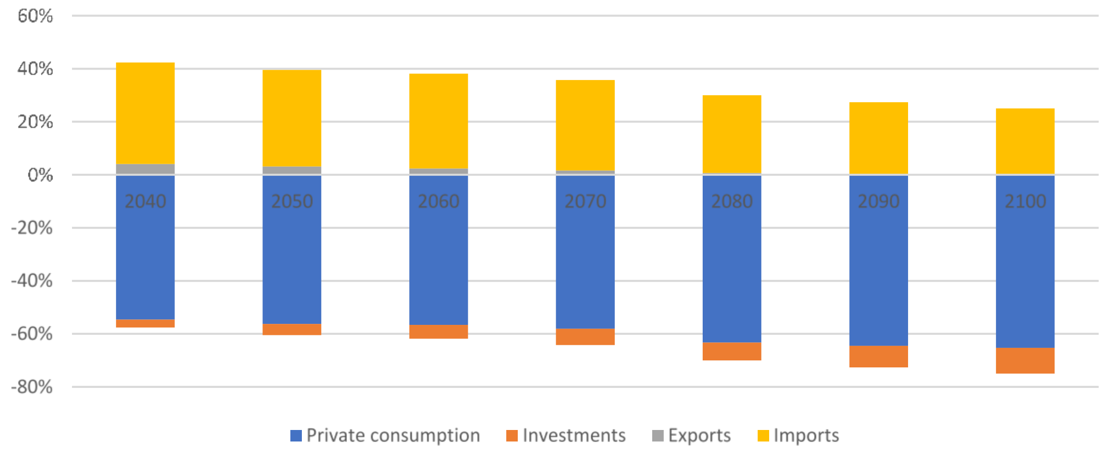
Figure 34: Changes from reference in selected macroeconomic variables (%) – RCP8.5



Source: GEM-E3-ISL

Figure 35: Contribution to GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

Decomposing private consumption and investment changes (in both climatic variants) we observe that changes associated to energy are driving the overall result (Figure 36-Figure 39). The foreseen increases in electricity consumption require a significant amount of investments to be dedicated in the expansion of power generation facilities as the island is not interconnected to an electricity network (hence imports are not an option for covering domestic demand). Assuming no external financing and considering that electricity is heavily subsidized; hence the increases in electricity consumption stress public finances and pose limits in the contribution of local authorities to the financing of these projects, the investments required have to be financed by households (in GEM-E3-ISL households are the owners of all primary production factors in the economy). But in the aggregate scenario, household's income is already lower due to the reduction of tourism revenues and the overall result in the aggregated scenario is a decrease both in the overall level of final consumption and of investments as a result of lack of financing resources.

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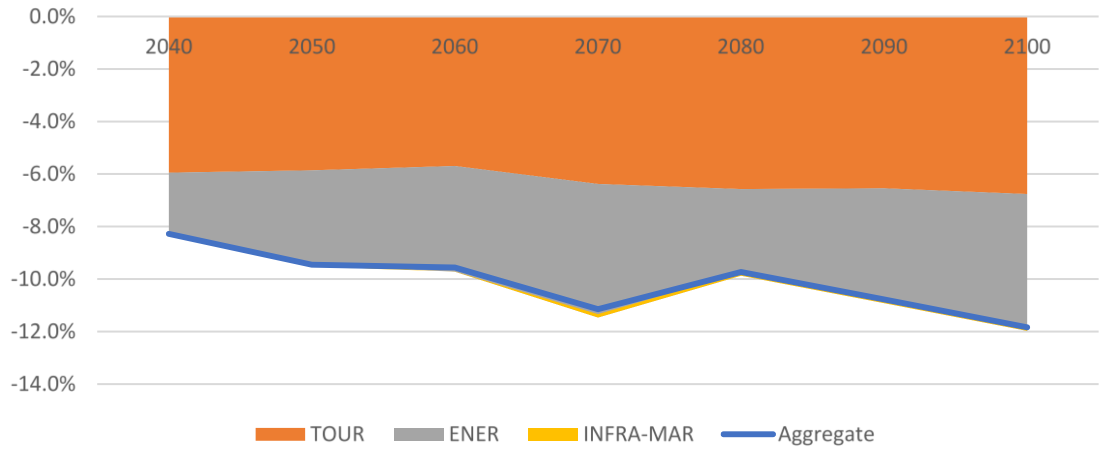
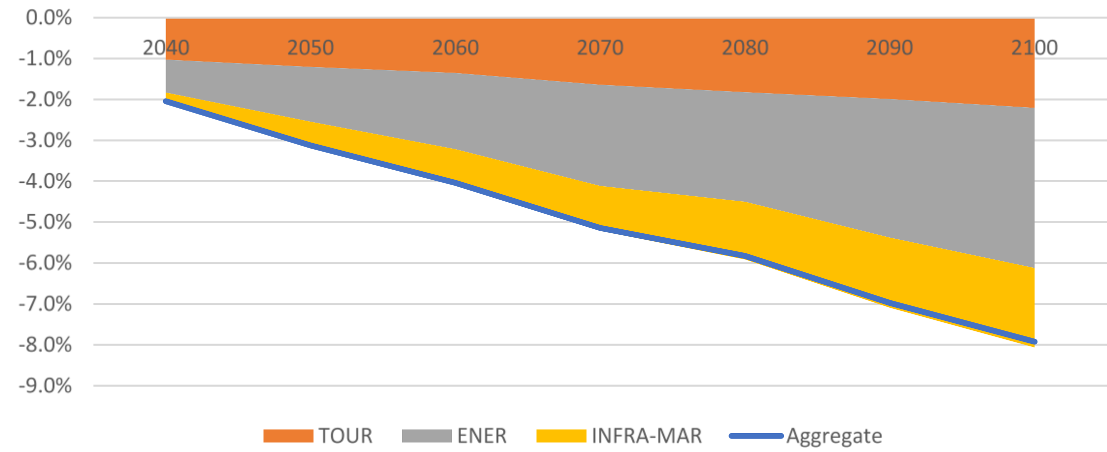
Figure 36: Changes in private consumption % from reference – RCP2.6



Source: GEM-E3-ISL

Figure 37: Changes in investments % from reference – RCP2.6



Source: GEM-E3-ISL

Figure 38: Changes in private consumption % from reference – RCP8.5

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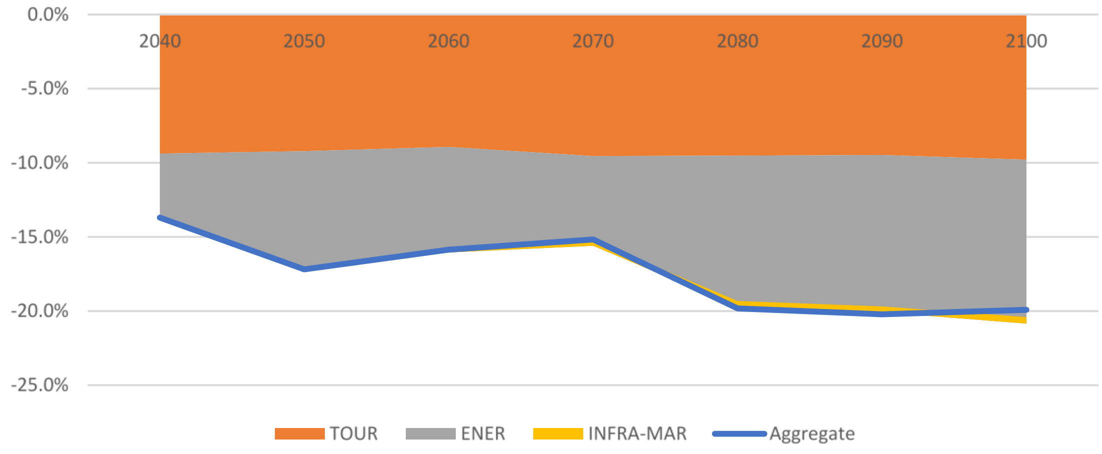
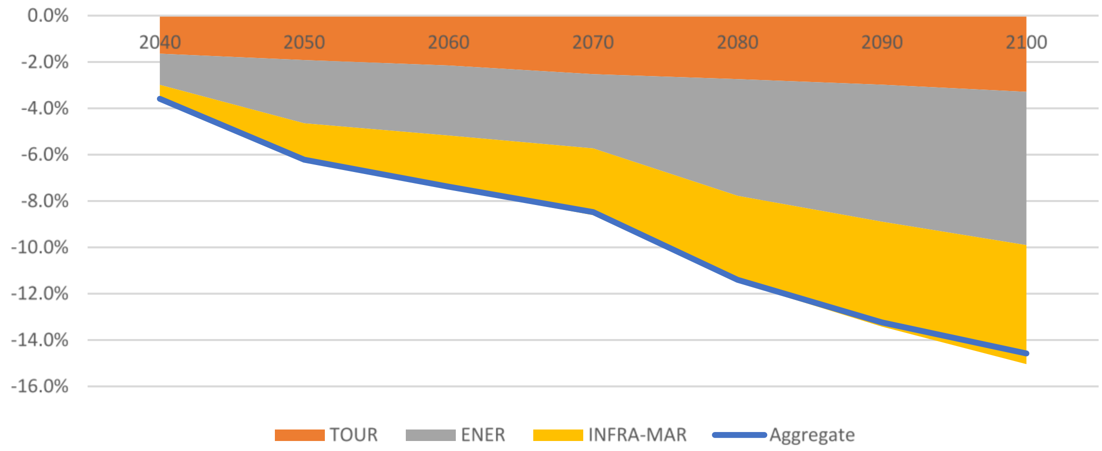


Source: GEM-E3-ISL

Figure 39: Changes in investments % from reference – RCP8.5



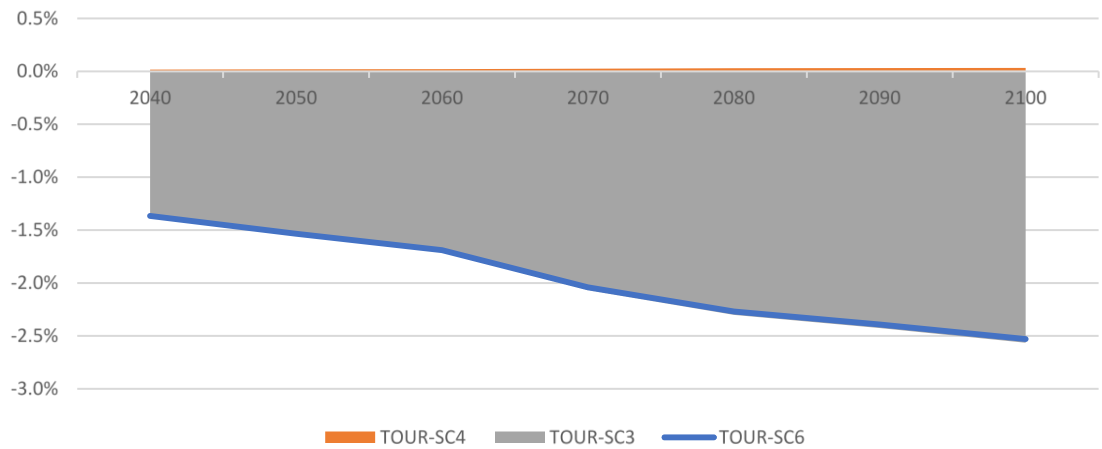
Source: GEM-E3-ISL

3.2.2.1.2 Macroeconomic impacts (tourism)

Tourism activities in Canary Islands is an important income source for the local economy as it contributes more than 20% of the regional value added (based on the reconciliation of Tourism Satellite Accounts and Input-Output table). For the Canary Islands, the inputs provided by D5.6 include only two impact chains: the loss in the available beach surface and changes in human comfort. In the RCP2.6 scenario the cumulative reduction in tourists' expenditure is estimated to be equal to 11.5% (compared to the reference scenario) and in the RCP8.5 scenario equal to 17.4% for the period 2040-2100. The cumulative impact of the simulated tourism-related changes on GDP is found to be equal to -2.1% in the RCP2.6 and -3.2% in the RCP8.5 which indicates with an elasticity of GDP to tourism of 0.18 a high sensitivity of the domestic economy to tourism variations.

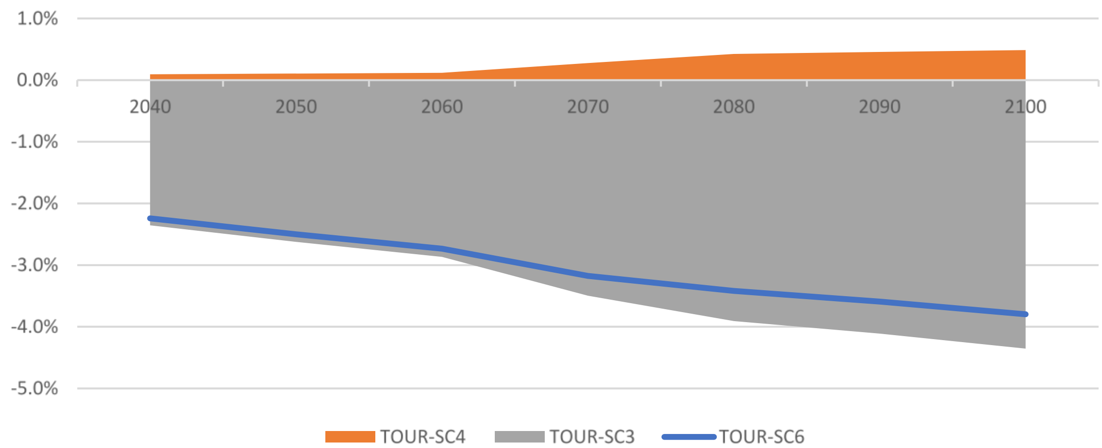
In both climatic variants a similar pattern of response of the main macro-economic variables to the implemented shock is identified: i) private consumption falls as the generated income from tourism related activities diminishes, ii) investments decrease relative to their reference levels as a result of lower activity of the tourism industries and lower final domestic demand and iii) trade balance ameliorates as imports fall (due to the overall decrease of domestic demand) and exports increase due to competitiveness gains steaming from the lower cost of primary production factors; the decreased demand for labor from tourism related industries exerts negative pressure on wages which in turns benefit all other sectors that employ labor intensively.

Figure 40: GDP change relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 41: GDP change relative to the reference (%) – RCP8.5

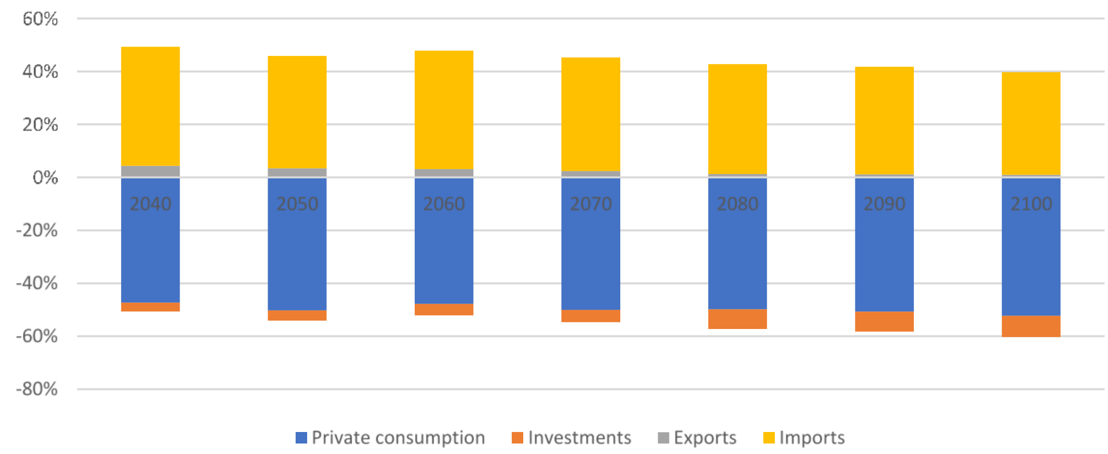


Source: GEM-E3-ISL

3.2.2.1.3 Macroeconomic impacts (energy)

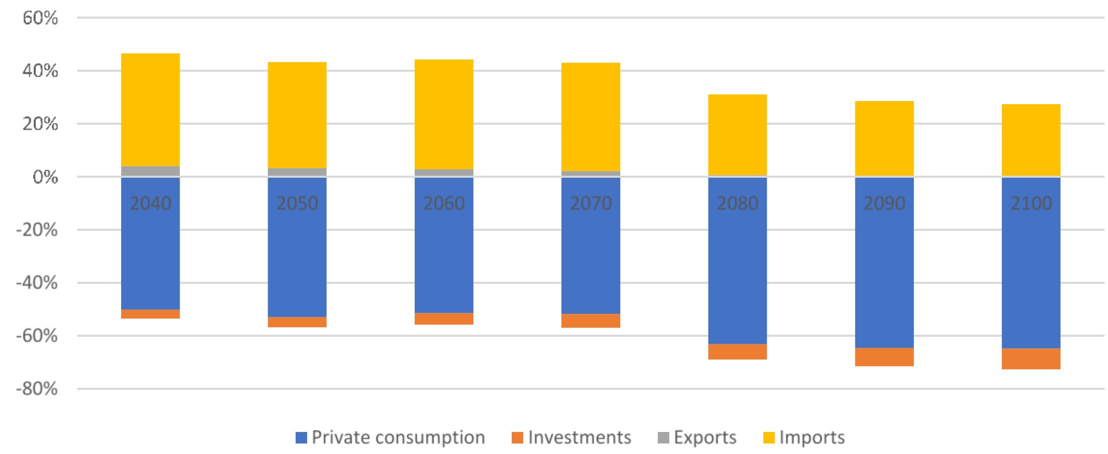
The increased demand for electricity is found to have strong negative impacts on the economy of Canary Islands compared to the reference case. Electricity consumption rises as temperature increases and precipitation rates fall implying higher utilization of cooling equipment both in production and in the residential sector, as well as increased supply of water from desalination facilities. In the Canary Islands, electricity demand is satisfied by domestic production as no interconnection in available and electricity prices are significantly subsidized. These two factors are responsible for the sensitivity of the domestic economy to permanent variations in electricity consumption. In the *near* period increased provision of water from desalination activities is exclusively responsible for the foreseen increases in electricity demand, while in the *distant* period for cooling and water desalination contribute to electricity increases with similar shares. In order to meet higher domestic demand, power generation capacity needs to expand; given the limited resources in the economy this implies a crowding out of other productive investments in the economy and will have a negative impact in the activity of other sectors. Moreover, high subsidies stress regional public finances and the additional financing requirements have to be met by increased households' savings. This has further negative repercussions for domestic activity levels as household's income shifts towards savings rather than consumption. Imports also fall as a consequence of decreased households' spending in both climatic variants examined.

Figure 42: Changes from reference in selected macroeconomic variables (%) – RCP2.6



Source: GEM-E3-ISL

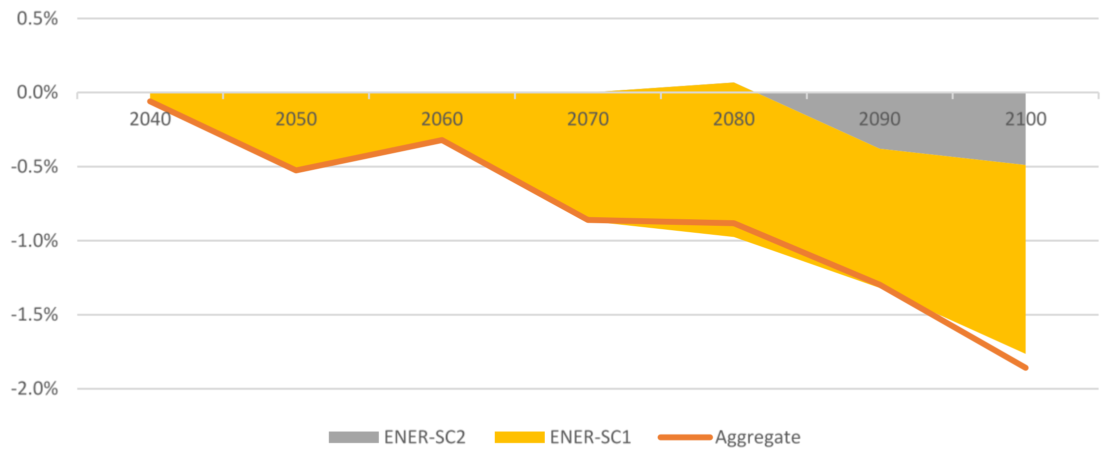
Figure 43: Changes from reference in selected macroeconomic variables (%) – RCP8.5



Source: GEM-E3-ISL

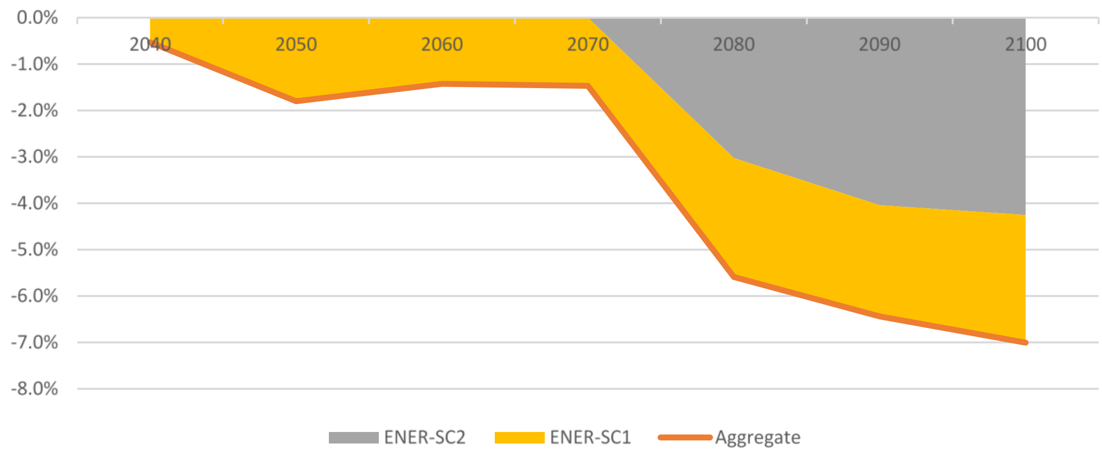
From the two energy-related scenarios examined, in the *long* period the effects are more pronounced in the cooling scenario as it foresees higher electricity consumption in both variants compares to the electricity consumption for desalination purposes. In the *near* period no additional cooling needs are foreseen and the effects are merely attributed to the increased electricity consumption of water desalination activities.

Figure 44: GDP changes relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 45: GDP changes relative to the reference (%) – RCP8.5



Source: GEM-E3-ISL

3.2.2.1.4 Macroeconomic impacts (maritime)

This scenario examined the effects of port infrastructure damages in the economy due to sea level rise. These damages are modelled as capital stock losses in the GEM-E3-ISL model. Lower capital stock stress the capital markets leading to increased capital rents affecting negatively sectorial activity as firms are now facing higher production costs and record competitiveness losses.

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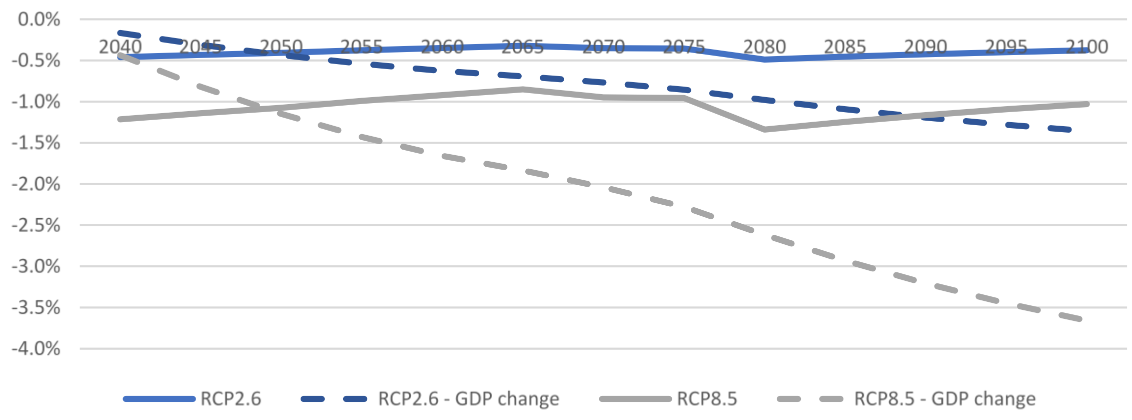
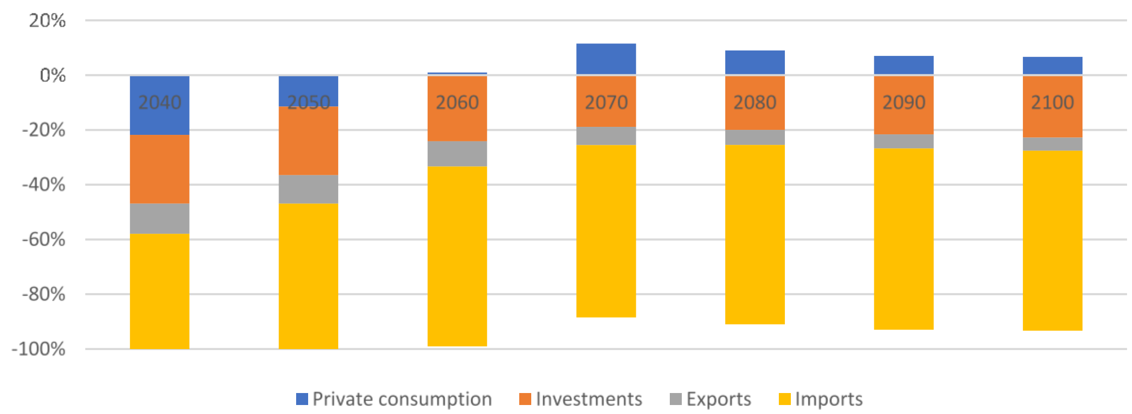
Figure 46: Capital losses (% of GDP)



Source: GEM-E3-ISL, D5.6

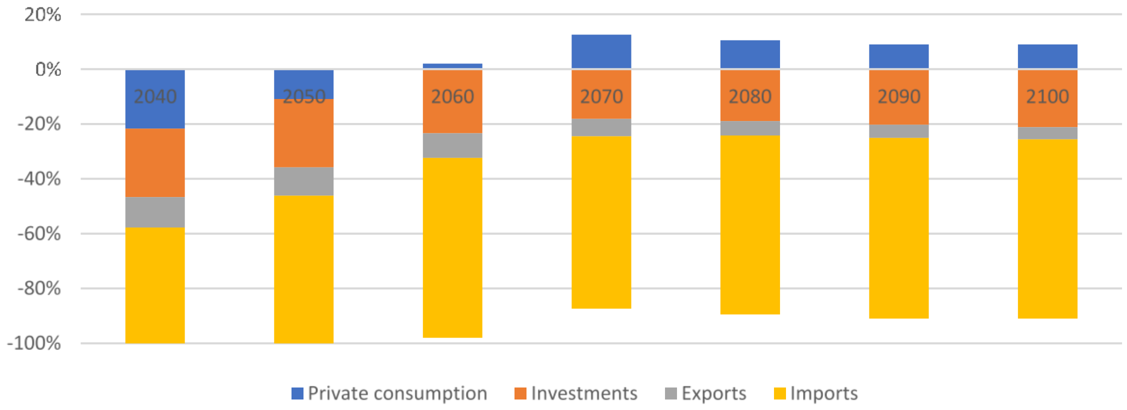
The scenario assessment shows that GDP contracts by 0.50% on average for the period 2040-2065 and by 1.20% for the period 2080-2100 in the RCP2.6; the respective figures for the RCP8.5 are 1.4% and 3.2%. Higher capital costs hinder the competitiveness of domestically produced who experience a decrease in their demand both from international markets (exports decrease over the period examined) and from domestic markets as they are substituted by cheaper imported goods. The impacts of infrastructure damages on the main macroeconomic variables are presented below:

Figure 47: Decomposition of GDP changes (%) – RCP2.6



Source: GEM-E3-ISL

Figure 48: Decomposition of GDP changes (%) – RCP8.5

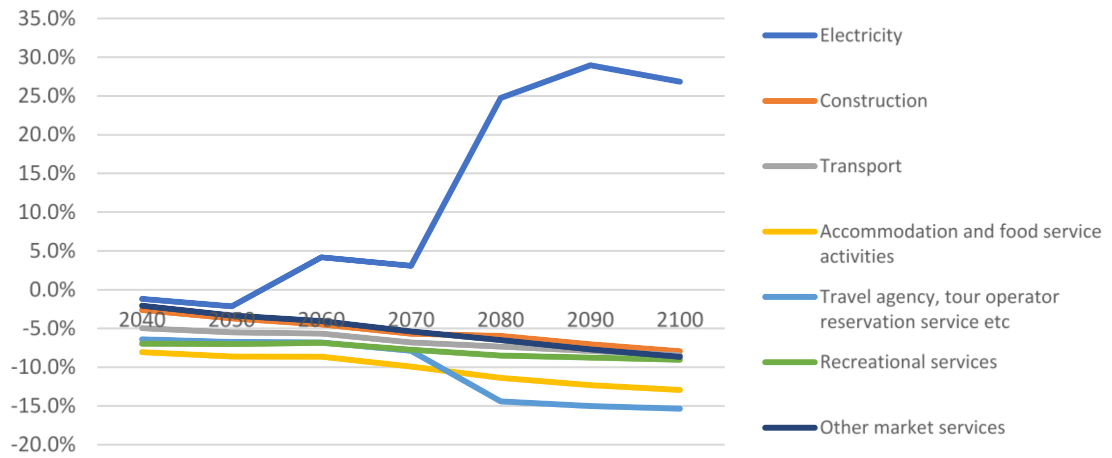


Source: GEM-E3-ISL

3.2.2.2 Sectorial results

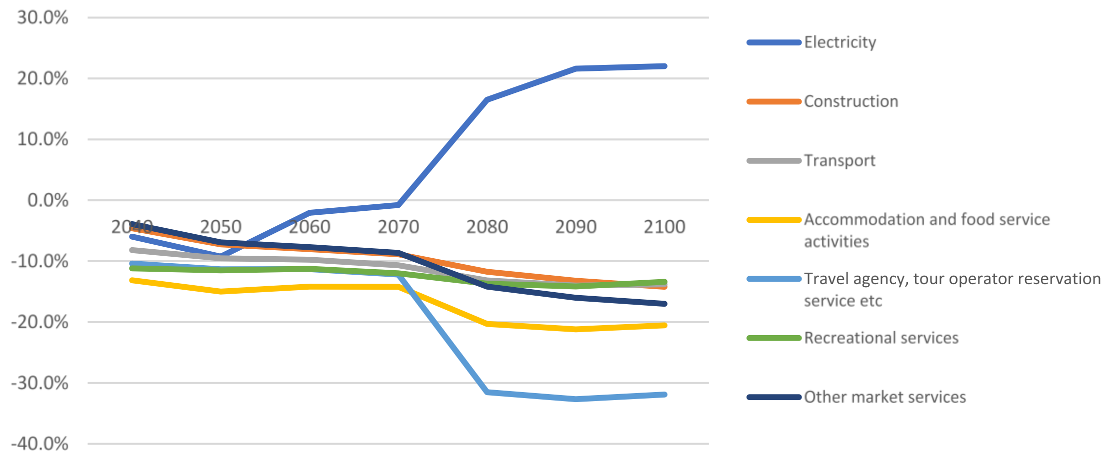
The effects on sectorial activity are more pronounced for those sectors whose activity depends almost exclusively on tourists. The activity of tourism related sectors decreases on average by 5.8% in the RCP2.6 and by 10% in the RCP8.5 while the activity of the tertiary sectors falls by 10% in the RCP2.6 and by 16.2% in the RCP8.5.

Figure 49: Sectorial activity (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 50: Sectorial activity (% from the reference) – RCP8.5

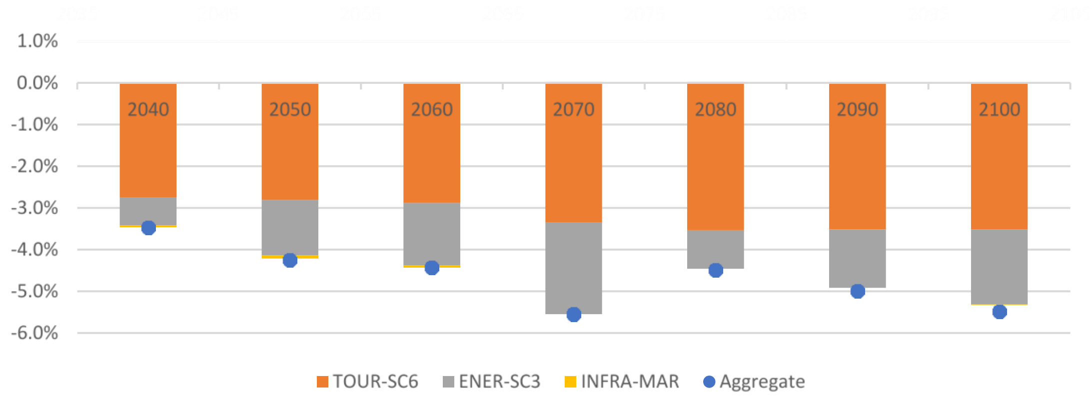


Source: GEM-E3-ISL

3.2.2.3 Labor market

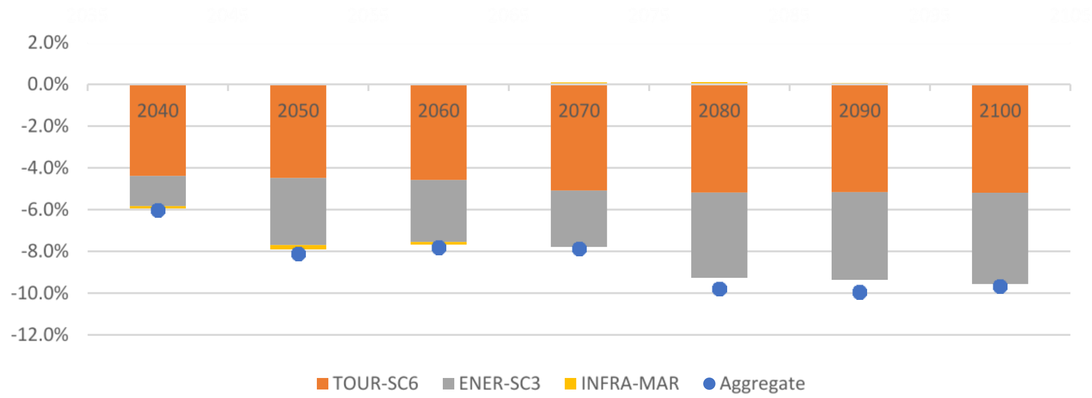
With respect to the labor market developments, the simulation results show decreased employment levels for both climatic and for both the *near* and the *long* period examined. In the *near* period employment decreases are equally distributed between the TOUR and the ENER scenarios in the RCP8.5 while in the RCP2.6 the reduction in employment levels are mainly attributed to the TOUR scenario.

Figure 51: Employment (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 52: Employment (% from the reference) – RCP8.5



Source: GEM-E3-ISL

3.2.3 GWS RESULTS

3.2.3.1 Macroeconomic

The Canary Islands' economy is coined by a large trade deficit in the present and the economic projections (D6.2) foresee this to continue, at least in the 30 years modeled with the GIN-FORS_E modeling framework. The loss of maritime infrastructure is assumed to be 1% of GDP, leading to high increases in transport prices and thus on all imported goods in both scenarios. Investment in the energy sector is marginal until 2050. The main losses can be attributed to the decrease in tourism and additional transport costs. Losses increase with temperature. The Canary Islands experience the largest damages at their Maritime Infrastructure, in absolute terms as well as in relative terms, across all Islands (D5.6), which in the GIN-FORS_E model leads to high additional costs for transport and feeds back to all imported goods. Note that the Canary Islands import 66% of all manufacturing goods and 59% of all consumption goods. The decrease in investment and private consumption is dominated by the Maritime Transport loss-induced price changes.

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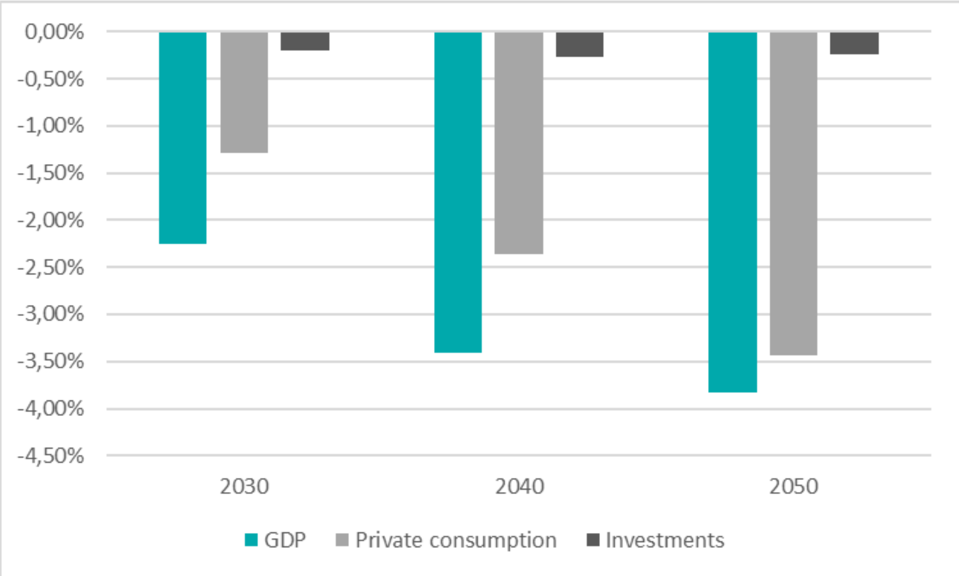
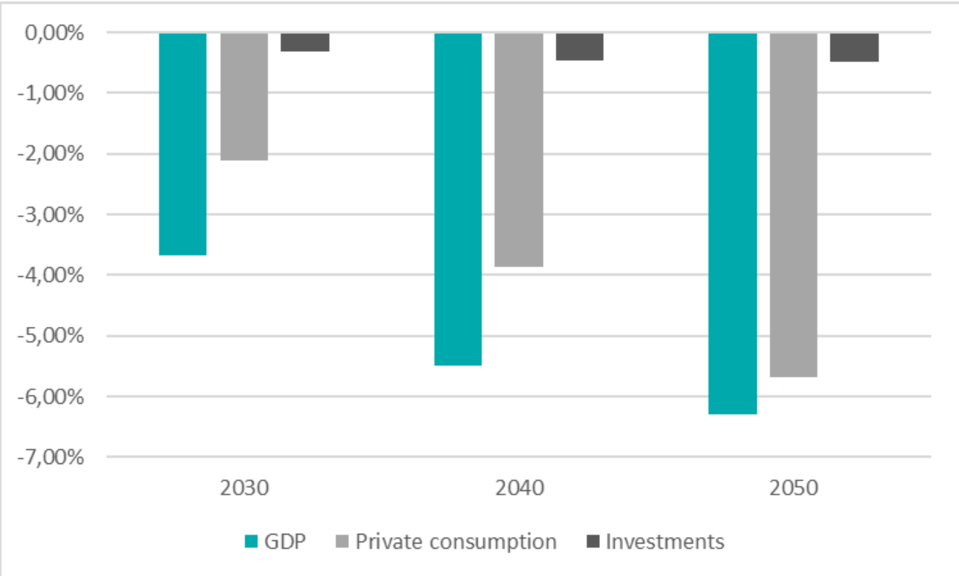
Note that the Canary Islands enjoy tax breaks, special taxes, and special prices. E.g. for electricity, prices must be at the same level as in mainland Spain, though electricity production is much more costly. This leads to value losses as shown in Figure 54.

Figure 53: Canary Islands: Components of GDP, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5



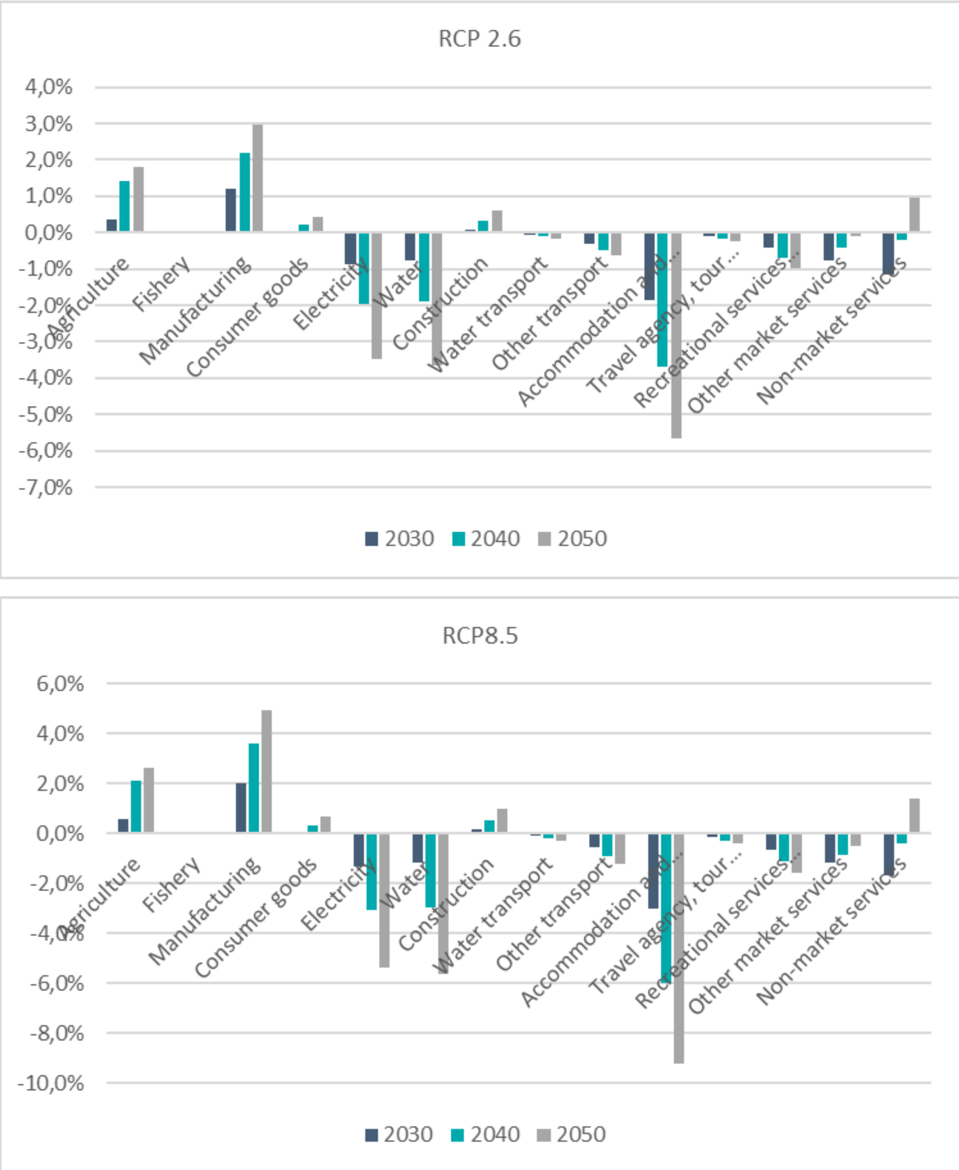


Source: GWS, own calculation.

3.2.3.2 Sectorial results

Figure 54 shows value added by sector as percentage difference between the respective climate scenario and the reference scenario. Value added decreases mainly in the tourism related sectors. Energy and water are two not negligible sectors on the Canary Islands. The energy sector has invested over time in the past and water is already desalinated to a large extent. This is the reason for the lack of additional investment compared to the other Islands. Additional domestic manufacturing is compensating partly for imported goods, but the percentage changes are referring to a rather low level of production.

Figure 54: Canary Islands: Value added by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5

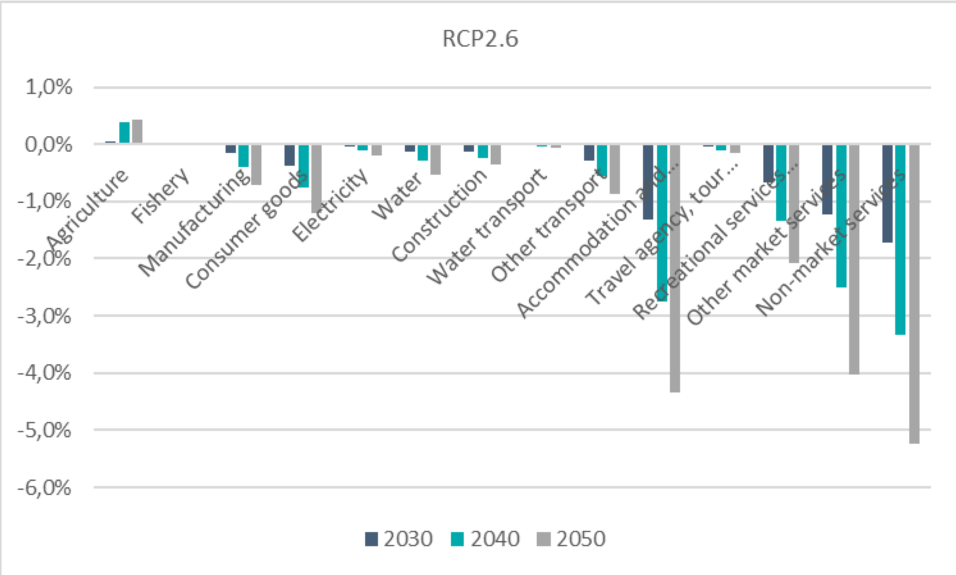


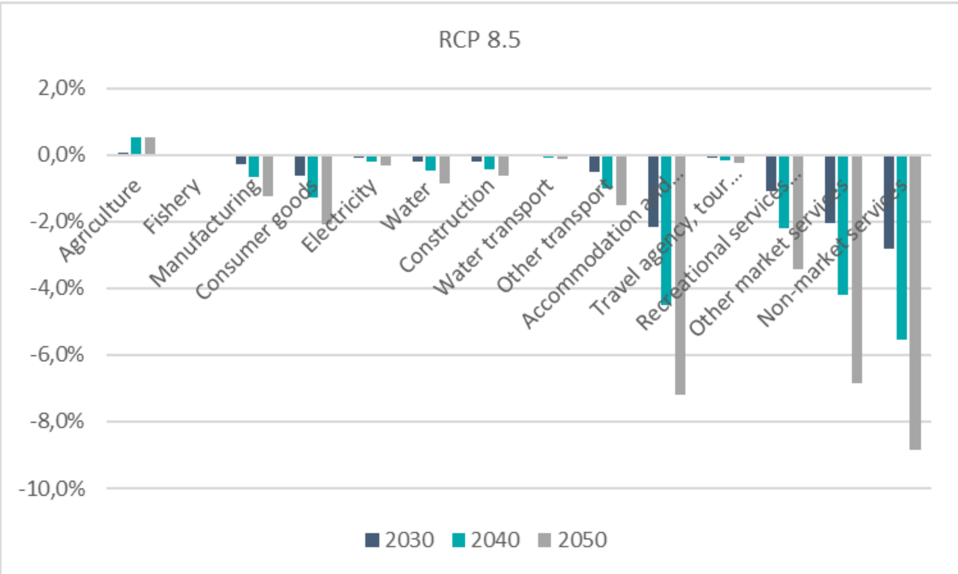
Source: GWS, own calculation.

3.2.3.3 Labor market

The Canary Islands have an unemployment rate of 15% which is projected to decrease significantly in the reference scenario. Thus, decreases in employment as compared to the reference scenario still mean increasing employment, at least in some sectors. The tourism related sectors, however, will exhibit the deepest job losses, of more than 7% only in accommodation in the RCP 8.5 scenario. Note that due to the high interdependences with all other sectors, services also exhibit large losses. Due to lower wages compared to the reference, employment effects are again smaller than changes in value added.

Figure 55: Canary Islands: Employment by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation

3.3 CYPRUS

3.3.1 SCENARIO DEFINITION

For Cyprus three sets of scenarios are simulated. The first set of scenarios examines the impact of climate change on tourism by assuming different expenditures by tourists due to bio-physical climate impacts on the natural environment and temperatures. In particular, the changes in touristic demand are directly linked to the perception of tourists regarding certain features such as beach surface, the marine environment, the risk of forest fires and warmer conditions and depend on how these features are impacted by climate change. The second set of scenarios refers to changes in electricity consumption due to increased cooling demand and water availability. Finally, the third set of scenarios refers to infrastructure damages, specifically to port infrastructure, due to sea level rise.

The impact of climate changes on tourists' spending, electricity demand and capital losses are estimated in D5.6 and are used as inputs for the scenario simulations as described in the Methodology Section. The GEM-E3-ISL model assesses their impacts on the main macroeconomic variables (GDP, private consumption, investments, exports and imports), sectorial activity and employment. The inputs provided by D5.6 and incorporated in GEM-E3-ISL for the Cyprus are described in the following tables:

The reduction of available beach surface is highlighted as the most important factor for tourists' decisions in the RCP2.6, while in the RCP8.5 its combined effect with the increased risk of forest fire leads to a reduction of tourists' expenditures of approximately 50% (*Table 20)*.

Table 8: Changes in tourists' expenditures with respect to the reference case (%)

	TOUR -SC1 (marine environment)	TOUR -SC2 (forest fire)	TOUR -SC3 (beach reduction)	TOUR -SC4 (thermal comfort)	TOUR -SC5 (V-disease)	TOUR –SC6 (aggregate)
RCP2.6 near	0	0	-10.88	-2,81	0	-10.88
RCP2.6 distant	0	0	-14.83	-2,80	0	-14.83
RCP8.5 near	0	-22.54	-18.79	-2,80	0	-41.33
RCP8.5 distant	0	-22.54	-26.70	-2,82	0	-49.24

The second set of scenarios examined refers to the effects of warmer and dryer weather conditions on electricity consumption. The scenario specification foresees increases in the consumption of electricity in order to maintain the same level of thermal comfort (e.g. higher use of air-conditions and other cooling options) as well as to maintain water availability through the increase of water supply from desalination facilities. Additional electricity needs are mainly attributed to cooling and to a lesser extent to water desalination, in both climatic variants. *Table 21* describes the estimated electricity consumption increases as deviations from their reference levels:

Table 9: Changes in electricity consumption with respect to the reference case (%)

	ENER -SC1 (desalination)	ENER -SC2 (cooling)	ENER –SC3 (aggregate)
RCP2.6 near	2.3	17.0	19.3
RCP2.6 distant	2.3	14.3	16.6

RCP8.5 near	5.4	31.6	37.0
RCP8.5 distant	11.3	57.3	68.6

Table 10: Changes in electricity consumption with respect to the reference case (%)

	INFRA-MAR
RCP2.6 near	-0.0002
RCP2.6 distant	-0.0002
RCP8.5 near	-0.0006
RCP8.5 distant	-0.0007

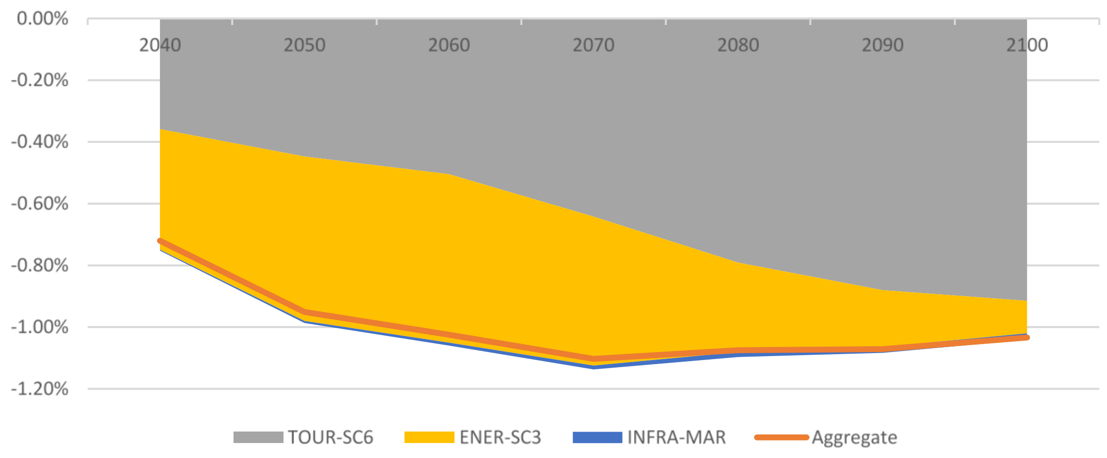
3.3.2 GEM-E3-ISL RESULTS

3.3.2.1 Macroeconomic

3.3.2.1.1 Macroeconomic impacts (aggregate)

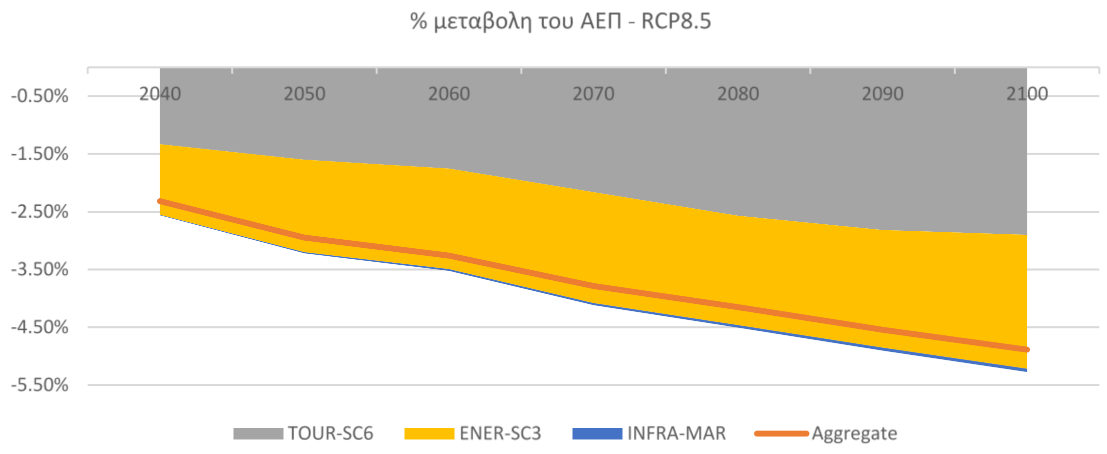
The estimated impacts of the combined changes on Cyprus's GDP are calculated cumulatively to -1% for the RCP2.6 (Figure 56) and -4% for the RCP8.5 (Figure 57) over the period 2040-2100. The two specifications, tourism and electricity, are found to have similar effects in the economy in the *near* period in the RCP2.6, while the impacts of tourists' expenditures being relatively higher throughout the simulation period in the RCP8.5. With respect to the time frame, GDP impacts are relatively equal distributed both in the RCP2.6 scenario (-0.96% in the *near* period compared to -1.7% in the *distant* period) while in the RCP8.5 the effects are more pronounced in the long run (-3.4% vs -4.8%).

Figure 56: GDP changes from reference (%) – RCP2.6



Source: GEM-E3-ISL

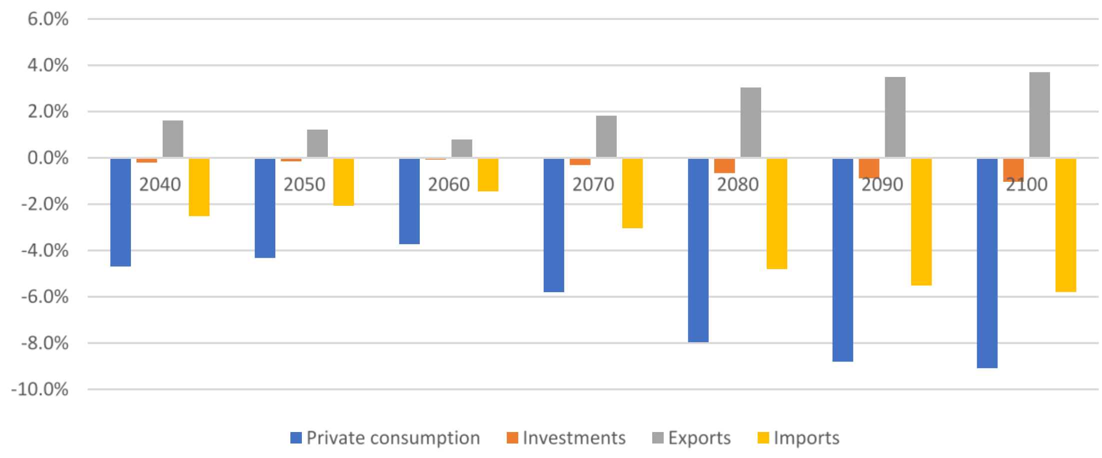
Figure 57: GDP changes from reference (%) – RCP8.5



Source: GEM-E3-ISL

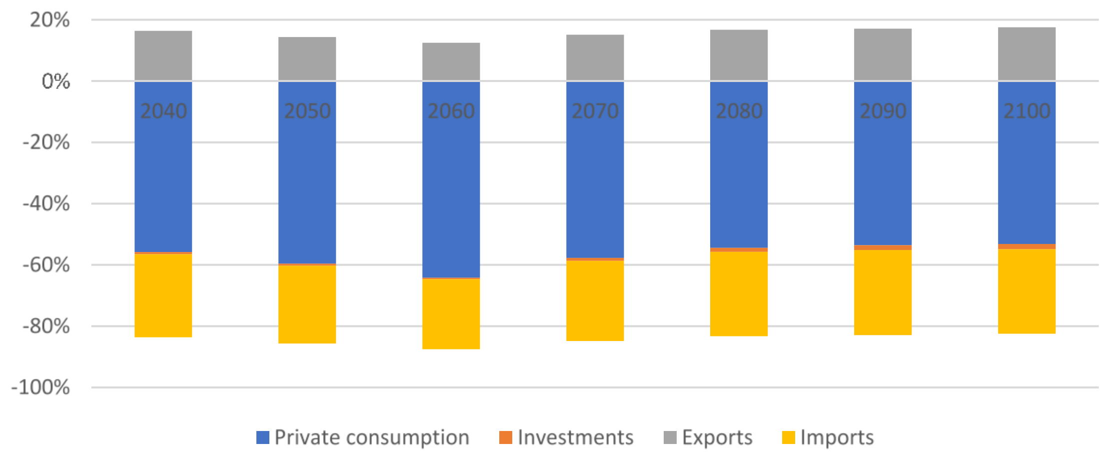
Private consumption expenditures fall in both aggregate scenarios examined as a result of decreased income, while the trade balance improves as exports increase and imports fall. Tourism related industries are rather labor intensive and the decrease of their activity exerts negative pressure in the labor market, leading to lower wages and higher unemployment. Hence households wage income falls and lower resources lead to lower consumption. When analyzing the impact on trade of simulated changes we identify two counteracting forces. On the one hand, increased electricity needs tend to increase production costs as electricity prices are driven upwards. On the other hand, firms benefit from the new labor market conditions as their labor costs diminishes. The overall effect depends on the production structure of firms and the magnitude of wage and electricity price changes. The economy of Cyprus is service oriented; hence the labor market effect dominates the electricity effect and production prices fall. This in turn, leads to a substitution of imported with domestically produced products and a higher demand for domestic products for abroad. The increased competitiveness in combination with the higher demand for electricity leads to small deviations in the overall level of investments.

Figure 58: Changes from reference in selected macroeconomic variables (%) – RCP2.6



Source: GEM-E3-ISL

Figure 59: Contribution to GDP changes – RCP2.6



Source: GEM-E3-ISL

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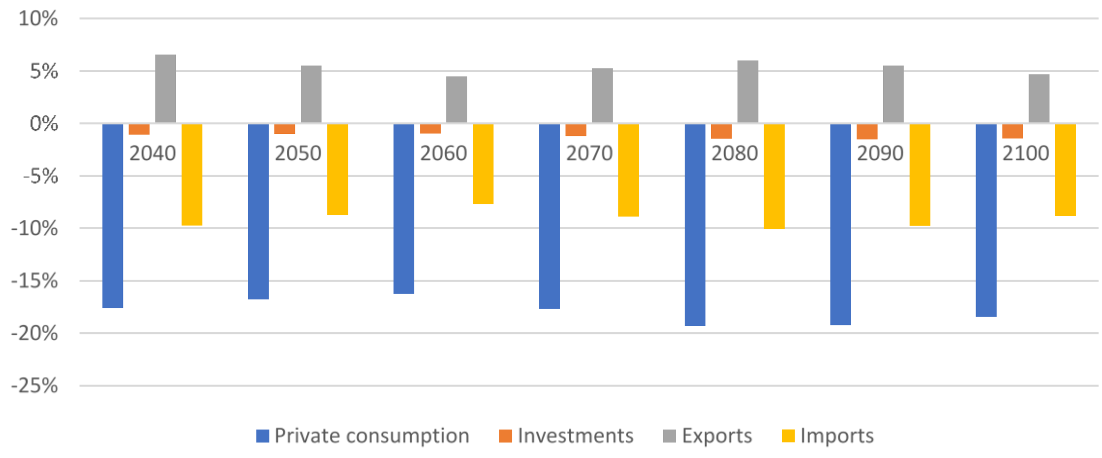
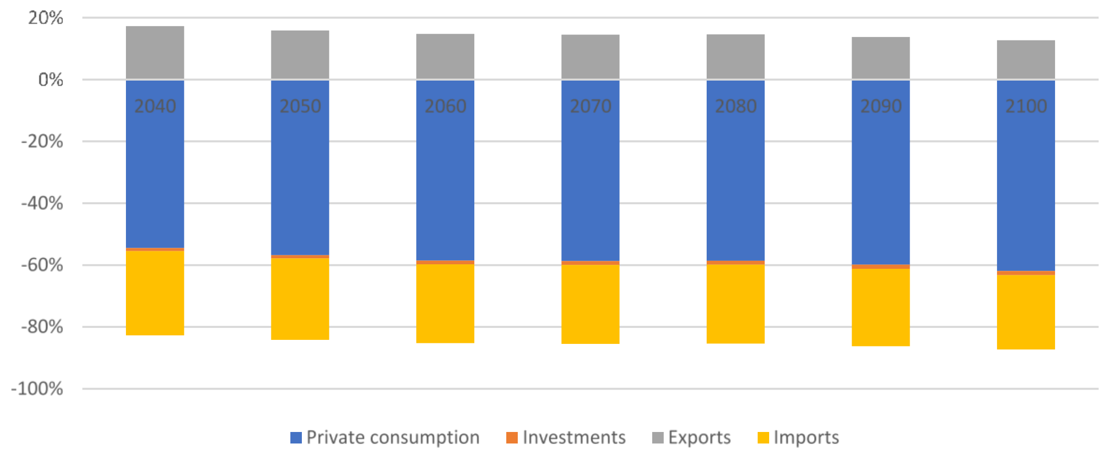
Figure 60: Changes from reference in selected macroeconomic variables (%) – RCP8.5



Source: GEM-E3-ISL

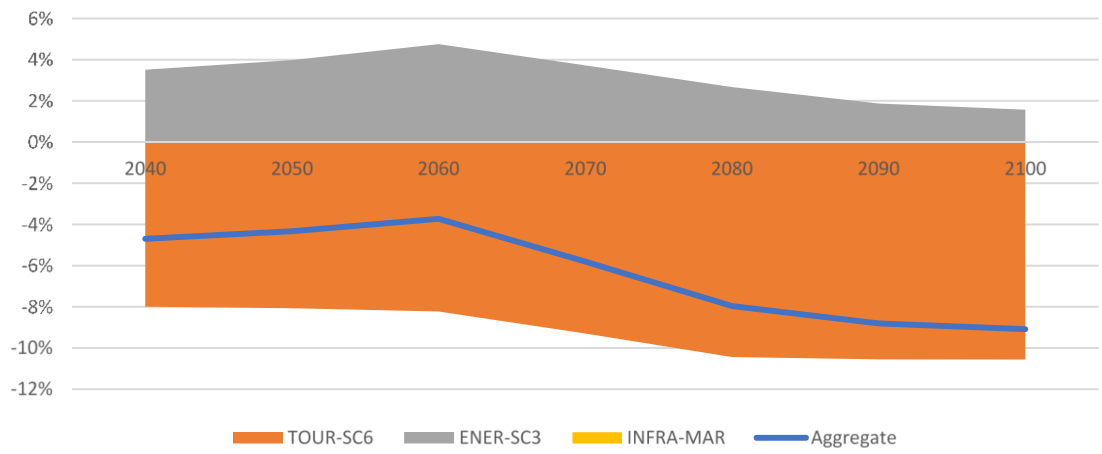
Figure 61: Contribution to GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

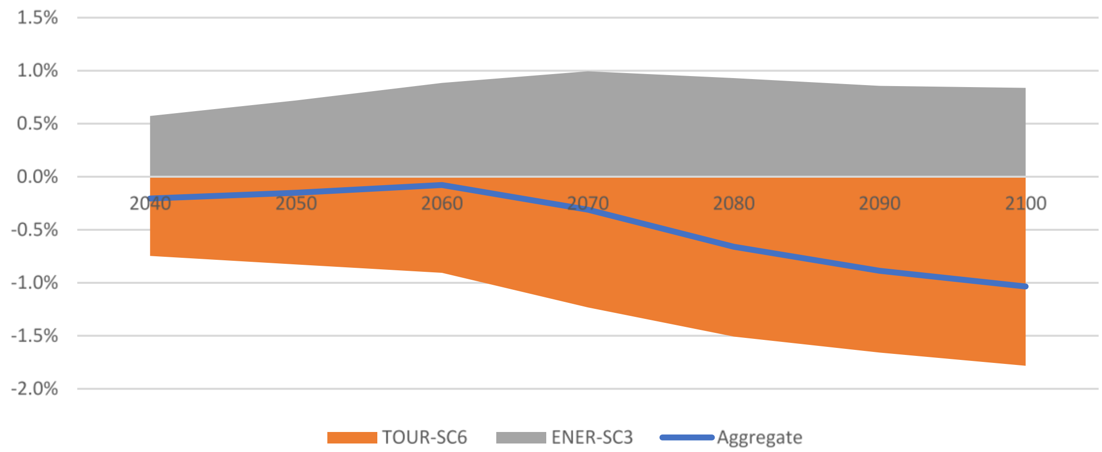
Decomposing private consumption and investment changes (in both climatic variants) we observe that changes associated to tourism are driving the overall result (Figure 62-Figure 65). In terms of private consumption, we find a positive effect in the ENER scenario for both climatic variants. Higher capital requirements of investments in power generation and the increase in construction activities lead to higher household income offsetting increases in production costs due to higher electricity inputs. Regarding the tourism component of the aggregate scenario, we find that the cut in tourists' spending affects negatively both private consumption (as the income generation of tourism related sectors fall) and a decrease in investments steaming from the overall fall of domestic activity levels.

Figure 62: Changes in private consumption % from reference – RCP2.6



Source: GEM-E3-ISL

Figure 63: Changes in investments % from reference – RCP2.6



Source: GEM-E3-ISL

Figure 64: Changes in private consumption % from reference – RCP8.5

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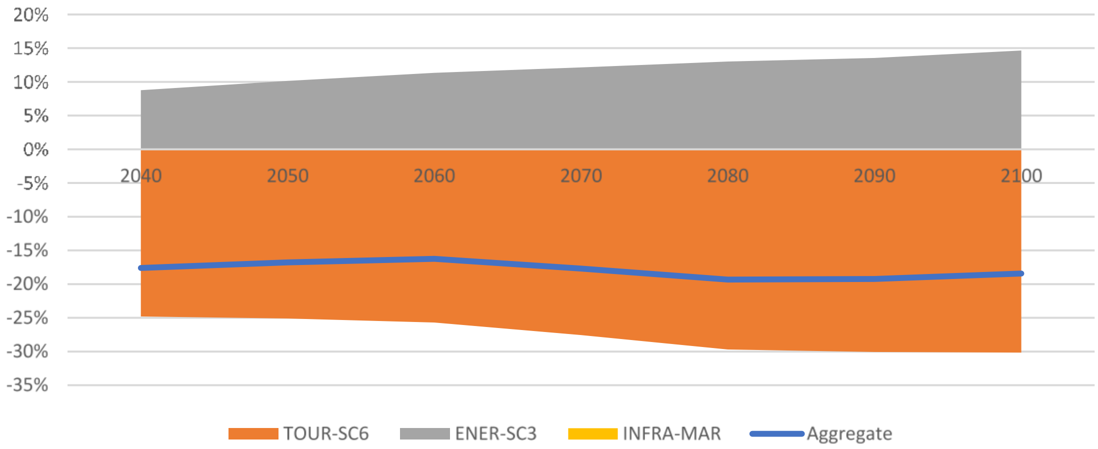
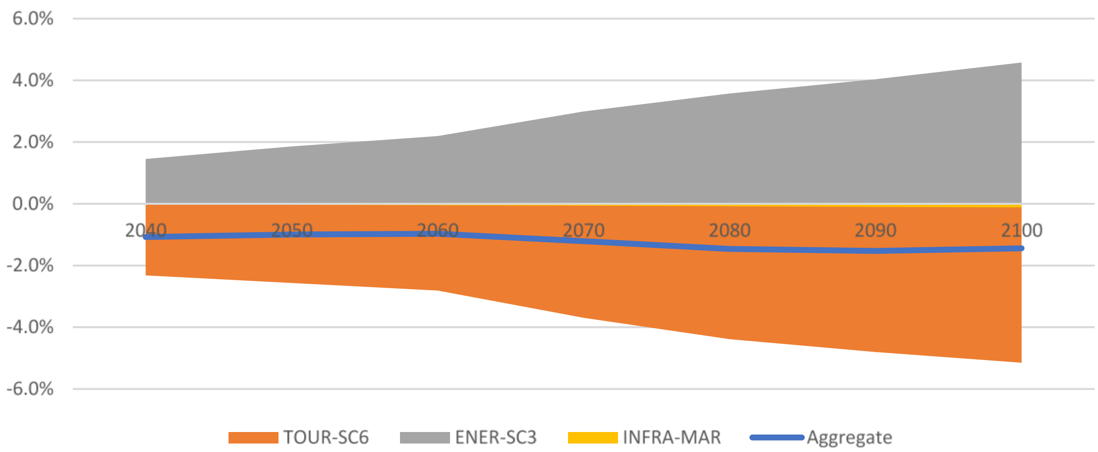


Source: GEM-E3-ISL

Figure 65: Changes in investments % from reference – RCP8.5



Source: GEM-E3-ISL

3.3.2.1.2 Macroeconomic impacts (tourism)

Tourism activities in Cyprus are projected to increase considerably compared to their base year levels[19] and to reach approximately 15% of the national gross value added in the period 2040-2100. In the RCP2.6 scenario the cumulative reduction in tourists' expenditure is estimated to be equal to 16% (compared to the reference scenario) and in the RCP8.5 scenario equal to 48.6% for the period 2040-2100. The cumulative impact of the simulated changes is found to be equal to -0.70% in the RCP2.6 and -2.32% in the RCP8.5 which implies that the

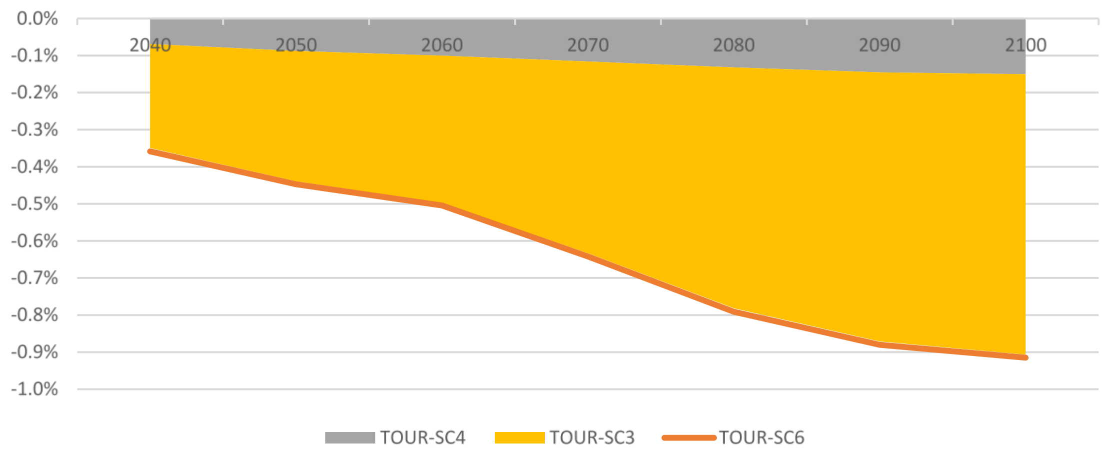
19 http://www.mcit.gov.cy/mcit/mcit.nsf/CDF3979F7DFBA8BCC22581BC002FCEAB/$file/1%20%CE%9C%CE%B5%CE%BB%CE%AD%CF%84%CE%B7%20THR.pdf

elasticity of GDP to tourism is between 0.04 and 0.05 and is compatible with the literature[20].

In the RCP2.6, beach reduction (TOUR-SC3) is identified as having the greatest impact on the economy, while on the RCP8.5 both the scenario examining the impact of increased risk of forest fires (TOUR-SC2) and that examining the impact of beach losses (TOUR-SC3) are responsible for the greatest part of the assessed impacts (Figure 66,Figure 67). All scenarios exhibit similar pattern with respect to the response of the main macro-economic variables to the implemented shock: i) private consumption decreases primarily due to the reduced revenues of tourism related activities which lead to lower labor income, ii) investments decrease relative to their reference levels as a result of lower activity of the tourism industries and iii) trade deficits reduce as imports fall (due to the overall decrease of domestic demand) and exports increase; the decreased demand for labor from tourism related industries exerts negative pressure on wages which in turns benefit all other sectors that employ labor intensively. As services hold the greatest part of gross value added, the developments in the labor markets are expected to raise opportunities for the tertiary sector which eases the negative effect of lower tourism spending.

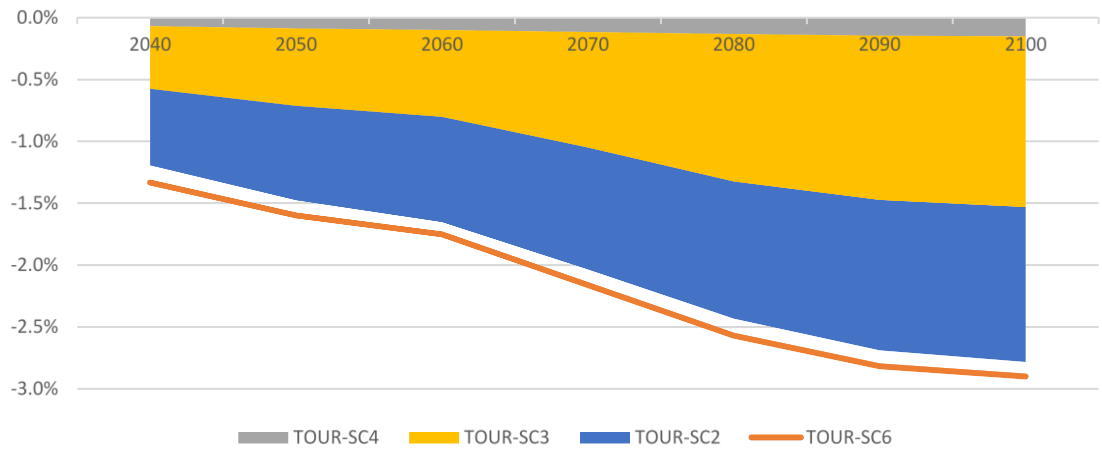
[20] Castro-Nuño, M. & Molina, José & Pablo Romero, Maria. (2013). Tourism and GDP A Meta-analysis of Panel Data Studies. Journal of Travel Research. 52. 745-758. 10.1177/0047287513478500

Figure 66: GDP change relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 67: GDP change relative to the reference (%) – RCP8.5

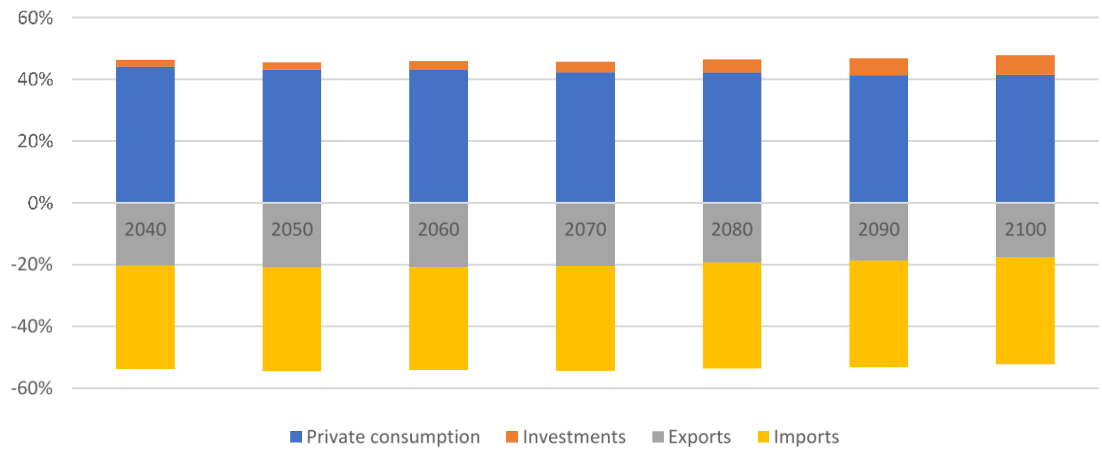


Source: GEM-E3-ISL

3.3.2.1.3 Macroeconomic impacts (energy)

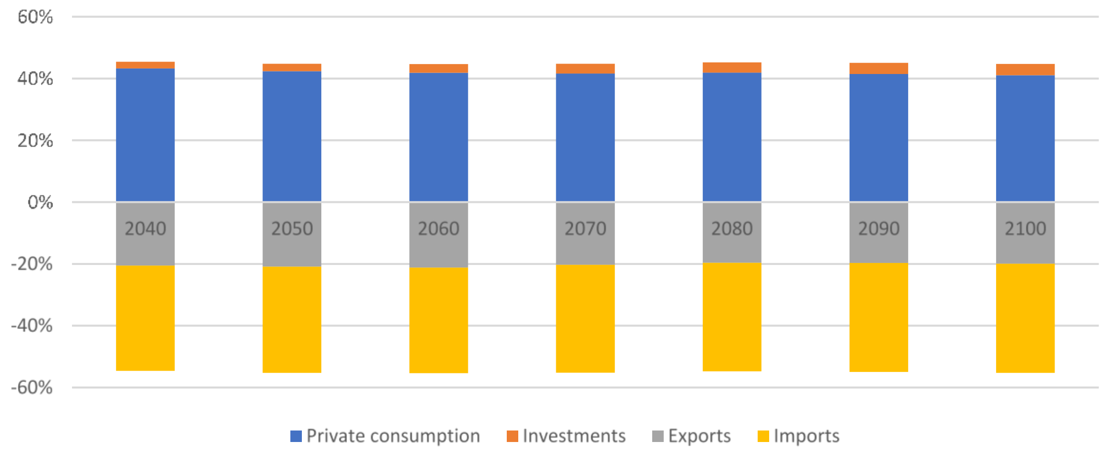
The increased demand for electricity is found to have negative impacts on the economy of Cyprus compared to the reference case. Temperature increases and reduction in precipitation rates imply higher utilization of cooling equipment both in production and in the residential sector, as well as increased supply of water from desalination facilities. Electricity prices are expected to increase in response to the increased demand. This implies competitiveness losses for domestic firms and their exports are expected to fall. Investments will rise as the expansion of installed capacity is required to meet the increased electricity requirements of both households and firms. Increased investments have beneficiary effect for the economy (e.g. in terms of employment) as the sectors actively engaged in the realization of investments projects (e.g. construction) have relatively low import dependence. Imports increase both due to electricity requirements and due to competitiveness losses of sectors as their production costs increase.

Figure 68: Decomposition of GDP changes (%) – RCP2.6



Source: GEM-E3-ISL

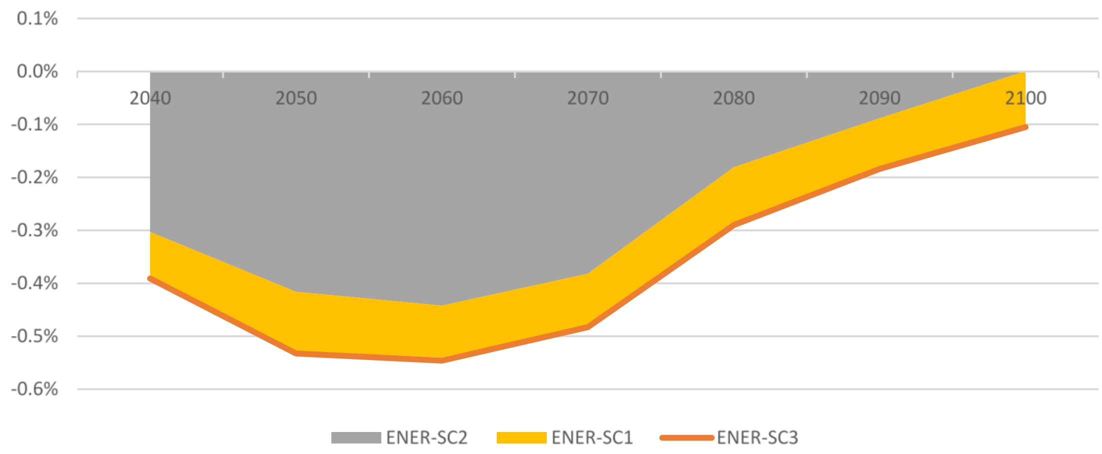
Figure 69: Decomposition of GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

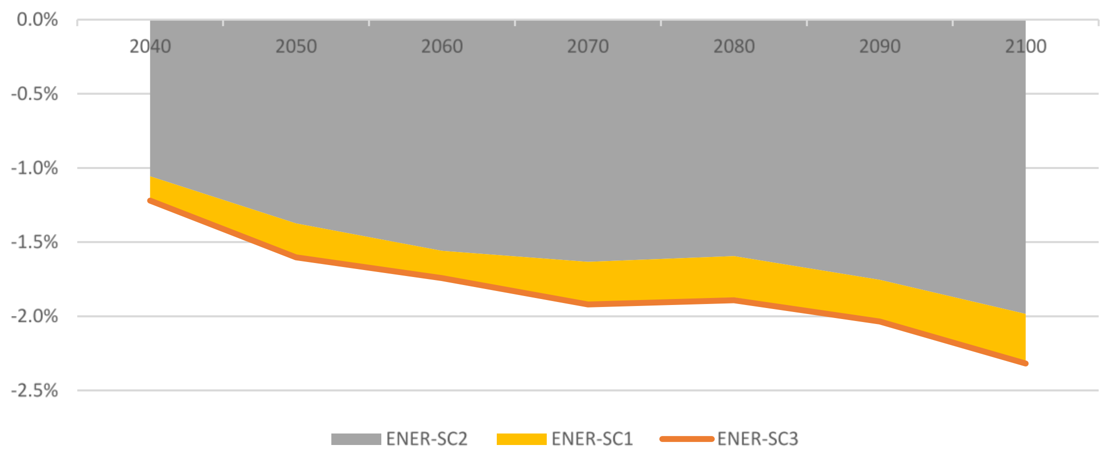
From the two energy-related scenarios examined the effects are more pronounced in the cooling scenario as it foresees higher electricity consumption in both variants compares to the electricity consumption for desalination purposes.

Figure 70: GDP changes relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 71: GDP changes relative to the reference (%) – RCP8.5

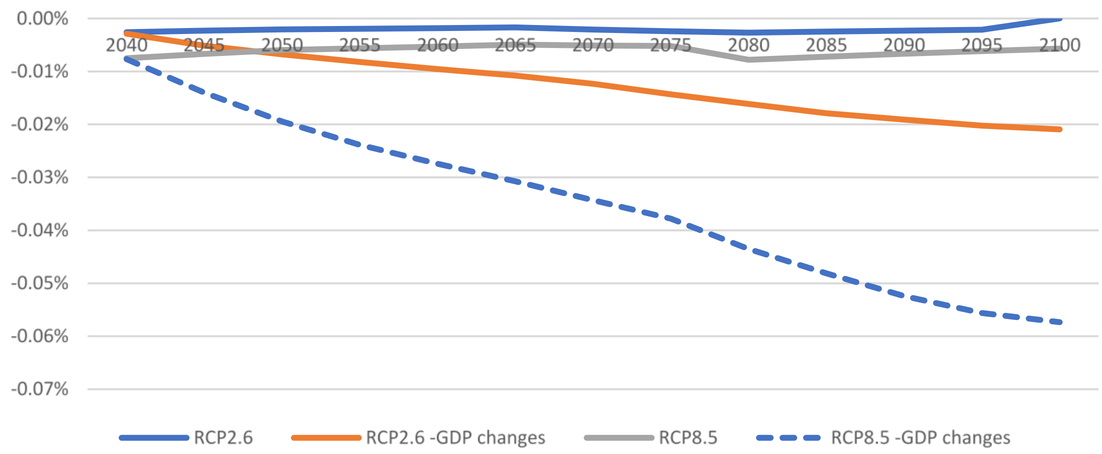


Source: GEM-E3-ISL

3.3.2.1.4 Macroeconomic impacts (maritime)

This scenario examined the effects of port infrastructure damages in the economy due to sea level rise. These damages are modelled as capital stock losses in the GEM-E3-ISL model. Lower capital stock stress the capital markets leading to increased capital rents affecting negatively sectorial activity as firms are now facing higher production costs and record competitiveness losses.

Figure 72: Capital losses (% of GDP)



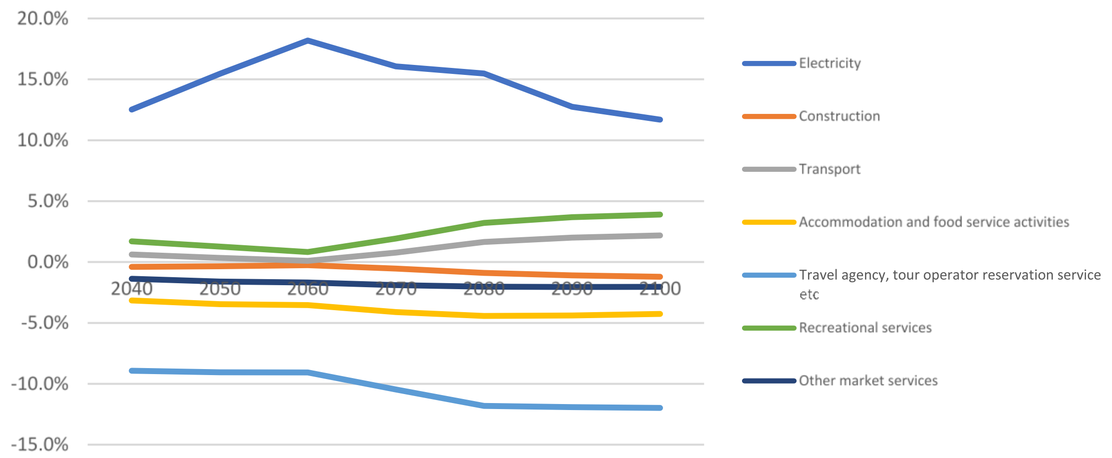
Source: GEM-E3-ISL, D5.6

The scenario assessment shows that GDP contracts by 0.01% on average for the period 2040-2065 and by 0.02% for the period 2080-2100 in the RCP2.6; the respective figures for the RCP8.5 are 0.04% and 0.05%. Higher capital costs hinder the competitiveness of domestically produced who experience a decrease in their demand both from international markets (exports decrease over the period examined) and from domestic markets as they are substituted by cheaper imported goods.

3.3.2.2 Sectorial results

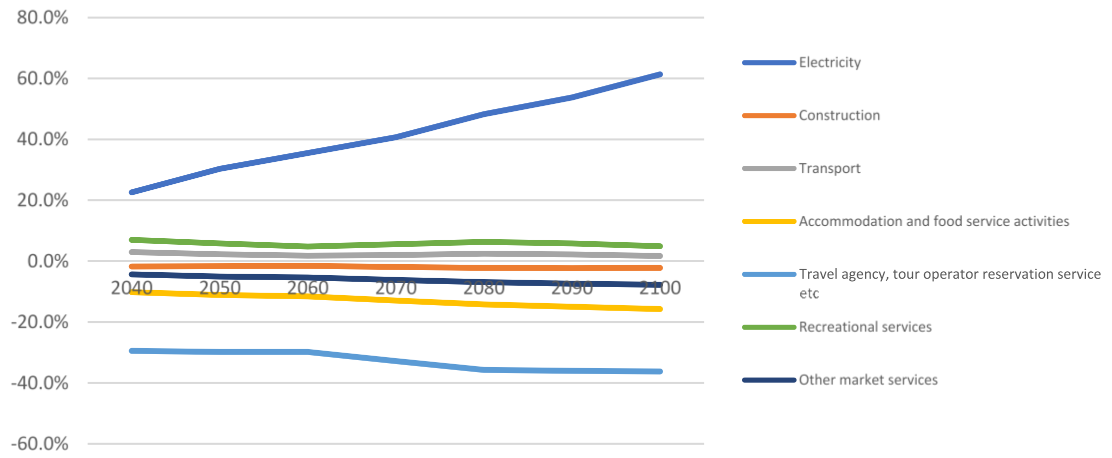
The simulation results of the abovementioned scenarios indicate that the sectors with that experience the steepest decrease, in terms of activity levels, are those associated to the delivery of services to tourists while sectors actively engaged in the realization of investments, such as construction, also record increases in their activity levels. On the tourism side, in both climatic variants activity levels of related industries fall relative to the baseline; in the RCP8.5 this effect is almost double due to the magnitude of the simulated changes. Moreover, in the RCP8.5 scenario electricity requirements continue to grow throughout the simulation compared to the RCP2.6 where the foreseen increases in electricity demand dwindle over the long-term. In both variants, the activity of the market service sector increases as the reduction of activity of tourism sectors suppresses wages.

Figure 73: Sectorial activity (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 74: Sectorial activity (% from the reference) – RCP8.5



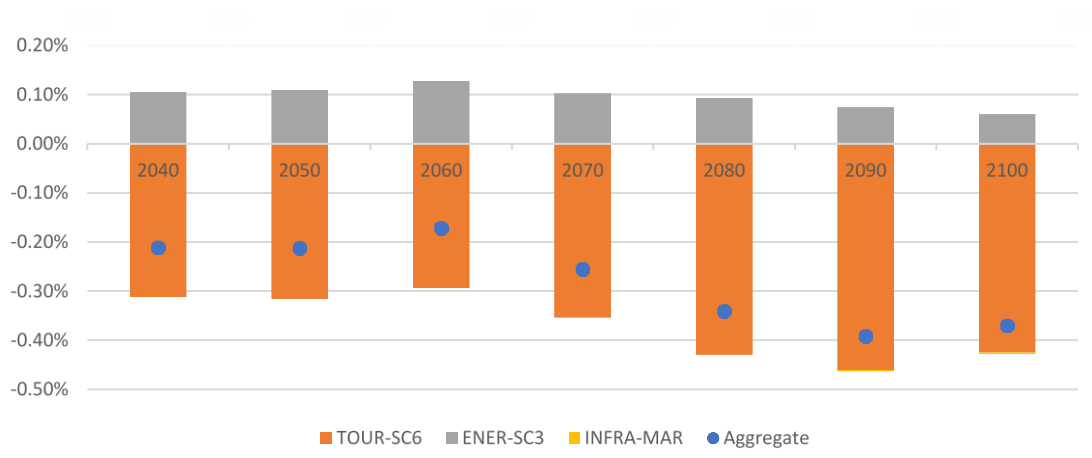
Source: GEM-E3-ISL

3.3.2.3 Labor market

With respect to the labor market developments, the simulation shows decreased employment levels for both climatic variants (RCP2.6 and RCP8.5) and for both periods (*near* and *long*) examined. The employment losses recorded are attributed mainly to the decreased employment of the tourism sectors: -2.2% on average in the RCP2.6 and -8.3% in the RCP8.5 for the core tourism sectors [21].

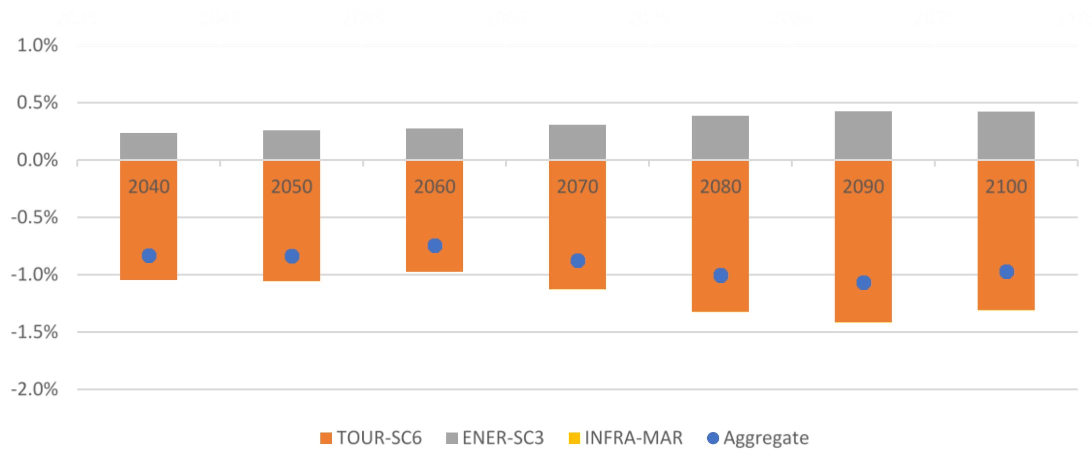
Figure 75: Employment (% from the reference) – RCP2.6

[21] Accomodation and restaurants, travel agencies and recreational services



Source: GEM-E3-ISL

Figure 76: Employment (% from the reference) – RCP8.5



Source: GEM-E3-ISL

3.3.3 GWS RESULTS

3.3.3.1 Macroeconomic

Cyprus, as well as Malta, are special cases in the development of economic simulations of climate change for European Islands. The statistical database for both islands, which at the same time are Member States, is wider than for the other islands. Also, in terms of modeling approach in the GWS modeling framework, Cyprus and Malta are explicitly part of the large global model GINFORS_E, which serves for the other islands merely as driver for the respective mother countries' results.

In Cyprus, currently tourism contributes to GDP with 15% (cf. D6.2). The share is projected to rise until the end of the century but decreases slightly until the end of GINFORS_E's modeling horizon 2050. Services (non-market and market) contribute almost 75% to value added, the share staying constant over the simulation period.

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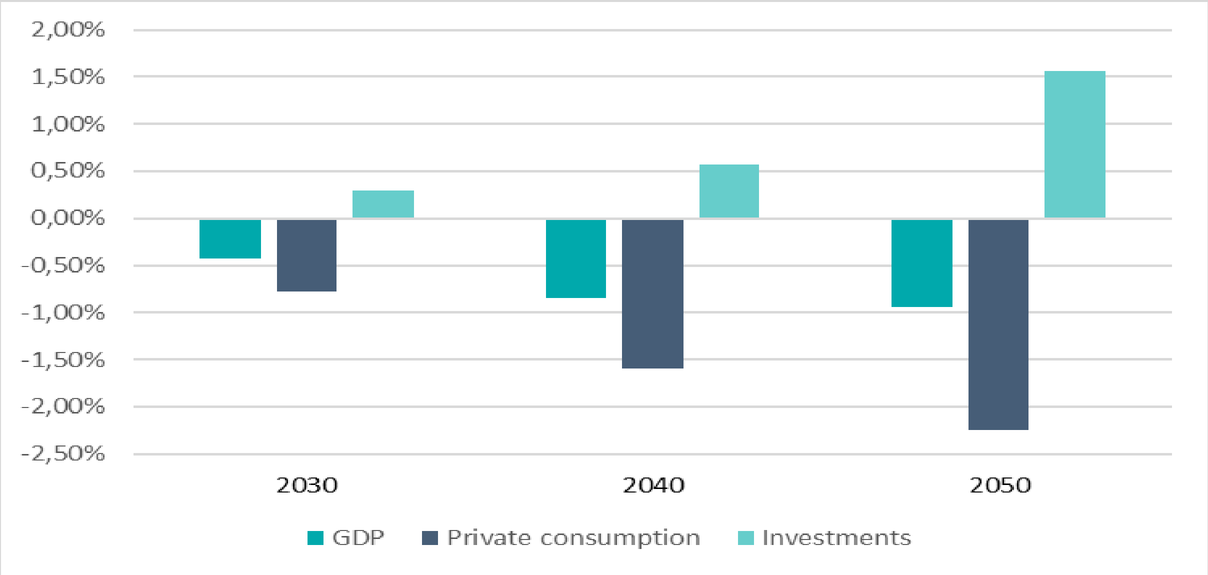
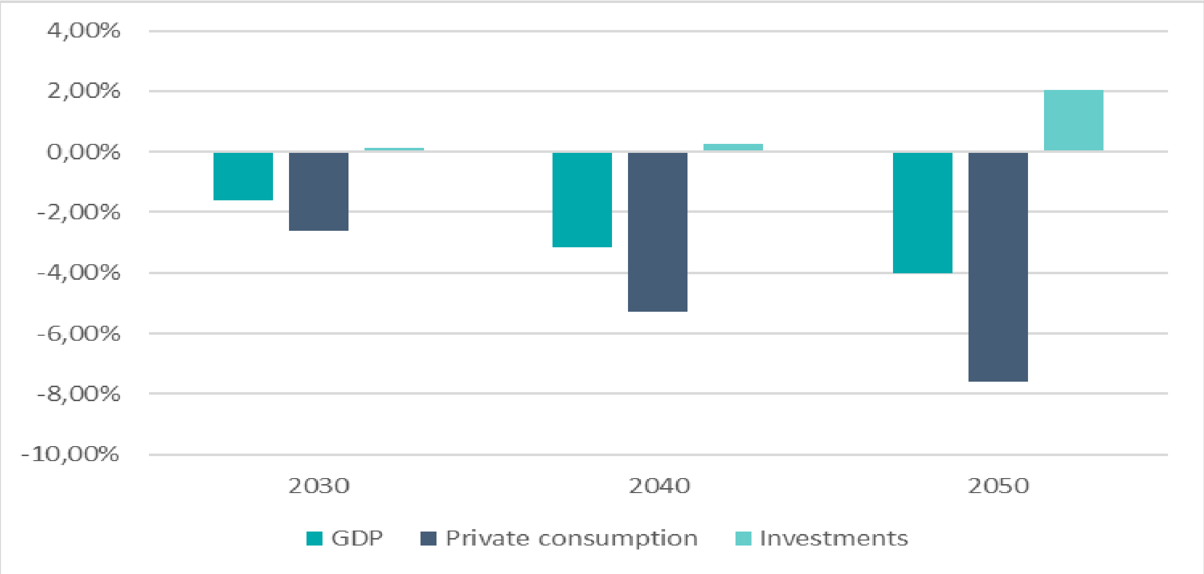
With a location in the Eastern Mediterranean, the impacts from climate change in Cyprus are rather high. Under the RCP 2.6, tourism losses almost 12%, more than 40% under the RCP 8.5. Electricity demand rises by 19% (RCP 2.6) and 37% (RCP 8.5), leading to the need of large additional investment for the sector and to price increases as this investment is re-financed. Figure 77 gives an overview of the macroeconomic results. GDP will be up to 1% lower under the 2.6 RCP scenario than in the baseline. The effect will reach 4% under scenario 8.5 RCP in 2050.

Figure 77: Cyprus: Components of GDP, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





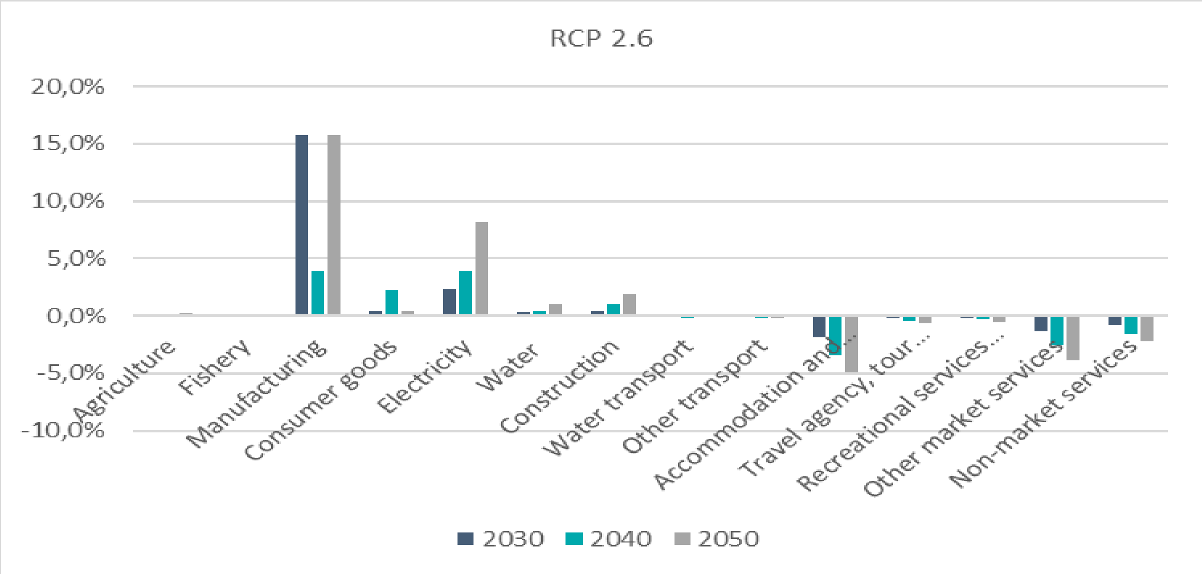
Source: GWS, own calculation.

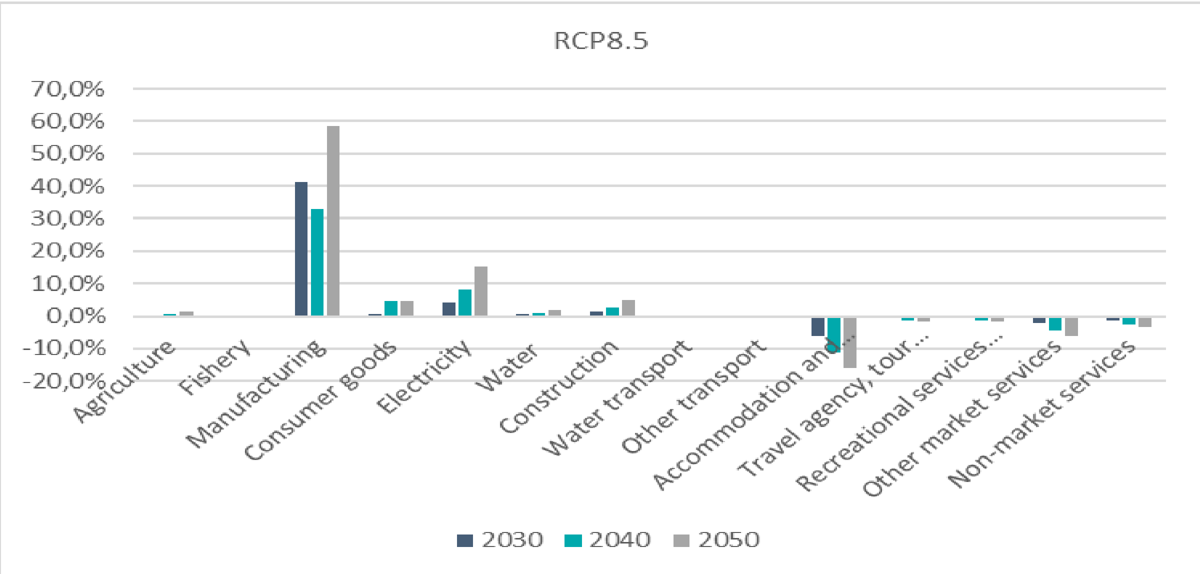
3.3.3.2 Sectorial results

Sector specific results reflect the economic structure of Cyprus. From the IO table (D6.1) for Cyprus, we understand that the Cypriot economy has large manufacturing, construction, services, and tourism sectors. Due to its economic structure, it is less vulnerable to climate change than smaller islands like the Balearic, which highly depend on tourism.

Negative impacts on the latter therefore lead to negative impacts on related services, while positive demand from additional electricity generation infrastructure has positive impacts on manufacturing and the construction sector. Additional labor in these sectors increases income and demand for consumption goods, which is depicted in Figure 78.

Figure 78: Cyprus: Value added by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5



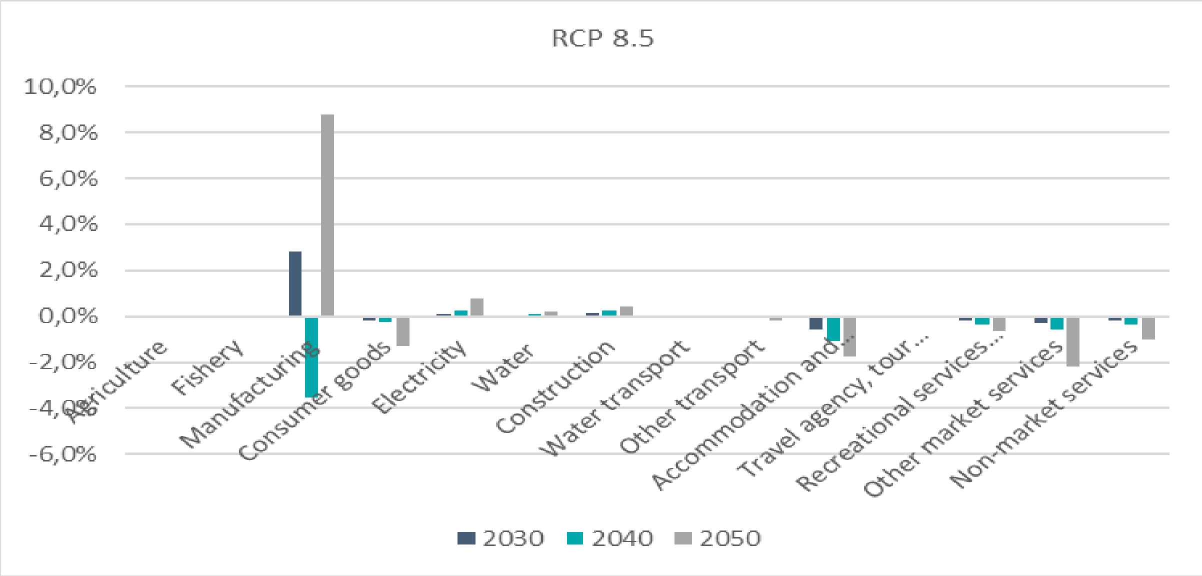


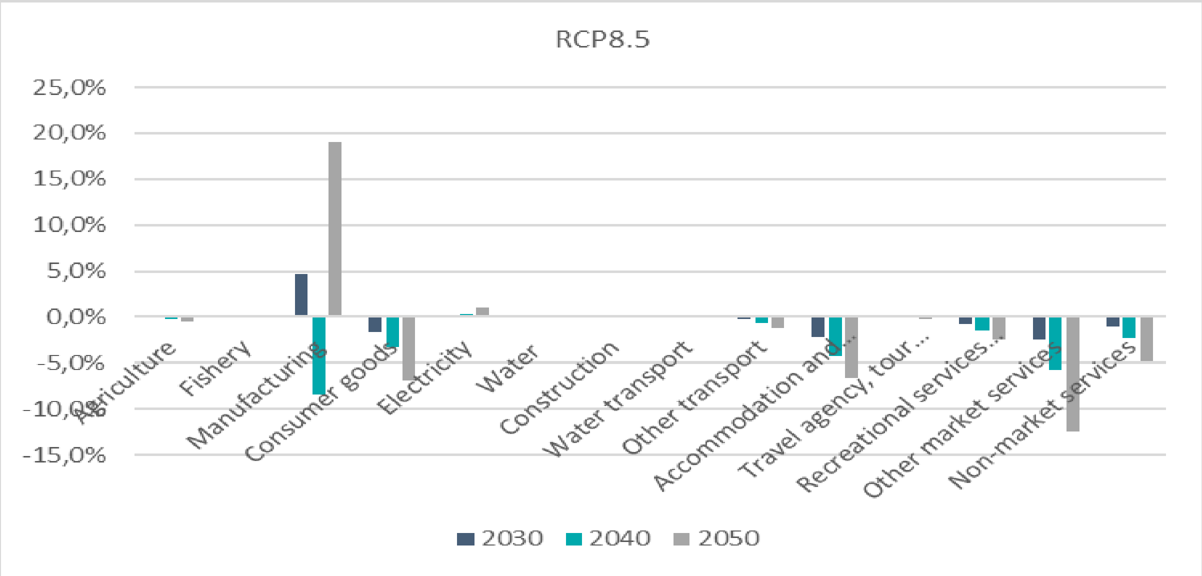
Source: GWS, own calculation.

3.3.3.3 Labor market

The labor market follows the vale-added results and exhibits the same structure. Since Cyprus does not depend as heavily on tourism as other countries and invests a lot in infrastructure in both scenarios, labor market effects are more balanced. Since the manufacturing sector is actually quite small, changes in percent seem more pronounced.

Figure 79: Cyprus: Employment by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation.

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3.4 MALTA

3.4.1 SCENARIO DEFINITION

For the Malta, three sets of scenarios are simulated for each island. The first set of scenarios examines the impact of climate change on tourism by assuming different expenditures by tourists due to biophysical climate impacts on the natural environment and temperatures. In particular, the changes in touristic demand are directly linked to the perception of tourists regarding certain features such as beach surface, the marine environment, the risk of forest fires and warmer conditions and depend on how these features are impacted by climate change. The second set of scenarios refers to changes in electricity consumption due to increased cooling demand and water availability. Finally, the third set of scenarios refers to infrastructure damages, specifically to port infrastructure, due to sea level rise.

The impact of climate changes on tourists' spending, electricity demand and capital losses are estimated in D5.6 and are used as inputs for the scenario simulations as described in the Methodology Section. The GEM-E3-ISL model assesses their impacts on the main macroeconomic variables (GDP, private consumption, investments, exports and imports), sectorial activity and employment. The inputs provided by D5.6 and incorporated in GEM-E3-ISL for the Malta are described in the following tables:

Table 11: Changes in tourists' expenditures with respect to the reference case (%)

	TOUR -SC1 (marine environment)	TOUR -SC2 (forest fire)	TOUR -SC3 (beach reduction)	TOUR -SC4 (thermal comfort)	TOUR -SC5 (V-disease)	TOUR –SC6 (aggregate)
RCP2.6 near	0	0	--9.03	-1.28	0	--10.31
RCP2.6 distant	0	0	-12.90	-1.29	0	-14.19
RCP8.5 near	0	0	-18.7	-1.33	0	-20.03
RCP8.5 distant	-8.95	0	-22.57	-1.90	0	-33.42

Table 12: Changes in electricity consumption with respect to the reference case (%)

	ENER -SC1 (desalination)	ENER -SC2 (cooling)	ENER –SC3 (aggregate)
RCP2.6 near	1.1	5.8	6.9
RCP2.6 distant	1.3	2.9	4.2
RCP8.5 near	2.4	11.6	14.0
RCP8.5 distant	5.6	20.1	25.7

Table 13: Capital losses (% of GDP)

	INFRA-MAR
RCP2.6 near	-0.26
RCP2.6 distant	-0.29
RCP8.5 near	-0.69
RCP8.5 distant	-0.77

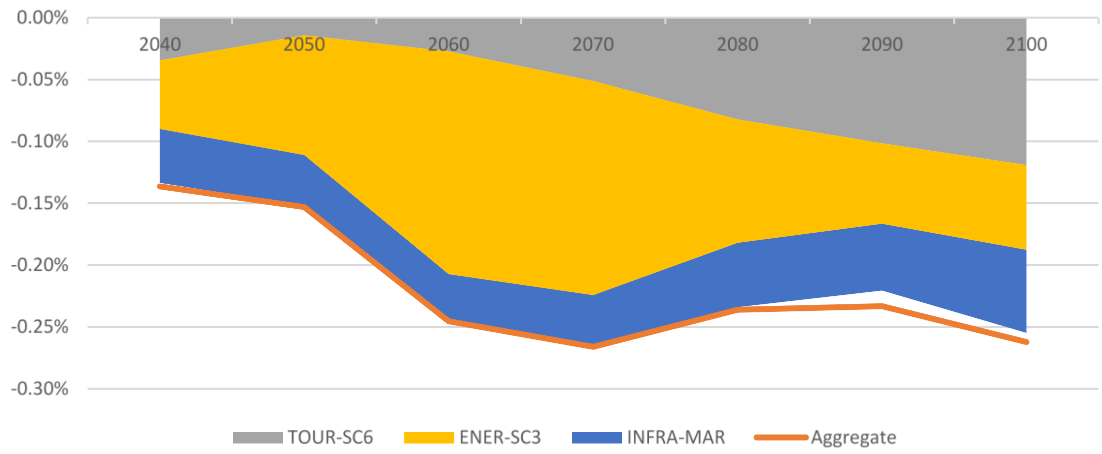
3.4.2 GEM-E3-ISL RESULTS

3.4.2.1 Macroeconomic

3.4.2.1.1 Macroeconomic impacts (aggregate)

The estimated impacts of the combined changes on Malta's GDP are calculated cumulatively to -0.21% for the RCP2.6 (Figure 80) and -0.9% for the RCP8.5 (Figure 81) over the period 2040-2100. The driver in both climatic variants is electricity demand and the impact on GDP is more pronounced in the long-term as an intensification of climate impacts is projected. The results are compatible with the structure of the Maltese economy, which is highly service-oriented but depends mainly on market services (e.g. financial services, consultant services etc.) while tourism-related activities contribute only a small share (5%) in national gross value added. With respect to the time frame, GDP impacts are relatively equal distributed in the RCP2.6 scenario (-0.16% in the near period compared to -0.24% in the distant period) while of the RCP8.5 the effects in the *distant* period almost double compared to the *near* (-1.36% vs -0.57%).

Figure 80: GDP changes from reference (%) – RCP2.6



Source: GEM-E3-ISL

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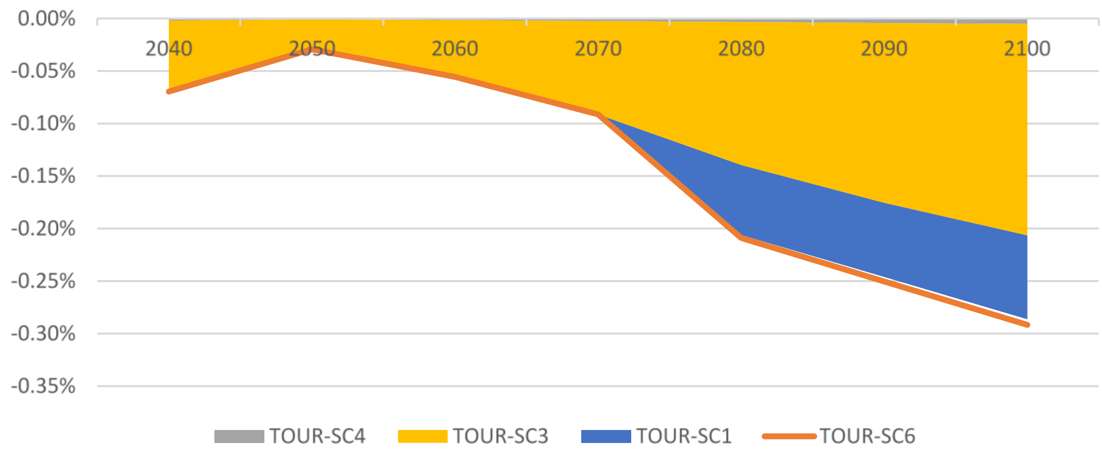
Figure 81: GDP changes from reference (%) – RCP8.5



Source: GEM-E3-ISL

Analyzing the response of the main macroeconomic variables to simulated changes, investments increase as a consequence of increased electricity demand and continue to be higher than the reference value almost throughout the period examined. Private consumption, on the other hand, falls as the reduced expenditure of tourists result in lower demand for tourism related sectors, which leads to lower labor and capital earnings. Household demand has negative repercussions for the level of imports which fall (slightly) relative to their reference levels. Finally, with regards to exports, there are two countervailing forces: on the one hand increased electricity consumption tends to drive electricity prices higher hence production costs and hinders the competitiveness of domestic products while on the other hand, decreased activity due to the assumed reduction in tourists' expenditures drive wages and capital rents lower due to lower demand. In the RCP2.6 where electricity increases are assumed to be higher in the *near* time relative to *distant*, exports increase as the higher investments in the "early" years are more than enough to satisfy the increased demand at relatively competitive prices. In the RCP8.5, electricity demand grows throughout the period and stresses production costs upwards reducing total exports.

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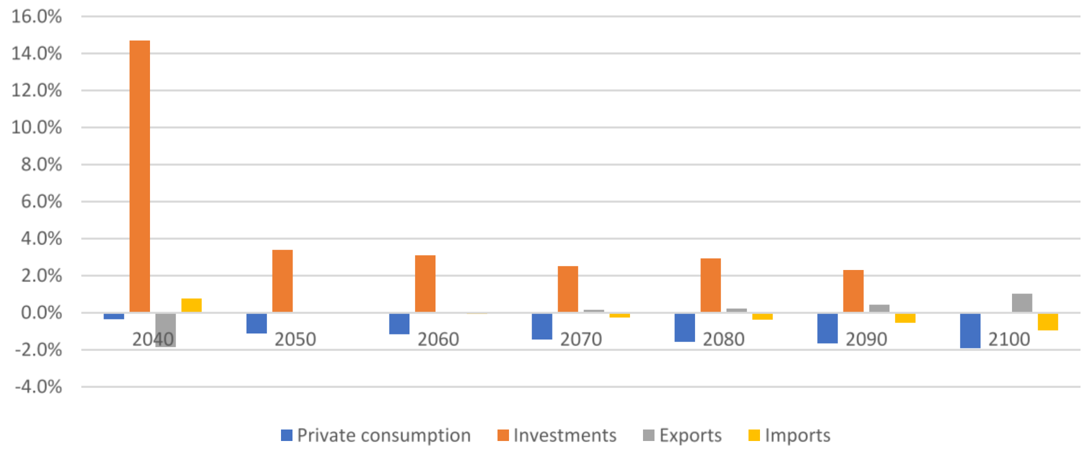
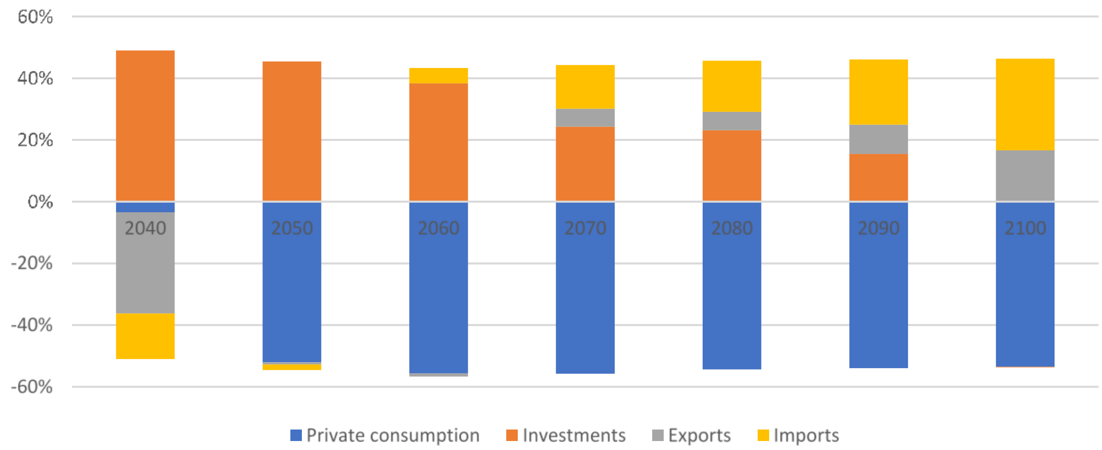
Figure 82: Changes from reference in selected macroeconomic variables (%) – RCP2.6



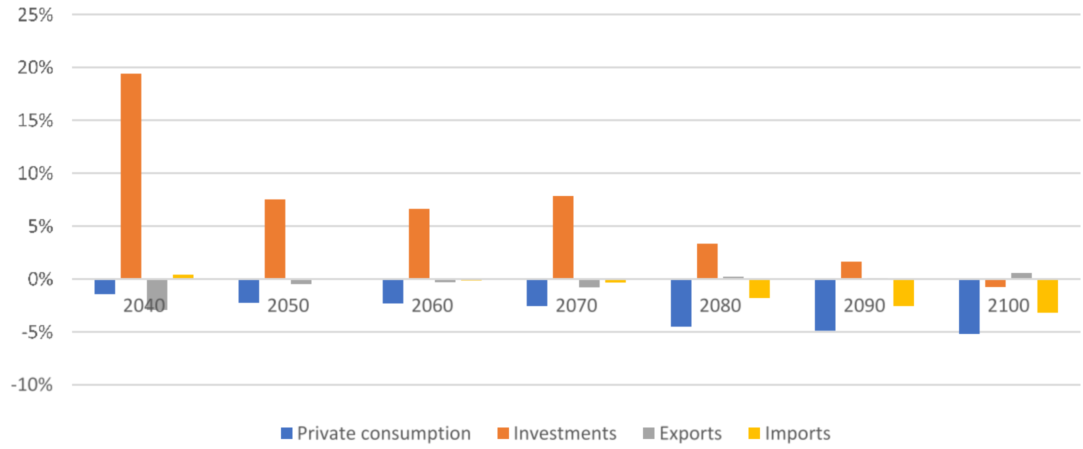
Source: GEM-E3-ISL

Figure 83: Contribution to GDP changes – RCP2.6



Source: GEM-E3-ISL

Figure 84: Changes from reference in selected macroeconomic variables (%) – RCP8.5

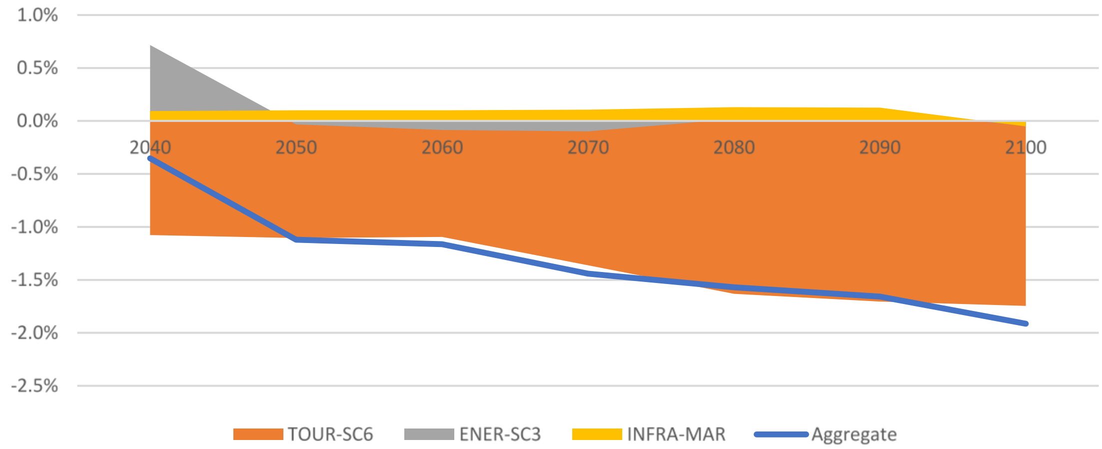


Source: GEM-E3-ISL

Figure 85: Contribution to GDP changes (%) – RCP8.5

Decomposing private consumption and investment changes (in both climatic variants) we observe that changes associated to tourism are driving the overall result (Figure 86-Figure 89). Increased electricity demand for water desalination and cooling has a positive impact as increased investments needed to meet the new electricity consumption has beneficial effect (although marginal) for the income of households and the same holds in the scenario where infrastructure damages are examined. With respect to investments, increased demand on the energy scenarios and infrastructure destruction are driving them upwards while in the tourism scenarios the decreased activity of tourism related industries leads to a decrease in capital costs which increases capital profitability and leads to a re-orientation of capital towards other activities.

Figure 86: Changes in private consumption % from reference – RCP2.6



Source: GEM-E3-ISL

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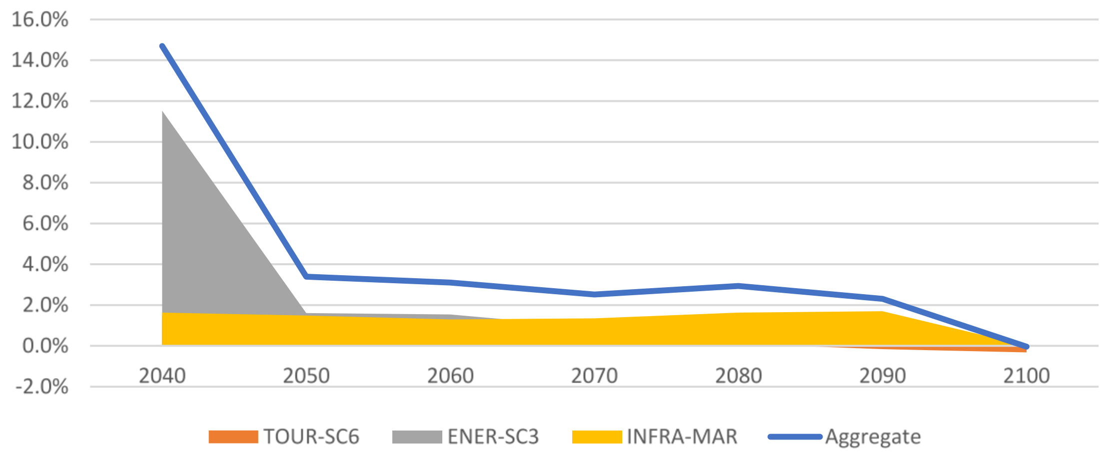
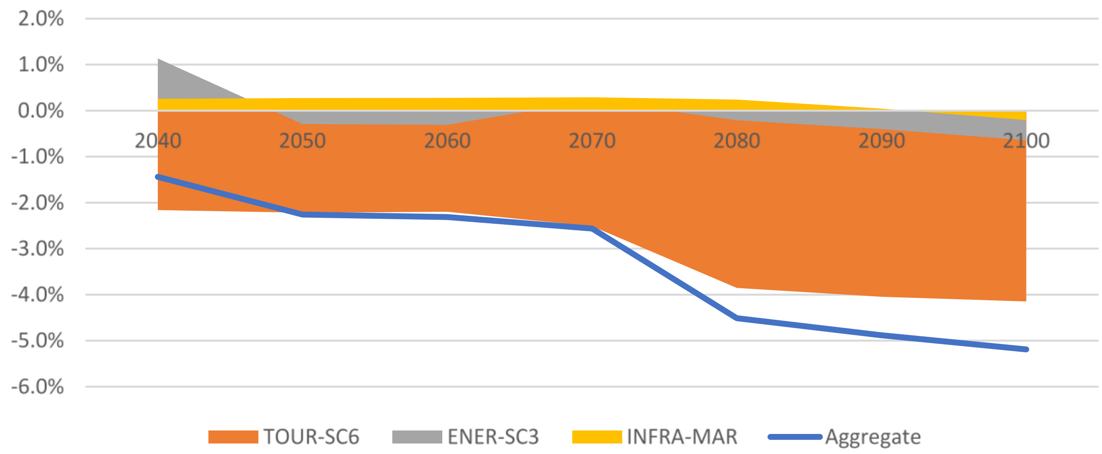
Figure 87: Changes in investments % from reference – RCP2.6



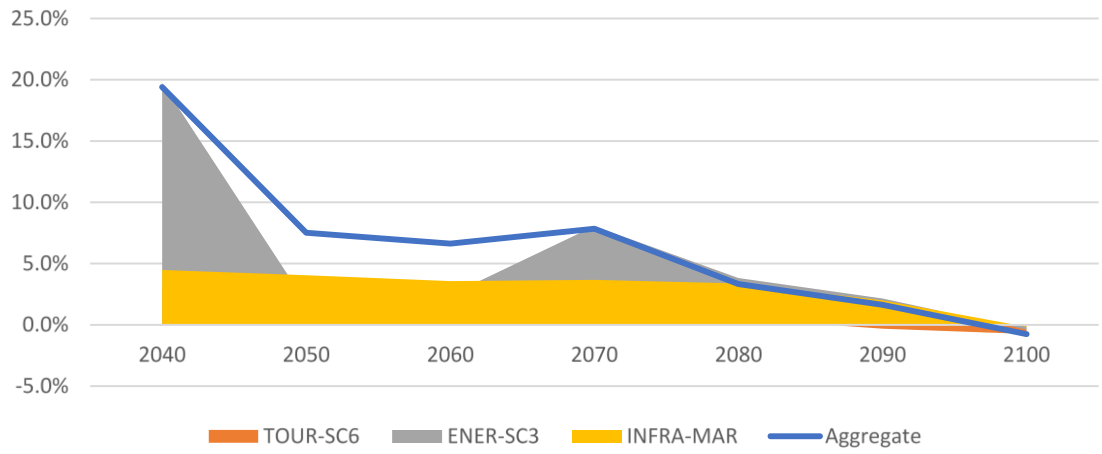
Source: GEM-E3-ISL

Figure 88: Changes in private consumption % from reference – RCP8.5



Source: GEM-E3-ISL

Figure 89: Changes in investments % from reference – RCP8.5



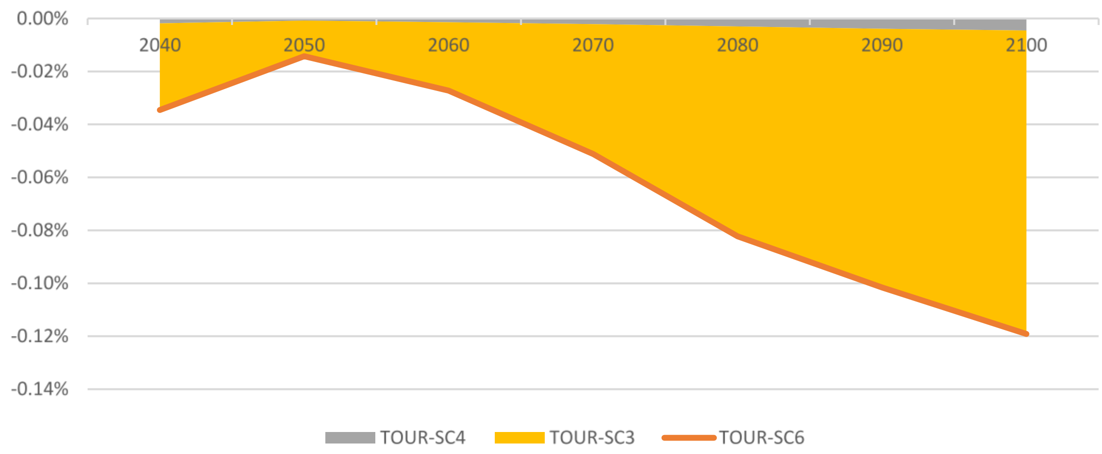
Source: GEM-E3-ISL

3.4.2.1.2 Macroeconomic impacts (tourism)

Tourism activities in Malta are responsible on average for 6% of the national gross value added over the period 2040-2100. Hence, changes in total tourist spending are expected to have only mild effect on the economy of Malta. Tourism industries employs intensively domestic factors and the first order effects of expenditure reduction is expected to be equivalent to the initial shock. In the RCP2.6 scenario the cumulative reduction in tourists' expenditure is estimated to be equal to 11.7% (compared to the reference scenario) and in the RCP8.5 scenario equal to 25.4% for the period 2040-2100.

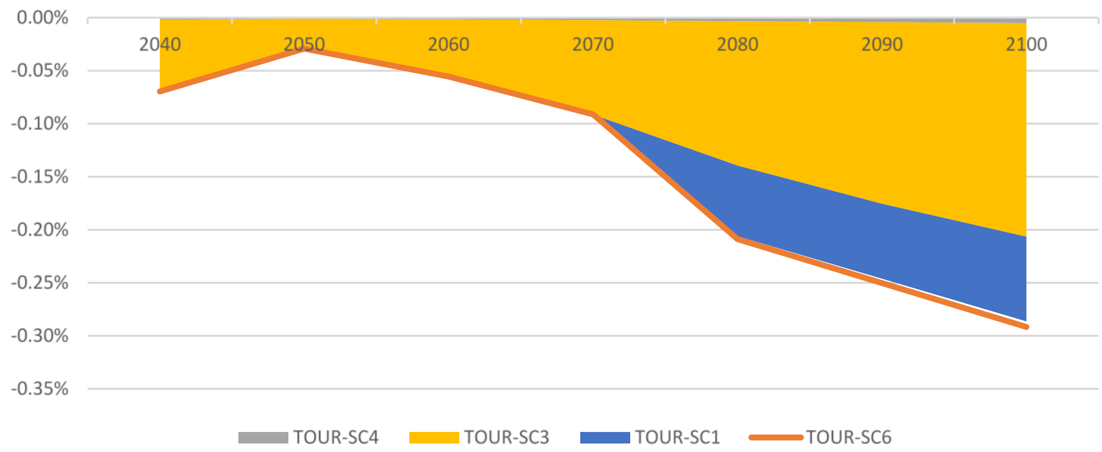
Out of the three tourism related scenarios examined the highest impact on the economy is found in the TOUR-SC3 (in both climatic variants), which examines the effects of beach reduction on tourism receipts (Figure 90,Figure 91) highlighting the importance of coastal tourism for the Maltese economy relevant to the other two factors. In the RCP8.5 variant the degradation of the marine environment is found also to exert significant pressure on the tourism industry. All scenarios exhibit similar pattern with respect to the response of the main macro-economic variables to the implemented shock: i) private consumption decreases primarily due to the reduced revenues of tourism related activities which lead to lower labor income, ii) investments increase relative to their reference levels as a result of increased capital profitability and the re-orientation of capital towards other sectors and iii) trade deficits reduce as imports fall (due to the overall decrease of domestic demand) and exports increase; the decreased demand for labor from tourism related industries exerts negative pressure on wages which in turns benefit all other sectors that employ labor intensively. The economy of Malta relies heavily on services, hence the developments in the labor markets are expected to raise opportunities for the tertiary sector which eases the negative effect of lower tourism spending.

Figure 90: GDP change relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 91: GDP change relative to the reference (%) – RCP8.5



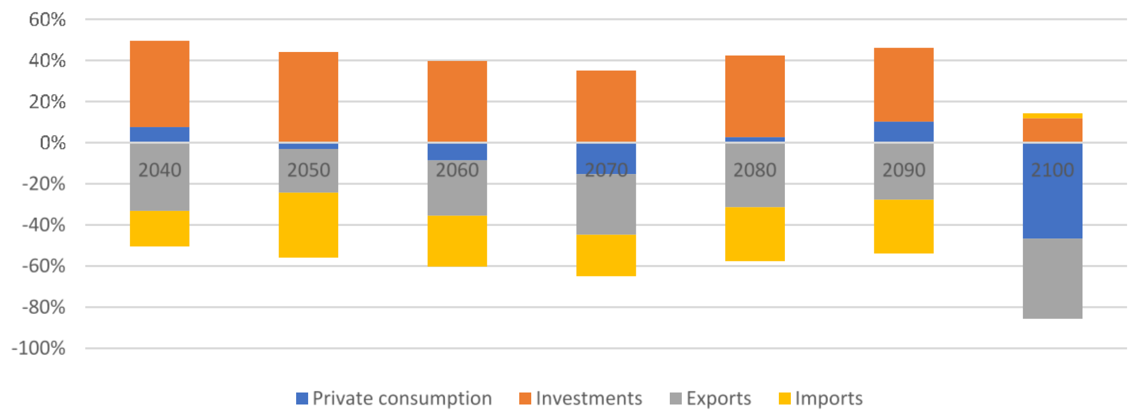
Source: GEM-E3-ISL

3.4.2.1.3 Macroeconomic impacts (energy)

The increased demand for electricity is found to have negative impacts on the economy of Malta compared to the reference case. The increase in the cooling degree days implies higher utilization rate of cooling systems (as well as the purchase of additional equipment), mainly from tertiary activities and from households. From the household's perspective this translates into higher consumption per utility level, while for firms it implies higher electricity input per unit of output. To the extent that electricity comes at higher costs, the impact on the economy is negative as the disposable income for other goods and services decrease, while production costs are driven upwards and domestic products lose their competitiveness compared to imported ones.

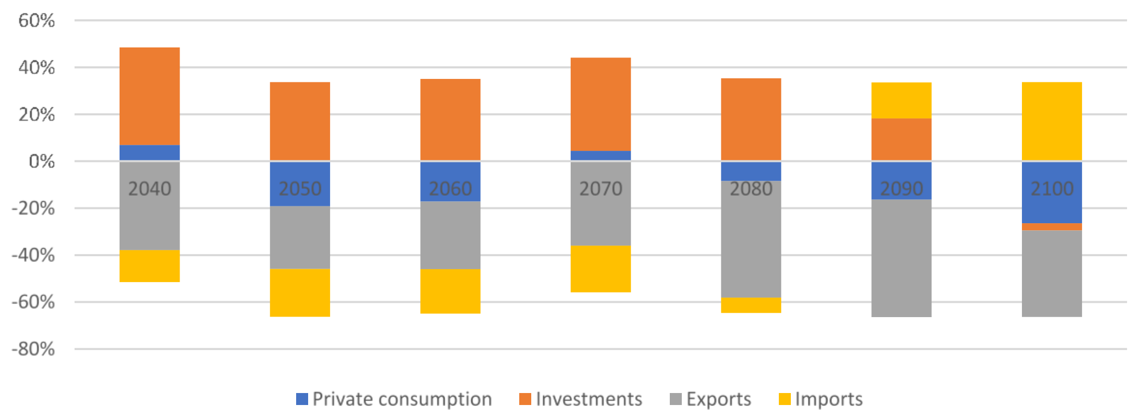
Malta's electricity system is interconnected to Italy, which implies that a part of the increased demand will be satisfied by imported electricity while the rest will be handled by the domestic electricity network. To do so, investments to increase capacity are needed and the positive effect steaming from the increased activity of sectors associated to the realization of investment projects will counterbalance the above-mentioned negative pressures on the economy. The scenario results show that the activity of construction and of the manufacturing sector (which deliver the necessary investment goods) increases. This has direct repercussion for employment and wage incomes as construction is characterized by increased employment of local resources and almost zero import intensity.

Figure 92: Decomposition of GDP changes (%) – RCP2.6



Source: GEM-E3-ISL

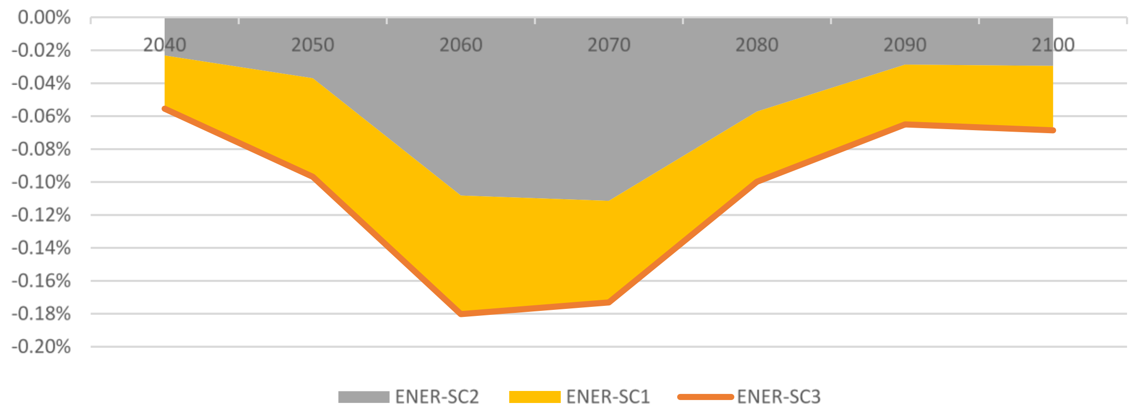
Figure 93: Decomposition of GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

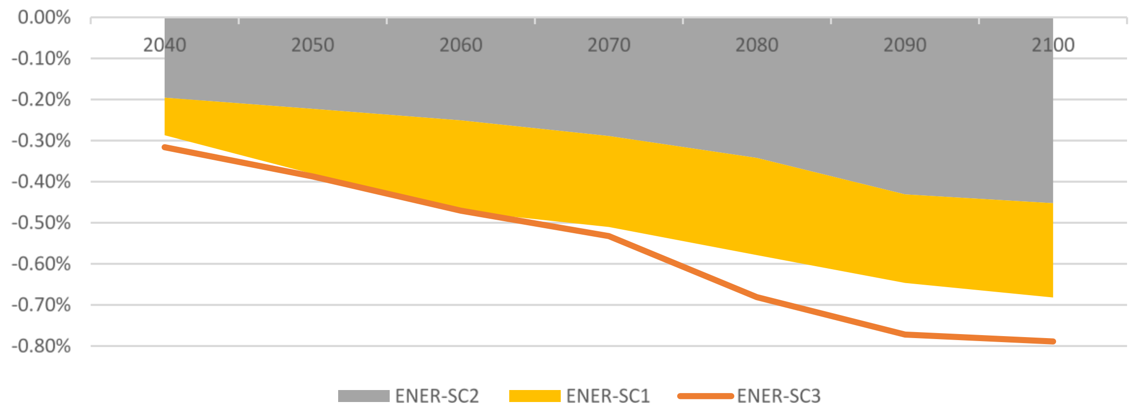
From the two energy-related scenarios examined the effects are more pronounced in the cooling scenario as it foresees higher electricity consumption in both variants compares to the electricity consumption for desalination purposes.

Figure 94: GDP changes relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 95: GDP changes relative to the reference (%) – RCP8.5



Source: GEM-E3-ISL

3.4.2.1.4 Macroeconomic impacts (maritime)

In this scenario the effect of infrastructure damages is assessed and more specifically those associated to ports and port facilities. Infrastructure damages, one the one hand increase the financing requirements of the economy and stress the capital markets leading to increased capital costs, hence there is a negative impact on the economy. On the other hand, increased investments influence positively domestic activity, as the construction sector which is intensively engaged in the realization of investments employs intensively domestic resources, softening the effect of infrastructure damages.

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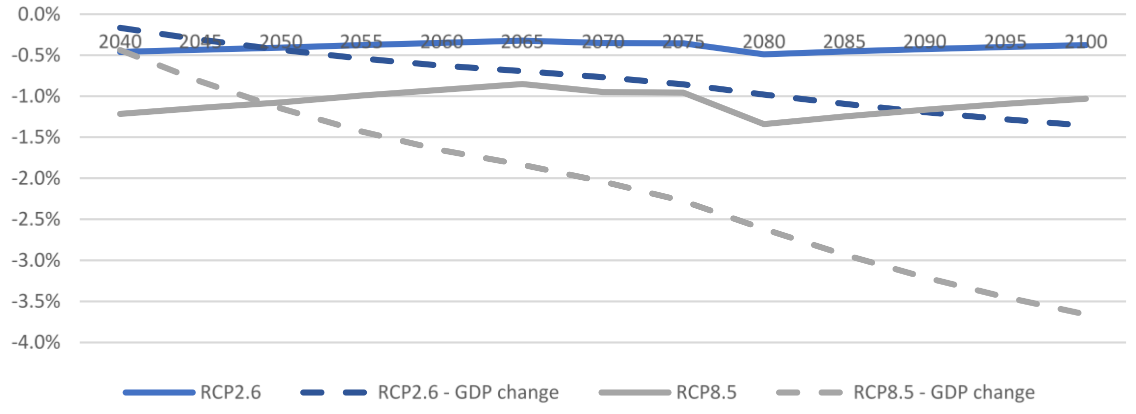
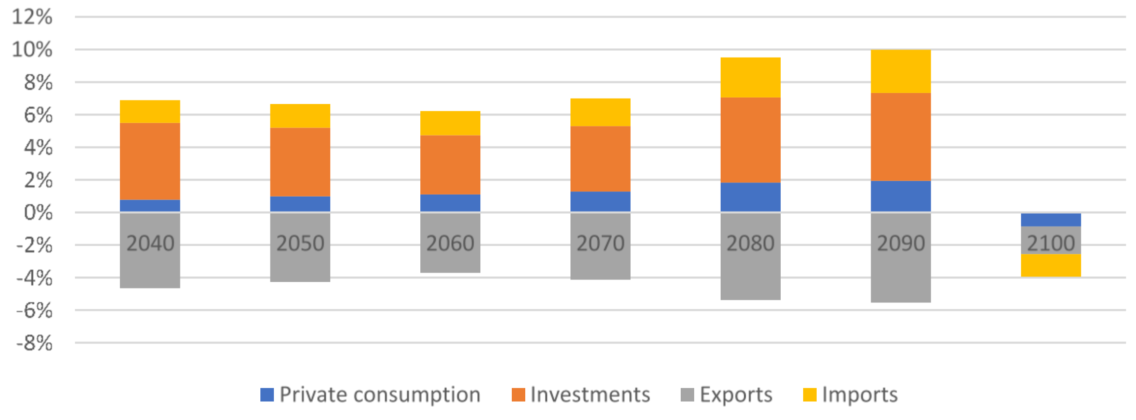
Figure 96: Capital losses (% of GDP)



Source: GEM-E3-ISL, D5.6

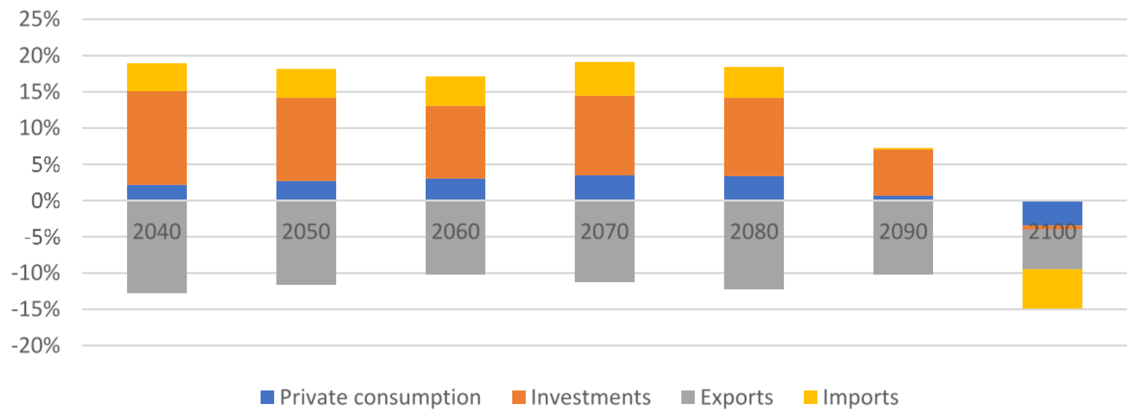
The scenario assessment shows that GDP contracts by 0.04% on average for the period 2040-2065 and by 0.06% for the period 2080-2100 in the RCP2.6; the respective figures for the RCP8.5 are 0.11% and 0.21%. As the economy of Malta is dominated by services, the capital requirements of the economy are relatively lower than industrialized economies, hence the effects of capital costs on the economy are modest. In both scenarios examined there is an increase in investments which leads to higher demand both for capital and for labor. This increased demand combined with the foreseen capital losses exerts upward pressure in the markets of primary production factors, leading to increases in wages and capital rents. In turn, this has a negative impact on the export performance of the economy and domestically produced goods are substituted by cheaper imported products (total imports increase). The impacts of infrastructure damages on the main macroeconomic variables are presented below:

Figure 97: Changes from reference in selected macroeconomic variables (%) – RCP2.6



Source: GEM-E3-ISL

Figure 98: Changes from reference in selected macroeconomic variables (%) – RCP8.5

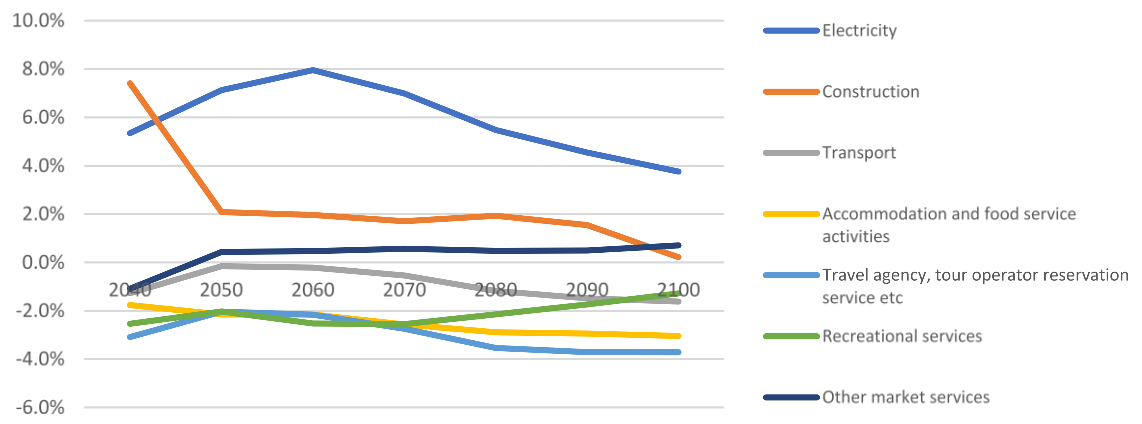


Source: GEM-E3-ISL

3.4.2.2 Sectorial results

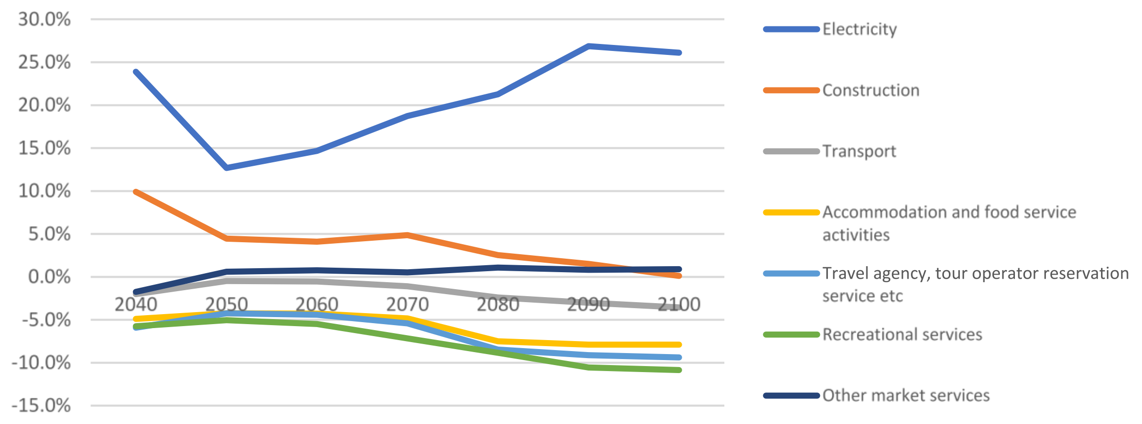
The simulation results of the abovementioned scenarios indicate that the sectors with that experience the steepest decrease, in terms of activity levels, are those associated to the delivery of services to tourists while sectors actively engaged in the realization of investments, such as construction, also record increases in their activity levels. On the tourism side, in both climatic variants activity levels of related industries fall relative to the baseline; in the RCP8.5 this effect is almost double due to the magnitude of the simulated changes. Moreover, in the RCP8.5 scenario electricity requirements continue to grow throughout the simulation compared to the RCP2.6 where the foreseen increases in electricity demand dwindle over the long-term. In both variants, the activity of the market service sector increases as the reduction of activity of tourism sectors suppresses wages.

Figure 99: Sectorial activity (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 100: Sectorial activity (% from the reference) – RCP8.5

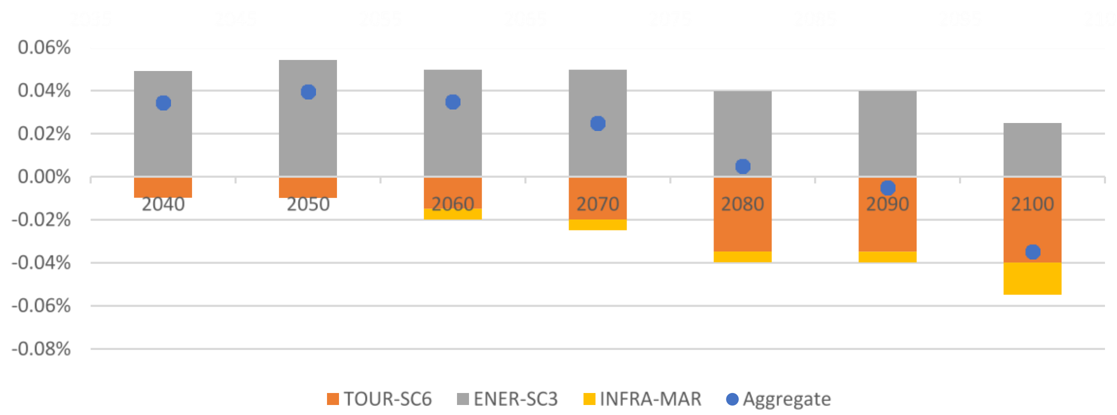


Source: GEM-E3-ISL

3.4.2.3 Labor market

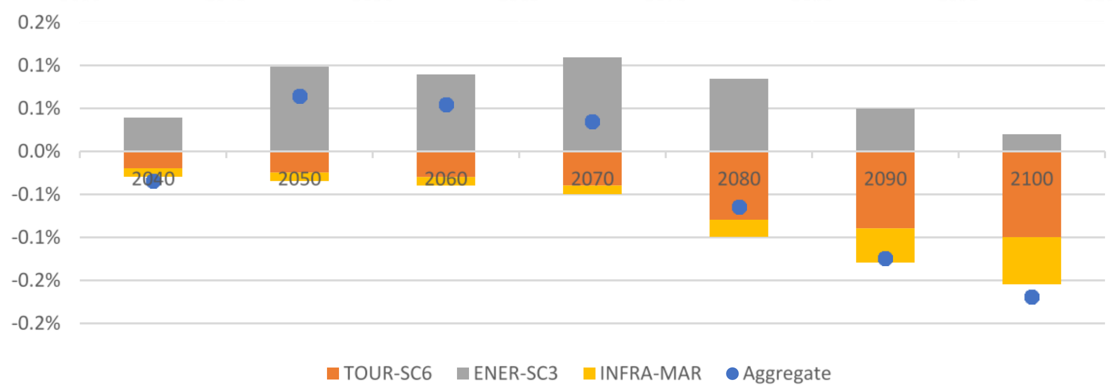
With respect to the labor market developments, the simulation shows increased levels for the RCP2.6 for both the *near* and the *long* period examined, while for the RCP8.5 employment levels are higher than the reference levels during the *near* period and lower during the *long* period as the decrease in tourism activity is much sharper. The employment gains recorded are attributed to the increased activity of market services and construction and to the reduction in the wage rate which enables, to the extent that is possible, the substitution of other production inputs with cheaper labor.

Figure 101: Employment (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 102: Employment (% from the reference) – RCP8.5



Source: GEM-E3-ISL

3.4.3 GWS RESULTS

3.4.3.1 Macroeconomic

Malta has the highest tourism dependence; tourism related activities contribute with almost 35% to GDP by 2050. 71% of all consumer goods are imported in 2015, followed by 50% of agricultural products. Manufacturing companies have been attracted to Malta by tax exemptions, so that the small island hosts a variety of international manufacturers.

However, the energy sector needs larger investment under the climate change scenarios, to cover energy demand, mainly in heat stressed urban areas. As of today, Malta already has limited natural freshwater resources and increasingly relies on desalination.

The economic effects of climate change are smaller compared to other Islands. Under the RCP 8.5 scenario, GDP losses amount to almost 4%. Investment in renewable energy lead to a positive effect on GDP.

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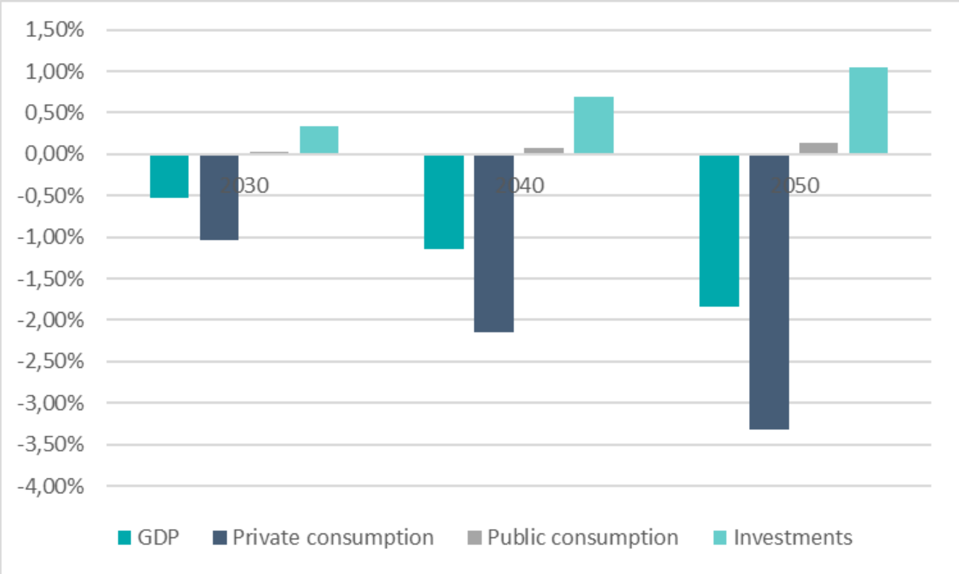
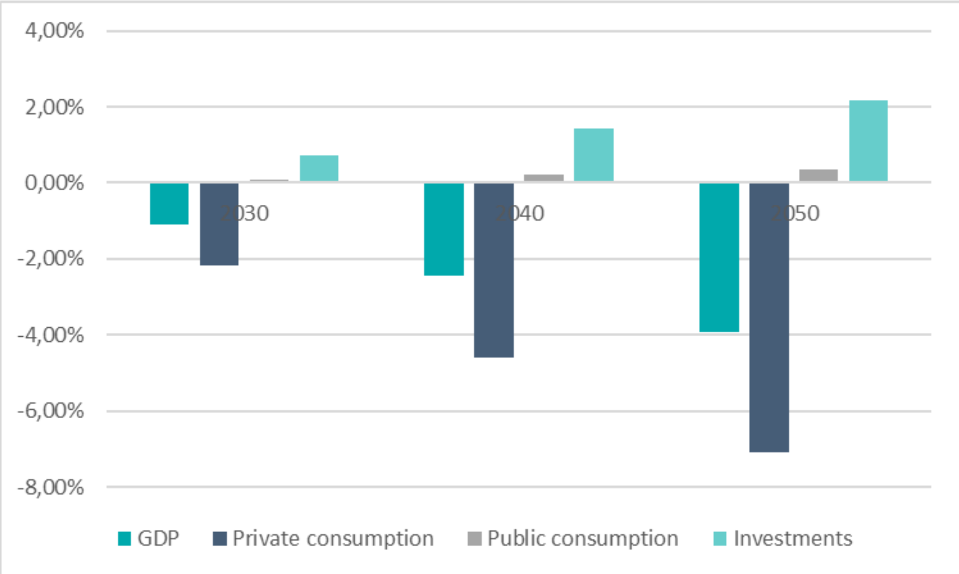
Figure 103: Malta: Components of GDP, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5

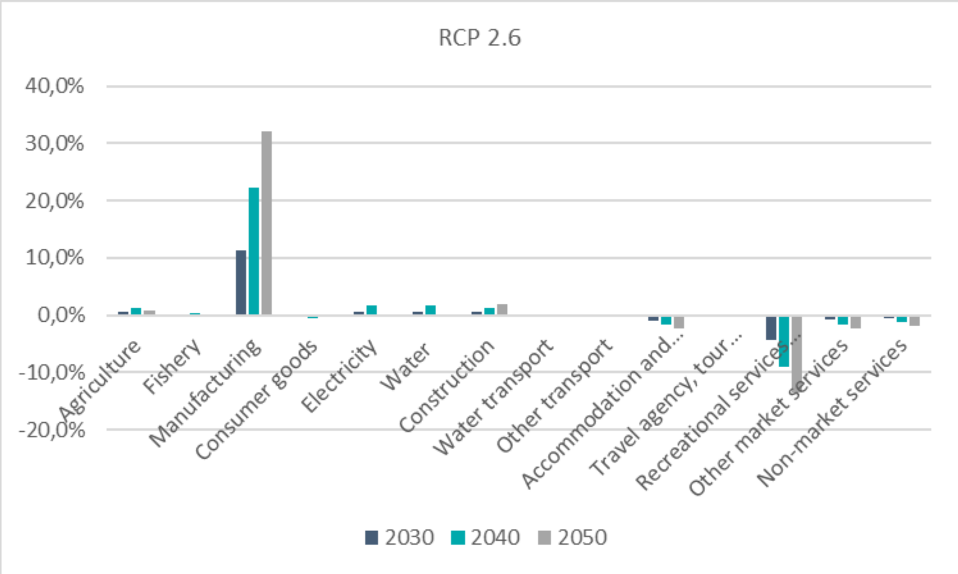


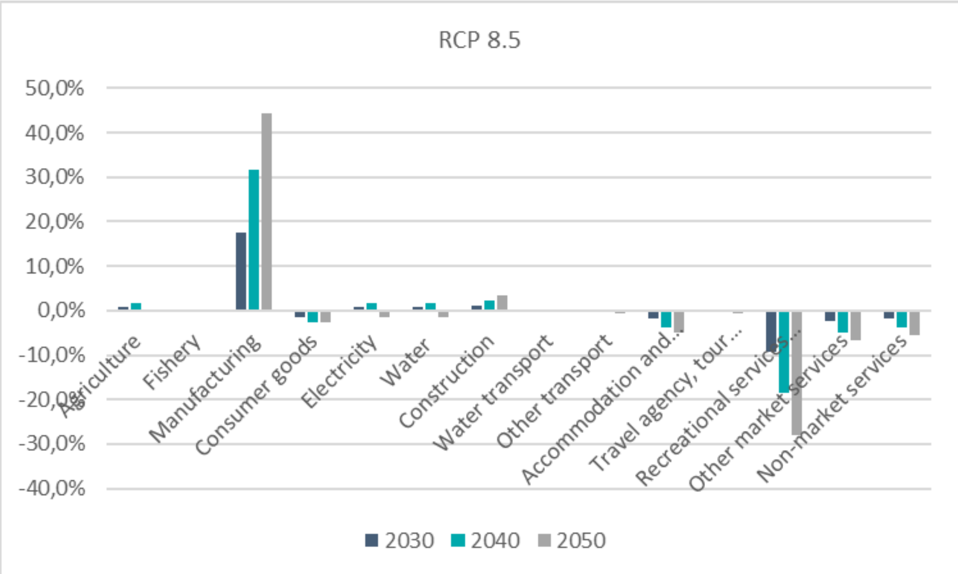


3.4.3.2 Sectorial results

The manufacturing sector benefits from additional investment and from a shift from imported to domestic goods because of higher transport costs. Other sectors show little response to the climate change scenario assumptions, which, as already mentioned above, are comparably small.

Figure 104: Malta: Value added by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5



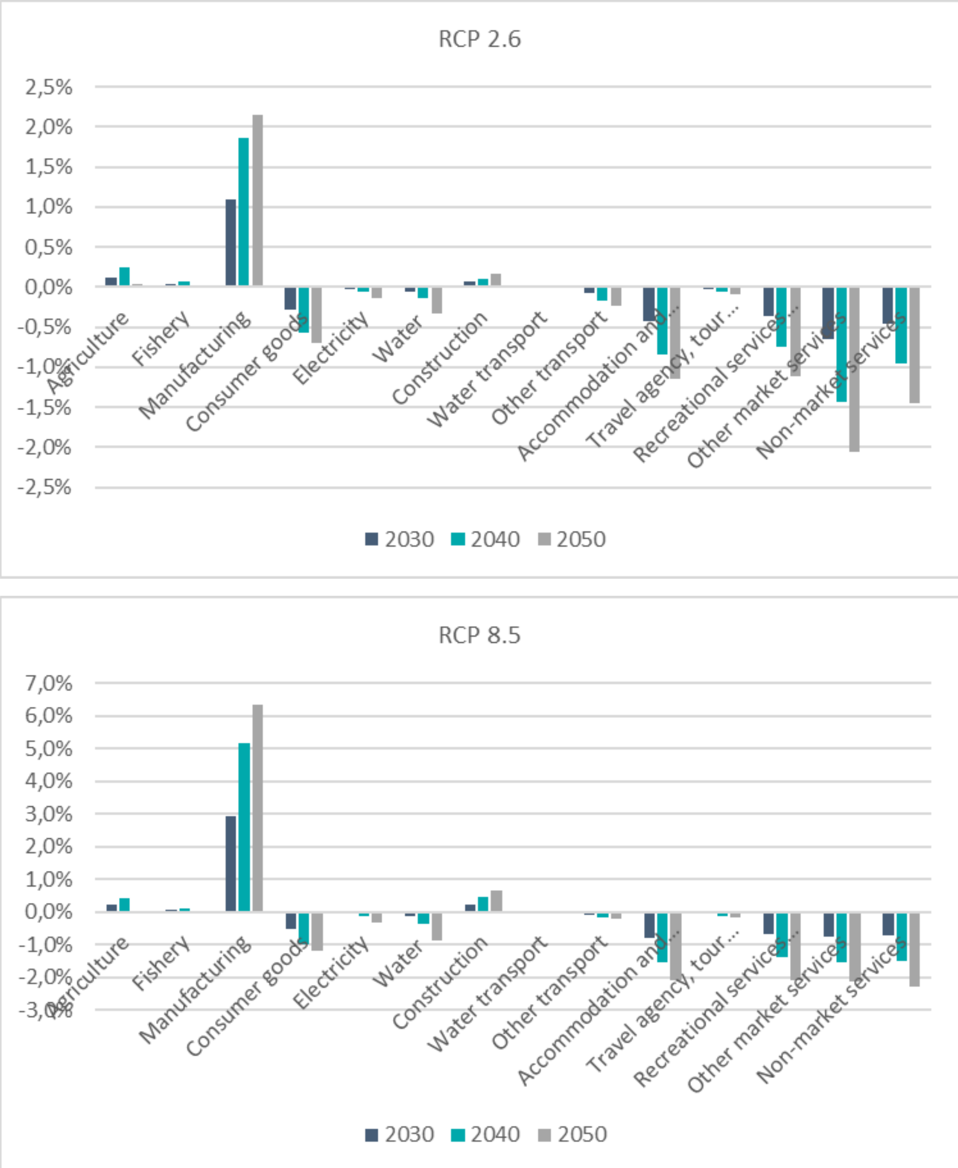


Source: GWS, own calculation.

3.4.3.3 Labor market

The labor market results follow the results for value added quite closely. It is clearly visible how losses in the services lead to overproportionate job losses, while gains in manufacturing lead to underproportionate job gains. This is due to a high degree of automation, in particularly with some of the multinational companies also based on Malta.

Figure 105: Malta: Employment by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5



Source: GWS, own calculation.

3.5 SARDINIA

3.5.1 SCENARIO DEFINIION

As described in the previous sections, three types of scenarios are simulated for each island. The first type of scenarios examines the impact of climate change on tourism by assuming different expenditures by tourists due to biophysical climate impacts on the natural environment and temperatures. In particular, the changes in touristic demand are directly linked to the perception of tourists regarding certain features such as beach surface, the marine environment, the risk of forest fires and warmer conditions and depend on how these features are impacted by climate change. The second set of scenarios refers to changes in electricity consumption due to increased cooling demand and water availability. Finally, the third set of scenarios refers to infrastructure damages, specifically to port infrastructure, due to sea level rise.

The impact of climate changes on tourists' spending, electricity demand and capital losses are estimated in D5.6 and are used as inputs for the scenario simulations as described in the Methodology Section. The GEM-E3-ISL model assesses their impacts on the main macroeconomic variables (GDP, private consumption, investments, exports and imports), sectorial activity and employment. The inputs provided by D5.6 and incorporated in GEM-E3-ISL for Sardinia are described in the following tables:

Table 14: Changes in tourists expenditures with respect to the reference case (%)

	TOUR -SC1 (marine environment)	TOUR -SC2 (forest fire)	TOUR -SC3 (beach reduction)	TOUR -SC4 (thermal comfort)	TOUR -SC5 (V-disease)	TOUR –SC6 (aggregate)
RCP2.6 near	0	0	-11.17	0	0	-11.17
RCP2.6 distant	0	0	-15.64	0	0	-15.64
RCP8.5 near	0	-20.37	-18.76	0	0	-39.17
RCP8.5 distant	-12.40	-20.37	-25.91	0	0	-58.68

Table 15: Changes in electricity consumption with respect to the reference case (%)

	ENER -SC1 (desalination)	ENER -SC2 (cooling)	ENER –SC3 (aggregate)
RCP2.6 near	0.1	4.4	4.5
RCP2.6 distant	0.0	0.9	0.9
RCP8.5 near	0.2	10.7	10.9
RCP8.5 distant	0.5	19.0	19.5

Table 16: Capital losses (% of GDP)

	INFRA-MAR
RCP2.6 near	-0.07
RCP2.6 distant	-0.09
RCP8.5 near	-0.19
RCP8.5 distant	-0.25

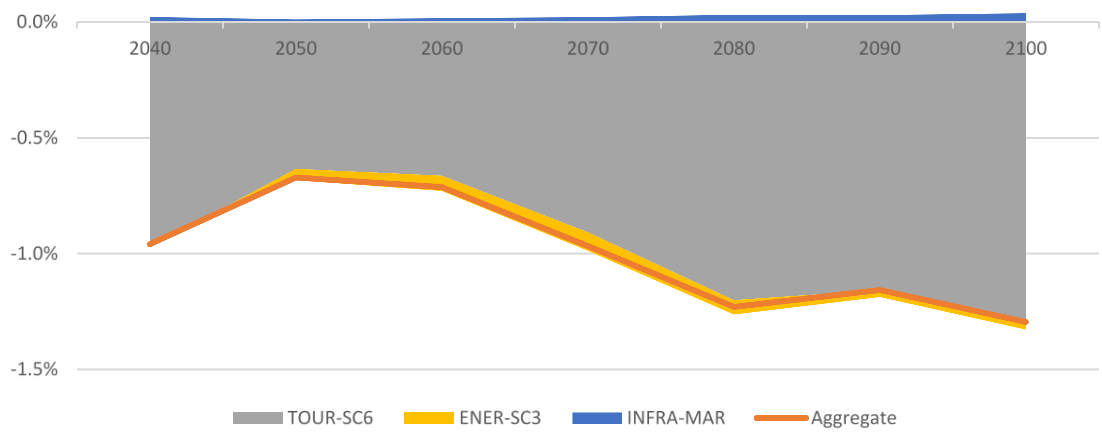
3.5.2 GEM-E3-ISL RESULTS

3.5.2.1 Macroeconomic impacts

3.5.2.1.1 Full Scenario macroeconomic impacts

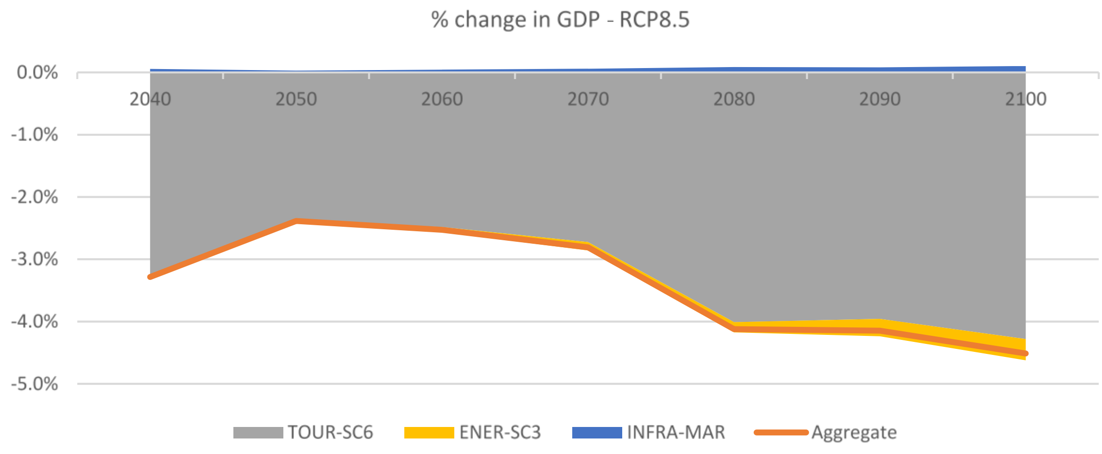
The estimated impacts of the combined changes on Sardinia's GDP are calculated cumulatively to -1.1% for the RCP2.6 (Figure 106) and -3.8% for the RCP8.5 (Figure 107) over the period 2040-2100. The effects in both variants examined are driven by changes in tourism revenues; while the overall effects in the economy are found to be higher in the long-run (2080-100) compared to the medium-run (2040-2065). More specifically, in the RCP2.6 scenario the cumulative reduction for the period 2040-2065 is equal to -0.8% while the long-term GDP impacts are calculated to -1.3%; the respective changes in the RCP8.5 scenario are -2.6% and -4.3%. Noticeably, the impacts in 2040 where the initial shock takes place is higher than in the following period (until 2065).

Figure 106: GDP changes from reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 107: GDP changes from reference (%) – RCP8.5



Source: GEM-E3-ISL

Analyzing the response of the main macroeconomic variables to simulated changes, we find that both private consumption and investments decrease and so does the trade deficits as imports fall and exports increase. This behavior is dictated by the impacts of reduced tourism revenues in the economy. The direct effect of the abovementioned changes is a decrease in the activity of tourism-related industries fall, which consequently leads to lower employment. Households disposable income decreases; hence private consumption falls. This is turn, affects negatively the activity of domestic industries which now face lower domestic demand. Ultimately, the economy's new equilibrium point is characterized by higher unemployment and lower wages.

In terms of trade, the above-mentioned changes have a beneficial effect in regional trade balance. As domestic consumption falls, so do imports. With respect to exports, the new equilib-

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rium in the labor and in the capital markets leads to lower production costs, hence the competitiveness of domestic products improve and international demand grows.

Comparing the response of the imports and exports in the aggregate scenario with TOUR-SC6 (the aggregate tourism scenario) we observe that in terms of magnitude there is a slight difference. For example, in the aggregate RCP8.5 we find that exports grow cumulatively over the period 2045-2100 by 12.5% compared to the baseline, while in the TOUR-SC6 RCP8.5 exports grow by 14.2%. This difference is explained by the energy and the infrastructure component. As electricity demand increases, production costs increase both due to the increased electricity requirements per unit of output and due to the increased electricity prices (in the RCP8.5 on average by 0.24%). Moreover, the destruction of infrastructure has negative implications for capital rents, leading to cost increases and to competitiveness losses.

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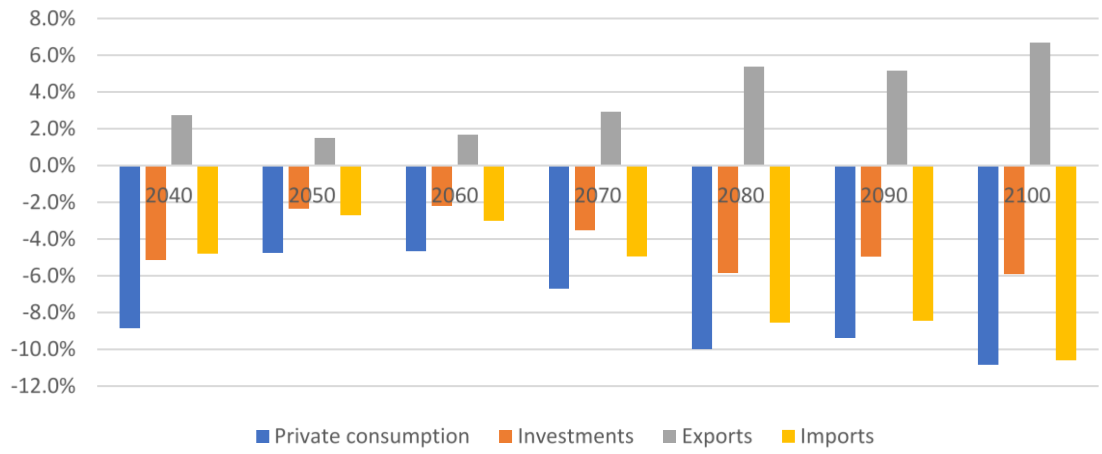
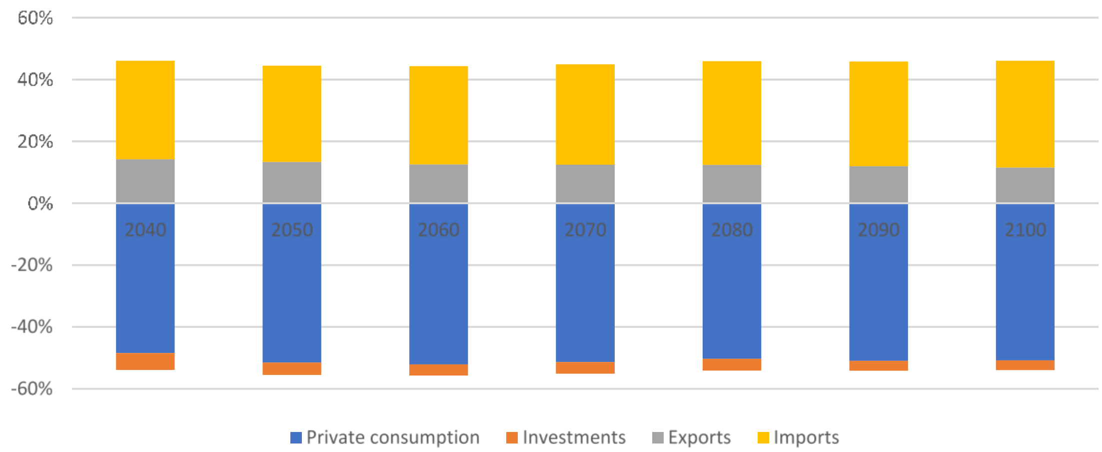
Figure 108: Changes from reference in selected macroeconomic variables (%) – RCP2.6



Source: GEM-E3-ISL

Figure 109: Contribution to GDP changes – RCP2.6



Source: GEM-E3-ISL

Figure 110: Changes from reference in selected macroeconomic variables (%) – RCP8.5

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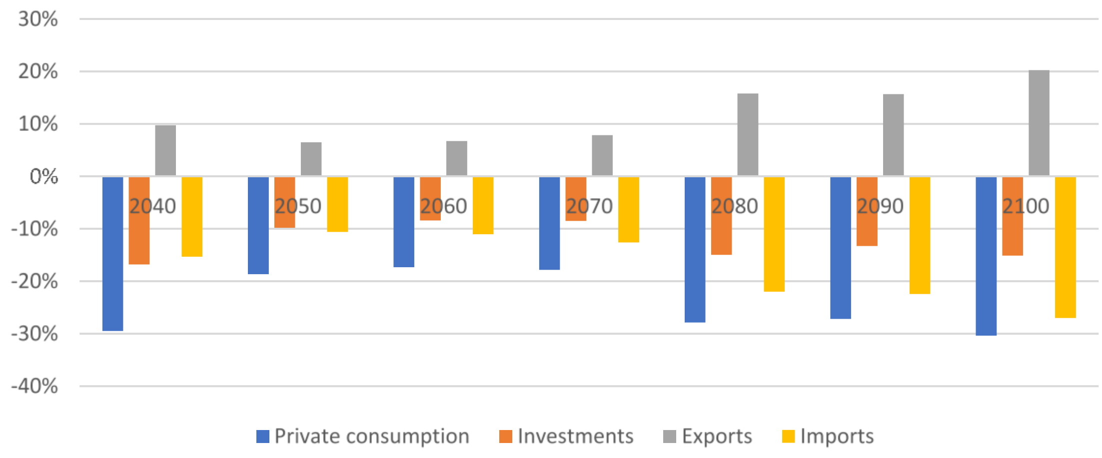
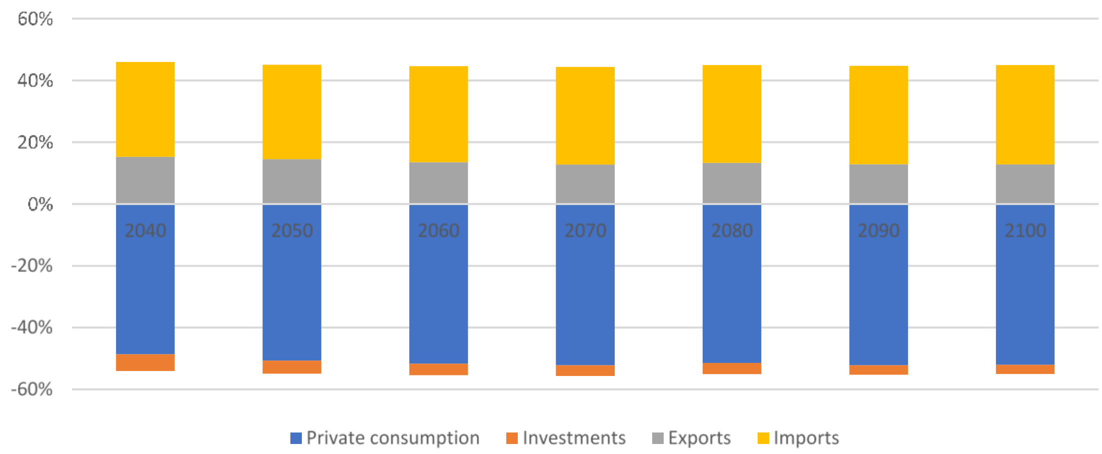


Source: GEM-E3-ISL

Figure 111: Contribution to GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

Decomposing private consumption and investment changes (in both climatic variants) we observe that changes associated to tourism are driving the overall result (Figure 112-Figure 115). Increased electricity demand for water desalination and cooling as well as the infrastructure needs have a positive impact on investments in both climatic variants; however, in the RCP2.6 in the long-run this effect disappears as the electricity increases are significantly lower compared to the period 2045-2100. With respect to private consumption, lower income levels associated to the decreased touristic consumption lead to a decrease compared to the baseline in both variants (by 7.9% in the RCP2.6 and by 23.6% in the RCP8.5 cumulatively over the period 2040-2100).

Figure 112: Changes in private consumption % from reference – RCP2.6

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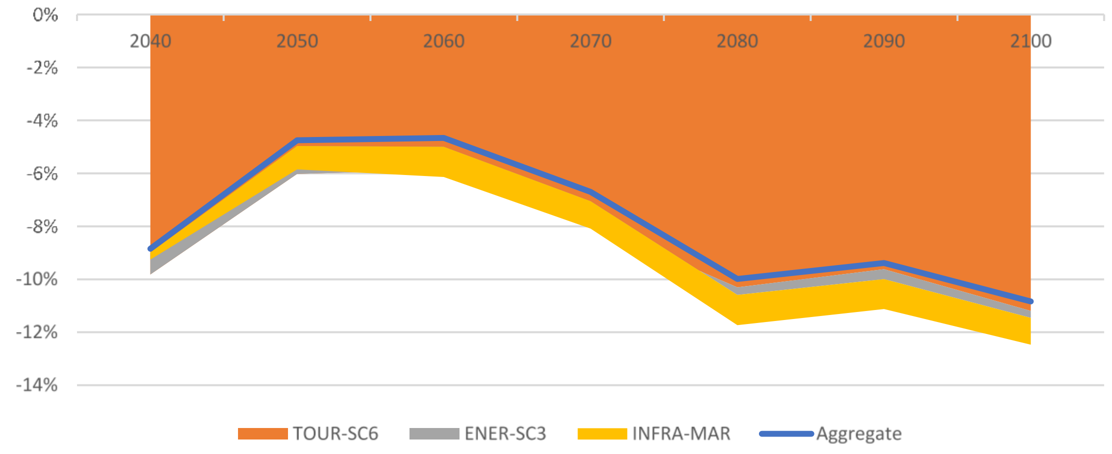
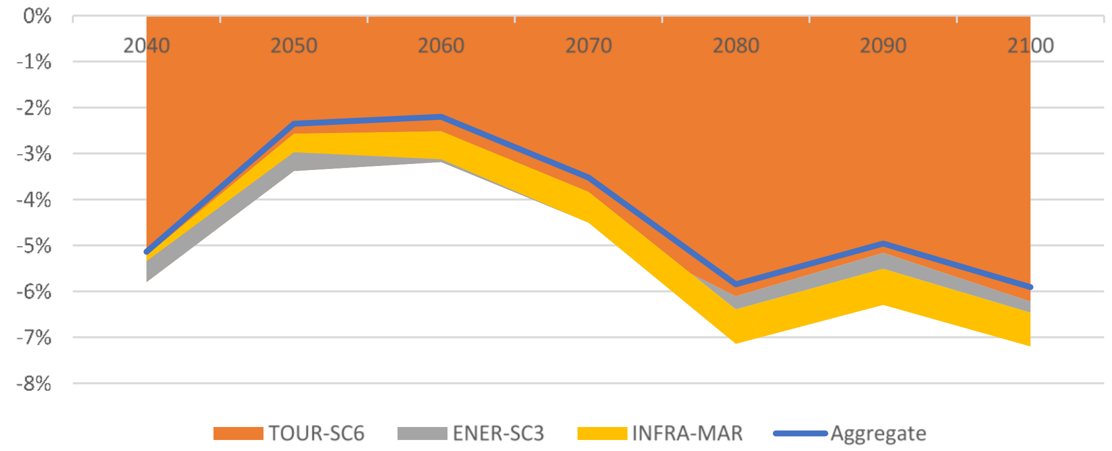


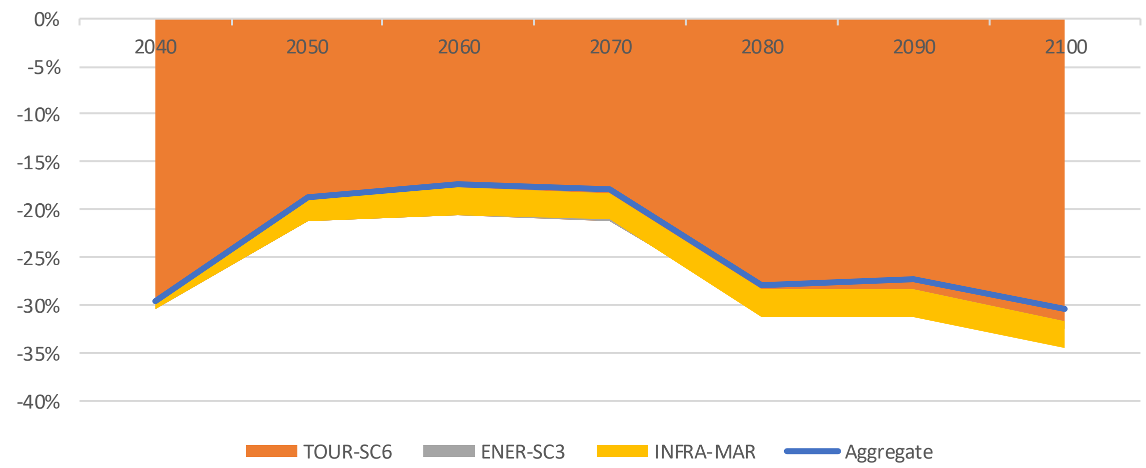
Source: GEM-E3-ISL

Figure 113: Changes in investments % from reference – RCP2.6



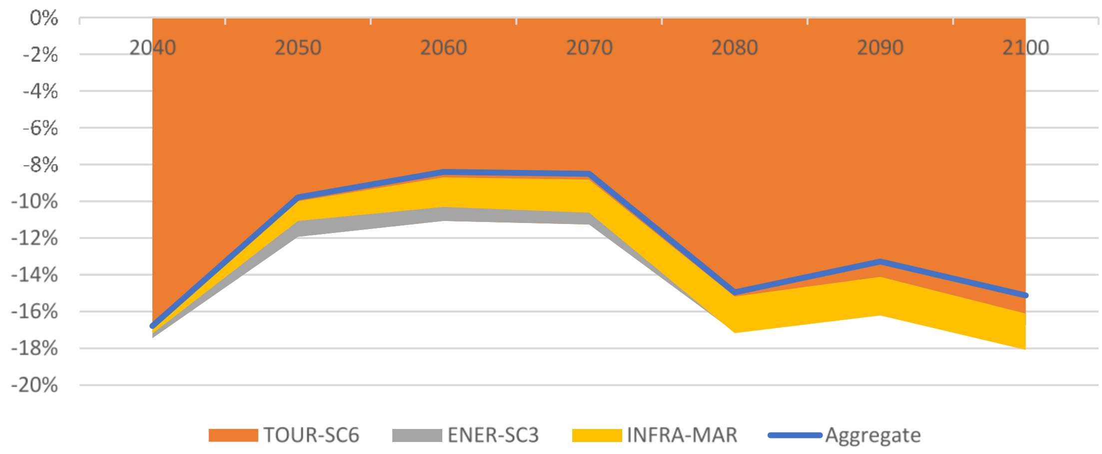
Source: GEM-E3-ISL

Figure 114: Changes in private consumption % from reference – RCP8.55



Source: GEM-E3-ISL

Figure 115: Changes in investments % from reference – RCP8.5



Source: GEM-E3-ISL

3.5.2.1.2 Macroeconomic impacts (tourism)

In Sardinia the tourism industry was responsible for approximately 6% of the regional gross value added in 2015. In the RCP2.6 scenario the cumulative reduction in tourists' expenditure is estimated to be equal to 13.3% (compared to the reference scenario) and in the RCP8.5 scenario equal to 47.1% for the period 2040-2100. In the RCP2.6 variant, the quantification of climate changes to tourism expenditures was performed only for TOUR-SC3 (beach reduction) hence the results of the aggregate scenario and of the sub-scenario coincide. In the RCP8.5, out of the three scenarios examined the variants examining the impacts of beach reduction (TOUR-SC3) and the increased risk of fires (TOUR-SC2) near touristic places are found to have the greatest impact on GDP. In TOUR-SC3, where tourism revenues fall by 22.1% cumulatively over the period 2040-2100 compared to the baseline, GDP contracts by 1.74% cumulatively compared to the baseline, while in the TOUR-SC2, where expenditures of tourists fall by 20.3% cumulative GDP losses are also found to be equal to 1.52% over the examined period. The scenario examining the impacts of marine degradation, includes changes in tourism consumption of approximately -12.4% but are present only in the period after 2080; the effects on GDP for the respective period are found equal to -1.14%. In the composite scenario where the impact of all components is examined, GDP losses are somehow lower and equal to -3.33% over the period 2040-2100 (due to the positive impact of the human comfort – TOUR-SC4-)). Across all climatic and tourism variants, namely RCP2.6 and RCP8.5, a similar pattern with respect to the response of the main macro-economic variables to the implemented shocks is observed: i) private consumption decreases primarily due to the reduced revenues of tourism related activities which lead to lower labor income (by 8.6% and 23% in the RCP2.6 and RCP8.5 respectively), ii) investments decrease relative to their reference levels as a result of lower activity (by 4.7% and 13%) and iii) trade deficits reduce as imports fall (due to the overall decrease of domestic demand) and exports increase (by 4% and 13%); the decreased demand for labor from tourism related industries exerts negative pressure on wages which in turns

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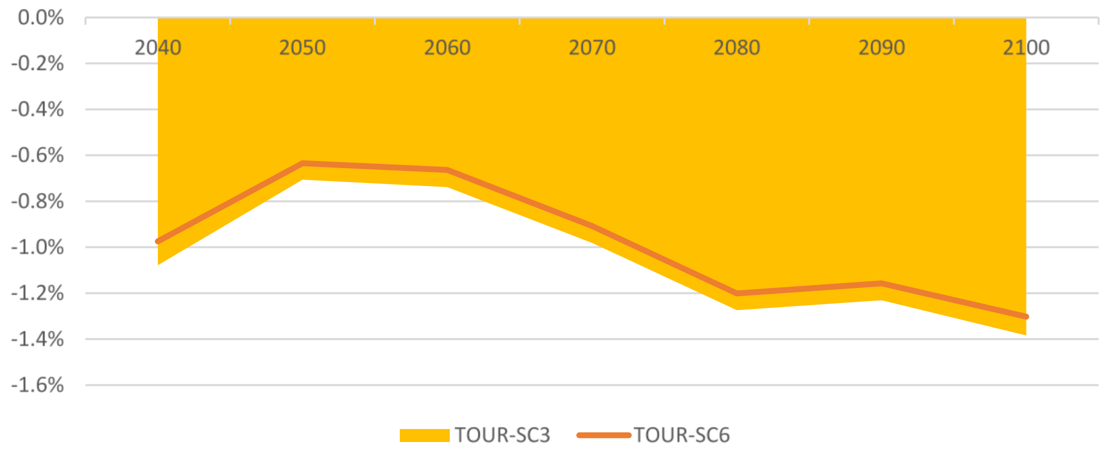
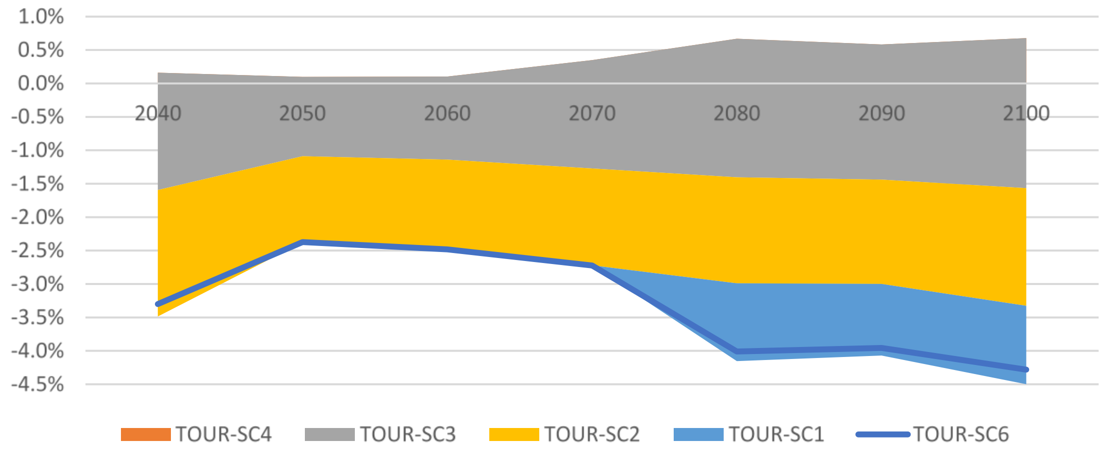
benefit other sectors, mainly those that employ labor intensively.

Figure 116: GDP change relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 117: GDP change relative to the reference (%) – RCP8.5



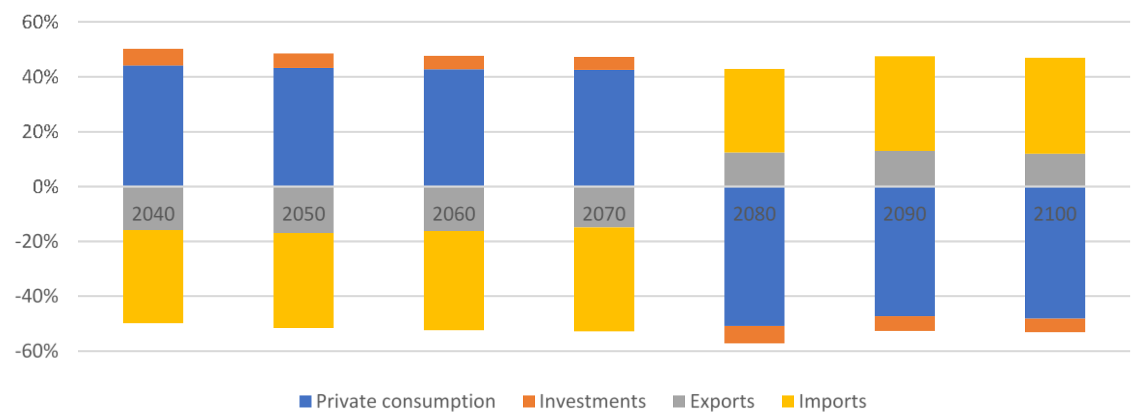
Source: GEM-E3-ISL

3.5.2.1.3 Macroeconomic impacts (energy)

The increased demand for electricity is found to have negative impacts on the economy of Sardinia compared to the reference case. The increase in the cooling degree days implies higher utilization rate of cooling systems, mainly from tertiary activities and from households. From the household's perspective this translates into higher consumption per utility level, while for firms it implies higher electricity input per unit of output. To the extent that electricity comes at higher costs, the impact on the economy is negative as the disposable income for other goods and services decrease, while production costs are driven upwards and domestic products lose their competitiveness compared to imported ones.

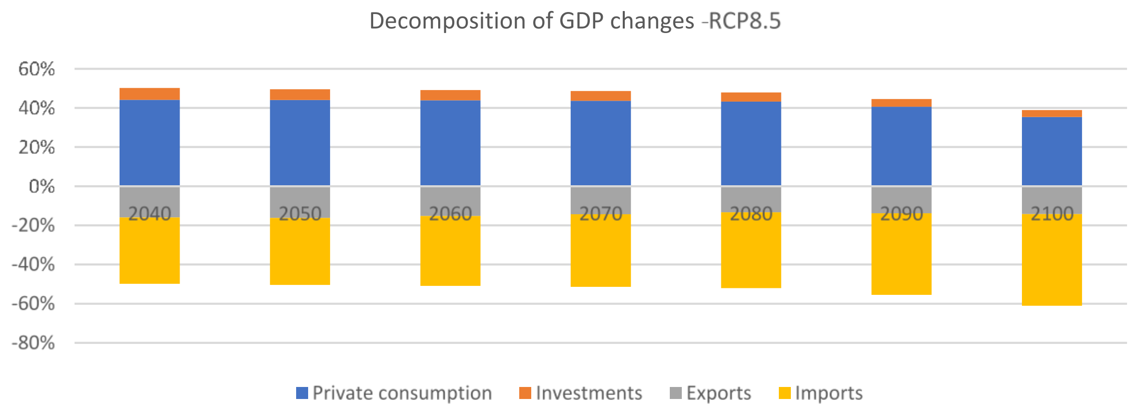
Sardinia's electricity system is interconnected to Italy, which implies that a part of the increased demand will be satisfied by imported electricity while the rest will be handled by the domestic electricity network. Investments increase in both climatic variants, although in the RCP2.6 this effect is present only in the period up to 2070 as afterwards the foreseen additional electricity needs are much lower (10.5% vs 3.1%).

Figure 118: Decomposition of GDP changes (%) – RCP2.6



Source: GEM-E3-ISL

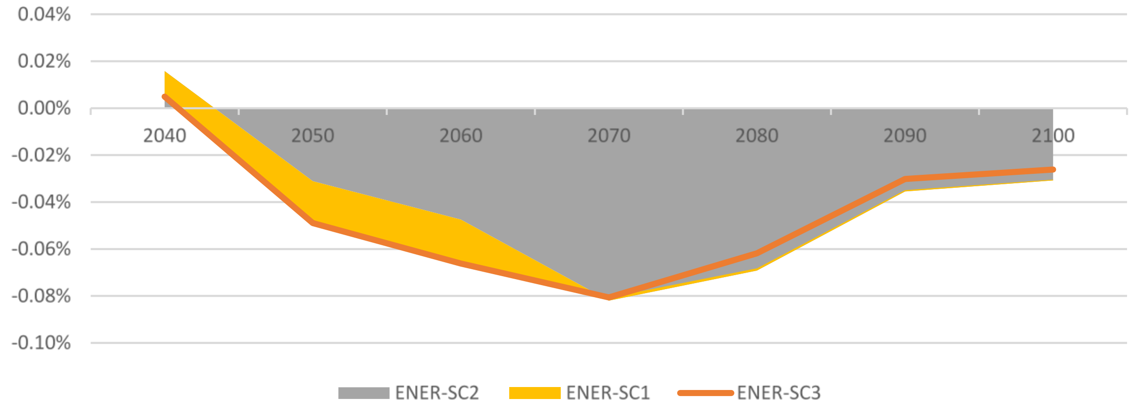
Figure 119: Decomposition of GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

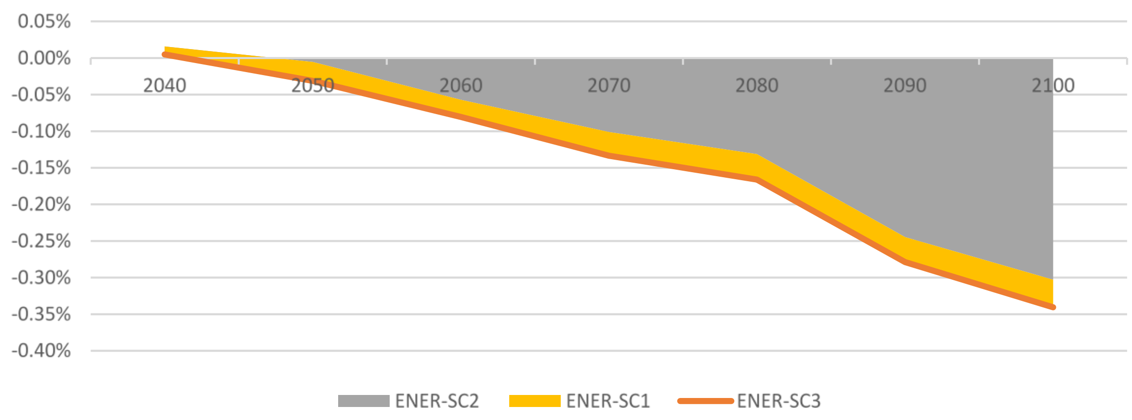
From the two energy-related scenarios examined the effects are more pronounced in the cooling scenario as it foresees higher electricity consumption in both variants compares to the electricity consumption for desalination purposes.

Figure 120: GDP changes relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 121: GDP changes relative to the reference (%) – RCP8.5

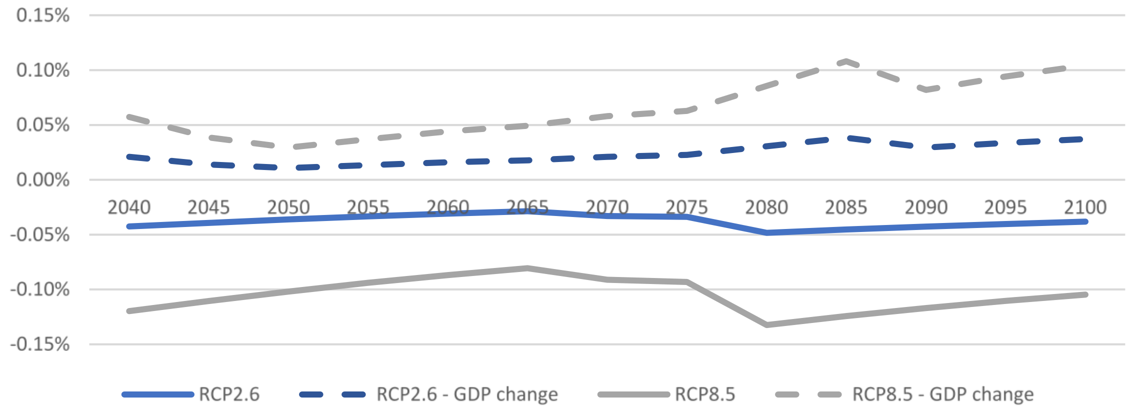


Source: GEM-E3-ISL

3.5.2.1.4 Macroeconomic impacts (maritime)

In this scenario the effect of infrastructure damages is assessed and more specifically those associated to ports and port facilities. Infrastructure damages, one the one hand increase the financing requirements of the economy and stress the capital markets leading to increased capital costs, hence there is a negative impact on the economy. On the other hand, increased investments influence positively domestic activity, as the construction sector which is intensively engaged in the realization of investments employs intensively domestic resources, softening the effect of infrastructure damages.

Figure 122: Capital losses (% of GDP)



Source: GEM-E3-ISL, D5.6

The scenario assessment shows that GDP increases by 0.01% on average for the period 2040-2065 and by 0.03% for the period 2080-2100 in the RCP2.6; the respective figures for the RCP8.5 are 0.04% and 0.10%. The positive effects are attributed to the increased investments; the sectors actively engaged in the realization of investments are characterized by low import intensity (e.g. construction). Hence increased employment leads to higher income for households and consumption.

3.5.2.2 Sectorial results

The simulation results of the abovementioned scenarios indicate that the sectors with that experience the steepest decrease, in terms of activity levels, are those associated to the delivery of services to tourists as well as construction (the activity of which is very tightly related to investments). On the tourism side, in both climatic variants activity levels of related industries fall relative to the baseline; in the RCP8.5 this effect is significantly higher due to the magnitude of the simulated changes. In the RCP8.5 scenario electricity requirements continue to grow throughout the simulation compared to the RCP2.6 where the foreseen increases in electricity demand dwindle over the long-term.

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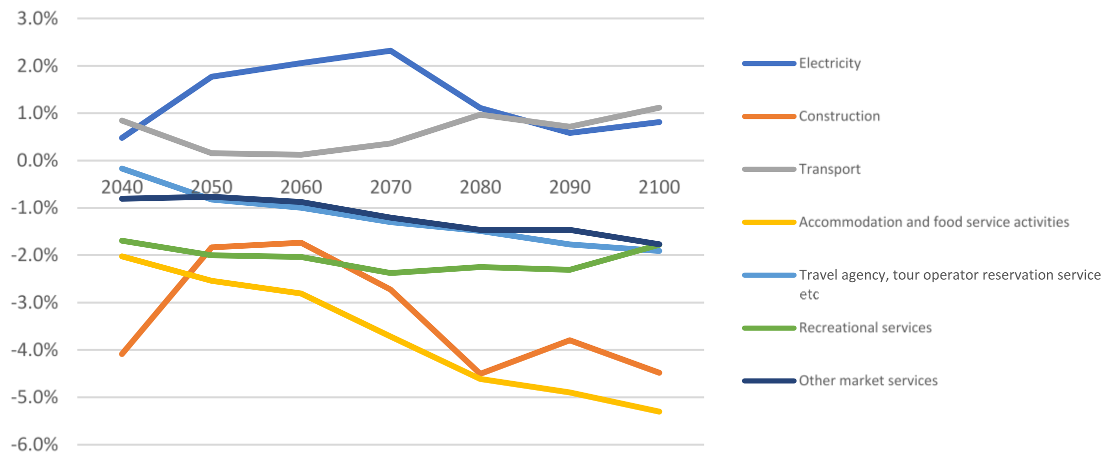
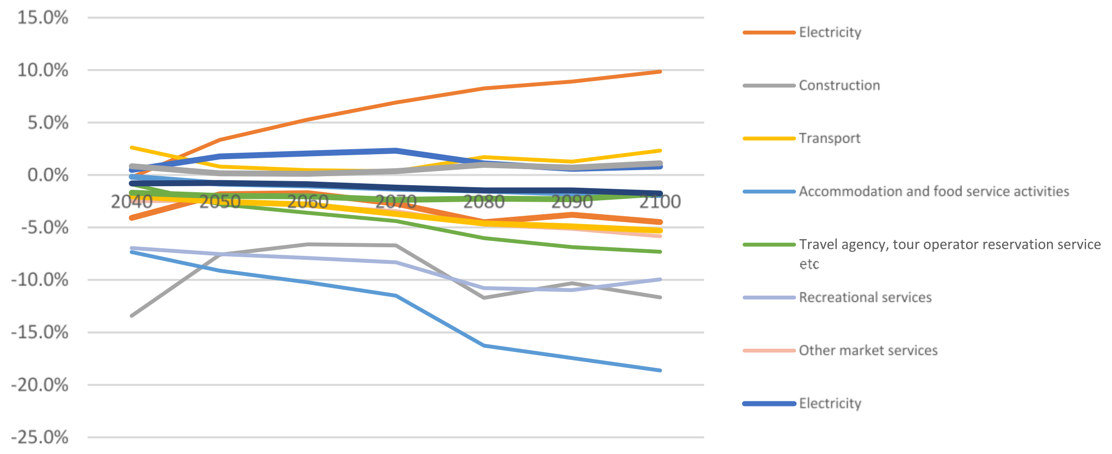
Figure 123: Sectorial activity (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 124: Sectorial activity (% from the reference) – RCP8.5



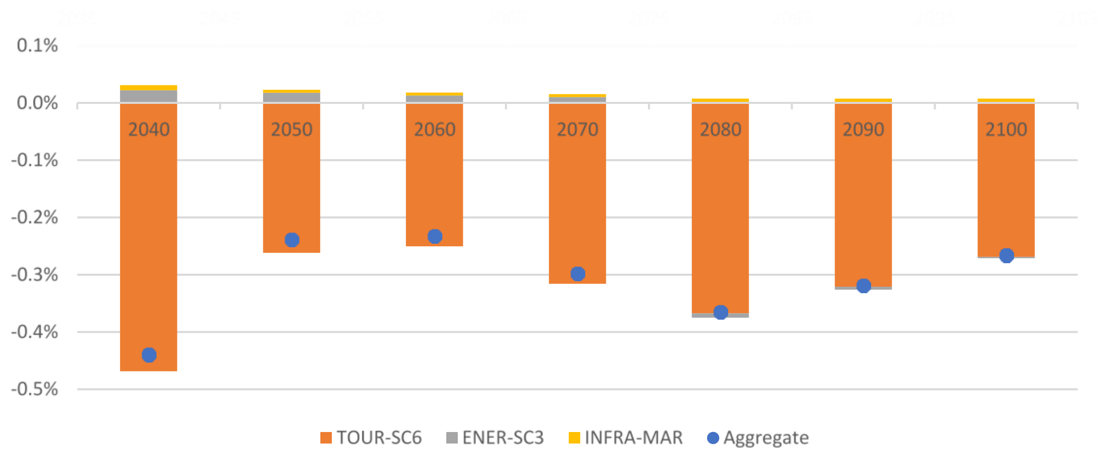
Source: GEM-E3-ISL

3.5.2.3 Labor market

With respect to the labor market developments, the simulation shows decreased employment levels in both variants. Employment impacts are higher in 2040 and in 2080 (i.e. the first years of the *near* and *long* period respectively). The effects on the activity of the core tourism industries[22] decreases by 3.3% on average in the RCP2.6 and by 13% in the RCP8.5.

Figure 125: Employment (% from the reference) – RCP2.6

[22] Accommodation and restaurants, travel agencies, recreational activties



Source: GEM-E3-ISL

Figure 126: Employment (% from the reference) – RCP8.5

Source: GEM-E3-ISL

3.5.3 GWS RESULTS

3.5.3.1 Macroeconomic

Sardinia belongs to the islands in the medium range of economic damages from climate change. Private consumption goes down by 2.2% in 2050 in the RCP 2.6 scenario and by almost 8% in the RCP 8.5. This contributes largely to the losses in GDP, which amount to over 3% and over 7% respectively. The negative trade balance increases, also, since transport costs due not increase largely from damages to Maritime transport. Sardinia needs to invest in the energy sector and suffers from tourism losses.

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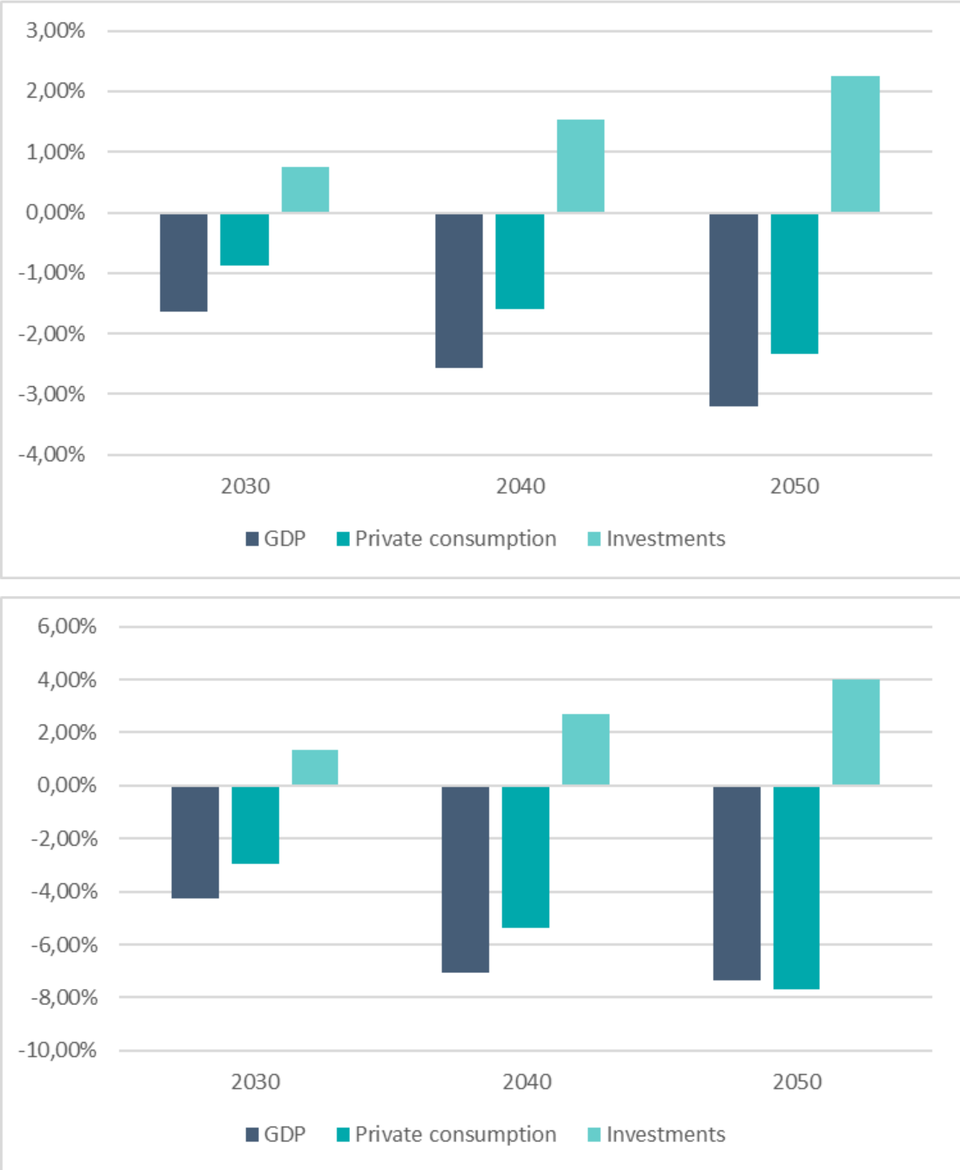
Figure 127: Sardinia: Components of GDP, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5

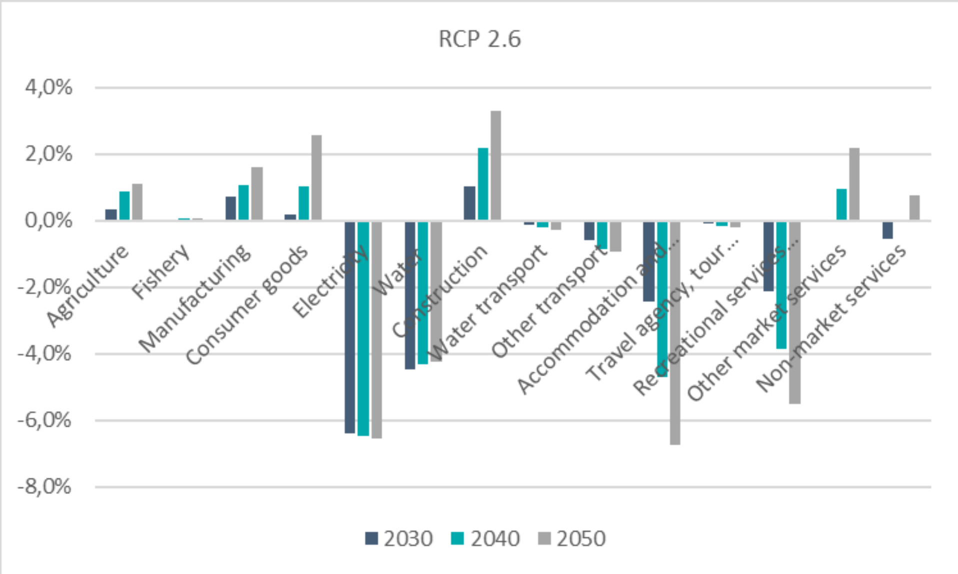


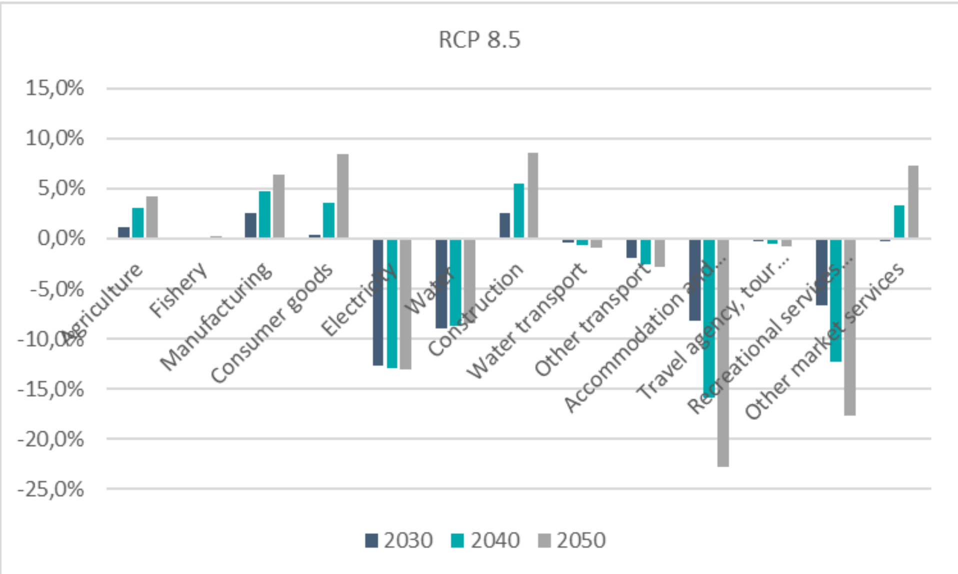
Source: GWS, own calculation.

3.5.3.2 Sectorial results

Most value-added effects in Sardinia are negative, construction being the largest exemption. Infrastructure investment contributes to the increase in value added in the construction sector. Some spillovers from this additional activity can be observed, but they are small compared to the damages, for instance from the losses of tourism or from price increase in the transport sector.

Figure 128: Sardinia: Value added by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation.

3.5.3.3 Labor market

On the Sardinian labor markets, all effects turn into negative, except for the almost non-detectable additional jobs in construction. The small manufacturing sector suffers indirectly from losses in value and turnover in the travel related sectors. In the service sectors, value added increases slightly and jobs are lost. This points to higher overall price levels, mainly from energy and transport.

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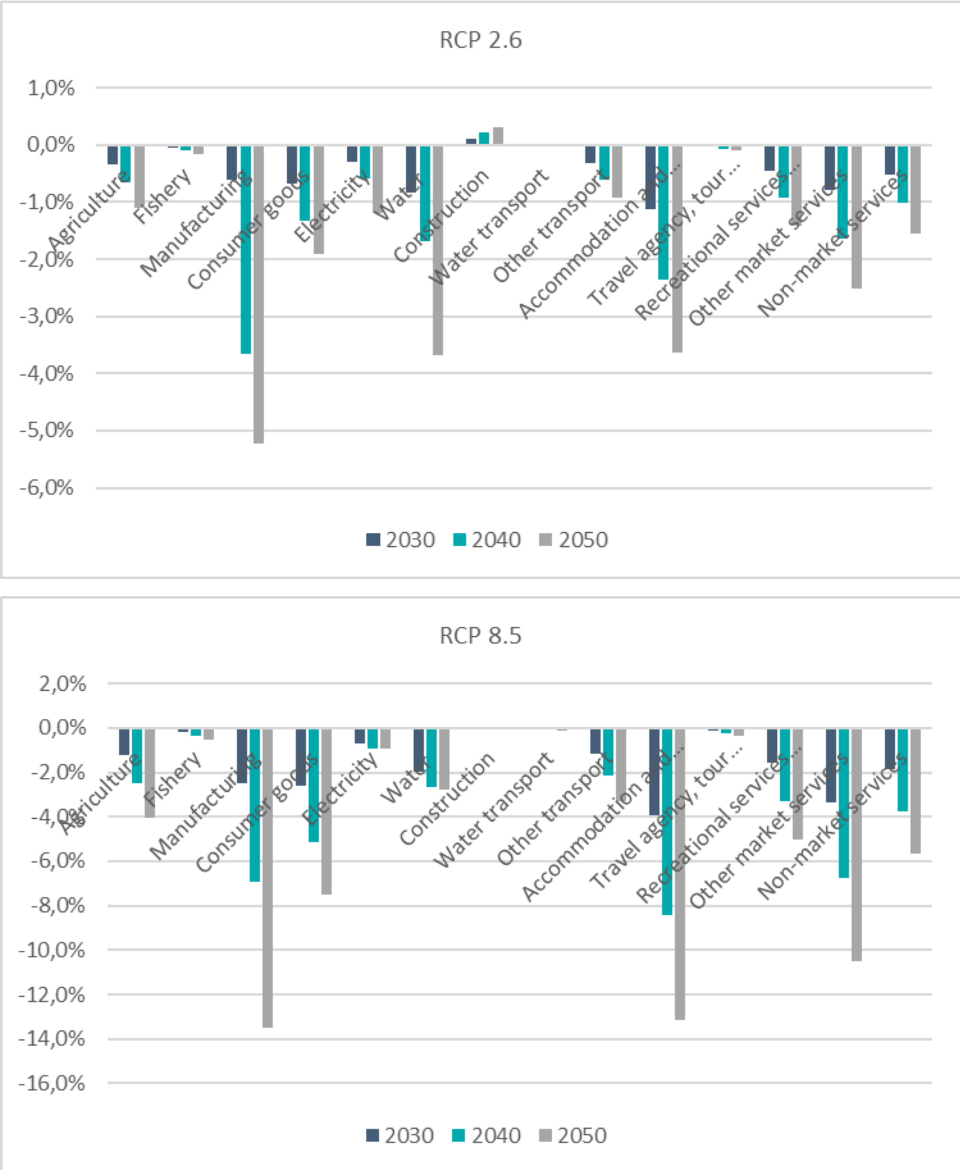
Figure 129: Sardinia: Employment by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5



Source: GWS, ow n calculation.

3.6 SICILY

3.6.1 SCENARO DEFINITION

The first type of scenarios examines the impact of climate change on tourism by assuming different expenditures by tourists due to biophysical climate impacts on the natural environment and temperatures. In particular, the changes in touristic demand are directly linked to the perception of tourists regarding certain features such as beach surface, the marine environment, the risk of forest fires and warmer conditions and depend on how these features are

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impacted by climate change. The second set of scenarios refers to changes in electricity consumption due to increased cooling demand and water availability. Finally, the third set of scenarios refers to infrastructure damages, specifically to port infrastructure, due to sea level rise.

The impact of climate changes on tourists' spending, electricity demand and capital losses are estimated in D5.6 and are used as inputs for the scenario simulations as described in the Methodology Section. The GEM-E3-ISL model assesses their impacts on the main macroeconomic variables (GDP, private consumption, investments, exports and imports), sectorial activity and employment. The inputs provided by D5.6 and incorporated in GEM-E3-ISL for Sicily are described in the following tables:

Table 17: Changes in tourists' expenditures with respect to the reference case (%)

	TOUR -SC1 (marine environment)	TOUR -SC2 (forest fire)	TOUR -SC3 (beach reduction)	TOUR -SC4 (thermal comfort)	TOUR -SC5 (V-disease)	TOUR –SC6 (aggregate)
RCP2.6 near	0	0	-6.86	-0.38	0	-7.24
RCP2.6 distant	0	0	-9.72	-0.34	0	-10.06
RCP8.5 near	0	0	-13.44	-0.32	0	-13.76
RCP8.5 distant	-7.94	-13.03	-17.44	0.03	0	-38.44

Table 18: Changes in electricity consumption with respect to the reference case (%)

	ENER -SC1 (desalination)	ENER -SC2 (cooling)	ENER –SC3 (aggregate)
RCP2.6 near	1.3	9.2	10.5
RCP2.6 distant	1.3	1.8	3.1
RCP8.5 near	3.0	22.3	25.3
RCP8.5 distant	7.3	36.5	43.5

Table 19: Damages of port infrastructure (% of GDP)

	INFRA-MAR
RCP2.6 near	-0.04
RCP2.6 distant	-0.04
RCP8.5 near	-0.10
RCP8.5 distant	-0.12

3.6.2 GEM-E3-ISL RESULTS

3.6.2.1 Macroeconomic

3.6.2.1.1 Full scenario macroeconomic impacts

The estimated cumulative GDP impacts of the composite scenario equal to -0.54% for the RCP2.6 (Figure 130) and -2.6% for the RCP8.5 (Figure 131-Figure 130) over the period 2040-2100. In both climatic variants the simulated changes are found to have negative impact on the economy; these impacts are more pronounced in the RCP8.5 where tourism decline is steeper and electricity needs increase substantially. Comparing the time profile of the estimated impacts between the two variants (RCP2.6 and RCP8.5) we observe that while in the RCP8.5 the effects intensify over time (i.e. the cumulative GDP impacts are equal to -1.05% in the *near* period and -4.4% in the *long* period), in the RCP2.6 GDP impacts peak around 2070 and then weakens mainly due to the -lower- foreseen electricity increases (in the *near* period cumulative GDP impacts are equal to -0.45% while in the *long* period these are equal to -0.51%).

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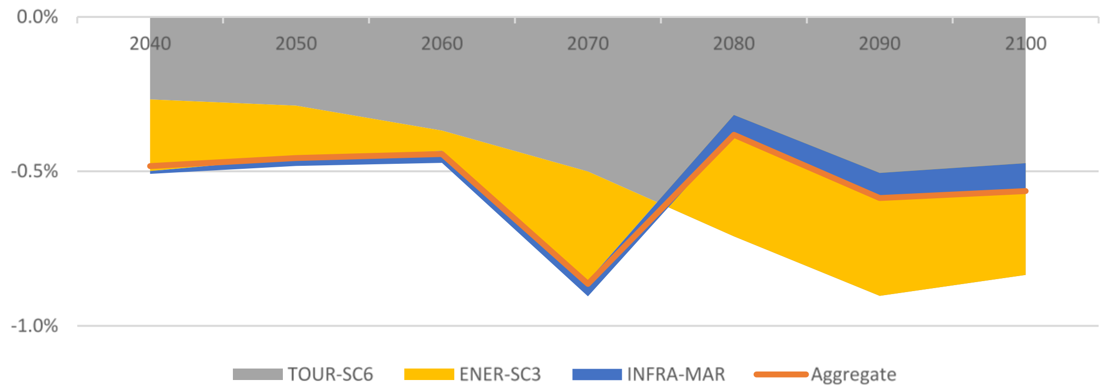
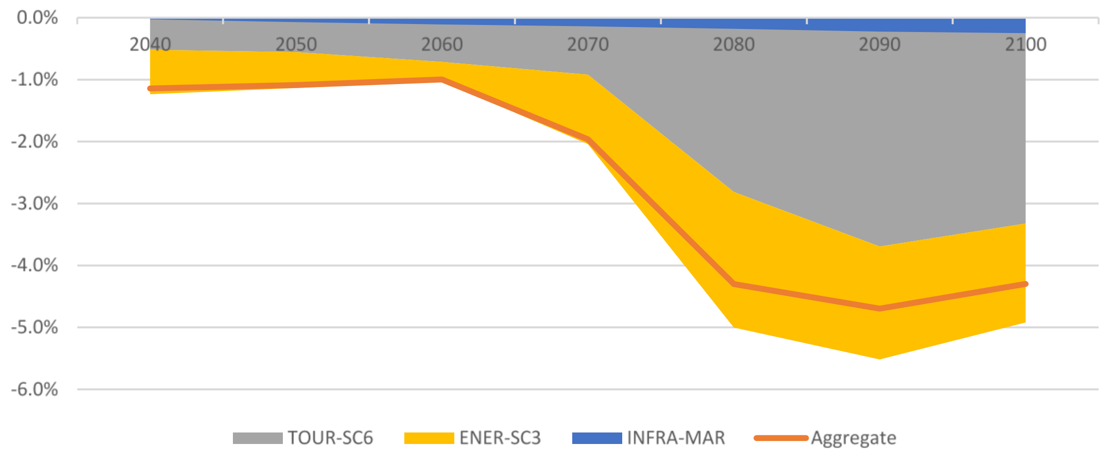
Figure 130: GDP changes from reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 131: GDP changes from reference (%) – RCP8.5



Source: GEM-E3-ISL

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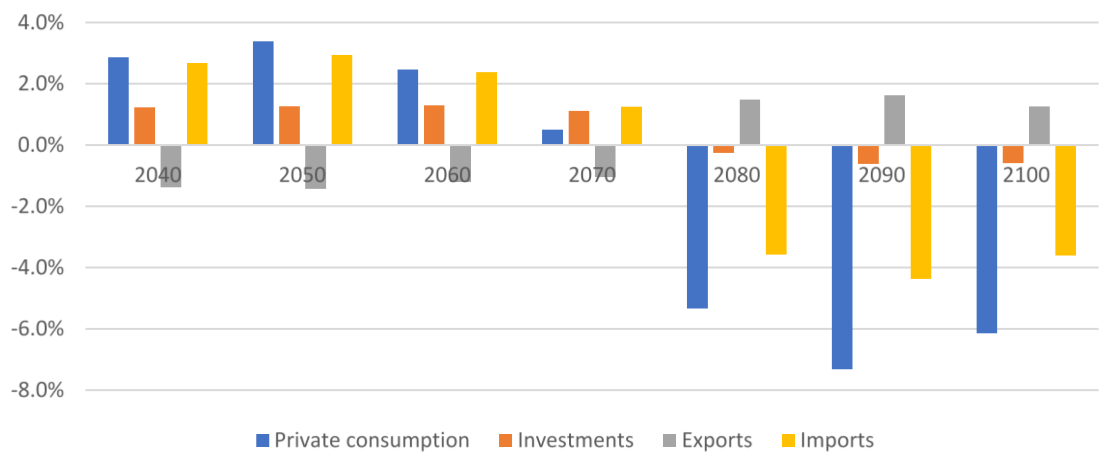
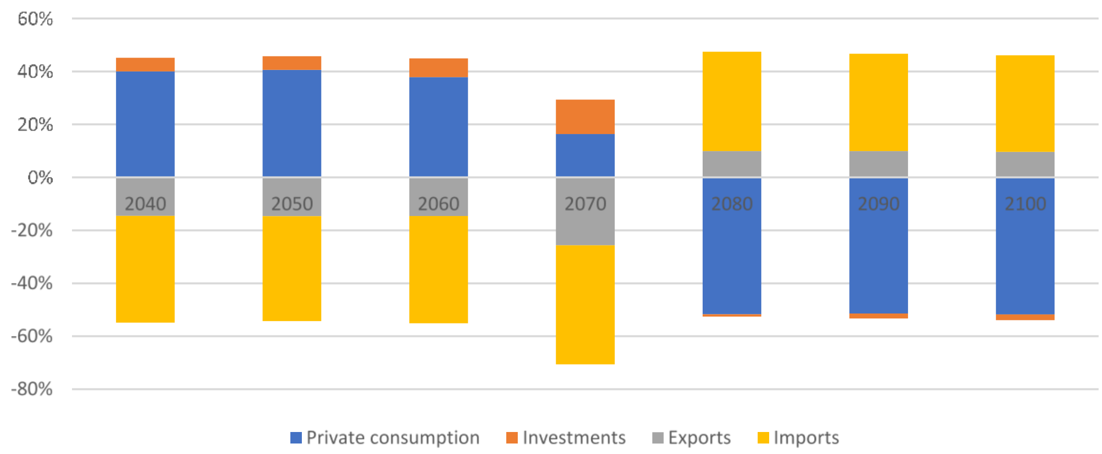
Looking further into, the response of the main macroeconomic, we note that investments increase in both variants in the period between 2045-2070 due to the increased electricity demand while the trend continues in the RCP8.5 until 2100. On the contrary in the RCP2.6 investments decrease in the period after 2070 as the electricity increases are lower compared to the previous period and the no additional capacity is required to satisfy the additional electricity demand. With respect to household consumption we observe a similar pattern between the two variants, as private expenditures increase in the medium-run (up to 2070) due to the higher electricity consumption and the fall as tourism impacts intensify. The reduced expenditure of tourists results in lower demand for tourism related sectors, which leads to lower labor and capital earnings. Household demand has negative repercussions for the level of imports which fall (slightly) relative to their reference levels. Finally, with regards to exports, there are two countervailing forces: in the tourism scenario exports tend to increase as the prices of domestic primary production factors, hence production costs, fall as result of the lower activity while in the energy scenario increased electricity demand hinders competitiveness as the price of electricity needs increase driven upwards.

Figure 132: Changes from reference in selected macroeconomic variables (%) – RCP2.6



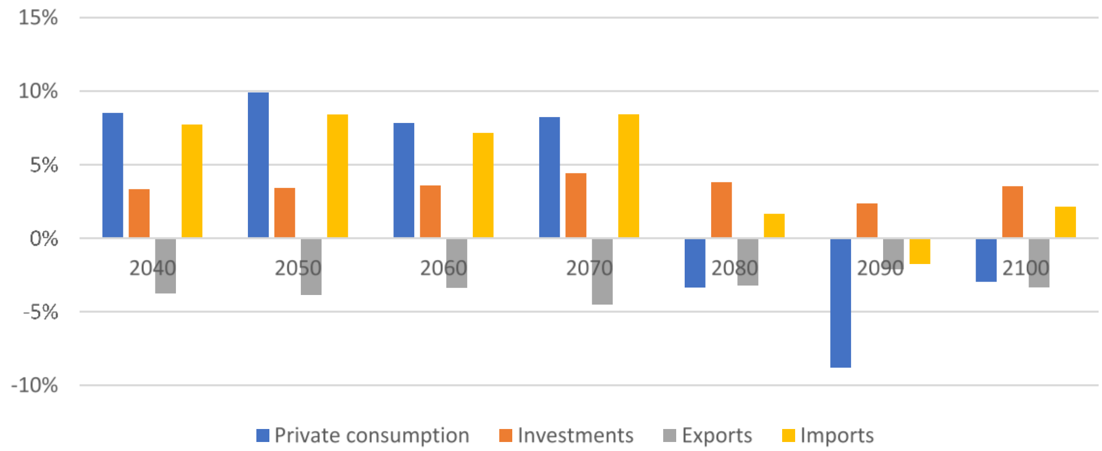
Source: GEM-E3-ISL

Figure 133: Contribution to GDP changes – RCP2.6



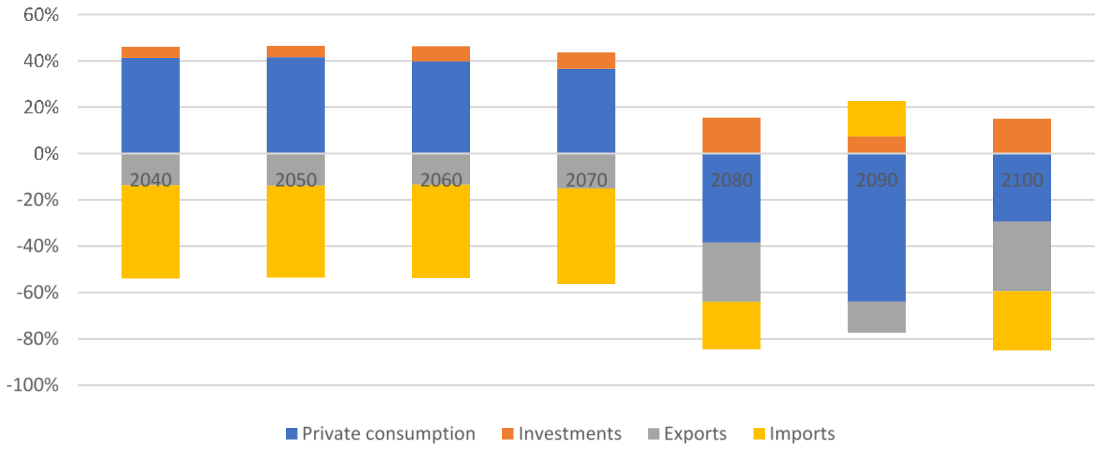
Source: GEM-E3-ISL

Figure 134: Changes from reference in selected macroeconomic variables (%) – RCP8.5



Source: GEM-E3-ISL

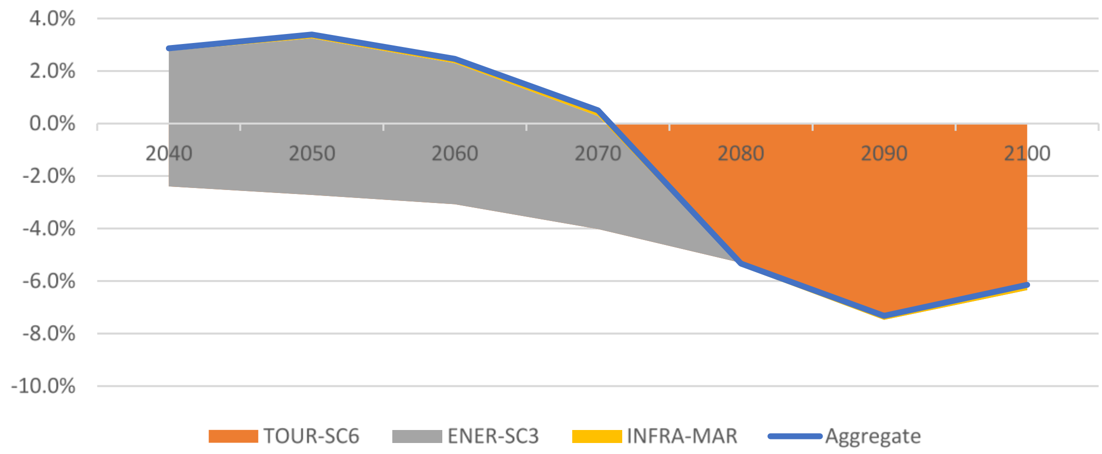
Figure 135: Contribution to GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

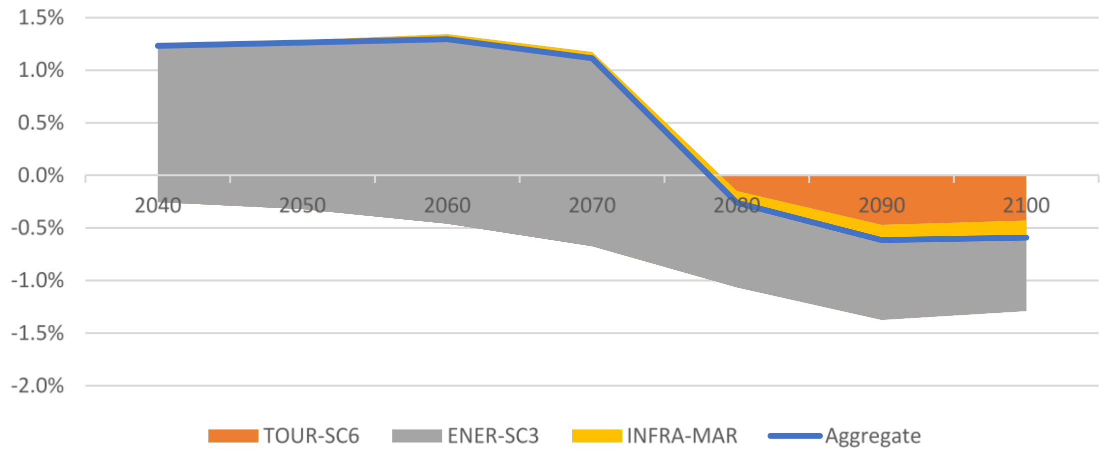
Decomposing private consumption and investment changes (Figure 136-Figure 138) we find that increased electricity demand for water desalination and cooling has a positive impact on increased investments due to the expansion of power generation facilities while in terms of private consumption, increases in the RCP8.5 are associated to higher electricity expenditures but in the *long* term income losses associated to the contract of the tourism industry lead to a decrease in the overall level of household consumption compared to the baseline.

Figure 136: Changes in private consumption % from reference – RCP2.6



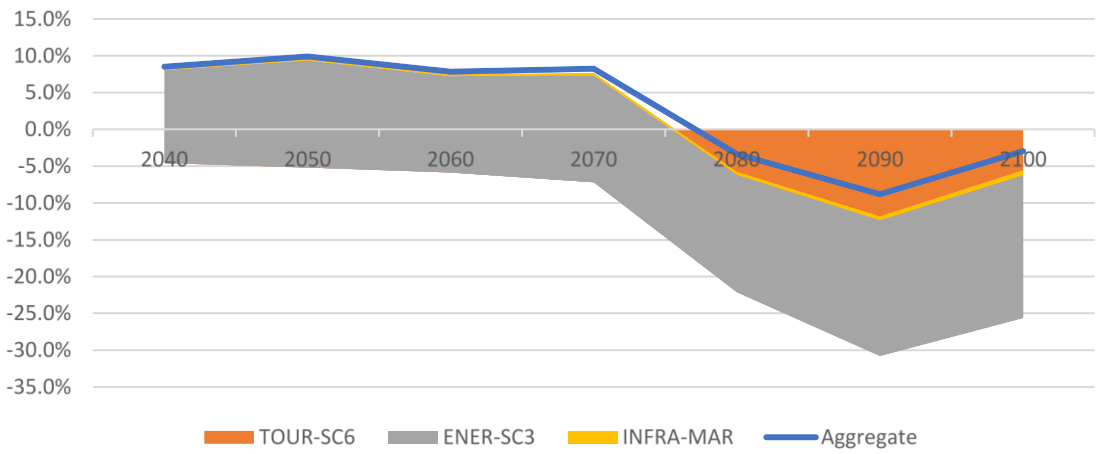
Source: GEM-E3-ISL

Figure 137: Changes in investments % from reference – RCP2.6



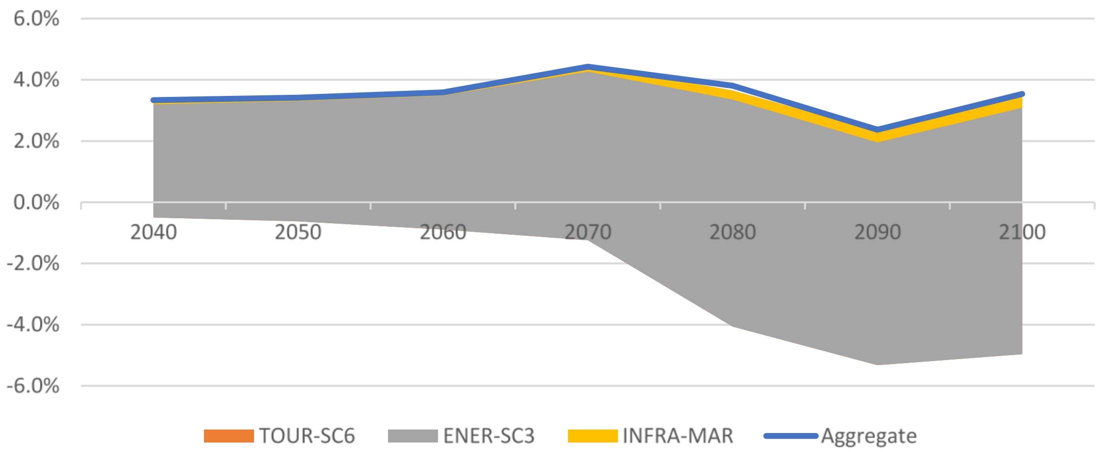
Source: GEM-E3-ISL

Figure 138: Changes in private consumption % from reference – RCP8.5



Source: GEM-E3-ISL

Figure 139: Changes in investments % from reference – RCP8.5

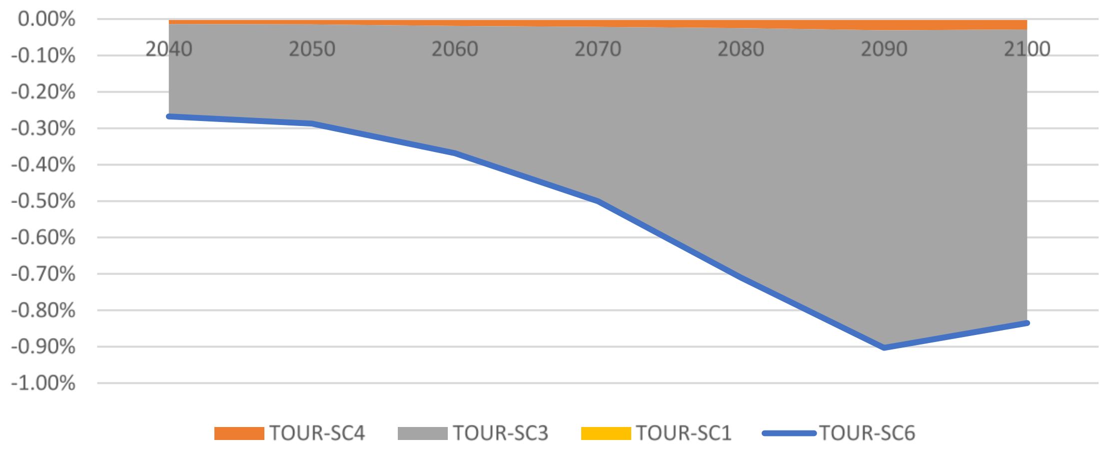


Source: GEM-E3-ISL

3.6.2.1.2 Macroeconomic impacts (tourism)

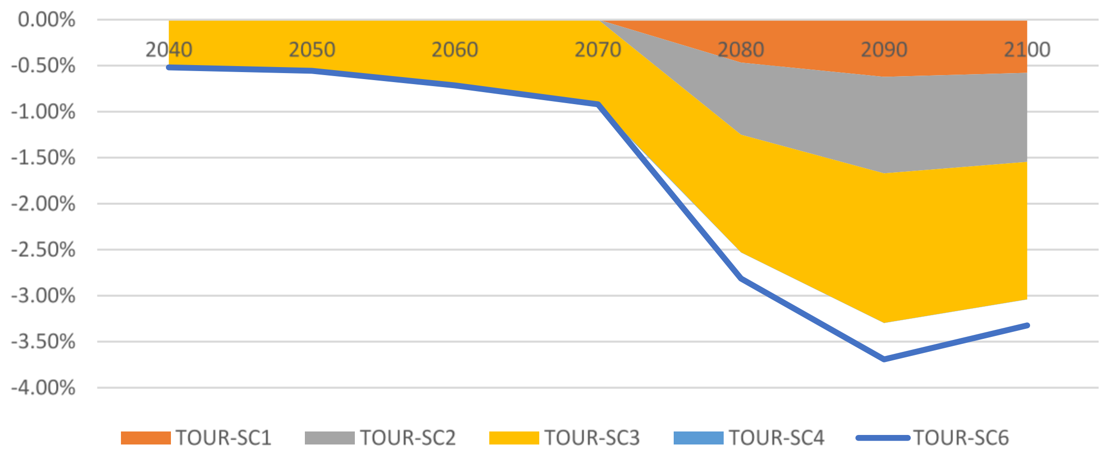
In Sicily the tourism industry was responsible for approximately 6% of the regional gross value added in 2015. In the RCP2.6 scenario the cumulative reduction in tourists' expenditure is estimated to be equal to 8.8% (compared to the reference scenario) and in the RCP8.5 scenario equal to 25.6% for the period 2040-2100. In the RCP2.6 variant, the quantification of climate changes to tourism expenditures was performed only for TOUR-SC3 (beach reduction) hence the results of the aggregate scenario and of the sub-scenario coincide. In the RCP8.5, out of the three scenarios examined the variant examining the impacts of beach reduction are found to have the highest effect on the regional economy (cumulative GDP contracts by -1.03% over the period 2040-2100), followed by the variant examining the increased risk of forest fires (-0.40%) and finally the one assuming a degradation of the marine environment (-0.24%). In the composite scenario examining the aggregate effect of all tourism-related impacts on the economy, GDP losses are somehow higher and equal to -1.80%. Across all climatic variants, namely RCP2.6 and RCP8.5, and across all tourism variants examined, a similar pattern with respect to the response of the main macro-economic variables to the implemented shocks is observed: i) private consumption decreases primarily due to the reduced revenues of tourism related activities which lead to lower labor income (by 4.6% and 15.8% in the RCP2.6 and RCP8.5 respectively), ii) investments decrease relative to their reference levels as a result of lower activity (by 0.8% and 2.6%) and iii) trade deficits reduce as imports fall (due to the overall decrease of domestic demand) and exports increase (by 0.9% and 3.5%); the decreased demand for labor from tourism related industries exerts negative pressure on wages which in turns benefit other sectors, mainly those that employ labor intensively.

Figure 140: GDP change relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 141: GDP change relative to the reference (%) – RCP8.5



Source: GEM-E3-ISL

3.6.2.1.3 Macroeconomic impacts (energy)

The increased demand for electricity is found to have negative impacts on the economy of

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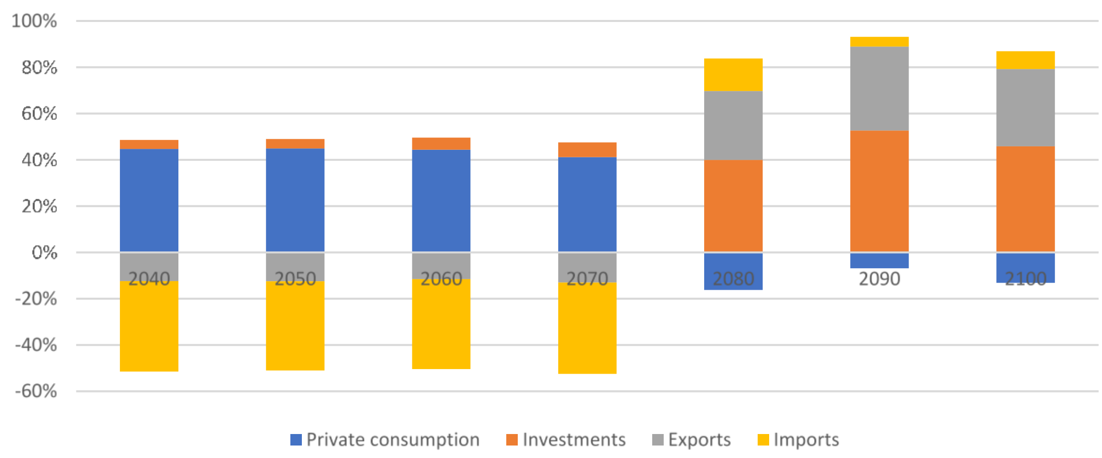
Sicily compared to the reference case. In reality, an increase in the cooling degree days would require the purchase of additional cooling equipment as well as a higher utilization of existing cooling systems. From the household's perspective this is equivalent to higher consumption of electricity per utility level, while for firms it implies higher electricity input per unit of output. To the extent that electricity comes at higher costs, the impact on the economy is negative as the income available for the consumption of other goods and services decrease, while production costs are driven upwards and the competitiveness of domestic products deteriorates.

The Sicilian electricity system is interconnected to Italy's electricity grid, which implies that increased electricity demand will be partly satisfied by imports (electricity imports increase by 6.3% and 34.1% in the RCP2.6 and in the RCP8.5 respectively over the period 2040-2100), while the rest will be handled by the domestic electricity network. To do so, additional investments to increase capacity are needed and the activity of sectors actively engaged in the realization of investment projects, such as construction and market services, increases.

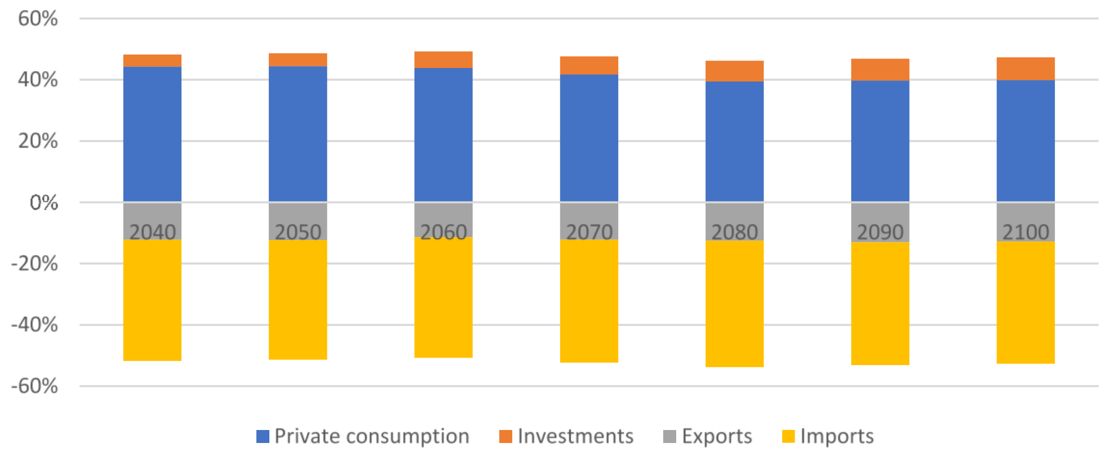
In the RCP2.6 the estimated electricity needs are lower in the long-run compared to the medium run (3.1% vs 10.5% compared to the baseline case), and the negative pressure of electricity prices on production cost is alleviated.

Figure 142: Decomposition of GDP changes (%) – RCP2.6



Source: GEM-E3-ISL

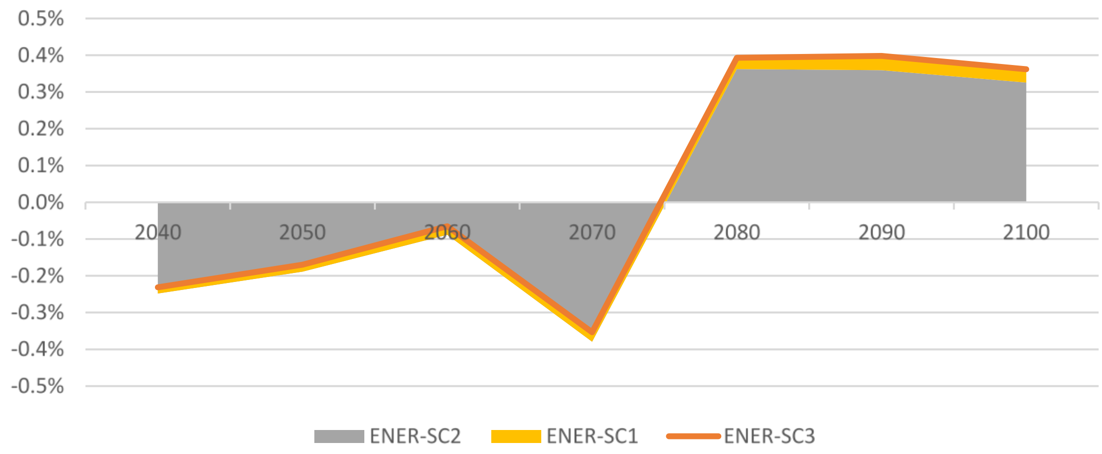
Figure 143: Decomposition of GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

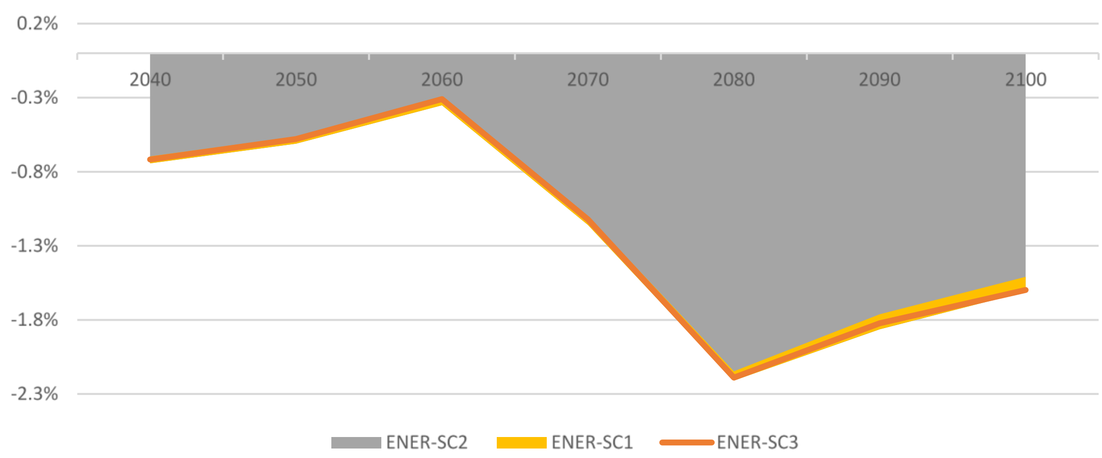
From the two energy-related scenarios examined the effects are more pronounced in the cooling scenario as it foresees higher electricity consumption in both variants compares to the electricity consumption for desalination purposes.

Figure 144: GDP changes relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 145: GDP changes relative to the reference (%) – RCP8.5

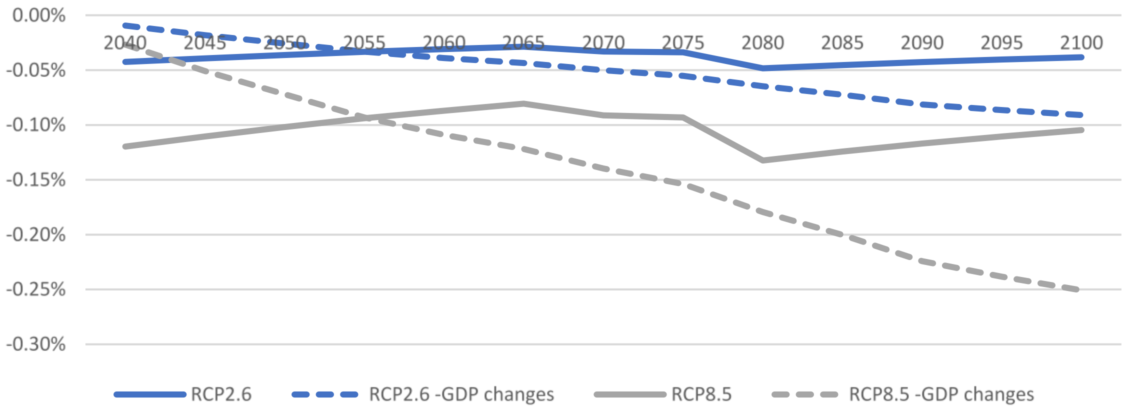


Source: GEM-E3-ISL

3.6.2.1.4 Macroeconomic impacts (maritime)

In this scenario the effect of infrastructure damages is assessed and more specifically those associated to ports and port facilities. Infrastructure damages, one the one hand increase the financing requirements of the economy and stress the capital markets leading to increased capital costs, hence there is a negative impact on the economy. On the other hand, increased investments influence positively domestic activity, as the construction sector which is intensively engaged in the realization of investments employs intensively domestic resources, softening the effect of infrastructure damages.

Figure 146: Capital losses (% of GDP)



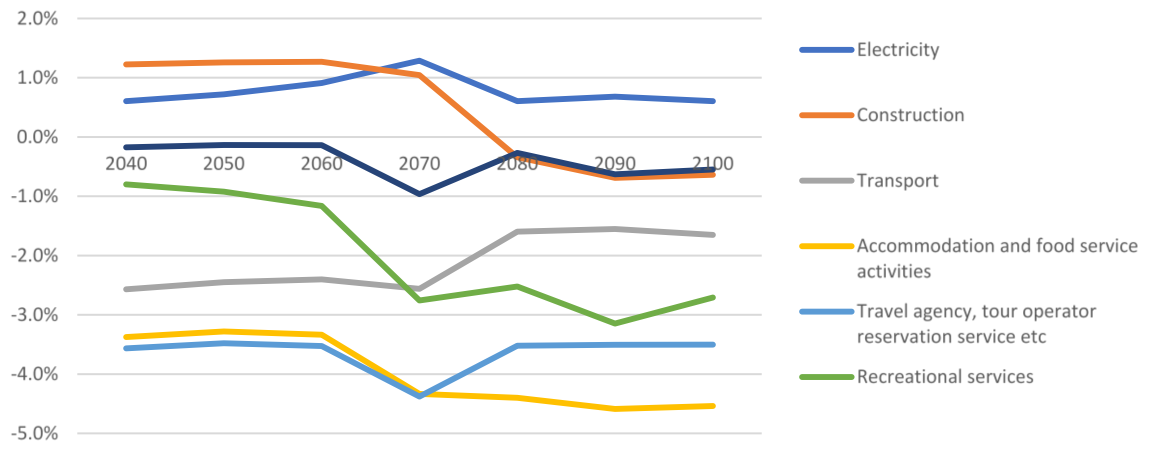
Source: GEM-E3-ISL

The scenario results indicate that GDP contracts by 0.03% on average for the period 2040-2065 and by 0.08% for the period 2080-2100 in the RCP2.6; the respective figures for the RCP8.5 are 0.08% and 0.22%. Looking closer at the time profile of the simulation results, we observe that the impacts on GDP are more pronounced in the long-run as capital losses are additive; capital losses exert upward pressure in the markets of primary production factors, leading to increases in wages (due to the substitution effect) and capital rents. In turn, this has a negative impact on the export performance of the economy and domestically produced goods are substituted by cheaper imported products (total imports increase).

3.6.2.2 Sectorial results

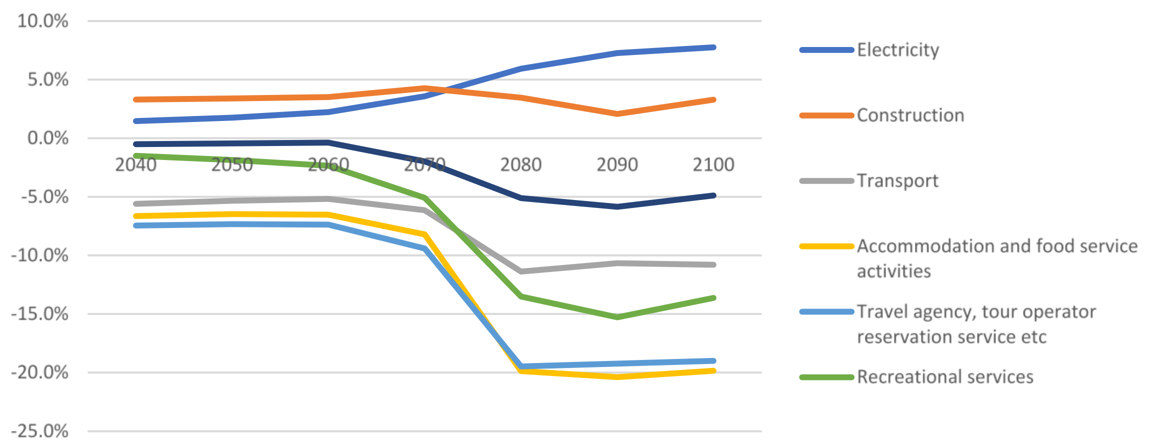
The simulation results of the abovementioned scenarios indicate that the sectors with that experience the steepest decrease, in terms of activity levels, are those associated to the tourism industry, while the electricity sector as well as the construction sector record increases in their activity levels. This effect is explained by the increased electricity demand for cooling and water desalination as well as from the increased investments (regarding construction). On the tourism side, in both climatic variants activity levels of related industries fall relative to the baseline with the effect being higher in the long-run. Comparing the two climatic variants the main differences in terms of sectoral activity (besides the magnitude of the effects) observed are that the activity increases of the electricity and of the construction sector weakens over time in the RCP2.6, compared to the RCP8.5 scenario electricity requirements continue to grow throughout the simulation. The activity of the market service sector is the least affected between the sectors presented as it benefits partly from labor cost decreases.

Figure 147: Sectorial activity (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 148: Sectorial activity (% from the reference) – RCP8.5

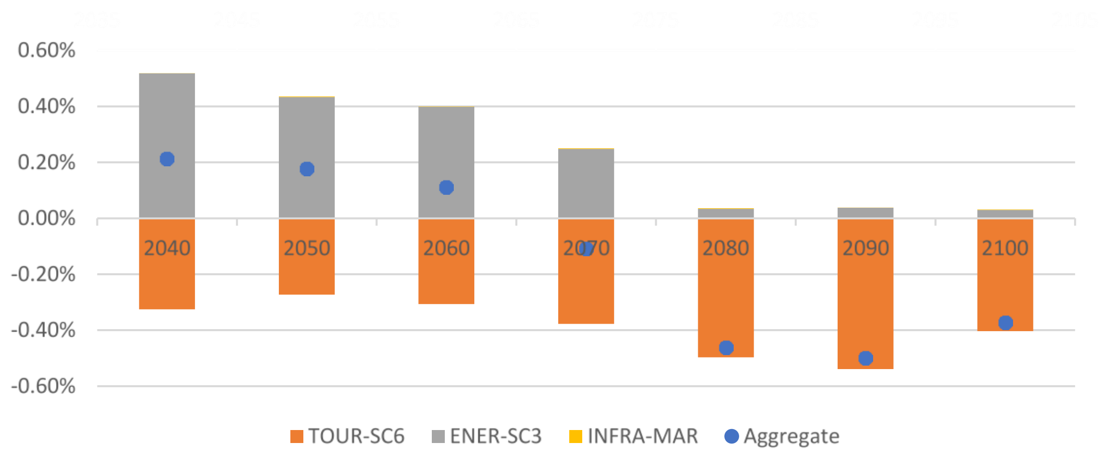


Source: GEM-E3-ISL

3.6.2.3 Labor market

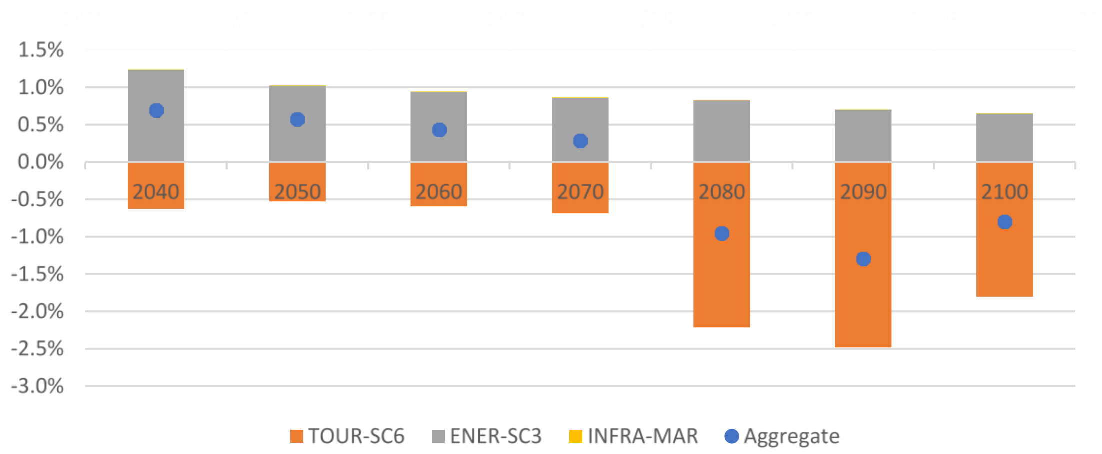
With respect to the labor market developments, the simulation shows increased levels for the for the *near* for both climatic variants and negative impacts in the *long* period. The employment gains during the period 2045-2100 are attributed to the increased employment in the construction and the market service sectors (which benefits from the lower wage rates compared to the reference case and increase its employment levels), while in the long run the steep decrease in tourism revenues leads to a decrease in overall employment (activity of services which are the main employers in the economy sharply falls compared to the first simulation period as discussed in the previous section).

Figure 149: Employment (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 150: Employment (% from the reference) – RCP8.5



Source: GEM-E3-ISL

3.6.3 GWS RESULTS

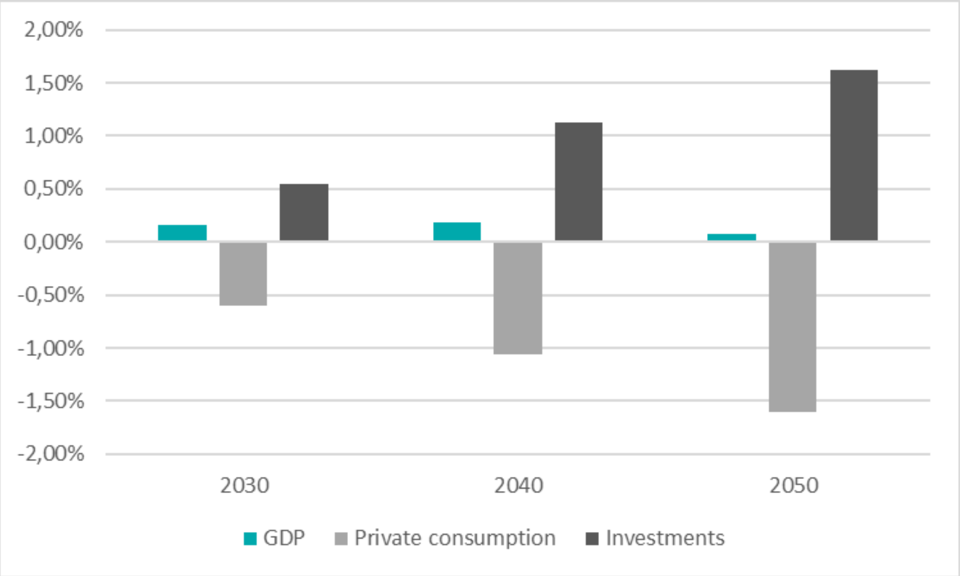
3.6.3.1 Macroeconomic

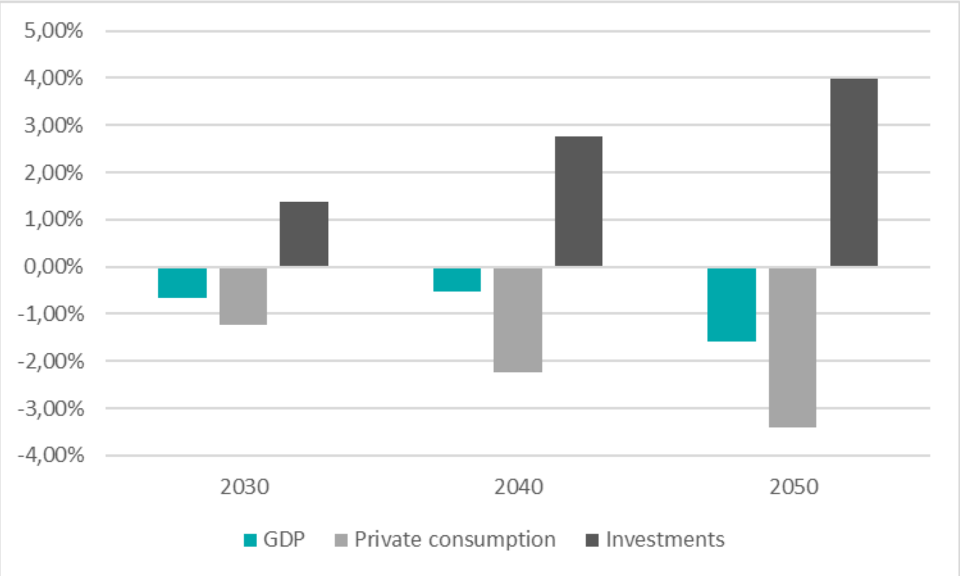
Under the RCP 2.6, investment compensates for other losses and GDP is slightly higher than before. The picture flips under the RCP 8.5 scenario. Though investments are high, other losses are even higher and the GDP effect is negative.

Sicily had a projected growth of close to 1% until 2040, which was projected to pick up in the last decades of the century. The trade balance is negative and increases, this is emphasized under the RCP 8.5. Maritime transport losses are more than twice as high in this scenario, compared to the RCP 2.6. Facing Covid19, Sicily is discussing a bridge across the Messina

Strait again[23]. This has been discussed since Roman times, latest under the Berlusconi government. However, this strategy is not yet included in our simulations.

Figure 151: Sicily: Components of GDP, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation.

3.6.3.2 Sectorial results

In the modeling exercise, additional energy demand leads to additional investment and the respective price increases to refinance. However, Sicily is well connected to mainland Italy, so

[23] https://www.derstandard.de/story/2000119840305/und-ploetzlich-traeumt-italien-wieder-von-der-bruecke-nach-sizilien

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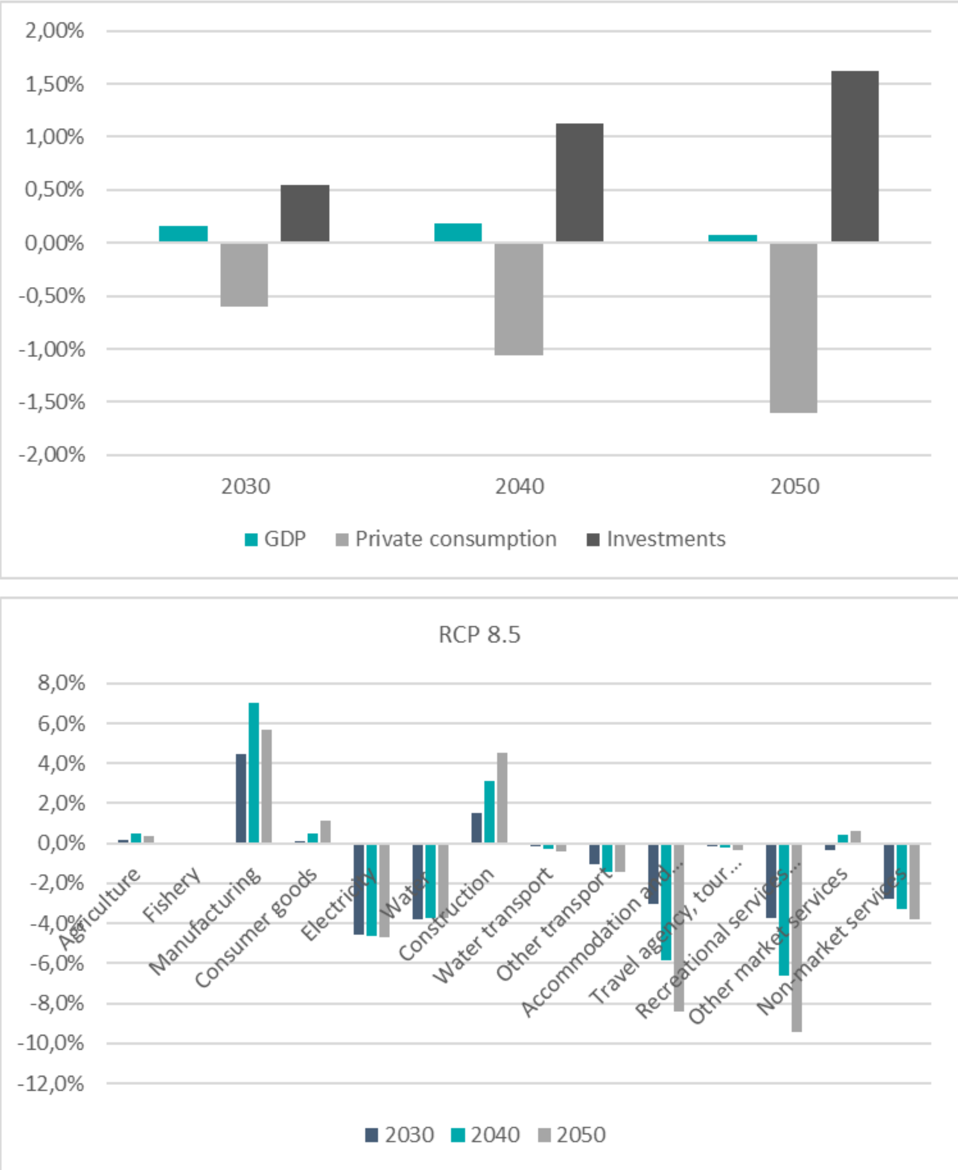
that additional energy investment might be taken there, and the burden of additional costs been borne there. Without this assumption the percentage losses in energy and water sectors are significant.

Figure 152: Sicily: Value added by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5

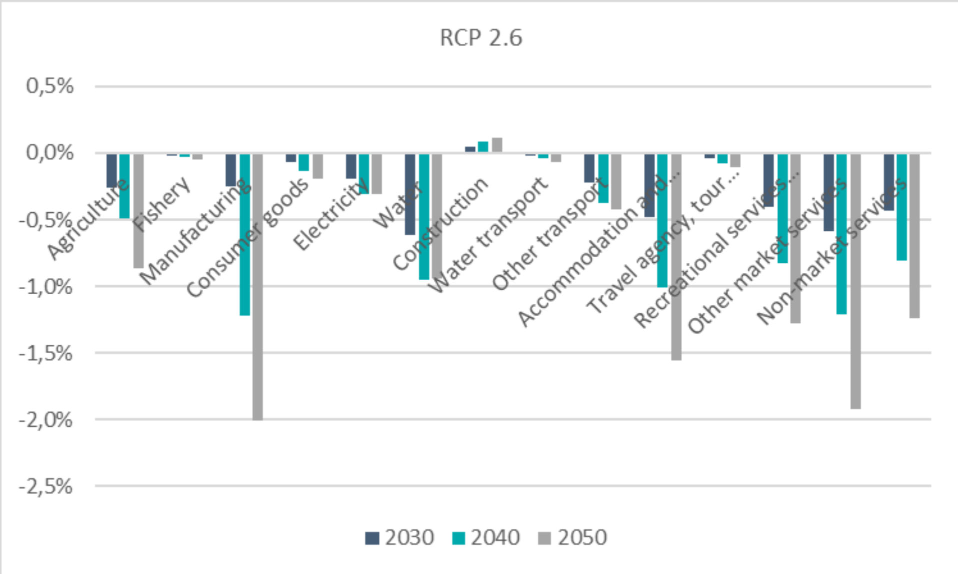


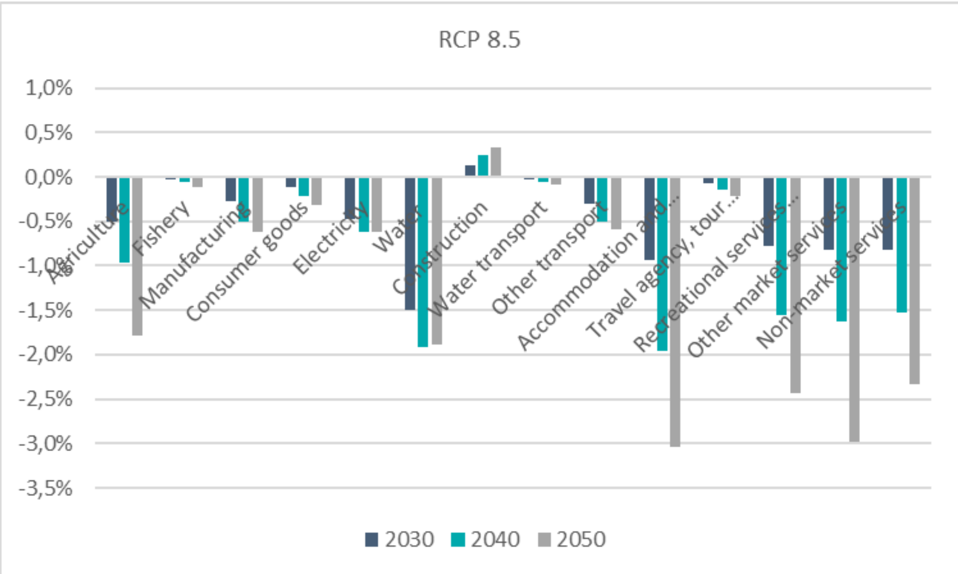
Source: GWS, own calculation.

3.6.3.3 Labor market

b losses are much smaller than losses in value added, pointing to large profits been made in the respective sectors. Job losses are estimated in most sectors between 2 and 3%.

Figure 153: Sicily: Employment by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation.

3.7 CRETE

3.7.1 SCENARIO DEFINITION

The first set of scenarios examined refers to the effect of climate change on tourism performance. The direct impact on tourism, expressed as deviations of tourists' expenditures with respect to the reference case, is fed into the GEM-E3-ISL in order to assess the indirect impacts and to capture the general equilibrium effects of the abovementioned changes to the economy of Crete. The increased risk of forest fires as well as reduction of available beach surface are highlighted as the most important long-term threats for the tourism industry in

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Crete; together these developments are responsible for 99% of the estimated reduction in tourism consumption (*Table 20)*.

Table 20: Changes in tourists' expenditures with respect to the reference case (%)

	TOUR -SC1 (marine environment)	TOUR -SC2 (forest fire)	TOUR -SC3 (beach reduction)	TOUR -SC4 (thermal comfort)	TOUR -SC5 (V-disease)	TOUR –SC6 (aggregate)
RCP2.6 near	0	0	-10.5	-0.71	0	-11.21
RCP2.6 distant	0	0	-14.83	-0.71	0	-15.54
RCP8.5 near	0	-17.8	-20.7	-0.69	0	-39.19
RCP8.5 distant	0	-17.8	-26.5	-0.52	0	-44.82

The second set of scenarios examined refers to the changes in energy demand, and more specifically on electricity consumption, associated to changes in temperature and water availability. Changes in precipitation rates and increases in temperature (increase in the cooling degree days) are expected to drive demand for electricity upwards. Households and services are expected to increase their electricity consumption in order to i) maintain the same level of thermal comfort and ii) meet their demand for water as with the decreased availability of water due to lower precipitation an increased provision of water from desalination facilities is expected. In Crete, electricity increases are associated mainly to the cooling of residential and tertiary in both scenarios examined; the production of water in desalination facilities has a slighter impact on total demand. *Table 21* describes the effect of the abovementioned changes in total electricity consumption as deviations from the reference case:

Table 21: Changes in electricity consumption with respect to the reference case (%)

	ENER -SC1 (desalination)	ENER -SC2 (cooling)	ENER –SC3 (aggregate)
RCP2.6 near	0.2	3.6	3.8
RCP2.6 distant	0.2	0.5	0.7
RCP8.5 near	0.3	10	10.3
RCP8.5 distant	0.8	14.6	15.4

Finally, the third set of scenarios examined, looks into the impact of capital losses (e.g. due to extreme weather events) on local economies. More specifically we examine the impact of damages on port facilities due to sea level rise on regional macroeconomic performance (*Table 22*).

Table 22: Capital losses (% of GDP)

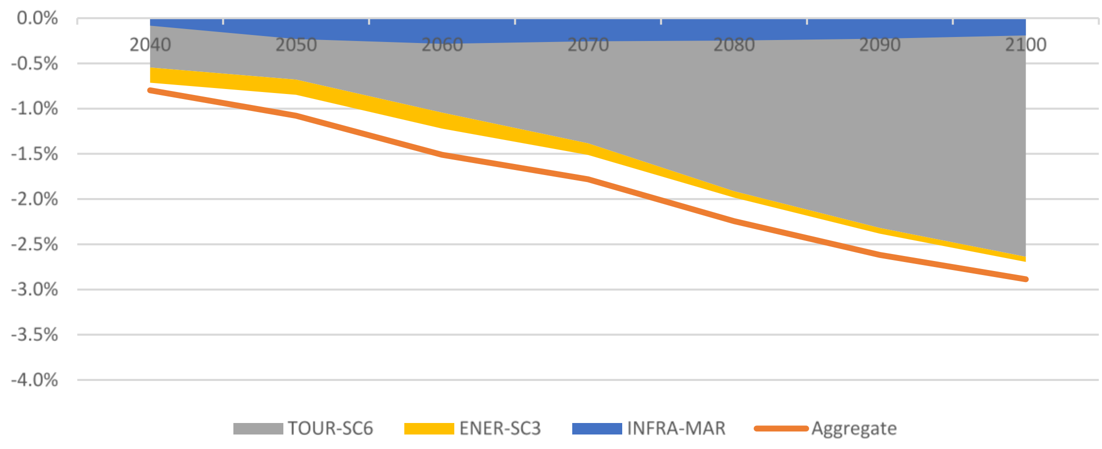
	INFRA-MAR
RCP2.6 near	-0.26
RCP2.6 distant	-0.25
RCP8.5 near	-0.69
RCP8.5 distant	-0.68

3.7.2 GEM-E3-ISL RESULTS

3.7.2.1.1 Macroeconomic impacts (aggregate)

The estimated impacts of the combined changes on Crete's GDP are calculated cumulatively to -2.1% for the RCP2.6 (Figure 154) and -7.9% for the RCP8.5 (Figure 155) over the period 2040-2100. The driver in both climatic variants is the tourism industry and the impact on GDP is more pronounced in the long-term as an intensification of climate impacts is projected. The effects on the economy almost double in the *distant* period compared to the *near* (-2.6% vs. -1.3% in the RCP2.6 and -10.0% vs. -4.7% in the RCP8.5).

Figure 154: GDP changes from reference (%) – RCP2.6



Source: GEM-E3-ISL

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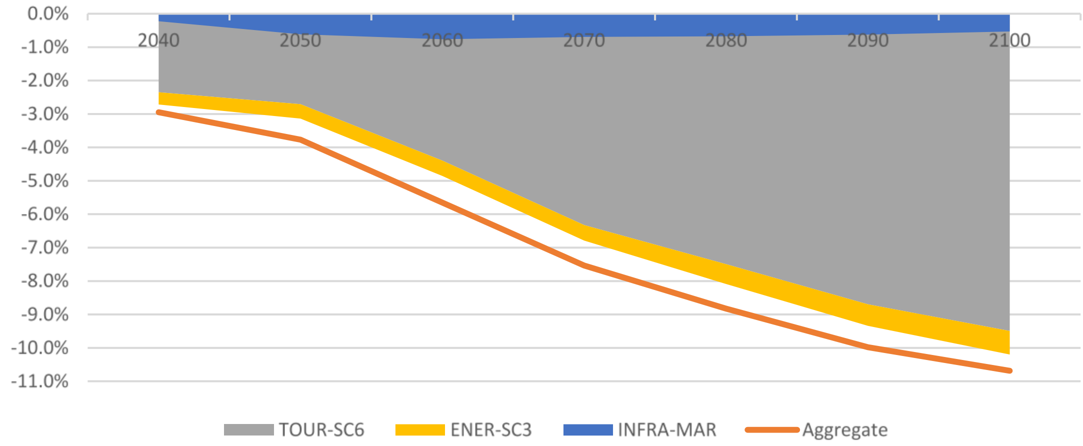
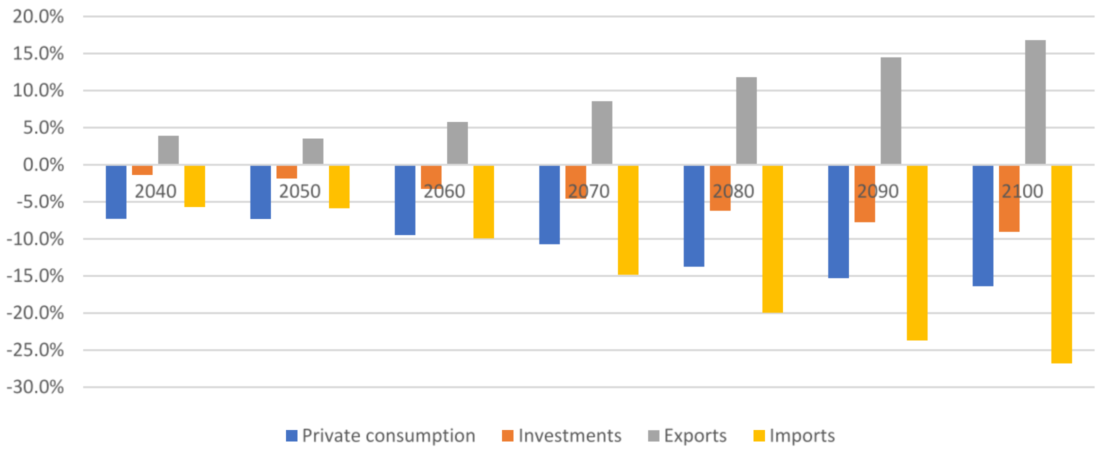
Figure 155: GDP changes from reference (%) – RCP8.5



Source: GEM-E3-ISL

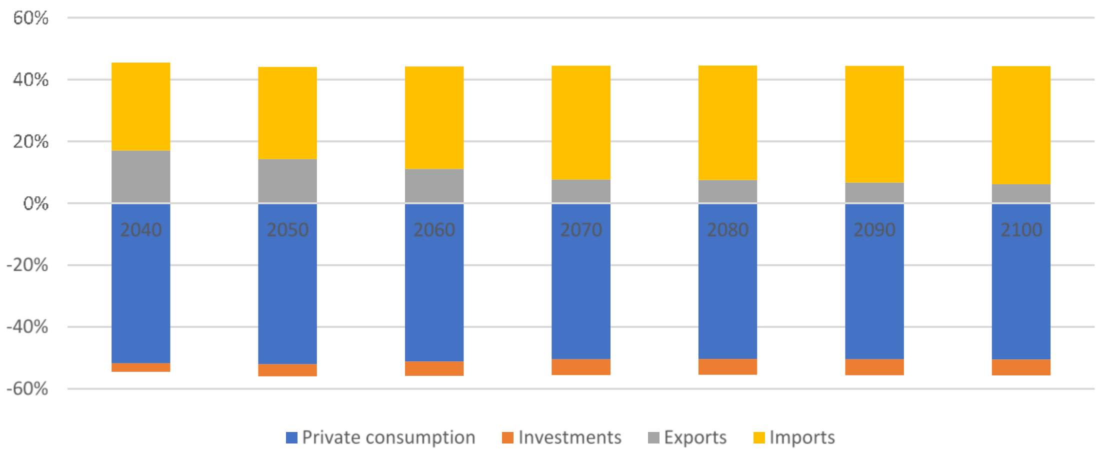
Private consumption expenditures fall significantly over the examined period as household income decreases as a consequence of the decreased activity in tourism-related sectors. Furthermore, the scenario specification implies that a larger share of available for consumption income will be directed towards electricity consumption; hence, demand for other goods and services falls creating additional pressure to the local economy. This in turn will lead to lower investments as firms do not face those profitable conditions that incentivize the expansion of their production capacity. Finally, in both scenarios examined a positive impact on regional trade balance is found as lower consumption does not affect only domestic but also imported products and services, while exports increase as lower demand for domestic goods and services results in higher availability of resources, thus more competitive production costs. This effect is in line with what is observed where when firms meet unfavorable conditions in the domestic market become more extroverted in order to find markets for their products.

Figure 156: Changes from reference in selected macroeconomic variables (%) – RCP2.6



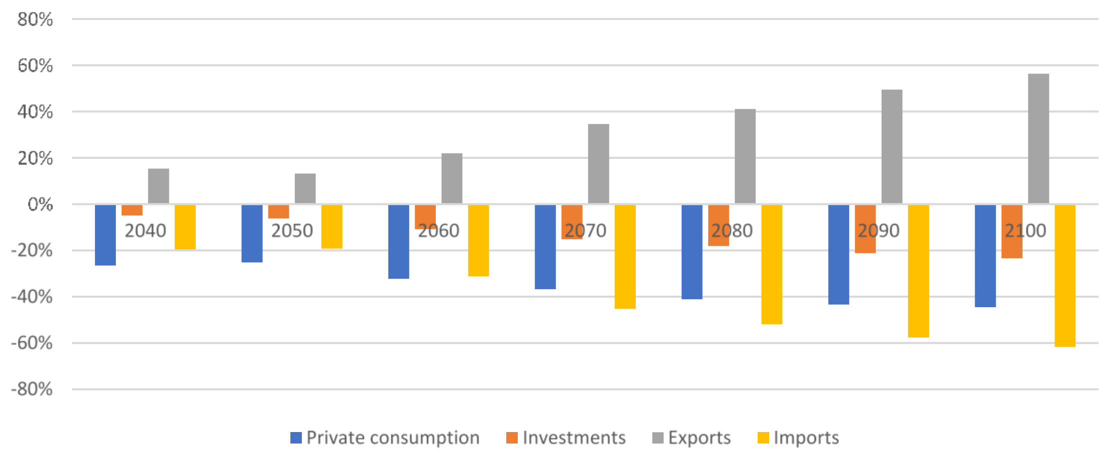
Source: GEM-E3-ISL

Figure 157: Contribution to GDP changes – RCP2.6



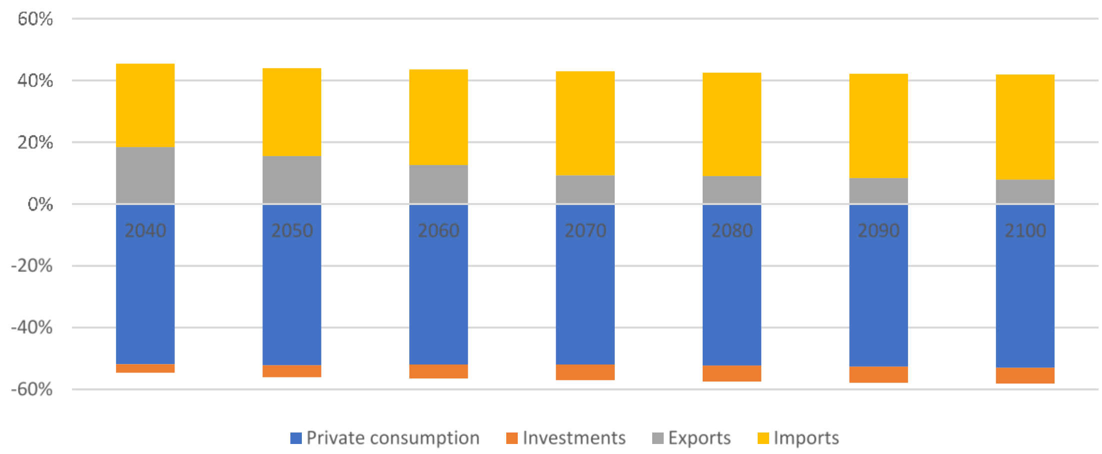
Source: GEM-E3-ISL

Figure 158: Changes from reference in selected macroeconomic variables (%) – RCP8.5



Source: GEM-E3-ISL

Figure 159: Contribution to GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

Decomposing private consumption and investment changes (in both climatic variants) we observe that once again changes associated to tourism are driving the overall result (Figure 160-Figure 163). Increased electricity demand for water desalination and cooling decreases has a smaller relative impact as higher electricity prices (which increase due to consumption) on the one hand crunches the income available for other goods and services and on the other hand increase the overall costs of production (especially of electricity intensive industries and services). On average private consumption falls by 0.3% over the period in the RCP2.6 and by 1.5% in the RCP8.5. The effect of damages in maritime infrastructure is another factor contributing to consumption shrinkage as the price of maritime services increases (e.g. lower ship and cargo capacity, increased time of loading and unloading cargo ships etc.). Since most of the products are transported by sea the overall product price increases; hence, consumption falls (2.5% on average over the period 2040-2100).

With respect to investments the decrease is attributed both to the lower activity of tourism-related sectors and to the crowding-out effect induced by investments in electricity.

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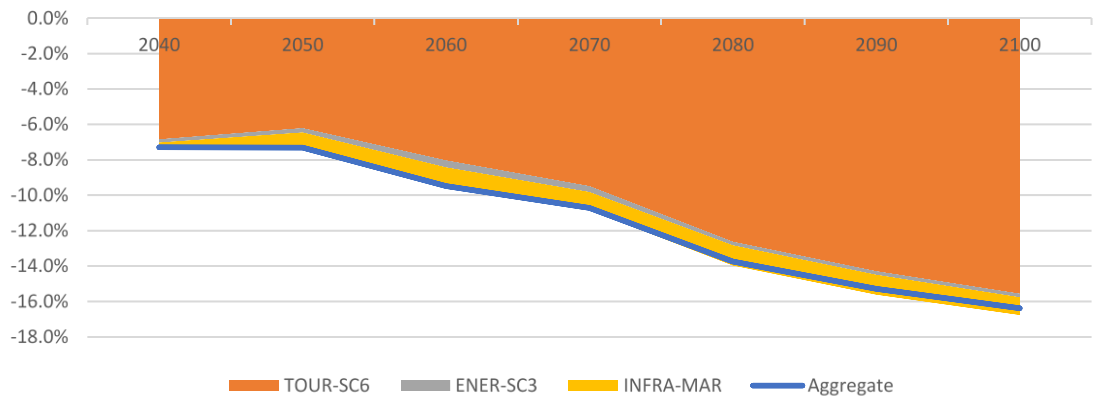
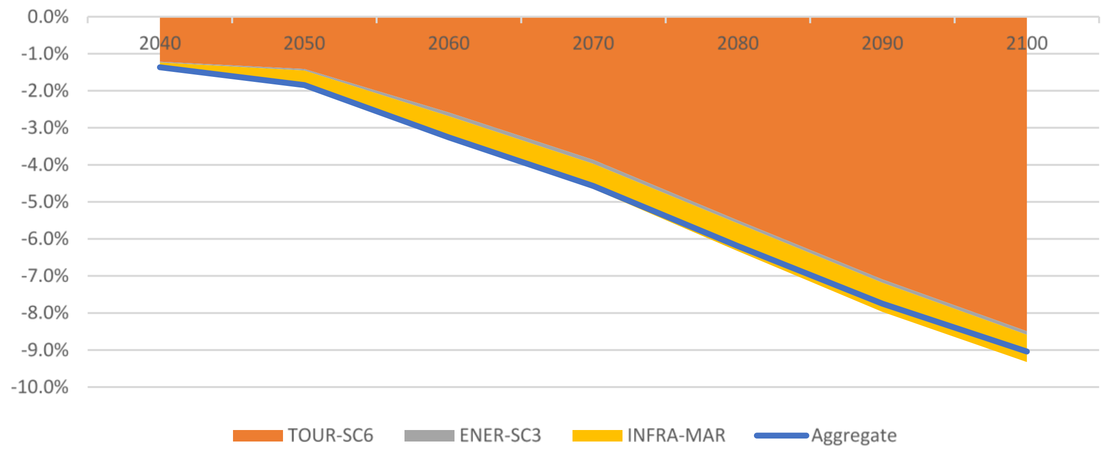
Figure 160: Changes in private consumption % from reference – RCP2.6



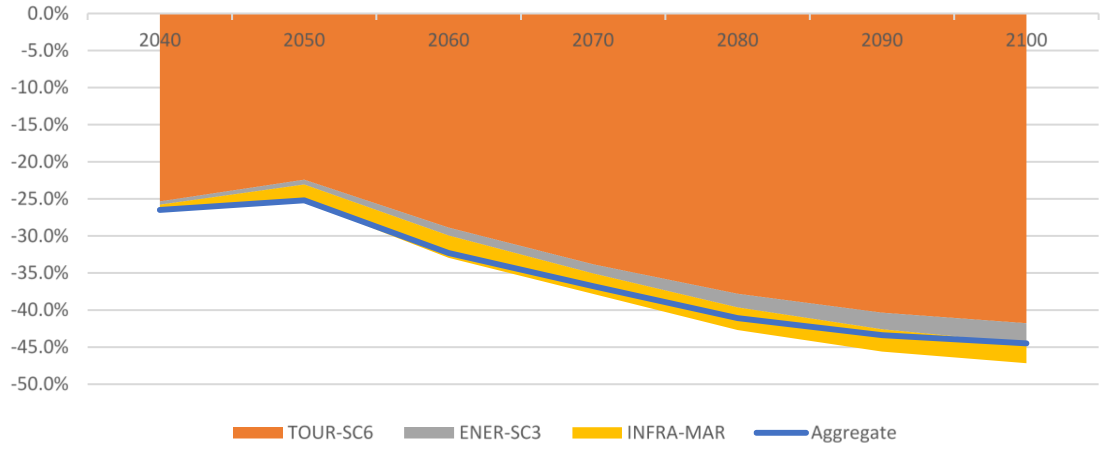
Source: GEM-E3-ISL

Figure 161: Changes in investments % from reference – RCP2.6



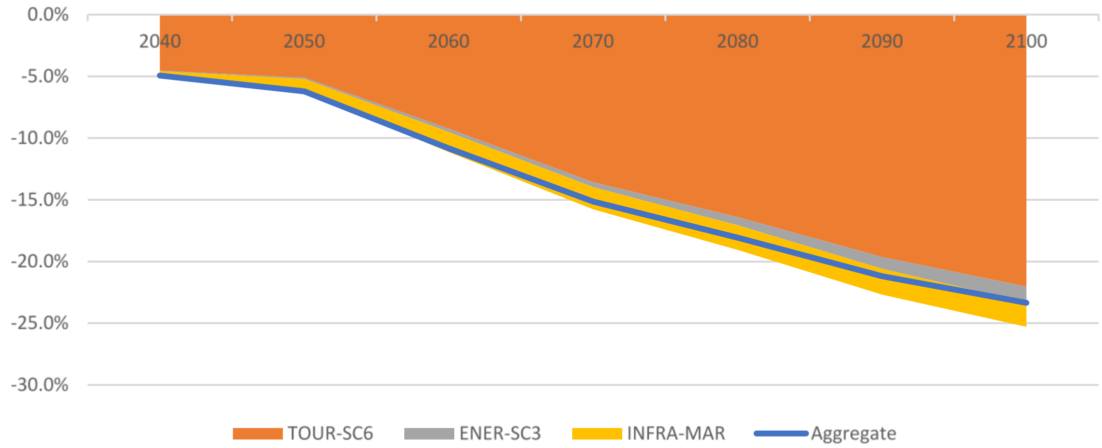
Source: GEM-E3-ISL

Figure 162: Changes in private consumption % from reference – RCP8.5



Source: GEM-E3-ISL

Figure 163: Changes in investments % from reference – RCP8.5



Source: GEM-E3-ISL

3.7.2.1.2 Macroeconomic impacts (tourism)

Tourism is an essential pillar of Crete's economy, throughout the projection period, as it contributes on average 23% of the island's GDP. Volatility in tourism arrivals or in expenditures per overnight stay is expected to have significant repercussions for the local economy, as the tourism industry employs intensively domestic factors (primary production factors and intermediate inputs) and has low import intensity. In the RCP2.6 scenario the cumulative reduction in tourists' expenditure is estimated to be equal to 13.6% (compared to the reference scenario) and in the RCP8.5 scenario equal to 42.5% for the period 2040-2100.

Out of the three tourism related scenarios examined the highest impact on the economy is found in the TOUR-SC3 (in both climatic variants), which examines the effects of beach reduction on tourism receipts (Figure 164, Figure 165) highlighting the importance of coastal tourism for the Cretan economy. In the RCP8.5 variant the increased the risk of forest fires exerts also

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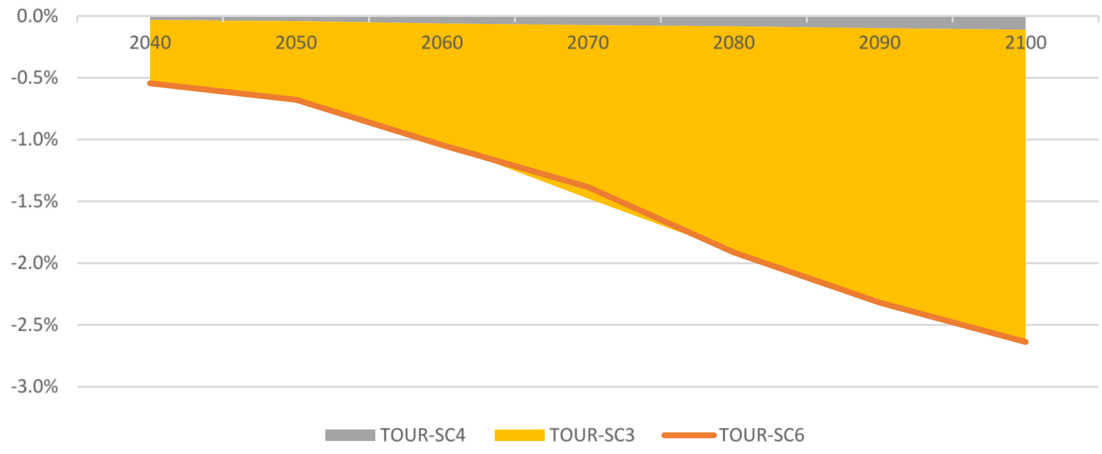
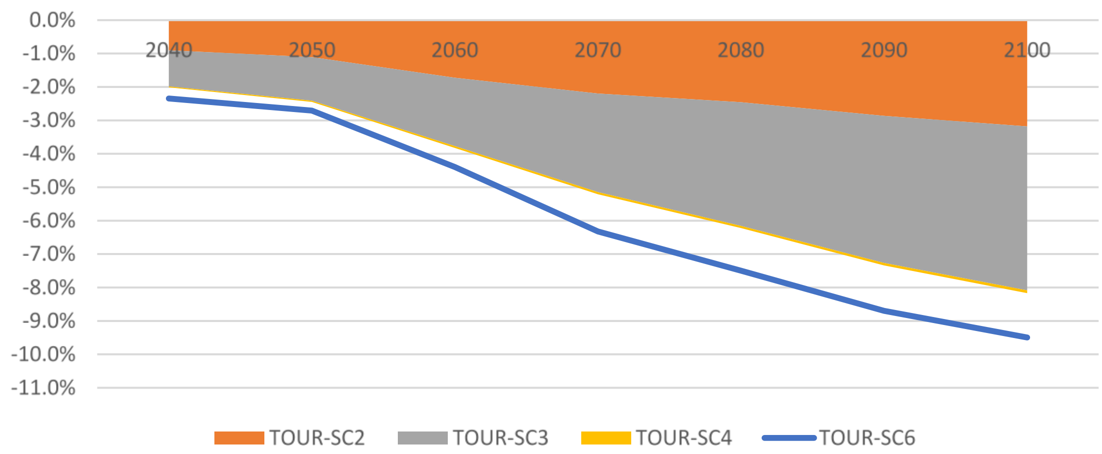
significant pressure on the tourism industry (as tourists value highly safety of destinations). All scenarios exhibit similar pattern with respect to the response of the main macro-economic variables to the implemented shock: i) private consumption decreases primarily due to the reduced revenues of tourism related activities which lead to lower labor income, ii) investments fall relative to their reference levels as a result of activity slowdown and iii) trade deficits reduce as imports fall (due to the overall decrease of domestic demand) and exports increase (as products become more competitive due to changes in factors markets).

Figure 164: GDP change relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 165: GDP change relative to the reference (%) – RCP8.5



Source: GEM-E3-ISL

3.7.2.1.3 Macroeconomic impacts (energy)

The increased demand for electricity is found to have negative impacts on the economy of Crete compared to the reference case. From a technical point of view, the increase in the

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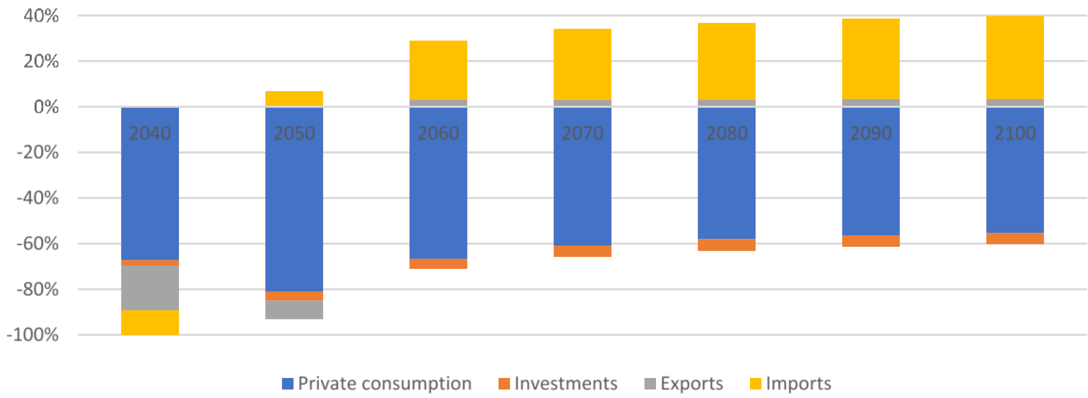
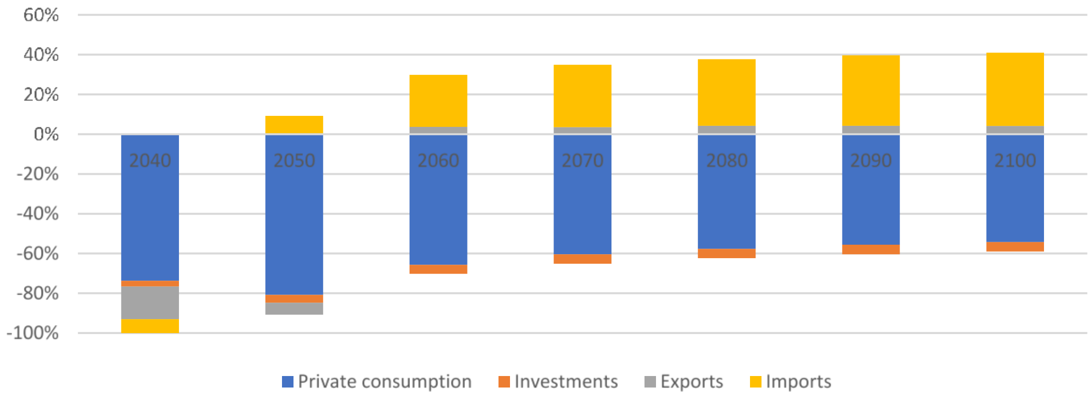
cooling degree days means that higher amounts of electricity are needed per unit of output while for households it means that they have to increase electricity consumption for achieving the same level of utility. For households, this development results in lower disposable income for other consumption categories, hence lower final demand which ultimately leads to lower activity in the economy. From the point of view of firms, the increased electricity input will have repercussion in their production cost which influences negatively competitiveness. To the extent that their energy systems are isolated, and imports are not available the increased demand, which have to be satisfied only from domestic sources, will increase investments to expand capacity and to a certain degree will drive prices upwards.

Figure 166: Decomposition of GDP changes (%) – RCP2.6



Source: GEM-E3-ISL

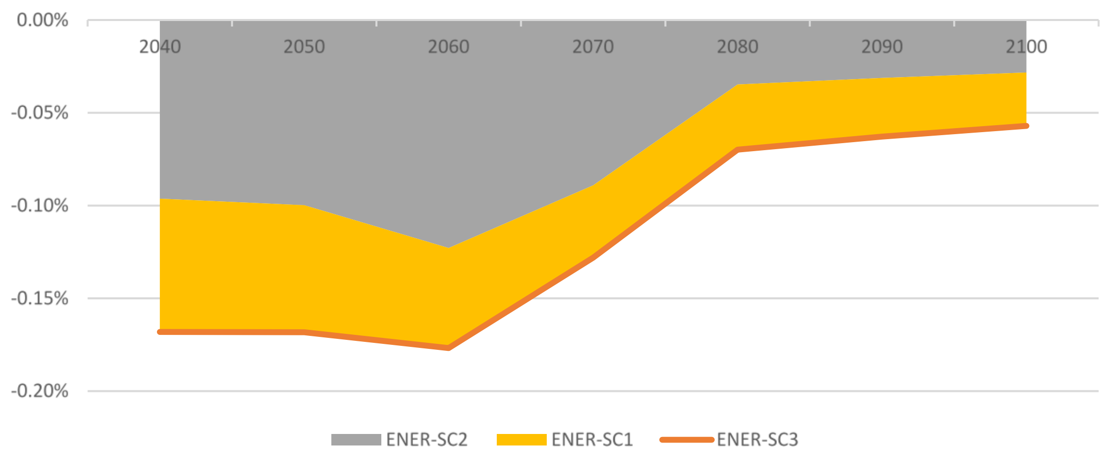
Figure 167: Decomposition of GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

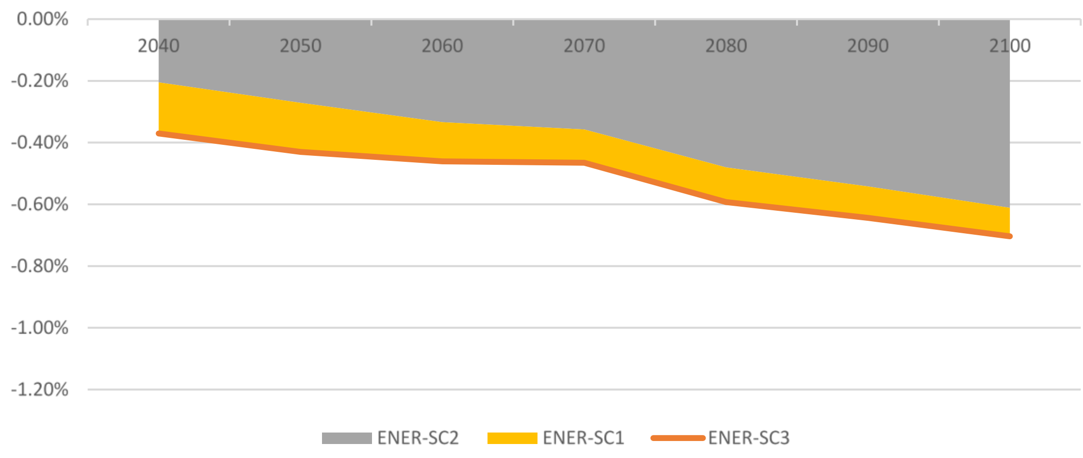
From the two energy-related scenarios examined the effects are more pronounced in the cooling scenario as it foresees higher electricity consumption in both variants compares to the electricity consumption for desalination purposes.

Figure 168: GDP changes relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 169: GDP changes relative to the reference (%) – RCP8.5

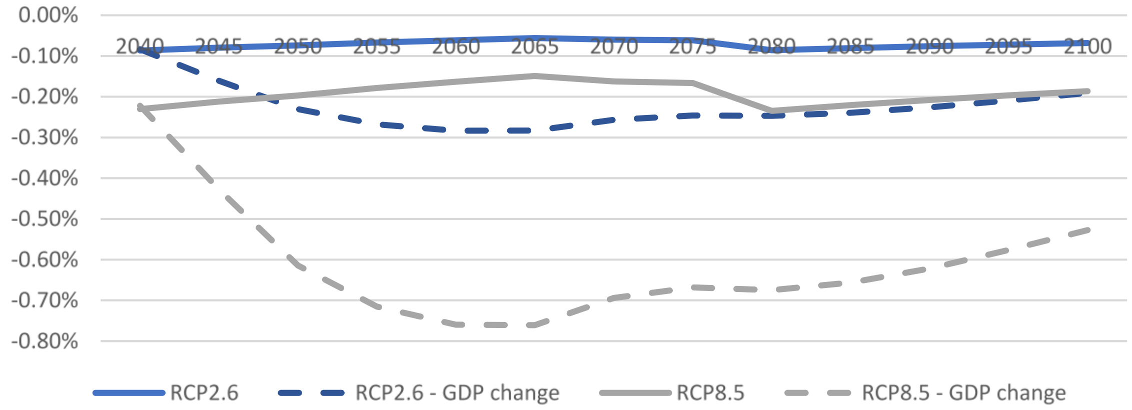


Source: GEM-E3-ISL

3.7.2.1.4 Macroeconomic impacts (maritime)

In this scenario the effect of infrastructure damages are assessed and more specifically those associated to ports and port facilities. Infrastructure damages are translated into losses of productive capital which in turn leads to relatively higher capital prices, hence costs of production.

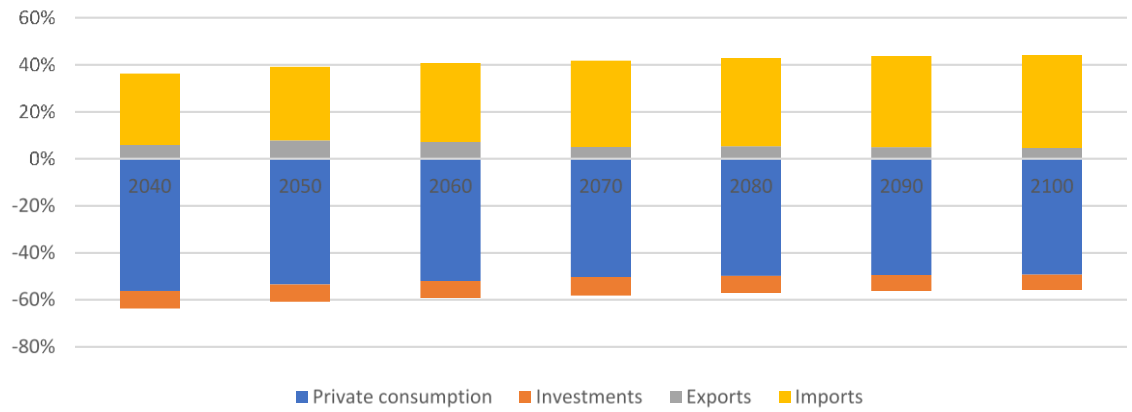
Figure 170: Capital losses (% of GDP)



Source: GEM-E3-ISL, D5.6

The scenario assessment shows that GDP contracts by 0.7% on average for the period 2040-2065 and by 1.1% for the period 2080-2100 in the RCP2.6; the respective figures for the RCP8.5 are 0.8% and 1.2%. As the overall capital rents in the economy shrink, so does private consumption and investments. The impacts of infrastructure damages on the main macroeconomic variables are presented below:

Figure 171: Decomposition of GDP changes (%) – RCP2.6



Source: GEM-E3-ISL

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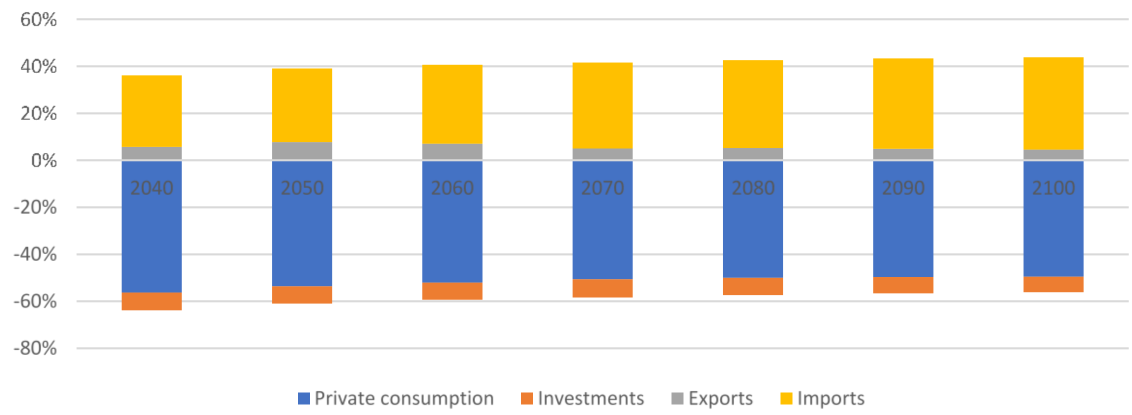
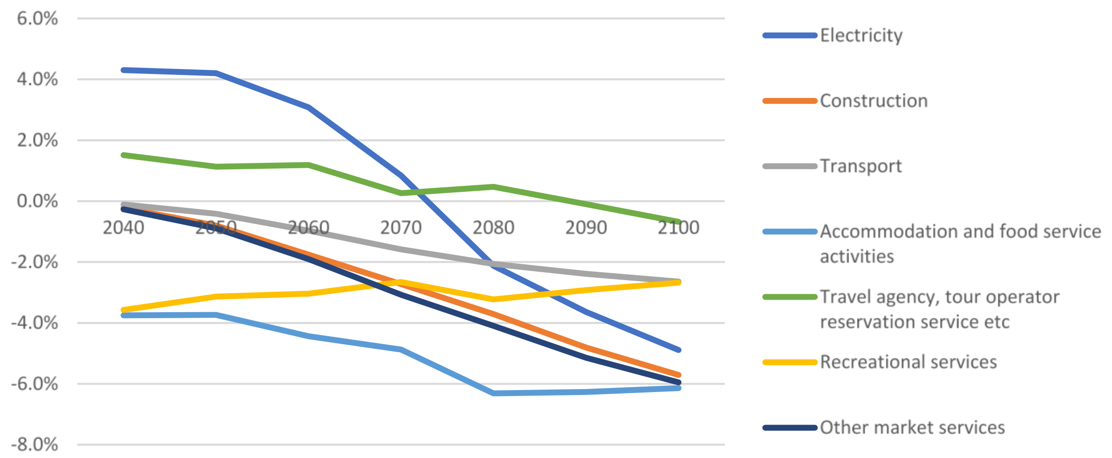
Figure 172: Decomposition of GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

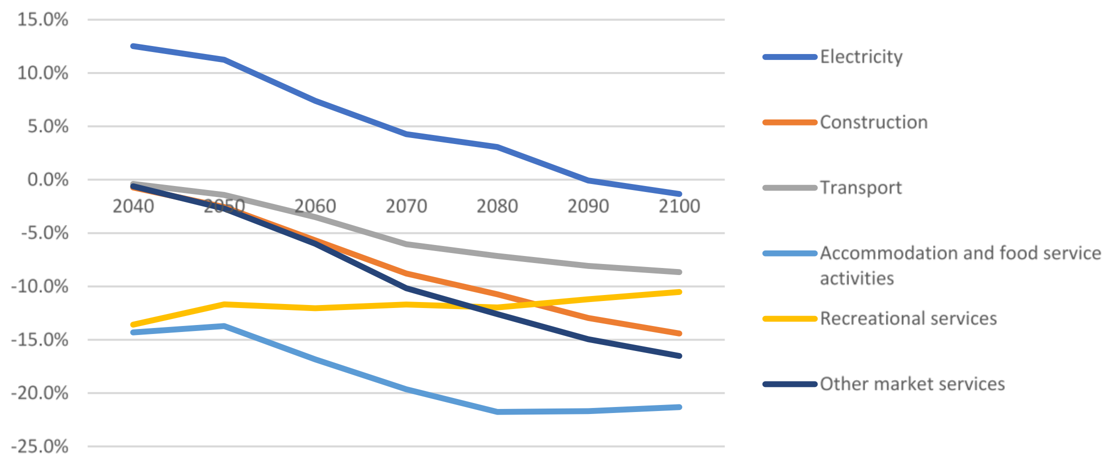
The simulation of the abovementioned scenarios indicates that the sectors that experience the steepest decrease, in terms of activity levels, are those associated to the delivery of services to tourists while the increased electricity demand for cooling and water desalination leads to increases in the activity of the electricity sector.

Figure 173: Sectorial activity (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 174: Sectorial activity (% from the reference) – RCP8.5



Source: GEM-E3-ISL

3.7.2.2 Labor market

Regarding labor market impacts, these are found to be negative in both climatic variants examined and throughout the simulation period. Employment losses are higher in the tourism scenario compared to the energy and the infrastructure scenario. In RCP2.6 employment falls by 0.6% on average in the tourism composite scenario (TOUR-SC6) and by 0.03% in energy scenario (ENER-SC3) during the period 2040-2100 while in the RCP8.5 employment losses are equal to 2% and 0.1% respectively. The "core"[24] tourism sectors record an average loss of 2.7% and 4.4% in the RCP2.6 and in the RCP8.5 respectively; while the services in total record an average loss of 9.4% and 16.6% respectively. Employment falls also in the transport sector

[24] Accommodation and food service activities, travel agencies and recreational services.

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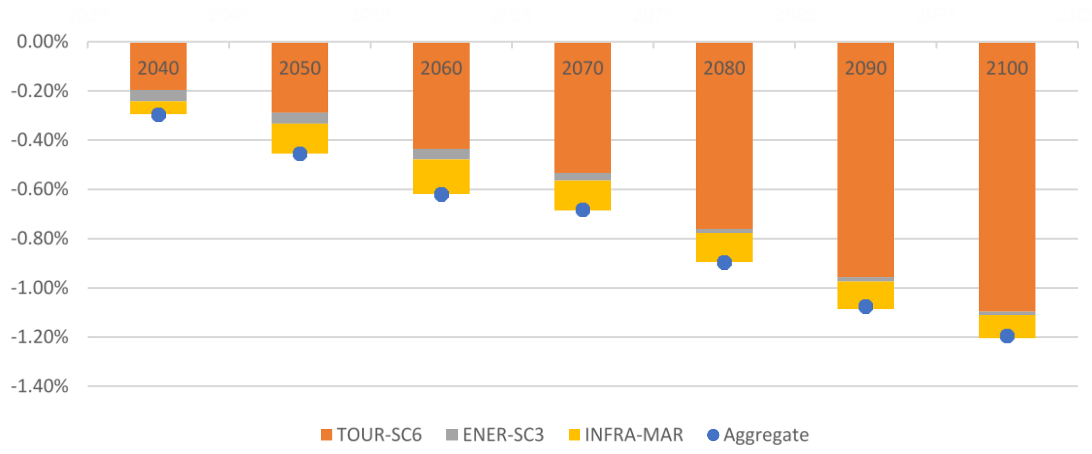
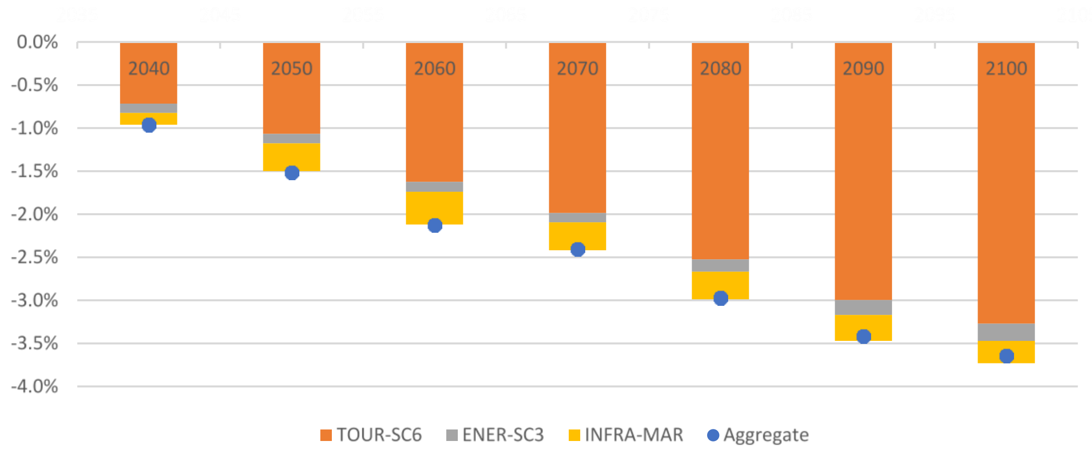
by 1.2% (RCP2.6) and by 3.7% (RCP8.5) on average, while employment gains are recorded for the agricultural, the manufacturing and the electricity sectors.

Figure 175: Employment (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 176: Employment (% from the reference) – RCP8.5



Source: GEM-E3-ISL

3.7.3 GWS RESULTS

3.7.3.1 Macroeconomic

The macroeconomic effects on Crete are dominated by the severe losses of tourism and the higher costs from ports and transport. Since additional investment is very low in the scenarios, all components of GDP bar trade point to a negative direction. The sum is, obviously, negative, the slightly positive development of trade is not able to compensate for losses.

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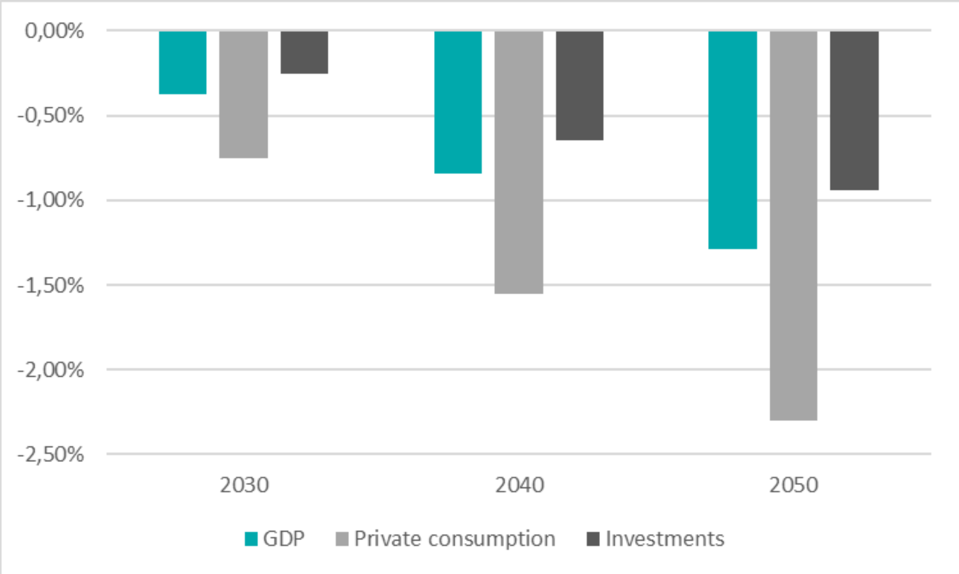
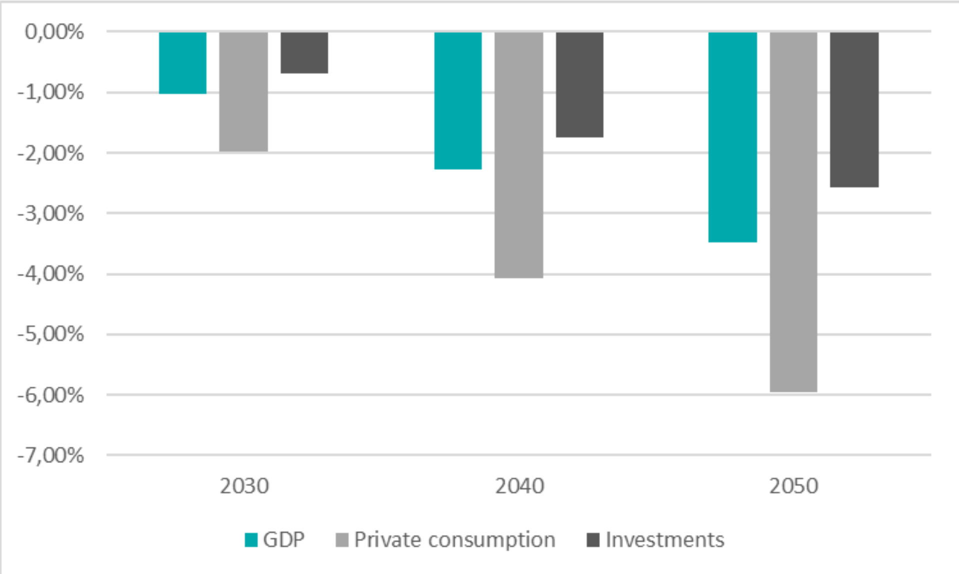
Figure 177: Crete: Components of GDP, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation

3.7.3.2 Sectorial results

alue added shows the large losses in the tourism related sectors. The losses in other sectors are partly attributed to indirect effects and partly to higher costs of transportation, i.e. on im-parted goods. However, the positive trade balance of Crete remains stable.

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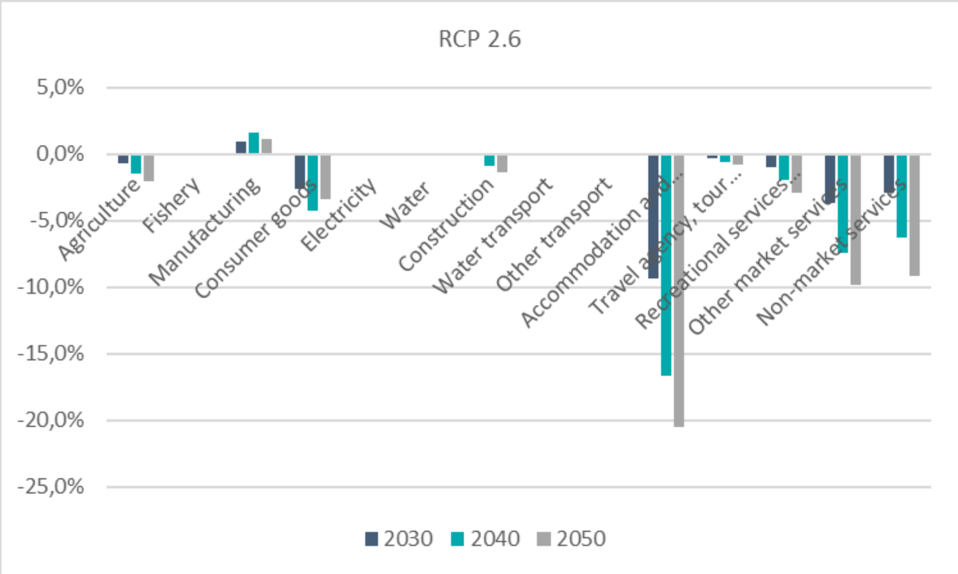
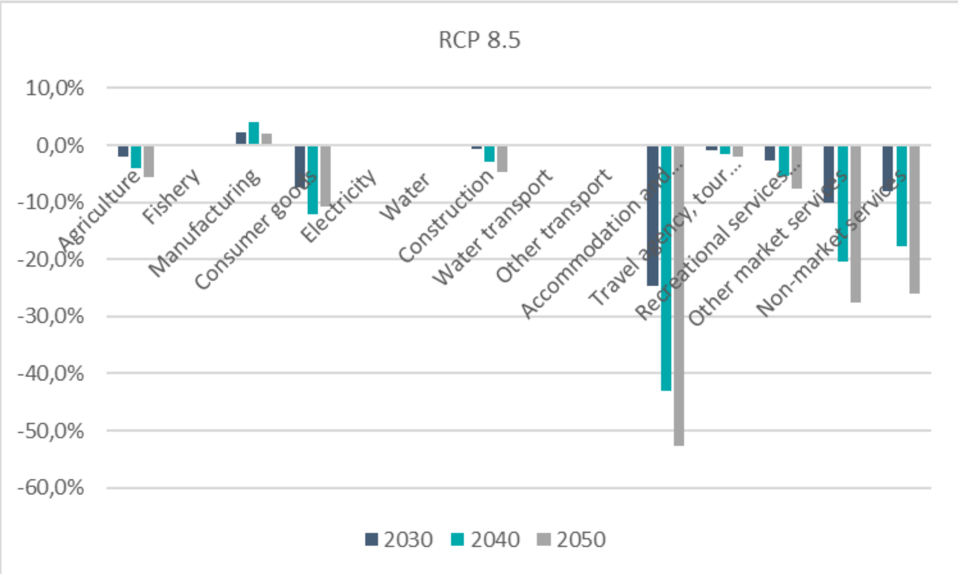
Figure 178: Crete: Value added by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation.

3.7.3.3 Labor market

The services respond to value added losses with job losses around 10% already under the RCP 8.5 scenario.

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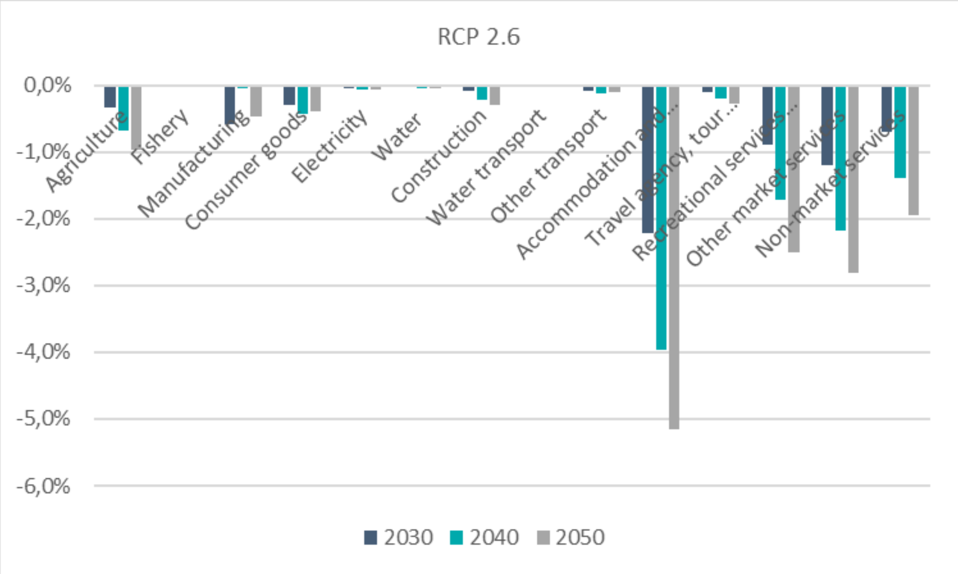
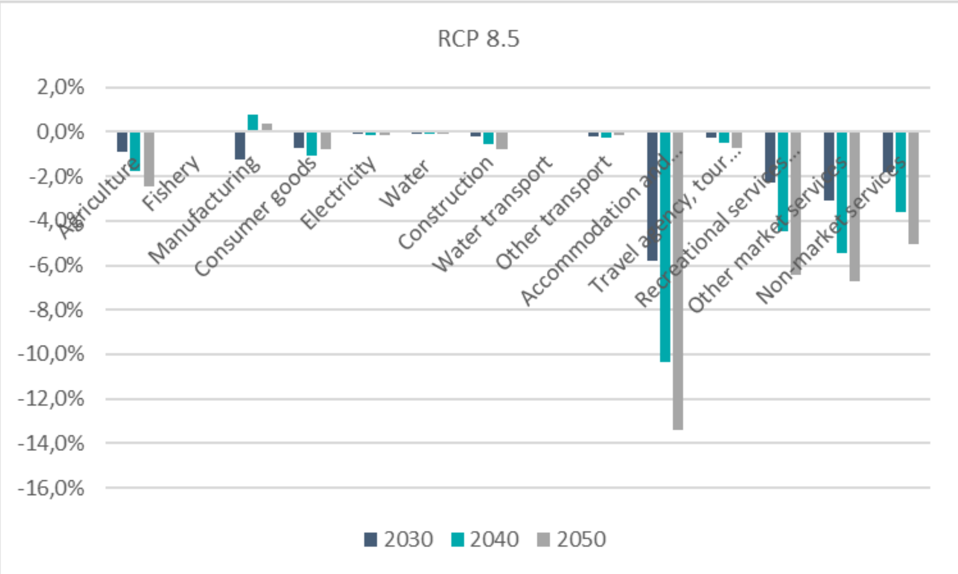
Figure 179: Crete: Employment by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation.

3.8 AZORES

3.8.1 SCENARIO DEFINITION

The first type of scenarios examines the impact of climate change on tourism by assuming different expenditures by tourists due to biophysical climate impacts on the natural environment and temperatures. In particular, the changes in touristic demand are directly linked to the perception of tourists regarding certain features such as beach surface, the marine environment, the risk of forest fires and warmer conditions and depend on how these features are impacted by climate change. The second set of scenarios refers to changes in electricity consumption due to increased cooling demand and water availability. Finally, the third set of scenarios refers to infrastructure damages, specifically to port infrastructure, due to sea level rise.

The impact of climate changes on tourists' spending, electricity demand and capital losses are estimated in D5.6 and are used as inputs for the scenario simulations as described in the Methodology Section. The GEM-E3-ISL model assesses their impacts on the main macroeconomic variables (GDP, private consumption, investments, exports and imports), sectorial activity and employment. The inputs provided by D5.6 and incorporated in GEM-E3-ISL for Azores are described in the following tables:

Table 23: Changes in tourists' expenditures with respect to the reference case (%)

	TOUR -SC1 (marine environment)	TOUR -SC2 (forest fire)	TOUR -SC3 (beach reduction)	TOUR -SC4 (thermal comfort)	TOUR -SC5 (V-disease)	TOUR –SC6 (aggregate)
RCP2.6 near	0	0	-21.72	1.10	0	-20.62
RCP2.6 distant	0	0	-25.40	0	0	-25.40
RCP8.5 near	0	0	-34.83	1.80	0	-33.03
RCP8.5 distant	0	0	-40.56	0	0	-40.56

Table 24: Changes in electricity consumption with respect to the reference case (%)

	ENER -SC1 (desalination)	ENER -SC2 (cooling)	ENER –SC3 (aggregate)
RCP2.6 near	0	0	0
RCP2.6 distant	0	18.4	18.4
RCP8.5 near	0	0	0
RCP8.5 distant	0	33.1	33.1

Table 25: Capital losses (% of GDP)

	INFRA-MAR
RCP2.6 near	-0.04
RCP2.6 distant	-0.04
RCP8.5 near	-0.10
RCP8.5 distant	-0.12

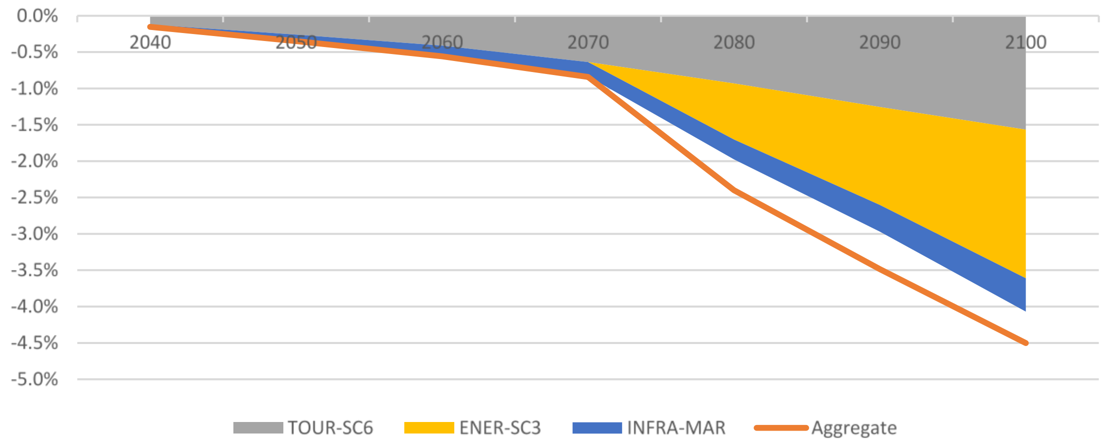
3.8.2 GEM-E3-ISL RESULTS

3.8.2.1 Macroeconomic

3.8.2.1.1 Full scenario macroeconomic impacts

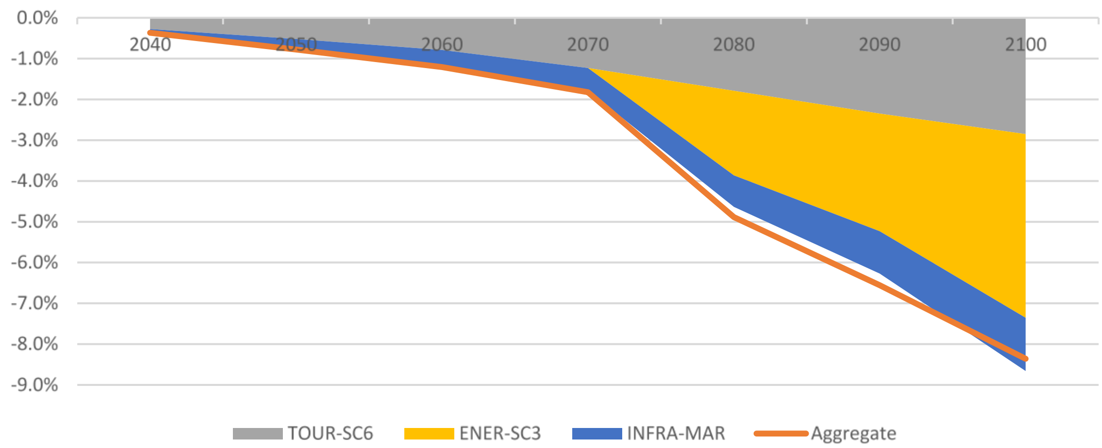
The estimated cumulative GDP impacts of the composite scenario equal to -2.1% for the RCP2.6 (Figure 180) and -4% for the RCP8.5 (Figure 181) over the period 2040-2100. In both climatic variants the simulated changes are found to have negative and escalating impact on the economy; i.e. the cumulative GDP impacts are equal to -0.43% in the *near* period and -3.6% in the *distant* period for the RCP2.6 and equal to -0.94% and -6.75% for the RCP8.5. The driver of changes for the Azores is the energy component. The Azores electricity network is isolated; hence electricity consumed is satisfied entirely by domestic production. The foreseen electricity increases are expected to stretch the island's capital requirements and to induce crowding-out effects. The latter in the case of Azores has significant repercussion for the economy's performance. The scenario implementation does not assume any financing tool, for example funding of power generation facilities from the central governments, which potentially could alleviate the crowding out effects.

Figure 180: GDP changes from reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 181: GDP changes from reference (%) – RCP8.5



Source: GEM-E3-ISL

In both climatic variants the result of the simulated changes is a decrease in private consumption, investments and imports. The reduced tourism activity results in lower income for regional households and suppresses private consumption. As a consequence of the decreased consumption and activity imports (serving either final demand or intermediate demand) fall throughout the simulation period. In the RCP2.6 imports decrease by 23 % while in the RCP8.5 they decrease by 31% cumulatively over the simulation period, while exports increase by 0.6% and 0.8% respectively. The increase in exports is attributed to the lower labor and capital costs prevailing at the new equilibrium point.

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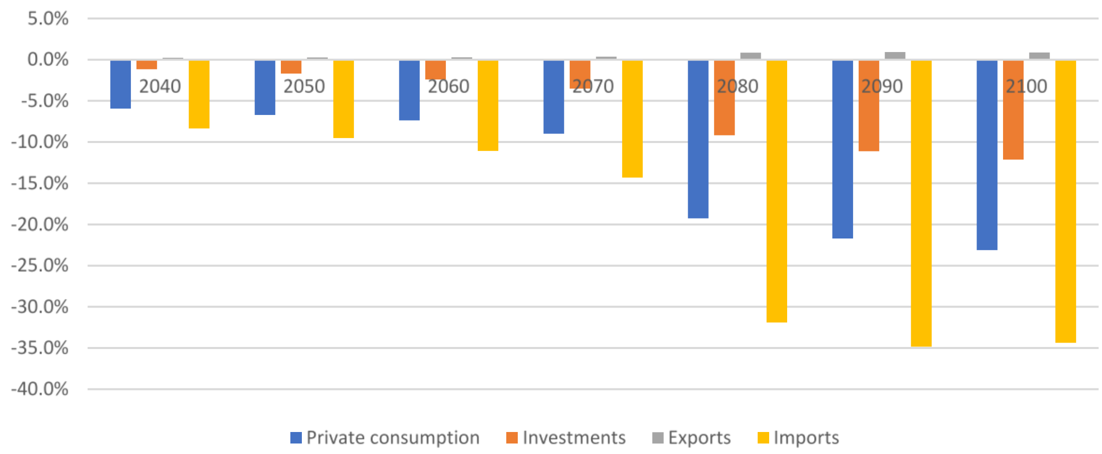
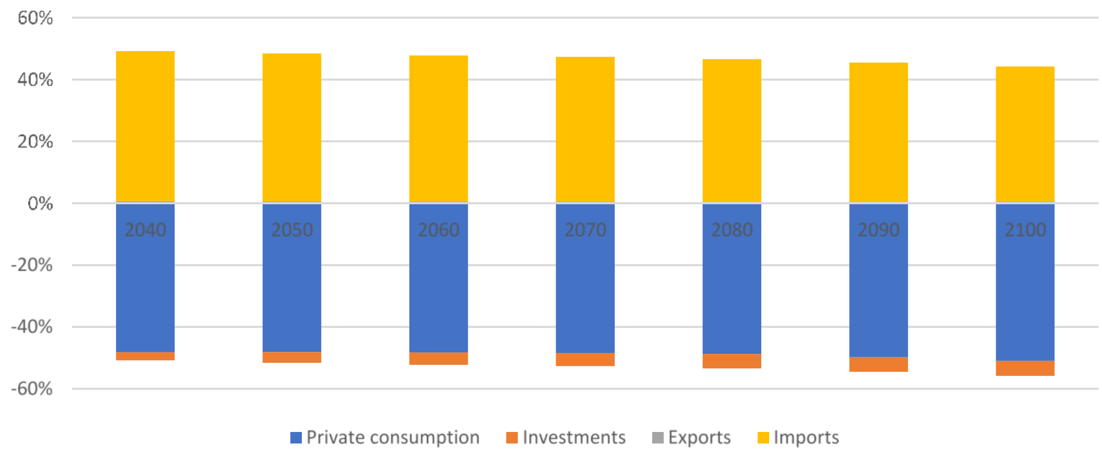
Figure 182: Changes from reference in selected macroeconomic variables (%) – RCP2.6



Source: GEM-E3-ISL

Figure 183: Contribution to GDP changes – RCP2.6



Source: GEM-E3-ISL

Figure 184: Changes from reference in selected macroeconomic variables (%) – RCP8.5

SOCLIMPACT

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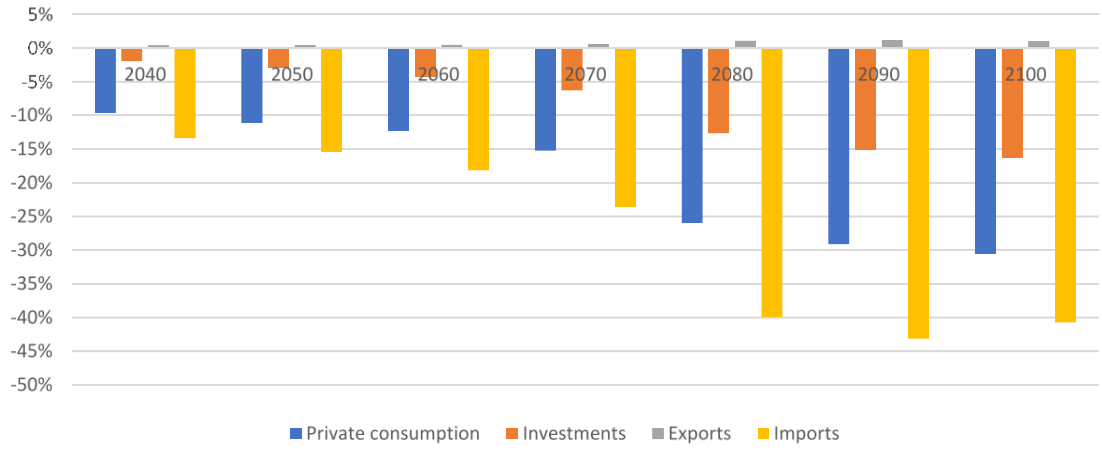
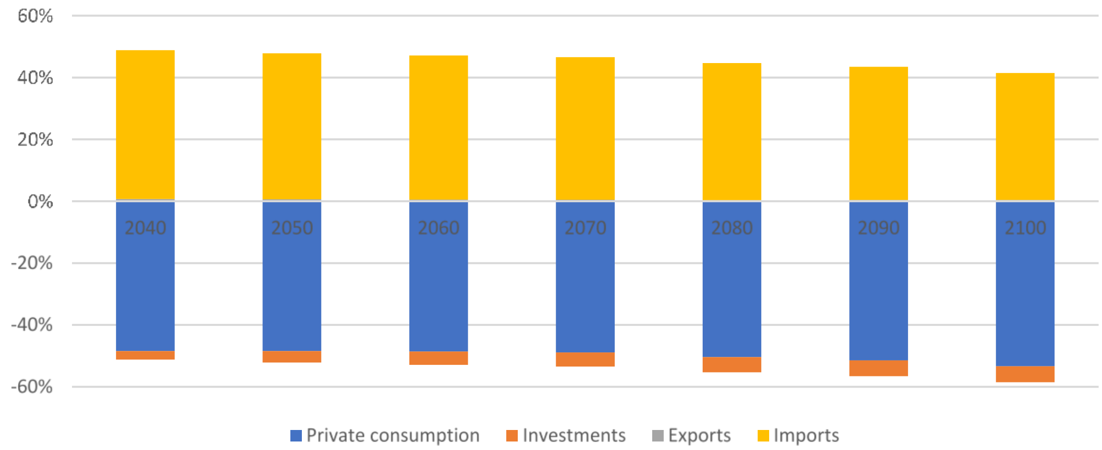


Source: GEM-E3-ISL

Figure 185: Contribution to GDP changes (%) – RCP8.5



Source: GEM-E3-ISL

Decomposing private consumption and investment changes (Figure 186-Figure 189) we find a negative effect in all scenarios examined. In the tourism scenario, lower income generation from the tourism industries leads to lower consumption expenditures while in the energy scenario and investments, while in the energy scenario the crowding out effect caused by the increased investment demand of the electricity sector combined with increased electricity costs leads to a reduction in domestic activity levels, hence private consumption decreases.

Figure 186: Changes in private consumption % from reference – RCP2.6

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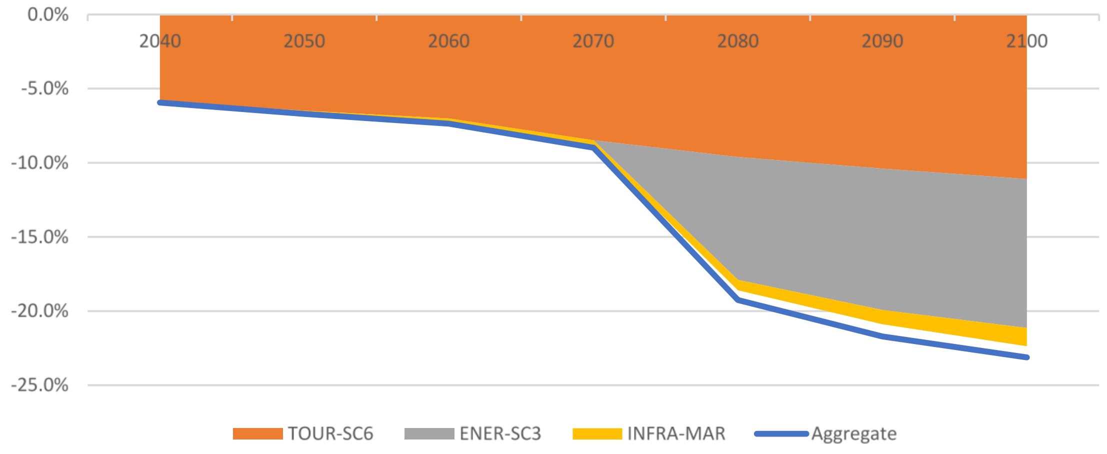
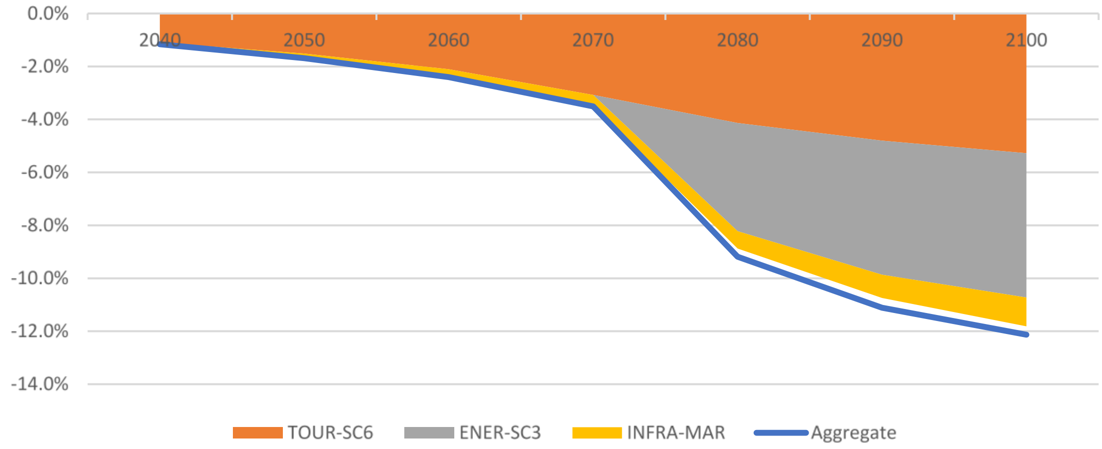


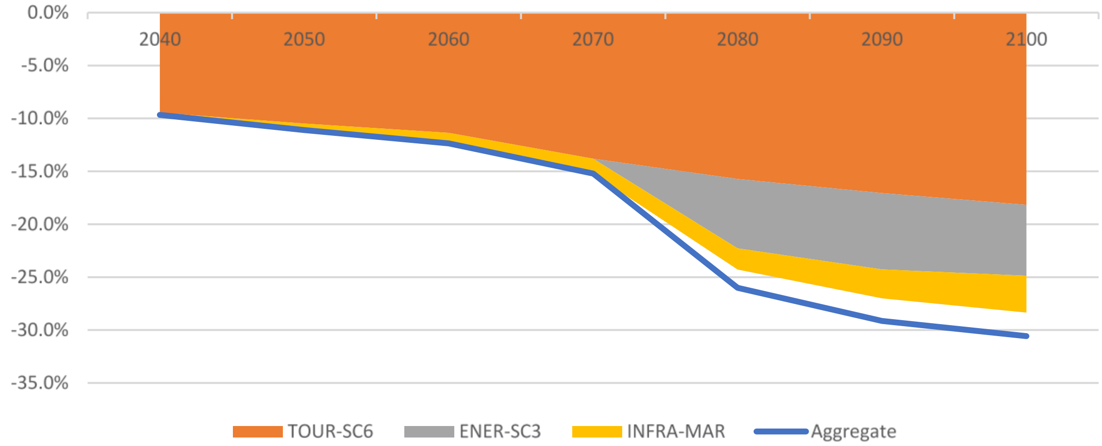
Source: GEM-E3-ISL

Figure 187: Changes in investments % from reference – RCP2.6



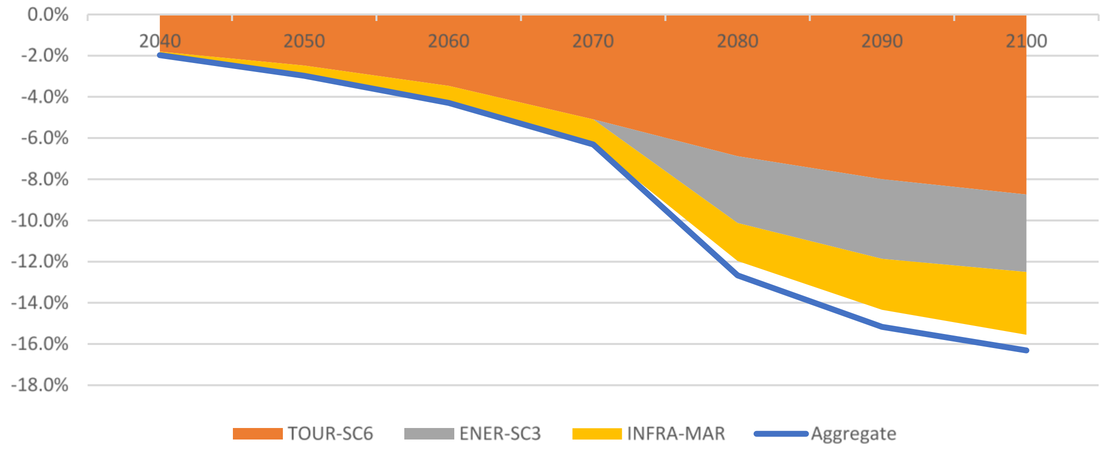
Source: GEM-E3-ISL

Figure 188: Changes in private consumption % from reference – RCP8.5



Source: GEM-E3-ISL

Figure 189: Changes in investments % from reference – RCP8.5

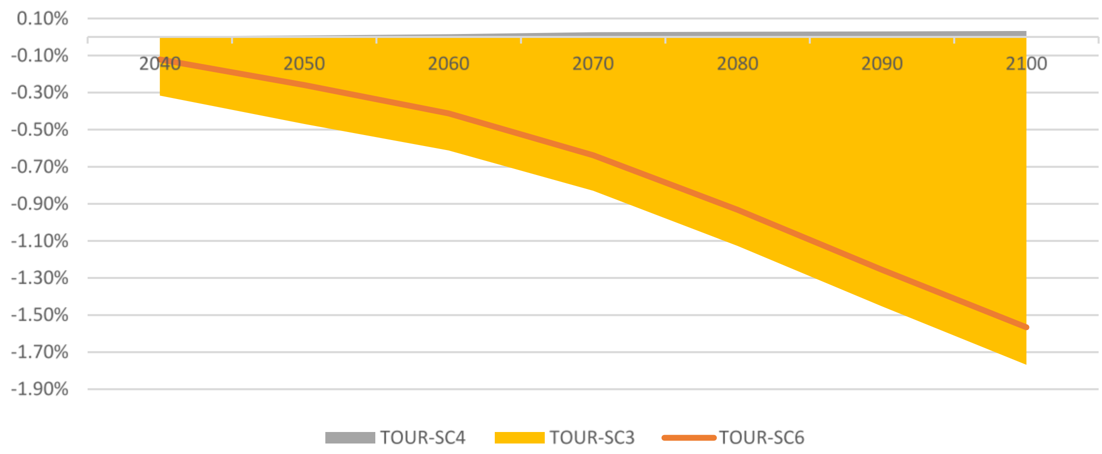


Source: GEM-E3-ISL

3.8.2.1.2 Macroeconomic impacts (tourism)

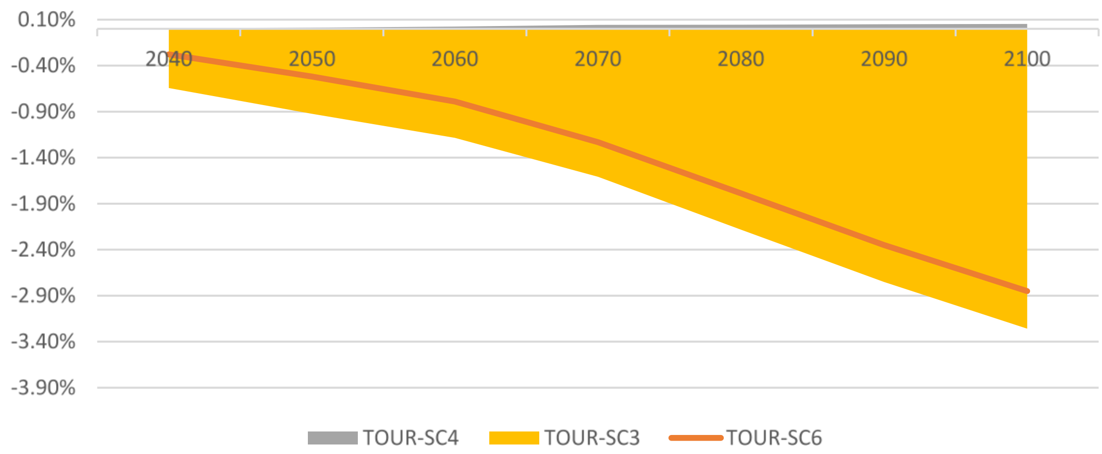
In Azores the tourism industry was responsible for approximately 7% of the regional gross value added in 2015. In Azores the only scenario examined is the one associating tourism revenues to the reduction of the available beach surface (TOUR-SC3). Hence, the results of the composite scenarios and of the tourism variant coincide. In the RCP2.6 scenario the cumulative reduction in tourists' expenditure is estimated to be equal to 23.5% (compared to the reference scenario) and in the RCP8.5 scenario equal to 37.6% for the period 2040-2100. The cumulative GDP impacts are calculated to -0.87% for the RCP2.6 scenario and to -1.6% for the RCP8.5 scenario over the period 2040-2100. Changes in the economy are mainly attributed to the reduction of private consumption expenditures, which comes primarily as a consequence of the decrease activity of tourism related sectors; cumulative private consumption losses are equal to -9 % in the RCP2.6 scenario and -14.7% in the RCP8.5 scenario. Moreover, the reduction in both touristic and domestic demand leads to lower investments (by 3.4% and 5.6% in the RCP2.6 and in the RCP8.5 scenario respectively). Finally, an improvement in the regional trade balance is observed, as lower consumption leads to a reduction in imports demand (by 14.3% in the RCP2.6 and by 23% in the RCP8.5) and exports increase (by 0.4% and 0.6%) as lower employment of tourism related industries exerts negative pressure on wages and capital rents which in turn leads to a reduction in production costs.

Figure 190: GDP change relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 191: GDP change relative to the reference (%) – RCP8.5



Source: GEM-E3-ISL

3.8.2.1.3 Macroeconomic impacts (energy)

The increased demand for electricity is found to have negative impacts on the economy of Azores compared to the reference case. In reality, an increase in the cooling degree days would require the purchase of additional cooling equipment as well as a higher utilization of existing cooling systems. From the household's perspective this is equivalent to higher consumption of electricity per utility level, while for firms it implies higher electricity input per unit of output. To the extent that electricity comes at higher costs, the impact on the economy is negative as the income available for the consumption of other goods and services decrease, while production costs are driven upwards and the competitiveness of domestic products deteriorates.

The electricity system of Azores is isolated which means that all additional electricity requirements needs to be handed by domestic generation facilities. Increased demand, given the

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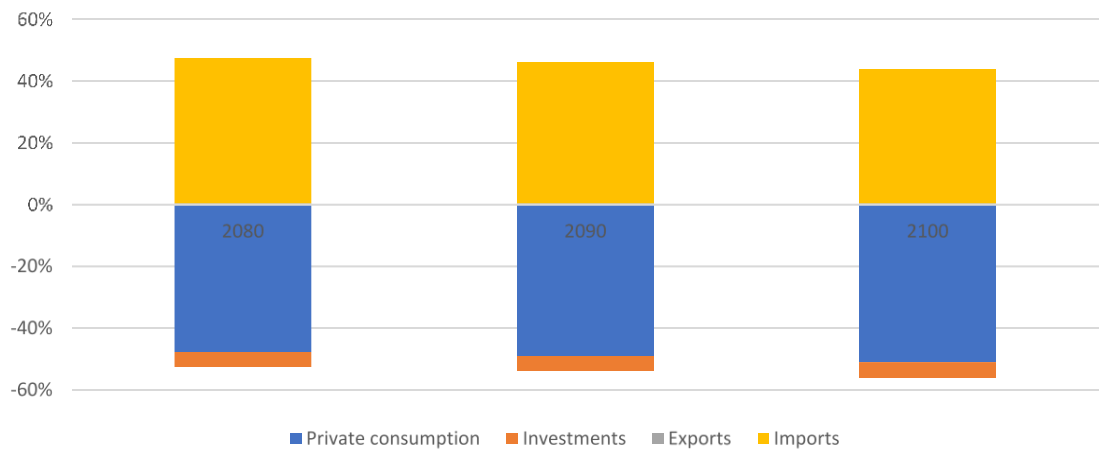
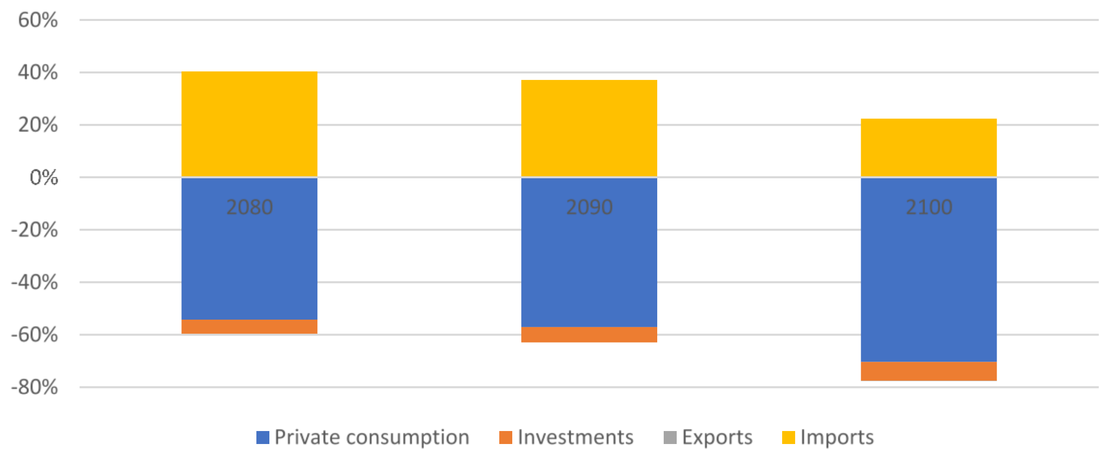
installed generation will lead to higher electricity prices while capacity expansion to meet the increased demand is expected to generate crowding out effects given the limited resources of the regional economy. The model does not feature financing schemes for additional investments in power generation that would alleviate the pressure in the capital markets. For example, a co-financing of investments by the central government or flexible financing schemes (that allocate the relevant expenditures over the years) would limit crowding out in the economy.

Figure 192: Decomposition of GDP changes (%) – RCP2.6



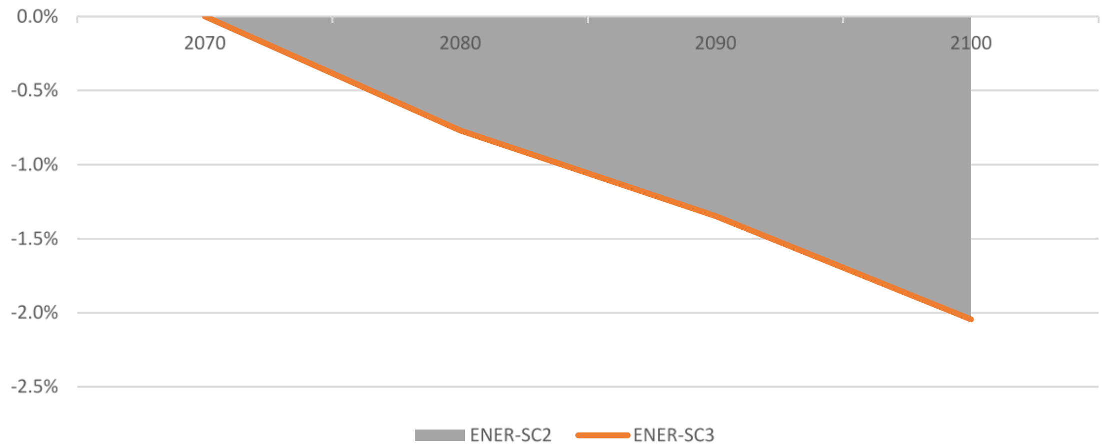
Source: GEM-E3-ISL

Figure 193: Decomposition of GDP changes (%) – RCP8.5



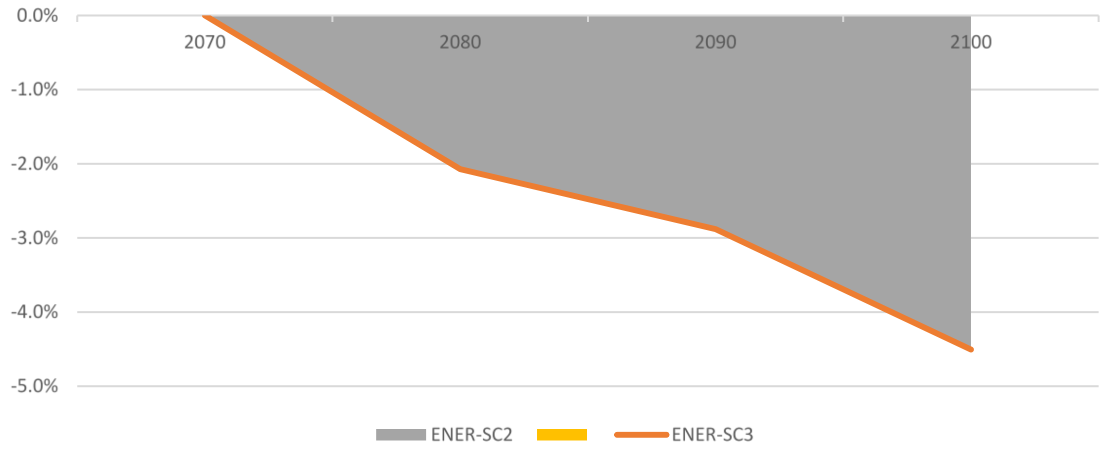
Source: GEM-E3-ISL

Figure 194: GDP changes relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 195: GDP changes relative to the reference (%) – RCP8.5

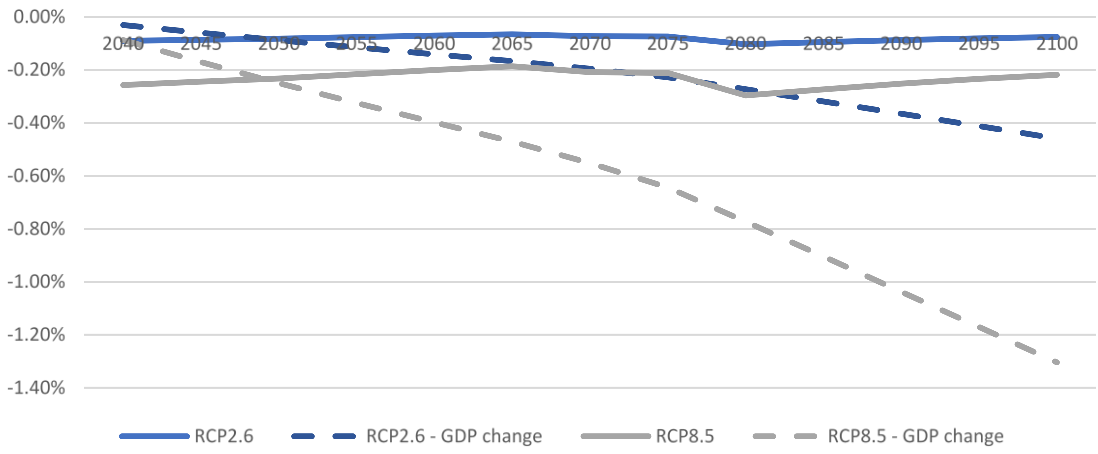


Source: GEM-E3-ISL

3.8.2.1.4 Macroeconomic impacts (maritime)

In this scenario the effect of infrastructure damages is assessed and more specifically those associated to ports and port facilities. Infrastructure damages, one the one hand increase the financing requirements of the economy and stress the capital markets leading to increased capital costs, hence there is a negative impact on the economy. On the other hand, increased investments influence positively domestic activity, as the construction sector which is intensively engaged in the realization of investments employs intensively domestic resources, softening the effect of infrastructure damages.

Figure 196: Capital losses (% of GDP)



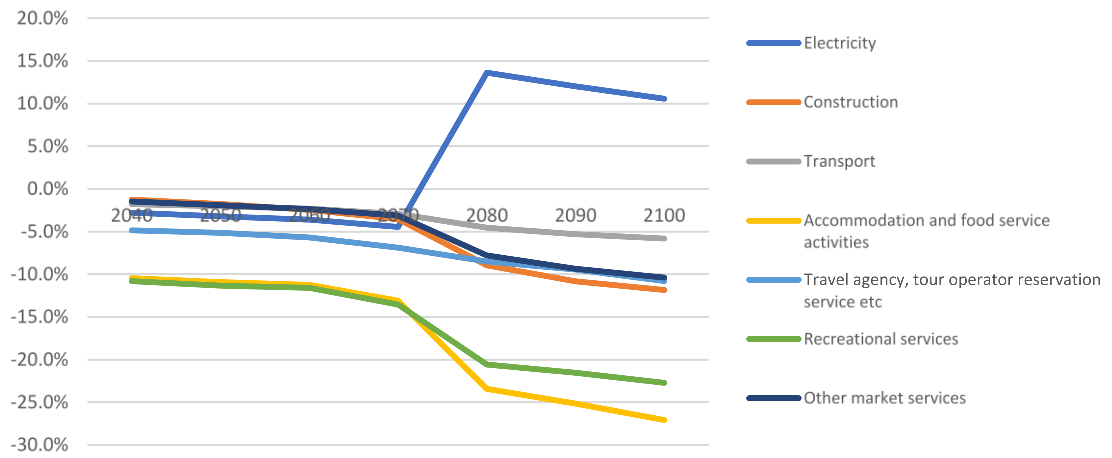
Source: GEM-E3-ISL, D5.4

The scenario results indicate that GDP contracts by 0.12% on average for the period 2040-2065 and by 0.40% for the period 2080-2100 in the RCP2.6; the respective figures for the RCP8.5 are 0.33% and 1.13%. Looking closer at the time profile of the simulation results, we observe that the impacts on GDP are more pronounced in the long-run as capital losses are additive; capital losses exert upward pressure in the markets of primary production factors, leading to increases in wages (due to the substitution effect) and capital rents. In turn, this has a negative impact on the export performance of the economy and domestically produced goods are substituted by cheaper imported products (total imports increase).

3.8.2.2 Sectorial results

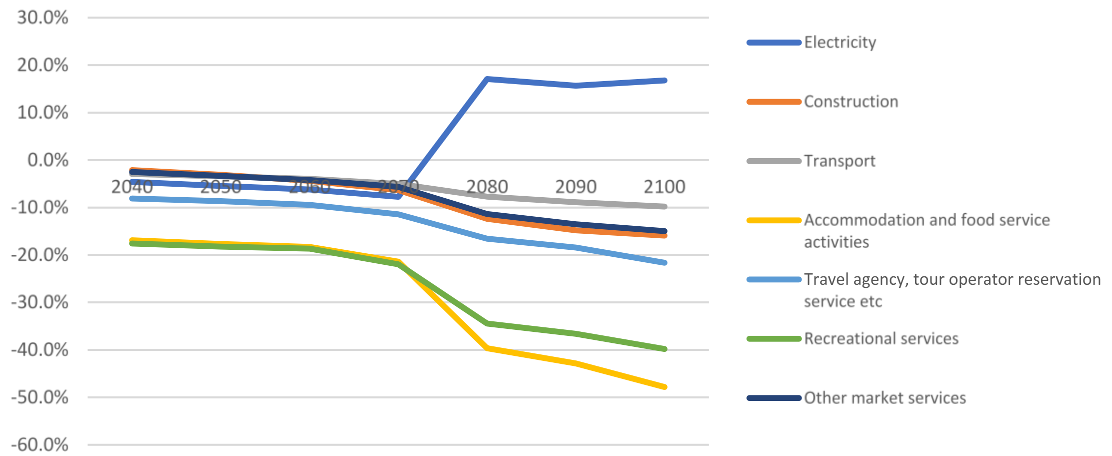
The simulation results of the abovementioned scenarios indicate that the sectors with that experience the steepest decrease, in terms of activity levels, are those associated to the tourism industry, while electricity production increases following the foreseen demand growth. On the tourism side, in both climatic variants activity levels of related industries fall relative to the baseline with the effect being higher in the long-run.

Figure 197: Sectorial activity (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 198: Sectorial activity (% from the reference) – RCP8.5



Source: GEM-E3-ISL

3.8.2.3 Labor market

With respect to the labor market developments, the simulation shows negative impacts for both variants and throughout the simulation period. Th results in the *near* period are driven by the tourism component since electricity demand increases are foreseen only for the period 2080-2100.

Figure 199: Employment (% from the reference) – RCP2.6

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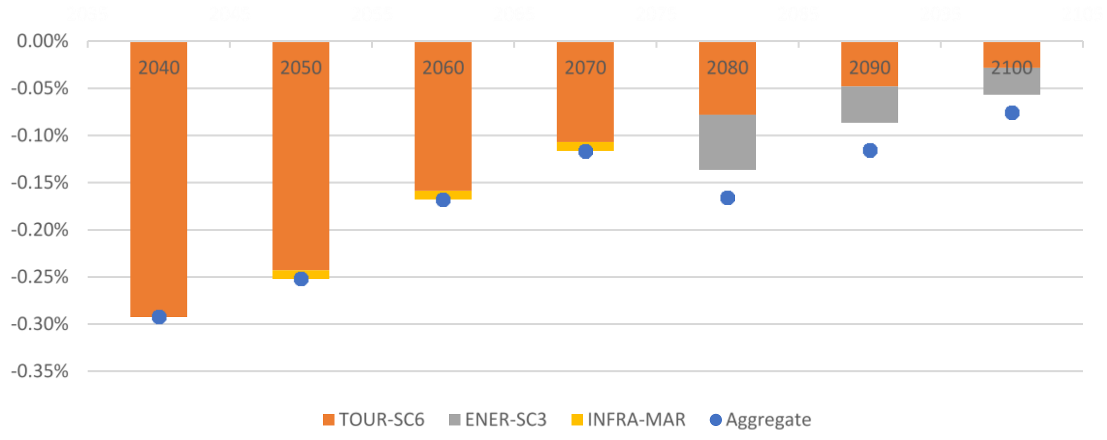

Source: GEM-E3-ISL

Figure 200: Employment (% from the reference) – RCP8.5

Source: GEM-E3-ISL

3.8.3 GWS RESULTS

3.8.3.1 Macroeconomic results

The scenario assumptions (cf. D5.6) on investments on the Azores are zero under the RCP 8.5 scenario. Thus, results are driven by losses, without any counterbalancing activity. GDP losses amount to 4% in the RCP 8.5 scenario in 2050. In the other climate change scenario (RCP 2.6) , investment takes place and is affecting GDP positively, so that there is a small net gain in GDP in 2050 In the years before, GDP effects are also negative..

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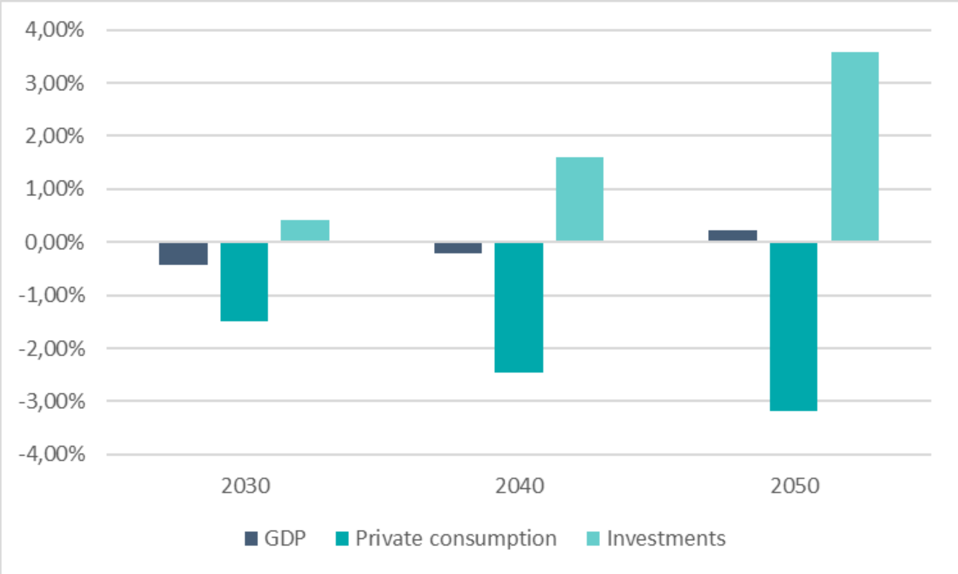
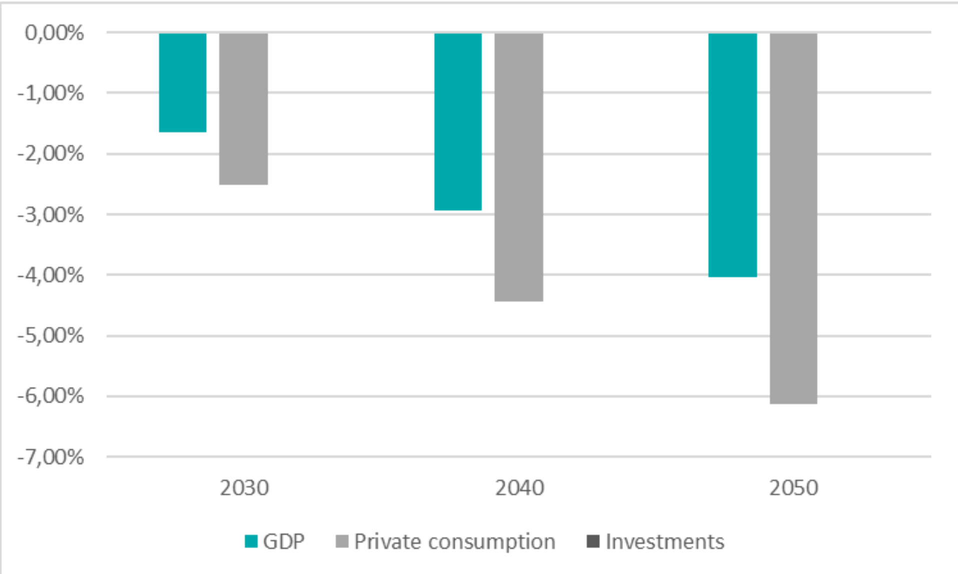
Figure 201: Azores: Components of GDP, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation.

3.8.3.2 Sector specific results

Agriculture gains from climate change because the average temperature on the Azores is increasing. Some other sectors gain from spill over effects of investment in particular Manufacturing and some services. Construction gains directly.

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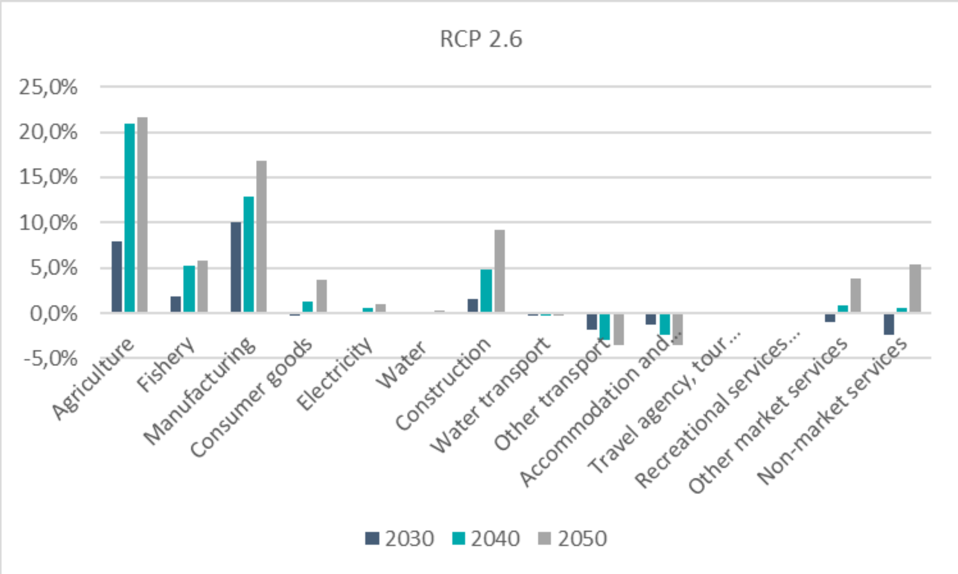
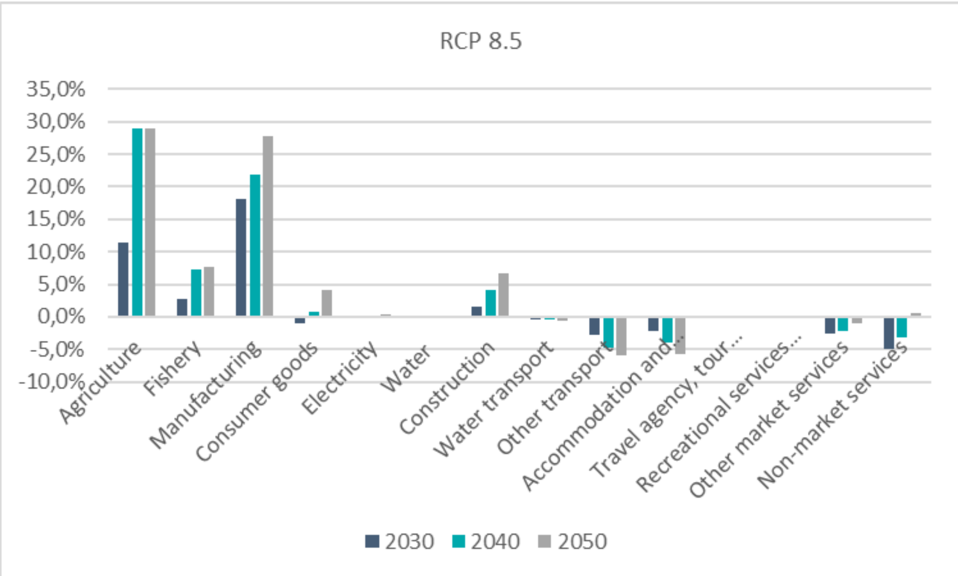
Figure 202: Azores: Value added by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5



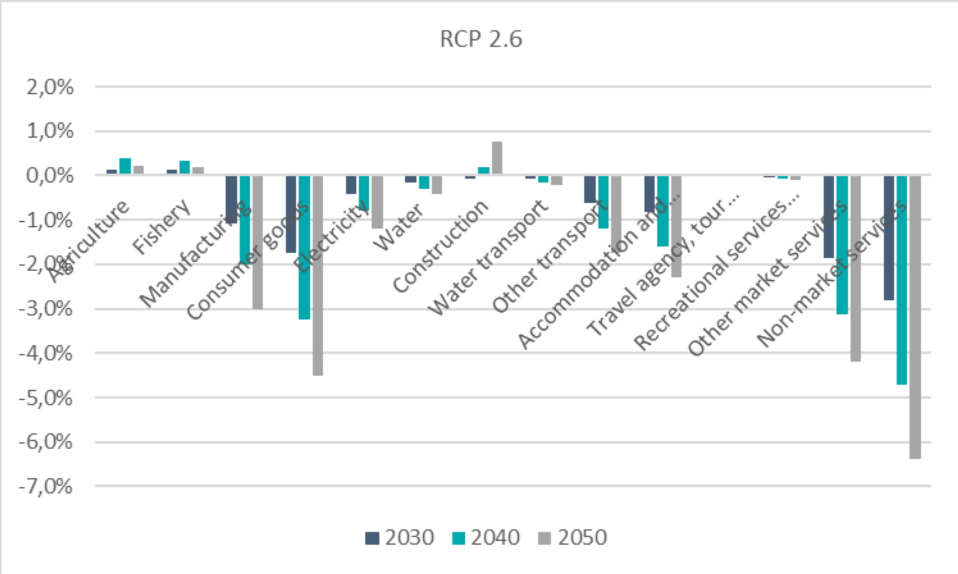


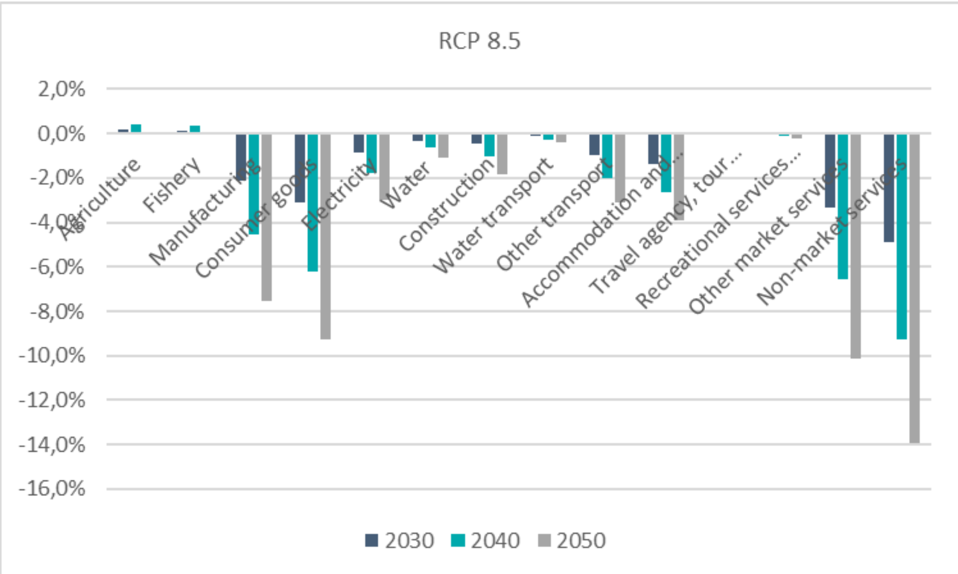
Source: GWS, own calculation.

3.8.3.3 Labor market

Labor market effects are less pronounced than value added changes, due to increased price levels, in most sectors jobs are lost.

Figure 203: Azores: Employment by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation.

3.9 MADEIRA

3.9.1 SCENARIO DEFINITION

The first type of scenarios examines the impact of climate change on tourism by assuming different expenditures by tourists due to biophysical climate impacts on the natural environment and temperatures. In particular, the changes in touristic demand are directly linked to the perception of tourists regarding certain features such as beach surface, the marine environment, the risk of forest fires and warmer conditions and depend on how these features are impacted by climate change. For Madeira the only scenario quantified (inputs are provided by

D5.4) refers to the impact of beach losses on tourism. The second set of scenarios refers to changes in electricity consumption due to increased cooling demand and water availability. Finally, the third set of scenarios refers to infrastructure damages, specifically to port infrastructure, due to sea level rise.

The impact of climate changes on tourists' spending, electricity demand and capital losses are estimated in D5.6 and are used as inputs for the scenario simulations as described in the Methodology Section. The GEM-E3-ISL model assesses their impacts on the main macroeconomic variables (GDP, private consumption, investments, exports and imports), sectorial activity and employment. The inputs provided by D5.6 and incorporated in GEM-E3-ISL for Madeira are described in the following tables:

Table 26: Changes in tourists' expenditures with respect to the reference case (%)

	TOUR -SC1 (marine environment)	TOUR -SC2 (forest fire)	TOUR -SC3 (beach reduction)	TOUR -SC4 (thermal comfort)	TOUR -SC5 (V-disease)	TOUR –SC6 (aggregate)
RCP2.6 near	0	0	-14.36	0.01	0	-14.35
RCP2.6 distant	0	0	-17.05	0.03	0	-17.02
RCP8.5 near	0	0	-23.34	0.09	0	-23.25
RCP8.5 distant	0	0	-28.42	1.05	0	-27.37

Table 27: Changes in electricity consumption with respect to the reference case (%)

	ENER -SC1 (desalination)	ENER -SC2 (cooling)	ENER –SC3 (aggregate)
RCP2.6 near	1.7	0	1.7
RCP2.6 distant	1.5	39.6	41.1
RCP8.5 near	3.2	0	3.2
RCP8.5 distant	8.4	-4.9	3.5

Table 28: Capital losses (% of GDP)

	INFRA-MAR
RCP2.6 near	-0.20
RCP2.6 distant	-0.25
RCP8.5 near	-0.54
RCP8.5 distant	-0.69

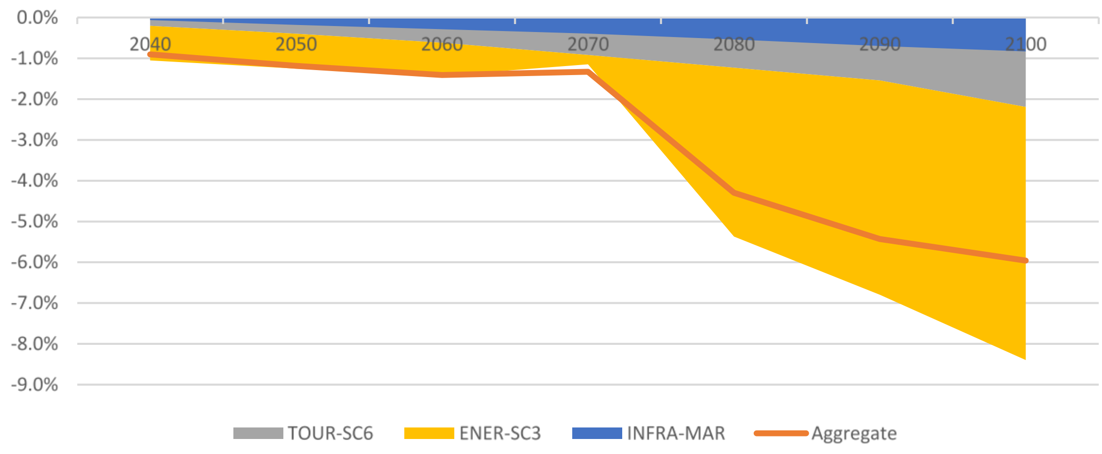
3.9.2 GEM-E3-ISL RESULTS

3.9.2.1 Macroeconomic

3.9.2.1.1 Macroeconomic impacts (aggregate)

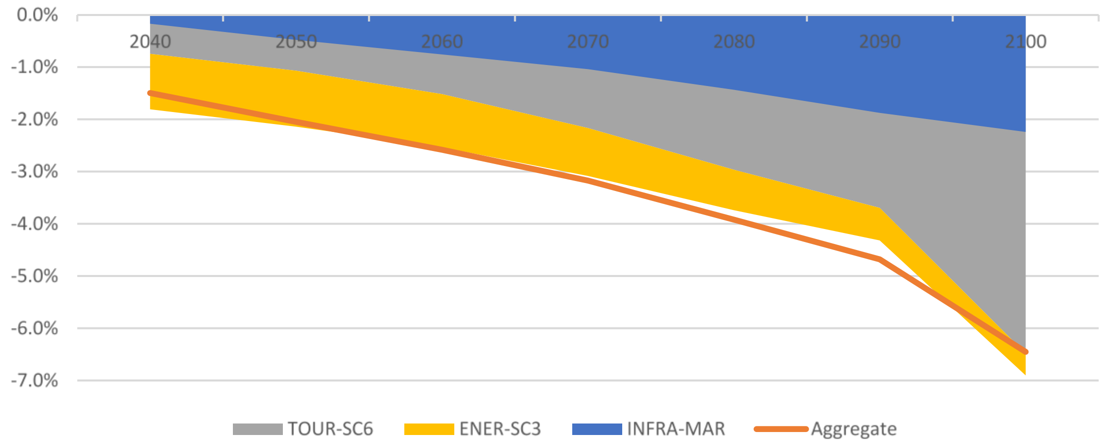
The estimated cumulative GDP impacts of the composite scenario equal to -3.4% for the RCP2.6 (Figure 204) and -3.7% for the RCP8.5 (Figure 205) over the period 2040-2100. In both climatic variants the simulated changes are found to have negative and escalating over time impact on the economy; i.e. the cumulative GDP impacts are equal to -1.27% in the *near* period and -5.59% in the *distant* period for the RCP2.6 and equal to -2.26% and -4.86% for the RCP8.5. The greater effect between the specifications examined in the RCP2.6 is the energy component, which is driven mainly by increases in electricity demand for cooling purposes, while in the RCP8.5, the main effect is related to the tourism component as the foreseen increases in electricity demand are quire lower than the RCP2.6.

Figure 204: GDP changes from reference (%) – RCP2.6



Source: GEM-E3-ISL

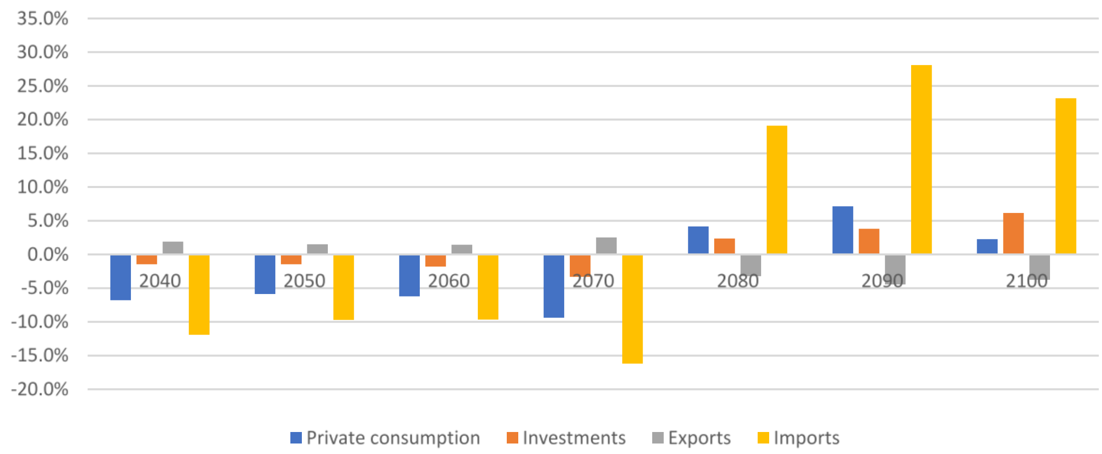
Figure 205: GDP changes from reference (%) – RCP8.5



Source: GEM-E3-ISL

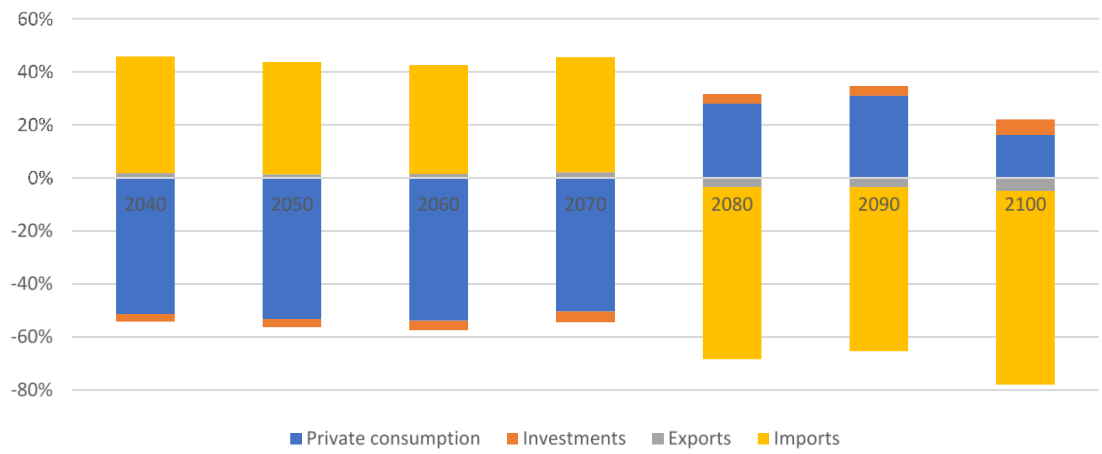
In both climatic variants there is a decrease in private consumption (by 0.4% in the RCP2.6 and by 16.4% in the RCP8.5 cumulatively over the period 2045-2100), while investments and imports follow a different course in the two climatic variants mainly due to the different assumptions on the evolution of electricity demand. While both cumulative investments and imports increase in the RCP2.6 by 0.6% and by 7.8%, in the RCP8.5 they respective changes are -7.2% and -25%.

Figure 206: Changes from reference in selected macroeconomic variables (%) – RCP2.6



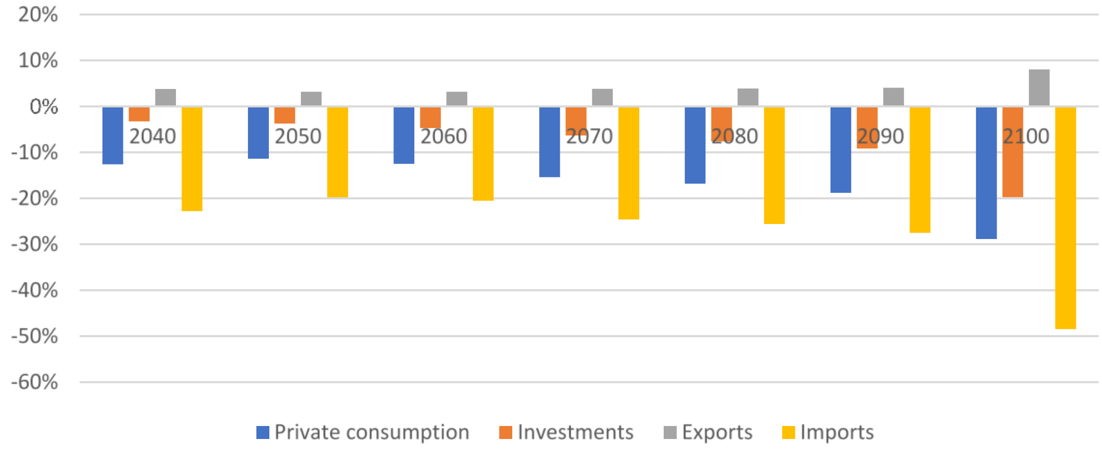
Source: GEM-E3-ISL

Figure 207: Contribution to GDP changes – RCP2.6



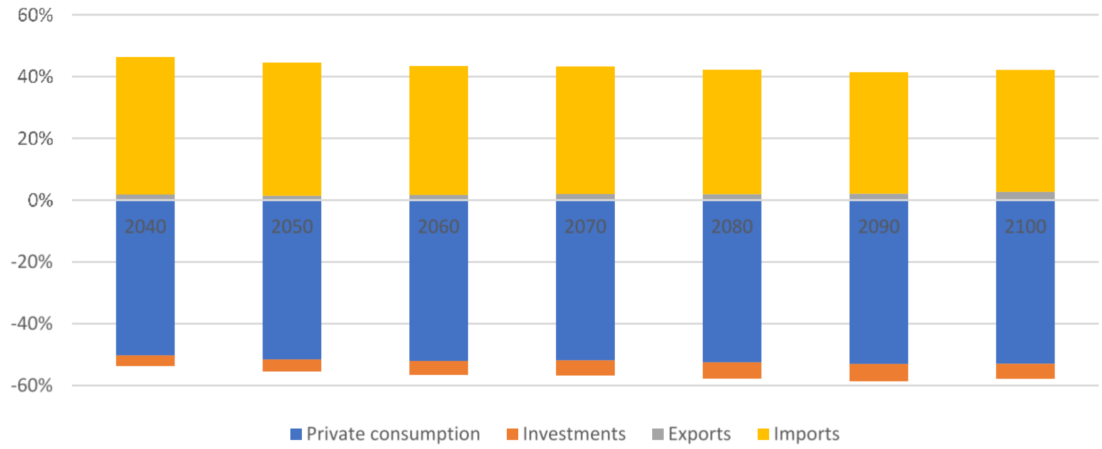
Source: GEM-E3-ISL

Figure 208: Changes from reference in selected macroeconomic variables (%) – RCP8.5



Source: GEM-E3-ISL

Figure 209: Contribution to GDP changes (%) – RCP8.5



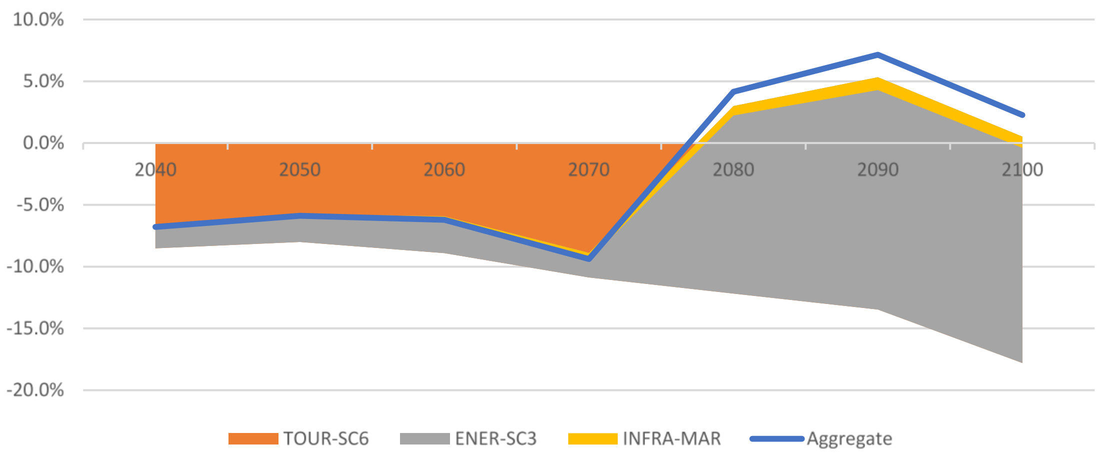
Source: GEM-E3-ISL

Decomposing private consumption and investment changes (

With respect to investments the decrease is attributed both to the lower activity of tourism-related sectors and to the crowding-out effect induced by investments in electricity.

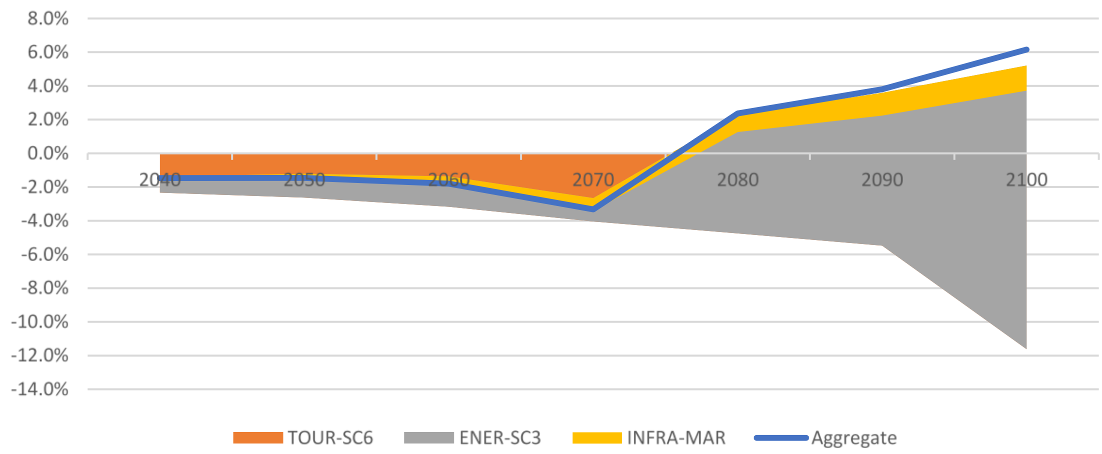
Figure 160-Figure 163) we observe that in the RCP8.5 both variables decrease as the results ae mainly driven by impacts on tourism revenues. In the RCP2.6 there is a sign difference between the effects in the *near* and in the *distant* period which is attributed to assumption regarding the evolution of electricity demand associated with cooling purposes. The scenario specification foresees an increase in total electricity consumption of approximately 40%, which leads to an increase of electricity from households and an increase in investments which expand the productive so supply can match the increased needs for electricity.

Figure 210: Changes in private consumption % from reference – RCP2.6



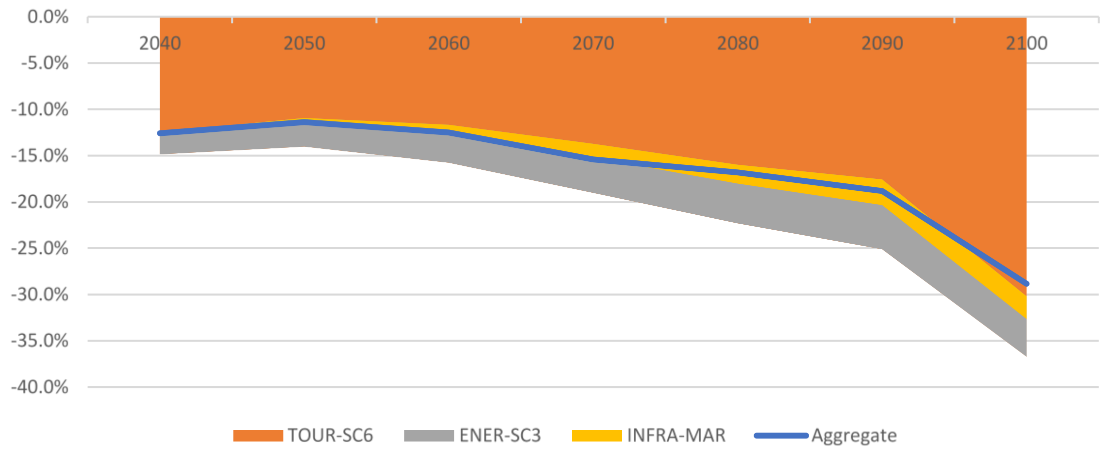
Source: GEM-E3-ISL

Figure 211: Changes in investments % from reference – RCP2.6



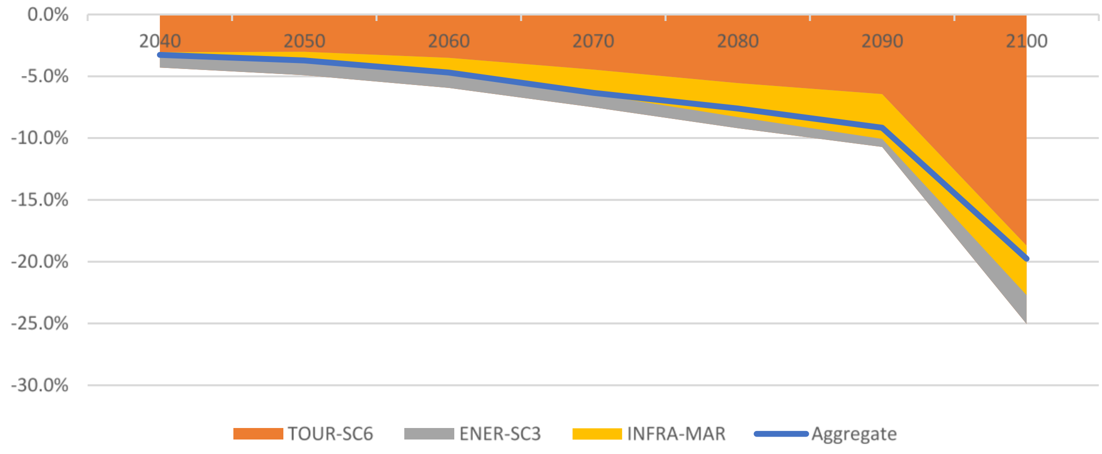
Source: GEM-E3-ISL

Figure 212: Changes in private consumption % from reference – RCP8.5



Source: GEM-E3-ISL

Figure 213: Changes in investments % from reference – RCP8.5



Source: GEM-E3-ISL

3.9.2.1.2 Macroeconomic impacts (tourism)

In Madeira the tourism industry was responsible for approximately 13% of the regional gross value added in 2015. The only scenario examined for Madeira is the one associating tourism revenues to the reduction of the available beach surface (TOUR-SC3). Hence, the results of the composite scenarios and of the tourism variant coincide. In the RCP2.6 scenario the cumulative reduction in tourists' expenditure is estimated to be equal to 15.9% (compared to the reference scenario) and in the RCP8.5 scenario equal to 25.1% for the period 2040-2100. The cumulative GDP impacts are calculated to -1.1% for the RCP2.6 scenario and to -3.7% for the RCP8.5 scenario over the period 2040-2100. Changes in the economy are mainly attributed to the reduction of private consumption expenditures, which comes primarily as a consequence of the decrease activity of tourism related sectors; cumulative private consumption losses are equal to -16.4% in the RCP2.6 scenario and -21.2% in the RCP8.5 scenario. Moreover, the reduction in both touristic and domestic demand leads to lower investments (by 4.5% and 9.1% in the RCP2.6 and in the RCP8.5 scenario respectively). Finally, lower consumption leads to a reduction in imports demand (by 21% in the RCP2.6 and by 26% in the RCP8.5) and exports increase (by 3.6% and 4.1%) as lower employment of tourism related industries exerts negative pressure on wages and capital rents which in turn leads to a reduction in production costs.

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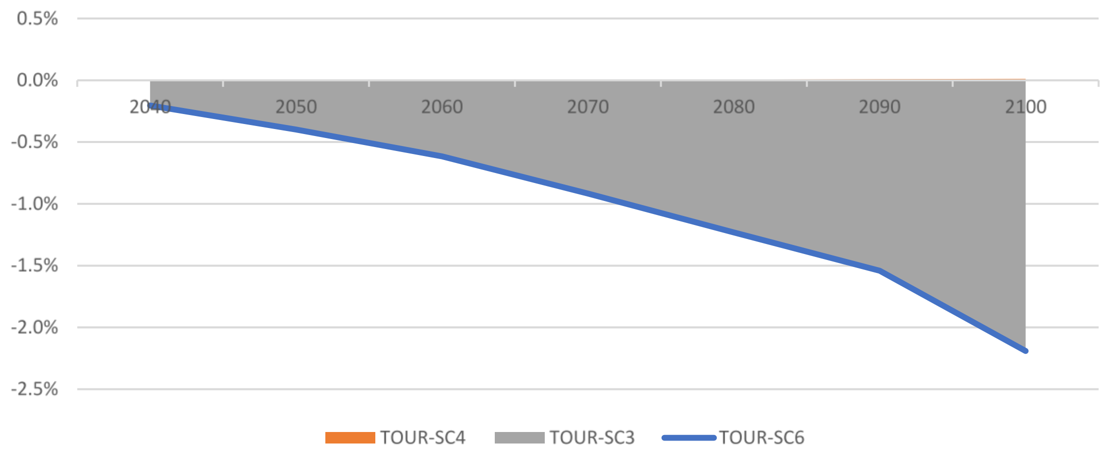
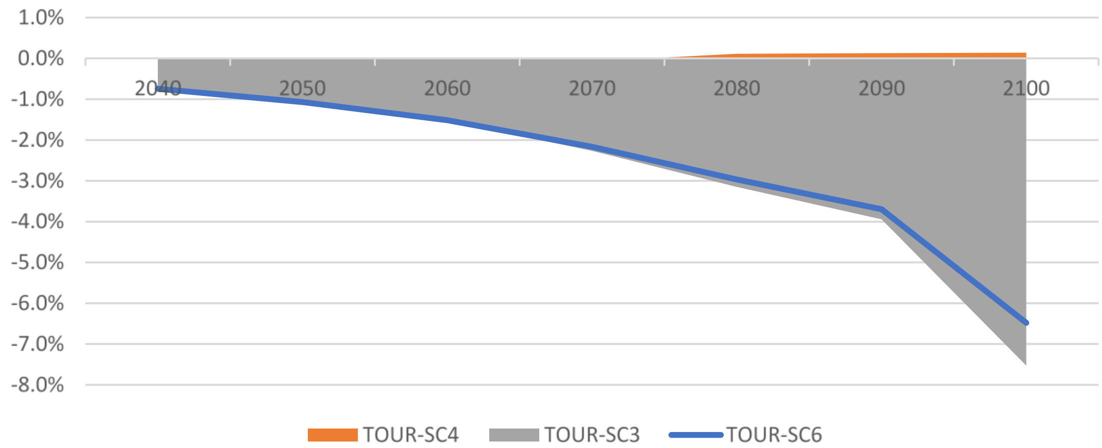
Figure 214: GDP change relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 215: GDP change relative to the reference (%) – RCP8.5



Source: GEM-E3-ISL

3.9.2.1.3 Macroeconomic impacts (energy)

The increased demand for electricity is found to have negative impacts on the economy of Madeira compared to the reference case. In reality, an increase in the cooling degree days would require the purchase of additional cooling equipment as well as a higher utilization of existing cooling systems. From the household's perspective this is equivalent to higher consumption of electricity per utility level, while for firms it implies higher electricity input per unit of output. To the extent that electricity comes at higher costs, the impact on the economy is negative as the income available for the consumption of other goods and services decrease, while production costs are driven upwards and the competitiveness of domestic products deteriorates. The electricity system of Madeira is isolated which means that all additional electricity requirements needs to be handed by domestic generation facilities. Investments in both variants increase, by 5.2% in the RCP2.6 and by 3.3% in the RCP8.5. Higher electricity costs, electricity prices

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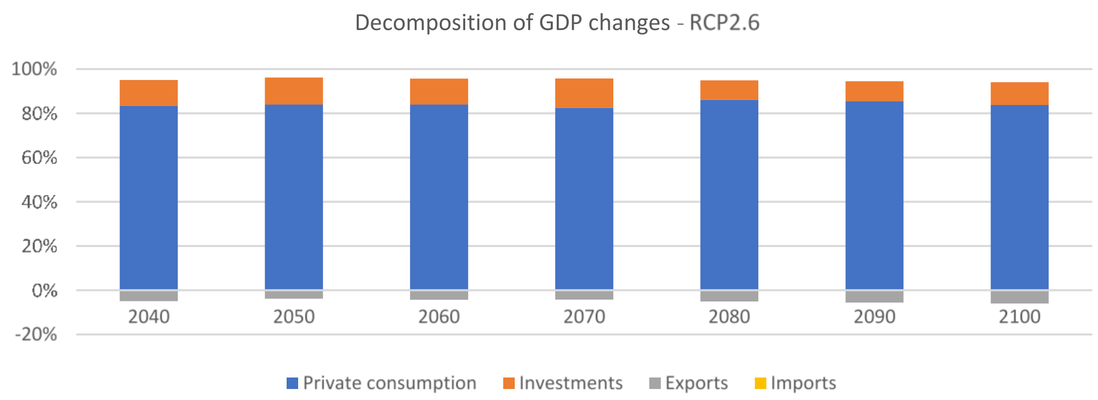
increase on average by 15.2% in the RCP2.6 and 12.9% in the RCP8.5, hinders the competitiveness of domestic products and exports fall by 4.2% in the RCP2.6 and by 2% in the RCP8.5.

Figure 216: Decomposition of GDP changes (%) – RCP2.6



Source: GEM-E3-ISL

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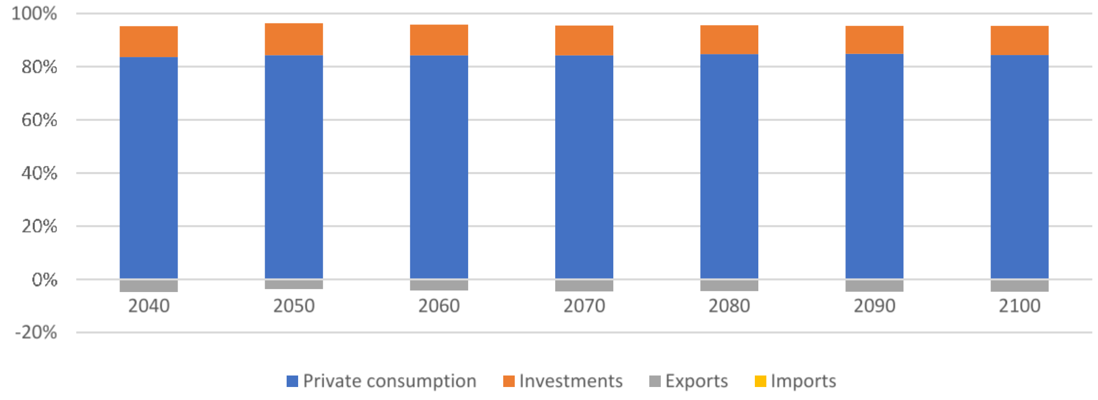
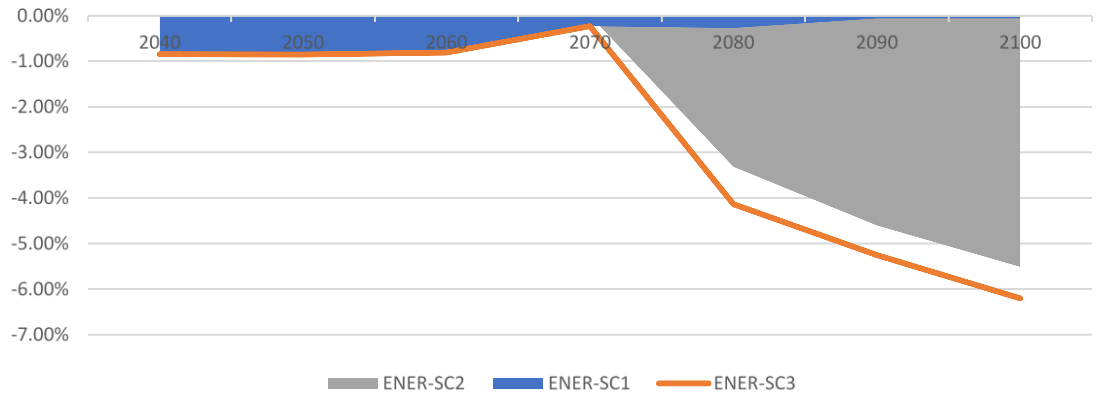
Figure 217: Decomposition of GDP changes (%) – RCP8.5



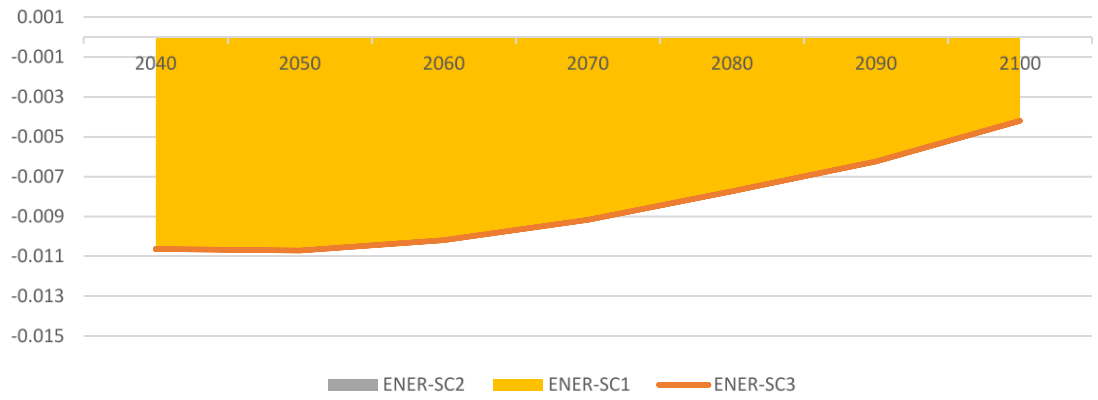
Source: GEM-E3-ISL

Figure 218: GDP changes relative to the reference (%) – RCP2.6



Source: GEM-E3-ISL

Figure 219: GDP changes relative to the reference (%) – RCP8.5

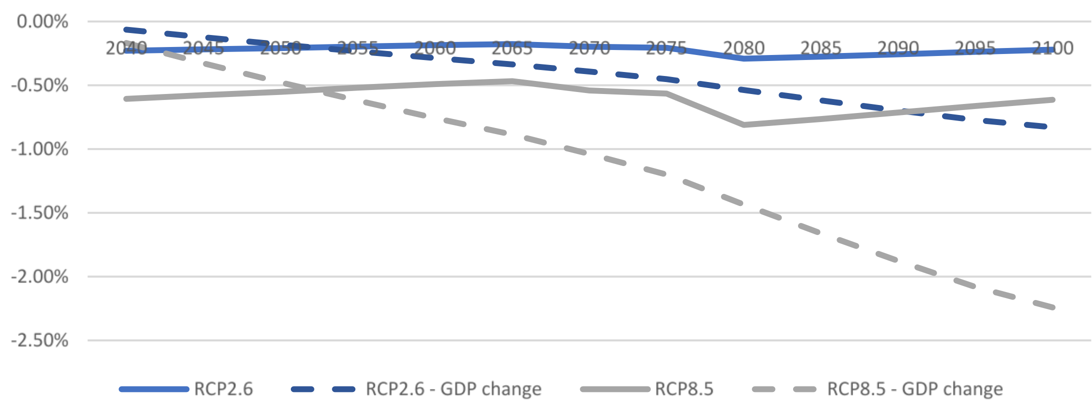


Source: GEM-E3-ISL

3.9.2.1.4 Macroeconomic impacts (maritime)

In this scenario the effect of infrastructure damages is assessed and more specifically those associated to ports and port facilities. Infrastructure damages, one the one hand increase the financing requirements of the economy and stress the capital markets leading to increased capital costs, hence there is a negative impact on the economy. On the other hand, increased investments influence positively domestic activity, as the construction sector which is intensively engaged in the realization of investments employs intensively domestic resources, softening the effect of infrastructure damages.

Figure 220: Infrastructure losses (% of GDP)



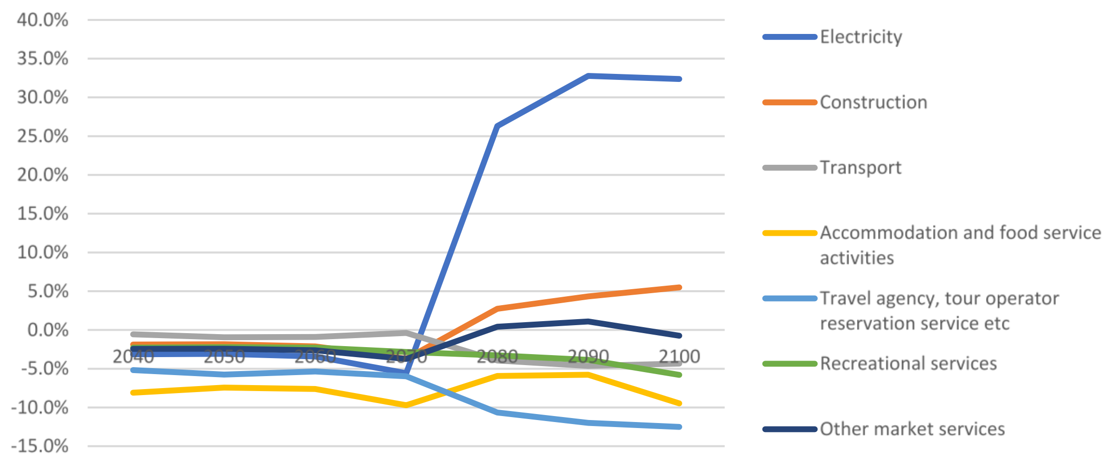
Source: GEM-E3-ISL

The scenario results indicate that GDP contracts by 0.22% cumulatively over the period 2040-2065 and by 0.71% for the period 2080-2100 in the RCP2.6; the respective figures for the RCP8.5 are 0.6% and 1.9%. Looking closer at the time profile of the simulation results, we observe that the impacts on GDP are more pronounced in the long-run as capital losses are additive; capital losses exert upward pressure in the markets of primary production factors, leading to increases in wages (due to the substitution effect) and capital rents. In turn, this has a negative impact on the export performance of the economy and domestically produced goods are substituted by cheaper imported products (total imports increase).

3.9.2.2 Sectorial results

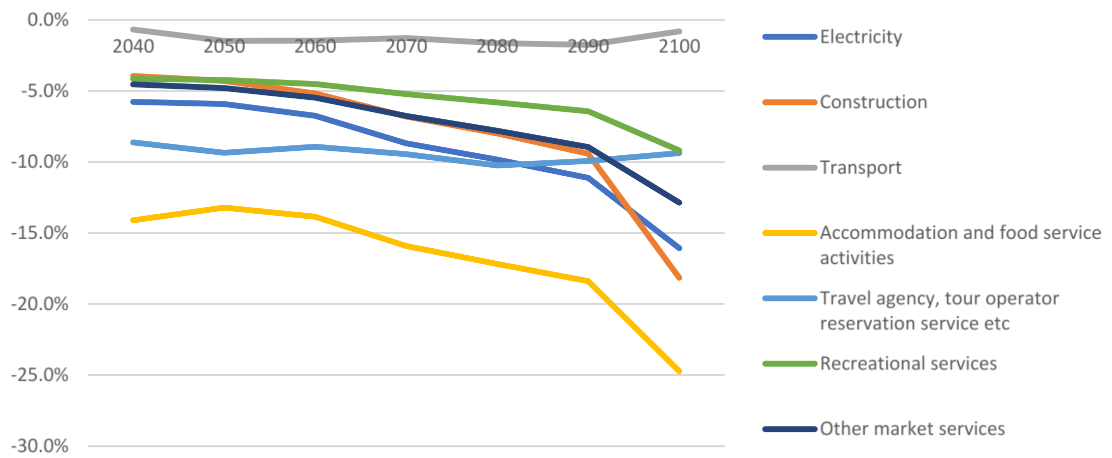
The simulation results of the abovementioned scenarios indicate that the sectors with that experience the steepest decrease, in terms of activity levels, are those associated to the tourism industry. In the RCP2.6 electricity and construction activity increase in the long-run driven by increased electricity demand for cooling, while in the RCP8.5 where additional electricity needs are modest their production falls due to the impact of the decreased tourism revenues. On the tourism side, in both climatic variants activity levels of related industries fall relative to the baseline with the effect being higher in the long-run.

Figure 221: Sectorial activity (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 222: Sectorial activity (% from the reference) – RCP8.5

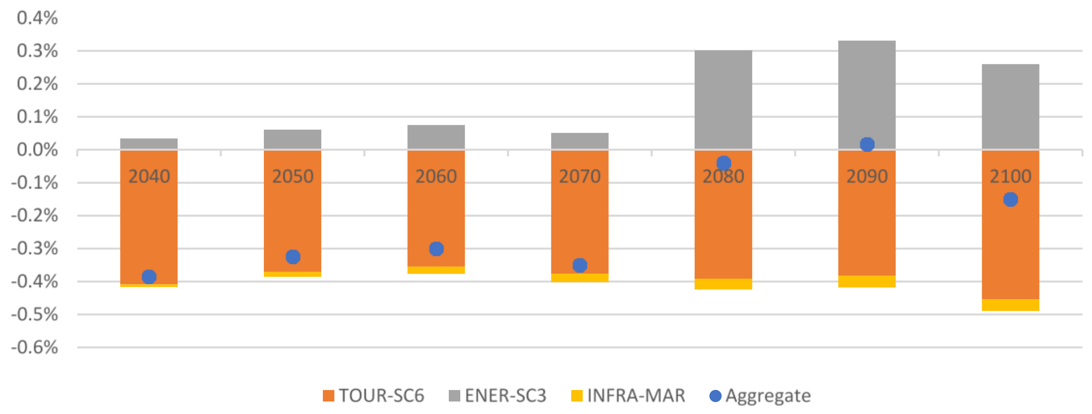


Source: GEM-E3-ISL

3.9.2.3 Labor market

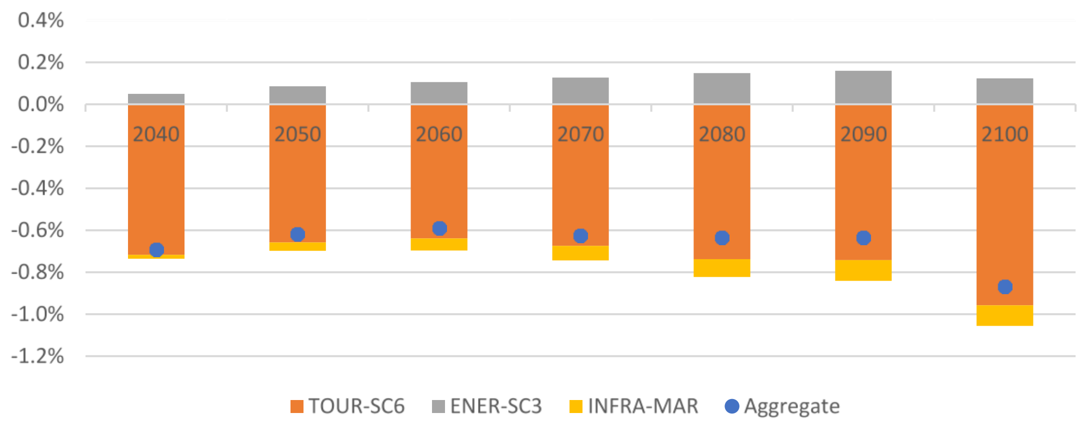
With respect to the labor market developments, the simulation shows negative impacts for both variants and throughout the simulation period. In the RCP2.6, in the period 2080-2100 the employment effects are much smaller in magnitude compared to the RCP8.5 due to increased employment in the construction and in the electricity sector.

Figure 223: Employment (% from the reference) – RCP2.6



Source: GEM-E3-ISL

Figure 224: Employment (% from the reference) – RCP8.5



Source: GEM-E3-ISL

3.9.3 GWS RESULTS

3.9.3.1 Macroeconomic

Madeira is losing up to 3.2% in GDP, due to tourists and higher transportation costs. Investment increases only by 1% and thus is not sufficient to counterbalance these effects. Under the RCP 8.5, these effects increase only by a small amount. The main reason lies in the way climate change affects the Island: tourism losses do not increase dramatically under the RCP 8.5.

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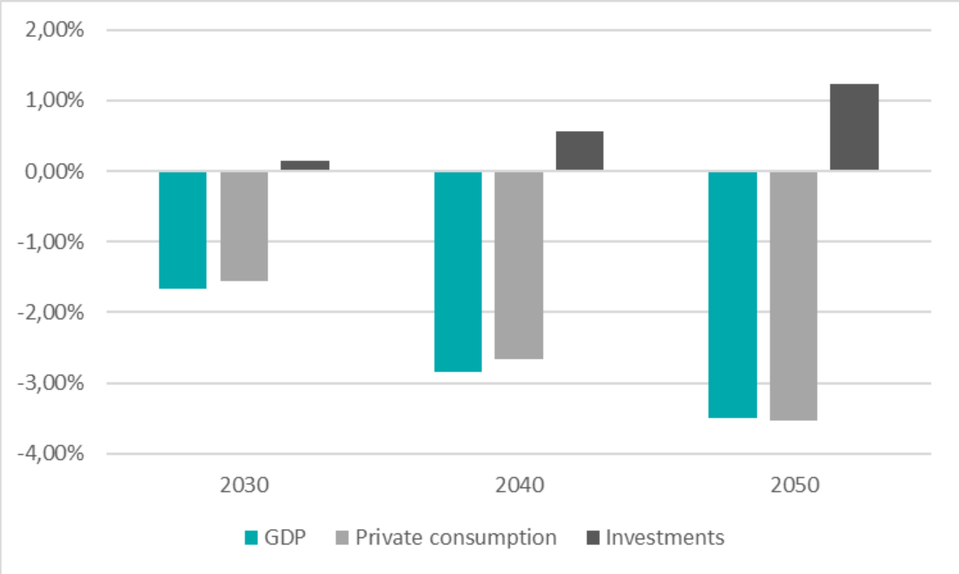
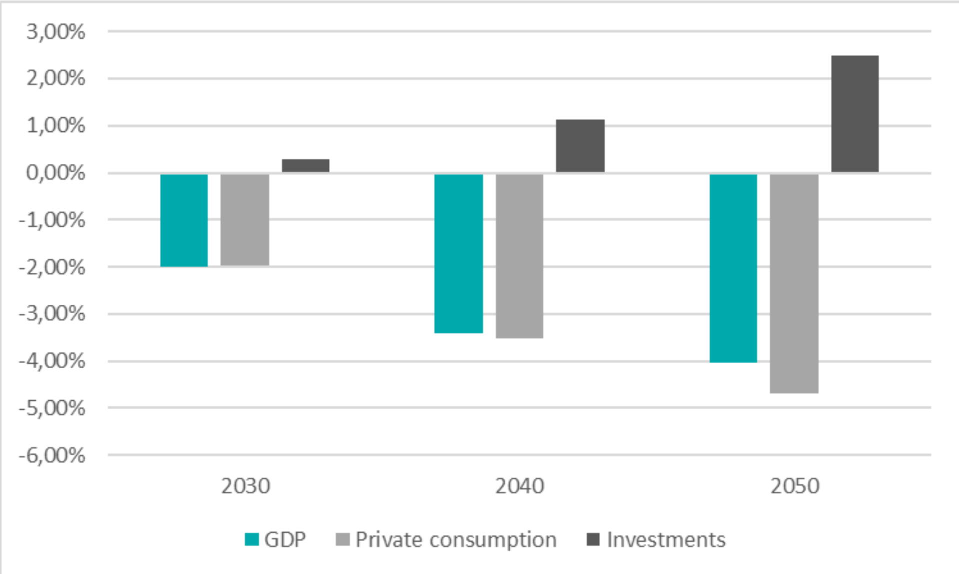
Figure 225: Madeira: Components of GDP, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5



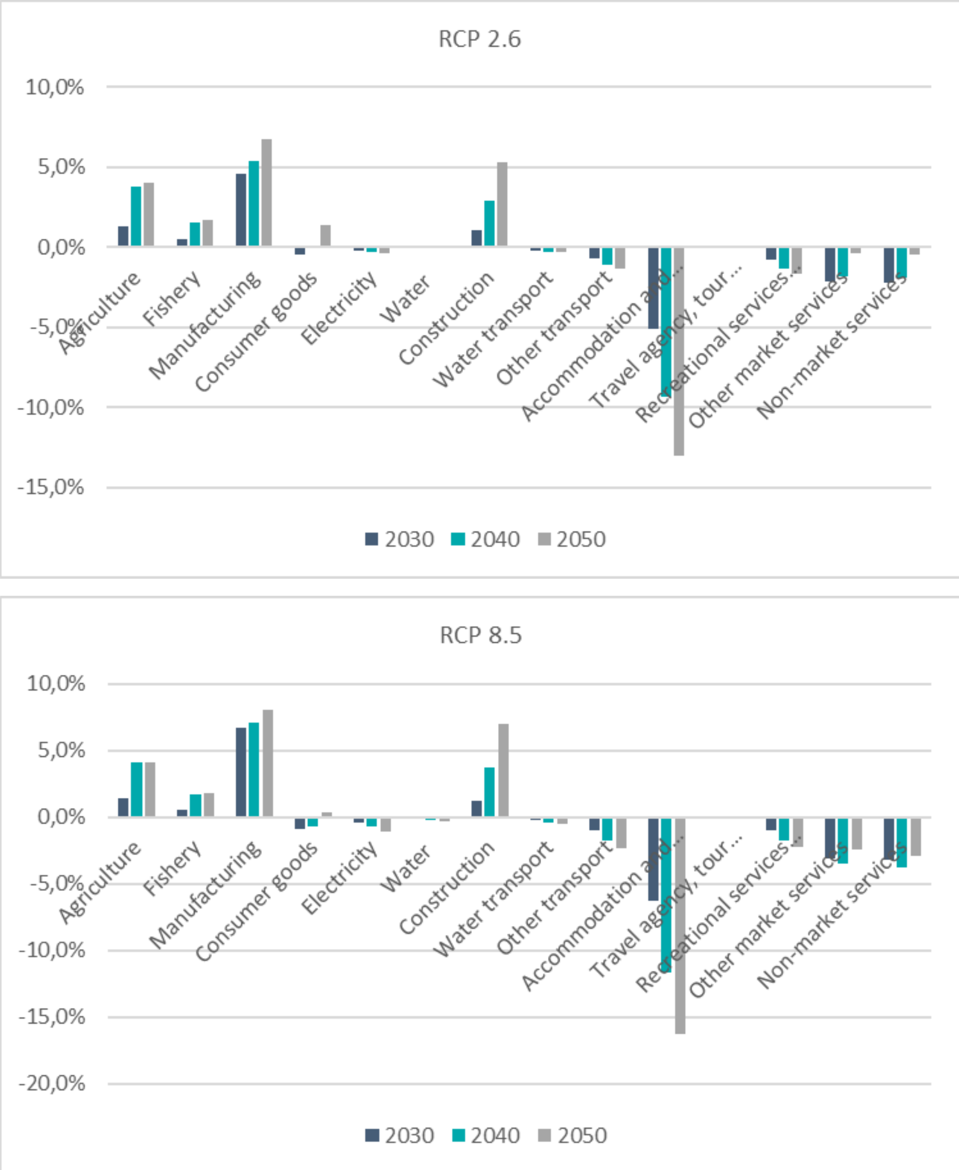


Source: GWS, own calculation.

3.9.3.2 Sectorial results

Manufacturing and construction benefit from additional investment. The small manufacturing sector grows by up to 5% under RCP 2.6. However, value added from tourism related sectors is lost by more than 12% in the upper scenario, and by 16% in the lower scenario. As pointed out above, the difference in tourism loss between the two scenarios is not very large.

Figure 226: Madeira: Value added by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5



Source: GWS, own calculation.

3.9.3.3 Labor market

Labor market results follow mostly the pattern of lost value added, due to increased price levels, in most sectors jobs are lost.

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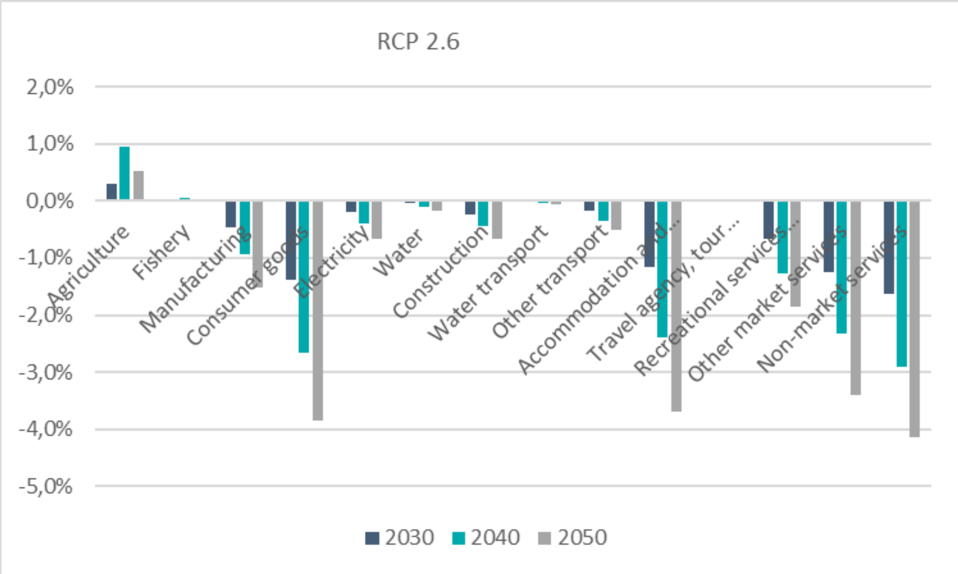
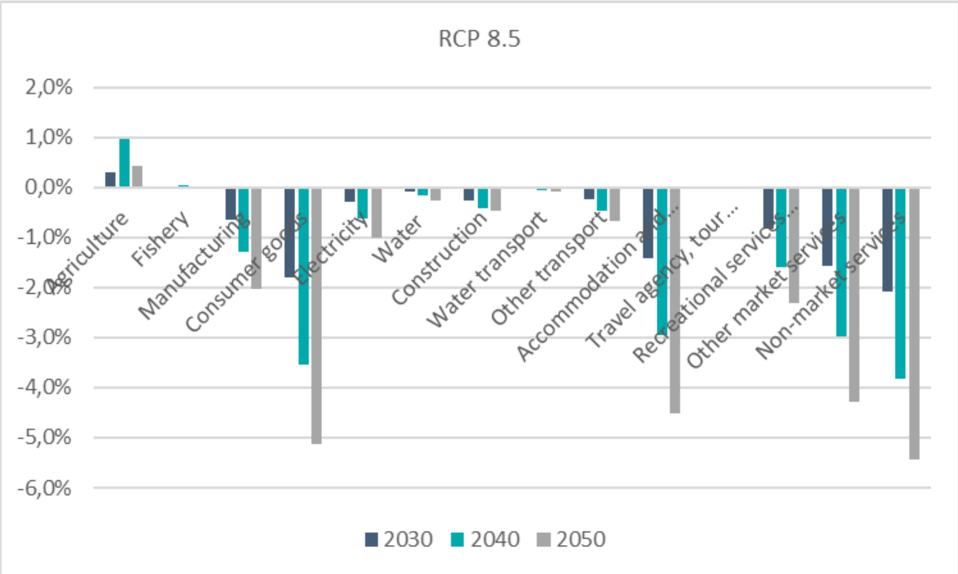
Figure 227: Madeira: Employment by sector, percent change to reference. Upper figure: RCP 2.6, lower figure: RCP 8.5





Source: GWS, own calculation.

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4 CONCLUSION AND OUTLOOK

This report presents the economic impacts from climate change damages simulated by two models that are based on different theoretical underpinnings. The insights are common whereas in some cases the model results are complementary providing together a robust analytical framework. Among others the two model differ in their time -horizon coverage. While long term simulation is standard for CGE models, (being structural optimization models), macro-econometric models are based on estimated time series from the past, and thus only valid under a shorter time horizon (Lucas critique). Macro-econometric models are characterized by a certain rigidity in adjusting to exogenous shocks, which is valid on mid-range simulations. In the long term, of course, the economy can better adjust, for instance to a warmer climate.

GINFORS solves sequentially on an annual basis. Thus, the results for the pathway to the first damages identify ed for the near future (starting 2040) are reported, too. The far future damages are not included in the GINFORS simulations. The long-term effects are captured by the CGE model.

In the short term (up to 2050), GDP results for both models are similar. For instance, GDP changes in the Balearic Islands reported by GEM-E3-ISL and GINFORS are between -1.5% and over 2% under RCP2.6 and between 2.5% and 3.5% under RCP8.5 until 2050. Sector specific changes, however, differ. While construction receives in both scenarios positive impacts, the spill-over effects into other sectors are more pronounced in the GINFORS model. Travel related sectors, of course, receive the negative impacts. Transport loses from increasing transport costs in GINFORS. The Islands' economies respond differently depending on their respective economic structure, the relevance of the Blue Economy Sector hit hardest by climate change, i.e. tourism for the overall economy and the relevance of transport on the islands. The assessment suggests that islands should intensify their efforts for economic diversification, promoting local products and small manufacturers.

The exercise shows the importance of modeling all Islands individually, because the reactions to climate change and the damages in the respective sectors differ widely across islands and from the main countries. Malta and Cyprus, for instance, experience smaller GDP losses than the Canaries. The Azores, located in a colder area in the center of the Atlantic, suffer the least from climate change compared to all other islands.

The analysis on the down-scaled level of islands helps to better inform and better target adaptation policies by Island decision makers.

In the future, modelling climate change and adaptation measures for the islands can be expanded. This includes more detailed economic data and further integrating models for the Islands with the national level. It is important to understand the specific socio-economic developments and challenges of the Islands in the future. Knowledge about damages due to climate change and effects of adaptation measures for the islands should be improved continuously to better design policies.

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