Chapter 5
Findings and strategy for addressing climate change in Greece

5.1 Findings of Chapter 1*

The Mediterranean is universally recognised as particularly vulnerable to the impacts of anthropogenic climate change. Climate change in Greece was studied based on the results of a series of climate simulation models. Temperature is projected to rise significantly by the end of the 21st century, while precipitation is projected to decrease. Available observations indicate that precipitation over the previous century decreased by around 20% in Western Greece and by 10% in Eastern Greece. This is attributed in part to the positive trend in the North Atlantic Oscillation (NAO) index. Future climate projections also indicate that the next decades will see a significant increase in the frequency of extreme temperature and precipitation events.

According to the simulations of anthropogenic climate interference under the two extreme scenarios (B2 and A2), by 2100 the air temperature will have increased by 3.0ºC and 4.5ºC respectively. The temperature increase will be greater in the mainland than in the island areas, and more pronounced in summer and autumn than in winter and spring. Meanwhile, the decrease in rainfall, countrywide, is expected to range between 5% (Scenario B2) and roughly 19% (Scenario A2). The climate simulations estimate that relative humidity, countrywide, will decrease by between 1% (Scenario B2) and 4.5% (Scenario A2). Relative humidity levels are projected to drop more markedly in the mainland regions, especially in summer, but are expected to remain unchanged in the island areas.

The simulations also point to a decrease in cloud cover in Greece in coming decades, compared with the baseline period 1961-1990, by between 8% (Scenario B2) and 16% (Scenario A2). Solar radiation on a national scale is expected to increase by between 2.3 W/m² (Scenario B2) and 4.5 W/m² (Scenario A2), while mean annual wind speed is not expected to change significantly, apart from the Etesian winds the intensity of which is expected to increase by as much as 10%.

* Sub-chapter 5.1 was co-authored by Christos Zerefos, John Kapsomenakis and Costas Douvis.

Based on the available simulations, even under the intermediate Scenario A1B, the Greek mainland in 2071-2100 will, compared to now, have some 35-40 more days with a maximum daily temperature of 35ºC or more, while even greater will be the increase (by around 50 at the national level) in the number of tropical nights (when minimum temperatures do not fall below 20ºC). On the other hand, the number of frost nights is expected to drop significantly, especially in Northern Greece (by as many as 40). Moreover, the rise in average temperature will prolong the vegetation period by 15-35 days.

One of the major impacts of global warming is that the energy demand for cooling in summer months is expected to increase. More specifically, the low-lying areas of continental Greece are projected to have increased cooling needs for up to an extra 40 days per year during the period 2071-2100, while the increase in cooling needs is expected to be smaller in the islands and the mountain areas. A positive aspect of climate change is that energy needs for winter heating are expected to decrease.

Changes are also projected in precipitation extremes. In Eastern Central Greece and North-Western Macedonia, the maximum amount of precipitation occurring within 3-day periods is expected to increase by as much as 30%, whereas in Western Greece it is expected to decrease by as much as 20%. By contrast, the greatest increases in drought periods are projected for the eastern part of the mainland and for Northern Crete, where 20 more drought days are expected per year in 2021-2050 and up to 40 more drought days are expected in 2071-2100. As a result of climate pattern changes, the number of days with a very high risk of fire is expected to increase significantly by 40 in 2071-2100 across Eastern Greece (from Thrace down to the Peloponnese), while smaller increases are expected in Western Greece. The number of days with a humidex value of >38ºC will be prolonged by as many as 40 in the coastal areas along the Ionian Sea and in the Dodecanese, and by somewhat less (roughly 25 additional days) in the low-lying areas of continental Greece and Crete, as projected for the period 2071-2100.

Based on calculations, the sea level is projected to rise by between 0.2 m and 2 m by the year 2100. Of course, any assessment of an area's vulnerability to a rise in average sea level (coastal risk assessment) inevitably involves considerable uncertainty, as such risk is determined not only by the rate and extent of the sea level rise, but also by other local factors, such as tectonics, sediment supply (from inland) and coastal geomorphology/lithology.

Typical examples are the coastal areas of the Northern Peloponnese (projected to gain 0.3 to 1.5 mm/year in elevation), Crete (0.7 to 4.0 mm/year) and Rhodes (1.2 to 1.9 mm/year). Thus, for instance, an average sea level rise of about 4.3 mm/year could be reduced to 3.5 mm/year as a result of a compensatory, tectonically-induced mean elevation uplift of about 0.8 mm/year. Changes in sediment-laden inflows to the deltaic estuaries of large rivers can potentially offset a sea level rise, if the sediment deposits increase, causing the delta in question to advance. Conversely, a decrease in fluvial sediment discharge could result in a greater marine inundation of the area in the event of a sea level rise. Finally, coastal morphology, especially in terms of coastal slope inclination and lithologic composition, is an important factor, directly related to the rate of erosion.

Calculations of shoreline length showed that of Greece's total 16,300 kms in coastline, some 6% (or 960 km) correspond to coastal deltaic areas of high vulnerability, 15% (or 2,400 km) to newly-formed soft sediment layers of moderate vulnerability, while the remaining 79% (or 12,900 km) correspond to rocky coastal areas of low vulnerability. Therefore, the total length of shoreline with a moderate-to-high vulnerability to sea level rise comes to about 3,360 km, i.e. 21% of Greece's total shoreline.

Assuming that there are no tectonically-induced and geodynamic corrections, a sea level rise of 0.5 m to 1 m would result in a shoreline retreat of between 30 m and 2,750 m in the high risk deltaic areas, such as the Axios-Aliakmon or the Alfeios deltas, while a sea level rise of 1 m would result in a shoreline retreat of between 400 m and 6,500 m.

5.2 Findings of Chapter 2*

Our analysis of the impacts of climate change per sector of the economy enabled a first quantification and cost valuation in Greece of the anticipated impacts. This, it is hoped, will serve as a valuable basis for the elaboration of adaptation policies covering most of the Greek economy. The climate change impacts identified in the respective sectoral studies are summarised below.

Water reserves

Climate change is expected to have the following negative impacts on the water resource sector in all of Greece's water districts and under all the scenarios considered:

- An overall decrease in aquifer infiltration and recharge, as a result of decreased rainfall and higher evapotranspiration;
- Increased salinity of coastal and subsea aquifers, particularly karstic ones, as a result of the advance of the sea-water intrusion farther inland due to the decline of groundwater levels caused by lower inflow and overpumping;
- Higher pollutant load concentrations in coastal water bodies and the sea, due to lower dilution;

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• The faster breakdown of deltaic regions, in cases where degradation has already begun as a result of transversal dam construction upstream (reduced drainage and sediment discharge) and parallel levee construction in the flat zone of the deltas (debris channelled to a single outlet);

• Contamination or drainage of coastal wetlands; and

• Amplification of the desertification phenomenon, due to water deficits and soil changes (compaction, sealing, etc.).

Rainfall countrywide is projected to decrease by between 3% (Scenario B2) and 8% (Scenarios A1B and A2) in the period 2021-2050, and by between 7% (Scenario B2) and 20% (Scenarios A1B and A2) in the period 2071-2100. The corresponding decreases in volume of water infiltration are projected to be between 14% (Scenario B2) and 22% (Scenario A2) for the period 2021-2050, and between 30% (Scenario B2) and 54% (Scenario A2) for the period 2071-2100. These variations, together with changes in agricultural practices, will have direct implications on crop type and area.

From an economic standpoint, the total cost for the Greek economy will —depending on the scenario and the discount rate used— range, in net present values, from 0.34% of GDP (Scenario A1B, discount rate: 3%) to 1.69% of GDP (Scenario A2, discount rate: 1%). The most vulnerable climate zones for which the heaviest cost estimates were recorded were found to be Central, Eastern and Western Greece and, in the northern part of the country, Central Macedonia. However, there appears to be considerable leeway for adaptation measures.

Sea level rise (SLR)

Coastal zones play an important role in the economy of Greece, a country with 16,300 km of coastline, and only one land-locked administrative region (out of a total of 13). Indicatively, coastal tourism alone accounts for 15-18% of national GDP. Projections place the sea level rise (SLR) at between 0.2 m and 2 m by 2100. The impact of rising sea levels will, apart from the built environment and human populations, also affect environmental systems.

The economic impacts of a sea level rise were studied from two standpoints: first in view of the long-term impact of gradual SLR, and, second in view of the short-term impacts associated with storm-driven wave and surge events as a result of climate change. This dual approach was judged necessary, as storm surges in the Eastern Mediterranean are expected to increase in both frequency and intensity as a direct result of the disruption to the hydrologic cycle. The total cost of long-term SLR in Greece's coastal zone, measured as the negative impact on housing, tourist, wetland, forest and agricultural land uses, was estimated at between €4.4 billion (assuming an SLR of 0.5 m) and €8 billion (assuming an SLR of 1 m). The costs arising from the loss, over time, of the coastal areas' aesthetic/recreational and cultural value were estimated at between €10.5 billion (assuming an SLR of 0.5 m) and €19 billion (assuming an SLR of 1 m). Finally, the social costs of storm surges in Greece's coastal zone were estimated at roughly €620 million.

The value of ecosystem services provided by the Greek coastal zone was estimated mainly as use-values (i.e. in relation to five specific land uses: tourism, housing, agriculture, forestry and wetlands). These valuations thus represent a lower bound for each resource's real economic value. Adaptation options to be considered in light of SLR are the following: managed retreat (moving all human activities and land uses away from the affected coastal areas), accommodation (adapting human activities and land uses in the affected coastal areas) and protection (soft and hard protective engineering works to minimise the impact that would otherwise occur). Our estimates of the cost of adaptation measures show adaptation to be more cost effective than inaction.

Fisheries

As shown by the sample studied, a rise of 1°C in mean sea surface temperature (SST) in the Aegean would cause decreases in catches of benthic fish by 724 tonnes (1.1% of the mean) and of mesopelagic fish by 160 tonnes (1.3%), while the catches of large and small pelagic fish would increase by 12 tonnes each, i.e. by 0.5% and 0.04%, respectively. Total catches would thus decrease by 859 tonnes or 0.8%. An increase of 3.3°C in SST by 2100 would, based on present data, cause decreases of roughly 3.6% in benthic fish catches and of 4.2% in mesopelagic fish catches, but increases of 1.7% and 0.13%, respectively, in large and small pelagic fish catches. Total catches would fall by 2.5%.

Given that global warming is expected to benefit warmer-water species, total fisheries production may decrease only insignificantly, if at all. Whatever the outcome, there will be a redistribution in fish catches. Moreover, with the rise in temperature, catches are increasingly likely to include migrant species. Finally, the analysis showed that the estimated decrease in rainfall under Scenario A1B would lead to a small decrease (2%) in the production of cephalopods and crustaceans, whereas the production of other species was unlikely to be affected.

The present value of lost revenue for commercial fisheries was estimated at €14.8 million to €2.5 million depending on the discount rate (1% or 3%), while the total cost of biodiversity loss is expected to range between €287 million and €1,896 million.

These cost estimates are tentative and provisional. Considering the ecological diversity of Greece's water bodies and the gaps in our knowledge of anthropogenic impacts, more scientific evidence and data are needed for economists to perform a more reliable cost valuation of global warming impacts on Greek fisheries and aquaculture.

Agriculture

Calculations were made to assess the impact of climate change and desertification on arable and tree crops, primarily wheat, cotton, maize, olives and vines. The impact analysis was conducted both factoring in and excluding soil desertification.

The anticipated decline in rainfall and the higher frequency and intensity of extreme events lead some to believe that the current forecasts will be raised by an additional 5-10%. Of the climate change scenarios considered, Scenario B2 appears to be the most favourable to plant production, especially in NE Greece (Macedonia and Thrace are, depending on the crop, expected to be the most favourably or least negatively affected). Scenario A2 will have the most negative impact on agricultural production. The most sensitive arable crop was shown to be wheat, while cotton production is projected to decrease the most (by as much as 10%) under Scenarios A1B and A2 in Central and Eastern Greece. The impact of climate change on tree crops by 2050 will range from neutral to positive, but will become increasingly negative by 2100, especially in the country's southern and island areas. Horticulture will move northward and the cultivation period, longer than it is today due to milder (warmer) winters, will result mostly in increased production.

The present value of the total economic impact of climate change by 2100, expressed in terms of the change in agricultural revenue (% of GDP) and calculated using a discount rate of 1%, varies, depending on the scenario, from gains of 2.92% of GDP (Scenario A2) to gains of 13.37% of GDP (Scenario B2). Factoring in the negative effects of desertification, the overall impact ranges between gains of 3.31% of GDP (Scenario B2) to losses of 14.84% of GDP (Scenario A2). The impacts vary further if account is taken of changes in other factors affecting agricultural production and directly related to climate change, such the impact of weeds, diseases and insect pests (including invasive species) and possible changes in pollinator activity levels.

Forests

Forest ecosystems cover some 65% of Greece's land surface (forests 25%, rangelands 40%). Assuming that today's management strategy remains in place, it is estimated that as a result of climate change by the year 2100, Mediterranean coniferous and evergreen broadleaf forests will expand by 2% to 4%, in areas presently occupied by more productive temperate forest species such as spruce, fir, beech and black pine, which will shrink by 4% to 8% depending on the scenario (B2 or A2). As a result, wood biomass production is expected to decrease by 80,000 m^3/year to 330,000 m^3/year. The decrease on average in total wood biomass production is expected to be from 27% (529,200 m^3/year, Scenario B2) to 35% (686,000 m^3/year, Scenario A2) by 2100. Meanwhile, rangeland production is projected to fall by 10% (312,000 tonnes/year, Scenario B2) to 25% (780,000 tonnes/year, Scenario A2). Furthermore, because of the rise in sea level, rangeland production will fall by an additional 26,000 tonnes/year (Scenario B2) to 52,000 tonnes/year (Scenario A2).

With the rise in temperature, the number of summer wildfires and the total burned area will increase by 10% to 20%, resulting in increased yearly firefighting costs of €40 million (Scenario B2) to €80 million (Scenario A2). Surface runoff and erosion are also expected to worsen, curtailing the amount of available usable water by 25% (5 billion m^3, Scenario B2) to 40% (8 billion m^3, Scenario A2) per year and drastically increasing erosion by 16% (Scenario B2) to 30% (Scenario A2).

The present value of the direct economic impact of climate change estimates ranges from €1.4 billion (Scenario B2; 3% discount rate) to €9.5 billion (Scenario A2; 1% discount rate), without considering the impact on other products and services, such as non-material forest services, biodiversity, etc. which may be higher than the material losses.

On the other hand, the cost of adaptation by the year 2100 can be summarised as amounting to:

(A) €2.35 billion (Scenario B2) or €4.7 billion (Scenario A2) for constructions including: (a) sediment retention barriers: €0.5 billion (Scenario B2), €1.0 billion (Scenario A2); (b) rainwater harvesting dams: €1.75 billion (Scenario B2), €3.5 billion (Scenario A2); (c) sea levees (total length 100 km or 200 km depending on the scenario): €0.1 billion or € 0.2 billion.

(B) €0.2 billion (Scenario B2) or €2.3 billion (Scenario A2) for additional management costs (forest cultivation, firefighting, grazing systems application, etc.).

Biodiversity

Species abundance is expected to decrease in Southern Europe, in parts of the Iberian Peninsula, Italy and Greece, and species distribution will depend on habitat suitability. It has been recorded that 60 of the 127 native freshwater fish (about 47%) found in Greece are threatened by climate change. With regard to Greece's forest ecosystems, climate change is expected to lead to a contraction in distribution of cold temperate conifers (spruce, forest pine, etc.) and to warm temperate conifers invading into deciduous oak forests. Turning to wetlands, several ephemeral ecosystems are expected to disappear, while other permanent ones will shrink.

The economic impact of biodiversity loss was calculated on the basis of the present value, over the period 2011-2100, of the costs arising from the loss of the ecosystem services provided by forests and the habitats of Lakes Chimaditis and Kerkini, as envisaged under Scenarios A2 and B2 for Greece. The total cost in present value terms for the period 2011-2100 ranges from €1.14 billion to €240.8 billion for the forest ecosystems, depending on the economic value assigned to the services likely to be lost (low/high value) and from €15.6 million to €172.1 million for Lakes Chimaditis and Kerkini. Due to the difficulty in quantifying many of the impacts, these cost assessments should be regarded as lower-bound estimates of the total economic impact of climate change on biodiversity.

Tourism

Climate change is expected to have a significant impact Greek tourism, mainly in the form of a seasonal and geographical redistribution of tourist arrivals, and thus on the revenue of the tourism sector. These estimates are based on the projected impact of climate change on the

Tourism Climatic Index (TCI) by 2100. Our projections at the national level indicate that, after a slight decline during the first three decades of this century, tourist arrivals will increase significantly, by as many as 10 million additional arrivals per year, corresponding to 25% of total arrivals in the decade 2091-2100. However, these overall projections mask considerable seasonal and regional differences, as shown by the detailed breakdown of tourist arrivals. We found that Greece's major tourist destinations will experience a significant decrease in tourist arrivals in summer, i.e. at the peak of the demand for Greece's tourism. Our estimates for Crete and the Dodecanese show that total revenue in summer during the decade 2091-2100 will fall by €370 million/year in Crete and by €280 million/year in the Dodecanese. If we factor in the increase in operating costs needed to adapt to climate change, estimated at €70-90 million/year (5-7% of operating costs), the impact on the sector's annual profits will be critical to the viability of many operations and establishments. These negative economic impacts could be mitigated or even entirely offset (considering that the TCI improves significantly in spring and autumn), provided that an appropriate adaptation strategy is designed and implemented. Although it is not possible to accurately estimate the overall impact of climate change on Greek tourism, the results of the present study clearly point to the need to (a) expand the tourist season, (b) geographically diversify Greece's tourism product, and (c) develop new alternative forms of tourism. Achieving these objectives will crucially depend on the ability of the Greek state, in close cooperation with the tourism industry, to design and implement a long-term strategy plan for Greek tourism. The main goals of such a strategy plan should include: (a) marketing Greece's many still unexploited natural attractions; (b) developing and promoting alternative eco-friendly forms of tourism; (c) attracting new tourist target groups; and (d) taking measures to reduce the industry's environmental footprint.

The built environment

Buildings accounts for roughly one-third of Greece's CO_2 emissions and about 36% of its total energy consumption, meaning that Greece's buildings have the highest energy consumption in Europe. The physical impacts that climate change is projected to have on the built environment include: changes in the energy consumption of climate-controlled buildings and changes in the indoor climate of buildings without additional energy. Future improvements in power production technologies and the upgrading of building standards will to a large extent offset the impacts of climate change.

The total cost of the measures needed to adapt the existing and future building stock to the technological standards likely to be in effect in 2050 will amount to some €230 billion, about 50% of which will involve upgrading building envelopes. Interestingly, the costs of additional photovoltaic systems, needed to achieve zero energy consumption, will be small, given the very low energy needs for heating and cooling, thanks to the thermal insulation of building envelopes and improved energy-saving systems. In order to estimate the impact of climate change on these costs, we considered an alternative scenario for energy demand, assuming that climatic conditions will remain similar to the mean values for the baseline period 1960-1990. The additional costs arising from the impact of climate change range from 7.6% to 10.3% of present costs, depending on the region.

Transport

The direct physical impacts of climate change on the transport sector can be broken down into three main categories: (a) impacts on transport infrastructure from natural disasters, requiring infrastructure repair/reconstruction, as well as the implementation of additional proactive/preventive protection infrastructure projects; (b) impacts on transport infrastructure maintenance; and (c) impacts on the transport system's operation and reliability (e.g. delays and rerouting).

Based on the climate change scenarios assuming a sea level rise of 40-50 cm, a significant part of Greece's transport infrastructure would obviously be at risk from climate change impact, while the operations of a very large number of Greece's ports would be directly affected, thereby causing a direct impact on the country's maritime transport system.

The costs of transport maintenance to make up for the impact of climate change ranges from €594.8 million/year to €195 million/year, depending on the climate change scenario, while the costs of transport delays on account of climate change (extreme weather events, overheating of transport infrastructure, etc.) ranges from €28,031 billion to €9,311 billion.

Health

Climate change can cause premature death due to the increased frequency of extreme weather events, but it can also have an indirect impact on health as a result of the environmental changes and the ecological disruptions it causes (e.g. higher risk of vector-borne or rodent-borne infectious diseases), as well as other effects for segments of the population confronted with environmental degradation and economic problems due to climate change (e.g. nutritional or even psychological problems). An increasing trend in the number of extreme event deaths due to climate change is expected for Greece in the course of the century. Assuming that by 2100 the mean maximum summer temperature in Attica will increase by about 4.4ºC (Scenario A1B), the number of deaths due to anthropogenic overheating in the Athens basin would increase by around 25%. On the other hand though, the number of deaths from exposure to very low temperatures during the winter months would decrease. It should be noted that the projected drop in deaths from exposure to cold weather conditions comes at most to 3%.

Thus, the additional annual deaths in Greece during the decade 2091-2100 are estimated at 21 per day in the summer, while three fewer deaths per day are projected for winter. Based on these figures, the additional number of deaths due to anthropogenic climate change at the end of the 21st century would total 1,620 per year. Given, furthermore, that one year of life is valued at €59,000 (PESETA Report), it is estimated that the annual economic impact under Scenario A1B for the decade 2091-2100 will come to €95 million for the Attica region alone. Using the same method, the annual economic impact for Scenarios B2 and A2 was estimated for the decade 2091-2100 at €85 million and €135 million, respectively.

Mining and quarrying

The impacts of climate change on the mining industry can be divided into two categories, depending on whether they are direct or indirect. The direct impacts include: (a) damage to infrastructure (e.g. haul road erosion, failure of impoundment structures, etc.) due to extreme weather events, (b) wildfires due to drought and high temperatures, (c) decrease in water resource availability due to lower precipitation and higher evaporation, (d) increase in emissions of suspended particulates due to decreased humidity and higher temperatures, (e) loss in working-hours due to ambient temperature changes, and (f) reinforcement of environmental protection and rehabilitation measures and actions. The indirect impacts, ensuing from the need to reduce greenhouse gas (GHG) emissions, include: higher energy costs (incorporating, as of 2013, the costs of GHG emission permits and the reduction in lignite-fired electricity production), decreased employment due to reduced activity in specific sectors in compliance with GHG reduction requirements, and higher operating costs associated with the mining sector's climate mitigation strategies (e.g. adopting low GHG emissions technologies).

The cost of climate change for the mining sector, under Scenario A1B for the period 2021-2050 in present value terms, was assessed at roughly €927 million, assuming a discount rate of 1%, and €575 million, assuming a discount rate of 3%.

* * *

The following observations can be made with regard to the findings of the above sectoral analyses:

1. The present study marks a first attempt to record the qualitative and tentative quantitative impacts of climate change on the Greek economy. This is the first time that the impacts have been systematically presented for a wide range of sectors. Previous studies were either fragmentary or simply adapted and transposed the findings of international studies to the case of Greece.

2. For all of the sectors examined, the impacts of climate change were found to be negative and, in many cases, significantly so. There were a few exceptions in specific sub-sectors of agriculture and fisheries, but the overall impact (even on agriculture and fisheries as a whole) was negative.

3. The economic impact assessments are indicative of the lower cost bound per sector, given that the valuation of many important impacts was not possible at this stage.

4. As shown by the study, the impact of climate change on certain key sectors of the economy, such as tourism, transport and forestry, could have broader implications for the national economy. **Sector-specific** adaptation policies will therefore need to be designed in such cases. As for the built environment, where the costs of reducing energy consumption will be significant, a **tailor-made** policy will need to be designed to improve power production system technology and to upgrade building standards.

5. Due to its small size and share of responsibility in climate change, Greece will be confronted with climate change developments largely determined by other players and international agreements. Therefore, it is important that the impact assessments presented in this study serve as a basis for the formulation of a national adaptation policy.

6. As shown by the findings of the sectoral studies, research must be pursued in the fields of climate change impact valuation and quantification and, more importantly, effective adaptation policy design.

5.3 Cost-benefit analysis of climate policy for Greece*

Climate change will have significant negative impacts on several sectors in Greece, with agriculture, forestry, fisheries, tourism, transport, coastal activities and the urban built environment all expected to be affected by the rise in temperature, drought, extreme weather events and sea level rise. According to the sectoral analyses presented in Chapter 2, these impacts will lead to reduced productivity, loss of capital and additional expenditure for damage repair. Negative impacts will also affect biodiversity, ecosystems and health.

The cost of climate change for the Greek economy incorporates: the direct impacts of the phenomenon on a number of sectors (as estimated in Chapter 2), the indirect impacts, as well as the impacts from interaction between sectors. Data available for the sectors of agriculture, forestry, fisheries, tourism, transport, coastal areas and the built environment were used to estimate total costs. Due to technical difficulties, the impact on biodiversity, ecosystem and health were not taken into account.

The future intensity of climate change remains difficult to predict because of the uncertainty surrounding the manner in which global greenhouse gas (GHG) concentrations will evolve. The intensity of climate change will differ depending on the scope and timing of GHG reduction action worldwide. As discussed in Chapter 1, various emission scenarios were taken into account with regard to the intensity of climate change.

* The analysis for this sub-chapter was conducted at the E3MLab of the NTUA, under the scientific direction of Prof. Pantelis Capros, by key researchers Marilena Zambara, Leonidas Paroussos and Nikolaos Tasios.

5.3.1 Cost of the Inaction Scenario

The worst-case scenario in terms of climate change intensity, corresponding to no action whatsoever being taken to reduce emissions, was called the Inaction Scenario.

Based on the estimated intensity of climate change in the years 2050 and 2100 under the Inaction Scenario, we were able to make a quantitative estimate of the direct economic impact on specific sectors of the Greek economy, in terms of productivity, capital and expenditure. These estimates were then fed into the general equilibrium model GEM-E3 in order to calculate the aggregate costs for the Greek economy. These costs were measured as changes in GDP, sectoral activity and employment, as well as equivalent changes in wellbeing. Both static and dynamic valuations were made relative to the state of the economy in base year. The aggregate cost of the Inaction Scenario was found to comprise a decline in GDP and a negative equivalent change in wellbeing.

As shown by the results using the general equilibrium model, presented in Section 3.3, the Inaction Scenario will cause Greek GDP to contract by an annual 2%[1] assuming the climate change intensity projected for 2050, and by an annual 6% assuming the climate change intensity projected for the year 2100.

The total cumulative cost of the Inaction Scenario for the Greek economy for the period extending up to 2100, expressed as a drop in base year GDP [P1],[2] came to €701 billion (at 2008 constant prices). The estimate of the cumulative cost was based on nonlinear interpolation for the time period in question, under zero discount rate. The loss of Greek GDP from not taking action against climate change both in Greece and at the global level, taken cumulatively, would be equivalent to three times Greece's current GDP.

5.3.2 Cost of the Mitigation Scenario

Climate change mitigation calls for an immediate and drastic reduction in global greenhouse gas (GHG) emissions. Averting climate change altogether does not appear to be likely, given how high today's GHG concentration levels already are, relative to pre-industrial levels. Climate change mitigation is, however, still possible, provided that global GHG emissions are steadily reduced over the period 2020-2100. Mitigation —according to the Copenhagen Accord of 2009— is universally accepted as limiting the rise in the Earth's mean temperature to 2°C. According to global emission projection models, mitigation can be achieved if global emissions are reduced by 2050 to 50% of the emissions level of 1990 and provided that this reduction is continuous (and linear) from 2020 onwards. Based on the mathematical models and as sup-

1 Decrease in GDP size, not in the GDP growth rate.

2 A dynamic simulation of the course of the Greek economy through 2100 was not attempted. We estimated the dynamic evolution of the aggregate cost for the Greek economy as a percentage decrease in GDP and applied it to the base year GDP in order to calculate the cumulative cost for the entire period. Therefore, the cumulative cost, measured in monetary units, refers to base year GDP. The base year used was 2008.

ported by many experts, for this goal to be reached, the OECD countries would have to reduce their GHG emissions by at least 80% by 2050, relative to the 1990 levels. The European Union has, accordingly, adopted this target for all the Member States, including Greece.

Greece's climate change mitigation policy would therefore have to be geared towards a continued and drastic reduction in GHG emissions, as of today, in order to reduce emissions by 70-75% by 2050, relative to 1990 emissions levels.[3] As much as 70% to 80% of all GHG emissions are attributed to the fossil fuel combustion associated with energy consumption and power production. Agriculture/animal husbandry and industry account for the rest. Climate change mitigation can of course be achieved only if all countries worldwide reduce emissions in compliance with the targets mentioned above. Action by one country alone, no matter how significant, cannot suffice to mitigate climate change.

For the purpose of the present study, the Mitigation Scenario was defined as a situation where Greece achieves a continuous and drastic reduction in GHG emissions as part of a successful global effort to contain the mean temperature rise to 2°C. Thus, the climate change impact on the Greek economy would be very limited, but still present.

Ways to reduce GHG emissions by 2050 were examined in Chapter 4, using the mathematical model PRIMES, specially developed for simulating the energy system and other activities responsible for GHG emissions. Using this model, we estimated the expenditure and investment costs that the Greek economy would incur in order to reduce emissions, compared with a 'business-as-usual' scenario under which today's trends and policies would continue and, though expected to achieve certain emission reductions relative to the past, would not achieve the drastic reduction required by the Mitigation Scenario.

These extra costs translate into a loss of GDP (compared to the 'business-as-usual' scenario) and would occur mainly until 2050. Expressed as a decrease in GDP relative to base year GDP, the cumulative costs of the mitigation policy for the Greek economy were estimated at €142 billion (at 2008 constant prices), using a zero discount rate. In other words, the total cost for the Greek economy of implementing the mitigation measures through 2100 would be equivalent to a loss of about half the base year's GDP.

Despite the emissions reduction, the cost analysis, however, also estimates the costs that the Greek economy would incur as a result of the damage caused to several sectors by the low-intensity climate change corresponding to the 2°C mean temperature rise scenario. The total cumulative damage costs for the Greek economy up to 2100 were estimated at €294 billion (at 2008 constant prices). These costs were expressed as a loss of GDP relative to base year GDP, using a zero discount rate.

3 The ability to drastically reduce emissions by 2050 would imply that the economy has the proper technological structure to remain a low-carbon economy beyond 2050.

These mitigation measures, provided that they are globally adopted, would result in cumulative savings of €407 billion, by containing the intensity of climate change. The benefit-to-cost ratio of the mitigation measures was estimated at 2.86.

The aggregate cost of the Mitigation Scenario for the Greek economy consists of the cost of emission reduction measures (€142 billion) *plus* the cost of the residual climate change impacts (€294 billion). Therefore, the cumulative aggregate cost of the Mitigation Scenario up to 2100, expressed as a loss of GDP relative to base year GDP, came to €436 billion (at 2008 constant prices).

In other words, the overall cost of mitigation was found to be €265 billion less than the cost of the Inaction Scenario, meaning that the mitigation policy reduces the total cumulative costs of inaction by 40%. All of these estimates were calculated using a zero discount rate.

5.3.3 Cost of the Adaptation Scenario

Despite its obvious advantages over inaction, the mitigation policy can only yield results if implemented immediately and unwaveringly by the entire global community. Any flaws or delays in mitigation policy implementation at the global level would cause a much greater intensity of climate change than the one associated with a rise in mean global temperature of just 2°C. It would not be wise for any country to rely solely on GHG reduction measures as a means of tackling climate change. A policy of adaptation is also necessary to reduce the possible impact of climate change, under every possible intensity scenario.

Adaptation consists in taking sector-specific action to reduce future damage from climate change. Chapters 2 and 3 (Sub-chapter 3.4) both detail adaptation measures for specific sectors and understandably concentrate on those sectors assessed as being more vulnerable to climate change. For the most part, these measures consist of public works and involve public expenditure aimed at providing protection against the impacts of temperature rise, extreme weather events, drought and water shortage, and sea level rise. Part of the cost of these adaptation measures would have to be borne by the private sector (e.g. in the tourism and agriculture sectors), as well as by households, particularly in urban centers.

In order for adaptation measures to be effective in containing the damage from climate change, they must be implemented before climate change takes on great intensity. Thus, much of the difficulty in drawing up a strategic plan for adaptation measures arises from the uncertainty about the future intensity of climate change. Adaptation measures will therefore have to be subject to updating and fine-tuning, and the strategy of adaptation redefined, drawing on collaboration between the public and the private sector.

Chapter 3 (Sub-chapter 3.4) presents a cost analysis for an indicative adaptation scenario, consisting of measures judged capable of reducing the damage from the climate change intensity associated with the Inaction Scenario. The procedure consisted in estimating the direct expenditure costs needed for adaptation measures and in allocating these costs between the public and the private sector. These costs were then entered as exogenous changes into the general equilibrium model GEM-E3. Using this model, we were then able to estimate the indirect impact (i.e. costs) on the Greek economy.

The total cost of the adaptation measures for the Greek economy, as estimated using the GEM-E3 model, will have negative consequences, expressed as a loss of GDP and calculated for the entire time span covered by the study. Even though the adaptation measures would generate additional activity and employment for construction projects, their funding through public expenditure, coupled with the non-productive nature of these private and public investments, means that they will be at the expense of productive and export-generating investment and activities. The adaptation measures were therefore found to have a negative impact on GDP and thus the total (direct and indirect) costs of the adaptation measures were estimated at €67 billion (at 2008 constant prices), cumulatively up to 2100, expressed as a drop in GDP relative to base year GDP and using a zero discount rate.

The adaptation measures do not eliminate all of the damage induced by climate change, but simply serve to contain it. Thus, it was estimated that the residual damages from climate change would cost the Greek economy a total of €510 billion (at 2008 constant prices) cumulatively up to 2100, expressed as a drop in GDP relative to base year GDP. This expenditure, which corresponds to containing climate change damage, would cost the Greek economy some €190 billion less than the total cumulative damage from climate change under the Inaction Scenario. The benefit-to-cost ratio of the adaptation measures was thus estimated at 2.82, using a zero discount rate.

The total cost of the Adaptation Scenario for the Greek economy is the sum of the costs of the adaptation measures and the costs of containing the damage from climate change. The total cost of the Adaptation Scenario was estimated at €578 billion (at 2008 constant prices), cumulatively up to 2100, expressed as a decrease in GDP relative to base year GDP.

5.3.4 Scenario cost comparison

Table 5.1 presents the total cost estimates for the Greek economy of the Inaction, Adaptation and Mitigation Scenarios. These estimates are based on the results of general equilibrium model GEM-E3, using the direct cost and direct expenditure estimates produced by the sectoral studies. The cost figures given in Table 5.1 were all calculated relative to base year GDP.[4]

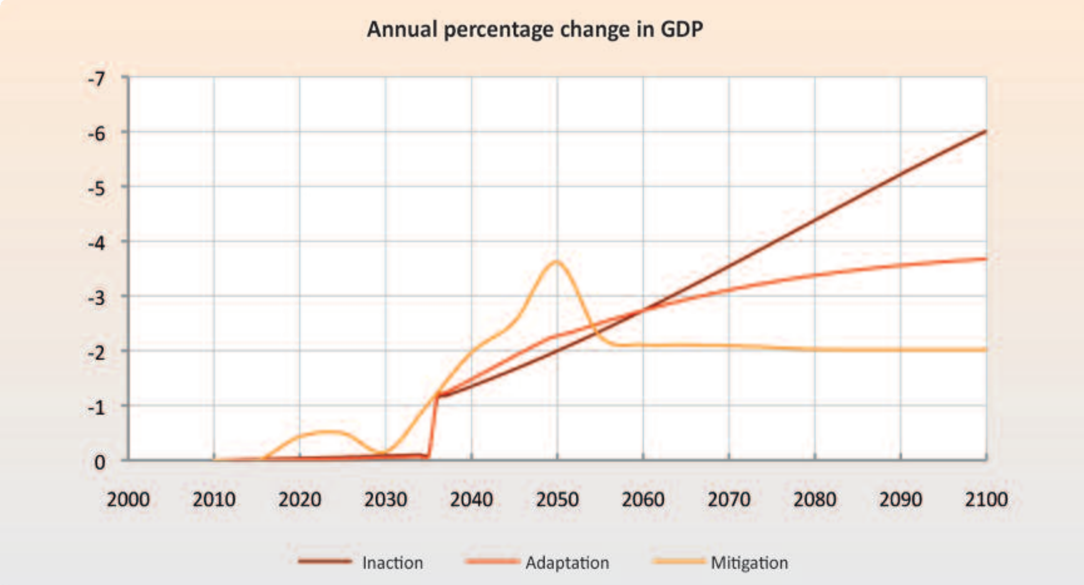
Figure 5.1 plots the estimated annual cost of the Inaction, Adaptation and Mitigation Scenarios in terms of GDP loss.[5] The cost of the Mitigation Scenario includes the costs of mitiga-

4 Estimated at roughly €240 million at 2008 constant prices.
5 Not in the rate of change of GDP.

Table 5.1 The cost of climate change and adaptation and mitigation policies for the Greek economy until 2100

Cumulative cost (EUR billions) in base year (2008) GDP values		Adaptation			Mitigation				
Period	Inaction	Total cost	Adaptation measures	Unavoided impact	Total cost	Mitigation measures	Unavoided impact	Benefit of Adaptation over Inaction	Benefit of Mitigation over Inaction
Discount rate 0%									
2011-2050	79	86	36	50	130	113	17	-7	-51
2051-2070	182	178	24	154	125	26	99	5	57
2071-2100	439	314	8	306	181	3	177	125	259
2011-2100	701	578	67	510	436	142	294	123	265
Discount rate 2%									
2011-2050	41	44	18	26	70	62	8	-3	-29
2051-2070	65	64	9	55	45	10	35	1	19
2071-2100	96	70	2	68	40	1	40	26	56
2011-2100	202	177	28	149	156	73	83	24	46

Figure 5.1 **Annual cost of climate change in GDP loss terms under three different scenarios**



tion measures (emissions abatement) *plus* the damage costs associated with a climate change intensity corresponding to a 2°C rise in mean temperature. The cost of the Adaptation Scenario includes the costs of the adaptation measures *plus* the costs of residual damage from climate change intensity similar to that of the Inaction Scenario.

As shown by the results, the cumulative benefit up to 2050 of both the adaptation and mitigation policies, relative to the Inaction Scenario, would, as expected, be negative, given that climate change intensity is expected to be low until then. As soon as we extended the horizon to 2070, the cumulative benefit from adaptation or mitigation turned positive relative to inaction, though remaining small in absolute terms. When the cost projections for the decades 2070 to 2100 were included, the cost of inaction for the Greek economy by far exceeded the cost of either the adaptation or mitigation policies, even when the costs of residual climate change impacts were taken into account.

It should be recalled that our damage containment estimates for the adaptation policy were based on the assumption that climate change would be of the same intensity as in the Inaction Scenario. The mitigation policy, however, presupposes a global effort to drastically reduce GHG emissions, as a result of which climate change intensity will have been contained at a level corresponding to an increase in mean temperature of up to 2°C.

Cumulatively up to 2100, the Adaptation Scenario achieves cost savings of €123 billion (at 2008 constant prices), relative to the Inaction Scenario, while the Mitigation Scenario achieves cost savings of €265 billion.

The analysis clearly points to the economic benefit of implementing a mitigation policy. It is, however, necessary to underline the considerable uncertainty surrounding mitigation as a policy, since its overall effectiveness will largely be determined by how strictly emission abatement policies are implemented at the global level. It is precisely this uncertainty that tilts the balance in favour of adaptation policies. As shown by our analysis, if the global effort to mitigate climate change is expected to fail and if climate change intensity is expected to be significant, then the implementation of adaptation measures would, from an economic standpoint, be advisable.

A question which naturally ensues is whether it might be even wiser to combine mitigation measures (to reduce emissions) and adaptation measures (to contain climate change impact). Simultaneous implementation of adaptation and mitigation measures would result in increased costs for the Greek economy. However, based on the estimates presented in Table 5.1, with the total cost of the adaptation measures amounting to €67 billion and the total cost of Mitigation Scenario amounting to €436 billion, there would be a significant (cost-saving) benefit of €200 billion, relative to the cost of Inaction.

Deciding on the optimal mix of mitigation policy and adaptation measures is no more, no less a matter of determining an optimal strategy under conditions of heightened uncertainty. This uncertainty will obviously decrease to some extent over time, as global efforts to reduce emissions unfold and phenomena attributable to climate change begin to manifest themselves. However, the time by which these uncertainties will dissipate does not coincide, which makes managing them a difficult task. One thing is certain: the strategy for reducing emissions as well as for adaptation measures will need to be re-evaluated periodically.

Given present circumstances and Europe's commitments, Greece has an obligation to implement an ambitious policy across all sectors to reduce GHG emissions. This policy, up to 2020, is clearly outlined in EU Directives. High cost adaptation measures will need to be extended beyond 2030, whereas a number of important low-cost adaptation measures, mostly of an institutional nature, can be taken in the upcoming decade. In other words, the mitigation and adaptation strategy is clearly marked out and economically sound at least as far as 2030. This strategy would need to be reevaluated in the course of the next decade.

All the cumulative cost estimates given earlier were obtained using a zero discount rate. However, even when using a 2% discount rate[6] (see Table 5.1), the conclusions drawn from the cost-benefit analysis remained the same: mitigation remains a better option than inaction, while an eventual parallel implementation of adaptation and mitigation measures, as opposed to inaction, would lead to a reduction in total cumulative costs.

6 The 2% discount is slightly higher than the one used in the Stern Report.

Figure 5.2 Sensitivity analysis using a range of discount rates

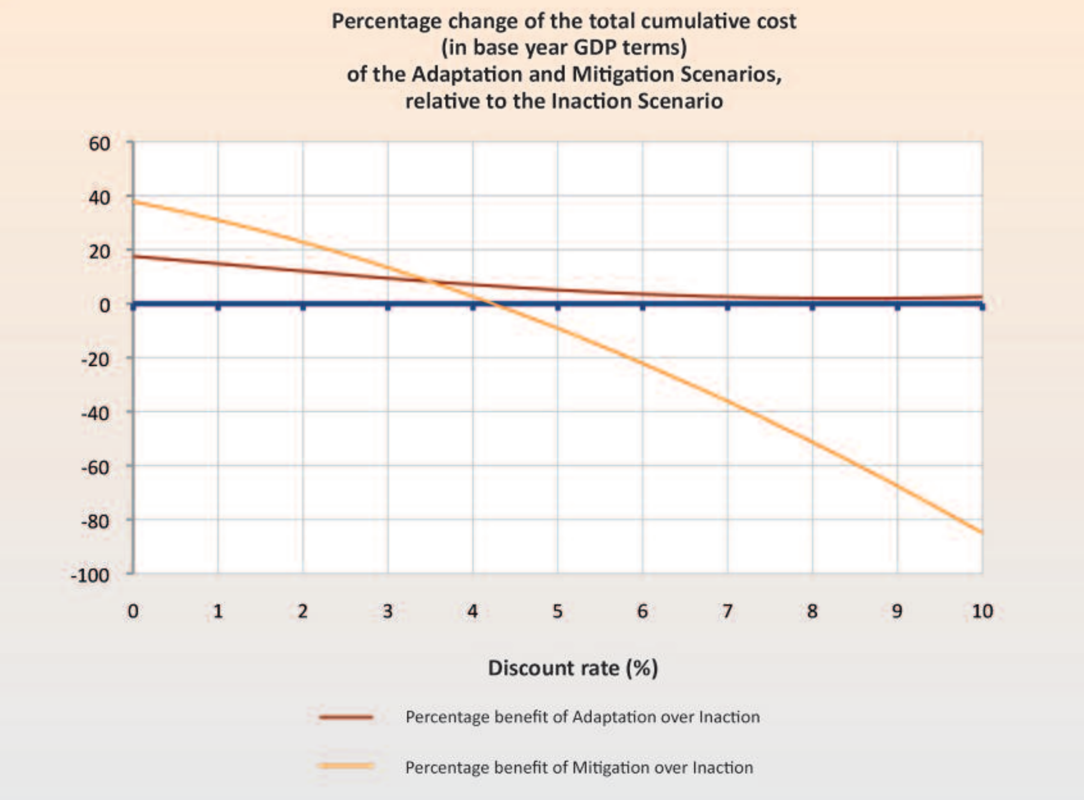


Figure 5.2 graphically represents the sensitivity analysis of cost estimates across a range of discount rates. For discount rates above 4.2%,[7] the total cumulative cost of the Mitigation Scenario exceeds the cost of the Inaction Scenario. However, the cost of the Adaptation Scenario remains lower than the cost of the Inaction Scenario.

It is worth noting that, on the basis of the theoretical premises discussed in Chapter 3 (Sub-chapter 3.1), the case for action to reduce emissions and mitigate climate change should not be based solely on the results of cost-benefit analysis, like the one carried out in this section and which estimated the climate change cost burden most likely to ensue in the event of inaction. However, there is a small, but distinct possibility that climate change intensity and the damage associated with it could be colossal. In such an eventuality, any action to reduce emissions and mitigate climate change would be safeguarding against devastation. And as soon as an action is shown to have safeguarding value, it becomes worth implementing, no matter the cost.

7 See Chapter 3 (Sub-chapter 3.1) on the choice of discount rates.

5.4 Social impacts*

The UN Millennium Summit of 2000 concluded with the setting of 'Millennium Development Goals' for the period till 2015. These goals included: eradicating extreme poverty, improving health worldwide and fostering global growth. The distributional effects of climate change on the poor, the unemployed and the less developed countries call for in-depth research and effective policy formulation. Considerable progress in combating poverty and social exclusion worldwide has, without a doubt, already been made. It is, however, feared that the adverse effects of climate change on society and the economy could significantly undermine these achievements. According to estimates from the United Nations (UNFCCC), a mean temperature increase of 2°C could cause GDP to decline by 4-5%. In the absence of sufficient data, the present report has only selectively, rather than comprehensively, touched upon certain of the social dimensions of climate change and of relevant policy in Greece. Research in this area, however, is ongoing.

Since the early 2000s, Greece has seen its per capita GDP converge remarkably with the EU27 average. Poverty indicators have, however, remained relatively stable over the period 2000-2009, with 20% of the population remaining persistently below the poverty line. When designing strategies to combat poverty and social exclusion, policy-makers will need to take into account that the impacts of climate change will be more acute for lower-income earners (without the means to address the problems induced by climate change and, even less so, to take *timely preventive* measures). The adoption of adaptation or mitigation measures would require households to make certain *capital* expenditures *today* (e.g. to improve the insulation and energy efficiency of their homes, be able to use solar energy, relocate away from vulnerable coastal areas) if they want to face less expenses in the future, as opposed to a scenario where no protective action is taken. This, however, is beyond the means of poor households already facing liquidity constraints, without sufficient savings or access to bank credit. Therefore, poor households, minorities and immigrants already living in deprivation and facing significant environmental and social problems, not to mention inadequate access to social and health services, will see their situation deteriorate further in terms of housing, food, health, education and access to basic services. Equally questionable will be their ability to join energy-saving programmes, purchase advanced technology equipment and pay more for cleaner energy, as would be required under a policy for reducing greenhouse gas (GHG) emissions. Poorer households thus risk losing out on the benefits of adaptation policies and measures, as well as on developments in terms of a low-emissions economy, which will arise from climate change mitigation policy.

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* Sub-chapter 5.4 was co-authored by John Yfantopoulos, Isaac Sabethai and Pantelis Capros.

The risk of a **vicious cycle** of *poverty, lack of access to energy and technologies, and limited protection against losses induced by climate change* is therefore real and is expected to lead to an exacerbation of phenomena commonly referred to in the literature as 'energy poverty' and 'climate poverty'.[8]

Similarly, climate change is expected to impact developed and developing countries differently. Both the Netherlands and Bangladesh are, for instance, among the countries most at risk from sea level rise. Bangladesh has already taken action, primarily at a societal level, to protect its population by setting up an impending cyclone and flood warning system. The possible benefits of this measure, however, appear to be limited, given the country's low per capita income (US$ 450 per year). The Netherlands, on the other hand, with a per capita income 100 times higher, have pressed ahead with extensive investments to support relocation programmes to safer areas.

Thus, just as with social groups, economically weaker countries will be more vulnerable to the impacts of climate change that have already begun to be felt. Extreme weather events like drought, tropical storms and storm surges, but also the gradual sea level rise due to climate change, will be a matter of increasing concern to the international scientific community in the future.

According to data from the United Nations High Commissioner for Refugees (UNHCR), the number of migrants fleeing poverty, extreme deprivation, environmental disasters, climate change and armed conflict has grown significantly in recent years, with the term 'environmental refugees' now frequently used in discussions on climate change-induced migration. According to estimates,[9] the number of environmental refugees today is in the vicinity of 50 million and could reach as many as 200 million by 2050. Although these estimates, produced by N. Myers (2005), have been corroborated by N. Stern, there are still numerous reservations about the exact number.

Greece has already received large numbers of immigrants, and these numbers will increase significantly in future as the flow of environmental refugees increases. In the meantime, internal migration from low-lying coastal areas to higher altitudes will obviously also have become an issue, thereby pointing to the serious need for further investigation, based on which adequate policy can be formulated (as mentioned previously).

8 See, for instance: (a) Ruth, M. and M. E. Ibarraran (eds) (2009), *Distributional impacts of climate change and disaster – concepts and cases*, Edward Elgar Publishing, (b) Skoufias, E., M. Rabassa and S. Olivieri (2011), "The poverty impacts of climate change – a review of the evidence", World Bank policy research paper No. 5622, April, (c) Greenstein, R., S. Parrott and A. Sherman (2007), "Designing climate-change legislation that shields low-income households from increased poverty and hardship", Center for Budget and Policy Priorities, Washington D.C., 25 October.

9 (a) Myers, N. (2005), "Environmental Refugees: An Emergent Security Issue", 13th Economic Forum, Prague, 23-27 May; (b) Simms, A. (2003) "The Case for Environmental Refugees", New Economics Foundation, London; (c) Brown, O. (2008), "Migration and Climate Change", IOM, No. 31, Geneva, (http://www.migrationdrc.org/publications/resource_guides/Migration_and_Climate_Change/MRS-31.pdf).

As clearly indicated by the findings of the present study, **the strategic planning of both adaptation measures and emissions reduction measures**, in the context of a global mitigation effort, is necessary to address climate change and reduce its negative impact on wellbeing, the environment and economic growth. This implies that a key focus of future policy must be the fight against poverty and, in particular, against the further worsening of poverty and social exclusion induced by climate change and policies to address it.

Along with adaptation measures and an emissions abatement policy, *each individual country*, including Greece, will have to draw up an adequate corrective policy to effectively address the problem of poor households and their inability to pay for what is needed to cope with climate change impacts at their micro-level and gain access to clean energy and technologies.

This is a problem that can only be solved through public intervention. The State will have to create the necessary conditions for the financing of large-scale infrastructure projects (obviously, entailing a corresponding level of financial risk) that will improve the housing conditions of poor households and their access to energy. Moreover, the duty to provide public services, i.e. guaranteeing access to standard public services or goods (e.g. electricity, potable water) will have to be upgraded, in the light of climate change and global warming, by ensuring special rates (discounts) for low-income consumers. For the rest of society, the rates for services affected by climate change should be set through free market competition.

At the *global level*, protection of the more vulnerable countries will have to be achieved with the help of developed and economically more robust countries, through multilateral agreements negotiated under the auspices of the UN. As shown by the experience of the last two years, progress in this field may have been slow, but is nonetheless imperative and urgent.

Protecting the planet from climate change also means that consumer behaviour will have to change. Apart from public policy and the contribution of technology, the cost of harnessing climate change can undoubtedly be reduced if consumers and producers alike modify their behaviour so as to adapt to climate change and reduce emissions. Any strategy development geared towards adaptation and mitigation, in order to be effective, will imperatively have to involve collaboration between the public and the private sector, and will have to be periodically revised. This will help make up for the large degree of uncertainty both about the future extent of climate change and about the consistency with which the global economy will remain on track towards drastic emissions reduction.