Western Greece Regional Climate Change Adaptation Plan: Future Projections, Vulnerability Assessment and Adaptation Measures and Actions in a Transnational Area

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The present work constitutes a full-scale analysis of the future climate projections in the geographic area of the Region of Western Greece. The region of Western Greece has its capital at Patra and is divided into three Regional Units (Aitoloakaranania, Achaia and Ilia), which are further subdivided into 19 municipalities.

The results presented in this paper are part of the Regional Climate Change Adaptation Plan and the Strategic Environmental Study that followed, which were conducted from ENVIROPLAN Consultants and Engineers S.A. on behalf of the Region of Western Greece.

The Regional Climate Change Adaptation Plan is in line with the requirements of the Law 4414/2016 (Government Gazette 149/A/09-08-2016) and the Ministerial Decree 11258/2017 (Government Gazette 873/B/16-03-2017) that proposes the specification that the study should follow.

Following the elaboration of the report "The Environmental, Economic and Social Impacts of Climate Change in Greece" in 2011 by the interdisciplinary Climate Change Impacts Study Committee (EMEKA – in Greek) and the National Climate Change Adaptation Strategy by the Hellenic Ministry of Environment and Energy (YPEN – in Greek), the Regional Plan of Western Greece, is the third step for the evaluation of climate change in different sectors of the economy and spatially in regional level.

After a brief description of the study's objectives in relation with the National Strategy and the presentation of the natural and anthropogenic environment of the Region, the authors assessed the evaluation of climate change using the latest global projections and estimations, downscaled into regional level.

To estimate the climate variations and analyse the vulnerability of specific sectors and geographic areas in climate change, the authors used the latest timeseries of different climate indices in the best available spatial detail from the available climate scenarios. The 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014), introduced four (4) new scenarios of anthropogenic GHG emissions, called Representative Concentration Pathways (RCPs), which are used for making projections and describe four different 21st century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions and land use. The authors used the more stringent mitigation scenario (RCP2.6) which is in line with the Paris Climate Agreement (COP 21, 2015), one intermediate scenario (RCP4.5) and one scenario with higher GHG emissions (RCP8.5).

The climate indices were transformed from Global Circulation Models (GCMs) into Regional Climate Models (RCMs), using the EURO-CORDEX database and supercomputers. Data were available into a grid of high spatial resolution (0.11^{o}) in a daily step for the period 2006 – 2100. Moreover, a historical period between 1966 – 2005 was available to be used as reference period. The authors selected five different climate models (integrated into CORDEX) with availability of data in order to minimize the statistical error. The models used were the following, CNRM_CCLM4, EC-EARTH_KNMI, IPSL_WRF331F, MPI_CCLM4, MPI_REMO2009. Those models were analysed in three twenty-year horizons and in comparison, with a twenty-year reference period. The periods were 2011 – 2030 (short term), 2031 – 2050 (medium term) and 2081 – 2100 (long term) time horizon and in comparison, with the historical - reference period 1986 – 2005.

The authors calculated thirteen (13) basic climate indices and multiple supporting ones which were based on the basic indices and could evaluate climate phenomena like heatwaves, floods, storms, cold periods, drought, comfort and many more. Approximately 45 to 50 climate indices were calculated for all three RCP scenarios and three, time horizons in comparison with a reference period.

The next step was the extraction from those timeseries of all the available information that could be useful to evaluate the sensitivity of each sector of the economy and its exposure on climate change. The sensitivity analysis aims at identifying the relative climate hazards for each sector of the economy, irrespectively of the location. The exposure analysis aims at identifying the relevant hazards for each geographic area, irrespectively to

the sector of the economy. The exposure and sensitivity analysis then led to the vulnerability assessment of each economic sector and geographic area.

After completing the vulnerability assessment, the authors estimated the direct and long-term impacts of climate change on the different sectors of the economy and the geographic areas. Sectoral and geographic priorities were then introduced based on the climate change vulnerability analysis. The impact analysis was the step, needed to propose measures and actions for the prioritized sectors of the economy and geographic areas from the previous step. The measures were divided into those targeting the avoidance of consequences, those reducing the intensity of the impacts and the rehabilitation of areas that already have faced severe impacts of climate change. This represents a key outcome of the study, as it proposed the ideal governing bodies and the stakeholders to implement the measures. Last but not least, in this step the authors proposed possible financial mechanisms for the implementation of the measures and integration of climate positive investments into the financial policy of the Region.

Following the delivery of the Regional Climate Change Adaptation Plan, a Strategic Environmental Assessment (SEA) study was elaborated, a dynamic process that aimed to fulfill the objective of sustainable development through its integration with the environmental dimension at the earliest possible stage of the plan design process.

Through the analysis of the various climate indices, it is understood that climate change is a reality and the delay or even avoidance in taking measures can lead to a significant worse situation. The mean temperature in the three climate change scenarios varies between + 0.45 ºC in the RCP2.6 scenario and can rise up to 3.92 ºC in the worst-case scenario. The municipalities that are most exposed into the increase of the mean temperature are Patras, Kalavryta, Agrinio, Thermo, Nafpaktia and Ancient Olympia with a rise of the average temperature of up to + 4.08 ºC (scenario RCP 8.5 in the period 2081 - 2100, relative to the reference period). Similar results come up from the evaluation of the minimum and maximum daily temperatures. The demand for heating, cooling and growth degree days (DD) is, as expected, affected by the temperature increase. Moreover, the duration of heatwaves and distress is explained. Regarding precipitation, variations were witnessed in future projections (positive and negative). This was explained through the evaluation of days with extreme precipitation and the number of days with continuous precipitation. The annual mean precipitation is expected to vary between + 49.17 mm to – 117.14 mm in Achaia, between + 89.09 mm and – 89.58 in Aitoloakarnania and between + 68.21 mm to – 146,92 mm in Ilia. Snowfall is also affected by the different climate change scenarios. Kalavryta, a municipality well associated with winter tourism will be highly affected with a decrease of snowfall up to 131.31 mm in the worst-case scenario (RCP 8.5 in 2081 – 2100 in comparison with the reference period). Last but not least, sea level rise will also highly affect the Region and especially the coastal zone and the financial sectors associated with the coastal zone (fishing and aquaculture, summer tourism etc.). The biggest impacts are expected once again in the worst-case scenario, with the sea level rise up to 0.55 m. The municipalities of Dytiki Achaia, Mesologgi, Nafpaktia, Xiromerou, Pyrgou, Ilidas and Zacharos will face the worst impacts of sea level rise. Even in the case of the most stringent scenario (RCP 2.6), sea level rise will be present (sea level rise, up to 0.34 m). Twelve of the nineteen municipalities of Western Greece have coastal areas and as a result, major efforts and measures should be introduced to avoid the consequences or reduce the intensity of future impacts.