Developing a climate adaptation Action Plan in Greek cities - A study case in the Municipality of Thessaloniki

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SCHOOL OF SCIENCE AND TECHNOLOGY

A thesis submitted for the degree of

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Abstract

Nowadays, climate change is a worldwide concern. Action plans to mitigate and adapt to the changing climate are one of cities' priorities in order to diminish greenhouse gas emissions, as carbon dioxide, and increase cities' resilience to climate change while reducing their vulnerability. Mitigation and adaptation techniques are equally important to minimize the impact of climate change and build resilient and decarbonized cities.

This thesis aims to offer tools that can be used to develop an Adaptation Plan, within the Covenant of Mayors Framework, to tackle climate change at the Municipality of Thessaloniki. The methodology adopted was based on the identification of current and projected causes and impacts of climate change at the Municipality, based on literature review and cases of study. The key documents and tools, Mayors Adapt and SECAP, were used as important consultative tools to propose adaptation actions and, in the future, they will be used to monitor the commitments made by the Municipality of Thessaloniki. The result is a set of urban strategies providing resilient adaptive solutions which could enhance new opportunities and values for the Municipality. This dissertation concluded that social awareness, participation of stakeholder and key actors in policy making at local, regional and national level, are essential for achieving an effective adaptation strategy that addresses climate change.

Keywords: Climate Change; Municipality of Thessaloniki; Adaptation Plan; Mayors Adapt; Covenant of Mayors.

Preface

The development of this research was motivated by my true passion for creating and establishing better strategies and behaviors to mitigate and adapt to the changing climate. Eventually, I carried out this work, however, it would have been very difficult to accomplish it without the support and help from many people in my surroundings.

I want to sincerely thank my supervisor, Dr. Ifigeneia Theodoridou, for her advice and assistance throughout the writing of this thesis.

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Nikolle Nebl Jardim Aravanis

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Chapter 1: Introduction

The population is growing. In 2018, “more than half of the world’s population (55%) resided in urban areas, a percentage that, according to projections, will reach 68% by 2050” (UN DESA, 2018, para. 1). Urban areas are becoming the world’s population home, making urbanization one of the critical tendencies of the 21st century. This movement to urban areas creates new cities and diffuse megacities, which contributes to the economic and social importance of cities, but also their poor environmental sustainability (Albino *et al*., 2015).

Given the significant increase in urbanization levels, a growing segment of the human population will encounter severe implications of climate change. The relationship between urban environment and climate change is of constant interaction. The impacts of the changing climate considerably influence the city environment while it has significant contributors to aggravate it.

Urbanization can alter local microclimates, surroundings and, localized regional climate dynamics. That may happen through a “series of physical phenomena that can result in local environmental stresses, such as an increase of the urban heat island local range by altering small-scale processes and even modifying synoptic scale meteorology” (Revi *et al*., 2014 as cited in IPCC, 2014, p. 551).

According to the National Center for Atmospheric Research (2013), urban environments produce daily heat due to human activities (for instance, commercial, industrial, service); this heat can modify wind and precipitation patterns, humidity, atmospheric jet stream and, other atmospheric systems. Heat also influences local temperatures and temperatures of regions located kilometers away.

Urban infrastructures as grey pavement and roof surfaces, during summer days, can reach very high temperatures becoming hotter than the air temperature, while the air of surrounding areas with less urban infrastructures remains close to air temperatures (Berdahl and Bretz, 1997). The temperature increase in urban areas, as the main function of heat collected and re-radiant by pavements, building, and other urban features, and that lead to the phenomenon of atmospheric heat island effect that occurs at urban environments. The

heat island effect is “attributed mainly to the replacement of permeable surfaces with dryer impermeable surfaces which influences energy availability and leads to a higher Bowen ratio at the land surface and consequently warmer temperatures” (Arnfield, 2003; Oke, 1982 as cited in Cosgrove and Berkelhammer, 2018, p. 1). The footprint of urban heat island can reach vast areas – approximately 2.3 to 3.9 times the city extension itself -, while keep affecting the temperature (Zhou et al., 2015). Georgescu *et al*. (2013), demonstrated that the continued growth and expansion of urban areas in the United States could led to an alteration and increase in local temperatures (up to 4 °C) and “mesoscale regional warming of 1–2 °C” (Georgescu *et al*., 2014 as cited in Cosgrove and Berkelhammer, 2018, p. 1).

The EPA (n.d.) understands that the increased temperature, originated by the urban heat island, can influence and alter the social environment, well-being, and quality of life. That influence can lead to different implications, for instance, on water quality, human health, and on the rise in energy consumption and demand for cooling, especially throughout the summer season.

The consumption pattern for those that live in urban regions is considered higher and different from people that are residents of rural areas, mainly due to the living standards and electricity access (Parikh *et al*., 1991). Torrey (2004) suggested that the energy requirement and usages for basic needs, such as space heating/cooling and cooking, and also for means of transportation is substantially higher in metropolitan areas. Hence, the urban heat islands effect enhances the total energy requirement, along with the peak electricity demand. Research shows that the broad need for electricity is an attempt to compensate for the heat island effect, and “electricity demand for cooling increases 1.5–2.0% for every 1°F (0.6°C) increase in air temperatures, starting with temperature from 68 to 77°F (20 to 25°C)” (Akbari, 2005 as cited in EPA, n.d., para. 3). NASA’s GISS noted that the surface temperature on Earth, at the beginning of 21st century, was 0.8 °C higher when compared to the beginning of the previous century, “with two-thirds of this warming has occurred since 1975” (Hansen *et al*., 2010 as cited in Carter *et al*., 2015, p. 3).

EPA (n.d., para. 8) concluded that warmer temperatures during the day and less cool temperatures during nighttime, along with air pollution, can affect human health by contributing, for instance, with general discomfort, heat cramps and exhaustion, and heat-related mortality and morbidity.” Direct exposure to heat can lead to adverse health

implications, which can range from aggravating small existing morbidities and disorders in sensitive populations and those with existing health conditions and illness, to an enhanced risk of hospitalization and mortality (Basu, 2009).

Adverse health effects are enhanced, especially during the summer season, where the possibility of encounter very high temperatures, extreme heat events, or abrupt heat waves is existent (Heaviside *et al*., 2017). The constant exposure to extreme heat events can increase mortality risks. More than 8,000 premature died in the United States, between 1979 and 2003, due to extreme exposure to heat events (Centers for Disease Control and Prevention, 2006, as cited in EPA n.d.). Death risks can be associated with the temperature increase and heatwaves episodes caused by the UHI effect. As a consequence of the changing climate, risk increases are expecting in the future (Hajat *et al*., 2014).

Apart from human health, urbanization can also affect aquatic ecosystems. "Replacing natural vegetation with impermeable surfaces and introducing environmental stressors through increased anthropogenic activity can significantly modify aquatic ecosystems" (Garrett, 2010, p. 2), especially the reproduction of several aquatic species and its metabolism. Climate change is also able to threaten water quality, water supply (Miller and Hutchins, 2017) and aggravate flooding that happens at the local level (Revi *et al*., 2014). Significant to state that climate change can also impact on food and water security, human security, livelihood, social and economic well-being.

Urban environments are considered large contributors to global anthropogenic greenhouse gas emissions (GHG), of which the main source of these gases is related to fossil fuel combustion and consumption. The "consumption of fossil fuel includes energy supply for electricity generation; transportation; energy use in commercial buildings and residential housing for lighting, cooking, space heating and cooling; industrial production; and waste" (EIA, 2003, p. 36).

The urban structure and infrastructure, the built environment, the building, and street aspects, are capable of modifying the greenhouse gases emissions to the atmosphere and intensify the adverse effects of climate change.

Climate events like "tropical storms and extreme precipitation, warm and cold spells, drought, heat events, and associated sea-level rise can have its duration, frequency and or intensity altered as result of climate change" (IPCC, 2007, p. 53, IPCC, 2012, 2019;

Patricola and Wehner, 2018; Trenberth *et al*., 2018). The sea-level rise constitutes a noteworthy threat to the seaside and low-lying areas and systems. This threat may cause flooding, gradual destruction of coastlines, a decrease of livable land spaces and contamination of freshwater reserves and food crops, food stability, utilization, and safety (Nicholls, 2010 as cited in IPCC, 2014). Climate change can increase the number of undernourishment due to negative impacts on food production and availability, with a small increase in global warming.

All these climate effects mentioned before will be "compounded by other climate impacts, creating threats and challenges for both rich and poor populations occupying low-elevation coastal zones" (UN-HABITAT, 2011, p. 1). Many sectors, namely the building and infrastructure sector, transport sector, biodiversity, and ecosystems sector and human health sector, will suffer the repercussions of climate change impacts in the metropolitan area (Revi et al., 2014). Climate events, such as storms and heavy precipitation, can also put physical structures, such as buildings and infrastructures at risk.

It is safe to say that cities are the place where the population is more vulnerable and exposed to climate change effects. However, these urban areas are also the key to innovation and economy, along with the location of major economic assets and city services. This situation makes urban environments and their population highly vulnerable to climate change.

The term vulnerability encompasses a diversity of "ideas and components, including sensitivity or vulnerability to injury and lack of capacity to handle, respond, and adapt" (IPCC, 2019, p. 560). In other words, it is the predisposition to be negatively impacted and or influenced. The vulnerability applies to different sectors (energy, water, mobility, etc.) and natural systems.

The IPCC report from 2012 (IPCC, 2012) understands that catastrophes and hazards can happen as a consequence of extreme weather and climate events, mainly when interacted with vulnerabilities in the ecosystems or human systems. On the other hand, resilience is "the capacity of social, economic, and environmental systems to cope with a hazardous event or disturbance, in ways that maintain their essential function and structure, while also maintaining the capacity for adaptation, awareness, and transmutation" (IPCC, 2014a, p. 5).

Resilience and vulnerability are the opposite. Once vulnerability concerns a particular population group, resilience worries about the systemic capacity to protect these groups while reducing the impact of specific hazards through infrastructure or climate-risk sensitive land use management" (IPCC, 2014, p. 548). Each time more, the concept of resilience applied to the relationship between urban areas and climate change is receiving importance and recognition within the Academy and literature. That recognition can be attributed to a broad agreement that cities need to become resilient to address climate change disturbances and impacts while promoting sustainable urban growth (Cutter *et al.*, 2008 as cited in Rafael *et al.*, 2015).

Many studies and literature reviews stated the necessity to enhance cities and metropolitan areas resilience, to achieve successful implementation of adaptation and mitigation in these areas.

The most recent IPCC report (2019) express that climate change impact can strongly affect, positively or negatively, different sectors, such as biodiversity and environment, human quality of life, well-being and health, while influences physical infrastructure, socio-economic aspects, and costumes. The same report also states that one route toward sustainable development is for cities to become climate-resilient.

Denton et al. (2014) suggested that to cities become climate-resilient and to meet the Sustainable Development Goals (SDGs), a full comprehension of current and future climate change vulnerabilities, risks, and impacts are necessary Denton *et al.*, 2014). Climate-resilient pathways involve two overarching characteristics. The first one include efforts to "reduce climate change and its impacts, including both mitigation and adaptation, and the second, steps to guarantee that effective strategies can be recognized and implemented as an integrated part of the development processes" (Edenhofer *et al.*, 2012 as cited in Denton *et al.*, 2014, p. 1112).

Mitigation, adaptation, or the integration of mitigation and adaptation strategies are nowadays the significant strategies to try to tackle a real challenge of this century, the climate change. Mitigation measures "involve a direct reduction of human emissions or enhancement of carbon sinks that are essential for limiting long-term climate impacts and hazards" (FAO, 2012, p. 7). In other words, comprehends mitigation as efforts and strategies for reducing anthropogenic greenhouse gas emissions and stabilizing the levels of

heat-trapping GHG in the atmosphere, which can happen by lowering the direct greenhouse gas sources or strengthening natural "sinks" that accumulate and store these gases. The aim of the GHG stabilization is to provide enough timeframe for the ecosystem to naturally adapt to climate change while allowing economic-sustainable development, reducing disturbances, difficulties and impacts related to climate change and weather phenomena events (Washington *et al*., 2009; Lenton, 2011; IPCC, 2012).

Some mitigation technologies, changes and practices contribute for the sustainable development and reduction of GHG. Strategies as utilization of nature-based solutions can "diminish local and regional air pollution, while enhance prospects for multilevel governance and integrated management of resources, and encourage wider involvement in development processes" (Lebel, 2005; Seto *et al.,* 2010 as cited in IPCC, 2014, p. 1114). Other practices such as the utilization of renewable energy technologies instead of fossil fuel, waste minimization processes and efficient public transport can also be solutions (McMichael, 2014).

Adaptation techniques address climate change impacts that are currently witnessed and prepare cities and its population for future climate and its implications. The IPCC (2014a, p. 5) is aware that "in human systems, adaptation seeks to moderate, reduce or avoid harm or exploit beneficial socioeconomic opportunities, while in some natural systems, anthropogenic intervention may assist adjustment to foreseen climate and its effects."

To reduce any residual damage deriving out of climate events in the present and the future (FAO, 2012), the adoption of adaptation techniques is crucial. Adaptation is also essential to reduce city vulnerability related to climate changes' harmful effects. Considers adaptation a different and brand new perspective of analyzing, think, and redress vulnerabilities, risks, and threats (Climate ADAPT, n.d.).

Different sectors in a region have opportunities to adapt to climate change. The chance to adapt will vary in context, approach, and potential. Fundamental strategies to put into practice adaptation actions in the water sector are the "water storage, the improvement of irrigation efficiency, while the transport sector includes design standards and planning for roads, rail, and other infrastructure to deal with warming and drainage" (Knittel, 2016, para. 4). On the other hand, the energy sector should not rely on one energy source; it is

necessary for a portfolio of options. As an example of benefits of implementation of adaptation techniques at energy sector, has the Ireland's EirGrid, that developed ways of "Using Climate Change Risk Assessment Wisely" to identify the risks posed by sea-level rise, storm and heavy rainfall episodes and due to that led to some benefits, as minimization of damages during floods and increased network resilience (Braun and Fournier, 2016).

Another approach adopted to address the climate change issue is the geo-engineering (also entitled climate engineering, geoengineering). Shepherd et al. (2009, p. 9) define climate engineering as "the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change." It is essential to mention that most of the climate engineering technologies are still in the underdevelopment stage. However, nowadays, there are two dominant geoengineering proposals, the Carbon Dioxide Removal (CDR) and Solar Radiation Management (Gordijn and ten Have, 2012).

Mitigation and adaptation planning play vital roles in identifying vulnerabilities, as well as in projecting and responding to impacts of climate change and building resilience. Developing adaptation and mitigation approaches first require looking into current strengths, such as existent policies and regulations, society initiatives that bolster climate resilience, and at a later stage, it involves evaluating how these strengths compare to the identified vulnerabilities (MAGIC, 2017). The local governments for sustainability ICLEI in the run-up to COP21, understand that:

> "Local and regional authorities are key components in order to tackle climate change and its effects in cities. Metropolitan areas are accountable for large emissions of greenhouse gas, more specifically more than 70%. Engaging these authorities could bring about the type of consistent multi-level effort that is necessary to fight the changing climate and allow cities to grow and develop sustainably". (Arikan and Brekke, 2015, p. 2)

Climate change should be incorporated into local planning processes and policies, in particular, since several tools and values have been developed to assist cities in this process (UN CC: Learn, 2016). In this scenario, one relevant tool is the Covenant of Mayors (CoM). The aim of this initiative that was launched in 2008 by the European

Commission (EU) is to support investments and implementation of energy policies that value sustainability.

The main goal of the Covenant of Mayors initiative is to endorse and engage municipalities, cities, and their authorities (e.g., local and regional) willingly into committing, implementing and reaching the objectives set by the EU, regarding climate mitigation and adaptation. Besides implementing these objectives, the Covenant of Mayors initiative aims to reduce climate events vulnerabilities in the territories of the local and regional authorities (Covenant of Mayors for Climate and Energy (n.d.a).

The Covenant of Mayors for Climate and Energy (n.d.a, para. 3) recognize that "local authorities are key drivers of the energy transition and the fight against climate change at the level of governance which is closest to citizens; they share the responsibility for climate action with regional and national government levels."

The Covenant of Mayors for Climate and Energy has been, in so far, described as a successful tool of EU policy. Through it, local and regional authorities commit to increasing cities' resilience while decarbonized it and provide secure, sustainable, and affordable energy to the inhabitants (Covenant of Mayors & Mayors Adapt Offices, 2016). In that context, the principal purpose of this paper is to offer tools for developing a climate adaptation action plan for the Municipality of Thessaloniki based on the CoM framework. It is essential to mention that this dissertation does not aim to propose a Mitigation Plan for the Municipality, since it already has one, but rather to suggest tools and strategies, based on literature review, for developing an Adaptation Plan. This thesis does not include intent to propose a new SECAP for the Municipality either, but, instead, to offer some adaptation strategies to tackle climate change that can fit into its already existing SECAP.

Chapter 2: Climate and Energy

The Covenant of Mayors' background dates back to 2008, when the European Union, acknowledging the role of local authorities, decided to involve municipalities in achieving and exceeding the targets stabilized by the EU climate and energy package for

2020. “By committing to the Covenant, 300 mayors voluntarily promised to adopt a sustainable energy action plan (SEAP), rethink the way their cities function, while bringing these cities closer to energy self-sufficiency” (Covenant of Mayors, 2013, p. 2). These measures aimed at promoting local economic development and enhancing residents’ citizens’ well-being and quality of life (Covenant of Mayors, 2013, p. 2).

In other words, local and regional authorities’ commitment to EU targets would lead to implementation and employment of renewable energy sources in their territories and better energy performance (Kona et al., 2017), which would result in a carbon dioxide and other greenhouse gases reduction. Since its launch, the CoM initiative has demonstrated a prosperous outcome. The initiative’s results were beyond expectation, leading to the broadening of the Covenant and attracting new local and regional authorities both within and outside Europe. As its number of stakeholders also increased, the CoM has established “itself as one of the most emblematic examples of multi-level governance and bottom-up action in Europe” (Covenant of Mayors, 2013, p. 2).

The significant role of the Covenant of Mayors has been mention and recognized in numerous European Commission policy documents, and, in 2014, this Commission introduced a new initiative named Mayors Adapt. This new initiative stemmed from the Covenant of Mayors model, but to engage towns and municipalities into responding to climate change, adapting to it (SETIS, 2017). In 2015 inaugurates the new Covenant of Mayors for Climate and Energy. This initiative consisted of a merger between Covenant of Mayors and Mayors Adapt, aiming to endorse a comprehensive approach to climate and energy measures based on three crucial pillars - mitigation, adaptation, and secure, sustainable, and affordable energy.

Based on these pillars, the new CoM signatories commit to employing measures to reduce and remove carbon of their territories (reducing CO2 emissions by degrees of 40% by 2030), strengthening their capacity to adapt to unavoidable climate events impacts, and facilitating access to inexpensive, secure and sustainable energy (Covenant of Mayors, n.d.b, para. 1-2).

To put the new initiative into practice, “the new Covenant of Mayors determines a framework for adoption of measures, which helps local and regional governments to

translate their mitigation and adaptation goals into reality while acknowledging the ground" (Covenant of Mayors, n.d.a, p. 6).

There are two main pathways that the authorities can take, the mitigation and adaptation pathway. The mitigation pathway provides some flexibility for signatories (Covenant of Mayors, n.d.a). On the other hand, the adaptation pathway has to be "performed within a two-year timeframe, and the result will serve as a base to enhance the city resilience; the adaptation strategy needs be integrated into the SECAP" (Covenant of Mayors, n.d.a, p. 6).

Actions taken by local authorities and cities based on the frameworks are the key to successful mitigation and adaptation measures and schemes to deal with the changing climate.

2.1 Mitigation Strategies

Mitigation strategies, such as reduction of greenhouse gas concentrations via dropping GHG emissions and enhancing carbon sinks to meet the goal of combat climate change, have been at the core of climate change strategies and measures over the years. At the end of the previous century, more precisely in 1992, the United Nations Framework Convention on Climate Change ultimate objective was the "stabilization of GHGs concentrations in the atmosphere at a level that would limit critical anthropogenic obstruction with the climate system" (United Nations, 1992, p. 4). Following this idea, many national and international agreements were set to establish targets to limit and reduce greenhouse gas emissions. Nevertheless, achieving those targets is not an easy task, and to accomplish them, implementation of policies and measures is necessary.

Since a large portion of GHG emissions is attributable to cities (The World Bank, 2010) due to activities undertaken in urban regions (IEA, 2008), cities should be the heart to climate change mitigation techniques and carrying out low-carbon development strategies. It is relevant to indicate that cities need to adopt an integration mitigation approach and bearing in mind energy use and production, human health and quality of life, land use, urban development and infrastructure, and environment.

Climate change mitigation initiatives to reduce greenhouse gases from fossil fuels can bring many benefits. In 2016, the health expenditure due to air pollution was close to 10% of GDP in the EU (WHO, 2018; OECD, 2018). The reduction of air pollutants would bring potential health co-benefits, such as the reduction of respiratory diseases, cardiovascular morbidity/mortality, mental problems, and premature deaths per year (Barrett, 2014). Besides public health and quality of life improvements, reducing dependence on fossil fuels could also bring other positive consequences by decreasing the risks of disruptions of energy supply from importing nations or the potential for economic damages and losses due to price volatility (UNECE, 2016). Reduction in energy costs through an increase in energy efficiency and energy security, positive environmental impacts, including the preservation of biodiversity and sustainability, are also co-benefits from GHG reduction.

According to a recent IPCC report (2019), four pathways working alongside different mitigation strategies can achieve net emissions and limit global warming. These pathways include a reduction in energy demand, alteration of how is the production of energy and products; it targets sustainability and investing in technologies to reduce emissions like carbon capture storage and bioenergy (Rogelj *et al*., 2018 as cited in IPCC, 2018). The "mitigation approaches within the pathways embrace potential synergies or co-benefits when comparing the interrelationships between energy demand, energy supply, and land use" (Race, 2018, para. 7).

The 2030 Agenda and the Sustainable Development Goals (SDGs), supported by UNECE, considered those pathways and focused in areas where it would be feasible to achieve GHG reductions and bring benefits and promote actions such as (UNECE, n.d.):

- The creation and extension of Intelligent Transport Systems and utilization of railroad and inland waterways to reduce emissions and improve efficiency;
- Best practices for methane management in the energy sector through the use of clean and renewable energy and sustainable technologies (for instance, Carbon Capture and Storage (CCS))
- Cleaner energy production from wood (requires way less energy than concrete and steel and contributes to carbon storage);

- Switch to Renewable Energy (RE) to endorse low carbon energy systems and energy efficiency. That transition should be made through supports to the countries.

A study developed at the University of Toronto's Department of Civil Engineering analyzed series of technical alternatives and urban planning policies that could apply as strategic approaches for mitigating greenhouse gas (GHG) emissions in cities (Glenn, 2010). Although this study focused on Canadian cities, its proposed methods and policies, as set out below, can also be applied to other cities.

Table 1: Strategies to reduce greenhouse gases by sector (Glenn, 2010).

Sector	Description of Approach	Technological and Policy Options
Buildings	As major consumers of heating fuels and electricity, the operation and maintenance of buildings account for up to 40% of GHG emissions. Fortunately, the state-of-the-art in sustainable building design is capable of producing carbon neutral buildings even in Canada. By employing modern technologies, such as energy efficient envelopes, photovoltaics, solar water and air heaters, passive solar design and ground source heat pumps, GHG emissions from buildings can be cut to nearly zero.	1. Reduce energy demand by: retrofitting residential, commercial and industrial buildings to increase the level of insulation; upgrading windows; minimizing air leakage; and installing energy efficient appliances and equipment. 2. Utilize solar energy through photovoltaics, solar water and space heating and passive solar design. 3. Exploit waste heat through ground source heat pumps.
Transportation	There are two fundamental approaches to reducing transport-related GHG emissions: (1) reduce automobile use by encouraging electric public transit, walking and cycling; and (2) promote the use of low emission vehicles, including electric cars, by providing the necessary infrastructure and offering financial incentives to vehicle owners to change behaviour.	4. Maintain appropriate land use and population densities to reduce the average passenger kilometres travelled. 5. Improve public transportation (i.e. bus rapid transit, light rail transit, subways and commuter rail). 6. Support active transport modes, such as biking and walking. 7. Introduce financial policies to reduce vehicle use, including tolls, taxes, HOV lanes and increased parking fees. 8. Promote the use of alternative vehicles powered by biomass, fuel cells and electricity.

Sector	Description of Approach	Technological and Policy Options
Energy Supply	Municipalities have a wide array of options for reducing the carbon footprint of their energy supplies. To approach carbon neutrality, greater investments in renewable energy technology will be needed. On a community or neighbourhood scale they can promote and facilitate the development of more efficient district heating and cooling, underground thermal storage, cogeneration, and combined heat and power systems. The same strategic land use planning principles that reduce transportation emissions – density, diversity and site design – resonate in planning low-carbon community energy systems.	9. Develop electricity from renewable sources, including wind, solar radiation, tides, waves, and geothermal. 10. Promote underground thermal energy storage that uses aquifers or boreholes. 11. Promote highly efficient district heating and cooling systems that directly service a group of buildings through a network of piping. 12. Promote co-generation or combined heat and power systems that recover waste heat and improve system efficiencies. 13. Promote integrated community energy systems that provide an economy of scale for infrastructure investment and resource recovery.

However, although there are different benefits and possible pathways to reduce the net of GHG emissions, there is still a significant obstacle to overcome. The main challenge for mitigation policies and measures is minimizing cost (Lu, 2013). Even though the decision to adopt climate mitigation policies and techniques requires massive investment, the costs of delaying action may be even higher (The World Bank, 2010). Besides, the application of mitigation strategies in the present may also affect and save later energy costs.

In this context, urban environments are seen as a portion of the solution to addressing climate change, both in "terms of the role of urban governments and because of the potential for private-sector and civil society actors to respond to climate change at the urban level" (UN-HABITAT, 2011, p. 10).

Local and municipal authorities are key actors in addressing the challenge of mitigating climate change because they have juridical and administrative accountability for important procedures that shape GHG emissions. "Cities can act as laboratories where solutions for addressing climate change can be tried and tested; and municipal governments also provide a key interface for engagement with stakeholders in the private sector and civil society" (UN-HABITAT, 2011, p. 43). In other words, cities and municipalities can formulate and asses multiple situations where mitigation policies and strategies can be

applied to design a practical approach or action plan that meets the territory requirements (Glenn, 2010).

2.2 Adaptation Strategies

Climate change is emerging as a significant concern of the current century. It can affect the city infrastructure, services, and functions while interacting with any existing environmental stresses, possibly aggravating it. The reflection of these climate impacts can be perceived in situ and through interconnected distant cities and rural areas (Wackernagel *et al.*, 2006; Seto *et al*., 2012). The "interaction between climate change and any existing stresses offers a range of synergies, challenges, and opportunities for adaptation" (Ernstson *et al*., 2010; Revi *et al*., 2014, p. 556).

Urban areas can are essential places when we talk about greenhouse gas production and reduction strategies, particularly in decreasing dependence on fossil fuel (Lankao, 2007). However, while the need for the city, local and regional authorities and social groups to act to decrease the emissions of greenhouses gases, is well established, the need to work to reduce the vulnerabilities of the city inhabitants' to the climate change direct and indirect effects still is not (Satterthwaite *et al*., 2007).

Nowadays, cities are redefining their priorities, focusing on reducing vulnerability to climate change impacts and building resilience. In other words, adapt to climate change.

Adaptation to climate change "is the process by which human and natural systems respond to long-term changes in climatic conditions, where some of these adaptations may occur very rapidly many others require decades of planning and implementation" (Holman *et al.*, 2019, p. 712). The process of adaptation also are categorized as autonomous (actions that are undertaken mainly by private parties), planned (private or public actors began actions), and natural actions (Chambwera *et al.*, 2014 as cited in Knittel, 2016). Biological actions may suffer from human intervention.

Even though the idea of urban climate changes adaptation being relatively new, there have been notable advances on the topic over the years. Through dissemination of knowledge, awareness, evidences a work program called Nairobi was settled, in 2005, at

the Conference of the Parties (COP11), to support adaptation policies and approaches. (United Nations, 2005 as cited in Knittel, 2016).

The Cancun Adaptation Framework, adopted in 2010 under the UN Framework Convention on Climate Change (UNFCCC), enacted that adaptation strategies to tackle climate change are as vital as mitigation strategies in the context of reducing GHG emissions (Carter *et al.*, 2015). Being that said, adaptation actions must be treated with equal importance as mitigation ones. The same Framework encourages and supports countries to develop plans to adapt to the changing climate.

In 2013, some European Union Member States adopted a national Adaptation Strategy, that even though there was no "one-size-fits-all" framework, some elements of adaptation concepts were common (European Commission, 2013).

> "All adaptation approaches need to be developed with a sectoral focus, and they need to be incorporated and mainstreamed in current national programs and policies. Stakeholders need to be involved during all different phases of the adaptation development process. Also, all Members of the State need to understand that knowledge, awareness, education, and communication are fundamental tools for a successful adaptation. All adaptation approaches that demand to be treated as developing documents which will be reviewed and updated, in a stipulated timeframe" (European Commission, 2013, p. 6)

The Paris Agreement, at COP 21 in 2015, established global goals on adaptation. These goals are "improving adaptive capacity, increasing and enhancing resilience and reducing vulnerability to climate change, strengthening national adaptation efforts, including through support and international cooperation, and recognized that all Parties should engage in adaptation (UNFCCC, 2019, para. 12)."

Climate change adaptation can be applied to projects and policies to reduce risks and vulnerabilities while benefiting from any opportunities associated with the changing climate itself. "It affects all levels of decision-making, all regions as well as most sectors and needs to be structured as a cross-sectoral and multi-level activity bringing together actors with different knowledge, interests, and values" (Climate ADAPT, n.d., para. 1).

Since climate change is a global phenomenon, cities and municipalities also experience its effect, ensuring the need to adapt (NASA, n.d.). Adaptation to climate change is a process that involves different groups and knowledge. It "requires local knowledge, local competence, local capacity within local governments, households and community organizations with the knowledge and capacity to act, and it also requires a willingness among local governments to work with lower-income groups" (Satterthwaite *et al*., 2007, p. 8). According to Hunt and Watkiss (2011, p. 2) "the "main benefit of grounding global climate change at the local scale is that it may make the associated risks, or opportunities, more relevant to many private and public agents who are responsible for designing and implementing possible responses." One example is Rotterdam. Through the implementation of adaptation measures and smart solutions, the city can turn climate-proof while becoming more pleasant and appealing to live and work (Rotterdam Climate Initiative Climate Proof, 2013). Adaptation techniques can be energy beneficial since energy demand and climatic conditions are connected. "The climate change effect can likely decrease the demand for winter heating, but increase for summer cooling. However, the climatic zone and socio-economic conditions strongly determine the scale of these effects (Hunt and Watkiss, 2011, p. 19)."

Adoption of adaptive measures, such as green or white roofs, efficient building design, or passive ventilation, can affect and change the energy demand, decreasing the temperature during the summer season, for example.

Adaptation strategies also make economic sense at the local level. A study accomplished at a local level within the UK (Dawson *et al*., 2009) analyzed the potential damages connected with cliff erosion and coastal flooding and cost-benefit ratio of adapting to it and found that it would be more economically effective and viable to adapt to the flood risk rather than repair after the damage.

In July 2011, Copenhagen was hit by a devastating cloudburst that corresponded, in more or less 2 hours, to a 1000-year rain, which led to nearly one billion Euros in insurance claims in the area, damages in vital infrastructures and jeopardize of emergency services and facilities (Fink, 2014 as cited in Haghighatafshar *et a*l., 2014; Haghighatafshar *et al*., 2014). After analysis, stipulated that the probable costs of future heavy precipitation episodes were incredible high that they justified spending 12 billion DKK in over 300

stormwater management projects across the city over 20 years" (Climate ADAPT, n.d.a; Climate ADAPT, 2016, para. 3).

Different adaptation strategies can address health problems and risks originated by climate change outcomes. Adaptation strategies such as increased or enhanced green spaces, improving public transportation, or developing walkable neighborhoods can directly reduce extreme heat events, air pollution, heat stress, obesity, and cardiorespiratory diseases (Cheng and Berry, 2013). Since green spaces have a direct influence on temperatures, is expected to find more areas with a mild and cool temperature, which may encourage people to leave their houses and enjoy outdoor activities. The positive effects regarding outdoors activities are that it might be incentive practice of exercises, which can improve psychological well-being and health, as well as create social connections between neighbors (Friel *et al*., 2011; Woodcock *et al*., 2009 as cited in Cheng and Berry, 2013). Adoption of these kinds of strategies, when correctly designed, can reduce greenhouse gas emission (WHO, 2009) and strengthen social capital, particularly in the context of health issues related to climate events (Ebi and Semenza, 2008).

Even though the implementation of adaptation strategies at the local level brings many benefits, some limiting factors for the efficient work of local authorities exist. To illustrate, the absence of leadership, lack of focal points, insufficient knowledge, experience and information, limited funding and resources, deficiency of monitoring actions, and not enough cooperation from stakeholders and householders. Also, the relevance of regional and local authorities, in the adaptation process, is not always recognized by some national governments. To guarantee sustainable development and reduce climate change impacts, overcoming these barriers is essential. Consider transformation where "necessary modifications on economic or environmental systems are understood as the most suitable instrument for reducing risk and where maintaining existing system offers small capacity for adaptation" (Pelling and Manuel-Navarette, 2011 as cited in IPCC, 2014, p. 575).

One key strategy to overcome aforementioned barriers, and to reach a successful adaptation, is integrating adaptation concepts and actions into city planning, land management, and frameworks. Klein *et al*. (2005, p. 584) implied that "adaptation mainstreaming involves the integration of policies and measures to address climate change in ongoing sectoral development planning and decision-making, aimed at ensuring the

sustainability of investments and reducing the sensitivity of development activities to current and future climatic conditions". In other words, guaranteeing that through local government policies action taken by stakeholders and householders will contribute to the adaptation process.

Saying this, adaptation has become an unavoidable strategy, especially if the consequences of an already warmed planet are considered (IPCC, 2013). Adaptation actions not only increase cities' resilience while decreasing their vulnerability but also create benefits in terms of improved public health, quality of life, increase in investments, etc. Given the cross-cutting nature of the issue, adaptation requires an integrated, comprehensive, and interdisciplinary approach, the involvement of all levels of decision-making as well as collaboration with the surrounding municipalities and regions, to do things differently (Covenant of Mayors, 2018).

Adaptation to climate change is one of the priorities addressed under the framework of numerous EU policies relevant to urban areas; beyond EU policy, the UN, national, and regional governments provide a supportive framework for urban adaptation (Climate ADAPT, n.d.b).

2.2.1 Adaptation cases of study on Mediterranean countries

One of the regions that are vulnerable to climate change is the Mediterranean region. Climate predictions for the area suggest that, as result of modification in precipitation patterns, temperature increases and its sensitivity to drought, the "Mediterranean will become warmer and drier and the occurrence of extreme weather events will be more frequent" (Alcamo *et al*. 2007 as cited in Giannakopoulos *et al.*, 2011, p. 836).

These extreme weather events can be harmful to human health and may aggravate some environmental problems, by way of illustration the presence of contaminants in the atmosphere. Climate change can directly affect natural ecosystem and might also present negative impacts to important socio-economic sectors, for instance, agriculture and tourism, as well as directly impact people's quality life and standard of living as it affects sectors

like energy and water resource (Giannakopoulos *et al.*, 2011; Henderson and Muller 1997; Subak *et al.*, 2000; Körner *et al*., 2005; Giannakopoulos *et al.*, 2009).

Mediterranean countries have been implementing and developing adaptation strategies at the local and regional levels, hoping to increase resilience while decrease vulnerability to extreme weather events.

For instance, Barcelona, one of Spain's biggest cities, has faced issues relating to heat island effect, heatwaves, and drought, as some of the consequences to its high urban density and global position. To overcome these problems, Barcelona has bet on nature-based solutions by planting and managing trees. The "Barcelona's Green Infrastructure and Biodiversity Plan 2020 aims to link many areas of the town with green infrastructure, to enlarge the tree coverage and improve the climate resilience of urban trees" (European Environment Agency, 2018, para. 10). The adaptation strategies to fight heatwaves and drought had it basis on "picking tree species that are more resilient to water and heat stresses, making sure that exist a diversification of these tree species, increased use of runoff water for watering trees, automatic irrigation, and control of water leaks (European Environment Agency, 2018, para. 10)".

Similarly, in 2015, Paris adopted its Adaptation Strategy to adapt to climate change impacts and combat resource scarcity. The most prominent climate issues in the French capital are heatwaves, heavy rains, flooding, fire, and drought. Some adaptation strategies adopted by the city to fight those issues consisted of reinvesting/redesigning buildings (e.g., adding greenery to structures, light-colored materials) and roofs (e.g., green roofs, rainwater collectors). Some others include increasing the number of green spaces, tree and urban forest in Paris, using permeable surface materials for roads, developing more wetlands and blue belts. Another idea is building stormwater management structures, such as "container with different levels of water and rainwater storage tank; and, to decrease the risk of fire in woods, watering the vegetation with collected rainwater or water that is unfit for drinking (City of Paris, 2018, p. 62, 63 and 69)".

Zadar is a Croatian town located on the eastern coast of the Adriatic Sea. The city suffers from extreme weather events like drought, fires, flooding, and heatwaves. Some actions taken included educational activities to raise public awareness of climate change; support offered to projects involving local urban gardening and green roofs; implementing

rainwater collection for irrigation; incorporating climate change issues into urban transport planning, e.g., more permeable material surface (Bajilo, 2017).

Considering not only Zadar but the Republic of Croatia as a whole, the country has experienced for years the impacts of climate change, leading, among other things, to considerable losses. To overcome those losses, many strategies to reduce high vulnerability in different sectors were adopted by the country. Some adaptive actions involved breeding species, which are more resistant to any changing in the agriculture clime. Developing water accumulation systems, establishing green infrastructure inside of the city, growing fire protection ability, and enhancing the resilience of local communities in the tourism sector, are some other adaptive ideas (EPTISA ADRIA, 2017, p. 36).

Embracing a population of 10.47 million inhabitants, of which 84% live in urban areas (Worldometers, 2019), Greece is located in the southern end of the Balkan Peninsula, in the Mediterranean Region. Given that, the review of adaptation study cases from Mediterranean countries is considered essential to help understand how countries from the same region adapt to climate change, decreasing risks and vulnerabilities, and increasing resilience.

Chapter 3: Case Study

Greece's climate is typically the Mediterranean. The summer season in Greece usually is hot and dry. The winter in the archipelagos and south part of the country can be characterized as mild and wet. On the other side, the winter can be "quiet cold in the northern-central part of Greece, especially in mountain areas" (HMSO, 1962; Bolle, 2003 as cited in Giannakopoulos, 2011, p. 830). In these areas, the presence of snow and blizzard is probable.

Of all Mediterranean countries, Greece is the one that has the most extensive coastline, measuring 13,780 km, besides including many islands (Europe Commission, 2009). Greece's mainland "accounts for 80% of the country's land area, with the remaining 20% divided among nearly 3,000 islands" (Ministry of Environment, Energy and Climate

Change, 2014, p. 1). That extensive coastline, along with the country position on the globe and its complex topography, influences different local climate characteristics.

A report from the Bank of Greece (2011) presented that the climate change in Greece may affect and change the precipitation regime, the air temperature, relative humidity, wind intensity, incident solar radiation, flood regime, duration of dry intervals, etc. The same study also demonstrated that climate changes would result in losses to the already-damaged Greek economy.

> "The transportation sector comes with high costs according to the Bank of Greece; more specifically, the cost for infrastructure maintenance ranges between €195m/year to €594,8m/year depending on GHG emissions. In addition, service related setbacks caused by extreme weather phenomena are estimated to worth €28bn to €9.3bn annually; for example, a possible sea level rise of 0.5m, will affect coastal areas causing damages of €4.4bn (Bank of Greece, 2011, p. 451)".

Climate change might adversely impact different sectors. However, the two major Greek economic activities, agriculture, and tourism are perhaps the most affected ones, since both depend on weather conditions. Since the importance of these two sectors goes beyond the local level, their development would considerably help to support and promote the local economy while alleviating financial distresses and issues (Georgopoulou *et al.,* 2017). The report from the Bank of Greece (2011) concludes that "if climate change continues as projected until the years 2050 and 2100 without any global effort to decrease GHG emissions, it will cause significant damage to the Greek economy, with figures as high as 701 billion Euros by 2100" (Kitsikopoulos, 2015; Bank of Greece, 2011, p. 365). According to these expectations, if the target of keeping the temperature rise to below 2 degrees above pre-industrial levels is not achieved, some Greek cities will suffer consequences, Thessaloniki is one of them.

3.1 Description of the studied area

Situated in the north of Greece, Thessaloniki is the second-largest Greek city. Located by Thermaikos Bay, at the northwest corner of the Aegean Sea, this midsize city is the center of the "country's second-largest export and transit port, and the nearest European Union port to the Balkans and the Black Sea zone" (Metropolitan Development Agency of Thessaloniki, 2017, p. 17).

With a population of over 1.1 million inhabitants (Metropolitan Development Agency of Thessaloniki, 2017), the Thessaloniki Metropolitan area has a vibrant and unique culture, which attracts residents and tourists from different places around the world. It is considered that Thessaloniki has direct influence over the whole Central Macedonia region.

Today, Thessaloniki is a multicultural, historic and lively city, with growing tourism and international ties, and a transformation taking place in terms of economy, society and civic life (Metropolitan Development Agency of Thessaloniki, 2017).

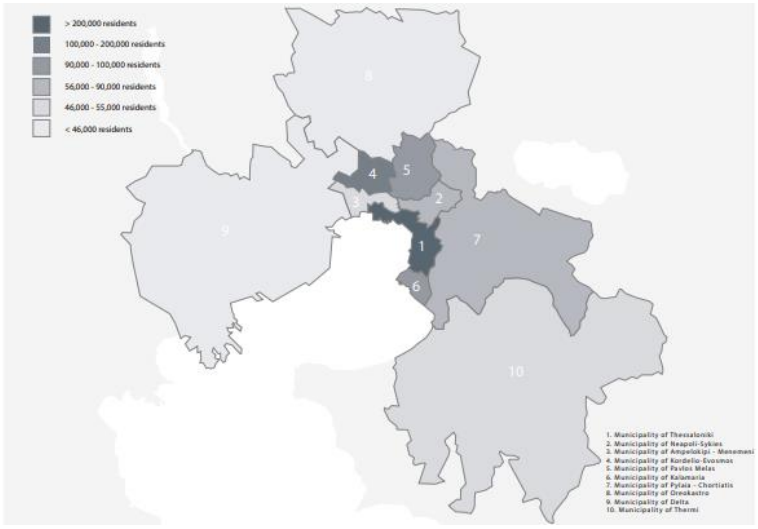


Figure 1: Thessaloniki population map (Metropolitan Development Agency of Thessaloniki, 2017a).

The sea, on which Thessaloniki is situated, influences the climate of the city directly. Different environments, including humid subtropical and Mediterranean climates, can be found in the town. Thessaloniki's winters are considered relatively dry, and snowfall events occur sporadically in each winter. During summer times, Thessaloniki's climate is

hot and quite dry, causing the city to experience strong heat waves (Downing *et al.*, 1999). During the summer season, rain episodes are mostly during thunderstorms (Wikipedia, n.d.). Thessaloniki presents a relative humidity considerably high, given that is situated near the sea. The relative humidity exhibit a range of 32.4–69% (Bourliva *et al.*, 2018), been more humid during wintertime.

Geologically, "Thessaloniki lies on the northern fringe of the Thermaic Gulf on its eastern coast and is bound by Mount Chortiatis on its southeast" (Wikipedia, n.d., para. 40). In Thessaloniki, strong earthquakes can be felt (USGS, 2005).

3.2 Climate change effect on Thessaloniki

The present climate in Thessaloniki is changing and will keep changing throughout the current century. Thessaloniki is exposed to some significant natural hazards and earthquakes. All these hazards, in conjunction with snow, subzero temperatures, local flooding, forest fires, heatwaves, and seasonal and weather-related events, can obstruct city services and business continuity (Metropolitan Development Agency of Thessaloniki, 2017). Those issues, among many others, must be predicted today to enhance the city's resilience to climate change impacts.

3.2.1 Temperature change and more frequent heatwaves

Thessaloniki is a city with limited open or green spaces. The absence of fragmentation of green and open space creates a shortage of suitable leisure environments while simultaneously intensifying the effect of natural events such as high temperatures during the warm season and intense rainfalls during the cold season (Metropolitan Development Agency of Thessaloniki, 2017).

Thessaloniki is already suffering from climate change.

The "UHI in Thessaloniki is stronger in the nighttime when compared to the daytime, decreases with increasing wind speed, and exist indications that the UHI is more pronounced during the warmer half of the year" (Giannaros and Melas, 2012, p. 103). Urban heat island (UHI) can cause thermal discomfort to the inhabitants of the Municipality and is also accountable for the increase of energy demand in the buildings.

Recent studies (Papakostas *et al.*, 2014) showed that the mean temperature in Thessaloniki, throughout the year, has increased 0.5ºC from the decade of 1983-1992 to the decade of 1993-2002, and another 0.6ºC from then to the decade of 2003-2012. During the entire period, the total increase in the annual average temperature in Thessaloniki was 1.1ºC.

According to a study by WWF Hellas (2009), along with the National Observatory of Athens, Thessaloniki's population, among those other cities, will feel the effect of climate change shortly. Yearly, the town will suffer with 20 more days of hot weather and heatwaves episodes (Figure 2) and around an additional month of warm nights (WWF Hellas, 2009). The same study concluded that heatwaves would be more intense and frequent, having its consequences aggravated by the urban heat island phenomenon.

The change in the number of hot days and nights will have implications for the entire Metropolitan area. As a result of the increase in temperature, electricity demand for cooling will increase in many days in the year, especially during summer. Giannakopoulos (2011, p. 837) concludes that the cooling demand will lead to "increased use of air conditioning, and in Thessaloniki, approximately 15 extra days per year will require cooling".

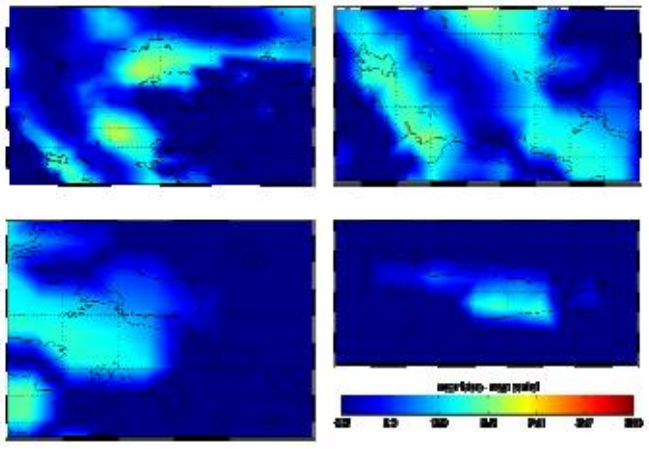


Figure 2: Changes in the number of days with temperature above 35 degrees Celsius during specific decades for specific Greek regions (WWF Hellas, 2009).

The temperature change will also affect winter temperatures in Thessaloniki, where average monthly temperatures will increase in winter as well as in summer periods (Papakostas *et al.*, 2014). The average minimum winter temperature, in "mountainous

areas, and especially in the mountain ranges of Pindos and Northern Greece, is projected to be 2ºC higher in 2021-2050 and 4ºC higher in 2071-2100" (Bank of Greece, 2011, p. 78).

3.2.2 Change in precipitation pattern, rise thunderstorms episodes and floods

Similarly to other cities (WWF Hellas, 2009, p. 12), "the total annual precipitation is found to decrease in Thessaloniki, in spite of the amount of a 3-day precipitation event that seems to increase by 10-20%". Therefore, the frequency in which extreme precipitation/thunderstorm episodes are inclined to happen is more regular, which means that the danger of floods, sea-level rise, and forest fires (peri-urban forest) will increase.

Extensive flooding in 2009 and 2014 demonstrated that, despite Thessaloniki's favorable topography, flood mitigation infrastructure needs to improve (Metropolitan Development Agency of Thessaloniki, 2017). The urban area of Thessaloniki has streams classified as prone to flooding.

Due to poor historical urban development regulation and dense urban environment, the Thessaloniki's current combined sewer system cannot handle peak flows during flood events, which has contributed to infrastructure failures and localized flooding (Metropolitan Development Agency of Thessaloniki, 2017).

3.2.3 Wildfire

Wildfires events are considered an integral part of Mediterranean ecosystems; however, urban infrastructure and the changing climate can be an issue for the protection of the peri-urban forest.

In 1997 the peri-urban forest of Chortiatis was partially destroyed by a wildfire. Since then, the city has sprawled towards the forest area (Metropolitan Development Agency of Thessaloniki, 2017).

Part of the Thessaloniki bypass road is now on the limits of its forest, and some of the city's infrastructure is located within the forest area; consequently, the threat of wildfire in or near the city has increased (Metropolitan Development Agency of Thessaloniki, 2017). The substantial increase in fire risk can affect not only the forest ecosystem itself but also agriculture, on the productive stage of crops.

3.2.4 Drought

The research from the WWF Hellas shows that due to the decrease in precipitation (rain) during wintertime, the incidents of drought are likely to increase, turning Greek fields into desert.

Another recent study (Anagnostopoulou, 2016) focused on the period from 2021-2050, predicted moderate drought episodes for Thessaloniki, by the start of the decade of 2030.

3.3 Impacted Sectors

3.3.1 Building & Infrastructure and Transport

Buildings and infrastructure, like any other sector, can be severely impacted by the changing climate. According to the European Commission (n.d.):

> "Climate change can damage infrastructure and buildings, structures that have a crucial role in the functioning of human societies and economies. The level of consequences and vulnerabilities that buildings and infrastructures can suffer as a result of impacts from extreme weather events will depend on its design and its position in the map (e.g., situated in a flooding area)". (European Commission, n.d., para. 1-3)

The Municipality of Thessaloniki already suffers from extreme temperatures, extended heatwaves and, with climate change, the number of days with high temperatures and the frequency of heatwaves are expected to increase. Those extreme weather events can have direct effects on the infrastructure of buildings and their energy requirements since their heating, and cooling necessities are directly connected to the temperature fluctuation (Papakostas *et al.,* 2014). Being that said, climate change and its effects will need to be taken into consideration when a building is being designed, redesigned, or renovated (Papakostas *et al*., 2014).

The change in climate pattern is also expected to directly impact the transport infrastructure, system, network, and operation.

3.3.2 Agriculture & Forestry and Environment & Biodiversity

Climate hazards like drought and forest fire can be considered significant risks to Greece, particularly under circumstances of the restrict amount of water available.

The changing climate will make forests more vulnerable to forest fire risks, as a consequence of the rising temperature and precipitation reduction. Under this unfavorable scenario led by the effects of climate change, the forest ecosystem, its health as well as its productivity will be threatened and even weakened, increasing risks against its fauna and flora and dangers for Greece's natural environment, infrastructure, as well as economy (Chrysopolitou *et al*., 2014, para. 2).

The changing climate pattern will affect viniculture. More specifically, due to the "precipitation reduction and substantial exacerbation of humidity deficit, wine-producing areas, located in Central and Southern Greece during the period of 2046-2065" (Georgakopoulos, 2017, para. 22).

Also, agriculture and forestry may suffer from climate change repercussions. Some consequences can be an outbreak of weeds, pests, and disease; decrease in production; increase in food insecurity; change in land and soil quality and quantity; all of which will affect forest health, its ecosystem, and biodiversity, fauna, and flora. The climate influences forests' growth, and according to the European Commission (n.d.), that growth is expected to change, decreasing in southern Europe and increasing in northern Europe.

Biodiversity acknowledged globally as one of the most vulnerable sectors to climate change. Countries located in the Mediterranean area are more prone to having their fauna and flora (particularly endemic species) and ecosystem challenged by climate, and environmental changes resulted from human activities, putting at risk the provisioning of most services they provide (MedEC, 2019). Climate change may "affect directly (e.g., species abundance and distribution) and indirectly (through changes in the use of land and other resources, which lead, for example, to habitat fragmentation and loss; and pollution of water and soil) biodiversity and all ecosystems" (European Commission, n.d.a, para. 2-3).

Greece has one of the richest biodiversities in Europe and the Mediterranean. That can be attributed to multiple factors, such as "plant and vertebrate species endemic to the Mediterranean region, certain mammals, 35 inland water fish species, forest ecosystems)

and the Mediterranean marine ecosystem seem to be particularly vulnerable to climate change" (Ministry of Environment, Energy and Climate Change, 2014, p. 19).

Severe weather conditions can have some influence in the fisheries activity and aquaculture. The increase in seawater temperatures could have adverse implications on marine biodiversity and therefore impact the whole food chain.

3.3.3 Tourism

In Thessaloniki, tourism has become the fastest growing economic activity, with "the number of international tourists increased by 30%, overnight stays by 110%, and international flights by 15% since 2009" (Metropolitan Development Agency of Thessaloniki, 2017, p. 19).

Climate change may alter tourism flows in areas where the climate is of vital importance, such as the Mediterranean. The high temperatures, heatwaves, change in precipitation pattern, increase stormwater events, flooding, and, biodiversity loss might lead to different consequences, such as damage to tourism infrastructure and areas for tourist use (e.g., beaches), health risks for tourists and locals, change in energy and water supply and quality, and the need of altering tourism and holidays time, causing change in tourism demand pattern (UNWTO, 2009).

The improvement in the conditions for the development of tourism industries in Northern and Western Europe may result in a gradual change in travelers' preferred destinations to the north and mountain destinations, affecting the preference of western European tourists for the Mediterranean (WWF Hellas, 2009). As an example, during the summer season, the mountains and highlands can become more attractive because of their cooler temperatures. In other words, "while tourists appreciate warmth during the day, visitors – particularly those from Scandinavian countries, Russia and the UK – who are unaccustomed to these conditions will start finding Greece a turn-off and book their vacations elsewhere" (Kitsikopoulos, 2015, para. 8).

Assumes that the desirability and appropriateness for tourism in southern Europe and Mediterranean regions suffer a reduction during the warm season, while it is projected an increase in the others less hot months, like spring and possibly autumn (European Commission, n.d.).

Since Thessaloniki is located in the coast area, its tourism could also be impaired by the sea level rise. Some low-lying coastal areas could be profoundly affected through flooding or erosion due to sea levels rise (Skuras *et al.*, 2012).

3.3.4 Water and Energy

The water system can also be impacted by climate change. The Bank of Greece (2011, p. 135) summarized some ways of how it can happen:

- The precipitation reduction would lead to a decrease in water percolation and recharge in aquifers;
- The reduction in precipitation along with the sea-level rise and intrusion inshore could increase aquifers salinity;
- Rainfall reduction, lack of water availability and change in soils structures might enhance drought and desertification;
- Climate change can lead to an increased concentration of pollutants in the shoreline and in the sea itself;
- The changing climate can also lead to the shoreline wetlands pollution and drainage.

The changing climate will also affect energy input-output and demand, particularly during the summer season, when buildings (primarily commercial and residential) will consume more energy for cooling. A study showed that energy demands for heating and cooling in Thessaloniki, changed over three decades (1983-1992), (1993-2002), (2003-2012), as the energy demand for heating the building subject to the study continued to decrease decade after decade (Papakostas *et al.,* 2014). The same review concluded that for the same period, the energy demand for cooling showed a continuous increase in the amount of 10.6% (Papakostas *et al.,* 2014). Since heating and cooling are generally not supplied by the same source, the climate change will probably implicate changes in the way energy is produced and provided.

3.3.5 Health

Climate, along with other environmental changes, can directly affect human health through higher temperatures, increased ultraviolet radiation, droughts, and other extreme events such as storms and floods (MedEC, 2019).

When exposed to heatwaves, very high temperatures and atmospheric pollutants the human health can suffer hazards, aside from being subjected to have cardiovascular and respiratory morbidity aggravated (DRAXIS, 2019).

Besides human health, some other challenges will rise due to climate change, for instance, the necessity of increasing energy requirement for space refrigeration and air conditioning and a modification in the tourism season pattern (Giannakopoulos *et al*., 2011). The increase in hot days, followed by warmer nights and heatwaves episodes, may affect tourists' tolerance to heat, which can result in heat stress and discomfort, leading to a shift of tourism season. While climate change may not generate new health threat, and it can aggravate existing warnings, risks, and effects, including for instance, according to Watkiss, (2009):

- More mortality and morbidity associated with temperature rise and heat, especially during the summer season. In the other hand, during winter the number of mortality and morbidity associated with heat decreases;
- Increasing air pollution, consequently decreasing air quality;
- Impacts on livelihood, quality of life, health and well-being of the population, as a consequence of extreme weather events (e.g., floods and fires);
- Since climate change affects wind patterns, precipitation, and other weather events, it might have a modification in the dissemination season and circulation of some diseases, viruses, pests, and allergenic pollen variety. Increase the frequency of contagious and epidemic illness attributed to climate change and severe weather episodes.

Human health, biodiversity agricultural and forestry systems can also be impacted by rising and re-appearing of animal diseases and plant pests. The outcome of climate

change on health can vary according to an individual's gender, age, education, and social class. The groups of the population more vulnerable to climate change are children, elderly, pregnant women, people with chronic illness, outside workers, and low-income people. In the Prefecture of Thessaloniki, between 2001 and 2011, the percentage of older adults rose 27%, accompanied by a small increase in the population of children until four years old (Yiannakou and Salata, 2017). Since 2009, due to the economic crisis, the Municipality of Thessaloniki, much like the Prefecture of Thessaloniki, exhibits high unemployment rates. Unemployment "can be considered a sensitivity of the population and can drive vulnerability, because it can be associated with social isolation, loneliness, low income and poor living conditions." (Buscail *et al*., 2011; Zhu *et al*., 2014; Ho *et al.*, 2015 as cited in Yiannakou and Salata, 2017, p. 5).

Another study concluded that male suicide in Thessaloniki was correlated with climate variables and high average annual temperature, but not with joblessness (Fountoulakis *et al.,* 2016). The same study also concluded, "through the multiple linear regression analysis results, that temperature is the only variable that determines male suicides and explains 51% of their variance" (Fountoulakis *et al*., 2016, p. 333).

A different study accomplished in Thessaloniki showed that exist a unique relationship between mortality and high temperatures in Thessaloniki. A survey performed by Kouis *et al*. (2019), showed that there was an elevation in the number of cardiovascular and respiratory mortality and morbidity risks associated to heat events, by 4,4% (95% CI 2.7%–6.1%) and 5,9% (95% CI 1.8%–10.3%) correspondingly on the same day and the day after the heat event.

Chapter 4: Methodology

Specific steps were adopted to develop an appropriate adaptation plan for the Municipality of Thessaloniki, based on the Covenant of Mayors (CoM) framework. First, an extensive international literature review was conducted to identify impacts of current climate tendency and future forecasts for the geographical region of Northern Greece, more specifically, Thessaloniki. Secondly, present and future vulnerabilities were identified

based on current/future forecasted climate scenarios and current/future climate vulnerabilities and risks. The collection of these facts came from the literature review since the Municipality of Thessaloniki does not have a Climate Change Risk and Vulnerability Assessment.

Thirdly, the current Mitigation Plan of the Municipality was reviewed to propose adaptation strategies using vital consultative tools, as Mayors ADAPT and SECAP.

This thesis will not propose a full adaptation plan, but instead, recommend adaptation actions that can be considered by the Municipality to minimize climate change impacts in Thessaloniki and be part of its Adaptation Plan within the CoM initiative framework.

4.1 SECAP and Mayors ADAPT key tools

After launching the Covenant of Mayors for Climate & Energy in 2015, the Covenant of Mayors Communities and Mayors Adapt combined the initiatives, founding a sole movement of local and regional authorities committed to mitigation and adaptation actions to address the climate change, considering the European Union 2030 framework for climate and energy.

The Sustainable Energy and Climate Action Plan (SECAP) is an important document that demonstrates how each Covenant signatory will take action to meet its mitigation and adaptation targets.

The action plan, which takes form of a Microsoft Excel spreadsheet, includes an evaluation of the current situation of the signatory, (e.g., Risk and Vulnerability Assessment identification of goals and targets; planned measures and their time frames, as well as assigned responsibilities and estimated impacts (Kona et al., 2018).

The action plan's section on adaptation to climate change (The Mayors Adapt Monitoring & Reporting Template) assists "signatories in presenting and structuring their adaptation strategy and action plan, as well as tracking their implementation progress" (Mayors ADAPT Office, 2016a, p. 4). In other words, the goals of this spreadsheet template that must be filled in English are to (Mayors Adapt Office, 2016):

- Identify and assess local (climate adaptation) constrains and obstacles;
- Control and report improvement towards commitments;
- Notify and assist authorities and decision-makers;
- Communicate results to the civilians and main partners;
- Demonstrate economic achievements to EU/national policymakers.

On the Mayors ADAPT template, the signatories have to complete the Adaptation Scoreboard, which is a self-assessment of the status of the process of adaptation to the changing climate, indicates the goals and vision, inform the probable risks and vulnerabilities, and the taken actions.

4.2 Adaptation actions for the Municipality of Thessaloniki

This segment aims to provide and suggest some potential measures, and also promising interventions to fight existing and projected vulnerabilities and risks to climate change for the impacted sectors of the Municipality of Thessaloniki. The following steps aim to serve as helpful guidance for the future development of a complete and formal Adaptation Plan for the Municipality of Thessaloniki.

Some steps were taken to suggest adaptation actions:

- Assess the current climate trend and future projection for the Municipality based on literature review and related reports;
- Estimate existent and projected risks and vulnerabilities to ongoing climate change and future projection scenarios and trends for the Municipality. Since the Municipality had not collected and analyzed this information, it was developed from scratch based on a literature review. Geographic Information System (GIS) maps and related tools to analyze the local vulnerability were not used;
- Review of current development plans and priorities. The Municipality provided the guideline in English of the most critical actions and current status of the Mitigation

Plan. The complete study accomplished by the Municipality of Thessaloniki, Resilient Thessaloniki, was also taken into consideration for the proposal of some actions;

- Develop adaptation options using the Mayors Adapt tool and consultative tools;
- Propose strategies for monitoring, financing, barrier, etc.

The adaptation actions proposed were also based on the Mayors Adapt tool, which can be found in Appendix A. This tool shows the Municipality risks and vulnerabilities, specific adaption actions, the proposed strategies for monitoring, financial funding, between other things.

In the section below, are presented possible adaption actions for specific risks and vulnerabilities of the Municipality of Thessaloniki.

4.2.1 Increase in Temperature and Heatwaves

Due to the presence of buildings and high density concrete surfaces, cities are warmer than their surroundings, storing heat throughout the day and releasing it at night. Due to the limited open or green spaces present on Thessaloniki, it is possible to clearly feel the impact of natural phenomena such as high temperatures during the day and warm nights (heatwaves) during the summertime. Heat and heatwaves can negatively affect the well-being and health of the elderly, young children, and people in poor health, reduce workers' productivity and affect transport infrastructure.

Figure 3: Thessaloniki rank in Europe % green space in Urban Morphological Zone - Urban Adaptation Map Viewer, n.d.c.

Some adaptation actions that may be adopted in the Municipality to moderate the impacts of heatwaves and high temperature, especially during summer, including to:

- Identify urban heat islands and focus on implementation and increase of nature-based solutions, such as green walls, green roofs, parks, gardens, green open spaces, planting, managing street trees and existing grasses. Trees have a unique feature; they can work as an urban climate moderator due to its ability to cool it, reflecting the sunlight, helping to lower the air temperature through evapotranspiration and shading. Besides all that, trees can help avoid local flooding by reducing stormwater runoff;
- Expand the number of trees, by diversifying the tree species and selecting those that have higher resistance to water and heat stresses, pests and diseases. Expand gradually, preferably with native species, and avoid mono-specific populations vulnerable to pests and conditions (if needed, use biological control to control the pests). Change from individual tree pits to continuous tree pits can also be a solution (green corridors);
- Strategically plan the trees' implementation. It is essential to take into consideration street canyon geometry and orientation because it has direct effects on the city microclimate and citizens' comfortable feeling. The direction of the canopy should be in accord with the season;
- Redesign/Design more sustainable buildings. The idea is to implement green roofs, gardens, and green walls to decrease the temperature in densely built-up areas and prevent the buildings from absorbing heat. Also, through the use of natural ventilation, light-colored roofs, shading, and excellent thermal insulation are possible to reduce the overheating of indoor spaces. Another idea is to make use of cool materials on edifices roofs to reduce the heat transfer and, as a consequence, decrease cooling energy demands;
- Use of reflective or permeable pavements. This type of pavement can help reduce surface temperature. Promote car-free zones to encourage more use of public transport, reducing greenhouse emissions, pollutants, and heat emissions; promote eco-driving, carpool, school transport;
- Tactically plan land use and transport infrastructure implementation and design, bearing in mind how climate change will impact the city's physical infrastructure;

- Redesign/Revision of current building, infrastructure and transport infrastructure design specifications, taking climate change parameters into account. Use of smart technologies and systems;
- Create a heat action plan that encompasses the implementation of an alert system for heatwaves announcements during summer season special care for those people more vulnerable to the temperature increase, and modifying/rescheduling working hours for outdoor activities. The goal is to reduce morbidity associated with heatwaves by emitting heat and health warnings, raise awareness among the public and health sector workers, and mainstream health into all policies.

4.2.2 Precipitation change and Extreme Events

4.2.2.1 Flooding caused by extreme precipitation and stormwater episodes

The vast majority of the floods that take place in Thessaloniki are the result of substantial precipitation that occurs within a small period of time. The intensity of this precipitation, along with other extreme weather events, such as extreme precipitation and stormwater episodes, is expected to alter with climate change. These extreme weather events may result in losses in public and private sectors (e.g., interrupting city services and business continuity, and causing infrastructure failure), along with adversity and misfortune for the part of the population affected directly.

The city has already experienced significant rainfall events that resulted in urban flooding and damages to repair. It is foreseen an increase in the frequency and intensity of these precipitation events due to the changing climate. Extreme precipitation events and runoff can affect the drinkable and supplied water system, lead to contamination of shellfish and contribute to food-borne illness.

Therefore, preparation and emergency response plans are essential to address anticipated flooding.

Some solutions that could reduce the impacts of flooding would be:

- Use of local weather and hydrological monitoring stations for ongoing monitoring and warning future disaster risks;

- Development of a more sustainable and resilient drainage treatment system and temporary storage of excess rainwater in ponds or areas usually used for other functions, e.g., skateparks. Use infrastructural structure for flood detention, like ponds and weirs;
- Establish regular management and maintenance of stormwater drains to remove sediments and debris;
- Introducing nature-based solutions can help the Municipality to reduce the risk of flash/storm flooding by reducing the amount of surface water entering the drainage system. Green roofs and rainwater collection systems can help decrease water runoff from rooftops and introducing more permeable, and grass surface or planting trees can help reduce soil sealing, decrease flow and consequently floods;
- Nature-based solutions such as green roads and green walls can be used to help hold, confine or stop the water in minor streets and stormwater road and pipes that transport water towards any temporary storage of excess rainwater.

4.2.2.2 Wildfires

Due to more frequent occurrence of heatwaves, an increase in air temperature, a decrease in summer rainfalls and droughts, the frequency and intensity of wildfire hazards have increased, especially in southern European cities, such as Thessaloniki. Those factors, together with a change in land use, urban sprawls, expansion of the city's infrastructure towards the forest area, and part of the bypass road of Thessaloniki being located on the limits of the forest, intensify wildfire risks.

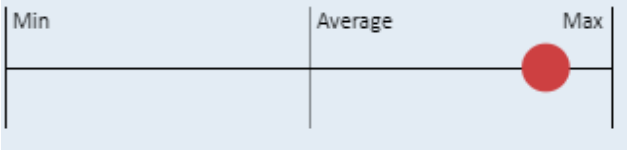


Figure 4: Average observed fire danger in Thessaloniki, related with other Urban Audit cities - Urban Adaptation Map Viewer, n.d.c.

Rapid climate change, with rising temperatures and alterations in precipitation patterns, may affect forest habitats and species. It can negatively affect the forest species regeneration, tree growth and vigor, biodiversity, soil structure (leading to erosion), forest

health, crop yield degradation, livestock production degradation and productivity. “Forested areas, for example, the combination of higher temperature and dryer soil could cause more frequent or intense wildfires, reducing forest cover, lowering moisture retention, and accelerating runoff” (Climate Action Team, 2009, p. 56). However, not only the forest and rural area will be affected by the wildfire, but also buildings and infrastructures at the rural-urban interface.

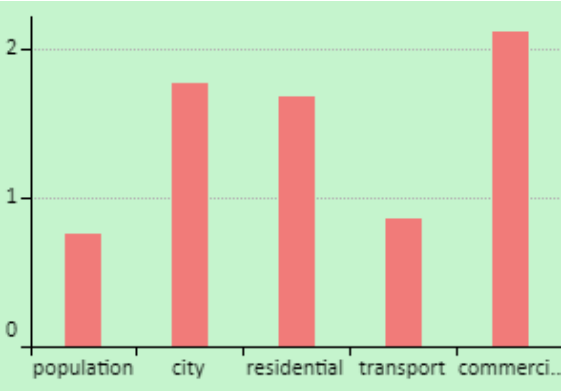


Figure 5: Percent (%) of city population, administrative area and land uses affected by forest fires 2000-2017 - Urban Adaptation Map Viewer, n.d.c.

Beyond all that, the ashes and smoke produced by wildfire may cause or intensify health issues and diseases, especially to vulnerable groups of society, in particular, the elderly, young people, and those with poor health.

The Municipality can adapt to that issue by:

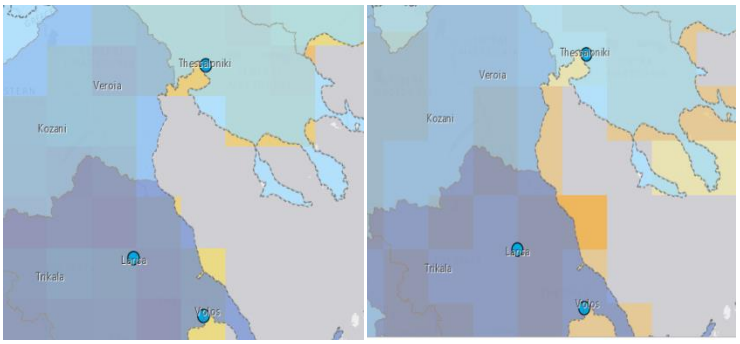
- Improving land management, planning, and use, to minimize the possibility of fire risks and fire loading. The Municipality should work along with local agencies and municipalities to reduce risk and possible hazards and enhance public safety options;
- Accurately selecting species planted in the urban-rural interface, removing plantations in areas where its productivity are projected to decrease, protecting like that the soil against erosion and evasive plants;
- Applying adaptation techniques into silviculture (e.g., promotion of positive selection);

- Biochar application. Because of its physical and chemical properties, the biochar use can bring many benefits to the soil, such as diminish the amount of water necessary for irrigation and improve crop yields; Limiting/controlling urban sprawl by rigorous urban planning and land management;
- Increasing the training, capabilities, and number (if needed) of firefighters and rangers, including a practical pre-event training to respond to fires (for example, using firefighting air tankers) and; purchasing firefighting equipment;
- Adopting fire management measure, including reduction of ignition points and use of fire breaks between the vegetation present in forest and agricultural areas and residential areas;
- Constantly monitoring (purchasing monitoring equipment in case of lacking).

4.2.2.3 Water Scarcity and Drought

The water in Greece is not uniformly distributed in time and space between its population, even though the country has significant water resource potential. In Greece, the agricultural and the tourism sectors constitute the sectors that consume and demand the most water, especially during the summer season, due to the high tourism in the country.

The competition for water use among cities is more specifically, between sectors, such as tourism and agriculture, which may lead to the urban centre being exposed to the risk of water scarcity, especially during drought periods. Water scarcity is driven by droughts and has become more frequent with climate change.



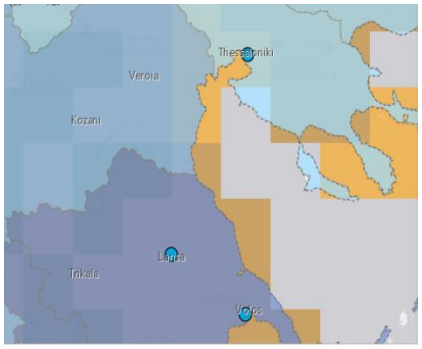


Figure 6: Comparison of trends in frequency of meteorological droughts in Thessaloniki between 1950-2012 events/decade (1); between 2041-2071 events/decade (2) and between 2071-2100 events/decade (3), according with European Environmental Agency - Urban Adaptation Map Viewer, n.d.c.

Droughts are a current risk and vulnerability for Thessaloniki, and studies have confirmed the increase of frequency of moderate drought episodes in Thessaloniki in the future. Drought impacts develop more slowly over time and may put in risk the public health, food production, and water supply and quality, by increasing contaminants' concentration in drinking water supplies.

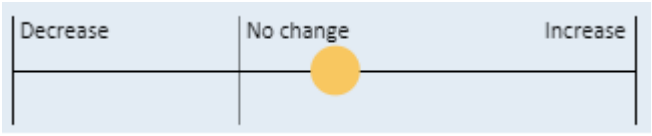


Figure 7: Observed changes in frequency of meteorological droughts in Thessaloniki between the period of1960-2015- Urban Adaptation Map Viewer, n.d.c.

Water scarcity can also, in point cases, be aggravated by overexploitation of accessible freshwater resources, population incidents, increasing water consumption, and change in land use. That can take place due to possible limited water management institutions and infrastructure, as well as the inadequacy of water sources.

In the urban center of Thessaloniki, water shortage is evident, and it is attributed to misplace of water or inefficient management, causing interruption of water supply and possibly compromising the capacity of a green infrastructure to perform its function, especially during the summer season.

In summer 2019, several parts of the Thessaloniki had been without water for few days caused by a "serious pollution problem" in Aliakmonas River, which provides water

to the city via a treatment plant (Ekathimerini, 2019). In 2018, a 40-year-old pipe burst to leave many parts of Thessaloniki without water (Smith, 2018).

Assessing adaptation actions in water management will help to diminish vulnerability to the projected climate change impacts in the Municipality. It will also improve the livelihoods of residents, as well as enhance the conservation of freshwater biodiversity. Some of the proposed actions include:

- Provide a reliable and safe water supply by improving the current system. The objective is to protect public health while guaranteeing water security for the Municipality;
- Reduction of water consumption through techniques of water-saving (e.g., precise irrigation technology, water-canopy cooling), implementation of water tariff (which tends to lower water demand), water rationing and restriction, and by enlightened human behavior. Development of a project to efficiently manage water distribution and consumption could lead to reducing treatment and distribution costs. Special protection of coastal aquifers which are more exposed to salinization;
- Maximize alternative water sources. The Municipality must be able to promote water recycling and reuse programs and initiatives with the purpose of increasing water supply. Constant monitoring of water quality and quantity; desalination facility;
- Reduction of leaks. Development of a project to upgrade and improve the current water supply lines, to decrease losses in the pipes to acceptable limits. Use of pressure management systems to reduce water losses;
- Use of nature-based solution to fight drought periods. Selection of drought-resistant species for green open spaces, urban parks, green walls and streets to guarantee that vegetation can resist periods without rain and continue to provide heat relief sensation to the city’s residents;
- In the agricultural sector, the right selection of drought-tolerant plants, crops and livestock can lead a decrease in water needed for irrigation and increase the water infiltration capacity of the soil which consequently will improve drought resistance; Practices like sustainable agroecosystem management, soil and water conservation,

forest conservation and use of reservoirs and water storage, can also help fight climate change impacts;

- Strengthen irrigation systems in order to increase its efficiency and minimize water loss. Upgrade of wastewater treatment to store treated water and to reuse it to wash vegetation;
- Promote initiatives to enhance local and regional food markets and producers. These initiatives are vital to building resilience to ensure future food security;
- Campaigns to educate and raise the residents' awareness regarding the importance of reducing the consumption of domestic water. These campaigns should be carried out by using social media, television, and pamphlets, as transmission ways.

4.2.3 Sea Level Rise

Vouvalidis *et al*. (2005) collected some data from boreholes drilled along Thessaloniki seaside region and concluded that in that area, existed marine sediments that were covered by debris originated by human activity from many ages. These findings imply that due to debris deposition, the shoreline shifted along the years, from inshore to offshore.

For more than 20 centuries, Thessaloniki has evolved as a harbor. Studies showed that that "the borehole data suggest that human activity over the centuries not only kept the seafront stable but even extended the city and the harbor seawards in order to provide more space to the inhabitants" (Vouvalidis, 2019, para. 16). That being said, Thessaloniki transformed into an allusion for the possible response of coastal cities for coping with the rise of the sea level.

However, a modification in global surface temperature is likely to be followed by global sea-level rise. Thus, adaptation options for the urban area of Thessaloniki would help to prevent future sea-level rise hazards and avoid coastal flooding. Some strategies would include:

- Introduction, maintenance, and monitoring of protection infrastructures to be installed in all seaside and Nea Paralia (e.g., breakwaters, sea walls), to protect city infrastructures, commercial and residential buildings, as well as sidewalks from the direct consequence of sea-level rise;

- Use of GIS to map coastal vulnerabilities and detect sites that will suffer potential impacts related to sea-level rise and direct wave action. Track possible water table rise by installing groundwater monitoring wells;
- Set up tide gauges to monitor sea level. The installment can be done by the Municipality or private companies (in this case, the Municipality should work along with the companies that plan to install the gauges); preferably, the tide gauges should be everlasting;
- Building and infrastructures in areas of risk of coastal flooding should be detected and redesigned to include flooding factors on their design. Development of a relocation plan for the population that lives on those sites and would be affected by coastal flooding;
- Evaluate, upgrade and reposition city buildings (e.g., residential, commercial buildings) and infrastructure (e.g., supply lines) to protect and adapt to the climate change impacts resulted from the sea level rise and coastal flooding.

4.2.4 Vulnerability

The repercussions of climate change hazards, such as flooding, heatwaves, stormwater, droughts, and others, can affect not only the city's infrastructures but also its inhabitants. Typically, the elderly, children and those in poor health are the socio-demographic groups that may struggle the most to prepare for, react to, and recuperate from the impacts of climate-related hazards events. Residents in many areas of Thessaloniki are characterized by high vulnerability because of low gross domestic products (GDP), limited employment prospects, and higher than average risk of poverty. Some proposed actions to mitigate vulnerabilities include:

- Improvement of access to health care, to guarantee that the population, particularly its vulnerable sector, is prepared for gradual and extreme climate change events;
- Monitoring of deaths and illnesses related to climate and severe events hazards, e.g., heat-related illness. To accomplish that, local health departments should work together with domestic health care sectors, health departments from other municipalities, and research collaboration from universities. A good strategy would

be to build an Emergency Episode Monitoring to track, in real-time, daily hospitalizations data, information on emergency department care, etc. Monitor emergencies on a regular basis and collect data.

- Improvement, expansion and or building of surveillance and adaptive capacity to gain insight and trail public health risks, environmental risks, vulnerabilities, and protective factors (e.g., heat warning system, water accessibility information);
- Building a Preparedness Plan to be ready for responding to the changing climate events through exercise practice and conduction.
- Educational awareness campaign. Development of different educational materials to reach diverse sectors of the population (e.g., children, elderly, labor workers, etc.), informing about the health impacts of climate change, what they need to know and what they can do to prevent and adapt. Use of existing network resources to disseminate information; promote workshops and educational activities to update about climate change risk and vulnerabilities, impacts, and responses; identify ways to reach all vulnerable groups to address climate-related health information.

Conclusion and Recommendation

Even though the changing climate and global warming are global challenges, there is a lot that can be done at the local and regional level to reduce their impact and seize adaptation and mitigation opportunities. Apart from our efforts to decrease GHGs emissions, it is also essential to accelerate actions towards the readiness to react adequately against extreme weather phenomena due to climate change. Implementing techniques of adaptation to climate will help build more resilient cities and communities and simultaneously minimize the severe impacts of climate change.

This dissertation proposes adaptation actions for current/future risks and vulnerabilities of the Municipality of Thessaloniki. It acts as a preliminary, broad overview of the estimated climate change impacts in the area. Further analysis would enhance its

impact and highlights specific pain-points to create a mature and integrated Adaptation Plan.

The suggestions and concepts presented within this dissertation derived from the elaboration of the findings of thorough literature. However, to guarantee the success of the hereby adopted methodology, the engagement of stakeholders is necessary. The stakeholders' role (e.g. municipal employees and offices, universities and research institutes, regional authority, national energy companies) is of high importance and should continue to be positioned at the heart of adaptation climate changing plans and projects. They are essential to point out vulnerable sectors and feasible climate adaptation ideas, as well as to bring on board experts on determinate subjects for consultative matter and decision-makers and politicians to fund and support the adaptive measures. Due to their expertise, their involvement is essential for the design, implementation, and management of adaptation measures to ensure such standards' of sustainability. Stakeholders' inputs also indicate the significance of monitoring adaptation processes, to inform decision-making and adaptation subsidy mechanisms.

Besides stakeholders' engagement, social awareness can also be considered a crucial point to achieve the practical implementation of adaptation measures. Increasing inhabitants' perception, knowledge, and accessibility to climate change risks, by providing information (what are they, how to respond to and better manage risk factors) can lead to the elimination of hazards and improvement of adaptation.

The success of adaptation policies and actions introduced by central authorities (governments) and decision-makers depend on public support. Nevertheless, to ensure public support, society must have an appropriate level of awareness of climate change risks and benefits. That being said, local, regional and national authorities need to develop a communication strategy that highlights the importance of climate change risks and validates the interests of citizens' engagement in order to address extreme weather phenomena due to climate change. Informative campaigns and workshops, should not be punctual, but instead go on throughout more extended periods, to properly establish the effectiveness of the actions and to ensure that there will not have any setbacks.

It is also essential to clarify that adaptation should not be understood as a group of repeated measures, but be pointed out as an ongoing improvement process as more

information emerges and becomes available every day. Consequently, it is crucial that the decisions made by local authorities and decision-makers are well thought out, flexible, and considering both short-term and long-term impacts.

In order to properly develop and implement policies and adaptation actions, local and regional authorities, stakeholders, and decision-makers should invite academics, members of the private sector, and citizens to collaborate throughout the Adaptation Plan design and monitoring phase.

Incorporating adaptation actions into active and continuous policies can be used as an incentive and influence citizen behavior, and further lead to a precise development of an Active Adaptation Plan for the Municipality of Thessaloniki within the Covenant of Mayors framework.

It is suggested that the Adaptation Plan will be reviewed and assessed yearly and updated every four years. Some other recommendations are:

- A commitment of the Municipality of Thessaloniki to Mayors Adapt;
- Incorporation of a variety of stakeholder groups (e.g., local, regional and national authorities, universities and research institutes, energy companies) in policy-making processes and their involvement throughout the different adaptation phases. Establishment of partnerships between stakeholder groups from different levels (e.g. local and national) in order to share the costs of adaptation changes;
- More detailed evaluation of the risks and vulnerabilities and the affected sectors highlighted by this study;
- Review of the identified actions, using the assistance of academia and researches;
- Identification of new adaptation risks and vulnerabilities, and activities;
- Review and identification of barriers towards the action (e.g. low level of knowledge and awareness regarding climate challenges at local and municipal levels, restricted assets and available funds, absence of a legislative framework);
- Re-examination of pre-determined timelines as new information on vulnerabilities and risks, probable obstacles and funding becomes available;
- Proper distribution of responsibilities between departments (e.g. monitoring). The departments should share ideas and information between them;

- Integration of updated scientific information and data (e.g. GIS mapping and data) to identify risks and vulnerabilities into the Adaptation Plan;
- Identification of potential new funding options, such as non-government organizations or EU funded programmes (e.g. LIFE, Horizon2020 etc.). Funding can be considered one main concern for climate change adaptation in Europe and elsewhere. Relying on a mix of funding sources can be a solution;
- Promotion of awareness campaigns and workshops that reach different sectors of the Municipality's population, from children to older people, toward raise people awareness related to the changing climate and the credibility of those who aim to participate in climate-related activities;
- After implementation of adaptation actions, keeping track of whether implementation is meeting the established resilience goals and the timeline proposed. Monitoring reports should be written annually;
- Adaption bottom-up initiatives should be supported by local, regional, and national policies and strategies.

All in all, this dissertation concludes that the Municipality of Thessaloniki should adopt an Adaptation Plan to reduce risks and vulnerabilities, both currently existing in the city and projected into the future. Investing in small measures today to adapt and prepare for the changing climate, instead of later, will reduce costs of recovery or infrastructure change after a disaster. In other words, it may circumvent high costs in the future.

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Appendix A: Mayors Adapt Monitoring & Reporting Template

This appendix A, will present the Mayors Adapt Monitoring & Reporting Template that was used as guidance to propose and suggest adaptation actions to tackle Thessaloniki's risks and vulnerabilities. Along with the adaptation actions, it was proposed strategies for monitoring, possible financial funding, to overcome possible barriers etc.

The Mayors Adapt M&R template includes five main tabs, which will be presented below:

- Signatory Profile (adding details about the local authority and the main contacts involved);
- Signatory Scoreboard (showing where the local authority is in the adaptation process);
- Strategy (providing details about adaptation strategy);
- Risks & Vulnerabilities (describing the main climate change risks and vulnerabilities);
- Actions (listing adaptation actions undertaken).

- **Signatory Profile**

1) Local authority

Name:	Municipality of Thessaloniki
Country:	Greece

	Number of inhabitants:	Year:	Source:
Population:	324,766	2017	http://www.100resilientcities.org/strategies/thessaloniki#/-_/
Size:	19,307	Km^2	

2) Contact persons

Contact Type	Name & Surname	Position	Email
Mayor (or equivalent)	Konstantinos Zervas	Mayor	
Main Contact in charge of adaptation	Socrates Dimitriadis	Vice-Mayor (Municipality of Environment	
Other contact (if any)			

ⓘ Add as many rows as necessary

3) Commitments

Commitment Type	Adhesion Date
Adaptation | Mayors Adapt	Has not commited yet
Mitigation | Covenant of Mayors	[06/10/2011]

- **Signatory Scoreboard**

Adaptation cycle steps	Actions	Self check of the Status
STEP 1 - Preparing the ground for adaptation STRATEGY	Adaptation commitments defined/integrated into the local climate policy	A
	Human, technical and financial resources identified	A
	Adaptation team (officer) appointed within the municipal administration and clear respondibilities assigned	B
	Horizontal (i.e. accross sectoral departments) coordination mechanisms in place	B
	Vertical (i.e. accross governance levels) coordination mechanisms in place	B
	Consultative and participatory mechanisms set up, fostering the multi-stakeholder engagement in the adaptation process	A
	Continuous communication process in place (for the engagement of the different target audiences)	A
STEP 2 - Assessing risks & vulnerabilities to climate change RISKS & VULNERABILITIES	Mappping of the possible methods & data sources for carrying out a Risk & Vulnerability Assessment conducted	A
	Assessment(s) of climate risks & vulnerabilities undertaken	A
	Possible sectors of action identified and prioritised	A
	Available knowledge periodically reviewed and new findings integrated	A
STEPS 3 & 4 - Identifying, assessing and selecting adaptation options ACTIONS	Full portfolio of adaptation options compiled, documented and assessed	B
	Possibilities of mainstreaming adaptation in existing policies and plans assessed, possible synergies and conflicts (e.g. with mitigation actions) identified	B
	Adaptation Actions developed and adopted (as part of the SECAP and/or other planning documents)	D
STEP 5 - Implementing ACTIONS	Implementation framework set, with clear milestones	D
	Adaptation actions implemented and mainstreamed (where relevent) as defined in the adopted SECAP and/or other planning documents	D
	Coordinated action between mitigation and adaptation set	D
STEP 6 - Monitoring and evaluating INDICATORS	Monitoring framework in place for adaptation actions	D
	Appropriate M&E indicators identified	D
	Progress regularly monitored and reported to the relevant decision-makers	D
	Adaptation strategy and/or Action Plan updated, revised and readjusted according to the findings of the M&E procedure	D

- **Strategy**

1) Vision

Thessaloniki long-term vision is to implement a climate strategy that, togheter with existent climate mitigation actions, will contribute to adapt to the visible impacts of climate change. The aim is increase quality of life of the inhabitants, by reducing climate change risks and vulnerabilities to the city and citizens. Thessaloniki is a multicultal and lively city, with historic building and an extense coastline that need be protected, as well as the city infrastructure, valued green spaces, and local economy.

2) Adaptation goals

The main goal of the Adaptation Strategy in Thessaloniki, is to reduce vulnerability to forest fire risk, floods in some areas, drought and reduce negatives impacts caused by heat increase.

Goal	Unit (% or other)	Target Year	Base Year	Progress towards target
Reduction on % of sealed/umpermeable ground surfaces in the Municipality		2025	2020	
Increase the number of green nature-based solution in the city (parks, green open spaces, forest, canopy, green walls, corridor, roof)		2022	2020	
Expand the number of bulding with sustainable design (green roofs, light-colored roofs, shading, and good thermal insulation)		2025	2020	
Development of a more sustainable and resilient drainage treatment system and temporary storage of excess rainwater, with regular maintenance of stormwater drains		2025	2020	
Improve land management and planning to reduce fire load and risk of fires		2022	2020	
Reduction of water consumptiom (commercial and rfesidential)		2022	2020	
Reduction of water loss through the improvement of irrigation efficiency and selection of drought-tolerant plants		2022	2020	
Introduction, maintenance and monitoring of protection infrastructures to be installed in all seaside and Nea Paralia		2022	2020	
Turn regular the use of monitoring and alert system for extreme wheater events and health issues		2021	2020	
Improve access to health care		2022	2020	
Regular awarenss and educational campaing for the city inhabitants about climate change, its impact and how to respond		2021	2020	

3) Assessment of the adaptation options

The assessment will be done through expert knowledge of citys teonhicans and possible contracted consultants along with stakeholder decision. Once the official risks and vulnerabilities are assessed, is important to identify the responsible for each sectors/area. After naming the responsibles, meetings betweem them and the teonhicants and consultants need be conducted to analyze action suggestions and officially define specific actions. The actions should be, mostly, cost-benefits. The defined actions should be incorporate in the Adaptation Plan. Each sector/person responsable for a action need present a report by the end of the year of what was accomplished. Important to follow the target year and monitor the adaptation actions.

4) Coordination and organisational structure(s) created/assigned

Thessaloniki should create an adaptation working group led by the departments of Sustainable Mobility and Network and Urban Design and Architectural Studies staffed with, for example, representatives from the departments of Culture and Tourism, Urban Environment Management, Municipal Police Division, Municipal Revenue and Resources Division, Social Protection and Public Health, Financial Managment Division. This working group also involve representatives of the academic and scientific communities (e.g. Aristotle University of Thessaloniki, International Hellenic University and University of Macedonia), non-governmental organisations, the Municipal Water and Sewage Company of Thessaloniki (DEYATH), as well as private companies.

5) Involvement of stakeholders and citizens

Type of stakeholders:	Stakeholder(s) involved:	Level of involment:
☑ Local authority's staff	Division of: Sustainable Mobility and Network, Culture and Tourism, Urban Planning Applications, Urban Design and Architectural Studies, Urban Waste Recycling and Management, Urban Environment Management, Construction	High
☑ External stakeholders at local level	Residents of the Municipality, local universities and research institutes, Environmental NGO, local energy utility, environmental companies.	High
☑ Stakeholders at other levels of governance	National energy companies, universities and research institute, Regional Authority.	Medium

Local authorities from the Municipality be involved in the national policy formulation through their participation in arranged public discussions/consultation or through their representatives in mutual working groups with national authorities (in order to facilitate the involvement of the local authorities and to incorporate their needs and priorities into the formulation and implementation of the measurues); Inter-departmental working groups; Urban-rural partnerships; forum, seminars, workshop, dialogues and meetings between departments and/or municipalities to learn and share ideas (and database) about then adaptation stratetegies, barriers benefits/impacts and goals.

6) Financing

Financing sources:	Specify
Public:	
☑ Local authority's own resources	Environment Budget
☐ National Funds & Programmes	
☑ EU Funds & Programmes	LIFE; NCFF
Private:	
☐ Other private sources	

7) Strategy in case of extreme weather events

After 2009 and 2014 flood events, Thessaloniki adopted mitigation strategies in order to mitigate it, however flood mitigation infrastructure needs to improve. Introduce of nature based solutions, raise population awareness, use of local weather and hydrological monitoring stations for ongoing monitoring and warning future disaster risks and • Development of a more sustainable and resilient drainage treatment system are example of strategies to adopt mitigate.

8) Monitoring process (* this field is only required to be completed 4 years after the formal signing of the commitment)

Monitor the number of citizens who participated in workshops, capabilities, campaigns, educational activities (monitor every 6 months) ;
Number of workshops, capabilities, campaigns and educational activities held (monitor every 6 months);
Number of assistance and participation provided by stakeholders (monitor every 6 months);
Number of areas flooded or with pipes leaks (monitor every 1 year);
Number of green open spaces, green roofs, urban trees, vegetation resistant to heat and water stress implemented and managed (monitor every 1 year);
Reduction of water consumption in commercial and residential building (monitor every 1 year);
Monitor the activity of monitoring equipment and systems (e.g. for alert heatwaves) (monitor every 6 months);
Monitor death and illness related with climate and extreme events hazards, e.g. heat-related illness (monitor every 6 months);
Monitor land and water management (monitor every 1 year)
Recommend reporting on progress of strategy delivery on maximum annual basis.

9) Barriers in progress

Identified barrier		Intensity	Solution(s) identified
Changes in the local political priorities		Strong	
Absence of / weak national (regulatory) framework		Strong	
Insufficient coordination / lack of contact with relevant municipal departments and/or other partners		Little	
Lack of (political or knowledge) support at other governance levels		Fair	Explain the importance and benefits from the Strategy. Mobilise the entire municipality behind the strategy. Involve the political opposition early on, and work and inform the municipal actively.
Lack of appropriate knowledge / data on adaptation		Fair	Hire consultants and technical expertise to develop and risk and vulnerability study and collect the appropriate data.
Limited technical expertise		Fair	Be part of the Adaptation Strategy (Mayors Adapt) process. Encourage the more marginalised groups, in separate focus groups if necessary. Organise a workshop on communication techniques and standards.
Limited human resources		Strong	
Limited financial resources		Strong	Be aware of the funding opportunities, especially from the European Funding Programmes. Keep the strategy simple.
Other Time availability	The partnership team does not work effectively, because its members are too busy with their regular jobs	Fair	Keep meetings short and focused. Use other communications means (newsletters, website, online opinion survey) in addition to formal gatherings. Ask each member of the partnership to appoint a replacement

- **Risks & Vulnerabilities**

2) Climate hazard risks particularly relevant for your local authority or region

	<< Current Risks >>	<< Anticipated Risks >>			
Climate Hazard Type	Current hazard risk level	Expected change in intensity	Expected change in frequency	Timeframe	Risk-related indicators
Extreme Heat	High	Increase	Increase	Current	Number of days/nights with extreme temperature (compared to
Extreme Cold	Low	Decrease	Decrease	Current	Due to increase in frequency and length of heatwaves, number of
Extreme Precipitation	Moderate	Increase	Increase	Current	Precipitation pattern change (Number of day/nights with extreme
Floods	High	Increase	Increase	Current	Pluvial flooding due to change in rain regime
Sea Level Rise	High	Increase	Increase	Medium-term	Increased frequency of extreme rainfall could lead to sea level rise
Droughts	Moderate	Not known	Increase	Current	precipitaton variation leading to drought
Storms	High	Increase	Increase	Current	Rain storm
Landslides	Not Known	Not known	Not known	Not known	
Forest Fires	High	Increase	Increase	Current	city's infrastructure is located within the forest area; change in rain

3) Vulnerabilities of your local authority or region

Vulnerability Type	Vulnerability Description	Vulnerability-related indicators
Socio-Economic:	The local economy may be impacted negatively since the several elements of the city infrastructure (e.g buildings, important roads, coastline) might be affected. Besides local economy the energy sector will be affected, with the increase on energy demand during summer due to temperature increase. The heat waves can affect the quality of life and health of citizens, specially elderly people. Last, but no least, there's the possibility of drought affect the city water supply.	% share of sensitive population groups (e.g. elderly (65+)/young (25-) people
Physical and Environmental:	The wildfire can affect, decreasing, not only the forest ecosystem/biodiversity itself, but also agriculture, on the productive stage of crops. Drought can affect the quality of area (turning Greek fields to desert). The sea level rise and flood caused by the extreme precipitation can affect the infrastructure of the city (e.g coastline, new and historic building, roads).	% change in average annual/monthly precipitation % change in average annual/monthly temperature Length of coastline / river(s) affected by extreme weather conditions / soil erosion (without adaptation) % of protected (ecologically and/or culturally sensitive) areas / % of forest cover % of (e.g. residential/commercial/agricultural/ industrial/touristic) areas at risk (e.g. flood/drought/heat wave/ forest or land fire) Length of transport network (e.g. road/rail) located in areas at risk (e.g. flood/drought/heat wave/ forest or land fire)

4) Expected impacts in your local authority or regio

Impacted Policy Sector	Expected Impact(s)	Likelihood of Occurrence	Expected Impact Level	Timeframe	Impact-related indicators
Buildings	Increased the number for cooling and insulation	Likely	Low	Current	Number or % of (public/residential/tertiary) buildings
Transport	Damage on transport infrastructure	Possible	Low	Current	Number or % of transport/energy/water/waste/ICT
Energy	damage to electrical infrastructure and power	Possible	Moderate	Current	Number of days with public service interruptions (e.g. energy/water
Water	damage on the sewage infrastructure; increase water	Likely	High	Current	% change in storage of rain water (for reuse); Number of days with
Waste	damage to waste infrastructure and treatment	Not known	Not Known	Not known	
Land Use Planning	Urban heat island/ erosion / floods	Likely	High	Current	% of grey/blue/green areas affected by extreme weather
Agriculture & Forestry	forest health, crop yield degradation, livestock	Likely	High	Current	
Environment & Biodiversity	escosystem degradation, species migration, insect	Likely	High	Current	% of areas affected by soil erosion / soil quality degradation; % of
Health	Incresed number of disease and mortality rate	Likely	Moderate	Short-term	Number of people injured/evacuated/relocated due to
Civil Protection & Emergency	Increased number of disasters	Not known	Not Known	Not known	
Tourism	Decline in tourism demand; change in the tourism high	Likely	High	Current	% change in tourist flows / tourism activities

- **Actions**

The actions presented in the Mayors Adapt template are a summary from all the actions proposed in this dissertation – more specifically in the topic *4.2 Adaptation actions for the Municipality of Thessaloniki*.

The implementation timeframe (start and end) was established based on literature review and personal opinion. The responsibility assigned in the Mayors Adapt template took into consideration only local authorities' staffs. However, they should work along with external stakeholders at local level (residents of the Municipality, local universities and research institutes, Environmental NGO, local energy utility, environmental companies) and stakeholders at other levels of governance (National energy companies, universities and research institute, Regional Authority). Some activities have been already started by the Municipality, such as implementation of green roofs, consequently its status are "ongoing".

Sector	Title [max. 128 chars]	Short description [max. 500 chars]	Responsible body/department	Implementation timeframe		Implementation status
				Start	End	
Environment & Biodiversity	Moderating urban climate by using diversificate tree species	These objective is to improve climate resilence, minimize heat island effect, prevent local flood by increasing the number of trees. The actions include expand the number of trees, by diversify the tree species and select those that are more resilient to water and heat stresses, and pests and diseases. Do the expansion gradually, preferable with native species and avoid mono-specific populations vulnerable to pests and diseases (if need, use biological control to control the pests). Change from individual tree pit to continuous tree pit can also be a solution (green corridors).	Division of: Sustainable Mobility and Network, Urban Design and Architectural Studies, Urban Environment Management, Construction and Maintance, Resources Division.	2020	2022	Not started
Land Use Planning	Green roofs to control flood risk	Green roofs serve as mitigation and adaptation measure. As adaptation measure it helps to lower indoor temperatures and reduce flood risk from the capacity of absorbing rainwater. Nature-based solutions as green roads and green walls can be used to help detain and hold back water in smaller side streets and, stormwater road and pipes that transport water towards any temporary storage of excess rainwater;	Division of: Sustainable Mobility and Network, Urban Waste Recycling and Management, Urban Design and Architectural Studies, Urban Environment Management, Construction and Maintance, Urban Planning Applications.	Not known	2023	Ongoing
Civil Protection & Emergency	Alert system for heatwaves	Create a heat action plan that encompass an implementation of an alert system for heatwaves announcements between summer season (May and September), special care for those people more vulnerable to the temperature increase, modify/reschedule working hours of outdoors activities. The goal is to decrease morbidity connected with heatwaves by issuing heat and health warnings; raise awareness among the public and health sector workers; and mainstream health in all policies.	Division of: Sustainable Mobility and Network, Culture and Tourism, Urban Planning Applications, Social Protection and Public Health.	2020	2020	Not started

Civil Protection & Emergency	Hydrological monitoring stations	Use of local weather and hydrological monitoring stations to ongoing monitor and warn future disaster risks; Constant monitoring (purchasing monitoring equipment in case of lacking).	Division of: Sustainable Mobility and Network, Urban Waste Recycling and Management, Urban Environment Management, Construction and Maintance, Urban Planning Applications.	Not known	Not known	Ongoing
Water	Reduction in economic losses, due to flooding can be achieved by adapting the traditional sewage network.	The change is rain pattern that lead to heavy rain and stormwater episodes result in economic negative impacts from flooding in the Municipality. Continue with the current traditional sewage system can result to different losses. Development of a more sustainable and resilient drainage treatment system and temporary storage of excess rainwater in ponds or areas normally used for other functions, e.g. skateparks. Use infrastructural structure for flood detention, as ponds and weirs. Introducing green roads to detain and hold back water in smaller side streets. More regular maintenance of stormwater drains to clear them of sand build-up and rubbish;	Division of: Urban Planning Applications, Urban Design and Architectural Studies, Urban Waste Recycling and Management, Urban Environment Management, Construction and Maintance, Financial Managment, Municipal Police Division and Municipal Revenue and Resources Division.	Not known	Not known	Not started
Health	Prevent health consequences associated with extreme wheater events using technologie	Monitor death and illness related with climate and extreme events hazards, e.g. heat-related illness. In order to accomplish local health departments should work together with local health care sectors, health departments from others municipalities, and research collaboration from universities; A good strategy would build an Emergency Episode Monitoring to track on real time, daily hospitalizations data, information on emergency department care, and etc. Monitor emergencies on daily basis and collect data	Division of: Sustainable Mobility and Network, Culture and Tourism, Urban Planning Applications, Social Protection and Public Health.	2022	2024	Not started
Civil Protection & Emergency	Increase professional capabilities to better assist the population	Increase the training, capabilities and number (if needed) of fire fighters and rangers, including training to rapid and effective response to fires (for example, using aircraft); purchasing firefighting equipment; Fire management measure, including appropriate fire break between vegetation and residential areas, reduction of ignition points;	Division of: Sustainable Mobility and Network, Department of Volunteerism, Youth and Administrative Assistance, Education and Sport Division, Culture and Tourism, Urban Planning Applications,	Not known	Not known	Ongoing
Agriculture & Forestry	Land protection by adoption of correct techniques	Selection of accurate choice of species planted in urban-rural interface, removal of plantations, in areas where future climate change might make them less productive, soil protection against erosion and control of evasive plants; Use of adaptation of silvicultural techniques, as changes in the rotation period, adoption of positive selection, favor of mixed species stands;	Division of: Sustainable Mobility and Network, Urban Waste Recycling and Management, Urban Design and Architectural Studies, Urban Environment Management, Construction and Maintance, Urban Planning Applications.	2022	Not known	Not started
Land Use Planning	Reduce fire load and risk of fires	Improve land management and planning to reduce fire load and risk of fires, including improvement in local land-use planning, and by working with local agencies and municipalities to reduce risk and possible hazards and enhance public safety options;	Division of: Sustainable Mobility and Network, Urban Waste Recycling and Management, Urban Design and Architectural Studies, Urban Environment Management, Construction and Maintance, Urban Planning Applications.	2021	Not known	Not started

Water	Control and monitoring of water consumption and use	Reduction of water consumption through techniques of water-saving (e.g. precise irrigation technology, water-canopy cooling), implementation of water tariff (tend to lower water demand), water rationing and restriction, and by enlightened human behavior. Development of a project to efficiently manage water distribution and consumption could lead to reduce treatment and distribution costs. Special protection of coastal aquifers which are more exposed to salinization;	Division of: Sustainable Mobility and Network, Urban Waste Recycling and Management, Urban Design and Architectural Studies, Urban Environment Management, Construction and Maintance, Urban Planning Applications.	2022	Not known	Not started
Water	Reduction of leaks	Reduction of leaks. Develop a project in order to upgrade and improve the current water supply lines, in order to decrease losses in the pipes to acceptable limits. Use of pressure management systems could be use, in order also to reduce water lost;	Division of: Sustainable Mobility and Network, Urban Waste Recycling and Management, Urban Design and Architectural Studies, Urban Environment Management, Construction and Maintance, Urban Planning Applications.	2022	Not known	Not started
Land Use Planning	Selection of drought-resistant species to fight drought	Use of nature-based solution to fight drought periods. Selection of drought-resistant species for green open spaces, urban parks, green walls and streets to guarantee that vegetation can resist periods without rain and continue to provide heat relief sensation to people living in cities.	Division of: Sustainable Mobility and Network, Urban Design and Architectural Studies, Urban Environment Management, Construction and Maintance, Resources Division.	2020	2021	Not started
Agriculture & Forestry	Selection of drought-resistant species to fight drought	In agricultural sector, the right selection of drought-tolerant plants, crops and livestock can lead to reduce water need for irrigation and increase the water infiltration capacity of the soil which consequently will improve drought resistance. Practices as sustainable agroecosystem management, soil and water conservation, forest conservation and use of reservoirs and water storage, can also help fight the climate change impacts;	Division of: Sustainable Mobility and Network, Urban Design and Architectural Studies, Urban Environment Management, Construction and Maintance, Resources Division.	2021	2023	Not started
Civil Protection & Emergency	Awareness	Carry out campaigns to educate and aware population about the importance of reducing the consumption of domestic water. Use social media, television, pamphlets, as transmission way.	Division of: Sustainable Mobility and Network, Culture and Tourism, Urban Planning Applications, Social Protection and Public Health.	Not known	2021	Ongoing
Land Use Planning	Sea level rise infrastructure protection	Introduction, maintenance and monitoring of protection infrastructures to be installed in all seaside and Nea Paralia (e.g. breakwaters, sea walls), to protect city infrastructure, commercial and residential buildings, sidewalk from direct effect from sea level rise;	Division of: Sustainable Mobility and Network, Urban Design and Architectural Studies, Urban Environment Management, Construction and Maintance, Resources Division.	2023	2025	Not started
Other	Educational awareness campaign	Educational awareness campaign. Develop different educational materials to reach diverse population (e.g. children, elderly, labor workers, etc.), informing about health impacts of climate change, what they need to know, what they can do to prevent and adapt. Use of existing network resources to disseminate information; promote workshops, educational activities to inform about climate change, impacts and responses; identify ways to reach all vulnerable groups to address the climate-related health	Division of: Sustainable Mobility and Network, Culture and Tourism, Urban Planning Applications, Social Protection and Public Health, Department of Volunteerism, Youth and Administrative Assistance, Education and Sport Division.	2020	2021	Not started
Tourism	Educational awareness campaign	Educational awareness campaign. Develop different educational materials to reach diverse population (e.g. children, elderly, labor workers, etc.), informing about health impacts of climate change, what they need to know, what they can do to prevent and adapt. Water conservation and consumption reduction. Increase nature-based solution in places needed. Be aware of adaptation strategies.	Division of: Sustainable Mobility and Network, Culture and Tourism, Urban Planning Applications, Social Protection and Public Health, Department of Volunteerism, Youth and Administrative Assistance, Education and Sport Division.	2020	2023	Not started
Civil Protection & Emergency	Preparedness Pla	Build a Preparedness Plan in order to be read for respond to climate change events through exercise practice and conduction.	Division of: Sustainable Mobility and Network, Culture and Tourism, Urban Planning Applications, Social Protection and Public Health, Department of Volunteerism, Youth and Administrative Assistance, Education and Sport Division.	2021	2022	Not started